To: Joshua Rose[Joshua_Rose@fws.gov]; Wendy Loya[wendy_loya@fws.gov]; Joanna Fox[joanna_fox@fws.gov]
From: Trawicki, John
Sent: 2018-06-13T13:09:00-04:00
Importance: Normal
Subject: Fwd: Annotated Literature Updates & Cumulative Effects Matrix
Received: 2018-06-13T13:09:53-04:00
Coastal Plain 1002 Area Oil & Gas Cumulative Lit Review 11Jun2018jwm.docx
MITIGATION MATRIX Coastal plain 1002 area DRAFT11Jun2018.docx

fyi
---------- Forwarded message ----------
From: **Martin, John** <john_w_martin@fws.gov>
Date: Mon, Jun 11, 2018 at 2:20 PM
Subject: Annotated Literature Updates & Cumulative Effects Matrix
To: Stephanie Brady <stephanie_brady@fws.gov>, John Trawicki <john_trawicki@fws.gov>, Margaret Perdue <margaret_perdue@fws.gov>, Greta Burkart <greta_burkart@fws.gov>, Paul Leonard <paul_leonard@fws.gov>

FYI

Latest updates per subject line - 11 Jun 2018. All are subject to change, further discussion and input, and may still be considered less-than-exhaustive.

Both have been added to RO Natural Resources Common Drive/1002ArcticRefuge/1-Working under Literature to support Resource Assessments.

Please distribute to whoever may benefit.

Thanks

John

--
John Trawicki
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"The single biggest problem with communication is the illusion that it has taken place"
George Bernard Shaw

Coastal Plain Oil & Gas Program: Refuge Annotated Literature Compendium

Contents | Page

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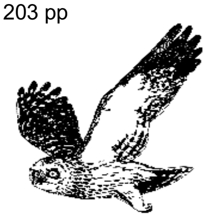

Synthetic General Literature Reviews

Douglas, D.C., P.E. Reynolds, and E.B. Rhodes. 2002. Arctic Refuge coastal plain terrestrial wildlife research summaries. Reston, VA: U.S. Department of the Interior, Geological Survey Biological Science Report USGS/BRD/BSR-2002-0001.

Moore, S. 1987. An annotated summary of recent literature on the effects of human disturbance on caribou. Yellowknife, NWT: Government of the Northwest Territories, Department of Renewable Resources File Report No. 62.

Introduction – This annotated summary cites journals, published reports, and unpublished reports which address the response of caribou to industrial development. Pertinent material, published between 1980 and 1986, was selected for two reasons. First, literature prior to 1980 focused on predicting the impacts of disturbance, whereas recent literature examines present and post-disturbance effects. The primary distinction between pre- and post-development is that the latter affords resource managers an opportunity to examine the significance of an impact, while the former attempts to assess potential hazards from usually limited baseline data sources. Secondly, the disturbance literature prior to 1980 has been extensively research and compiled by William et al. (1983).

Pearce, J.M., P.L. Flint, T.C. Atwood, D.C. Douglas, L.G. Adams, H.E. Johnson, S.M. Arthur, and C.J. Latty. 2018. Summary of wildlife-related research on the coastal plain of the Arctic National Wildlife Refuge, 2002-17. Reston, VA: U.S. Department of the Interior, Geological Survey Open-file Report 2018-1003.

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Williamson, S.C., and K. Hamilton. 1989. Annotated bibliography of ecological cumulative impacts assessment. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 89(11).

Oil and Gas Industry - Human Dimensions - Socioeconomics

ADNR (Alaska Department of Natural Resources). 2013. The oil and gas resource evaluation and exploration proposal for the Arctic National Wildlife Refuge 1002 area. Juneau, AK: Alaska Department of Natural Resources, Division of Oil and Gas. http://www.akleg.gov/basis/get_documents.asp?docid=190

Executive Summary

Introduction - The Arctic Refuge expands across the eastern portion of the northern tier of Alaska and is administered by the FWS. A small portion of the Refuge along the coastal plain has been specifically set aside to assess its oil and gas potential in the ANILCA. This document consists of a compilation of existing information and a proposed Exploration Plan for the oil and gas resources in the 1002 area.

Accurately defining the oil and gas resource potential is a critical part of understanding the value of the 1002 area to the nation. It is also a critical factor in understanding the human environment associated with the Refuge and Alaska's North Slope. Life in this area has changed dramatically with the discovery and development of Prudhoe Bay and the enactment of the ANCSA. However, the positive impacts of responsible development were not thoroughly considered in the 2011 Draft Comprehensive Conservation CCP/EIS. This omission is contrary to the requirements of NEPA.

The North Slope of Alaska is one of the world's great hydrocarbon basins. Alaska oil production has been contributing to the economic prosperity and energy security of our nation for decades. Despite repeated efforts to access federal lands for oil and gas exploration and development within Alaska's borders, the overwhelming majority of federal lands on the North Slope of Alaska remain off limits, including the 1002 Area. The oil and gas resource potential of the Refuge 1002 area is estimated to be in the billions of barrels of recoverable oil. Since the passage of ANILCA, the authority to allow oil and gas development in the Refuge has resided with the US Congress. Given that the federal government refuses to take the lead on fully understanding the resource potential of the 1002 area, the State of Alaska has developed an Exploration Plan to accomplish this federal directive in ANILCA.

The State of Alaska's *Oil and Gas Resource Evaluation and Exploration Proposal for the ANWR 1002 Area* is a reasonable proposal that will help foster a cooperative effort between the State, local, and federal governments and private parties to responsibly assess and explore the 1002 area. This work can be accomplished with little to no impact on the environment -- based on Alaska's high resource development and environmental protection standards -- using state of the art technology currently available on Alaska's North Slope. As stated in Governor Parnell's accompanying letter to Secretary of the Interior Jewell, the State of Alaska is willing to provide tens of millions of dollars of funding to help implement this Exploration Proposal. The goal of the State's Exploration Proposal is to provide updated and comprehensive information regarding the oil and gas resources in the 1002 area. This will engender transparent and sound public policy decision-making by Congress regarding the management of this critically important area of the US and State of Alaska.

Chapter-by-Chapter Overview - Chapter 1 provides a brief history of petroleum resource exploration in the Refuge to date, along with a statewide perspective on oil and gas discoveries that have driven responsible petroleum resource exploration and development in the Alaskan Arctic. Oil and gas exploration in the Refuge was authorized in 1980 when Congress enacted ANILCA. FWS subsequently issued regulations that would avoid significant adverse effects as required by ANILCA Section 1002(h). The previous limited 2-D seismic surveys conducted in 1983-85 in northern portions of the Refuge and a single exploration well on Kaktovik Inupiat Corporation (KIC) lands have comprised the only petroleum assessment actions in the Refuge. This review culminated in a legislative report to Congress that recommended oil and gas leasing in the coastal plain (Clough et al. 1987). The areas of highest oil and gas potential in the coastal plain were not explored in detail, and efforts to definitively determine the oil and gas potential in the 1002 area have since met with a myriad of issues and delays. Current planning efforts embodied in the CCP/EIS have not adequately addressed options to investigate oil and gas resources potential as a CCP alternative.

Chapter 2 discusses existing habitat, wildlife, fish, and subsistence uses in the 1002 area. The two ecoregions in the 1002 area, the Arctic coastal plain and the northern foothills of the Brooks Range, host a diverse network of terrestrial, wetland, and freshwater habitats. Resident and migrating wildlife and fish are present on the coastal plain, with highest population numbers present during summer months. Terrestrial habitats are used by a diversity of animals for grazing, nesting, breeding, and migration. The freshwater habitats of the coastal plain are important for spawning, rearing, and overwintering for migrating and resident fish populations.

The fish and wildlife of the coastal plain provide the resources for subsistence harvests, and for general fishing and hunting. ANILCA directs that subsistence activities for customary and traditional uses are part of the acceptable human uses of the Refuge's coastal plain and are to be allowed by FWS. Subsistence harvests are essential to many rural residents, who are able to access wide ranges and long seasons with modern equipment. General fishing and hunting are allowed within approved seasons. Protection of habitats and fish and wildlife populations during exploration is identified as a critical priority, and mitigation measures essential to preventing negative impacts to habitat, wildlife, fish, and subsistence uses during exploration operations are discussed.

Chapter 3 addresses the currently available data and interpretations of the geology and petroleum potential in the Refuge. The 2-D seismic surveys from 1983-1985 are the only data available. These lack the quality and statistical stability in the spatial context to make detailed assessments of the oil and gas resources in the area. Several federal agency assessments were published in 1987 (Clough et al. 1987), 1988 (FWS 1988), and 1998 (USGS Open File Report 98-34 - *The Oil and Gas Resource Potential of the Arctic National Wildlife Refuge 1002 Area, Alaska*), that attempted to characterize the potential plays containing oil and gas.

This document discusses the possibilities provided by modern technology to definitively assess the locations and volumes of hydrocarbon resources, and provides an economic analysis of feasible oil and gas production scenarios. Without definitive seismic and drilling data, an adequate determination of technically and economically recoverable resources cannot be made. Only additional 3-D seismic surveys and exploration drilling will yield the necessary data and provide new information for important long term management decisions about the Refuge. Bottom line: we have the ability with new technology to undertake a detailed exploration program that will have minimal impact on the environment.

Chapter 4 opens with descriptions of the historic exploration efforts using 2-D seismic surveys and geophysical investigations for some areas of the Refuge. These prior exploration activities did not provide enough detailed information about potential oil and gas resources in the Refuge, but were a positive first step. Chapter 4 goes on to describe the typical exploration methods currently used to understand subsurface zones of interest and to estimate the shape, extent and character of potential oil and gas resources. Geophysical and 3-D seismic surveys have improved significantly since the 1983-1985 program which may provide more accurate resource assessments with minimal surface impact. Winter drilling using ice roads and ice pads has minimal impact on the surface and surrounding environment. Ice-based facilities (roads, pads, airstrips) provide low to no impact access. Proven and new technologies, many in common use in Arctic regions, can accurately maximize the ability to assess the oil and gas resource potential with minimal surface impacts.

Chapter 5 presents a framework for a primarily winter-based exploration alternative for collecting information about petroleum potential, the subsurface geology, and the geographic extent of potential and recoverable resources. The proposed exploration program encompasses three phases over a 7-year life cycle with each phase determining the value of and need for the next phase. Field activities would include winter 3-D seismic surveys (Phase 1), summer site clearance activities to meet exploration permitting requirements (Phase 2), and construction and use of ice-based roads and pad facilities for winter-only exploration drilling (Phase 3). Expected activities and methodologies are described for 3-D seismic acquisition, construction of ice-based roads, pads, and airstrips, and seismic data evaluation to definitively assess the oil and gas resources of the Refuge 1002 area. The exploration proposal uses the proven technological advances for the Arctic with minimal, if any, impacts, based on the extent of surveys, site evaluation, and exploratory drilling. Importantly, the State of Alaska is willing to support these activities through existing exploration tax credits and other means.

Chapter 6 provides a detailed consideration of impacts expected from an exploration program similar to one previously authorized by Congress in the early 1980s, but improved with current technology and the highest environmental standards – which currently exist in Alaska. Exploration activities are primarily proposed for winter, when wildlife populations are absent or not present in large numbers. Coordination with local and rural residents reduces conflicts with subsistence, fishing, and hunting uses. Planning and approved permitting of these activities ensures the proposed exploration methods, timing, and locations optimize data collection and timing and significantly reduce the potential for negative effects. Project plans will determine the necessary regulatory permits, methods, and site locations for the actual exploration program (Phase 3). This resource study provides evidence that multiple land uses and definitive oil and gas exploration can occur concurrently in the 1002 area with minimal impacts, given the use of proven Arctic technologies and strategies.

Chapter 7 identifies and evaluates the benefits to the nation and the State of Alaska that a thorough study of the Refuges resources would provide. Increased domestic oil and gas production supports the possibility of achieving domestic energy independence. Revenues from development support Alaska's economic health, and are critical to maintaining the social health of communities at modern day levels. Development provides opportunity and sustained commerce throughout Alaska and the nation. A published economic budget report from the Congressional Budget Office (CBO) estimated $5 billion from leasing for a mid-case scenario over the life of development in ANWR, depending upon commercial interests (CBO 2012 - *Potential Budgetary Effects of Immediately Opening Most Federal Lands to Oil and Gas Leasing*). The State's further analysis presents a projected income from leasing revenues ranging from $1.3-$8.3 billion. Royalties from oil and gas production for one scenario can be projected to realize ranges near $78 billion for the US (CBO 2012 - *Potential Budgetary Effects of Immediately Opening Most Federal Lands to Oil and Gas Leasing*).

In addition to these economic benefits, increased oil and gas production could provide increased employment, the growth of goods and services, and an additional multiplier effect for the industry and support sectors. Trade, transportation, and service industries are integral components of the Alaskan economic network. It is estimated that for every oil company job, nine other jobs are generated in the State, and that for each dollar earned by oil company employees, 3.5 payroll dollars are generated in Alaska. Increased employment would provide positive impacts for the national, state, and local community workforce. Further, increased oil production is critical to prolonging the operational life of the Trans-Alaska Pipeline System (TAPS). TAPS is essential to bring Alaska's petroleum resources to market and its continued operation is critical to Alaska's future.

Chapter 8 provides a summary of the outcomes that may result from exploration and resource assessment. These include, and are not limited to: increasing domestic supply of crude oil to bolster energy security and independence; added oil throughput for TAPS; increased national, state, and local economic benefits through financial revenues; increased demand for goods and services, employment and national networks for commodity transport, and advancement of viable Arctic technologies for locating and developing conventional and unconventional oil and gas resources; and potential increase in natural gas resources for export.

As this exploration proposal details, oil and gas exploration resulting in a much more certain resource assessment will provide solid scientific evidence that Congress should consider when making decisions about the Arctic Refuge. Oil and gas development that meets national energy objectives and provides sustained economic returns for the U.S. should be a viable use of these lands. The path forward for the long-term, multiple use of the ANWR 1002 Area will depend upon balanced policies and planning. Social and economic aspects of the human environment must be considered during the federal, state, and local project reviews, permitting, and authorizations that are part of this planning process.

Congress and land managers in the mid-1980s recognized the unassessed potential and values this northern tier of Alaska holds. ANILCA provided the foundation for wise stewardship of the area's natural resources, and the opportunity to fully evaluate and realize the benefits within the 1002 area. Understanding the subsurface oil and gas resource potential underlying the 1002 area is an integral part of any decision making regarding the management of the area. By completing this study, management decisions can be aligned with the original intent of ANILCA and consistent with the requirements of NEPA. Without completing a more thorough study of the oil and gas potential of ANWR, the decisions being considered in the CCP/EIS will ignore valuable scientific information and will not comply with ANILCA and NEPA.

BLM (Bureau of Land Management). 2012. National Petroleum Reserve-Alaska: final integrated activity plan/environmental impact statement (7 vols.). Anchorage, AK: U.S. Department of the Interior, Bureau of Land Management, Alaska State Office. https://eplanning.blm.gov/epl-front-office/eplanning/planAndProjectSite.do?methodName=dispatchToPatternPage&currentPageId=14702

Clough, N.K., and A.C. Christiansen. 1986. Draft Arctic National Wildlife Refuge, Alaska, coastal plain resources assessment: report and recommendation to the Congress of the United States and legislative environmental impact statement. Washington, D.C.: U.S. Department of the Interior, Geological Survey and Bureau of Land Management.

[Editor's Note – the Draft Legislative EIS and Final Legislative EIS differ considerably in depth and breathe of narrative, with the Final being more basic and simplified. For example, there are no figures showing full build-out of the 1002 area in the Final Legislative EIS, which are included in the Draft Legislative EIS].

Executive Summary – In December 1980, the Congress passed the Alaska National Interest Lands Conservation Act (ANILCA) - landmark legislation setting aside more than 100 million acres of Federal lands in Alaska in conservation system units (that is, parks, refuges, and so on). Prior to ANILCA, the Arctic National Wildlife Range occupied 8.9 million acres northeastern Alaska. ANILCA enlarged the unit to 17.9 million acres and changed its name to the Arctic National Wildlife Refuge.

…

The 1002 Area - The 1.55-million-acre 1002 area, part of the tundra-covered Arctic Coastal Plain Province, is located in the remote northernmost part of the Arctic Refuge. It is bounded on the east by the Aichilik River, on the west by the Canning and Staines Rivers, to the north by the Beaufort Sea, and to the south by township lines through the foothills of the Brooks Range. The 1002 area constitutes about 75% of the total coastal plain of the refuge; the rest is east of the Aichilik River to the Canadian border, and is part of the refuge's designated wilderness area.

Its arctic marine climate has extremely cold winters and short, cool summers. Summer temperatures average about 40°F; in the winter temperatures drop well below 0°F, with wind-chill factors to -80°F. Persistent winds blow throughout the year. Precipitation over the 1002 area is light but frequent, with summer drizzle and light winter snows. Regardless of season, clear days on the coastal plain are uncommon. Fog and stratus clouds prevail during the summer. In the winter, fog and blowing snow reduce visibility. The sun is continuously above the horizon from mid-May to the end of Jul, and continuously below the horizon from the end of Nov to mid-Jan.

Freezeup begins by mid-Sep, and the ground in the 1002 area remains frozen until June. Snowfall is greatest from Sep through Nov, and again in Jan. Numerous measurements indicated that average snow accumulations were 12 inches in 1984 and 9 inches in 1985. The almost-continuous winds redistribute the snow, filling valleys and swales, but leaving ridgetops bare. Drifts along stream cutbanks can be as high as 20 feet. Rivers are fed by melting snow in the foothills and do not begin to flow until mid-May. Only a few large lakes occur and most of these are so shallow they freeze to bottom in winter. A few shallow thaw lakes are found near the coast, east of the Canning River delta.

The entire 1002 area is underlain by continuous permafrost except for a small area near the warm Sadlerochit Spring which flows year round. The upper layer of the surface of the ground that freezes and thaws annually is called the "active layer."

Vegtation and Terrain Types - Despite its barren and desolate appearance, the 1002 area actually consists of a variety of tundra vegetation and landform types.

Foothills cover about 45% of the 1002 area. These areas are rich in mosses and lichens, important components of the tundra vegetation. Barren deltas and braided river channels of the river flood plains make up as much as 25% of the area. Gently rolling, hilly coastal plains cover 22% of the 1002 area. Here numerous slightly elevated ridges and depressions cover the landscape. Vegetation includes sedges, mosses, lichens and prostrate shrubs in well-drained areas. Tussock tundra occurs frequently in this hilly terrain, and its vegetative complement includes cottongrass, dwarf willows, and birches. Flat thaw-lake plains comprise only about 3% of the 1002 area, and contain unusual surface features called polygons, a ground pattern similar in appearance to rice paddies. Polygons are caused by seasonal thawing and freezing of the active layer in wetter areas. Vegetation in the thaw-lake plains is dominated by aquatic and wet tundra species. Virtually the entire 1002 area can be classified as wetland.

Sadlerochit Spring is one of the largest perennial springs on the Alaskan North Slope. Located in the foothills in the southern part of the 1002 area, the spring and its surrounding area of approximately 4,000 acres has been nominated as a National Natural Landmark. The spring is unique owing to its large warm water discharge which maintains an open channel for nearly 5 miles downstream during the coldest part of the year.

Fish and Wildlife Species - Except for muskoxen and denning or burrowing animals such as polar bears and arctic ground squirrels, the harsh winters drive most species from the 1002 area. The brief spring, summer, and fall seasons; however, find the area host to large numbers of mammals and birds which use the coastal plain for important parts of their annual life cycles.

Caribou - Caribou of the Porcupine and Central Arctic herds are the most numerous large mammals using the 1002 area.

The Porcupine caribou herd, named for the Porcupine River in Canada where they winter, is the larger of the two herds that use the refuge. The Porcupine herd is currently estimated by the ADF&G at 180,000 animals. Each year the herd returns to its traditional calving grounds between the Babbage River in Canada and the Canning River in Alaska. Although distribution on the calving grounds varies from year-to-year, most calving usually takes place in the area between the Hulahula River and the Canadian border. Certain areas appear to be favored by pregnant cows for calving. During the last 14 years, a 2.1-million-acre area has been identified by biologists as a concentrated calving area. Of this, 934,000 acres, or 44 percent of the area, is within the 1002 area. In 1985, 82 percent of the pregnant cows in the Porcupine caribou herd used the 1002 area for calving.

The Central Arctic caribou herd uses a range entirely north of the Continental Divide, from the Itkillik and Colville Rivers on the west to the Sadlerochit River on the east. The TAPS, Dalton Highway, and Prudhoe Bay and Kuparuk oil fields all lie within this herd's range. Despite this, the herd has been increasing and in 1985 numbered ca 12,000-14,000 individuals. Cows tend to calve in an area on or near the Canning and Staines River deltas; calving activity has been concentrated near the lower Kuparuk River and Canning River delta. Most years as many as 1,000 females calve on the Canning River delta within the 1002 area, with some scattered calving as far east as the Sadlerochit River.

After calving in late May and early June, when huge swarms of mosquitoes emerge, caribou from both herds cluster in large aggregations and travel to coastal habitats for relief from insect harassment on points, river deltas and mudflats. Some groups may move to higher elevations in the southern mountains for relief.

In early Jul most of the Porcupine caribou move east and south, and vacate the 1002 area by mid-Jul, heading for their wintering grounds in Canada and in the southern Brooks Range. Occasionally, remnant groups may winter in the northern mountains and foothills. In late summer and fall, caribou of the Central Arctic herd are found scattered across the coastal plain south of Camden Bay, in the foothills north of the Sadlerochit Mountains, and in uplands south of the Sadlerochit Mountains where they winter. During most winters scattered groups of caribou of the Central Arctic herd range throughout the 1002 area west of the Katakturuk River and the adjacent uplands to the south.

Other Mammals - … Polar bears roam the pack ice of the Arctic Ocean throughout most of the year. Some females move to coastal areas and inland during Oct and Nov to seek suitable maternity den sites. Pregnant polar bears and, later, their cubs probably spend more time on the 1002 area than other segments of the population. At least 15 dens have been located in the 1002 area; 5 dens have been found on ice near the 1002 area.

Brown bears use the 1002 area seasonally. At their time of greatest abundance on the area, about 108 bears are found on the coastal plain. The bears appear in late May and remain through Jun and Jul to prey on caribou, ground squirrels and rodents. Food habits change with the seasons--spring finds a combination of meat and vegetation in their diets, and mid -to late summer, almost all berries and vegetation. Although the bears breed while on the 1002 area, they leave in Sep and Oct for den sites in the foothills and mountains.

Birds – The majority of bird species using the coastal plain are migratory, occurring in large numbers from May to Sep. A total of 108 species have been recorded.

Six species are considered permanent residents: Rock and Willow Ptarmigan, Snowy Owl, Common Raven, Gyrfalcon, and American Dipper, which winters in the warmer area around the Sadlerochit Spring. The lagoon systems are important feeding areas for oldsquaw, eider, seater, and other ducks; loons, phalaropes, terns, gulls, jaegers and black guillemots. Raptors nesting in the area include Rough-legged Hawks, Golden Eagles, Gyrfalcons, Snowy Owls, Short-eared Owls, and ~~threatened~~ Arctic Peregrine Falcons.

Tundra Swans are common breeding birds of the thaw-lake plains. As many as 150 nests and 400-500 adult swans have been counted on the 1002 area during annual surveys. Black Brant and Canada, Greater White-fronted, and Lesser Snow Geese regularly use the 1002 area. Canada Geese [now split taxonomically into Canada and Cackling Geese] and Black Brant breed there each year. Part of the Banks Island, Canada, population of Lesser Snow Geese use the 1002 area as a staging area for their annual fall migration. At their maximum, as many as 325,000 geese have been counted on the area.

Erect riparian willow stands support a diversity of perching birds such as Hoary redpolls and White-crowned, American Tree and Savannah Sparrows. Snow Buntings are found on coastal bluffs. Lapland Longspurs are the most abundant species, and nest in all tundra types.

Fish - Fish in the Arctic survive because of extreme adaptations to a harsh environment. Relatively few species occur in the marine, estuarine, and fresh-water environments of the 1002 area. Arctic char, arctic cisco, arctic flounder, arctic cod, boreal smelt, and fourhorn sculpin have been reported offshore of the 1002 area. The nearshore waters are important spawning and overwintering areas. Arctic char, arctic grayling, arctic cisco, arctic flounder, fourhorn sculpin, least cisco, round whitefish, broad whitefish, ninespine stickleback, chum salmon, and burbot have been reported in the Canning River system. Other streams that support fish populations include the Tamayariak, Sadlerochit, Hulahula, Akutoktak, Okpilak, and Aichilik Rivers, and ltkilyariak Creek. The remaining streams in the 1002 area apparently do not support major fish populations, most probably because they freeze to bottom or otherwise fail to provide suitable overwintering habitat.

…

Environmental Consequences of Oil Development on the 1002 Area - Biologists from the FWS assessed potential effects of each alternative: A - full leasing of the 1002 area; B - leasing limited to a portion of the 1002 area: C - further oil and gas exploration; D – No action pending further Congressional authorization; and E - wilderness designation.

Alternatives D and E would result in no adverse impacts on the fish and wildlife resources of the 1002 or on its wilderness value; however, they would preclude further exploration to determine the real hydrocarbon potential of the 1002 area and production of any economically recoverable resources.

Short-term activities associated with further exploration, such as exploratory wells, of the 1002 area will lead to generally short-term displacement and disturbance of fish and wildlife resources and Native subsistence users. There will probably be little or no residual or long-term effect on wildlife populations. Wilderness attributes of the area will be affected for a longer period of time.

Long-term losses in fish and wildlife resources, subsistence uses, and wilderness values would be the inevitable consequences of a long-term commitment to oil and gas development, production, and transportation. If producing fields were discovered, petroleum operations would last for 30-90 years. Oil and gas discovery will lead to industrial development. There will be pressure to use this area as a base to service exploration and development on the outer continental shelf, or to interface with projected oil and gas development in the Canadian Arctic. An oil development infrastructure in the 1002 area would be an impetus to develop State lands between the Canning River and the TAPS. Infrastructure in the 1002 area would serve potential offshore or other fields, adding to the long-term industrial commitment.

Oil and gas development will result in widespread, long-term changes in wildlife habitats, wilderness environment, and Native community activities. Changes could include displacement and reduction in the size of the Porcupine caribou herd. The amount of reduction and its long-term significance for herd viability is highly speculative. Geography apparently limits the availability of suitable alternative calving or insect-relief habitats for the herd. Mitigation measures can minimize some adverse effects to the Porcupine caribou herd as well as to other wildlife species, wilderness characteristics, and subsistence uses.

Industrial development could profoundly affect the Native culture. Although it may provide jobs for villagers from Kaktovik, it will hasten changes from a life style based on subsistence and community sharing and a dependence on the land to a society with a cash-based economy. Increased education, employment and health services would be positive benefits of this change in life style.
…

Clough, N.K., P.C. Patton, and A.C. Christiansen. 1987. Arctic National Wildlife Refuge, Alaska, coastal plain resources assessment: report and recommendation to the Congress of the United States and final legislative environmental impact statement. Washington, D.C.: U.S. Department of the Interior, Geological Survey and Bureau of Land Management. https://pubs.er.usgs.gov/publication/70039559

Summary

Type of Action - Recommendation for legislative action concerning future management of the 1.5-million-acre coastal plain of the 19-million-acre Arctic National Wildlife Refuge (referred to herein as the "1002 area"), located in northeastern Alaska.

Description of the Proposed Action - The Secretary of the Interior recommends to the Congress of the United States that it enact legislation directing the Secretary to conduct an orderly oil and gas leasing program for the 1002 area at such pace and in such circumstances as he determines will avoid unnecessary adverse effect on the environment.

The 1002 area is the Nation's best single opportunity to increase significantly domestic oil production. It is rated by geologists as the most outstanding petroleum exploration target in the onshore United States. Data from nearby wells in the Prudhoe Bay area and in the Canadian Beaufort Sea and Mackenzie Delta, combined with promising seismic data gathered on the 1002 area, indicate extensions of producing trends and other geologic conditions exceptionally favorable for discovery of one or more supergiant fields (larger than 500 million barrels).

There is a 19% chance that economically recoverable oil occurs on the 1002 area. The average of all estimates of conditional economically recoverable oil resources (the "mean") is 3.2 billion barrels. Based on this estimate, 1002 area production by the year 2005 could provide 4% of total U.S. demand; provide 8% of US production (about 660,000 barrels/day); and reduce imports by nearly 9%. This production could provide net national economic benefits of $79.4 billion, including Federal revenues of $38.0 billion.

Environmental Effects

Potential impacts were assessed for exploration, development drilling, and production. Impacts predicted for exploration and development drilling were minor or negligible on all wildlife resources on the 1002 area. Production of oil is expected to directly affect only 12,650 ac or 0.8% of the 1002 area. Consequences on species such as brown bears, snow geese, wolves, moose, and the Central Arctic caribou herd are expected to be negligible, minor, or moderate.

Potential major effects on wildlife from production are limited to the Porcupine caribou herd and reintroduced muskoxen. "Major biological effects" were defined as: "widespread, long-term change in habitat availability or quality which would likely modify natural abundance or distribution of species. Modification will persist at least as long as modifying influences exist."

The Porcupine caribou herd has shown some preference for calving on the 1002 area including the upper Jago River area (84,000 ac or 5.4% of the 1002 area). A potential consequence would be displacement of portions of the herd seeking to calve in the upper Jago River area-the case only if the area were the site of a major producing oil field. It is unlikely, though possible, that such displacement would result in any appreciable decline in herd size.

The potential effects of oil and gas activities on the area's muskoxen are unknown, although biologists predict that major effects could be: (1) substantial displacement from currently used habitat and (2) a slowing of the herd's growth rate, as distinguished from a diminution in herd size.

Potential effects on Native subsistence fall into two categories: the village of Kaktovik and villages outside the 1002 area. In the case of Kaktovik, a major restriction of subsistence activities could occur. This would likely result from the physical changes proximate to Kaktovik which could interfere with traditional activities. Subsistence effects on villages outside the 1002 area, including those in Canada, are expected to be minimal.

Alternatives to the Proposed Action

Alternatives for the Congress that were discussed in the report and legislative environmental impact statement include: (1) Authorize leasing limited to a part of the 1002 area based on environmental considerations (Alternative B); (2) authorize further exploration only, including exploratory drilling (Alternative C); (3) continue current refuge status with no further oil and gas activity allowed (Alternative D); and (4) designate the area as wilderness (Alternative E).

For purposes of environmental impact statement analysis, Alternative D is considered the "no action" alternative.

Summary of Mitigation Recommendations

	Mitigation Measure or Feature	Results - Consequence
1	Limit oil exploration, except surface geology studies, to Nov 1-May 1 (exact dates to be determined by Refuge Manager). Cease exploration activities & remove or store equipment at an approved site by May 15. Local exceptions may be made.	Will limit disturbance to periods when most fish & wildlife species are absent.
2	Consolidate, site, construct, & maintain facilities & pipelines to minimize effects on sensitive fish & wildlife habitats and species. Locate nonessential facilities outside concentrated caribou calving areas.	Will avoid or minimize disturbance in, or loss of, environmentally sensitive areas and allow free passage & natural movement of fish and wildlife.
3	Design all bridges and culverts to handle at least 50-year flood events.	Will prevent damage & disturbance of fish habitats.
4	Use ice or gravel-foam-timber pads, where feasible.	Will reduce gravel requirements & acres of habitat modified.
5	Prohibit: gravel removal from active stream channels on major fish-bearing rivers; winter water removal; from fish-bearing waters, or springs and tributaries feeding into fish-bearing waters; spring, summer, or fall water removal from fish-bearing waters to levels that will not easily pass fish or maintain quality rearing-habitat.	Will minimize disturbance to fish & degradation of fish habitats.
6	Elevate pipelines to allow free passage of caribou or place ramps or bury as feasible.	Will allow migration and other movements of caribou & large mammals.
7	Separate roads and pipelines 120-180 m (400-800 ft), depending on terrain, in areas used for caribou crossing.	Will enhance crossing of linear structures by caribou & other mammals.
8	Construct docks and causeways so that fish movements are not impeded and lagoon water chemistry is basically unchanged.	Will provide for fish and marine mammal movement & lessen degradation of near-shore marine habitat.
9	Avoid construction in coastal areas near river systems with topographic relief or bluffs; otherwise, minimize construction activities along the coast, through the denning period, approximately mid-Mar annually. Minimize activities along the	Will reduce disturbance to polar bears, and prevent destruction of potential bear den & raptor nest sites. * Polar bears listed with critical habitat identified since 1987.

	coast during late Oct-early Nov when polar bears* come ashore to den.	
10	Restrict surface occupancy in the zone from the coastline inland 4.8 km (3.0 mi) to marine facilities & infrastructure essential to move inland beyond the restricted zone; drill pads & production facilities could be allowed within the zone 2.4-4.8 km (1.5-3.0 mi) from the coast on a site-specific basis.	Will permit caribou use of coastal insect-relief habitat & reduce disturbance of nesting waterfowl and other species.
11	Prohibit surface occupancy in the Sadlerochit Spring Special Area.	Will prevent degradation of a unique environment & prevent loss of water essential for fish overwintering.
12	Minimize surface occupancy in immediate vicinity of areas identified as supporting *Thlaspi arcticum**. Include information on identification & need for avoidance of *T arcticum* in all environmental orientation briefings.	Will prevent destruction of *Thlaspi arcticum*. * Note, taxonomic nomenclature change from *T arcticum to Noccaea arctica,* arctic pennycress (https://plants.usda.gov/core/profile?symbol=NOAR2); species far more common than previously determined.
13	Use bear-proof fencing around certain facilities; develop solid waste management plans; incinerate putrescible waste daily; prohibit wildlife feeding; institute employee education programs as appropriate.	Will minimize bear/human confrontations, & reduce attraction of & increases in scavenger populations.
14	Inventory project areas for cultural resources, evaluate resources, & implement mitigation to avoid or minimize impact.	Will preserve cultural resources (archeological & historic sites) to the maximum extent possible.
15	Prohibit off-road vehicle use within 8.0 km (5 mi) of all pipelines, pads, roads, & other facilities, except by local residents engaged in traditional uses or if otherwise specifically permitted.	Will minimize disturbance to wildlife, reduce destruction of vegetation, & permit migration of large mammals.
16	Establish time and area closures or restrictions on certain surface activity such as exploration, vehicle movements, & other activity that can be reasonably rescheduled, in areas of wildlife concentration during muskox calving, Apr 15-Jun 5; caribou calving May 15-Jun 20; caribou insect harassment Jun 20-Aug 15; snow goose staging Aug 20-Sep 27; & fish overwintering & spawning.	Will protect species from disturbance during critical periods.
17	Limit use of development infrastructure, roads, & airstrips to persons on official business.	Will reduce disturbance & human/wildlife interaction.
18	Reinject drilling muds, cuttings, & other	Will minimize areas needed for reserve pits

	wastes where geologically feasible. Remove hazardous wastes off refuge to an approved disposal site.	& reduce potential for contaminant spills.
19	Close areas within 1.2 km (0.75 mi) of high-water mark of specified water courses to permanent facilities & limit transportation crossings. Gravel removal may occur on a site-specific basis.	Will protect riparian habitat and reduce stream pollution and disturbance in an important and limited habitat.
20	Prohibit use of explosives or other noisy activities within 3.2 km (2 mi) of raptor nest sites Apr 15-Aug 31 (Jun 1 if nest is unoccupied), unless specifically authorized by the FWS.	Will protect nesting peregrine falcons & other raptors from disturbance.
21	Prohibit ground level activity, permanent facilities, & long-term habitat alterations (material sites, roads, & airstrips) within 1.6 km (1 mi) of known peregrine* or other raptor nest sites Apr 15-Aug 31 (Jun 1 if nest is unoccupied) unless specifically authorized.	Will protect nesting peregrine falcons & other raptors from disturbance. * Peregrine Falcon delisted since 1987.
22	Survey suitable habitat annually to locate nesting peregrines & other raptors.	Will avoid conflicts between development & nesting raptors.
23	Establish no-activity zone of at least 0.8 km (0.5 mi) around any confirmed polar bear den.	Will prevent disturbance during denning.
24	Close area within 8 km (5 mi) of development & associated infrastructure to hunting, trapping, & discharge of firearms, except for subsistence uses only, on a site-specific basis, where there will be major effects on those uses.	Will increase public safety and reduce direct mortality of caribou, muskoxen, bears, and waterfowl; lower disturbance and increase the likelihood of habituation by species encountering development; however, will result in negative effects to subsistence uses of some areas.
25	Develop and implement plans for control, use, and disposal of fuel and hazardous wastes.	Will reduce potential for contaminant spills.
26	Monitor populations, productivity, movements, & general health of key species. Research measures to further minimize adverse effects of development. Implement corrective actions.	Will allow early identification of problems & implementation of corrective measures for caribou, muskoxen, polar bears, snow geese, arctic char, & others.
27	Provide: environmental orientation briefings for workers; program for monitoring development activities; continuation of fish & wildlife population monitoring; follow-up programs to evaluate effects.	Will increase environmental awareness of workers; give managers continuing baseline information to analyze effects of development and improve protective measures; help to ensure effectiveness of mitigation.
28	Develop plans in conjunction with area	Will minimize undesirable sociocultural &

	residents & organizations to properly manage impacts on communities.	socioeconomic impacts, such as chemical dependency, boom-&-bust cycle, & cultural disorientation.
29	Develop and implement an approved rehabilitation plan as part of the appropriate permit stages.	May provide total or partial restoration of habitat values in affected area.

DOI (Department of the Interior). 1982. Draft environmental impact statement and preliminary draft regulations: proposed oil and gas exploration within the coastal plain of the Arctic National Wildlife Refuge, Alaska. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Geological Survey, Minerals Management Service and Bureau of Land Management.

DOI (Department of the Interior). 1983. Final environmental impact statement and preliminary final regulations: proposed oil and gas exploration within the coastal plain of the Arctic National Wildlife Refuge, Alaska. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Geological Survey, Minerals Management Service and Bureau of Land Management. https://archive.org/details/arcticnationalwi02usfi

Abstract – The proposed action is to establish, by regulation, initial guidelines to govern surface geological exploration or geophysical exploration, or both, for oil and gas within the coastal plain of the Arctic National Wildlife Refuge in a manner that avoids significant adverse effects on the fish and wildlife, their habitats, or the environment. The proposed regulations (Appendix A) accompanying this legislative EIS were developed in consideration of the probable impacts of such exploration and were designed to prevent significant adverse effects, while permitting applicants to choose the exploratory methods and techniques they wish to use as long as the exploratory activities satisfy the environmental protections contained in these regulations. Alternatives to these proposed regulations evaluated in this EIS include Regulations Authorizing Government-prescribed Operations, Regulations Authorizing Applicant-defined Operations, and No Action (i.e., no regulations). In assessing the impacts of exploratory activities, four methods of seismic exploration are evaluated in detail, since seismic exploration provides the best methods allowed under the act [ANILCA ??] to estimate the location and volume of oil and gas resources. These seismic methods are: (1) winter operations using helicopters to transport equipment and personnel; (2) winter operations using ground-surface vehicles for transport (cat-trains); (3) summer operations using helicopters for transport; and, (4) summer cat-train operations. Impacts of these seismic methods are largely determined by season of the year and mode of access. Some variation in impacts would result from the seismic technique used: (1) air-shot (Poulter): (2) conventional (below-ground explosives); and, (3) mechanical (vibration or Vibroseis).

EPA (Environmental Protection Agency). 2008. An assessment of the environmental implications of oil and gas production: a regional case study. Washington, D.C.: U.S. Environmental Protection Agency, Office of Policy, Economics, and Innovation. https://archive.epa.gov/sectors/web/pdf/oil-gas-report.pdf

Exploration Production Forum. 1993. Oil and gas exploration and production in Arctic and subarctic onshore regions: guidelines for environmental protection. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources.

Overview - A considerable portion of the world's oil and gas production in the foreseeable future will come from hydrocarbon deposits in the Arctic and Subarctic regions. Mainly because of the severe climatic conditions and their remoteness from markets, these polar regions are among those least affected by human activities. They are inhabited by various ethnic groups, including indigenous peoples, many of whom depend on the sustainable use of natural resources.

Existing and potential threats to the Arctic and Subarctic environment, not necessarily related to oil and gas exploration and production, are the subject of increasing discussion and concern. These threats include the possibilities of pollution through marine contamination, including oil releases to the environment, the atmospheric deposition of acids, radionuclides and heavy metals, ozone depletion and climate change.

A growing international appreciation of the importance and vulnerability of Arctic and Subarctic ecosystems has led to an increased interest in the ecology of the tundra and taiga. Identification and establishment of additional protected areas and development of new conservation mechanisms for this region are topics of wide and continuing debate. Commercial development faces demands for stringent standards and safeguards for environmental protection. This creates both an opportunity and a responsibility to include the most efficient technologies and practices in any plan for commercial development which will protect the natural qualities of the region.

Cooperation between Canada, Denmark, Finland, Iceland, Norway, Sweden, the former Soviet Union and the United States led to the development of the *Arctic Environmental Protection Strategy*. This calls for management, planning and development activities to provide for the conservation, sustainable use and protection of natural resources for the benefit and enjoyment of present and future generations, especially the needs of indigenous peoples. This strategy is an indication that those countries recognize the importance of Arctic resources and the fact that international action is needed to protect them. The *Arctic Environmental Protection Strategy* applies generally to all onshore exploration and production projects. While its principles should be followed, projects will also be subject to the legislation and standards of the country in which they are situated.

Objectives of the Guidelines

The purpose of these Oil and Gas Guidelines is to establish internationally acceptable goals and guidance on environmental protection during oil and gas exploration and production operations in the onshore Arctic and Subarctic. Requirements and standards for activities in a particular location will be determined for the specific environment by adherence to extant laws and regulations and coordination between the appropriate authorities of the host country and the operating company.

The main objectives of these Guidelines are:

- protection of Arctic and Subarctic natural resources, ecosystems and their biological diversity, based on informed assessments of the possible impacts of oil and gas exploration and production on the environment;

- recognition and accommodation of the customary rights, cultural heritage, values and practices, and resource utilization patterns of indigenous peoples, including access to land and other natural resources, exploitation of the 'products' of these resources, and the avoidance of sacred and archaeological sites, whilst harmoniously addressing health, educational, social and economic needs;

- provision of decision-making tools to help achieve a reasonable and effective balance between resource development and environmental protection;
- encouragement of methods that ensure integration of environmental protection into the design, construction and operation of oil exploration and production facilities;
- and encouragement of consultation between operating companies and the host country at all levels throughout exploration and production operations.

FWS (U.S. Fish and Wildlife Service). 1983. 50 CFR Part 37 - Geological and geophysical exploration of the coastal plain, Arctic National Wildlife Refuge, Alaska: final rule. Federal Register 48(76):16838-16872.

[see DOI 1983].

FWS (Fish and Wildlife Service). 1988a. Acquisition of selected inholdings in Alaska National Wildlife Refuges draft legislative environmental impact statement. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service in cooperation with Bureau of Land Management.

[DRAFT legislative EIS].

FWS (Fish and Wildlife Service). 1988b. Acquisition of selected inholdings in Alaska National Wildlife Refuges final legislative environmental impact statement. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service in cooperation with Bureau of Land Management.

[Editor's note - FINAL legislative EIS – aborted, no further action by Alaska Region; in association with FWS 1990 – also aborted, no further agency action]

Introduction – This FEIS on the acquisition of selected inholdings in the Alaska NWRS incorporates results of the public review of the DEIS. Availability of the DEIS was announced in the 31 Aug 1988 Federal Register and the public review period ended 24 Oct 1988.

The DEIS evaluated various alternatives for acquiring selected inholdings. For the preferred alternative (Alternative A), that evaluation included descriptions of: (1) the inholdings to be acquired, and the oil and gas tracts to be exchanged; (2) operational stipulations for the oil and gas tracts and other terms of the contracts outlining the exhanges; and (3) environmental impacts associated with the proposed exchanges. Environmental impacts were also included for the other four alternatives evaluated. The unique opportunity to acquire vast inholdings and the lack of a significant adverse effect afforded by the preferred alternative. Alternative A would result in the exchange of limited Federal oil and gas interests on 166,000 acres in the coastal plain of the Arctic National Wildlife Refuge to private Native Corporations. The location of the coastal plain and oil and gas tracts to be exchanged are presented in Figure 1 and 2. In exchange for oil and gas interests, the private corporations would convey to the government approximately 896,000 areas of refuge inholdings in 7 Alaska NWRs (Figures 3 through 14).

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FWS (Fish and Wildlife Service). 1990. Management of oil and gas activity on the 1002 area of the Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Introduction – In 1980 Congress passed ANILCA setting aside over 100 million additional acres of Alaska for conservation purposes. In passing this legislation, Congress recognized the special significance of the coastal plain of Arctic National Wildlife Refuge for its oil and gas potential and significant wildlife values. Section 1002 of this Act required DOI to conduct biological and geological studies of the area, provide a report to Congress on the result of these studies, and make a recommendation for future management of the area.

On 1 Jun 1987, the DOI Secretary transmitted to Congress the report: *Arctic National Wildlife Refuge, Alaska, Coastal Plain Resources Assessment: Report and Recommendation to the Congress of the United States and Final Legislative Environmental Impact Statement* (hereafter *Coastal Plain Report*; Clough et al. 1987). Included was the Secretary's recommendation that Congress direct him "…to conduct an orderly oil and gas leasing program for the entire 1.5 million-acre 1002 area at such pace and in such circumstances as he determines will avoid unnecessary adverse effects on the environment.

Since the submission of the *Coastal Plain Report*, Congress has been deliberating the future management of the Arctic Refuge coastal plain. Essentially, this deliberation centers on whether to designate the 1002 area as a wilderness area or authorize oil and gas activities subject to some yet to be determined statutory guidelines. Should Congress decide in favor of wilderness designation, no dramatic changes in the current refuge management regime would be required. If, on the other hand, Congress should decide to allow oil and gas development to proceed, a major management redirection would be required to implement associated legislation.

In anticipation that Congress might open the coastal plain to oil and gas activities, and to be consistent with the national Memorandum of Understanding between the Service and the BLM, the Regional Director for each agency established the "1002 Work Group."

The information provided in this document constitutes the recommendations of the 1002 Work Group for conduct of oil and gas activities on the coastal plain. The scope of these recommendations is limited to those assumed responsibilities and functions ascribed to the two agencies. It is not intended to describe the more comprehensive interrelationships with other Federal, State or local entities having management or regulatory responsibilities on the area. The following assumptions were used in developing recommendations:

1. Congress, through stand-alone legislation, will authorize an oil and gas management program on the coastal plain of the Arctic Refuge leading to oil production and ultimately land reclamation.

2. Opening legislation will generally be consistent with the Secretary's recommendations in the *Coastal Plain Report*.

3. The Service, as lead agency and in close coordination with the BLM, will administer all Congressionally authorized oil and gas activities on the Arctic Refuge.

4. Opening legislation will include and require appropriate consistency among all land classifications within the coastal plain. Those classifications include:

   a. 1002 area lands, both surface and subsurface Federal ownership: This classification includes the vast majority of lands within the 1002 area as originally defined by ANILCA 1002(b)(1). Coastal lagoons within this area are currently the subject of litigation with the State of Alaska).

   b. Kaktovik Inupiat Corporation (KIC) lands, surface owned by Kaktovik, subsurface owned by Arctic Slope Regional Corporation: Surface lands (ca 92,000 acres) were conveyed to KCI pursuant to ANCSA (1971). The subsurface ownership was conveyed to Arctic Slope Regional Corporation subject to ANCSA, the Alaska Lands Act, and land exchange agreement with DOI in 1983.

   c. Arctic Refuge coastal lagoons, surface and subsurface ownership subject to litigation between State and Federal governments: Some of these lagoons lie north of Kaktovik lands and were not included in the 1002 area as defined by the Alaska Lands Act, but are included within the Arctic Refuge boundary.

   d. Native Allotments, surface in potentially private ownership, subsurface reserved to the Federal government: The Native Allotment Act (1906) enabled individual Natives of Alaska to acquire title to lands (not to exceed 160 acres) that they used and occupied. There are 21 applications pending for Native allotments involving 43 separate parcels (ca 1480 acres). These allotments are not scheduled for survey until after 1994. Final conveyance will occur after surveying.

Throughout the remainder of this document, the term *1002 area* refers to the area described in ANILCA 1002(b)(1) and further defined in 50 CFR 37, Appendix I. The term *coastal plain* will refer to the 1002 area plus Kaktovik lands and the refuge coast lagoons lying north of Kaktovik lands.

This document is subdivided into three major sections. The first section provides a series of flow charts and accompanying narratives that describe the major functional tasks and milestones associated with management of an oil and gas program on the coastal plain. The detailed information necessary to more fully develop these descriptions is provided in Appendix II. The second section consists of a series of issue papers that have a direct bearing on the conduct of the oil and gas management program. The section of issues treated in this section was based in large upon the likelihood that they might appear in the Congressional authorization opening the coastal plain. The third section deals with respective agency roles of the Service and the BLM in managing the program. This relationship is described by a proposed MOU between the two agencies. The three major sections are premised on the assumptions outlined previously and are to a degree interdependent. Appendix III lists references cited; Appendix IV contains a limited glossary of terms and short titles; and, Appendix V provides an overview of the entire management process in the form of a flow chart.

Concurrent with the preparation of the Coastal Plain Report, the concept of exchanging limited oil and gas interests on the 1002 area for Native surface inholdings in other Alaska

Refuges was proposed (DOI 1988). During 1985-1987, negotiations led to an "agreement in principle" with 6 Native groups representing 18 Native Corporations. In Dec 1988, a FEIS (FWS 1988b) was completed following publication and receipt of public comments on a DEIS (FWS 1988a). The DOI Secretary signed a ROD on 19 Jan 1989 supporting the proposed exchange and transmitted the statement, with supporting documents to Congress. The present Secretary has indicated that DOI is not interested in further pursuing the proposed exchange. Therefore, guidance from the Congress is necessary before DOI will take any further action on this matter, and reference to land exchanges in this document are provided for historical completeness.

This document is dynamic in nature and will be periodically updated to reflect changing policy, additional biological and subsistence information, advancing oil technologies, and the ultimate content of opening legislation.

Hanley, P.T., J.E. Hemming, J.W. Morsell, T.A. Morehouse, L.E. Leask, and G.S. Harrison. 1981. Natural resource protection and petroleum development in Alaska. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services FWS/OBS-80/22. https://pubs.er.usgs.gov/publication/fwsobs80_22

Abstract – This report reviews the administrative roles, authorities, procedures, and decision-making processes for oil and gas leasing and post-lease environmental management for both the State and Federal governments. Past and present oil exploration and development efforts in Alaska, and a general assessment of the most promising areas for future development are reviewed. The major refuges and game ranges are ranked according to their oil potential. Industry practices associated with each phase of petroleum development and identification of the physical impacts of these practices and their potential effects on fish and wildlife, and habitat are presented. Two case studies of petroleum development and environmental management in Alaska are provided: Kenai National Moose Range in southcentral Alaska and the National Petroleum Reserve in northern Alaska. Recommendations for strengthening protection of fish and wildlife in government surveillance of petroleum development projects are presented. Stipulations that have been applied for protection of fish wildlife during the past petroleum development in Alaska are discussed.

Hanley, P.T., J.E. Hemming, J.W. Morsell, T.A. Morehouse, L.E. Leask, and G.S. Harrison. 1983. A handbook for management of oil and gas activities on lands in Alaska. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services FWS/OBS-80/23.

Abstract – Information is presented on the characteristics of oil and gas activities on lands in Alaska and the environmental effects of such activities. Chapter 1 provides a brief overview of the procedural framework of environmental protection of Refuges in Alaska. Chapter 2 describes the 3 major phases of petroleum development and activities that occur in each phase; special emphasis is given to practices during the exploratory phase. Chapter 3 discusses the main environmental disturbances that may occur during all three phases of oil-related activity. Reference tables identify disturbances that may occur in forested, nonpermafrost terrain, potential effects on fish and wildlife that result from these industry-related environmental disturbances and disturbances that may occur in treeless permafrost terrain.

Chapter 4 presents the concept of impact mitigation and the use of stipulations. Chapter 5 identifies the kinds of information that are required for the design of effective impact mitigation measures.

Quotes - from Chapter III. Potential environmental disturbances (all Alaska ecosystems) - (Page 15; see Table III-I Environmental perturbations that may occur as a result of petroleum practices within treeless, permafrost terrain: Page 27).

Land surface disturbances destruction of vegetation
- tree clearing
- slash disposal
- altered soil characteristics
- thermal erosion and thermokarst
- hydraulic erosion
- altered surface water hydrology
- fill over land surface
- above ground obstructions

Steam or lake disturbances
- stream bank erosion
- siltation
- channel construction
- altered current velocity
- channel obstruction
- shock wave (exploration)
- perched drainage structure (culvert)
- bottom substrate disturbance
- long term channel changes
- reduced water volume
- altered water quality
- drainage of lake basin

Alteration of terrestrial habitat
- direct habitat loss
  - reduced primary productivity
  - wildlife range reduction
  - displacement of low mobility species
  - elimination of essential-life stage habitat(s)
  - interruption of energy and nutrient flow – ecosystem processes and functioning; animal uptake-optimal foraging
- altered habitat characteristics
  - reduced plant cover and productivity
  - altered community composition
  - altered wildlife use
  - outbreaks of pest organisms
  - pioneering of alien invasive species
  - interruption of energy and nutrient cycles
- interference with animal movements
  - interruption of critical life history stages
  - prevention of access to essential habitats

- high energy cost with lower survival outcomes
- injury to flying birds
- death or injury from toxic substances
- alteration of aquatic habitat
- direct animal loss
    - reduced productivity and/or recruitment
    - displacement of low mobility species
    - elimination of essential fish habitat
    - interruption of energy and nutrient flow

ICUN (International Union for the Conservation of Nature). 1993. Oil and gas exploration and production in Arctic and subarctic onshore regions: guidelines for environmental protection. Gland, Switzerland and Cambridge, UK: International Union for the Conservation of Nature and Natural Resources.

Kotchen, M.J., and N.E. Burger. 2007. Should we drill in the Arctic National Wildlife Refuge? An economic perspective. Energy Policy 35:4720-4729.

Abstract - This paper provides model-based estimates of the value of oil in Alaska's Arctic National Wildlife Refuge (ANWR). The best estimate of economically recoverable oil in the federal portion of ANWR is 7.06 billion barrels of oil, a quantity roughly equal to US consumption in 2005. The oil is worth $374 billion ($2005), but would cost $123 billion to extract and bring to market. The difference, $251 billion, would generate social benefits through industry rents of $90 billion as well as state and federal tax revenues of $37 billion and $124 billion, respectively. A contribution of the paper is the decomposition of the benefits between industry rents and tax revenue for a range of price and quantity scenarios. But drilling and development in ANWR would also bring about environmental costs. These costs would consist largely of lost nonuse values for the protected status of ANWR's natural environment. Rather than estimate these costs and conduct a benefit–cost analysis, we calculate the costs that would generate a breakeven result. We find that the average breakeven willingness to accept compensation to allow drilling in ANWR ranges from $582 to $1782 per person, with a mean estimate of $1141.

Kroh, K., and H. Marano. 2013. Adding fuel to the fire: climate consequences of Arctic Ocean drilling. Center for American Progress. https://www.americanprogress.org/wp-content/uploads/2013/03/ArcticDrillingBrief-2.pdf

Conclusion – Climate change is permanently altering the Arctic region, and the results are startling. As ecosystems unravel, fragile species such as polar bears are struggling to survive, shorelines are eroding, waters are becoming increasingly acidic, snow and ice are vanishing at an alarming rate, and storms are more severe and unpredictable than ever before.

At the heart of the problem, however; lies human activity – our addiction to fossil fuels. As Jason Box, Greenland expert at the Byrd Polar Research Center explains, "Those who claim it's all a cycle just don't understand that humans are driving the cycle right now, and for the foreseeable future."

Rather than respond to this crisis with serious policies to significantly and swiftly reduce our carbon emissions, governments with jurisdiction over the Arctic have taken the reckless approach of moving forward with plans to exploit the newly accessible fossil fuels and

accelerate the destruction. Decisions regarding whether to allow potentially destructive industrial activity, such as oil and gas development, in this fragile environment cannot be examined independently from the climate crisis they will perpetuate.

Taking serious action to curb the devastating effects of climate change means we must aggressively deploy clean technologies, internalize the actual price of pollution by putting a price on carbon, and make major investments in climate resiliency. The time for piecemeal solutions has passed and there is no room in the equation for major expansion in fossil-fuel production.

Maki, A.W. 1992. Of measured risks: the environmental impacts of the Prudhoe Bay, Alaska, oil field. Environmental Toxicology and Chemistry 11:1691-1702. https://setac.onlinelibrary.wiley.com/doi/abs/10.1002/etc.5620111204

Abstract - The 20th anniversary of the filing of the Trans-Alaska Pipeline System (TAPS) Environmental Impact Statement (EIS) affords an opportunity to assess retrospectively the environmental impacts of the resultant North Slope oil fields, now the largest single source of U.S. domestic oil production. As the oil field expanded, particularly to near-shore areas such as the Endicott Development, additional EIS documents were prepared to assess impacts not included in the original TAPS EIS. In the ensuing years, numerous agency-monitored and industry-sponsored environmental monitoring studies, estimated to average $4 million per year, have been conducted in and around the oil field, making the Alaskan North Slope one of the most studied environments in North America.

In this paper, the EIS requirement of the NEPA is examined as a predictive environmental risk assessment. A tabulated summary of the predicted environmental impacts from the original TAPS and offshore Endicott Development EIS documents is compared with the extensive amount of resultant monitoring data. These data confirm localized impacts to air and water quality; however, regulated discharges remain well below criteria established for the protection of human health and the environment. As predicted, some unavoidable habitat losses to resident and migratory wildlife have occurred within the oil field and pipeline corridors. Approximately 2% of the land surface in developed portions of the oil field was actually altered. However, careful monitoring of wildlife populations demonstrates that no species has experienced a measurable decline, and most continue to utilize oil field habitat for breeding, nesting, and summer forage. As habitat does not appear to be limiting the growth of North Slope caribou herds, the Central Arctic Herd has been able to accommodate the incremental habitat loss due to the oil field and has shown a sevenfold increase in numbers since the oil field development began in the early 1970s. Offshore monitoring data for the gravel causeways verify the predicted small, localized effects on water circulation and show the possibility is low that fish are experiencing resulting significant negative effects.

The challenge faced in the EIS process is not how to ensure zero impact, as this is not a realistic goal, but instead it is how to predict impacts and describe mitigation measures accurately to ensure that the resultant ecological responses remain within a normal range of ecosystem oscillations that can be used to describe sustainable development. This review demonstrates that in the EIS process, a well-designed program using the best available field data can indeed provide a relatively accurate prediction of subsequent impacts.

Mikkelsen, A., and O. Langhelle. 2011. Arctic oil and gas: sustainability at risk? Taylor and Francis.

incomplete citation

NRC (National Research Council). 1983. Research and information needs for management of onshore Arctic oil and gas operations on federal lands. Washington, D.C.: National Research Council, Committee on Onshore Energy Minerals Management Research. https://www.nap.edu/download/19489

Summary – Although Arctic Alaska is a huge and isolated region within a severe environment, a great deal has been learned over the past 15 years on how to lessen the impact of industrial development. The Prudhoe Bay and Kuparuk oil fields and the pipeline and haul road systems have been built and are operating so that there is minimal environmental and ecological impact. Any future research on these topics should be undertaken only after the development and evaluation of thorough case histories of this existing complex system. This report highlights general and specific research needs expressed by the industrial, environmental and biological experts who participated in the workshop. In aggregate, the research outlined here relates more to intent than to primary needs, and much of it is presented with the intent of reducing the economic impact of building and maintaining petroleum facilities.

Environmental Descriptions, Relevant Ecological Theory, Multiple Species and/or Asessments and Impact Evaluations

AFWRC (Alaska Fish and Wildlife Research Center). 1988. Research study plans: research on the potential effects of petroleum development on wildlife and their habitats, Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

[Editor's note – there is only a single, unscanned copy of this document in the administrative record for the coastal plain 1002 area legislative EIS].

Executive Summary – The *Arctic National Wildlife Refuge, Alaska, Coastal Plain Resources Assessment: Report and Recommendation to the Congress of the United States and Final Legislative Environmental Impact Statement* summarizing the potential impacts of petroleum development on wildlife resources of Arctic Refuge concluded that potential adverse effects would be significant on caribou and muskox and moderate on polar bears [unlisted at the time] and Lesser Snow Geese (Pp. 105ff : Clough et al. 1987). Most adverse effects on these species would result from displacement of animals from traditional use areas due to loss of habitat or, more frequently, from avoidance or abandonment of preferred habitat due to disturbance by activities associated with development, e.g., traffic along roads and overflights by aircraft. Unique characteristics of behavior, distribution, or habitat requirements contributes to the vulnerability of these species to loss of or inaccessibility to preferred habitat. Although there is substantial evidence and broad consensus that petroleum development on the Arctic Refuge will result in some adverse effects on these key species, there is widely divergent opinions as to the significance of these effects on populations.

Because of national and international implications regarding petroleum development on wildlife populations, the Alaska Fish and Wildlife Research Center (AFWRC) in cooperation with Arctic Refuge, ADF&G, UAF, Canadian Wildlife Service (CWS), and Yukon and Northwest Territory Departments of Renewable Resources have developed an integrated research program addressing major concerns for key species and their habitats. This document provides a summary of research to be funded and conducted by the AFWRC. Additional studies related to the petroleum activities on the 1002 area will be funded and conducted by the Service and cooperating agencies.

The AFWRC study program is divided into six Work Units – two on caribou, and one each on muskox, Lesser Snow Geese and habitats. A brief executive summary of objectives, background, methods and supplementary data is attached for each Work Unit. Target dates and products within each Work Unit are designed to address the issues identified in the *Coastal Plain Report* and provide recommendations during the leasing, exploration, and development phases.

- Potential impacts of petroleum exploration and development on the numbers, distribution and status of caribou on the Arctic coastal plain

- Habitat requirements and potential impacts of oil development on caribou

- The distribution and seasonal quality of habitat available for key wildlife species [caribou, muskox, polar bear, Lesser Snow Goose] of the Arctic coastal plain

- Potential effects of petroleum exploration and development on muskox using the 1002 area

- Impact of oil exploration and development on polar bears using the Arctic Refuge and adjacent areas

- Potential impacts of petroleum development on Lesser Snow Geese staging on the Arctic Refuge in fall

Allen, C.R., G.S. Cumming, A.S. Garmestani, P.D. Taylor, and B.H. Walker. 2011. Managing for resilience. Wildlife Biology 17:337-349. http://www.bioone.org/doi/pdf/10.2981/10-084

Abstract - Early efforts in wildlife management focused on reducing population variability and maximizing yields of selected species. Later, Aldo Leopold proposed the concept of habitat management as superior to population management, and more recently, ecosystem management, whereby ecological processes are conserved or mimicked, has come into favor. Managing for resilience builds upon these roots, and focuses on maintaining key processes and relationships in social-ecological systems so that they are robust to a great variety of external or internal perturbations at a range of ecological and social scales. Managing for resilience focuses on system-level characteristics and processes, and the endurance of system properties in the face of social or ecological surprise. Managing for resilience consists of actively maintaining a diversity of functions and homeostatic feedbacks, steering systems away from thresholds of potential concern, increasing the ability of the system to maintain structuring processes and feedbacks under a wide range of conditions, and increasing the capacity of a system to cope with change through learning and adaptation. The critical aspect of managing for resilience, and therefore ecosystem management, is undertaking adaptive management to reduce uncertainty and actively

managing to avoid thresholds in situations where maintaining resilience is desired. Managing adaptively for resilience is the approach best suited for coping with external shocks and surprises given the non-linear complex dynamics arising from linked social-ecological systems.

Barber, V.A., G.P. Juday, T. Osterkamp, R. D'Arrigo, E. Berg, B. Buckley, L. Hinzman, H. Huntington, T. Jorgensen, A.D. McGuire, B. Riordan, A. Whiting, G. Wiles, and M. Wilmking. 2009. A synthesis of recent climate warming effects on terrestrial ecosystems of Alaska. Pp. 110-139 in F. Wagner (ed.), Climate warming in western North America: evidence and environmental effects. Salt Lake City, UT; University of Utah Press. http://www.sel.uaf.edu/manuscripts/bk20_VBarber-2009BookChapterReprint.pdf

Abstract – The instrument-based climate record in Alaska displays a strong late-twentieth-century warming. Climate in Alaska also displays a record of sudden regime shifts. Precipitation there is highly variable and shows no strong trends. Effective moisture (P-PET), however, has decreased, resulting in widespread shrinkage and drying of lakes and ponds in regions of low or moderate precipitation. Overall, glacial mass balance is negative, and most show ice margin retreat, although some glacial systems are in positive mass balance. Permafrost is warming across the state, and ground subsidence associated with thawing of ice-rich permafrost is commonly observed. Since buildings and infrastructure, as well as natural disturbances, can cause warming of permafrost, it is difficult to distinguish from climatic warming in some cases. The annual period of snow and ice cover is decreasing, and growing season is increasing in length with greater normalized difference vegetation index (NDVI) greenness in the tundra region. North of the Brooks Range, tall shrubs have advanced into the tundra, and warming experiments show that low shrub cover would significantly increase with additional warming. White spruce populations at treeline include trees that grow more with warming as well as others that grow less with warming. Major species in the boreal forest region also include populations with similar responses, but growth on many of the most productive sites has declined. Recent high temperatures have caused widespread tree stress. Major outbreaks of tree-damaging insects have occurred due to both tree stress and direct temperature controls on insects. Millions of acres of beetle-killed trees on the Kenai Peninsula are a potential fire hazard. The extent of forest fires in Alaska is positively associated with specific temperature factors. These changes are confronting people with a variety of challenges, ranging from obtaining subsistence food and potable water to maintaining health and safety. Scenarios of future Alaska climate produced by general circulation models project significant future warming, which would exceed the apparent tolerance of some component species of current ecosystems.

Batten, J. 2004. When good animals love bad habitats: ecological traps and the conservation of animal populations. Conservation Biology 18(6):1482-1491. http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2004.00417.x/pdf

Abstract - The concept of the ecological trap, a low-quality habitat that animals prefer over other available habitats of higher quality, has appeared in the ecological literature irregularly for over 30 years, but the topic has received relatively little attention, and evidence for traps remains largely anecdotal. Recently, however, the ecological trap concept has been the subject of a flurry of theoretical activity that is likely to raise its profile substantially, particularly in conservation biology. Ecological trap theory suggests that, under most circumstances, the presence of a trap in a landscape may drive a local population to extinction. A number of empirical studies, almost all of birds, suggest the existence of traps and demonstrate the difficulties of recognizing them in the field. Evidence for ecological traps has primarily been found in habitats modified by human activities, either directly (e.g.,

through the mowing of grassland birds' nests) or indirectly (e.g., via human-mediated invasion of exotic species), but some studies suggest that traps may occur even in relatively pristine areas. Taken together, these theoretical and empirical results suggest that traps may be relatively common in rapidly changing landscapes. It is therefore important for conservation biologists to be able to identify traps and differentiate them from sinks. Commonly employed approaches for population modeling, which tend to assume a source-sink framework and do not consider habitat selection explicitly, may introduce faulty assumptions that mask the effects of ecological traps and lead to overly optimistic predictions about population persistence. Given the potentially dire consequences of ecological traps and the accumulating evidence for their existence, greater attention from the community of conservation biologists is warranted. In particular, it is important for conservation biologists and managers to incorporate into conservation planning an explicit understanding of the relationship between habitat selection and habitat quality.

BC [British Columbia] Oil and Gas Commission. 2017. Environmental protection and Management Guideline, Version 2.4. St. John, British Columbia: BC Oil and Gas Commission. https://www.bcogc.ca/node/5899

About - The Environmental Protection and Management Guideline is intended as a reference document for oil and gas applicants and permit holders. The guideline was developed to assist oil and gas companies and those potentially impacted by oil and gas activities to understand the requirements of the Environmental Protection and Management Regulation (EPMR). This guideline is not intended to take the place of the applicable legislation. It outlines the minimum legal requirements for environmental protection and management. Users are encouraged to read the full text of legislation applicable to each section.

The guideline has been prepared to be as comprehensive as possible; however it is not all encompassing and may not cover all situations. Where circumstances or scenarios arise that are not covered by this guideline, contact Commission staff for clarification and assistance.

Guideline Structure - This guideline is organized to closely reflect the structure and order of the Environmental Protection and Management Regulation (EPMR)

- Chapter1: Permit Considerations and Directions
- Chapter 2: Operating Area Requirements
- Chapter 3: Adjacent Areas
- Chapter 4: Classification, Identification and Establishment
- Appendix A: Definitions and Application
- Appendix B: Mitigation Planning
- Appendix C: Restoration and Reclamation
- Appendix D: High Priority Wildlife
- Appendix E: Relevant Legislation and Regulatory Requirements
- Appendix F: References

Guideline Scope - The EPMR applies only to Crown land and does not apply to subsurface oil and gas activities associated with an operating area (defined in the EPMR as a seismic line, wellsite, facility area and pipeline corridor). The regulation does not apply to private land. The guidance herein also applies to surface Crown land only. This includes stream crossings on private land that were not included as part of the original Crown land grant. The best management practices (BMPs) found in earlier versions of this guideline has been removed from this version, or in some cases, retained as Appendices. The EPMR is a results-based regulation, operating under the professional-reliance model of the Oil and Gas Activities Act (OGAA).

OGAA and its associated regulations specify the requirements that must be followed in applying for and conducting oil and gas activities. It is the responsibility of applicants and their qualified professionals to identify and apply the best technique, method or best management practice to meet the requirement.

This guideline is limited in scope to the Commission's application processes and the authorities and requirements established within OGAA or specified enactments established thereunder. Carrying out oil and gas and related activities may require additional approvals from other regulators or create obligations under other statutes. It is the permit holder's responsibility to know and uphold all of their legal obligations.

Beaubien, D., and J.C. Truett. 1990. Effects of habitat disturbance on Arctic wildlife: a review and analysis, final report. Anchorage, AK: LGL Alaska Research Associates for BP Exploration (Alaska) Inc. https://ecos.fws.gov/ServCat/DownloadFile/132210?Reference=86946

Executive Summary

- The major habitat disturbances caused by human activities in arctic tundra areas fall generally into 3 categories: (1) gravel fill; (2) disruptions of the tundra surface; and, (3) impoundments of water. In a highly-developed oilfield such as Prudhoe Bay, these disturbances may cover nearly 10% of the total landscape. In other areas, smaller percentages are involved.

- The introduction of gravel fill covers the existing vegetation and creates a landscape that is higher and drier than the original. Disrupting the tundra surface (by vehicle traffic, removal of vegetation, contaminant releases, etc.) and impounding water usually cause the reverse; a wet, more pond-dominated landscape which thermokarsts and becomes even wetter over time.

- These landscape changes lead to marked changes in the vegetation. On gravel fill surfaces, plants establish themselves slowly and their productivity (i.e. rate of growth) remains low for many years though recovery is often accelerated proactive management. Where surface disruptions or impoundments exist, soil warming and thermokarst speed up soil nutrient cycling, and plant productivity increases (Fig. 1).

- Arctic wildlife populations may be affected if these disturbances alter their food supplies, breeding (nesting) places, or vulnerability to predators. Similarities in habitat dependencies among species have allowed us to simplify analyses of these effects by grouping species into species assemblages (guilds) within which species respond somewhat similarly to given habitat disturbances.

Guild	Common Species or Groups
Tundra herbivores	caribou, muskox, Tundra Swan,

	geese, ptarmigan
Tundra invertebrate feeders	most shorebirds, Lapland Longspur
Pond invertebrate feeders	Pacific Loon, some ducks, some shorebirds
Lemming-eaters	Arctic Fox, Snowy Owl, jaegers
Juveniles sensitive to predation	most birds
Tundra nesters	most ducks, Greater White-fronted Goose, Black Brant, shorebirds, Lapland Longspur, ptarmigan
Pond nesters	some ducks, Canada Goose, Black Brant
High-ground denners	Arctic Fox, Arctic ground squirrel

- Gravel fill probably degrades habitat quality for most of these guilds except perhaps pond nesters (fill is typically not placed in ponds) and high-ground denners (foxes and ground squirrels den in gravel fill). Most adverse effects decrease with time as gravel fill surfaces become vegetated naturally or with human help.

- Surface disruptions and impoundments may benefit some tundra herbivores, tundra and pond invertebrate feeders, and pond nesters, but may be detrimental to tundra nesters. These potential benefits may decrease with time as the altered soil and water regimes stabilize.

- A few species may suffer habitat degradation from all types of disturbances, a few others seem to benefit from all disturbances, and others seem to be affected very little either way.

- Generally speaking, changes induced by gravel fill frequently have effects on wildlife habitat value that are the opposite of changes that result from surface disruptions or impoundments. Short-term influences of gravel fill on habitat values for most species are preferably negative; within the same time frame, surface disruptions or impoundments seem to enhance the habitat value for many species.

- The information reviewed supports the following generalized model of effects of oilfield disturbances on wildlife feeding and breeding habitat. As with all simplifications, there are exceptions and qualifications.

General Effects of Oilfield Disturbances on Wildlife Habitats

Habitat user (wildlife guild)	Effects of gravel fill (Assume none in ponds)	Surface disruptions & impoundments
Tundra herbivore	Negative	Positive
Tundra invertebrate feeders	Negative	Positive
Pond invertebrate feeders	Little Effect	Positive
Lemming-eaters	Little Effect	Little Effect
Predator-sensitive eggs/young	Little Effect	Little Effect

Tundra nesters	Negative	Negative
Pond nesters	Little Effect	Positive
High-ground denners	Positive	Little Effect

- If impacts of all kinds of man-induced disturbances to wildlife habitats could be summed in terms of potential effects, some species populations might suffer, others would probably benefit, and some would probably not show appreciable responses either way. Because of the usually small percentages of landscapes disturbed, and the tendency for the effects of some disturbances to counter the effects of others, responses of regional wildlife populations will undoubtedly be difficult to measure.

- Information collected to date is insufficient to quantify how most species populations have responded to habitat disturbances. Additional impact analysis research and testing of rehabilitation procedures are needed if impacts of habitat disturbance are to be quantified.

Becker, M.S., and W.H. Pollard. 2016. Sixty-year legacy of human impacts on a high Arctic ecosystem. Journal of Applied Ecology 53(3):876-884. http://onlinelibrary.wiley.com/doi/10.1111/1365-2664.12603/epdf

Summary

1. The high Arctic is the world's fasting warming biome, allowing access to sections of previously inaccessible land for resource extraction. Starting in 2011, exploration of one of the Earth's largest undeveloped coal seams was initiated in a relatively pristine, polar desert environment in the Canadian high Arctic. Due to the relative lack of historic anthropogenic disturbance, significant gaps in knowledge exist on how the landscape will be impacted by development.

2. At an abandoned airstrip located near the area of current exploration, we used a disturbance case–control approach to evaluate the long-term ecological consequences of high Arctic infrastructure disturbance to vegetation and sensitive, ice-rich permafrost. We quantified: (i) long-term effects on vegetation diversity, soil nutrients and abiotic ground conditions and (ii) the alteration of the ground surface topography and legacy of subsurface thermal changes.

3. **We found that in over 60 years since abandonment, the disturbed landscape has not recovered to initial conditions but instead reflects a disturbance-initiated succession towards a different stable-state community**.

4. Microtopography greatly influenced recovery patterns in the landscape. The terrain overlaying buried ice (ice-wedge polygon troughs) was the most sensitive to disturbance and had a different species composition, decreased plot-level species richness, significant increases in vegetation cover and a drastically reduced seasonal fluctuation in subsurface temperatures. In contrast, disturbed polygon tops showed resiliency in vegetation recovery, but still had remarkable increases in depth of seasonal soil thaw (active layer).

5. *Synthesis and applications*. Our results indicate that disturbance effects differ depending on microtopographic features, leading to an increased patchiness of the landscape as

found elsewhere in the Arctic. Managers who wish to lessen their impact on high Arctic environments should avoid areas of sensitive, ice-rich permafrost, constrain the geographic scale of near-surface ground disturbance, limit vegetation removal where possible and reseed disturbed areas with native species.

Beever, E.A., and J.L. Belant. 2012. Ecological consequences of climate change: mechanisms, conservation, and management. Boca Raton, FL: CRC Press.

Bliss, L.C., and K.M. Gustafson. 1981. Proposed ecological natural landmarks in the Brooks Range, Alaska. Seattle, WA: University of Washington.

Bliss, L.C., O.W. Heal, and J. Moore. 1981. Tundra ecosystems: a comparative analysis. New York, NY: Cambridge University Press, International Biological Programme 25.

Blumpton, A.K., R.B. Owen, Jr., and W.B. Krohn. 1988. Habitat suitability index models: American [Common] Eider (breeding). Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Office of Biological Services FWS/OBS-82/10.149. https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-149.pdf

Editor's Note – HSI developed for Common Eider (*Somateria mollissima dresseri*) and Maine coastal islands, with broader application to the entire breeding distribution for the subspecies. Use caution in Arctic applications but model components may prove useful for developing site-specific models. Model habitat requirements include (1) cover (nesting and non-nesting); (2) food and foraging habitat; and, (3) special considerations: interspecific aspects particularly egg/chick depredation, human disturbance, disease, and oil pollution.

BLM (Bureau of Land Management). 2016. North Slope rapid ecological assessment: manager's summary. Fairbanks, AK: U.S. Department of the Interior, Bureau of Land Management. http://accs.uaa.alaska.edu/files/rapid-ecoregional-assessments/north-slope/NorthSlope_REA_ManagerSummary.pdf

Brown, J. 1975. Ecological investigations of the tundra biome in the Prudhoe Bay region, Alaska. Biological Papers of the University of Alaska, Special Report No. 2.

Abstract - During the period 1970-1974, the U.S. Tundra Biome Program, which was stationed primarily out of Barrow, performed a series of environmental and terrestrial ecological studies at Prudhoe Bay. This volume reports specifically on the Prudhoe results and is divided into three major subdivisions: (1) abiotic and soil investigations; (2) plant investigations, and (3) animal investigations. The abiotic section contains papers on the air and soil temperature regimes; the snow cover, particularly its properties adjacent to the road system; major soil and landform associations, and the chemical composition of soils, runoff, lakes, and rivers. The plant section contains reports on a general vegetation survey; a follow-up vegetation mapping project, and a study of the growth of arctic, boreal, and alpine biotypes in an experimental transplant garden. The animal section contains reports on the tundra invertebrates; the bird, lemming, and fox populations, and the behavioral and physiological investigations of caribou and several experimental reindeer. Appendices contain a checklist of the vascular, bryophyte, and lichen flora of the Prudhoe Bay area and selected data on vegetation. Several of the papers draw comparisons with the Barrow tundra.

The volume includes a considerable number of tables in its attempt to document for the first time the abiotic, flora, and fauna of this relatively unknown arctic tundra landscape.

Brown, J., P.C. Miller, L.L. Tieszen, and F.L. Bunnell. 1980. An Arctic ecosystem: coastal tundra at Barrow, Alaska. Stroudsburg, PA: Dowden, Hutchinson and Ross, US/IBP Synthesis Series 12.

CAFF (Conservation of Arctic Flora and Fauna). 2010. Arctic biodiversity trends – 2010 selected indicators of trends. Helsinki: Conservation of Arctic Flora and Fauna, Arctic Biodiversity Assessment. https://www.caff.is/assessment-series/162-arctic-biodiversity-trends-2010-selected-indicators-of-change

Quotes – from *Population/ecosystem status and trends*. Currently wild reindeer and caribou have declined by about 33% since populations peaked in the 1990s and early 2000s (3.8 million compared to 5.6 million) which followed almost universal increases in the 1970s and 1980s. The declines are likely natural cycles, driven by continental and perhaps global atmospheric changes in combination with changing harvest practices and industrial developments. Regionally, there is a tendency for herds to show a measure of synchrony in their phases of increase and decrease. For example, currently all 7 of the major migratory tundra herds in Canada's Northwest Territories and Nunavut are declining from highs in the late 1980s/early 1990s, with 4 of these herds having decreased by 75% or more in 2009 than in the 1990s. In neighboring Alaska, the 2 larger herds are declining including the well-known Porcupine herd, while 2 smaller coastal herds are still increasing from the 1970s.

More is known about the status of caribou in Alaska than elsewhere as monitoring is more frequent. Of Alaska's 24 southern and interior herds where trends are known, 16 are declining, 6 are stable, and 2 are increasing. In Nunavut, the status of the several smaller herds on the northeast mainland and Baffin Island is unknown as the herds are not monitored. East of Hudson Bay, close to 1 million caribou from 2 herds occupy the Ungava Peninsula. Over the last 20 years, total numbers for both herds have decreased. …

The major stressors contributing to recent declines vary between individual herds. Generally, *Rangifer* in the far north, notably the Peary caribou in Canada and the marine reindeer in Russia, have been impacted by severity of local weather, primarily fall to spring icing. For the migratory mainland herds, continental climate trends are implicated, with current climatic changes likely exacerbating natural cycles and forcing lower population troughs and/or slowing the recovery period for some herds. Increased human activity and industrial development are also implicated in the declines of many herds, particularly in the more southern ones. The small mountain herds in Norway, for example, are affected by habitat fragmentation resulting from hydroelectric projects, roads, and recreational activities. In Russia and western Alaska, the overlap between wild and domestic reindeer, with the subsequent loss of domestic stock, undoubtedly complicates or masks normal wild reindeer or caribou trends. For of all these herds, as population numbers decline, the impact of harvesting increases and in many cases may promote further declines and delay recovery.

CAFF (Conservation of Arctic Flora and Fauna). 2013a. Arctic biodiversity assessment: status and trends in Arctic biodiversity. Helsinki: Conservation of Arctic Flora and Fauna, Arctic Biodiversity Assessment. https://www.caff.is/assessment-series/arctic-biodiversity-assessment/233-arctic-biodiversity-assessment-2013

CAFF (Conservation of Arctic Flora and Fauna). 2013b. Arctic biodiversity assessment: report for policy makers. Akureyri, Iceland; Conservation of Arctic Flora and Fauna. http://www.arcticbiodiversity.is/thereport/report-for-policy-makers

Key Findings

- 1 - Arctic biodiversity is being degraded, but decisive action taken now can help sustain vast, relatively undisturbed ecosystems of tundra, mountains, fresh water and seas and the valuable services they provide.

- 2 - Climate change is by far the most serious threat to Arctic biodiversity and exacerbates all other threats.

- 3 - Many Arctic migratory species are threatened by overharvest and habitat alteration outside the Arctic, especially birds along the East Asian flyway.

- 4 - Disturbance and habitat degradation can diminish Arctic biodiversity and the opportunities for Arctic residents and visitors to enjoy the benefits of ecosystem services.

- 5 - Pollution from both long-range transport and local sources threatens the health of Arctic species and ecosystems.

- 6 - There are currently few invasive alien species in the Arctic, but more are expected with climate change and increased human activity.

- 7 - Overharvest was historically the primary human impact on many Arctic species, but sound management has successfully addressed this problem in most, but not all, cases.

- 8 - Current knowledge of many Arctic species, ecosystems and their stressors is fragmentary, making detection and assessment of trends and their implications difficult for many aspects of Arctic biodiversity.

- 9 - The challenges facing Arctic biodiversity are interconnected, requiring comprehensive solutions and international cooperation.

Recommendations

Large tracts of the Arctic remain relatively undisturbed providing an opportunity for proactive action that can minimize or even prevent future problems that would be costly, or impossible, to reverse. The key findings of the ABA are interrelated and responding to them would benefit from a holistic approach. When taken together, three cross-cutting themes are evident:

- the significance of climate change as the most serious underlying driver of overall change in biodiversity;

- the necessity of taking an ecosystem-based approach to management; and

- the importance of mainstreaming biodiversity by making it integral to other policy fields, for instance by ensuring biodiversity objectives are considered in development standards, plans and operations.

A comprehensive and integrated approach is needed to address the interconnected and complex challenges facing biodiversity and to ensure informed policy decisions in a changing Arctic. In addition to many Arctic Council initiatives underway, there are other conventions and processes addressing these cross-cutting themes and many of the individual stressors acting on biodiversity. This includes many regulatory and non-regulatory measures that are in place or under development to provide consistent standards and/or approaches to development in the Arctic. Many of these can, or do, provide safeguards for biodiversity.

Care was taken in the development of the ABA recommendations to review recommendations from other major Arctic Council initiatives. Many of the recommendations overlap and are mutually supportive, emphasizing the importance of considering all recommendations together. Some of the ABA recommendations reinforce the significance to biodiversity of recommendations or actions already underway, others build upon existing recommendations or processes, and others are more specifically focused on biodiversity issues.

All are important to ensure the conservation of Arctic species, ecosystems and the services they provide.

Climate change

1. Actively support international efforts addressing climate change, both reducing stressors and implementing adaptation measures, as an urgent matter. Of specific importance are efforts to reduce greenhouse gas emissions and to reduce emissions of black carbon, methane and tropospheric ozone precursors.

2. Incorporate resilience and adaptation of biodiversity to climate change into plans for development in the Arctic.

Ecosystem-based management

3. Advance and advocate ecosystem-based management efforts in the Arctic as a framework for cooperation, planning and development. This includes an approach to development that proceeds cautiously, with sound short and long-term environmental risk assessment and management, using the best available scientific and traditional ecological knowledge, following the best environmental practices, considering cumulative effects and adhering to international standards.

Mainstreaming biodiversity

4. Require the incorporation of biodiversity objectives and provisions into all Arctic Council work and encourage the same for on-going and future international standards, agreements, plans, operations and/or other tools specific to development in the Arctic. This should include, but not be restricted to, oil and gas development, shipping, fishing, tourism and mining.

Identifying and safeguarding important areas for biodiversity

5. Advance the protection of large areas of ecologically important marine, terrestrial and freshwater habitats, taking into account ecological resilience in a changing climate.

a. Build upon existing and on-going domestic and international processes to complete the identification of ecologically and biologically important marine areas and implement appropriate measures for their conservation.

b. Build upon existing networks of terrestrial protected areas, filling geographic gaps, including underrepresented areas, rare or unique habitats, particularly productive areas such as large river deltas, biodiversity hotspots, and areas with large aggregations of animals such as bird breeding colonies, seal whelping areas and caribou calving grounds.

c. Promote the active involvement of indigenous peoples in the management and sustainable use of protected areas.

6. Develop guidelines and implement appropriate spatial and temporal measures where necessary to reduce human disturbance to areas critical for sensitive life stages of Arctic species that are outside protected areas, for example along transportation corridors. Such areas include calving grounds, den sites, feeding grounds, migration routes and molting areas. This also means safeguarding important habitats such as wetlands and polynyas.

7. Develop and implement mechanisms that best safeguard Arctic biodiversity under changing environmental conditions, such as loss of sea ice, glaciers and permafrost.

a. Safeguard areas in the northern parts of the Arctic where high Arctic species have a relatively greater chance to survive for climatic or geographical reasons, such as certain islands and mountainous areas, which can act as a refuge for unique biodiversity.

b. Maintain functional connectivity within and between protected areas in order to protect ecosystem resilience and facilitate adaptation to climate change.

<u>Addressing individual stressors on biodiversity</u>

8. Reduce stressors on migratory species range-wide, including habitat degradation and overharvesting on wintering and staging areas and along flyways and other migration routes.

a. Pursue or strengthen formal migratory bird cooperation agreements and other specific actions on a flyway level between Arctic and non-Arctic states with first priority given to the East Asian flyway.

b. Collaborate with relevant international commissions, conventions, networks and other organizations sharing an interest in the conservation of Arctic migratory species to identify and implement appropriate conservation actions.

c. Develop and implement joint management and recovery plans for threatened species with relevant non-Arctic states and entities.

d. Identify and advance the conservation of key wintering and staging habitats for migratory birds, particularly wetlands.

9. Reduce the threat of invasive alien/non-native species to the Arctic by developing and implementing common measures for early detection and reporting, identifying and blocking pathways of introduction, and sharing best practices and techniques for monitoring,

eradication and control. This includes supporting international efforts currently underway, for example those of the International Maritime Organization to effectively treat ballast water to clean and treat ship hulls and drilling rigs.

10. Promote the sustainable management of the Arctic's living resources and their habitat.

a. Improve circumpolar cooperation in data gathering and assessment of populations and harvest and in the development of improved harvest methods, planning, and management. This includes improving the use and integration of traditional ecological knowledge and science in managing harvests and in improving the development and use of community-based monitoring as an important information source.

b. Develop pan-Arctic conservation and management plans for shared species that are, or will potentially be, harvested or commercially exploited that incorporate common monitoring objectives, population assessments, harvesting regimes, guidelines for best practices in harvest methodology and consider maintenance of genetic viability and adaptation to climate change as guiding principles.

c. Support efforts to plan and manage commercial fisheries in international waters under common international objectives that ensure long-term sustainability of species and ecosystems. Encourage precautionary, science-based management of fisheries in areas beyond national jurisdiction in accordance with international law to ensure the long-term sustainability of species and ecosystems.

d. Support efforts to develop, improve and employ fishing technologies and practices that reduce bycatch of marine mammals, seabirds and non-target fish and avoid significant adverse impact to the seabed.

e. Develop and implement, in cooperation with reindeer herders, management plans that ensure the sustainability of reindeer herding and the quality of habitat for grazing and calving.

11. Reduce the threat of pollutants to Arctic biodiversity.

a. Support and enhance international efforts and cooperation to identify, assess and reduce existing and emerging harmful contaminants.

b. Support the development of appropriate prevention and clean up measures and technologies that are responsive to oil spills in the Arctic, especially in ice-filled waters, such that they are ready for implementation in advance of major oil and gas developments.

c. Encourage local and national action to implement best practices for local wastes, enhance efforts to clean-up legacy contaminated sites and include contaminant reduction and reclamation plans in development projects.

<u>Improving knowledge and public awareness</u>

12. Evaluate the range of services provided by Arctic biodiversity in order to determine the costs associated with biodiversity loss and the value of effective conservation in order to assess change and support improved decision making.

13. Increase and focus inventory, long-term monitoring and research efforts to address key gaps in scientific knowledge identified in this assessment to better facilitate the development and implementation of conservation and management strategies. Areas of particular concern identified through the ABA include components critical to ecosystem functions including important characteristics of invertebrates, microbes, parasites and pathogens.

14. Recognize the value of traditional ecological knowledge and work to further integrate it into the assessment, planning and management of Arctic biodiversity. This includes involving Arctic peoples and their knowledge in the survey, monitoring and analysis of Arctic biodiversity.

15. Promote public training, education and community-based monitoring, where appropriate, as integral elements in conservation and management.

16. Research and monitor individual and cumulative effects of stressors and drivers of relevance to biodiversity, with a focus on stressors that are expected to have rapid and significant impacts and issues where knowledge is lacking. This should include, but not be limited to, modeling potential future species range changes as a result of these stressors; developing knowledge of and identifying tipping points, thresholds and cumulative effects for Arctic biodiversity; and developing robust quantitative indicators for stressors through the Circumpolar Biodiversity Monitoring Program.

17. Develop communication and outreach tools and methodologies to better convey the importance and value of Arctic biodiversity and the changes it is undergoing.

Conclusion - Arctic biodiversity is a unique global asset, and it faces numerous serious threats. In a world where habitat degradation and species loss are increasingly prevalent, the scarcity and value of intact ecosystems and healthy species are increasing. The Arctic is one of the largest relatively undisturbed physical and ecological systems remaining on Earth, providing a rare opportunity to maintain the ecological integrity of an entire biome. Humans have a responsibility to make Arctic biodiversity conservation a priority and sustainable development in the Arctic a reality.

Many Arctic species and habitats exist nowhere else on Earth. Millions of migratory birds connect the Arctic with the entire globe and uniquely adapted marine mammal species swim in Arctic seas. Arctic peoples continue to live in this extreme environment, using innovations and knowledge to thrive far removed from humanity’s tropical origins. Unlike in much of the rest of the world, which has been developed and settled by large numbers of people, biodiversity in the Arctic remains largely intact.

Yet, as humans are increasingly drawn to and inspired by the beauty and potential of the Arctic, as we increasingly harvest its fish to feed ever-growing populations, as we increasingly exploit its minerals and petroleum, as we increasingly route our ships through its waters and especially as our actions alter its climate, Arctic biodiversity is no longer being left alone to take care of itself. As we recognize the unique values of the Arctic and its critical importance to the earth’s oceanographic, atmospheric and biological systems, we must also take on the global responsibility to sustain the Arctic and its biodiversity for ourselves and our descendants. Without the Arctic’s biodiversity and the services it provides, the world will be a far poorer place. With the Arctic’s biodiversity, humans can demonstrate a commitment to the beauty, mystery and indispensable importance of biodiversity in our world.

Cooper, E.J. 2014. Warmer shorter winters disrupt Arctic terrestrial ecosystems. Annual Review of Ecology, Evolution, and Systematics 45(1):271-295. https://doi.org/10.1146/annurev-ecolsys-120213-091620

Abstract - The Earth is warming, especially in polar areas in which winter temperatures and precipitation are expected to increase. Despite a growing research focus on winter climatic change, the impacts on Arctic terrestrial ecosystems remain poorly understood. Snow acts as an insulator, and depth changes affect the enhancement of thermally dependent reactions, such as microbial activity, affecting soil nutrient composition, respiration, and winter gas efflux. Snow depth and spring temperatures influence snowmelt timing, determining the start of plant growth and forage availability. Delays in winter onset affect tundra carbon balance, faunal hibernation, and migration but are unlikely to lengthen the plant growing season. Mild periods in winter followed by a return to freezing have negative consequences for plants and invertebrates, and the resultant ice layers act as barriers to foraging, triggering starvation of herbivores and their predators. In summary, knock-on effects between seasons and trophic levels have important consequences for biological activity, diversity, and ecosystem function.

Croonquist, M.J., and R.P. Brooks. 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian-wetland areas. Environmental Management 15(5):701-714. https://link.springer.com/article/10.1007/BF02589628

Abstract - A new method of assessing cumulative effects of human activities on bird and mammal communities of riparian-wetland areas was developed by using response guilds to reflect how species theoretically respond to habitat disturbance on a landscape level. All bird and mammal species of Pennsylvania were assigned values for each response guild using documented information for each species, to reflect their sensitivity to disturbances; high guild scores corresponded to low tolerance toward habitat disturbance. We hypothesized that, given limited time and resources, determining how wildlife communities change in response to environmental impacts can be done more efficiently with a response-guild approach than a single-species approach. To test the model, censuses of birds and mammals were conducted along wetland and riparian areas of a protected and a disturbed watershed in central Pennsylvania. The percent of bird species with high response-guild scores (i.e., species that had specific habitat requirements and/or were Neotropical migrants) remained relatively stable through the protected watershed. As intensity of habitat alteration increased through the disturbed watershed, percentage of bird species with high response-guild scores decreased. Only 2%–3% of the Neotropical migrants that had specific habitat requirements were breeding residents in disturbed habitats as compared to 17%–20% in reference areas. Species in the edge and exotic guild classifications (low guild scores) were found in greater percentages in the disturbed watershed. Composition of mammalian guilds showed no consistent pattern associated with habitat disturbance. Avian response guilds reflected habitat disturbance more predictively than mammalian response guilds.

Deneke, F.J., B.H. McCown, P.I. Coyne, W. Rickard, and J. Brown. 1975. Biological aspects of terrestrial oil spills: USA CRREL oil research in Alaska, 1970-1974; final report. U.S. Army Cold Regions Research and Engineering Laboratory, Research Report 346. https://ia801904.us.archive.org/28/items/DTIC_ADA047365/DTIC_ADA047365.pdf

Abstract – Knowledge concerning the biological effects of oil pollution on Arctic and subarctic terrestrial ecosystems is limited. USACE CRREL research personnel conducted investigations from 1970-1974 to expand information in this field. Objectives were to: (1)

define the ecosystems most sensitive to the presence of crude oil or its refined products, (2) quantify and understand the injury response, and (3) establish time frames for manifestation of damage and natural restorative processes in Arctic and subarctic regions. This was accomplished through: (1) surveys of natural oil seepages and pact accidental spills in the Arctic and subarctic, (2) initiation of controlled oil spills and (3) detailed laboratory investigations. Results demonstrated that terrestrial oil spills will to some degree be detrimental to both Arctic and subarctic plant communities. Degrees and longevity of damages will be influenced by the magnitude of the still, season of occurrence and existing soil moisture content. Rapid recovery of plant communities subjected to spills will occur only if root systems remain relatively unaffected. Damage will be more extensive and long-term when root systems are saturated with oil. Effects of damage will be manifested gradually over several seasons being influenced by winter stresses. Variation does exist in plant species susceptibility. *Carex aquatilis*, a predominant sedge of the Arctic is markedly resistant to crude oil damage. In the tiage, *Picea mariana* is very susceptible. Plant recovery can be enhanced through the applications of fertilizer. Fertilization, in addition to its direct effect on plant nutrition, will stimulate microbial decomposition of crude oil.

Franklin, A.B., B.R. Noon, and T.L. George. 2002. What is habitat fragmentation? Studies in Avian Biology 25:20-29.

<u>Abstract</u> - Habitat fragmentation is an issue of primary concern in conservation biology. However, both the concepts of habitat and fragmentation are ill-defined and often misused. We review the habitat concept and examine differences between habitat fragmentation and habitat heterogeneity, and we suggest that habitat fragmentation is both, a state (or outcome) and a process. In addition, we attempt to distinguish between and provide guidelines for situations where habitat loss occurs without frag-mentation, habitat loss occurs with fragmentation, and fragmentation occurs with no habitat loss. We use two definitions for describing habitat fragmentation: a general definition and a situational definition (definitions related to specific studies or situations). Conceptually, we define the state of habitat fragmentation as the discontinuity, resulting from a given set of mechanisms, in the spatial distribution of resources and conditions present in an area at a given scale that affects occupancy, reproduction, or survival in a particular species. We define the process of habitat fragmentation as the set of mechanisms leading to that state of discontinuity. We identify four requisites that we believe should be described in situational definitions: what is being fragmented, what is the scale of fragmentation, what is the extent and pattern of fragmentation, and what is the mechanism causing fragmentation

Fuller, T., D.P. Morton, and S. Sarkar. 2008. Incorporating uncertainty about species' potential distributions under climate change into selection of conservation areas with case study from the Arctic coastal plain of Alaska. Biological Conservation 141(6):1547-1559.

<u>Abstract</u> – This analysis presents a conservation planning framework for decisions under uncertainty and applies it to the Arctic Coastal Plain of Alaska. Uncertainty arises from variable distributional shifts of species' ranges due to climate change. The planning framework consists of a two-stage optimization model that selects a nominal conservation area network in the first stage and evaluates its performance under the climate scenarios in the second stage. The model is applied to eleven at-risk species in Alaska including the threatened Spectacled Eider and Steller's Eider sea ducks and the polar bear. The 109th United States Congress and 2008 federal budget proposed opening for oil and gas development the ''1002 Area'' of the Arctic National Wildlife Refuge, which intersects the Plain. This analysis finds that, if Arctic Alaska experiences 1.5°C of warming by 2040 (as predicted by the Intergovernmental Panel on Climate Change's A2 scenario), then potential

habitat will decrease significantly for eight of these at-risk species, including the polar bear. This analysis also shows that there is synergism between oil and gas development and climate change. For instance, climate change accompanied by no development of the 1002 Area results in an increase of potential habitat for Steller's Eider. However, if development accompanies climate change, then there is a 20% decrease in that area. Further, this analysis quantifies the tradeoff between development and maintenance of suitable habitat for at-risk species.

FWS (Fish and Wildlife Service). 1980a. Habitat as a basis for environmental assessments. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Division of Ecological Services ESM 101. https://www.fws.gov/policy/ESMindex.html

FWS (Fish and Wildlife Service). 1980b. Habitat Evaluation Procedures (HEP). Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Division of Ecological Services ESM 102. https://www.fws.gov/policy/ESMindex.html

FWS (Fish and Wildlife Service). 1980c. Human Use and Economic Evaluation (HUEE). Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Division of Ecological Services ESM 104. https://www.fws.gov/policy/ESMindex.html

FWS (Fish and Wildlife Service). 1981. Standards for the development of Habitat Suitability Index models. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Division of Ecological Services ESM 103. https://www.fws.gov/policy/ESMindex.html

FWS (U.S. Fish and Wildlife Service). 1982. Arctic National Wildlife Refuge coastal plain resource assessment: initial report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region

FWS (Fish and Wildlife Service). 1988a. Arctic National Wildlife Refuge comprehensive conservation plan, environmental impact statement, wilderness review, and wild river plans: final. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

FWS (Fish and Wildlife Service). 1988b. Record of decision: Arctic National Wildlife Refuge comprehensive conservation plan, environmental impact statement, wilderness review, and wild river plans. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

FWS (Fish and Wildlife Service). 1999. Guide to management of Alaska's land mammals. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Office of Subsistence Management.

FWS (Fish and Wildlife Service). 2002. Steller's Eider recovery plan. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service.

FWS (Fish and Wildlife Service). 2008. Birds of conservation concern 2008. Washington, D.C., U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Species.

FWS (Fish and Wildlife Service). 2008. Endangered and threatened wildlife and plants; Determination of threatened status for the polar bear (*Ursus maritimus*) throughout its range; final rule. Federal Register 73(95):28212-28303.

FWS (Fish and Wildlife Service). 2008. Endangered and threatened wildlife and plants; special rule for the polar bear [final]. Federal Register 73(242):76249-76269.

FWS (Fish and Wildlife Service). 2009. Endangered and threatened wildlife and plants; designation of critical habitat for the polar bear (*Ursus maritimus*) in the United States. Federal Register 74(208):56058-56086.

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FWS (Fish and Wildlife Service). 2016d. Biological Opinion for polar bears and conference opinion for Pacific walrus on the proposed issuance of 2016-2021 Beaufort Sea incidental take regulations. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Fairbanks Field Office.

GAO (General Accounting Office). 2002. Alaska's North Slope: requirements for restoring lands after oil production ceases. Washington, D.C.: U.S. General Accounting Office; Resources, Community, and Economics Development GAO/RCED-02-357. https://www.gao.gov/products/GAO-02-357

Summary - This report discusses the nature and extent of dismantlement, removal, and restoration requirements for oil industry activities that are occurring on both federal and state lands located on the North Slope of the state of Alaska. The state of Alaska, which owns the lands where most of the North Slope's current oil production occurs, has adopted general dismantlement, removal, and restoration requirements that contain no specific stipulations on what infrastructure must be removed or to what condition the lands used for oil industry activities must be restored once production ceases. Alaska's requirements are similar to those of some states but less explicit than those of other states, which create a fixed obligation to fully restore the land according to specific requirements. Until the state of Alaska defines the condition in which it would like its lands returned, there is no way to accurately estimate the cost of dismantling and removing the infrastructure and restoring the disturbed land on Alaska's North Slope. Existing financial assurances, such as bonding requirements, ensure the availability of only a small portion of the funds that are likely to be needed to dismantle and remove the infrastructure used for oil industry activities and to restore state-owned lands. Current dismantlement, removal, and restoration requirements and financial assurances for federal lands on the North Slope vary by agency, but are generally insufficient to ensure that any federal lands disturbed by oil industry activities will be restored.

Garner, G.W., and P.E. Reynolds. 1983. Arctic National Wildlife Refuge coastal plain resource assessment: 1982 update report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Garner, G.W., and P.E. Reynolds. 1984. Arctic National Wildlife Refuge coastal plain resource assessment: 1983 update report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Garner, G.W., and P.E. Reynolds. 1985. Arctic National Wildlife Refuge coastal plain resource assessment: 1984 update report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Garner, G.W., and P.E. Reynolds. 1986. Arctic National Wildlife Refuge coastal plain resource assessment: final report baseline study of the fish, wildlife, and their habitats (3 volumes). Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Garner, G.W., and P.E. Reynolds. 1987. Arctic National Wildlife Refuge coastal plain resource assessment: 1985 update report baseline study of the fish, wildlife, and their habitats (3 volumes). Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Glick, P., B.A. Stein, and N.A. Edelson. 2011. Scanning the conservation horizon: a guide to climate change vulnerability assessment. Washington, D.C.: National Wildlife Federation. www.nwf.org/vulnerabilityguide

Gliders, M.A., and M.A. Cronin. 2000. North Slope oil field development. Pp. 15-33 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA; Academic Press.

Summary - This chapter describes Alaska's North Slope Oil Field Development, highlighting the history, nature, and environmental impacts of oil development. The first geological surveys took place in the late 1950s and early 1960s. At that time, much of the interest was focused well to the west of the existing oil fields—within the boundaries of what became the National Petroleum Reserve in Alaska (NPRA)—and in the foothills of the Brooks Range. The marked seasonality of the Arctic presents both problems and solutions to those seeking to develop hydrocarbon reserves on the North Slope. Winters are long and severe, making the human work environment difficult and hazardous. However, environmental impacts can be significantly reduced at this time because the tundra is frozen and protected by snow cover, and most wildlife is absent. In summer, the thawing snow and lengthening days bring millions of shorebirds and waterfowl in search of nesting sites. The oil exploration and production process involves numerous stages that may take several years or even decades to complete for each oil field. New technologies involving reduced well spacing, elimination of reserve pits, directional drilling, winter maintenance and construction from ice pads and roads, aerial support, and the use of baseline and ongoing biological monitoring programs to facilitate decision making have reduced the areal impacts of development. The incorporation of baseline biological studies into the planning stages of field development helps planners minimize impacts to high-value habitats. Such studies can also help operators reduce direct encroachment on wildlife habitat and help avoid disturbance to wildlife during critical periods.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. New York, NY: Wiley.

Koranda, J.J., and C.D. Evans. 1975. A discussion of sites recommended as potential natural landmarks in the Arctic lowlands natural region, northern Alaska. [cover page only located].

Krausman, P.R., and L.K. Harris. 2011. Cumulative effects in wildlife management: impact mitigation. Boca Raton, FL: CRC Press.

Laidre, K.L., H. Stern, K.M. Kovacs, L. Lowry, S. Moore, E.V. Regehr, S.H. Ferguson, O. Wiig, P. Boveng, R.P. Angliss, E.K. Born, D. Litovka, L. Quakenbush, C. Lydersen, D. Vongraven, and F. Ugarte. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st Century. Conservation Biology 29(3):724-737. https://onlinelibrary.wiley.com/doi/full/10.1111/cobi.12474

Landres, P.B. 1983. Use of the guild concept in environmental impact assessment. Environmental Management 7(5):393-398. https://rd.springer.com/content/pdf/10.1007%2FBF01867118.pdf

Abstract – The purpose of this paper was to clarify and expand several ideas concerning use of the guild concept in environmental impact assessment. Background material on the concept and examples of its uses are given. It is argued that for purposes of environmental assessment a resource-based guild approach is preferable to a taxonomic-based approach. Validity of the guild concept, problems in classifying species into guilds, implications of guild membership, and usefulness of guild analysis are discussed. I conclude that only with a thorough knowledge of both its limitations and benefits will it be possible to fully use the guild concept for understanding organizational processes in communities and ecosystems and for assessing environmental impacts.

Landres, P.B., P. Morgan, and F.J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9(4):1179-1188. https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1890/1051-0761(1999)009[1179:OOTUON]2.0.CO;2

Abstract - Natural resource managers have used natural variability concepts since the early 1960s and are increasingly relying on these concepts to maintain biological diversity, to restore ecosystems that have been severely altered, and as benchmarks for assessing anthropogenic change. Management use of natural variability relies on two concepts: that past conditions and processes provide context and guidance for managing ecological systems today, and that disturbance-driven spatial and temporal variability is a vital attribute of nearly all ecological systems. We review the use of these concepts for managing ecological systems and landscapes.

We conclude that natural variability concepts provide a framework for improved understanding of ecological systems and the changes occurring in these systems, as well as for evaluating the consequences of proposed management actions. Understanding the history of ecological systems (their past composition and structure, their spatial and temporal variability, and the principal processes that influenced them) helps managers set goals that are more likely to maintain and protect ecological systems and meet the social values desired for an area. Until we significantly improve our understanding of ecological

systems, this knowledge of past ecosystem functioning is also one of the best means for predicting impacts to ecological systems today.

These concepts can also be misused. No a priori time period or spatial extent should be used in defining natural variability. Specific goals, site-specific field data, inferences derived from data collected elsewhere, simulation models, and explicitly stated value judgment all must drive selection of the relevant time period and spatial extent used in defining natural variability. Natural variability concepts offer an opportunity and a challenge for ecologists to provide relevant information and to collaborate with managers to improve the management of ecological systems.

Martin, P.D., J.L. Jenkins, F.J. Adams, M.T. Jorgenson, A.C. Matz, D.C. Payer, P.E. Reynolds, A.C. Tidwell, and J.R. Zelenak. 2009. Wildlife response to environmental Arctic change: predicting future habitats of Arctic Alaska. Report of the Wildlife Response to Environmental Arctic Change (WildREACH): Predicting Future Habitats of Arctic Alaska Workshop; 17-18 November 2008. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region. https://www.fws.gov/alaska/pdf/wildreach_workshop_report.pdf

Executive Summary - Climate is changing worldwide, but the Arctic is warming at a rate almost twice the global average. Changes already observed in arctic terrestrial landscapes include rapidly eroding shorelines, melting ground ice, and increased shrub growth at high latitudes. Because the Arctic will likely experience early and disproportionately large impacts of climate change, the U.S. Fish and Wildlife Service (Service) has identified America's Arctic as a priority region for developing management strategies to conserve fish, wildlife, and their habitats.

The Service convened a Wildlife Response to Environmental Arctic Change (WildREACH) workshop on 17–18 November 2008 in Fairbanks, Alaska. Our goal was to identify the priority research, modeling, and synthesis activities necessary to advance our understanding of the effects of climate change on birds, fish, and mammals of arctic Alaska, focusing on terrestrial and freshwater systems. We used a conceptual modeling approach to identify the potential changes that would most strongly influence habitat suitability for a broad suite of arctic species. In doing so, we embarked on the first essential step toward incorporating climate considerations into biological planning and conservation design for the Arctic. The workshop was attended by over 100 participants representing federal and state agencies, academia, and commercial and nonprofit organizations. WildREACH provided a forum for communication among specialists from multiple disciplines, a vital first step toward establishing effective partnerships. Summaries of each workshop report chapter are provided below.

Climate, Permafrost, Hydrology - The average annual temperature of Alaska's North Slope is projected to rise approximately 7°C by 2100. The magnitude of change is imprecisely known, but Global Circulation Models identify northern Alaska as one of the fastest warming regions of the planet. Annual precipitation is also expected to increase, although there is less certainty surrounding this prediction.

In the Arctic, climate affects habitat uniquely through the interdependencies of permafrost, hydrology, and vegetation. The deep, cold, continuous permafrost of the North Slope represents a reservoir of resilience for this landscape. Nevertheless, enhanced seasonal melting of near-surface ice is already measurably altering habitats and hydrology. Understanding how variation in the type and quantity of ground ice influences a landscape's susceptibility to warming is fundamental to predicting the extent and magnitude of habitat change.

Hydrologic processes are a pivotal determinant of climate-influenced habitat change in arctic Alaska. Changes in overall water balance and in timing and magnitude of seasonal water and energy fluxes will strongly affect habitat availability and quality for arctic-adapted species of fish and wildlife. The seasonal allocation of precipitation is key to ecosystem response in an environment where water remains frozen most of the year. Despite the expectation of higher annual precipitation, models predict a generally drier summer environment. Refining models to more confidently predict water balance and the resultant water supply available to various habitat types is one of our most important challenges.

<u>Habitat Change</u> - Effects of climate change on North Slope habitats will vary depending on the permafrost-influenced geomorphic processes specific to particular ecosystems. It is useful to consider the coastline, Coastal Plain, Foothills, and floodplains separately.

• In the coastal zone, rapid shoreline erosion is occurring, associated with the retreat of summer sea ice. Rising ocean temperatures, sea level rise, permafrost degradation, increased storm surges, and changes to river discharge and sediment transport will continue to affect habitat availability and quality in the coastal zone.

• The vast shallow wetlands of the Coastal Plain landscape are sensitive to changes in water balance that could lead to drying. Lakes may enlarge through melting and erosion at their edges. Alternatively, lakes may drain if surrounding ice wedges degrade, resulting in the formation of new drainage networks.

• The hilly terrain of the Arctic Foothills is prone to thaw slumps and gully formation. In the lower Foothills, extremely ice-rich soils are susceptible to ice wedge degradation, melting of massive ice, and formation or drainage of thermokarst lakes.

• Floodplains are very dynamic landscapes and could respond to climate change in a variety of ways. Floodplain processes are influenced more strongly by extreme flood events than by average conditions, and models of future flood frequency and severity must be better developed in order to predict habitat change.

Historically, tundra fires have been rare on the North Slope, but fire frequency will likely increase as the climate warms. A positive feedback relationship exists whereby soils tend toward a warmer and drier condition after fire, which in turn promotes shrub growth and a more fire-prone landscape. Although widespread conversion of North Slope tundra to spruce forest is not expected within this century, increased shrub cover has been documented in the Brooks Range and Foothills, a trend that is expected to continue. Changes in plant phenology (e.g., earlier green-up and senescence) are certain to occur as spring melt comes earlier.

Climate change may increase availability and uptake of contaminants for fish, wildlife, and their habitats. Contaminants currently contained within glacial ice, multi-year sea ice, and permafrost, including persistent organic pollutants and mercury, will almost certainly be released to aquatic ecosystems as the temperature rises.

<u>Climate Effects on Fish and Wildlife</u> - WildREACH workshop participants formed working groups for birds, fish, and mammals. Each working group developed conceptual models

to illustrate hypotheses of likely pathways by which fish and wildlife populations of arctic Alaska may be affected by climate change. Hydrologic process models for summer and winter provided linkages among climate variables, physical processes (hydrologic and permafrost), and habitat change. These processes were relevant to all species groups.

The bird working group developed conceptual models organized around four broad topics: abundance and distribution of surface water, vegetation community change, invertebrate community change, and coastal processes.

The fish working group developed a single conceptual model emphasizing pathways related to the effects of increased water temperature and hydrologic changes related to soil moisture, glacial input, drainage changes related to permafrost degradation, and changes in lake area.

The mammal working group developed separate models for the summer and winter seasons. Key factors in winter included changes in the timing, amount, and nature of precipitation (e.g., rain-on-snow events, deeper snow). In summer, changes in plant species composition, amount of forage, and seasonality were expected to have the greatest potential for affecting mammal populations.

Common Themes and Research Gaps - Despite the uncertainty in projecting climate change impacts on arctic species and habitats, workshop participants identified monitoring, research, and modeling priorities that will help improve our understanding of future conditions. Specific information gaps varied among species groups, but most fell into four crosscutting themes: 1) changes in precipitation and hydrology; 2) changes in vegetation communities and phenology; 3) changes in abundance and timing of invertebrate emergence; and 4) coastal dynamics.

All working groups emphasized that predictions regarding climate effects on fish and wildlife populations must be tentative, given the uncertainty surrounding climate forecasts and unavailability of models that couple climate, geophysical, and ecological processes at appropriate spatial and temporal scales. All working groups agreed that in order to more accurately predict climate change effects on species and habitats, multidisciplinary work is needed to better understand the underlying biological and physical processes that drive terrestrial and aquatic ecosystem function and the response of those systems to climate change. Hydrologic processes, in particular, are pivotal determinants of climate-related habitat change, and enhanced data collection and modeling in this area will benefit multiple users.

All working groups emphasized that information available on life history, habitat requirements, distribution, abundance, and demography is inadequate for many arctic species. Basic biological studies, therefore, are also needed. Focal species should be chosen based on their predicted vulnerability to climate change and potential to serve as indicators of hypothesized habitat changes.

Conclusions and Recommendations - WildREACH workshop discussions revealed several specific information gaps within the four major thematic areas previously listed. These gaps represent the highest scientific priorities for scientific inquiry, which should be pursued in an organized, multidisciplinary fashion. Specific recommendations include:

1. Establishment of at least three long-term observatories on the North Slope to collect integrated hydrologic, climate, and geophysical data. The central mission of these observatories should be to develop an understanding of the response of permafrost (active layer dynamics), hydrologic, and ecological systems to changes in thermal regime. To ensure applicability to fish and wildlife biology, water budgets should be estimated for key ecotypes.

2. Intensive observations at the observatory sites should be supplemented by instrumentation (e.g., meteorology, radiation, stream discharge, soil moisture) at dispersed sites arrayed across important environmental gradients.

3. Modeling that dynamically couples soil thermal and hydrologic regimes, and biological systems at appropriate spatial and temporal scales.

4. Centralized data storage and interpretation for the mutual benefit of multiple end-users.

We also recommend immediate attention to developing predictive models of habitat change, focusing initially on processes that are occurring now and that act on short (e.g., decadal) time scales. Priority topics include:

1. Coastal processes (e.g., erosion, storm surge, deposition, vegetation succession);

2. Seasonality (e.g., plant phenology, animal migration, life stages of aquatic invertebrates);

3. Shrub advance;

4. Fire regime (as a function of interactions among climate, permafrost, and vegetation); and

5. Thermokarst effects on surface water storage, drainage systems, and lakes.

The Service should engage the U.S. Geological Survey (USGS) and others in a structured decision-making process to refine the selection of indicator species/parameters as components of a long-term climate monitoring program. Upon reaching consensus, management agencies should seek stable funding for monitoring these species/attributes.

The Service recognizes that we must change the way we do business to succeed in managing fish, wildlife, and their habitats in a rapidly changing climate. We can no longer manage for the *status quo*— we must manage for an uncertain future. These challenges exceed the capacity of any one agency, and we must pool our collective resources. By strategically targeting financial resources, we can build Landscape Conservation Cooperatives that increase capacity, eliminate redundancy, and provide the technical expertise to implement conservation, research, and management at all scales.

The Service will improve communication and collaboration with the arctic research community to initiate building of wide-ranging partnerships. On a local, regional, and national level the Service will:

1. Work with the National Science Foundation (NSF) to define climate research priorities relevant to resource management agencies;

2. Increase collaboration with academia and other researchers to develop grant proposals that address priority questions;

3. Participate in planning and implementation of the interagency Study of Environmental Arctic Change (SEARCH) Program to ensure inclusion of research relevant to resource management agencies;

4. Work with arctic science program managers in the research agencies (e.g., NSF, USGS, National Oceanic and Atmospheric Administration) to obtain funding for work that addresses priority questions; and

5. Promote a collaborative approach to acquire, process, archive, and disseminate essential satellite-based remote sensing data products (e.g., snow cover, green-up, and surface water) needed for regional-scale monitoring.

Climate change presents an unprecedented challenge to managers of arctic natural resources. By initiating a collaborative process among biologists, physical scientists, and managers, the WildREACH workshop successfully identified priority information gaps and activities needed to provide the basis for adaptive management of arctic fish and wildlife resources. Since the workshop, the Service has identified America's Arctic as Alaska's first Landscape Conservation Region, which will be supported by the technical capacity housed in the Northern Alaska Landscape Conservation Cooperative. Adopting the WildREACH recommendations is the next step in strengthening our capacity to anticipate climate-related habitat change and to identify the most promising strategies to conserve fish and wildlife populations in America's Arctic.

McCabe 1989. Terrestrial research: 1002 area – Arctic National Wildlife Refuge, annual progress report field season - 1988. Fairbanks, AK: Alaska Fish and Wildlife Research Center and Arctic National Wildlife Refuge.

Introduction – The *Arctic National Wildlife Refuge, Alaska, Coastal Plain Resources Assessment: Report and Recommendation to the Congress of the United States and Final Legislative Environmental Impact Statement* (Clough et al. 1987) predicted that adverse negative effects on key wildlife species could occur from oil and gas development. Primary impacts would result from loss of or displacement from Arctic coastal plain habitats. To assess the identified potential problems, the Alaska Fish and Wildlife Research Center (AFWRC), in cooperation with the Arctic Refuge, ADF&G, UAF, Canadian Wildlife Service, and Yukon and Northwest Territory Departments of Renewable Resources, initiated an extensive research program in 1988. That research program built upon the findings of the Service's 1981-1985 baseline studies in the 1002 area (FWS 1982; Garner and Reynolds 1983, 1984, 1985, 1986, 1987). Together, these programs, in conjunction with surveys and monitoring programs conducted by Arctic Refuge, constitutes the database from which management decisions regarding wildlife resources in the 1002 area can be formulated.

These reports document the findings of the initial research field season and are presented in 3 sections. Section 1 reports the findings of Work Units I-IV and VI in the 1002 Research Study Plans (AFWRC 1988). Work Unit V is the research on polar bears which, by the nature of the field season, has a different reporting schedule; therefore, it is not included in these reports. Two Work Subunits are not addressed in this report. [Funding issues for one with new start date and other contracted]. Also included are products from 2 of the 4 Research Work Orders (RWOs) contracted via UAF and University of Idaho. The other 2 WROs are in final analyses so will be addenda to this report upon completion.

The second section is comprised of the seismic trail recovery monitoring program and the port site baseline data study being conducted by Arctic Refuge. Section Three contains the annual survey reports for caribou, muskox, and Lesser Snow Geese. The swan survey was not accomplished due to poor weather, so only the nesting data in the RWO is reported for 1988.

The data and conclusions contained within this research report are all preliminary, since the plans call for a minimum of 3 years of data collection. Unless otherwise specified in the Research Prospectus portion of these reports, the research programs will continue to collect the necessary data based on the Study Plan adopted in 1988 (AFWRC 1988).

McCabe 1990. Terrestrial research: 1002 area – Arctic National Wildlife Refuge, annual progress report field season - 1989. Fairbanks, AK: Alaska Fish and Wildlife Research Center and Arctic National Wildlife Refuge.

<u>Introduction</u> – The *Arctic National Wildlife Refuge, Alaska, Coastal Plain Resources Assessment: Report and Recommendation to the Congress of the United States and Final Legislative Environmental Impact Statement* (Clough et al. 1987) predicted that adverse negative effects on key wildlife species could occur from oil and gas development. Primary impacts would result from loss of or displacement from Arctic coastal plain habitats. To assess the identified potential problems, the Alaska Fish and Wildlife Research Center (AFWRC), in cooperation with the Arctic Refuge, ADF&G, UAF, Canadian Wildlife Service, and Yukon and Northwest Territory Departments of Renewable Resources, initiated an extensive research program in 1988. That research program built upon the findings of the Service’s 1981-1985 baseline studies in the 1002 area (FWS 1982; Garner and Reynolds 1983, 1984, 1985, 1986, 1987). Together, these programs, in conjunction with surveys and monitoring programs conducted by Arctic Refuge, constitutes the database from which management decisions regarding wildlife resources in the 1002 area can be formulated.

These summary reports document the findings of the second (FY1989) research field season and are presented in 3 sections. Section 1 reports the findings of Work Units I-IV and VI in the 1002 Research Study Plans (AFWRC 1988). Work Unit V is the research on polar bears which, by the nature of the field season, has a different reporting schedule; therefore, it is not included in these reports. Work Subunit IIIC has been eliminated due to priority allocations of funds and will not be initiated until Phase II of this research program. Also included are products from 4 Research Work Orders (RWOs) contracted through UAF and 1 RWO contracted through the University of Idaho.

The second section is comprised of port site baseline data study being conducted by Arctic Refuge. Section Three contains the annual survey reports of caribou, muskox, tundra swans, and Lesser Snow Geese.

The data and conclusions contained within these reports are all preliminary, since the plans call for a minimum of 3 years of data collection. Unless otherwise specified in the Research Prospectus portion of these reports, the research programs will continue to collect the necessary data based on the Study Plans adopted in 1988 (AFWRC 1988) and amended in 1989 and 1990.

McCabe, T.R., D.B. Griffith, N.E. Walsh, and D.D. Young. 1992. Terrestrial research: 1002 area – Arctic National Wildlife Refuge, interim report 1988-1990. Fairbanks, AK: Alaska Fish and Wildlife Research Center and Arctic National Wildlife Refuge.

Introduction – The *Arctic National Wildlife Refuge, Alaska, Coastal Plain Resources Assessment: Report and Recommendation to the Congress of the United States and Final Legislative Environmental Impact Statement* (Clough et al. 1987) predicted that adverse negative effects on key wildlife species could occur from oil and gas development. Primary impacts would result from loss of or displacement from Arctic coastal plain habitats. To assess the identified potential problems, the Alaska Fish and Wildlife Research Center (AFWRC), in cooperation with the Arctic Refuge, ADF&G, UAF, Canadian Wildlife Service, and Yukon and Northwest Territory Departments of Renewable Resources, initiated an extensive research program in 1988. That research program built upon the findings of the Service's 1981-1985 baseline studies in the 1002 area (FWS 1982; Garner and Reynolds 1983, 1984, 1985, 1986, 1987). Together, these programs, in conjunction with surveys and monitoring programs conducted by Arctic Refuge, constitutes the database from which management decisions regarding wildlife resources in the 1002 area can be formulated.

These summary reports document the interim findings of Work Units I-IV in the Service's 1002 Research Study Plans (AFWRC 1988). For some studies, comparable data from previous years was also available for integration with the current findings. Data from the 1988 and 1989 field seasons was previously presented in reports on each of those years (McCabe 1989). Also, included are summary products from four research work orders (RWO) contracted via UAF, and one RWO via University of Idaho.

The data and conclusions contained within these reports are the culmination of 3 years of data collection on numerous terrestrial issues. Findings on fisheries, water resources, contaminants, subsistence, and the recently completed migratory bird port site study are reported elsewhere (Martin et al. 1990; Willms and Crowley 1992). The 1002 study plans were designed in two phases, with the interim report finalizing the first research phase of the research program. The second phase of the 1002 research is predicated upon the initial findings of the findings reported here and encompasses the 1991 and 1992 field seasons. It is designed to refine or expand on the databases necessary to provide the Service with adequate information for determining policy or mitigation for potential development of petroleum resources in the coastal plain of the Arctic Refuge.

McCarter, S.S., A. Rudy, and S.F. Lamoureux. 2017. Long-term landscape impact of petroleum exploration, Melville Island, Canadian High Arctic. Arctic Science https://doi.org/10.1139/AS-2016-0016

Abstract - Industrial land use such as petroleum exploration and infrastructure development has important and lasting impacts on Arctic landscapes. Detailed, site-level investigations have noted impacts that include vehicle tracks, surface and vegetation alteration, soil compaction, and degradation of ice wedge features. We investigated the long-term impact of an extended period of hydrocarbon exploration on Melville Island in the Canadian High Arctic using available remotely sensed data supplemented with field observations over a $\sim$370 km^2 area. Aerial photographs from 1959, 1972, and 1977 and recent satellite imagery (2011 and 2013) were used to determine the effects of industrial activity over periods corresponding to pre-activity, mid-activity, and post-activity. We show that vehicle tracks, site disturbance, and vegetative impacts are still evident after 40 years in this area. Permafrost has degraded at sites with concentrated activity (drill sites, airstrips) and changes to vegetation are clearly discernable. The results demonstrate the utility of this approach for assessment of land use impacts on High Arctic landscapes and provide a means to determine locations for more detailed site-specific field studies. These results may contribute to strategies for environmental monitoring in remote areas where access is impractical or resource intensive.

Meehan, R., and P.J. Weber, and D. Walker. 1986. Tundra development review: toward a cumulative impact assessment method (2 volumes). Report prepared for U.S. Environmental Protection Agency, U.S. Department of Energy, and U.S Fish and Wildlife Service. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Investigations AI 87/02.

Millar, C.I., N.L. Stephenson, and S.L. Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17(8):2145-2151. http://www.esajournals.org/doi/pdf/10.1890/06-1715.1

Abstract – We offer a conceptual framework for managing forested ecosystems under an assumption that future environments will be different from present but that we cannot be certain about the specifics of change. We encourage flexible approaches that promote reversible and incremental steps, and that favor ongoing learning and capacity to modify direction as situations change. We suggest that no single solution fits all future challenges, especially in the context of changing climates, and that the best strategy is to mix different approaches for different situations. Resources managers will be challenged to integrate adaptation strategies (actions that help ecosystems accommodate changes adaptively) and mitigation strategies (actions that enable ecosystems to reduce anthropogenic influences on global climate) into overall plans. Adaptive strategies include resistance options (forestall impacts and protect highly valued resources), resilience options (improve the capacity of ecosystems to return to desired conditions after disturbance), and response options (facilitate transition of ecosystems from current to new conditions). Mitigation strategies include options to sequester carbon and reduce overall greenhouse gas emissions. Priority-setting approaches (e.g., triage), appropriate for rapidly changing conditions and for situations where needs are greater than available capacity to respond, will become increasingly important in the future.

Morrison, M.L., B.G. Marcot, and R.W. Mannan. 2006. Wildlife-habitat relationships: concepts and applications. Madison, WI; University of Wisconsin Press.

Nolan, M., R. Churchill, J. Adams, J. McClelland, K.D. Tape, S. Kendall, A. Powell, K. Dunton, D. Payer, and P. Martin. 2011. Predicting the impact of glacier loss on fish, birds, floodplains, and estuaries in the Arctic National Wildlife Refuge. Pages 49-54 in C.N. Medley, G. Patterson, and M.J. Parker (eds.), Proceedings of the Fourth Interagency Conference on Research in the Watersheds. U.S. Department of the Interior, Geological Survey Scientific Investigations Report 2011-5169. http://arcticlcc.org/assets/products/ARCT2011-18/publications/Nolan-et-al.-2011-Predicting-the-Impact-of-Glacier-Loss.pdf

Abstract - In this paper we explore the impacts of shrinking glaciers on downstream ecosystems in the Arctic National Wildlife Refuge. Glaciers here are losing mass at an accelerating rate and will largely disappear in the next 50-100 years if current trends continue. We believe this will have a measureable and possibly important impact on the terrestrial and estuarine ecosystems and the associated bird and fish species within these glaciated watersheds.

Discussion – There are many uncertainties regarding climate change and its impact on Arctic landscapes and ecosystems, but we believe we have identified a straightforward and testable hypothesis linking these together. Glaciers here exist solely at the mercy of climate, unlike tidewater glaciers that have strong non-climatic influences and major ice sheets that can influence their own climate; a 1-2ºC warming has caused them to enter a trajectory where they will likely disappear in the near future. Even if climate remains constant from this time forward, most glacier ice here will disappear because the late-summer snowline is higher than the elevation of most of the mountains. While direct effects of current climate change on fish and birds may be subtle and difficult to detect, the indirect effects on downstream ecosystems caused by the loss of glacial meltwater and silt may be enormous and predictable. Thus we hypothesize that loss of glaciers in the Arctic National Wildlife Refuge will exert strong influence on downstream ecosystems, affecting fish, birds, shrubs, and marine ecology. In this paper we have attempted to share what we know of these influences and predict future trajectories. We are just beginning to investigate relationships between climate, glaciers, and ecology in this region, and we welcome input from the broader scientific community as we pursue this work.

NRC (National Research Council). 2003. Cumulative environmental effects of oil and gas activities on Alaska's North Slope. Washington, D.C.: National Academies Press. https://www.nap.edu/download/10639

Executive Summary - Oil fields on land and off the coast of Alaska's North Slope, including the Prudhoe Bay field, have produced about 14 billion barrels (bbl) of crude oil through the end of 2002 (one barrel equals 42 U.S. gal or 159 L). North Slope oil has averaged about 20% of U.S. domestic production since 1977, and it currently provides about 15% of the annual domestic production of approximately 3.3 billion bbl and 7% of the annual domestic consumption of approximately 7 billion bbl.

If production of the large reserves of natural gas in the region were to become economically feasible, the strategic and economic importance of the North Slope's hydrocarbon energy resources would be even greater. Oil and gas production on the North Slope has brought positive and negative consequences—economic, social, and environmental. Environmental consequences of concern include the effects of oil-related structures and activities on the migration of fish and marine and terrestrial mammals, especially bowhead whales and caribou. Concerns have also been raised about the risk of toxic contamination of plants and animals used for food by Alaska Natives, effects of oil and gas exploration and development on tundra and marine ecosystems, and effects of oil spills on marine and coastal ecosystems. Also of concern are the effects of oil activities and structures on endangered or threatened species, migratory birds, polar bears and other mammals, and on wildland (wilderness) values. Some of the socioeconomic changes resulting from oil and gas development, including those involving employment, lifestyles, health, and other aspects of people's lives, also have been of concern.

Considerable research has been done on various actual and potential effects of oil and gas activity on the North Slope's physical, biotic, and human environments. Reviews of this research have appeared in environmental impact statements (EISs), in reports funded by the Department of the Interior and other federal and state agencies, in oil industry publications, in journals, and in National Research Council reports, among others. However, there has been little assessment of the *cumulative* effects of those activities, the elucidation of which is critical to support informed, long-term decision-making about resource management. To address this lack of information and understanding, Congress requested that the National Academies review and assess what is known about the cumulative environmental effects of oil and gas activities on Alaska's North Slope.

Chapter 8 Effects on Animals: Caribou, Findings (beginning page 116ff) - The intensively developed PBOC has altered the distribution of female caribou during the summer insect season. Elsewhere, a network of roads, pipelines, and facilities has interfered with their movements between coastal insect-relief and inland feeding areas.

Radio-collared female caribou west of the Sagavanirktok River shifted their calving concentration area from developed areas nearer the coast to undeveloped areas inland. No such shift has occurred for caribou calving east of the Sagavanirktok River where there is no development. The shift by caribou west of the Sagavanirktok River was into an area with lower green-plant biomass than the area previously used. From 1988-1994, parturition rates of radio-collared females in regular contact with oil-field infrastructure west of the Sagavanirktok River were lower than those of undisturbed females to the east. Reduction in parturition rates - the variable part of net calf production-for those caribou was exacerbated by intense insect harassment during the period. Thus, it appears that the effects of oil-field development accumulate with effects of insect harassment by impairing movements between coastal and inland habitats.

Possible consequences of these disturbances include reduced nutrient acquisition and retention throughout the calving and midsummer periods, poorer condition in autumn, and a lowered probability of producing a calf in the following spring.

As a result of conflicts with industrial activity during calving and an interaction of disturbance with the stress of summer insect harassment, reproductive success of Central Arctic Herd female caribou in contact with oil development from 1988 through 2001 was lower than for undisturbed females, contributing to an overall reduction in herd productivity. The decrease in herd size between 1992-1995, may reflect the additive effects of surface development and relatively high insect activity, in contrast to an increase in the herd's size from 1995 to 2000, when insect activity was generally low.

Expanded loss of preferred habitats, which could accompany the spread of industrial activity across the National Petroleum Reserve-Alaska and into the foothills of the Brooks Range, and climate change that increases insect harassment, are likely to depress energy and nutrient status and, therefore, summer weight gain of lactating females.

Unless future requirements for infrastructure can be greatly reduced, exploitation of oil and gas reserves within the calving and summer ranges of the CAH, TLH, and PCH will likely have similar consequences.

<u>Chapter 8 Effects on Animals: Caribou, Recommendations</u> (beginning page 116ff) - Determine the responses of caribou to seismic testing under different snow conditions and estimate the probable consequences in terms of energy intake and nutrient balance and reproductive success.

Determine the minimum distance between road-pipeline corridors that is compatible with continued use of an area by calving caribou and how design of corridors influences those effective distances.

Studies are needed to characterize the nutrient-energy tradeoffs associated with insect-induced movements; quantify the conditions of food intake and body condition associated with each of the various weaning decisions (tradeoffs) made by maternal females; and within known levels of exposure to disturbance, determine the over-summer nutritional performance of females and their calves.

Determine whether winter calf mortality is additive or compensatory, relative to early postnatal mortality; that is, do those that survive unfavorable foraging conditions in spring or summer die during the winter anyhow?

NRC (National Research Council, Committee on Ecological Impacts of Climate Change). 2008. Ecological impacts of climate change. Washington, D.C.; National Academy Press. http://www.nap.edu/catalog.php?record_id=12491

Impacts of Future Climate Change

Uncertainties in predictions - The record of climate-induced change over the last million years indicates that human-caused climate change, if not slowed significantly, will have a major landscape-transforming impact across most of North America and its coastal ocean in the next 100 years and beyond. The lessons from the recent and distant past allow us to picture the likely impacts of future climate changes, but the picture is incomplete for several reasons. First, future climate changes will be unprecedented in many respects. Depending on human actions climate change over the next century may produce a temperature change as large as the difference between full glacial and full interglacial conditions, and with temperatures warmer than Earth has experienced in many millions of years. Second, if “business as usual” practices continue, climate change in coming decades will be exceptionally rapid, much more rapid on a sustained global basis than the transitions into and out of past ice ages. The only global-scale climate changes in Earth’s history that have happened more rapidly are probably those associated with major cataclysms, such as meteor impacts. Third, climate change will occur in a setting where human actions have fundamentally altered terrestrial, aquatic, and marine ecosystems. Land use for farming and forestry has disrupted migration routes for some plants and animals, while improving them for others. Coastal ecosystems are increasingly squeezed between rising oceans and extensive human development along the coasts. Many rivers are dammed, diverted, or polluted. Wild stocks of fish are in many cases seriously depleted by overfishing or by changes in coastal and river habitats. Finally, human actions are very effectively facilitating species movements, both intentionally and unintentionally, making it possible for species that are good at moving to spread around the world, often eliminating native species in their path.

Making decisions in spite of uncertainty - Although evidence from the recent and distant past is incomplete, we can draw some important lessons. Perhaps the most important is that ecosystem responses to climate change, especially with interacting stresses, are extremely complex. Interactions that were unimportant in one setting may become critical in another. Healthy populations may be ravaged by pathogens that are newly at home in a formerly hostile or resistant environment. And some rare species may surprise us with their tenacity. Strategies for managing ecosystems in the future will need to pay special attention to uncertainty—making the best decisions based on available information and implementing decisions in a way that makes them adjustable as additional information becomes available.

Future climate change will affect many aspects of ecosystem composition, structure, and functioning. Some of these will have profound influences on ecosystem services. Others will have effects on the integrity of ecosystems and on their resilience (their ability to cope with future changes). Among all the possible impacts of climate change on ecosystems, the most permanent is extinction. Once a species is lost, it cannot be replaced. Everything that was unique about that species, perhaps its interactions with other species, perhaps its ability to deal with particular kinds of stresses, or perhaps its unique appearance or behavior, is lost forever. When we step back and probe the likely future consequences of human actions in causing climate change, increased extinctions are one of the key impacts. So far the number of known extinctions as a result of climate change is small, but quite a high number of species are currently considered functionally extinct, in other words, they are at risk of going extinct as the climate warms unless we directly intervene. For example, species currently living at the top of mountains have no place else to go and will likely become extinct unless we capture them, move them to a more hospitable habitat and monitor them to make sure they survive in the new habitat (Hoegh-Guldberg et al. 2008). Such a response would require money, people power and political will. If a warming of 2-3ºC (3.6-5.4° F) occurs, the Intergovernmental Panel on Climate Change has estimated that about 20 to 30 percent of studied species could risk extinction in the next 100 years. (Fischlin et al. 2007). Given that there are approximately 1.7 million identified species on the globe, an estimated 300,000 to 600,000 species could be committed to extinction primarily due to human activities. An important reason why climate change is expected to have such a major impact on biodiversity is that in most ecosystems climate change is occurring in the context of ongoing pressures from a range of other important factors, including loss of habitat from human land use, overfishing, fertilizer and pesticide runoff, and the encroachment of invasive species (Sala et al. 2000). Indeed, we seem to be standing at the brink of a mass extinction event, precipitated by the behavior of one species—*Homo sapiens*.

<u>What should we do about these trends?</u>

Climate change is undoubtedly one of the defining environmental and development issues of the 21st century. Never before have humans had the numbers and the technology to dramatically alter the climate of Earth at the global scale. Decisions about climate change over the coming decades will likely reverberate through centuries.

This document is not intended to make policy recommendations. Rather, it is focused on characterizing some of the changes to ecosystems that have already occurred and that are likely to occur in the future, with different levels of climate change. There is no question that the impacts of climate change on ecosystems become increasingly profound as the magnitude and rate of climate change increases and that disruptions to ecosystem services, including potentially irreplaceable services from biological diversity, become more severe.

The challenge is finding a set of policies, practices, and standards of behavior that provide long-term economic opportunities and improved quality of life around the world while maintaining a sustainable climate and viable ecosystems. Some authoritative recent analyses conclude that on economic grounds alone, the world should invest in curtailing the amount of climate change that occurs and in adapting to the changes that cannot be avoided. The appropriate level of these investments and the way they are financed and structured are relevant questions for a wide-ranging discussion among all members of society - in communities, businesses, places of worship, schools, and families. Some of the issues are quite technical and can only be effectively addressed at the level of governments. This includes decisions like whether and how best to impose a price on carbon emissions to the atmosphere or the kinds of technological alternatives to fossil fuel energy to receive government subsidies. Other decisions can be best addressed at the individual or family level. Each time a car, home appliance, or light bulb is purchased, a decision is made that has a small influence on the change in climate being driven by human-caused greenhouse gas emissions. But many small decisions, made by billions of people, can combine to have very large effects.

As has been illustrated throughout this report, climate change is not the only stress on our ecosystems. So another way that society can help reduce the negative ecological impacts of climate change is by creating conditions that make it easier for species in ecosystems to adapt. For example, the impacts of climate change on natural systems will be less harsh if other stresses on ecosystems that are in fact under human control are reduced. Ocean ecosystems could be strengthened by eliminating overfishing, guarding against invasive species, and reducing nutrient runoff. Ocean ecosystems could also be helped by protecting as much habitat and biodiversity as possible in a fashion that is designed to allow movement of species, for example, with networks of marine reserves where no fishing is allowed). Comparable protection on land would include preserves and parks connected by corridors. Carefully considered approaches to and investment in conservation, sustainable agricultural practices, pollution reduction, and water management can all work together to help ecosystems withstand the impact of a changing climate and maintain critical ecosystem services.

The climate challenge is big and complex. It is unlikely that it can be solved with any single strategy or by the people of any single country. But very likely it can be abated with the dedicated efforts of millions of people, working hard on diverse strategies, from many different angles.

Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology 17(2):358-366. http://onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.2003.01491.x/epdf

Abstract - Conservation decisions about how, when, and where to act are typically based on our expectations for the future. When the world is highly unpredictable and we are working from a limited range of expectations, however, our expectations will frequently be proved wrong. Scenario planning offers a framework for developing more resilient conservation policies when faced with uncontrollable, irreducible uncertainty. A scenario in this context is an account of a plausible future. Scenario planning consists of using a few contrasting scenarios to explore the uncertainty surrounding the future consequences of a decision. Ideally, scenarios should be constructed by a diverse group of people for a single, stated purpose. Scenario planning can incorporate a variety of quantitative and qualitative information in the decision-making process. Often, consideration of this diverse information in a systemic way leads to better decisions. Furthermore, the participation of a diverse group of people in a systemic process of collecting, discussing, and analyzing scenarios builds shared understanding. The robustness provided by the consideration of multiple possible futures has served several groups well; we present examples from business, government, and conservation planning that illustrate the value of scenario planning. For conservation, major benefits of using scenario planning are (1) increased understanding of key uncertainties, (2) incorporation of alternative perspectives into conservation planning, and (3) greater resilience of decisions to surprise.

Pickett, S.T.A., and P.S. White. 1985. The ecology of natural disturbance and patch dynamics. San Diego, CA: Academic Press.

Editors note – natural patch dynamics of ecosystem functions and processes, inclusive of resource distribution and allocation provide a foundation and considerable insight for anthropogenic changes whether intentional or accidental. Examples provided are from systems outside Alaska yet the principles are universal to any ecosystem or population. See also Picket and White 1985, Pp. 371-384.

Preface – Ecologists have always been aware of the importance of natural dynamics in ecosystems, but historically, the focus has been on successional development of equilibrium communities. While this approach has generated appreciable understanding of the composition and functioning of ecosystems, recently many investigators have turned their attention to processes of disturbance themselves and to the evolutionary significance of such events. This shifted emphasis has inspired studies in diverse ecosystems. We use the phrase "patch dynamics" (Thompson 1978) to describe their common focus.

Focus on patch dynamics leads investigators to explicit studies of disturbance-related phenomena – conditions created by disturbance; the frequency, severity, intensity, and predictability of such events; and, the responses of organisms to disturbance regimes. The phrase "patch dynamics" embraces disturbances external to the biotic community as well as internal processes of change. Patch dynamics includes not only such coarse-scale, infrequent events such as hurricanes, but also such fine-scale events as the shifting mosaic of badger mounds in a prairie. The scope of this book includes population, biological community, ecosystem, and landscape-scale levels. The most basic theme is an evolutionary one: how does the dynamic setting of populations influence their evolution? What are the implications for communities and ecosystems?

This book seeks to bring together the findings and ideas of investigators studying such varied systems as marine invertebrate communities; grasslands; and, boreal, temperate, and tropical forests. Our primary goal is to present a synthesis of diverse individual contributions. The book is divided into three main sections: (1) examples of patch dynamics in diverse systems; (2) adaptations of organisms and evolution of populations in patch dynamic environments; and (3) implications of patch dynamics for the organization of communities and the functioning of ecosystems. We feel this approach demonstrates the commonality of disturbance-generated phenomena over a wide range of scales and levels of organization and thus validates the broad work that may stimulate the generation of explicit hypotheses and theory and thus form an alternative to equilibrium concepts of the evolution of populations, composition of biotic communities, and functioning of ecosystems. We hope, in addition, that this volume will help identify areas of future research.

Thompson, J.N. 1978. Within-patch structure and dynamics in *Pastinaca sativa* and resource availability to a specialized herbivore. Ecology 59(3):443-448.

Pickett, S.T.A., and P.S. White. 1985. Patch dynamics: a synthesis. Pp. 371-384 in S.T.A. Pickett and P.S. White (eds.), The ecology of natural disturbance and patch dynamics. San Diego, CA: Academic Press.

Conclusion – The contents of this volume and the literature upon which it draws lead to these conclusions.

1. Disturbance is common to many different ecosystems. It functions or has functioned at all temporal and spatial scales and levels of organization of ecological and evolutionary interest.

2. The key processes common to all disturbances are alterations of resource availability and system structure.

3. Although an understanding of disturbance is of crucial importance in ecology, no coherent theory exists to further its study. Two major generalizations, one concerning intermediate disturbance intensity and the other the rate of competitive exclusion relative to disturbance frequency, are basic to the embryonic theory. Concepts of disturbance regime and of patch dynamics form a basic framework in which comparative and quantitative studies of disturbance should be couched.

4. In order to develop a theory of disturbance composed of unambiguous, testable hypotheses and capable of making sound mechanistic predictions, the relevant variables of disturbance must be established. These include at least magnitude, frequency, size, and dispersion.

5. The development of disturbance theory also requires an explicit statement of the parameters of systems that may respond to disturbance. Predictions must be made in terms of the variables of disturbance and the response parameters.

6. Predictions about disturbance must also recognize that disturbance will have a particular context that may enhance or constrain its impact in a given situation. At least the following factors are required to define the multivariate context of disturbance: (a) system structure; (b) resource base; (c) life history characteristics; (d) nature of the competitive hierarchy; and, (e) landscape composition and configuration.

An explicit statement of the parameters that respond to disturbance, the variables that determine the impact disturbance, and considerations of the context and constraints of disturbance, can form the basis of a theory of disturbance. Placing studies of disturbance in various systems, particularly understudies ones, in this framework will further our ability to generalize and make appropriate predictions about disturbances.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. American Naturalist 132:652-661. https://www.journals.uchicago.edu/doi/pdfplus/10.1086/284880

Abstract - Many animal and plant species can regularly be found in a variety of habitats within a local geographical region. Even so, ecologists often study population growth and regulation with little or no attention paid to the differences in birth and death rates that occur in different habitats. This paper is concerned with the impact of habitat-specific demographic rates on population growth and regulation. I argue that, for many populations, a large fraction of the individuals may regularly occur in "sink" habitats, where within-habitat reproduction is insufficient to balance local mortality; nevertheless, populations may persist in such habitats, being locally maintained by continued immigration from more-productive "source" areas nearby. If this is commonly the case for natural populations, I maintain that some basic ecological notions concerning niche size, population regulation, and community structure must be reconsidered.

Pulliam, H.R., and B.J. Danielson. 1991. Sources, sinks, and habitat selection - a landscape perspective on population-dynamics. American Naturalist 137 Supplement:S50-S66. https://www.journals.uchicago.edu/doi/abs/10.1086/285139?journalCode=an

Abstract - In the model described, we attempt to link breeding-site selection to population dynamics for situations in which there is more than one distinct type of habitat. The distribution of individuals between habitat types depends on the selective abilities of the

species. This distribution, in turn, influences the population dynamics of the species as a whole. We show that the consequences of habitat selection on population dynamics for an ideal free distribution of individuals across habitats is predictably different from what would be predicted if habitat selection were preemptive, that is, if individuals, upon selecting a site, prevented others from sharing the site. If preemptive selection is ideal, average reproductive success declines with increasing density because each individual selects the best site available from those sites not yet occupied. The model allows us to compare the relative contribution of different types of habitats to a species' growth rate and population size. Furthermore, we can also predict how the loss of habitat of a particular type may affect a population. This should make the model useful for environmental management problems as well as for describing the present distribution of a species across a spatially-heterogeneous landscape.

Renolds, J.F., and J.D. Tenhunen. 1996. Landscape function and disturbance in Arctic tundra. New York, NY: Springer-Verlag.

Reynolds, J.D., G.M.Mace, K.H. Redford, and J.G. Robinson. 2001. Conservation of exploited species. New York, NY: Cambridge University Press.

Remmert, H. 1980. Arctic animal ecology. New York, NY: Springer-Verlag.

Richardson, J.L. 1977. Dimensions of ecology. Baltimore, MD: Williams and Williams.

Editors note – Chapter 6 entitled *Organisms and communities in extreme environments: the desert* contrasts aridness and temperature extremes of hot and cold deserts with dry arctic deserts – much to consider in general for species and community adaptations to extreme events with hint of sensitivity to human intrusions.

Sayre. R., E. Roca, G. Sedaghatkish, B. Young, S. Keel, R. Roca, and S. Sheppard. 2000. Nature in focus: rapid ecological assessment. Washington, D.C.: The Nature Conservancy and Island Press.

Schamberger, M., A.H. Farmer, and J.W. Terrell. 1982. Habitat suitability index models: introduction. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Office of Biological Services FWS/OBS-82/10. https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-000.pdf

Severinghaus, W.D. 1981. Guild theory development as a mechanism for assessing environmental impact. Environmental Management 5(3):187-190. https://link.springer.com/content/pdf/10.1007%2FBF01873277.pdf

Introduction – The following proposed procedures are designed, through the use of guild theory, to allow relatively accurate, quantifiable predictions of environmental impact, which can be aimed at both quantitative (biomass) and qualitative (diversity) aspects of the flora and fauna of the proposed area of impact. Examination of impact on plant and animal guilds should allow determination of the cause-effect relationships between the impacting activity and the environment, thus giving insight into potential mitigating procedures. I am proposing that guilds designed from an applied perspective can be used as an analytical and predictive tool in environmental decision-making procedures.

Quote - “Guild theory states that organisms can be grouped by how they similarly use environmental resources (Root 1967). For use in assessing the environmental impact, this

statement can be rearranged as follows: Actions that affect environmental resources will similarly affect the members of guilds using those resources.”

Short, H.L. and K.P. Burnham. 1982. Technique for structuring wildlife guilds to evaluate impacts on wildlife communities. Washington, D.C.; U.S. Department of the Interior, Fish and Wildlife Service Special Report 244. https://pubs.er.usgs.gov/publication/ssrw244

Abstract - This paper describes a technique for ordering wildlife information according to physical strata and vegetative structure so that a variety of statistical analyses can be accomplished. Individual wildlife species are assigned to cells in a species-habitat matrix on the basis of feeding and breeding activities within physical strata in representative types of vegetative cover: the cells within the species-habitat matrix are assigned numeric values. The statistical analyses are thus based on the areas that individual species occupy within the species-habitat matrix. Computer graphics are used to represent the structure of wildlife communities and cluster analysis routines are used to describe the potential wildlife guilds that may exist in different vegetative communities. Different numbers of wildlife guilds will occur in species and presumably also of wildlife guilds present within a type of cover is modified by physical attributes of the vegetation within that cover type. The products of this analytical technique may be suitable for evaluating habitat quality, impact assessments, regional inventories and assessments of wildlife resources, and land-use planning activities.

Conclusions - We have described a technique for associating wildlife species with the structure of wildlife habitat so a variety of computerized analyses can occur to help predict impacts on wildlife caused by changes in the structure of habitat. The concepts developed in this paper were developed with a data base formulated for 275 wildlife species occurring in the eastern ponderosa pine type of forest (Ktichler 1964, type 16) in southeastern Montana and northeastern Wyoming. Our technique is based on the assumption that a wildlife species can be categorized as occupying a discrete area within a two-dimensional "species-habitat" matrix. Food sources and breeding niche requirements make up the two axes of the species-habitat matrix and numeric values identify the cells representing the food sources and breeding niche requirements necessary for each wildlife species. A variety of statistical analyses can be accomplished on the areas (combinations of cells) occupied by different wildlife species so that a description of the structure of the wildlife community within a habitat type can be developed. The assumptions made in the development of the species-habitat matrix are included in the text.

The models produced in the present study indicate that: (1) the species-habitat matrix provides a useful way to order wildlife information; (2) the statistical analyses provide a structuring of the wildlife community that is biologically reasonable; and, (3) a variety of management needs are served in a unique way because the analyses pertain to the total wildlife community. In particular, the computer graphics illustrate, as expected, the complexity of the wildlife community that can occur as guild blocks are added to surface cover, and results from the cluster analyses describe, as expected, the increase in numbers of wildlife guilds that occur as guild blocks are added to wildlife habitat.

The greatest difficulties in working with our guilding technique are associated with developing the data base to drive the guild analyses. Difficulties occur because wildlife species have not historically been associated with vertical strata in the environment (an important subdivision within the species-habitat matrix). We believe this is an imprecision in the quality of natural history information (field biologists have not historically associated species with strata), rather than a flaw in the design of the species-habitat matrix. The

correct positioning of wildlife species within vertical strata requires expert judgment even though food habit and breeding niche requirements are among the best known information about individual species. A second problem encountered in building the data base is the determination of "normal" and "abnormal" food habits and breeding activities. We consider "abnormal" feeding and breeding information to be those exceptions that are so unusual and occur so rarely as to be noteworthy events. Such noteworthy events are not considered in the development of the species database.

The suggested application of the principles determined from the guilding model is presumed and not proven. The determination of the utility of the proposed applications must wait until an applications study, presently under way, is completed. Still we can conclude that the ability to associate wildlife guilds with the structure of habitat allows good predictions to be made about the impacts of habitat change on the structure of the wildlife community, and that wildlife guilds actually occupying an area compared with the standard guild structure that can occupy an area may possibly be a useful measure of habitat quality. This measure compares the structure of the actual wildlife community with the structure of the wildlife community that would potentially occupy the area. The standard guild structure is determined for the climax community of the potential natural vegetation that can occur on an area and the actual guilds present on the area are determined by comparing species found on an area with lists of species comprising the guilds that can occur on the area. An additional utility of the guilding technique is that the structure of the wildlife community present at some future time can be simulated if the structure of the vegetation community present at the future time can be hypothesized. This capability should enhance the assessment of impacts of habitat change on the wildlife community.

SNAP/EWHALE (Scenarios Network for Alaska Planning and Ecological Wildlife Habitat Data Analysis for Land and Seascape Laboratory). 2012. Predicting future potential climate-biomes for the Yukon, Northwest Territories, and Alaska: a climate-linked cluster analysis approach to analyzing possible ecological refugia and areas of greatest change. Fairbanks, AK; University of Alaska, Scenarios Network for Alaska Planning and Ecological Wildlife Habitat Data Analysis for Land and Seascape Laboratory. https://www.snap.uaf.edu/attachments/Cliomes-FINAL.pdf

Executive Summary - The Alaska Climate-Biome Shift Project (AK Cliomes) and the Yukon (YT) and Northwest Territories (NWT) Climate-Biome Shift Project (Ca Cliomes) were collaborative efforts that used progressive clustering methodology, existing land cover classifications, and historical and projected climate data to identify areas of Alaska, the Yukon, and NWT that are likely to undergo the greatest or least ecological pressure, given climate change. Project results and data presented in this report are intended to serve as a framework for research and planning by land managers and other stakeholders with an interest in ecological and socioeconomic sustainability.

“Cliomes” can be considered to be broadly defined regions of temperature and precipitation patterns that reflect assemblages of species and vegetation communities (biomes) that occur or might be expected to occur based on linkages with climate conditions. They are not the same as actual biomes, since actual species shift incorporates significant and variable lag times, as well as factors not directly linked to climate. However, results serve as indicators of potential change and/or stress to ecosystems, and can help guide stakeholders in the management of areas of greatest and lowest resilience to changing climate.

Using climate projection data from SNAP and input from project leaders and participants, we modeled projected changes in statewide climate-biomes (cliomes). The primary data used were SNAP climate models based on downscaled global projections, which provided baseline climate data and future projections. Analysis of these data involved use of the Partitioning Around Medoids (PAM) clustering methodology, which defined regions of similar temperature and precipitation based on a Random Forests™ (Breiman, 2001) generated proximity matrix. Each cluster was used to define one cliome. Thus, for the purposes of this project, clusters are synonymous with cliomes. Further, the Random Forests™ algorithm was used to take the PAM classification and predict the spatial configuration of the cliomes given a changing climate. Alaska and the Yukon were modeled at 2km resolution. These fine-scale data are not available for NWT, so outputs for this territory are at 18.4 km resolution. For all areas, we addressed the inevitable uncertainty of climate projections by analyzing outputs for five different downscaled General Circulation Models (GCMs) as well as for a composite (average) of all five, and for three different greenhouse-gas emissions scenarios (B2, A1B, and A2), as defined for by Nakicenovic et. al. (2001).

The AK Cliomes and Ca Cliomes projects modeled projected shifts in climate-biomes based on current and historical climatic conditions and projected climate change. The eighteen cliomes used in this project were identified using the combined Random Forests™ and PAM clustering algorithms, which are defined by 24 input variables (monthly mean temperature and precipitation) used to create each cluster. They were also assessed via comparisons with four existing land-classification schemes for North America (NALCMS Land cover, AVHRR Land cover, GlobCover 2009, and a combination of the Unified Ecoregions of Alaska described by Nowacki et al. 2001 and Canadian Ecozones). We used Random Forests™ to model projected spatial shifts in climate-biomes, based on SNAP projections for monthly mean temperature and precipitation for the decades 2001–2009, 2030–2039, 2060–2069, and 2090–2099.

The results of this modeling effort show that profound changes can be expected across the study area, with most regions experiencing at least one cliome shift by the end of the century, and some areas shifting three times. Although results differed according to which GCM was used and which emissions scenario was selected, the general patterns of change were relatively robust. These patterns involved a northward movement of cliomes, with arctic clusters shrinking or disappearing, interior boreal and taiga clusters shifting, and clusters currently found only outside of the study area appearing in Alaska, the Yukon, and the Northwest Territories. Cliomes that are currently typical of the central and southern potions of British Columbia, Alberta, and Saskatchewan are likely to become prevalent in a large percentage of the study area. This can be interpreted as their being a high likelihood for changing precipitation/temperature conditions which may be beneficial to some existing plant and animal species and placing some under high stress.

We analyzed all outputs for resilience (defined as lack of projected cliome shift) and vulnerability (defined as multiple cliome shifts over time). The most resilient regions are projected to be the coastal rainforest of southcentral and southeast Alaska, and the most vulnerable areas are projected to be interior and arctic regions, with the exception of the islands of the NWT. However, these conclusions may be affected by the relative dissimilarity of the coastal rainforest to any other cluster in North America; species change may be less there simply because surrounding cliomes differ so greatly.

The ramifications of these projected changes for land managers and local residents are varied, and depend on the mandates and goals of the organizations and agencies involved.

By linking species-specific data and local details of landscape ecology to these projections, land managers can make informed decisions about how to adapt to a changing landscape in an active manner.

Sousa, W.P. 1984. The role of disturbance is natural communities. Annual Review of Ecology and Systematics 15:353-391.

Conclusions - I have attempted to summarize some of the key themes that run through the and rapidly expanding literature on disturbance in natural communities. These include: (a) the factors that determine natural regimes of disturbance, (b) organismal-level responses to disturbance and their evolution, and (c) the influence of disturbance on population and community structure and dynamics at both the local and regional scales.

Although all natural communities probably experience disturbance at some spatial and temporal scale, historically its role in community dynamics has been largely overlooked, except by some temperate-forest ecologists. There are many reasons for this neglect, but one of the prime causes may be that major disturbances often recur at intervals longer than the duration of an average research project or even than the lifespan of the investigator. Thus, the effects of disturbance cannot always be directly observed, which may lead one to conclude that disturbance is unimportant. Even a very long recurrence interval does not necessarily indicate that the impact of disturbance on the community is inconsequential, however. When the affected organisms are long-lived, the "compositional effects of disturbance can persist for centuries or even millennia."

There is a growing realization that disturbance may play as great a role in community dynamics as do biological interactions such as competition and predation, which have received far more empirical and theoretical attention from ecologists. The interplay between disturbance and these biological processes seems to account for a major portion of the organization and spatial patterning of natural communities.

Taylor, J., M. Storzer, C. Coon, S. Davis, G. Harrington, B. Anderson, J.W. Martin, and B. Merrill. 2017. Arctic cumulative impacts workshop: Final report. Anchorage, AK: U.S. Department of the Interior: Bureau of Land Management, Geological Survey, Bureau of Ocean Energy Management, and National Oceanic and Atmospheric Administration.

Executive Summary - On April 12-13, 2016, a workshop on Arctic Cumulative Impacts was held at the BLM Campbell Creek Science Center in Anchorage, AK. The workshop was initiated by a Department of the Interior, Office of the Secretary letter on cumulative impacts that charged the BLM and USGS, in cooperation with BOEM and NOAA, to host this inter-agency workshop.

Specific objectives for the workshop included:

- Reviewing and reporting on current practices for addressing cumulative impacts in the Arctic.
- Learning about partner organization experts' perspectives on cumulative impacts analyses in the Arctic.
- Exploring and proposing potential methods and process flows for conducting inter-agency, crosscutting, integrated cumulative impacts analyses.

Outcomes of the workshop were intended to inform:

• An integrated cumulative impacts case study.
• Implementation of Integrated Arctic Management and the National Strategy for the Arctic Region.
• A potential, forthcoming National Academy of Sciences study on methodologies for cumulative effects analyses in the U.S. Arctic.

The workshop was held over a two-day period. The first day included both governmental and nongovernmental partners, while only governmental partners convened on day two. The workshop was attended by nearly 50 participants over the two days, including 30 from local, state and federal governments, and 19 from the conservation community, industry and other partners. The workshop was structured in a series of short presentations by governmental and non-governmental agencies/organizations, followed by question and answer sessions and plenary discussion with participants. In addition, workshop participants engaged in smaller, focused discussions about cumulative impacts analysis approaches. Following the workshop, an interagency team reviewed suggestions expressed by participants during the Arctic Cumulative Impacts Workshop and identified a list of priority recommendations.

Arctic Cumulative Impacts Workshop Recommendations - Below are the priority recommendations for moving DOI bureaus toward greater integration with cumulative impacts analyses. The recommendations were identified by the interagency workshop planning and reporting team as the most salient, tangible steps forward from the various workshop presentations, break-out-group work, discussions, and daily reflections.

Improved Collaboration and Communication

• Hold regular, cross-bureau NEPA coordinator meetings (in part, to facilitate the following recommendations).
• Develop a common language, clear objectives, and standard practices for use within NEPA and related documents for cumulative impacts analyses across bureaus.
• Develop CEQ-based, cumulative impacts analyses training and implement as required, with consistent training across bureaus.
• Each bureau create and save (in a shared space accessible by all bureaus) a consistently formatted, comprehensive, up-to-date list of past, current, and reasonably foreseeable actions.
• Review, and consistently leverage across all bureaus, any best practices and/or lessons learned related to ecosystem-based, broad scale cumulative impacts analyses work completed by the Arctic Council working groups (e.g., CAFF, PAME, and SDWG).

Enhanced Integration

• Develop a platform/clearinghouse/database for comprehensive, up-to-date information and geospatial data on past, current, and reasonably foreseeable actions, where all bureaus access and work from the same database (perhaps maintained by NSSI).
• Create a shared, comprehensive, land and seascape scale, ecosystem-based, geospatial model to support fully integrated cumulative impacts analyses, where all bureaus are working from and maintaining the same geodatabases and maps (development leveraging NSSI STAP).
• Support hiring a cross-bureau landscape and seascape coordinator (not a manager, but expertise and capacity to work across and within bureaus) to support Arctic cumulative impacts analysis integration and advancement, possibly stationed at DOI Alaska Secretary's Office.

Terrell, J.W., and J. Carpenter. 1997. Selected habitat suitability index model evaluations. Washington, D.C.: U.S. Department of the Interior, Geological Survey Information and Technology Report USGS/BRD/ITR-1997-0005. https://www.nwrc.usgs.gov/wdb/pub/hsi/USGS-BRD-ITR_1997-0005.pdf

Thomas, D.N., G.E. Fogg, P. Convey, C.H. Fritsen, J.-M. Gili, R. Gradinger, J. Laybourn-Parry, K. Reid, and D.W.H. Walton. 2008. The biology of polar region. New York, NY: Oxford University Press.

Trammell, E.J., M.L. Carlson, N. Fresco, T. Gotthardt, M.L. McTeague, and D. Vadapalli. 2015. North Slope rapid ecological assessment. Report prepared for the Bureau of Land Management. Fairbanks, AK: University of Alaska, Alaska Center for Conservation Science, Institute of Social and Economic Research, and Scenarios Network for Alaska and Arctic Planning. http://accs.uaa.alaska.edu/rapid-ecoregional-assessments/north-slope-rea

Truett, J.C., and S.R. Johnson. 2000. The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Truett, J.C., R.G. Senner, K. Kertell, R. Rodrigues, and R.H. Pollard. 1994. Wildlife responses to small-scale disturbances in Arctic tundra. Journal of Wildlife Management 22(2):317-324. http://www.jstor.org/stable/pdf/3783263.pdf?refreqid=excelsior%3Aa9f68e34e5545a5eed7dd4fb26396613

Recommendations - Wildlife ecologists have long recognized the importance of small-scale disturbances to wildlife populations but have seldom measured their effects. Several steps can be taken to better address small-scale disturbances in impact assessment and mitigation planning in the Arctic.

Simple changes in the scale of measure can help assess changes in the abundance or nature of small-scale features. A measurement system that can accommodate units of a few square meters may be needed to accurately assess impacts of habitat change to tundra-nesting shorebirds. But preparation of maps that depict such fine scales may be difficult.

The emerging science of landscape ecology eventually may help remedy the problem by providing mechanisms to measure the responses of animals to landscape mosaics and to habitat heterogeneity at various scales. There is a proposed landscape ecology approach for analyzing impacts of Arctic development at small-to-large spatial scales. Potentially useful tools include appropriate mathematical models, hierarchy theory, and geographic information systems, but many of these are still under development.

Assessment of impact of small-scale disturbances in Arctic oil fields cannot wait for new developments in methodology. In the interests of both economic efficiency and wildlife conservation, current efforts must be made in two directions: improving the accessibility of existing research and altering the design of new research to better assess the responses of wildlife.

Existing research must be published. The rapidity of Arctic development in recent years has required a large amount of research but has allowed little time for results to be published; much of the information remains in so- called "gray" literature generated by government agencies and private consulting firms. Scientists and research sponsors can help to remedy this problem by insisting that research results be presented in manuscripts suitable for submission to peer-review journals.

New research can be improved by applying 3 basic steps essential for productive impact analyses: (1) reach consensus on wildlife management goals, (2) focus on population-level effects or other quantifiable impacts that relate to goals, and (3) design experiments to incorporate both temporal and spatial controls. To identify wildlife management goals, research planners must communicate with wildlife managers to determine priorities among species and the desired population status of each high-priority species. Biologists can keep research objectives focused on wildlife populations by emphasizing species abundance and productivity rather than short-term avoidance or other behavioral responses unlikely to affect populations. Research sponsors and permitting agencies can encourage the application of temporal (before-after) comparisons, absent from most impact-related field investigations, by providing for study prior to site-specific alterations and requiring follow-up studies of sufficient duration to determine population-level changes. Moreover, new research emphasizing the posing and testing of hypotheses through experimental small-scale landscape alterations would provide useful information for planning and mitigating adverse effects of arctic developments.

Information from both existing and new research is critical for planning appropriate mitigation for oil-related impacts to landscapes. First, those rehabilitating oil fields will find it impossible in practice to remove all traces of disturbance from arctic tundra landscapes and thus fully restore affected areas to their previous undisturbed condition. Therefore, it will be helpful to know which aspects of the disturbances produce the greater detrimental effects on the majority of species, so that rehabilitation strategies can emphasize alleviation of those effects. And second, some of the net beneficial effects of small-scale disturbances may be consistent with wildlife management goals. It will be helpful to quantify these net benefits and to learn how they are produced so that tundra rehabilitation efforts can be selective in retaining them, if desired.

Summary - In Arctic landscapes, birds and mammals often respond markedly to disturbances that occur at relatively small spatial scales. Knowledge of these response patterns is relevant for wildlife conservation in regions where human activities have locally altered plant communities or abiotic substrates and added elevated structural features. The science of impact assessment has lagged in its ability to quantify the impacts to wildlife of these changes, despite a pressing need to accurately measure impacts and to plan mitigation for those that are adverse.

Wildlife may benefit or suffer from small-scale landscape disturbances, depending on the species and the disturbance type. Linear disturbance features may serve as barriers to or corridors for movement. Disturbance may reduce or augment food supplies. Oil fields and other developments in the Arctic have introduced patchworks of disturbed vegetation, gravel roads, gravel pads, and elevated pipes and buildings. For some species, these disturbances could, without mitigation, hinder movement from one portion of range to another or reduce the amount of resources available to the animals. For other species, they seem to induce or attract higher levels of use than surrounding undisturbed areas. Because many of the disturbances occupy small areas and often affect wildlife populations out of proportion to their spatial extent, accurate assessment of their benefits and detriments has been difficult.

As analysts develop strategies for rehabilitating arctic tundra areas affected by industrial development, and particularly as producing oil fields are decommissioned in the future, information will be needed on how various species respond to small-scale disturbances. The

new science of landscape ecology offers potentially powerful tools for identifying wildlife habitat relationships. But until this science becomes more advanced, it seems desirable to use conventional impact analysis but to shift its spatial emphasis so that the effects of small-scale disturbances are better detected and measured. Mitigation planners should carefully evaluate the data as they become available, recommending mitigation procedures that will not only offset negative effects of the disturbances but that will retain their positive values.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901. http://www.jstor.org/stable/3808148

Abstract - Current methods of evaluating wildlife habitat for management purposes can be arranged in a hierarchy of increasing generality. The most general level is evaluation of wildlife habitat for entire communities on the basis of inferences drawn from vegetational structure. At the base of the hierarchy the high resolution studies, upon which accuracy at the higher hierarchical levels depends, usually assume that habitat quality for a species is positively correlated with the density of the species. If habitat quality for a wildlife species is a measure of the importance of habitat type in maintaining a particular species, habitat quality should be defined in terms of the survival and production characteristics, as well as the density, of the species occupying that habitat. Situations in which habitat quality thus defined is not expected to be positively correlated with density are described, along with the species and environmental characteristics that are most likely to produce these situations. Examples drawn from the literature in which density and habitat quality are not positively correlated are described. The positive correlation of density with habitat quality in specific instances cannot be assumed without supporting demographic data.

Management Implications - Management plans that depend only on habitat characteristics to infer habitat quality contain a large amount of guesswork, both with regard to viable population levels and with regard to predictability of species densities on the basis of habitat characteristics. Such plans depend heavily on the correct identification of favorable habitat for the wildlife species being managed. Intensive multi-annual demographic study of a single species over the range of habitats being measured is needed to interpret the broader surveys. Without attention to demography, even multi-annual surveys or censuses will not necessarily be sufficient to distinguish "source" and "sink" habitats. Management plans adopted on the basis of a species survey or census taken during only 1 year, or on the basis of measured habitat characteristics coupled with inadequate knowledge of the factors actually determining habitat quality, are particularly unsatisfactory. Thus, we cannot afford to ignore the processes that produce the densities we observe, or attempts to maintain target densities by retaining areas of specified habitat types will founder. We need to be much more careful in identifying high quality or critical habitat and not assume simple density-habitat quality relationships without the demographic data to support them.

Viereck, L.A., and J.C. Zasada. 1972. A proposal for an ecological reserve system for the taiga and tundra of Alaska. College, AK: U.S. Department of Agriculture, Forest Service, Institute for Northern Forestry.

Walker, L.R. 2012. The biology of disturbed habitats. New York, NY: Oxford University Press.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive management: the U.S. Department of the Interior Technical Guide. Washington, D.C.; U.S. Dept. Interior. http://www.usgs.gov/sdc/doc/DOI-Adaptive-Management-Applications-Guide-27.pdf

Wilson, R.R., J.R. Liebezeit, and Wendy M Loya. 2013. Accounting for uncertainty in oil and gas development impacts to wildlife in Alaska. Conservation Letters 6(5):350-358. http://onlinelibrary.wiley.com/doi/10.1111/conl.12016/epdf

Abstract - Around the world, oil and gas exploration and development are moving into areas previously undisturbed by industrial development. These activities and associated infrastructure can significantly impact wildlife populations and their habitat. Uncertainty in the location of oil and gas accumulations, however, makes it difficult to assess potential impacts to wildlife populations from future development. We present a modeling approach that takes this uncertainty into account by randomly sampling the locations of oil and gas accumulations across the landscape and building out simulated infrastructure. We evaluated four management alternatives outlined for the National Petroleum Reserve-Alaska to demonstrate how this model can quantify the relative impacts to caribou (*Rangifer tarandus*) calving habitat and passerine nest survival. We were able to identify clear differences in impacts for wildlife under the four alternatives and highlighted the range of variability in how development might proceed under each scenario.

Woodward, A., and E.A. Beever. 2011. Conceptual ecological models to support detection of ecological change on Alaska National Wildlife Refuges. Anchorage, AK; Department of the Interior, U.S. Geological Survey Open-File Report 2011-1085. http://pubs.usgs.gov/of/2011/1085/pdf/ofr20111085.pdf

Abstract - More than 31 million hectares (77 million acres) of land are protected and managed in 16 refuges by the U.S. Fish and Wildlife Service (USFWS) in Alaska. The vastness and isolation of Alaskan refuges give rise to relatively intact and complete ecosystems. The potential for these lands to provide habitat for trust species is likely to be altered, however, due to global climate change, which is having dramatic effects at high latitudes. The ability of USFWS to effectively manage these lands in the future will be enhanced by a regional inventory and monitoring program that integrates and supplements monitoring currently being implemented by individual refuges. Conceptual models inform monitoring programs in a number of ways, including summarizing important ecosystem components and processes as well as facilitating communication, discussion and debate about the nature of the system and important management issues. This process can lead to hypotheses regarding future changes, likely results of alternative management actions, identification of monitoring indicators, and ultimately, interpretation of monitoring results. As a first step towards developing a monitoring program, the 16 refuges in Alaska each created a conceptual model of their refuge and the landscape context. Models include prominent ecosystem components, drivers, and processes by which components are linked or altered. The Alaska refuge system also recognizes that designing and implementing monitoring at regional and ecoregional extents has numerous scientific, fiscal, logistical, and political advantages over monitoring conducted exclusively at refuge-specific scales. Broad-scale monitoring is particularly advantageous for examining phenomena such as climate change because effects are best interpreted at broader spatial extents. To enable an ecoregional perspective, a rationale was developed for deriving ecoregional boundaries for four ecoregions (*Polar*, *Interior Alaska*, *Bering Coast*, and *North Pacific Coast*) from then developed to illustrate resources and processes that operate at spatial scales larger than individual refuges within each ecoregion. Conceptual models also were developed for adjacent marine areas, designated as the North Pacific, Bering Sea, and Beaufort –Chukchi Sea Marine Ecoregions. Although many more conceptual models will be required to support development of a regional monitoring program, these an important foundation.

Young, S.B., J.C. Walters, and R.H. Hagenstein. 1982. Proposed geological and ecological natural landmarks in interior and western Alaska, Vol 2. Wolcott, VT: Center for Northern Studies Contributions No. 21, for U.S. Department of the Interior, National Park Service Contract CX 200-8-0017.

Water Resources (fresh water and marine) and Gravel – with considerable overlap with Fish

Bayha, K.D. 1996. Criteria for instream water rights for selected 1002 area lakes, Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service Water Resources Branch WRB 96-5.

<u>Preface</u> - "Instream flow" includes amounts, timing, and duration of water in streams and rivers, natural lakes, wetlands, other water bodies, and riparian zones (including flood plain inundation).

The term "instream flow" was originally used as an adjective that modified nouns such as uses, values, requirements, needs, and approximations. "Instream flow" was intended to denote the use, values, etc., that occurred in the stream channel and adjacent flood plain during flood stage as opposed to off-stream uses, values, etc. "Instream flow" is sometimes used as a noun, short for "instream flow requirements" for specified or unspecified uses. Notwithstanding Stalnaker and Arnette (1976) and Alaska regulation 11 AAC 93.970(19), "instream flow" is not synonymous with "stream flow." Stream flow is the amount of water in the stream at a given point at a given time. Instream flow is that portion of stream flow needed for the instream values and uses. This term was coined in the early 1970s when the water-planning community in the Pacific Northwest was focused on water withdrawals for out-of-stream uses and regarded any water left in the stream to be a temporary condition awaiting someone to "put it to use." In order to gain recognition in the water-planning community for the natural values associated with a river and the uses made of the water therein, a new term was needed. The term "instream flow" evolved from the earlier term "stream resource maintenance flow" adopted by an interagency team about 1971 in Boise, Idaho, and defined as that flow regime required to maintain a healthy aquatic ecosystem. The evolution was rapid among the fisheries wetland ecologists and much slower within other disciplines. This situation has produced a series of published definitions in various papers that today must be considered within the context of their place in the evolution.

Stalnaker, C.B., and J.L. Arnette. 1976. Methodologies for the determination of stream resource flow requirements: an Assessment. Logan, UT: Utah State University for U.S. Department of the Interior, Fish and Wildlife Service, USFWS/OBS.

Bring, A., and G. Destouni. 2014. Arctic climate and water change: model and observation relevance for assessment and adaptation. Surveys in Geophysics 35:853-877.

<u>Abstract</u> - The Arctic is subject to growing economic and political interest. Meanwhile, its climate and water systems are in rapid transformation. In this paper, we review and extend a set of studies on climate model results, hydro-climatic change, and hydrological monitoring systems. Results indicate that general circulation model (GCM) projections of drainage basin temperature and precipitation have improved between two model generations. However, some inaccuracies remain for precipitation projections. When considering geographical priorities for monitoring or adaptation efforts, our results indicate that future projections by GCMs and recent observations diverge regarding the basins where

temperature and precipitation changes currently are the most pronounced and where they will be so in the future. Regarding late twentieth-century discharge changes in major Arctic rivers, data generally show excess of water relative to precipitation changes. This indicates a possible contribution to sea-level rise of river water that was previously stored in permafrost or groundwater. The river contribution to the increasing Arctic Ocean freshwater inflow is similar in magnitude to the separate contribution from glaciers, which underlines the importance of considering all possible sources of freshwater when assessing sea-level change. We further investigate monitoring systems and find a lack of harmonized water chemistry data, which limits the ability to understand the origin and transport of nutrients, carbon and sediment to the sea. To provide adequate information for research and policy, Arctic hydrological and hydrochemical monitoring needs to be extended, better integrated and made more accessible. Further water-focused data and modeling efforts are required to resolve the source of excess discharge in Arctic rivers. Finally, improvements in climate model parameterizations are needed, in particular for precipitation projections.

Congressional Research Service [author redacted]. 2005. Legal issues to proposed drilling for oil and gas in the Arctic National Wildlife Refuge (ANWR). Washington, D.C.: Library of Congress, Congressional Research Service.

<u>Summary</u> - Congress is again considering whether to permit drilling for oil and gas in the coastal plain of the Arctic National Wildlife Refuge (Refuge), Alaska, to designate the area as wilderness, or to retain the status quo of maintaining the area as a Refuge without drilling. This area is rich in wildlife and wilderness values, but may also contain significant oil and gas deposits. H.R. 567 and S. 261 have been introduced in the 109th Congress to designate the coastal plain of the Refuge a wilderness, but H.R. 6 has passed the House. Title XXII of the bill would authorize oil and gas leasing in the Refuge. Both the House and Senate have approved H.Con.Res. 95, a budget resolution that may necessitate revenues from oil and gas development in the Refuge to meet the budget reconciliation targets, and allow enactment of such legislation without filibuster. This report provides background on the legal issues surrounding the Refuge development proposals, and will be updated as circumstances warrant. For an updated summary of current actions on bills, see CRS Issue Brief IB10136, *Arctic National Wildlife Refuge (ANWR): Controversies for the 109th Congress*.

H.R. 6 would authorize leasing in the Refuge and contains a 2,000 acre limitation on the “footprint” of leasing development in the Coastal Plain. However, if the current statutory prohibition against production of oil and gas anywhere in the Refuge is repealed, then oil and gas development and related activities could occur not only on the federal lands, but also on Native lands within the Refuge. Absent express language on the point, an acreage limitation would not apply to some, and possibly not to any, of the Native lands, in which case some or all of the more than 100,000 acres of such lands in the Refuge (inside and outside the officially designated Coastal Plain) could be developed. A 1983 Agreement with the Arctic Slope Regional Corporation (ASRC), a Native Regional Corporation, would govern oil exploration on ASRC subsurface and associated surface rights in the Refuge, unless these provisions are superseded by statute or regulations, and some assert that the environmental terms of the agreement are lenient. ASRC agreed to comply with statutes and regulations to protect wildlife, habitat, and the environment of the Coastal Plain. It is unclear whether some or all of ASRC’s lands are subject to the 2,000 acre limit, and how that acreage might be allocated among ASRC and federal lessees.

H.R. 6 gives primary responsibility for leasing to the Secretary DOI acting through the Director BLM rather than the Service, the agency that implemented the oil exploration program for the Coastal Plain. The environmental standard in H.R. 6 - “no significant adverse effect” — has been used in the past, but could allow a range of adverse effects compared to other standards that have also been used. H.R. 6 also would limit the NEPA process applicable to leasing in the Refuge, and limit and expedite judicial review. The bill states that leasing is to be under the Mineral Leasing Act (MLA), yet would establish a 50/50 revenue sharing formula different from the 90/10 formula in the MLA, a fact that might raise issues related to the Alaska Statehood Act.

Dunton K.H., T. Weingartner, and E.C. Carmack. 2006. The nearshore western Beaufort Sea ecosystem: circulation and importance of terrestrial carbon in arctic coastal food webs. Progress in Oceanography 71(2-4):362–378. https://doi.org/10.1016/j.pocean.2006.09.011

Abstract - The nearshore shelf of the Beaufort Sea is defined by extreme physical and biological gradients that have a distinctive influence on its productivity and trophic structure. Massive freshwater discharge from the Mackenzie River, along with numerous smaller rivers and streams elsewhere along the coast, produce an environment that is decidedly estuarine in character, especially in late spring and summer. Consequently, the Beaufort coast provides a critical habitat for several species of amphidromous fishes, some of which are essential to the subsistence lifestyle of arctic native populations. Because of its low in situ productivity, allochthonous inputs of organic carbon, identifiable on the basis of isotopic composition, are important to the functioning of this arctic estuarine system. Coastal erosion and river discharge are largely responsible for introducing high concentrations of suspended sediment from upland regions into the nearshore zone. The depletion in the ^{13}C content of invertebrate and vertebrate consumers, which drops about 4-5‰ eastward along the eastern Alaskan Beaufort Sea coast, may reflect the assimilation of this terrestrial organic matter into local food webs. In addition, the large range in ^{13}C values of fauna collected in the eastern Beaufort (nearly 8‰) compared to the same species in the northeastern Chukchi (3‰), indicate a lower efficiency of carbon transfer between trophic levels in the eastern Beaufort. The wider spread in stable isotope values in the eastern Beaufort may also reflect a decoupling between benthic and pelagic components. Isotopic tracer studies of amphidromous fishes in the Simpson Island barrier island lagoon revealed that terrestrial (peat) carbon may contribute as much as 30–50% of their total dietary requirements. On the eastern Alaska Beaufort Sea coast, the δ^{13}C values of arctic cod collected in semi-enclosed lagoons were more depleted, by 3-4‰, compared to fish collected in the coastal Beaufort Sea. Calculations from isotopic mixing equations indicate cod from lagoons may derive 70% of their carbon from terrestrial sources. The δ^{15}N values of lagoon fish were also 4‰ lower than coastal specimens, reflective of the lower δ^{15}N values of terrestrially derived nitrogen (0-1.5‰ compared to 5-7‰ for phytoplankton). The role of terrestrial carbon in arctic estuarine food webs is especially important in view of the current warming trend in the arctic environment and the role of advective processes that transport carbon along the nearshore shelf. Biogeochemical studies of the arctic coastal estuarine environment may provide more insights into the function of these biologically complex ecosystems.

Dunton K.H., S.V. Schonberg, and L.W. Cooper. 2012. Food web structure of the Alaskan nearshore shelf and estuarine lagoons of the Beaufort Sea. Estuaries and Coasts 35(2):416-435. https://link.springer.com/article/10.1007/s12237-012-9475-1

Abstract - The eastern Alaska Beaufort Sea coast is characterized by numerous shallow (2-5 m) estuarine lagoons, fed by streams and small rivers that drain northward from the Brooks Range through the arctic coastal plain, and bounded seaward by barrier islands and shoals. Millions of birds from six continents nest and forage during the summer period in this region using the river deltas, lagoons, and shoreline along with several species of anadromous and marine fish. We examined biogeochemical processes linking the benthic community to the overall food web structure of these poorly studied but pristine estuaries, which are largely covered by 1.8 m of ice for 10 months annually. In summer, these lagoons are relatively warm with brackish salinities (5–10°C, S = 10–25) compared to more open coastal waters (0–5°C, S > 27). The stable isotopic composition of organic materials in sediments (i.e., benthic particulate organic matter) and water column suspended particulate organic matter from both streams and lagoons are largely indistinguishable and reflect strong terrestrial contributions, based upon $\delta^{13}C$ and $\delta^{15}N$ values (−25.6‰ to −27.4‰ and 1.4‰ to 3.3‰, respectively). By comparison, shifts toward more heavy isotope-enriched organic materials reflecting marine influence are observed on the adjacent coastal shelf (−24.8‰ to −25.4‰ and 3.4‰ to 5.3‰, respectively). The isotopic composition of lagoon fauna is consistent with a food web dominated by omnivorous detritovores strongly dependent on microbial processing of terrestrial sources of carbon. Biomagnification of ^{15}N in benthic organisms indicate that the benthic food web in lagoons support up to four trophic levels, with carnivorous gastropod predators and benthic fishes ($\delta^{15}N$ values up to 14.4‰) at the apex.Lyons, S.M., and J.M. Trawicki. 1994. Water resource inventory and assessment, coastal plain, Arctic National Wildlife Refuge: 1987-1992 Final Report. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch WRB 94-3.

Elliot, G.V. 1989. Winter water availability on the 1002 area of the Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch, Alaska Fisheries Technical Report Number 3.

Abstract – During 25-30 March 1988, an inventory of winter water availability was conducted within the 1002 area of the Arctic National Wildlife Refuge. A helicopter mounted radar system was used to identify the presence of sub-ice water. Water was found to be widely distributed throughout much of the 1002 area in several settings: springs and associated aufeis formations; lakes; a deep river pool; and, localized pools beneath ice pressure ridges occupying braided river floodplains.

Pressure ridge pools accounted for the most frequent and widespread occurrence of water identified during this inventory. They were identified from portions of river drainages where water was not previously documented during winter. These small but numerous pools may greatly expand the know distribution of overwinter habitat for fish in this region, especially for small juvenile fish.

A full inventory of winter water presence within the 1002 area was not completed due to equipment limitations and time constraints. Recommendations for further investigation and completion of the area wide inventory are made.

Elliot, G.V., and S.M. Lyons. 1990. Quantification and distribution of winter water within river systems of the 1002 area, Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch, Alaska Fisheries Technical Report Number 6.

Abstract – An inventory of the distribution and quantity of winter water in rivers was conducted within the 1002 area of the Arctic National Wildlife Refuge as part of an effort to develop a hydrologic data base, map sources of winter water, and determine water availability for oil and gas activities.

During 10-19 Apr 1989, locations of ice hummocks on all major river drainages in the area were identified using a LORAN navigation instrument. A subsample of 9 hummocks was drilled to delineate water pool volumes. A positive linear relationship between ice hummock size and pool volume was developed and used to estimate the total volume of water available beneath all hummocks inventoried.

Although winter water was found to occur over a widespread area in most of the major river drainages in the 1002 area, the quantities were not great. Nearly 9 million gallons of water were estimated to be available along the 237 miles of river channel inventoried. **It takes approximately 1,350,000 gallons of water to construct and maintain each mile of ice road used to support oil exploration activities and 30,000 of water per day to support an oil exploration drill**.

Hayes, M.J. 1977. Water management at Prudhoe Bay, Alaska – a case study in policy development. Fairbanks, AK: University of Alaska, M.S. thesis.

Abstract – On 1 Apr 1976, the Commissioner of Fish and Game ordered the cessation of all water withdrawals within Prudhoe Bay Development Area. The physical and political conditions surrounding this closure are reviewed and evaluated in relation to the resultant policy. This study finds that political and bureaucratic interests influence natural resource policy to a greater extent than concern with the physical and biological environment.

Joyce, M.R., L.A. Rundquist, and L.L. Moulton [Woodward-Clyde Consultants]. 1980. Gravel removal guidelines manual for Arctic and subarctic floodplains. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service Biological Services Program FWS/OBS-80/09. http://www.arlis.org/docs/vol2/hydropower/SUS10034.pdf

Comment - Studies of gravel removal in Arctic and subarctic floodplains have found that specific site locations coupled with the depth of scraping proved to be the most influencing factors in how detrimental or long-term the effects of gravel removal are on terrestrial wildlife (refer to Woodward-Clyde Consultants 1980; *Gravel removal studies in Arctic and subarctic floodplains in Alaska*).

Summary of Project Results and Conclusions - Study of 25 floodplain material sites has shown that disturbance resulting from gravel removal operations can be minimized. Two gravel mining techniques were used at the study sites, scraping of surface or near-surface deposits and pit excavation of deep deposits.

In general, approaches to minimize environmental changes caused by scraping including maintaining buffers between active channels and the work area and avoiding:

- instream work
- mining to depths and in locations that induce permanent channel shifts or ponding of water
- clearing or riparian vegetation

- disturbance to natural banks

Large rivers and braided rivers generally provide the most accessible gravels for scraping. Gravel mining using scraping techniques in these areas frequently resulting in the least environmental damage.

Pit excavations resulted in permanent loss of terrestrial riparian habitat; however, many pits increased local habitat diversity. These newly created habitats frequently received concentrated utilization by local fauna, particularly fish, waterfowl, shorebirds, and furbearers. Large quantities of material were excavated using pit mining techniques. Pits that were located on the inactive side of the floodplain, and were separated by vegetated buffers in the range of 50-100 m, generally did not influence active channel hydraulics.

Pits were found to be the most beneficial to local fauna when they exhibited the following characteristics.

- 2 ha or more in size

- contained diverse shoreline configuration

- contained diverse water depths

- contained islands

- contained an outlet connected to active channels

Kozlenko, N., and J.O. Jefferies. 2000. Bathymetric mapping of shallow water in thaw lakes on the North Slope of Alaska with spaceborne imaging radar. Arctic 53(3):306-316.

Abstract - Few bathymetric maps are available for the thousands of thaw lakes on the North Slope of Alaska. We describe a semi-automated procedure for bathymetric mapping of water up to 2 m deep (i.e., less deep than the maximum ice thickness) in these lakes. A sequence of ERS-1 synthetic aperture radar (SAR) images and a simulated ice growth curve for winter 1991-1992 are used to derive a digital elevation model of lake basins. The method is based on discriminating between floating ice and grounded ice in the SAR images to define raw isobaths; assigning an ice thickness or water depth to each isobath from the simulated ice-growth curve, and interpolating to create equally spaced (0.25 m) isobaths. There is modest agreement between SAR-derived maps and the few available bathymetric maps. Differences between the SAR maps and the original maps are probably unavoidable because of different production methods and original data formats. The concept of using SAR and a simulated ice-growth curve for bathymetric mapping of thaw lakes would benefit from verification based on a comparison with new maps derived from accurate field measurements at a selection of lakes with different morphological characteristics. Nevertheless, it is concluded that this technique is sound and could be used routinely for inexpensive and accurate bathymetric mapping across the entire North Slope and elsewhere (e.g., in Siberia, where large numbers of thaw lakes also occur). Such mapping would greatly increase the amount and spatial coverage of bathymetric data and would provide an accurate baseline against which to detect changes in the size, shape, bottom topography, and location of lakes.

Lyons, S.M. 1989. Water resource inventory and assessment, Arctic National Wildlife Refuge, 1989 stream discharge gaging data. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 8.

Lyons, S.M., and J.M. Trawicki. 1994. Water resources inventory and assessment, coastal plain, Arctic National Wildlife Refuge: 1987-1992 final report. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch WRB-94-3.

Discussion and Recommendations (Pp. 22ff).

The North Slope of Alaska is a vast remote region with an abundance of natural resources. Due to the extreme climatic conditions and limited access, the extent of the natural resources is largely unknown. As resource demands increase and technology advances, the natural resources along the North Slope will become economically and technologically accessible.

There has been little interest by State, federal or private sector in the water resources along the coastal plain primarily because of a lack or competitive uses. The potential for oil and gas exploration along the coastal plain of Arctic NWR resulted in a water resource inventory and assessment. The intent of the inventory and assessment is to provide resource managers with the hydrologic information required to make informed water allocation decisions concerning industrial development, mitigation measures, and fish and wildlife habitat protection.

The water resource studies conducted along the coastal plain of Arctic NWR (1987-1992) provide a hydrologic database that will aid in resource management decisions. The studies provide a general understanding of the hydrologic regime and the physical processes that occur along this portion of the coastal plain. In general, breakup is the most significant hydrologic event of the year for streams that originate in the coastal plain. In most years more than 50% of the average annual discharge occurs during the breakup period. Streamflow quickly diminishes once snowmelt is complete. Summer discharge will go to zero on many streams. The presence of permafrost reduces infiltration resulting in quick stream response to storm events. Storm peaks are high and rapid, and recede quickly. Figure 2, is a generalized hydrograph for streams along the coastal plain. (Note that the hydrograph is from mid-May through mid-Oct). Most years there was an increase in discharge just prior to freeze-up. The increase is discharge was due to snowfall followed by warmer temperatures and/or rain. By late-Sep flow has diminished and ice has begun to form. With the exception of isolated pools and springs, rivers freeze to substrate. Lakes located along the coastal plain tend to be small shallow thaw lakes congregated near the mouth of the Canning River or west of Okpilak River. Lakes less than 7 feet in depth generally freeze to substrate.

The average daily discharge reported in Appendix A are considered to be good. With the short period of record (5 years) statistical analysis is limited, but the 5 years of stream discharge data collected along the coastal plain of the Arctic NWR are representative of the long-term average annual discharge. Comparing the 1988 through 1992 average annual discharge of the Kaparuk and Sagavanirktok Rivers with the long-term average annual discharge of these rivers, indicate that the 5 years of discharge data for the coastal plain of Arctic NWR are representative of the expected long-term average annual discharge of the coastal plain. The 5 years (1988-1992) were 2% below and 6.5% above the long-term average annual discharge of the Kaparuk and Sagavanirktok Rivers, respectively. During the 5 years there was considerably variation in discharge. In 1989, the Kaparuk and Sagavanirktok Rivers were considerably higher than their long term average, 60% and 18%, respectively. The converse occurred in 1990. The Kaparuk River was 35% below the average long term annual discharge while the Sagavanirktok River was 15% below. These trends are evident on the streams of the coastal plain of the Arctic NWR. The annual hydrograph of the Tamayariak River (Figure 3) is representative of the variation among the 5 years of data.

Breakup data for the gaged streams located on the coastal plain have been estimated. These estimates are considered to be poor, but are the best available. During breakup the normal relationship between water surface elevation (depth) and discharge does not always hold true. Initially, water from the melting snow flows over thick layers of river ice. The water flowing over ice creates a temporary and extremely high water surface elevation. Once the ice has eroded from the channel the relationship between water depth and discharge may be established. Stream gaging stations were not installed until river channels were ice free.

Estimates for missing data, other than breakup, were made using existing data from gaging stations located within the coastal plain, Arctic NWR. These estimates are also considered to be poor. USGS stream gaging stations are located too far from streams of the coastal plain area of Arctic NWR to be used to estimate local rainfall events.

The distribution and timing of water is critical for the management of resources located along the coastal plain. The water resources data in this report provide information required to make management decisions, but are by no means conclusive. In the planning stages of resource development along the coast plain additional water resource data will be required. It is recommended that stream gaging stations be installed on the Canning River, Hulahula River, Okpilak River and the Jago River prior to development. These rivers were identified as high priority streams but were not gaged due to logistical and technical restraints. The Hulahula and Canning Rivers have significant resource and recreational values. There are several spring areas associated with each river. These spring areas provide overwintering habitat for Arctic char populations. The Hulahula River is also used for subsistence purposes by the residents of Kaktovik.

The Kogopak River was also identified as a high priority during the scoping process, but data for this stream can be synthesized and a gage is not required. Gages could also be reinstalled on the Tamayariak River, Sadlerochit River, Akutotak River, and the Sikrelurak River to augment the existing database. It is also recommended that summer and winter precipitation data could be collected in the headwaters and along the coastal plain. The new and additional data would increase the existing database and allow for a more rigorous statistical analysis.

Since many biological processes are dependent on the hydrologic cycle it is recommended that the USFWS secure instream water rights on the streams, springs, wetlands, and lakes along the coastal plain of the Arctic NWR. Water resources are limited 10 months of the year. The little water that is available during the winter and the low flow summer periods provide the only available aquatic habitat. The relatively high flows associated with breakup provide the water necessary for fish passage in and out of streams, and provide the volume of water required to establish the salinity and temperature gradients in the estuaries and lagoons.

Regular and periodic flooding are an integral part of the hydrologic cycle and are required to maintain the long term functional integrity of most ecosystems. Ninety-nine percent of the coastal plain is classified as wetland (Clough et al. 1987) with the majority falling into the palustrine system (moist tundra)(NWI unpublished data). Based on this classification almost the entire watershed for all drainages in the coastal plain are moist tundra system. The river systems themselves are a dominating factor influencing the physical characteristics of the riverine systems. Instream water rights need to incorporate flood flows on a periodic basis for the purpose of maintaining the stream and connected habitats. Securing instream water rights at the present would be prudent of the USFWS and alleviate future conflict with respect to water allocation.

The topographic relief on the western portion of the study area is distinctly different from the Prudhoe Bay region and the eastern portion of the 1002 area. The topographic relief prohibits the formation of thaw lakes. Except for regions with topographic relief, thaw lakes generally provide a more abundant source of winter water than naturally-occurring water pools in springs and rivers. Should oil and gas development occur along the coastal plain the topographic relief will present engineering problems different from those of Prudhoe Bay. Roads and/or pipelines that run east-west will cross several drainages and will run perpendicular to the slope of the landscape. Roads running perpendicular to the slope of the landscape will create a barrier to sheetflow during breakup and storm events. To maintain the integrity of the wetlands, road culverts (18 inch or larger) should be located a minimum of every 1000 feet, and at all natural depression or drainage locations.

The physical and biological processes in the Arctic ecosystem are dynamic. For every change in the physical environment there is a biological response. Managing to maintain the functional integrity of the Arctic ecosystem and providing for its socioeconomic use is and will continue to be a challenge. The intent of this report was to provide resource managers with information required to make resource management decisions along the coastal plain of Arctic NWR.

Meehan, R. Oil development in northern Alaska: a guide to the effects of gravel placement on wetlands and waterbirds. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Investigations, Branch of Wetlands and Marine Ecology.

<u>Abstract</u> – This report provides guidance for resource managers involved with oil and gas development on Alaska's North Slope. The information is specific to the Arctic coastal plain, and much is drawn from the Prudhoe Bay area. Guidance on development impacts is most applicable in the Prudhoe Bay area and is generally applicable to other areas in the Arctic coastal plain. The review focuses on development impacts on tundra and the related changes in habitat value to waterbirds. Background information on development patterns and specific information on oilfield facilities are included.

General information is followed by an overview of the impacts related to development and discussion of specific impacts.

The three appendices contain specific information on vegetation and birds. Appendix A is an annotated bibliography of major references on North Slope birds and physical impacts related to oilfield development. Appendix B contains species accounts of the most common North Slope birds. Appendix C contains a list of common and scientific names for birds and plants commonly occurring on the Arctic coastal plain.

Trawicki, J.M., S.M. Lyons, and G.V. Elliot. 1991. Distribution and quantification of water within the 1002 Area, Arctic National Wildlife Refuge, Alaska. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fishery Technical Report Number 10.

Abstract – An inventory of lake basins in the 1002 area of the Arctic National Wildlife Refuge was conducted as part of an effort to develop a hydrologic database, map sources of water, and quantify water availability.

Using a recording fathometer, depth profile measurements were taken on 119 lakes within the 1002 area during the summer months of 1988, 1989 and 1990. Fathometer output was used to construct lake contour maps, calculate volumes, and estimate winter water volumes beneath ice cover.

Total estimated volume of the study lakes ranged from 55,382 acre-feet when free of ice to 3,336 acre-feet beneath 7 feet of ice, the maximum ice thickness. In April, when ice thickness is at maximum, 90% of the available water is contained within 9 of the 119 lakes surveyed. The lakes are not evenly distributed across the 1002 area. A large number of lakes are congregated near the mouth of the Canning River, and only 2 lakes are located in the region between the Katakturuk and Sadlerochit Rivers.

During the winter months, winter water is more abundant in lakes than in pools located beneath ice hummocks along major river drainages of the 1002 area.

Observation of fish presence in lakes was more frequent and widespread than previously suspected. Ninespine stickleback (*Pungitius pungitius*) were found in 34 of the 52 lakes (65%) surveyed in 1989.

van der Valk, A.G. 2012. The biology of freshwater wetlands. New York, NY: Oxford University Press.

Woodward-Clyde Consultants. 1980. Gravel removal studies in Arctic and subarctic floodplains in Alaska. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service Biological Services Program FWS/OBS-80/08. http://www.arlis.org/docs/vol1/Susitna/11/APA1179.pdf

Studies of gravel removal in Arctic and subarctic floodplains have found that specific site locations coupled with the depth of scraping proved to be the most influencing factors in how detrimental or long-term the effects of gravel removal are on terrestrial wildlife (refer to Joyce et al. 1980; *Gravel Removal Guidelines Manual for Arctic and Subarctic Floodplains*).

Plants and Plant Communities

Billings, W.D. 1973. Arctic and alpine vegetations: similarities, differences and susceptibility to disturbance. BioScience 23(12):697-704.

Susceptibility to disturbance - Arctic and alpine vegetation evolved almost entirely without the presence of man. The severe environment and low productivity made primitive man a late- comer to such ecosystems and kept his populations at a low density. But in this century, modern man has brought his technology to these regions and made them accessible to both industry and recreation. The resultant changes, damage, and debris are often highly visible, at least locally, leading to the oft-repeated statement that these ecosystems are "fragile."

In view of the wide range of differences within arctic systems, within alpine systems, and between them, it would be surprising if they were all equally "fragile." They exist in what are among the most rigorous terrestrial environments, and without man they seem capable of persisting almost indefinitely. Both general types do tend to be susceptible to man's disturbance, whether by industrial, agricultural, or recreational activities. However, the degree of destruction depends not only on the intensity and kind of disruption but upon the kinds of vegetation, soil, permafrost, and animal life that were there when man arrived.

Some arctic and alpine vegetation recover from disturbance without too much difficulty but the majority, do not. This situation of slow vegetation recovery is due to many things, the very short cold growing season being one. Some arctic and alpine soils are relatively resistant to disturbance; others erode rapidly. It is soil destruction-by compacting, by melting of the underlying permafrost or by erosion due to grazing or marginal agriculture - that also makes vegetation re-establishment very difficult. Once the soil is gone in a cold climate, the unknown time required to replace it certainly must be calculated in terms of thousands or tens of thousands of years. The great erosional gullies caused by poor agricultural practices in the paramo are a case in point.

The drastic effects of a tracked vehicle crossing the tundra during summer thaw are shown in Fig. 6, taken at a site near Barrow, Alaska. The vehicle several years ago damaged the turf and upper layers of peaty soil, which had served as insulation to preserve the underlying permafrost at a depth of no more than 3 to 4 dm. As a result, meltwater from snow in early June runs down the tracks left by the vehicle and every year erodes more of the soil. This allows solar energy to heat the soil and melt more of the top of the permafrost. At the point where the picture was taken, the erosion is at least 1.5 m deep. Such accelerated erosion of wet peaty soils over permafrost is termed "thermokarst." Bliss (1970) cites some fascinating examples of thermokarst caused by man in the Mackenzie River delta.

Since many tundra and polar desert soils are rocky or dry, such thermo- karst damage is not universal in the Arctic. Ives (1970) pointed out that, in general terms, the fragility of tundra to destruction is directly proportional to the ice content of the permafrost and inversely proportional to the mean ground temperature. He suggested a formula to indicate this susceptibility: F OC i/tg, where F is tundra fragility, i is the percentage ice content of the permafrost, and tg is the mean annual ground temperature. Perhaps this formula could be improved by terms for length of growing season and some other factors, but at least it is a start toward the necessary analysis of the process.

Alpine disturbances seldom involve thermokarst, since permafrost is local in such places. However, alpine meadows and bogs are vulnerable to permanent destruction; so are rocky soils and their vegetation. It is not at all un- usual to see several deepening trails crossing a peaty, wet meadow, as people and pack animals have moved away from entrenched water-filled tracks which originated in previous years. The sheer density of people has increased in recent years, due to the use of alpine areas for camping and hiking; the result has been severe local disturbance of even relatively dry areas, by repeated foot-trampling and the proliferation of trails and campsites.

Alpine vegetation, like arctic vegetation, returns very slowly after destruction. In the use plans for both arctic and alpine regions, considerable attention must be paid to the kinds of vegetation and soils present and their differential susceptibilities to change and destruction.

Chapin, F.S., III, and G.R. Shaver. 1981. Changes in soil properties and vegetation following disturbances of Alaskan Arctic tundra. Journal of Applied Ecology 18:605-617.

Abstract

(1) Soil characteristics and vegetation were studied in vehicle tracks and adjacent undisturbed tundra along local moisture gradients at four tundra sites in northern Alaska. Vehicle tracks generally had 2 OC higher soil temperatures, deeper thaw, and higher concentrations of available soil phosphate than adjacent undisturbed tundra, but did not differ consistently from controls in soil bulk density, volumetric moisture content, pH, or soil organic content.

(2) Vegetation in vehicle tracks had fewer species than controls, reflecting decreased abundance of shrubs, particularly evergreens, and increased dominance by a few species of graminoids.

(3) Wet and mesic tracks exhibited a 2- to 15-fold increase in above-ground standing crop of nitrogen and phosphorus as a result of increased leaf nutrient concentrations and increased leaf biomass of graminoids, a consequence of increases in both shoot density and shoot weight.

(4) We reject our original hypothesis that the known temperature effects upon root growth, nutrient absorption, and organic matter mineralization account for the increased standing crop of biomass and nutrients in vehicle trails. We conclude that other factors, perhaps related to soil water and nutrient movement, are in large part responsible for the increased nutrient status and production of vehicle tracks and exert an important control over growth in undisturbed tundra.

Cortes-Burns, H., M.L. Carlson, R. Lipkin, L. Flagstad, and D. Yokel. 2009. Rare vascular plants of the North Slope: a review of the taxonomy, distribution, and ecology of 31 rare plant taxa that occur in Alaska's North Slope region. U.S. Department of the Interior, Bureau of Land Management, BLM Alaska Technical Report 58 (BLM/AK/GI-10/002+6518+F030). www.blm.gov/ak

Abstract - The taxonomy, distribution, and ecology of rare, imperiled, and critically imperiled vascular plants of Alaska's North Slope are summarized in this report. These data are synthesized to aid the BLMs Arctic Field Office in protecting the natural floristic resources of the region and the National Petroleum Reserve - Alaska in particular.

After discussions with local experts and reviewing the Alaska Natural Heritage Program rare plant database and the University of Alaska Museum database, it was determined that 31 rare plant taxa occur on the North Slope. Of this total, 8 taxa are globally rare to imperiled, while the remainder are more globally widespread, but with few populations in Alaska. Eight taxa are ranked as critically imperiled in the state and either occur, or are considered, very likely to occur, within the boundaries of the National Petroleum Reserve - Alaska. None of the 31 taxa are listed by the U.S. Fish and Wildlife Service as Threatened or Endangered, and only 14 are included in the Bureau of Land Management - Alaska's sensitive species list.

Emers, M., J.C. Jorgenson, and M.K. Raynolds. 1995. Response of Arctic plant communities to winter vehicle disturbance. Canadian Journal of Botany 73(6):905-919. https://doi.org/10.1139/b95-099

Emers, M. and J. C. Jorgenson. 1997. Effects of winter seismic exploration on the vegetation and soil thermal regime of the Arctic National Wildlife Refuge, Alaska. Pp. 443-456 in

R.M.M. Crawford (ed.), Disturbance and recovery in Arctic lands: an ecological perspective. Dordrecht, Netherlands: Kluwer Academic Publishers.

Conclusions - Vehicle traffic over snow-covered tundra can cause long-term changes to vegetation and the soil thermal regime. This study documents continuing impacts a decade after disturbance from winter seismic exploration occurred. Eighty percent of the disturbed plots studied still had not recovered to level 0 disturbance by 1994. Sixty percent of the sites had significantly different thaw depths than controls. Most were still visible from ground-level (65%) and from aircraft (75%) in 1994. Plots with higher levels of initial disturbance generally continued to be the most disturbed and visible, but continued visibility and effects on thaw depths were also noted for some plots with low initial disturbance. Previous studies of winter vehicle disturbance had predicted only short-term impacts. Ten years after disturbance, we found that the soil thermal regime in disturbed plots had not yet equilibrated with that of the surrounding tundra in the majority of the sites. This suggests that vehicle traffic over snow-covered tundra can cause long-term changes and the effects of disturbance may persist into the future.

Felix, N.A., and M.K. Raynolds. 1989a. The role of snow cover in limiting surface disturbance caused by winter seismic exploration. Arctic 42(2):62-68. http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/article/view/1641

Abstract - The relationship between snow cover and the degree of surface disturbance caused by winter seismic vehicles was investigated on the Arctic Coastal Plain of the Arctic National Wildlife Refuge in northeastern Alaska. Ninety study plots were established on seismic lines and camp moves in tussock tundra and moist sedge-shrub tundra. Total snow depth and its components, slab layer and depth hoar, were measured during the winter. Plant cover changes, tussock disturbance, visibility and disturbance levels were determined at the study plots in the summer. Disturbance was found to be generally lower when snow depths were greater. In tussock tundra, plots with snow depths over 25 cm had significantly less disturbance than those with under 25 cm ($p < 0.05$). The relationship between snow cover and disturbance was less clear in moist sedge-shrub tundra, where disturbance appeared to be less at snow depths above 25 cm, but these differences were not statistically significant ($p < 0.05$). Slab depth, which does not include the loose layer of depth hoar, provided a better measure of protective snow cover in most sedge-shrub tundra, as slab depths over 20 cm resulted in significantly less disturbance ($p < 0.05$). Moderate-level disturbance (25-50% decrease in plant cover) did not occur on trails where snow depths were at least 25 cm in tussock tundra and 35 cm in moist sedge-shrub tundra. Low-level disturbances (less than 25% decrease in plant cover) occurred on trails with snow depths as high as 45 cm in tussock tundra and 72 cm in moist sedge-shrub tundra.

Felix, N.A., and M.K. Raynolds. 1989b. The effects of winter seismic trails on tundra vegetation in northeastern Alaska, U.S.A. Arctic and Alpine Research 21(2):188-202.

Abstract - Industrial land use such as petroleum exploration and infrastructure development has important and lasting impacts on Arctic landscapes. Detailed, site-level investigations have noted impacts that include vehicle tracks, surface and vegetation alteration, soil compaction, and degradation of ice wedge features. We investigated the long-term impact of an extended period of hydrocarbon exploration on Melville Island in the Canadian High Arctic using available remotely sensed data supplemented with field observations over a $\sim$370 km^2 area. Aerial photographs from 1959, 1972, and 1977 and recent satellite imagery (2011 and 2013) were used to determine the effects of industrial activity over periods corresponding to pre-activity, mid-activity, and post-activity. We show that vehicle tracks,

site disturbance, and vegetative impacts are still evident after 40 years in this area. Permafrost has degraded at sites with concentrated activity (drill sites, airstrips) and changes to vegetation are clearly discernable. The results demonstrate the utility of this approach for assessment of land use impacts on High Arctic landscapes and provide a means to determine locations for more detailed site-specific field studies. These results may contribute to strategies for environmental monitoring in remote areas where access is impractical or resource intensive.

Felix, N.A., M.K. Raynolds, J.C. Jorgenson, and K.E. DuBois. 1992. Resistance and resilience of tundra plant communities to disturbance by winter seismic vehicles. Arctic and Alpine Research 24(1):69-77.

<u>Abstract</u> – Effects of winter seismic exploration on Arctic tundra were evaluated on the coastal plain of the Arctic NWR, 4 to 5 growing seasons after disturbance. Plant cover, active layer depths, and track depression were measured at plots representing major tundra plant communities and different levels of initial disturbance. Results are compared with the initial effects reported earlier. Little resilience was seen in any vegetation types, and most plots still had visible trails. Decreases in plant cover persisted on most plots, although a few species showed recovery or increases in cover above predisturbance level. Moist sedge-shrub tundra and dryas terraces had the largest community dissimilarities initially, showing the least resistance to high levels of winter vehicle disturbance. Community dissimilarity continued to increase for 5 seasons in moist sedge-shrub tundra, with species composition changing to higher sedge cover and lower shrub cover. The resilience amplitude may have been exceeded in 4 plots which had significant track depression.

Galant, A.L., E.F. Binnian, J.M. Omernik, and M.B. Shasby. 1995. Ecoregions of Alaska. U.S. Geological Survey Professional Paper 1567. Washington, D.C.; U.S. Printing Office.

Hanson, H.C. 1953. Vegetation types in northwestern Alaska and comparisons with communities in other Arctic regions. Ecology 34(1):111-140. http://www.jstor.org/stable/pdfplus/1930313.pdf?&acceptTC=true&jpdConfirm=true

<u>Summary and Conclusion</u>

1. As a result of study during the summers of 1949-1951, a preliminary classification of the vegetation of northwestern Alaska is presented. It contains 6 major physiognomic classes and 22 types.

2. A characterization. is given of each type, including the species composition, some of the environmental conditions, and aerial recognition characteristics.

3. Eight new phytosociological analyses of different communities are presented in tables.

4. The types occupying the largest land areas are the cottongrass-sedge-dwarf shrub-heath complex, sedge marshes, al-pine *Dryas*, dwarf shrub, willow shrub, birch shrub, and white spruce-shrubs.

5. Important factors influencing the development and the maintenance or changes in the species composition within types are soil moisture, mineral and organic composition of the soil, soil texture, soil reaction, depth to which the soil thaws during the summer, freezing and thawing processes in the soil (congeliturbation), drainage conditions, depth and duration of snow cover, exposure to wind, biotic influences such as grazing and trampling by reindeer

and other animals, rodent activities, plant competition, and various man-caused influences such as burning, drainage, flooding, earth-moving, etc.

6. Similarities of the Alaskan communities to those in other arctic and sub-arctic regions, especially Scandinavia, are pointed out.

7. Suitable conditions for good growth of lichens, furnishing winter pasturage for reindeer, occur in many of these type, particularly in open forest types, open stands of the birch shrub type, the dwarf birch-heath-lichens type, the blueberry-heath-lichens type, and the cottongrass-sedge-dwarf shrub heath complex. The lichens have, however, been depleted over large areas by overgrazing and fire.

8. This classification has been found useful in making aerial surveys of lichen range suitable for grazing during the winter by reindeer. The various types are valuable in indicating soil conditions such as depth to perennial frost, kind of surface and subsurface materials, and moisture and drainage conditions. As a result, the classification is of value when surveys are made for locating roadways, camp sites, landing fields, etc.

Hope, A.G., E. Waltari, D.C. Payer, J.A. Cook, and S.L. Talbot. 2013. Future distribution of tundra refugia in northern Alaska. Nature Climate Change 3:931-938. https://doi.org/10.1038/nclimate1926

Abstract - Climate change in the Arctic is a growing concern for natural resource conservation and management as a result of accelerated warming and associated shifts in the distribution and abundance of northern species. We introduce a predictive framework for assessing the future extent of Arctic tundra and boreal biomes in northern Alaska. We use geo-referenced museum specimens to predict the velocity of distributional change into the next century and compare predicted tundra refugial areas with current land-use. The reliability of predicted distributions, including differences between fundamental and realized niches, for two groups of species is strengthened by fossils and genetic signatures of demographic shifts. Evolutionary responses to environmental change through the late Quaternary are generally consistent with past distribution models. Predicted future refugia overlap managed areas and indicate potential hotspots for tundra diversity. To effectively assess future refugia, variable responses among closely related species to climate change warrants careful consideration of both evolutionary and ecological histories.

Hope, A.G., E. Waltari, J.L. Malaney, D.C. Payer, J.A. Cook, and S.L. Talbot. 2015. Arctic biodiversity: increasing richness accompanies shrinking refugia for cold-associated tundra fauna. Ecosphere 6(9):1-67. http://dx.doi.org/10.1890/ES15-00104.1

Abstract – As ancestral biodiversity responded dynamically to late-Quaternary climate changes, so are extant organisms responding to the warming trajectory of the Anthropocene. Ecological predictive modeling, statistical hypothesis tests, and genetic signatures of demographic change can provide a powerful integrated toolset for investigating these biodiversity responses to climate change, and relative resiliency across different communities. Within the biotic province of Beringia, we analyzed specimen localities and DNA sequences from 28 mammal species associated with boreal forest and Arctic tundra biomes to assess both historical distributional and evolutionary responses and then forecasted future changes based on statistical assessments of past and present trajectories, and quantified distributional and demographic changes in relation to major management regions within the study area. We addressed three sets of hypotheses associated with aspects of methodological, biological, and socio-political importance by

asking (1) what is the consistency among implications of predicted changes based on the results of both ecological and evolutionary analyses; (2) what are the ecological and evolutionary implications of climate change considering either total regional diversity or distinct communities associated with major biomes; and (3) are there differences in management implications across regions? Our results indicate increasing Arctic richness through time that highlights a potential state shift across the Arctic landscape. However, within distinct ecological communities, we found a predicted decline in the range and effective population size of tundra species into several discrete refugial areas. Consistency in results based on a combination of both ecological and evolutionary approaches demonstrates increased statistical confidence by applying cross-discipline comparative analyses to conservation of biodiversity, particularly considering variable management regimes that seek to balance sustainable ecosystems with other anthropogenic values. Refugial areas for cold-adapted taxa appear to be persistent across both warm and cold climate phases and although fragmented, constitute vital regions for persistence of Arctic mammals.

Hulten, E. 1968. Flora of Alaska and neighboring territories: a manual of the vascular plants. Stanford, CA; Stanford University Press.

Johnson, A.W., L.A. Viereck, R.E. Johnson, and H. Melchoir. 1966. Vegetation and flora. Pp. 277-354 in N.J. Wilmovsky and J.N. Wolfe (eds.), Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Division of Technical Information PNE-481. Washington, D.C.; Government Printing Office.

Abstract – The vegetation of Ogotoruk Valley is divided into eight types as follows: *Eriphorum* tussock, *Dryas* fell-field, *Eriphorum-Carex* solifluction slope, ericaceous shrub polygon, *Dryas* step and stripe, *Carex bigelowii* high-center polygon, and saline meadow. Another group of highly diverse plant communities growing on snow-bed sites, gravel bars and benches, talus slopes and rock outcrops, marine strands, and on transitional sites between types is not aggregated into types because of high stand-to-stand diversity. Each vegetation type is composed of a group of characteristic species, many of which occur in more than one type. All vegetation units blend with each other at their margins and in a continuous manner, thus, the boundaries around any community are regarded as arbitrary. The mosaic of habitats in the area includes broad wet meadows, dry fell-fields, gravel bars and benches, snow beds, tundra ponds, and strands. Each habitat is modified locally by frost action, permafrost, local relief, parent-material differences, drainage patterns, irregular snow accumulation, and animal activity.

About 300 species of vascular plants, 100 byrophitic species, 81 lichens, and an undetermined number of fleshy fungi are included in the terrestrial flora.

Johnson, P.L. 1969. Arctic plants, ecosystems, and strategies. Arctic 22(3):341-355. http://arctic.synergiesprairies.ca/arctic/index.php/arctic/article/view/3226

Abstract - Reviews and develops a perspective of what is known about the structure, function, and adaptive strategy of arctic tundra ecosystems, with emphasis on plants, the primary biological producers of an ecosystem. The short-term change in plant arrays following disturbance of the natural assemblage, due to ecological succession, is poorly understood in the tundra. Distribution and migrations of tundra flora give insight into Pleistocene events and evolutionary strategies, one clue to which is frequently of polyploidy. Implicit in understanding tundra dynamics or vegetation associations is study of topographic microrelief, soils and thaw depths, as well as description of the flora. Progress is noted in knowledge of the structure and function of vegetation in arctic ecosystems: the morphological adaptation, carbohydrate cycle, chlorophyll content, physiologic processes in adaption to severe environments such as photosynthesis, respiration, light saturation, photoperiodic requirements and temperature tolerance.

Jorgenson, J.C., B.E., Reitz, and M.L. Raynolds. 1996. Tundra disturbance and recovery nine years after winter seismic exploration in northern Alaska. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Arctic National Wildlife Refuge.

Abstract - Seismic exploration was conducted during the winters of 1984 and 1985 on the coastal plain tundra of the Arctic National Wildlife Refuge, Alaska. In 1986, 1989, and 1993, we rated disturbance levels on randomly selected transects on the trails. Disturbance decreased greatly over time, but some trails still showed impacts in 1993, nine years after exploration. In 1986, 17% of the 200 plots visited on the transect had little or no disturbance. By 1993, 90% had recovered to this level.

Trails included seismic lines made by tracked vehicles and adjacent camp-move trails made by D-7 Caterpillar tractors pulling ski-mounted trailers. Recovery of the camp-move trails was slower than recovery of seismic lines. By 1993, 85% of the plots on camp-move trails had little or no disturbance, while 97% of the seismic line plots did. The difference is probably due to the higher ground contact pressure of the camp-move vehicles. The main long-term disturbance to tundra from winter seismic exploration may be from heavy support vehicles used to transport camps.

Extensive winter seismic exploration is conducted on the North Slope of Alaska. A newer technology used to create a 3-dimensional subsurface image, known as 3-D seismic, requires a much denser grid of trails than that in the Arctic Refuge. While the trails in the Arctic Refuge were about five kilometers apart, those being made now are from 200 to 500 meters apart. A greater proportion of the tundra surface in the exploration area is driven on. Our findings that some damage can persist for long periods indicate that efforts should continue to develop technology to decrease the effects of vehicle traffic on tundra. Alternative camp vehicles or support by aircraft could greatly reduce disturbance and recovery time.

Jorgenson, J.C., M.K. Raynolds, J.H. Reynolds, and A.-M. Benson. 2015. Twenty-five year record of changes in plant cover on tundra of northeastern Alaska. Arctic, Antarctic, and Alpine Research 47(4):785-806.

Abstract - Northern Alaska has warmed over recent decades and satellite data indicate that vegetation productivity has increased. To document vegetation changes in the Arctic NWR, we monitored plant cover at 27 plots between 1984 and 2009. These are among the oldest permanently marked and continuously monitored vegetation plots in the Arctic. We quantified percent cover of all plant species by line-point intercept sampling and assessed change over time for seven plant growth forms. Cover of bryophytes and deciduous shrubs showed slight decreasing trends. Evergreen shrubs, horsetails, and depth of thawed soil above permafrost had no trends. For lichens, graminoids, and forbs, trends varied by plant community type. Overall, vegetation in the plots changed little over the study period, in contrast to results from other studies in northern Alaska. A few plots had dramatic changes, however, which we attributed to subsidence from melting ground ice or to floodplain dynamics. Our results demonstrate that vegetation change on the Arctic Refuge coastal plain over the past quarter century has been spatially heterogeneous and facilitated by disturbance. The findings highlight the need for greater work linking plot-level and regional remote sensing measurements of change.

Jorgenson, J.C., J.M. Ver Hoef, and M.T. Jorgenson. 2010. Long-term recovery patterns of arctic tundra after winter seismic exploration. Ecological Applications 20(1):205-221.

Abstract - In response to the increasing global demand for energy, oil exploration and development are expanding into frontier areas of the Arctic, where slow-growing tundra vegetation and the underlying permafrost soils are very sensitive to disturbance. The creation of vehicle trails on the tundra from seismic exploration for oil has accelerated in the past decade, and the cumulative impact represents a geographic footprint that covers a greater extent of Alaska's North Slope tundra than all other direct human impacts combined. Seismic exploration for oil and gas was conducted on the coastal plain of the Arctic National Wildlife Refuge, Alaska, USA, in the winters of 1984 and 1985. This study documents recovery of vegetation and permafrost soils over a two-decade period after vehicle traffic on snow-covered tundra. Paired permanent vegetation plots (disturbed vs. reference) were monitored six times from 1984 to 2002. Data were collected on percent vegetative cover by plant species and on soil and ground ice characteristics. We developed Bayesian hierarchical models, with temporally and spatially autocorrelated errors, to analyze the effects of vegetation type and initial disturbance levels on recovery patterns of the different plant growth forms as well as soil thaw depth. Plant community composition was altered on the trails by species-specific responses to initial disturbance and subsequent changes in substrate. Long-term changes included increased cover of graminoids and decreased cover of evergreen shrubs and mosses. Trails with low levels of initial disturbance usually improved well over time, whereas those with medium to high levels of initial disturbance recovered slowly. Trails on ice-poor, gravel substrates of riparian areas recovered better than those on ice-rich loamy soils of the uplands, even after severe initial damage. Recovery to pre-disturbance communities was not possible where trail subsidence occurred due to thawing of ground ice. Previous studies of disturbance from winter seismic vehicles in the Arctic predicted short-term and mostly aesthetic impacts, but we found that severe impacts to tundra vegetation persisted for two decades after disturbance under some conditions. We recommend management approaches that should be used to prevent persistent tundra damage.In response to the increasing global demand for energy, oil exploration and development are expanding into frontier areas of the Arctic, where slow-growing tundra vegetation and the underlying permafrost soils are very sensitive to disturbance. The creation of vehicle trails on the tundra from seismic exploration for oil has accelerated in the past decade, and the cumulative impact represents a geographic footprint that covers a greater extent of Alaska's North Slope tundra than all other direct human impacts combined. Seismic exploration for oil and gas was conducted on the coastal plain of the Arctic National Wildlife Refuge, Alaska, USA, in the winters of 1984 and 1985. This study documents recovery of vegetation and permafrost soils over a two-decade period after vehicle traffic on snow-covered tundra. Paired permanent vegetation plots (disturbed vs. reference) were monitored six times from 1984 to 2002. Data were collected on percent vegetative cover by plant species and on soil and ground ice characteristics. We developed Bayesian hierarchical models, with temporally and spatially auto-correlated errors, to analyze the effects of vegetation type and initial disturbance levels on recovery patterns of the different plant growth forms as well as soil thaw depth. Plant community composition was altered on the trails by species-specific responses to initial disturbance and subsequent changes in substrate. Long-term changes included increased cover of graminoids and decreased cover of evergreen shrubs and mosses. Trails with low levels of initial disturbance usually improved well over time, whereas those with medium to high levels of initial disturbance recovered slowly. Trails on ice-poor, gravel substrates of riparian areas recovered better than those on ice-rich loamy soils of the uplands, even after severe initial damage.

Recovery to pre-disturbance communities was not possible where trail subsidence occurred due to thawing of ground ice. Previous studies of disturbance from winter seismic vehicles in the Arctic predicted short-term and mostly aesthetic impacts, but we found that **severe impacts to tundra vegetation persisted for two decades after disturbance under some conditions**. We recommend management approaches that should be used to prevent persistent tundra damage.

Kemper, J. T., and S. E. Macdonald. 2009a. Directional change in low-arctic upland tundra plant communities 20–30 years after seismic exploration. Journal of Vegetation Science 20: 557–567.Kemper, J.T. and S.E. MacDonald. 2009a. Effects of contemporary winter seismic exploration on low Arctic plant communities and permafrost. Arctic, Antarctic, and Alpine Research 41(2):228-237. https://doi.org/10.1657/1938-4246-41.2.228

Abstract - We studied effects of oil and gas exploration, using the most recent seismic exploration technologies, on tundra plant communities and soils in four vegetation types in the Low Arctic of western Canada, two to three years post-disturbance. For all four vegetation types, seismic lines had less vascular plant cover and more bare ground than adjacent "reference" tundra. For the two upland tundra vegetation types, mosses and lichens were less abundant on seismic lines than in reference plots. There were no apparent differences in organic layer thickness between seismic lines and reference areas, but active layer depth (at the time of sampling) was significantly greater on seismic lines for the upland tundra and one of the wetland vegetation types. Diversity and richness were lower, and community composition was different, on seismic lines (as compared to reference plots) in upland tundra vegetation types but not in wetland types. The results suggest that (1) upland vegetation types are less resistant to seismic disturbance, (2) active layer depth increases following seismic disturbance, and (3) **impacts from modern seismic techniques in upland tundra are similar to, or somewhat greater than, the initial impacts observed from the earliest phases of winter exploration ~30 years ago**.

Kemper, J.T., and S.E. Macdonald. 2009b. Directional change in low-arctic upland tundra plant communities 20-30 years after seismic exploration. Journal of Vegetation Science 20(3): 557-567. http://onlinelibrary.wiley.com/doi/10.1111/j.1654-1103.2009.01069.x/epdf

Question - What is the disturbance response of low-arctic plant communities two to three decades after seismic exploration.

Location - Mackenzie River Delta, low-arctic, northwestern Canada.

Methods - Plant communities in two upland tundra vegetation types were compared between winter seismic lines, created between 1970 and 1986, and adjacent "reference" tundra. Also, we used aerial surveys to quantify the total area impacted by visible linear features.

Results - Vascular plant cover was significantly higher, and lichen cover significantly lower, on seismic lines than in reference tundra. The increase in vascular plant cover was attributable to deciduous shrubs and graminoids. There were significant differences in plant community composition between seismic lines and reference tundra but no differences in species diversity or richness. *Betula glandulosa* and *Arctagrostis latifolia* were significant indicator species for seismic lines, while *Saussurea angustifolia* was a significant indicator for reference tundra. Based on the aerial surveys, these effects apply to at least 90% of seismic lines from two-dimensional programs in these habitat types during the 1970s.

Conclusions - Vegetation composition and structure on 20-30-year-old seismic lines differs from reference upland tundra despite no persistent differences in organic layer depth or

depth to permafrost. We propose that this reflects: (1) successional redevelopment following changes in soil conditions and nutrient availability arising from the disturbance, and/or (2) **disturbance-initiated succession towards a community reflecting current climatic conditions**.

Kevan, P.G., B.C. Forbes, S.M. Kevan, and V. Behan-Pelletier. 1995. Vehicle tracks on high Arctic tundra: their effects on soil, vegetation, and soil arthropods. Journal of Applied Ecology 32(3):655-667.

Summary

1. Examination of the effects of vehicle and pedestrian tracks of known age (13 or more years) and intensity of use (single to multiple passages) on vegetation, soil chemistry, soil arthropods, soil thaw characteristics, and small-scale hydrological changes showed clear and inter-related patterns.

2. In general, all tracks, regardless of age, showed small increases in the depth of thaw beneath them (c. 2-8 cm).

3. Tracks were generally depleted of carbon and to a lesser, but significant extent, of potassium and phosphorus. Slight increases in NO3, NH4, and calcium were noted. Magnesium and total nitrogen seemed unaffected.

4. On all tracks which had suffered multiple passages vegetation cover was significantly reduced. In a few sites where single passages were recorded, cover increased through proliferation of the sedge, *Kobresia myosuroides*.

5. Abundance of soil arthropods was significantly reduced on tracks, but the diversity was not.

6. In most sites, soil moisture and over-ground water flow did not seem affected. Only in sedge meadows where compression from a single passage resulted in channeling of water, and where multiple passages removed vegetation and initiated gulley erosion, were effects serious.

Monz, C.A. 2002. The response of two Arctic tundra plant communities to human trampling disturbance. Journal of Environmental Management 64(2):207-217. https://www.sciencedirect.com/science/article/pii/S0301479701905249

Abstract - A 4-year study was conducted to evaluate the consequences of human trampling on dryas and tussock tundra plant communities. Treatments of 25, 75, 200 and 500 trampling passes were applied in 0·75 m^2vegetation plots at a time of approximately peak seasonal biomass. Immediately after and 1 and 4 years after trampling, plots were evaluated on the basis of plant species cover, percent bare ground, vegetation height, and soil penetration resistance. One year after trampling, soils were collected for nitrogen analysis in highly disturbed and control plots. Immediately after trampling, 500 trampling passes resulted in approximately 50% cover loss in the dryas tundra and 70% cover loss in tussock tundra, but both communities showed a substantial capacity for regrowth. Plots where low and moderate levels of trampling were applied returned to pre-disturbance conditions by 4 years after trampling, but impact was still evident in plots subjected to high levels of disturbance. These results suggest that these tundra communities can tolerate moderate levels of hiking and camping provided that use is maintained below disturbance thresholds and that visitors employ appropriate minimum-impact techniques. By utilizing this information in a visitor education program combined with impact monitoring and management, it is possible to allow dispersed camping and still maintain these vegetation communities with a minimum of observable impact.

Myers-Smith, I.H., B.K. Arnesen, R.M. Thompson, and F.S. Chapin, III. 2006. Cumulative impacts on Alaskan arctic tundra of a quarter century of road dust. Ecoscience 13(4):503-510.

Abstract – Tundra ecosystems are sensitive to disturbance and slow to recover. To account for environmental costs of development in the north, cumulative impacts of roads and dust deposition must be quantified. After a previous study, we re-examined tundra adjacent to the 577-km long Dalton Highway in northern Alaska to assess 13 yr of additional calcareous road deposition. Dust loading continues to alter substrate properties and community composition. Moist, acidic, tussock-sedge tundra typically has a soil pH of 4. At the road margin the pH of the fibric horizon had increased to pH 5.5 by 1989 and to pH 6.0 by 2002. Plots adjacent to the road have significantly higher graminoid and *Rubus chamaemorus* biomass and less moss, evergreen shrub, lichen, and forb biomass. Graminoid cover ranges from 30% in undisturbed tundra to over 80% within 5 m of the road. We observed an 80 g/m^2 increase in graminoid biomass and a 130 g/m^2 decline in moss biomass across the study site between 1989 and 2002. Ordinations indicate a broadened zone of dust disturbance in 2002. The evidence of cumulative impacts of dust will improve our evaluation of the ecological costs of future road development in the north.

Nowacki, G., P. Spencer, T. Brock, M. Fleming, and T. Jorgenson. 2001. Narrative descriptions for the ecoregions of Alaska and neighboring territories. Reston, VA: U.S. Geological Survey Final Draft 6-1-00.

Nowacki, G., P. Spencer, M. Fleming, T. Brock, and T. Jorgenson. 2002. Unified ecoregions of Alaska. Reston, VA: U.S. Geological Survey Open File Report 02-297.

Raynolds, M.K., D.A. Walker, K.J. Ambrosius, J. Brown, K.R. Everett, M. Kanevskiy, ,G.P. Kofinas, V.E. Romanovsky, Y. Shur, and P.J. Webber. 2104. Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay oilfield, Alaska. Global Change Biology 20:1211-1224. https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.12500

Abstract - Many areas of the Arctic are simultaneously affected by rapid climate change and rapid industrial development. These areas are likely to increase in number and size as sea ice melts and abundant Arctic natural resources become more accessible. Documenting the changes that have already occurred is essential to inform management approaches to minimize the impacts of future activities. Here, we determine the cumulative geoecological effects of 62 years (1949–2011) of infrastructure- and climate-related changes in the Prudhoe Bay Oilfield, the oldest and most extensive industrial complex in the Arctic, and an area with extensive ice-rich permafrost that is extraordinarily sensitive to climate change. We demonstrate that thermokarst has recently affected broad areas of the entire region, and that a sudden increase in the area affected began shortly after 1990 corresponding to a rapid rise in regional summer air temperatures and related permafrost temperatures. We also present a conceptual model that describes how infrastructure-related factors, including road dust and roadside flooding are contributing to more extensive thermokarst in areas adjacent to roads and gravel pads. We mapped the historical infrastructure changes for the

Alaska North Slope oilfields for 10 dates from the initial oil discovery in 1968–2011. By 2010, over 34% of the intensively mapped area was affected by oil development. In addition, between 1990 and 2001, coincident with strong atmospheric warming during the 1990s, 19% of the remaining natural landscapes (excluding areas covered by infrastructure, lakes and river floodplains) exhibited expansion of thermokarst features resulting in more abundant small ponds, greater microrelief, more active lakeshore erosion and increased landscape and habitat heterogeneity. This transition to a new geoecological regime will have impacts to wildlife habitat, local residents and industry.

Truett, J.C., and K. Kertell. 1992. Tundra disturbance and ecosystem production: implications for impact assessment. Environmental Management 16(4):485-494. https://link.springer.com/article/10.1007/BF02394124

Abstract - Environmental regulations governing industrial activities in tundra environments stem largely from the expected ecological effects of the activities. One of the major ecological effects of industrial activities is the surface subsidence associated with thermokarst, which can result in changes in primary and secondary production. The primary production changes associated with thermokarst are strongly governed by three ecosystem properties—soil temperature, water regime, and nutrient availability. Most disturbances set in motion a more-or-less predictable sequence of landscape change related to these properties: soil warming, thermokarst, surface flooding, accelerated organic matter decomposition, and increased nutrient availability. The warmed soil and the enhanced nutrient availability typically lead to increased annual primary production, increased dominance by graminoids, and reduced plant species diversity. These vegetational changes may in turn potentially enhance secondary production, but in general these second-level responses have yet to be quantified. More information is needed about the food-chain effects of tundra landscape disturbances before regulators can make well-informed predictions of impacts or plan useful habitat rehabilitation.

Spetzman, L.A. 1959. Vegetation of the Arctic Slope of Alaska [Exploration of naval Petroleum Reserve No 4 and adjacent areas, northern Alaska 1944-1953: Part 2, regional studies. Washington, D.C.: U.S. Department of the Interior, Geological Survey Professional Paper 302-B. http://pubs.usgs.gov/pp/0302b/report.pdf

Abstract - The environment of the Arctic Slope is described by physiographic provinces, namely, the coastal plain, foothills, and mountains. Topography, rock composition, soil, vegetation, and climate are considered for each province.

Six major plant communities, which together compose the tundra of the Arctic Slope, are described. These are the niggerhead [*Echinacea* spp] meadows, wet sedge meadows, dry upland meadows, floodplain and cutbank vegetation, outcrop and talus vegetation, and aquatic vegetation of lakes. The dominant and secondary plants in each community are given, as well as local variations in the vegetation which are related to minor habitat differences such as slope exposure or bedrock.

Lines of successional change, primarily for the vegetation in the foothills, are suggested. Seven localities, representing the common habitats of vegetation occurring on the Arctic Slope, are described to illustrate natural mosaics of plant communities.

Included is a list of 439 species of higher plants which grow on the Arctic Slope, together with their distribution, altitude range, abundance, flowering period, and habitat. This list is

based on about 4,500 collections of plants made from 1945 through 1951, supplemented by information of previous collections which is compiled in Hulten (1968).

Talbot, S.S., B.A. Yurtsev, D.F. Murray, G.W. Argus, C. Bay, and A. Elvebakk. 1999. Atlas of rare endemic vascular plants of the Arctic. Akureyri, Iceland; Conservation of Arctic Flora and Fauna (CAFF) Technical Report No. 3. https://oaarchive.arctic-council.org/bitstream/handle/11374/165/EDOCS-3990-v1A-Technical_Report_No3-CFG_Atlas_Rare_Endemic_Arctic_Plants_June_1999.PDF?sequence=5

Abstract - The vascular flora of the Arctic was surveyed by specialists from 8 Arctic countries to: (1) identify rare taxa endemic to the region; (2) establish an annotated list of these taxa; and (3) determine the level of protection currently afforded these plants. "Arctic" is defined as those lands beyond latitudinal treeline. Ninety-six rare endemic taxa were identified. Information compiled for each included taxonomy, geographic distribution, habitat preferences, biological characteristics, estimates of endangerment, and citations of supporting literature. Gap analysis determined the relation of the taxa to areas of protected habitats. Taxa were grouped into 3 categories: (1) unprotected (no occurrences are within protected areas); (2) partially protected (some occurrences are within protected areas); and (3) protected (all occurrences are within protected areas). Results indicate that 47% of the rare endemics are unprotected, 23% partially protected, and 30% protected. According to IUCN Red List threat categories, 19% of the taxa are vulnerable, 29% near threatened lower risk, 26% least concern lower risk, 1% endangered, and 24% data deficient. The majority of rare endemic taxa, 61%, occur outside IUCN protected areas (categories I-V); 25% occur within strict nature/scientific reserves (IUCN category I); I 2% in managed nature reserves/wildlife sanctuaries (IUCN category IV); and 1.6% in national parks (IUCN category II).

Viereck, L.A., C.T. Dyrness, A.R. Batten and K.J. Wenzlick. 1992. The Alaska vegetation classification. U.S. Department of Agriculture, Forest Service General Technical Report PNW-GTR-286. Portland, OR; U.S. Forest Service Pacific Northwest Forest Research Station.

Abstract – The Alaska vegetation classification presented here is a comprehensive, statewide system that has been under development since 1976. The classification is based, as much as possible, on the characteristics of the vegetation itself and is designed to categorize existing vegetation, not potential vegetation. A hierarchical system with 5 levels of resolution is used for classifying Alaska vegetation. The system, an agglomerative one, starts with 888 known Alaska plant communities, which are listed and referenced. At the broadest level of resolution, the system contains 3 formations – forest scrub, and herbaceous vegetation. In addition to the classification, this report contains a key to levels I, II, and III; complete descriptions of all level IV units; and, glossary of terms and uses.

Walker, A.M., and K.R. Everett. 1987. Road dust and its environmental impact on Alaskan tiaga and tundra. Arctic and Alpine Research 19(4):479-489.

Abstract - The physical and chemical characteristics and ecological consequences of road dust in arctic regions are reviewed with emphasis on recent information gathered along the Dalton Highway and the Prudhoe Bay Spine Road in northern Alaska. The primary observed ecological effects of dust are (1) early snowmelt in roadside areas, resulting in a snow-free band of vegetation within 30 to 100 m of the road in early spring, which is used by waterfowl and numerous other species of wildlife; (2) a decrease in Sphagnum and other acidophilous mosses near the road; (3) an increase in many minerotrophic mosses; (4) a decrease in soil

lichens, particularly species of Cladina, Peltigera, and Stereocaulon; (5) elimination of corticolous lichens near the road in areas of particularly high dust fall; (6) a general opening of the ground cover near the road and a consequent colonization of these barren surfaces [**i.e., invasive species and known pathway**] by many taxa that are common on mineral-rich soils; (6) few effects on vascular plant abundance except in areas of very high dust, where ericaceous taxa and conifers are affected; (7) increased depth of thaw within 10 m of the road, possibly due to decreased plant cover and earlier initiation of thaw; and (8) contribution to thermokarst in roadside areas. Enhanced dust control measures should be considered, particularly where the road passes through scenic lichen woodlands, acidophilous tundra, and in calm valleys where dust commonly is a traffic safety hazard.

Walker, D. A., D. Cate, J. Brown, and C. Racine. 1987. Disturbance and recovery of arctic Alaskan tundra terrain: A review of recent investigations. CRREL Report 87-11. U.S. Army Cold Regions Research and Engineering Laboratories, Hanover, New Hampshire, USA.Walker, D.A., D. Cate, J. Brown, and C. Racine. 1987. Disturbance and recovery of arctic Alaskan tundra terrain: a review of recent investigations. Hanover, NH: U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratories CRREL Report 87-11.

Abstract - This report summarizes over a decade of CRREL-managed research regarding disturbance and recovery in northern Alaska. Themes emphasized include: (1) Most anthropogenic disturbances have natural analogs, which can provide much inexpensive information that can be related to modern disturbances and their rates of recovery. (2) Most single-event disturbances will heal and develop a functioning ecosystem within a human life span, but a return to the original ecosystem can rarely be expected for major impacts. (3) **The concept of recovery must be based on consistent terminology that recognizes the distinction between ecosystem resistance (the ability to withstand impact) and resilience (the ability to return to the previous undisturbed state) and also the distinction between complete recovery (a return to the original ecosystem) and functional recovery (the development of a functional ecosystem different from the original).** In permafrost regions with massive ground ice, recovery of the vegetation is limited by alterations to the permafrost regime.

Walker, D.A., and M.D. Walker. 1991. History and pattern of disturbance in Alaskan arctic terrestrial ecosystems: a hierarchical approach to analyzing landscape change. Journal of Applied Ecology 28(1):244-276. http://www.jstor.org/stable/2404128?origin=JSTOR-pdf

Abstract

(1) The history, types, and scales of disturbance in Arctic Alaska are reviewed and disturbances organized according to the spatial and temporal domains of Delcourt, Delcourt and Webb. This system is also used as a framework for a regional hierarchical geographic information system (GIS). (2) Natural disturbances vary from frequent small disturbances, such as needle-ice formation, to infrequent large disturbances, such as major glaciations. Most natural disturbances are either directly or indirectly climatically driven and are affected by climate changes, particularly changes to hydrologic regimes. The latter could be influenced by changes in either summer or winter precipitation patterns; increased temperature, which would melt ground ice; or changes in vegetation, which would affect evapotranspiration and run-off. (3) Most anthropogenic disturbances are microscale (10-1 to 106 m2) phenomena, but cumulative impacts associated with large developments, such as the Prudhoe Bay Oil Field, have affected mesoscale regions (106-1010 m2), and global

warming could affect the tundra ecosystem at the macroscale level (1010-1012 m2). (4) In the Arctic, recovery of the vegetation following disturbance is particularly closely linked to recovery of the physical system because of the presence of ice-rich permafrost. Maps of terrain sensitivity to disturbance must consider the influence of ground ice and heat flux to the system following disturbance. (5) A three-tiered GIS hierarchy with five sublevels is presented, with examples of typical scientific questions being addressed at each level, scales and types of databases, and linking elements between levels. (6) At the regional (macroscale and mesoscale) levels, the primary data sources are satellite-derived digital data. At the site level, integrated geobotanical databases derived from field surveys and photointerpretation are used in combination with digital terrain models. At the most detailed (plot or microsite) level, point sampling is used to portray vegetation structure and species composition in 1-m2 plots. (7) Linking or `scaling-up' elements that affect landscape patterns at all scales are hydrology, geochemistry, and primary production.(1) The history, types, and scales of disturbance in Arctic Alaska are reviewed and disturbances organized according to the spatial and temporal domains of Delcourt et al. (1983). This system is also used as a framework for a regional hierarchical geographic information system (GIS).

(2) Natural disturbances vary from frequent small disturbances, such as needle-ice formation, to infrequent large disturbances, such as major glaciations. Most natural disturbances are either directly or indirectly climatically driven and are affected by climate changes, particularly changes to hydrologic regimes. The latter could be influenced by changes in either summer or winter precipitation patterns; increased temperature, which would melt ground ice; or changes in vegetation, which would affect evapotranspiration and runoff.

(3) Most anthropogenic disturbances are microscale (10^{-1} to 10^{6} m^2) phenomena, but cumulative impacts associated with large developments, such as the Prudhoe Bay Oil Field, have affected mesoscale regions (10^{6}-10^{10} m^2), and global warming could affect the tundra ecosystem at the macroscale level (10^{10}-10^{12} m^2).

(4) In the Arctic, recovery of the vegetation following disturbance is particularly closely linked to recovery of the physical system because of the presence of ice-rich permafrost. Maps of terrain sensitivity to disturbance must consider the influence of ground ice and heat flux to the system following disturbance.

(5) A three-tiered GIS hierarchy with five sublevels is presented, with examples of typical scientific questions being addressed at each level, scales and types of databases, and linking elements between levels.

(6) At the regional (macroscale and mesoscale) levels, the primary data sources are satellite-derived digital data. At the site level, integrated geobotanical databases derived from field surveys and photointerpretation are used in combination with digital terrain models. At the most detailed (plot or microsite) level, point sampling is used to portray vegetation structure and species composition in 1-m^2 plots.

(7) Linking or “scaling-up” elements that affect landscape patterns at all scales are hydrology, geochemistry, and primary production.

Delcourt, H.R., P.A. Delcourt, and T.A. Webb, III. 1983. Dynamic plant ecology: the spectrum of vegetation change in space and time. Quaternary Science Reviews 1:153-175.

Walker, D.A., P.J. Webber, E.F. Binnian, K.R. Everett, N.D. Lederer, E.A. Nordstrand, and M.D. Walker. 1987. Cumulative impacts of oil fields on northern Alaskan landscapes. Science 238(4828):757-767.

Abstract - Proposed further developments on Alaska's Arctic Coastal Plain raise questions about cumulative effects on arctic tundra ecosystems of development of multiple large oil fields. Maps of historical changes to the Prudhoe Bay Oil Field show indirect impacts can lag behind planned developments by many years and the total area eventually disturbed can greatly exceed the planned area of construction. For example, in the wettest parts of the oil field (flat thaw-lake plains), flooding and thermokarst covered more than twice the area directly affected by roads and other construction activities. Protecting critical wildlife habitat is the central issue for cumulative impact analysis in northern Alaska. Comprehensive landscape planning with the use of geographic information system technology and detailed geobotanical maps can help identify and protect areas of high wildlife use.

Webber, P.J., P.C. Miller, F.S. Chapin, III, and B.H. McCown. 1980. The vegetation: pattern and succession. Pp. 186-218 in J. Brown, P.C. Fliller, L.L. Tieszen, and F.L. Bunnell (eds.), An Arctic ecosystem: the coastal tundra at Barrow, Alaska. Stroudsburg, PA: US/IBP Synthesis Series 12.

Welsh, S.L. 1974. Anderson's flora of Alaska and adjacent parts of Canada. Provo, UT; Brigham Young University Press. http://aknhp.uaa.alaska.edu/wp-content/uploads/2011/09/Welsh-Flora-of-AK-reduced-size-file.pdf

Wiggins, I.L., and J.H. Thomas. 1962. A flora of the Alaskan Arctic Slope. Special Publication 4. Arctic Institute of North America. Special Publication 4.

Abstract - When the Arctic Research Laboratory was established at Barrow on the Alaskan Arctic Slope in 1946, it was realized that a manual of the flora of the area would be useful to biologists engaged in research in the Arctic. In 1950, Professor Wiggins and J. H. Thomas, with the assistance of others, began collecting in the area, and the present volume is the outcome of their labors. The Alaskan Arctic Slope, lying between 68° and 70°N., is a region where only three months in the year have average temperatures above freezing, where the soils are always damp, wet, saturated or frozen and are underlain by a permanently frozen layer, and where precipitation is less than 6 inches a year, with the result that the vegetation, having little or no snow cover, is often exposed to severe damage by abrasive particles of snow, ice or soil driven by the strong winds. Under such conditions it is not surprising that the flora, so far as it is known at present, includes less than 470 species and intraspecific taxa of vascular plants. Detailed descriptions of these, and keys to their identification, form the main bulk of the book. An interesting introductory section describes the more important edaphic, climatic and biotic factors affecting the vegetation and the main types of habitats found. The volume concludes with a series of distribution maps, a glossary of botanical terms, a list of references and an index to the species.

Invasive Species (all taxa)

Carlson, M.L., and M. Shephard. 2007. Is the spread of non-native plants in Alaska accelerating? Pp. 117-133 in T.B. Harrington and S.H. Richard (eds.), Meeting the challenge: invasive plants in Pacific Northwest ecosystems. Forest Service General Technical Report PNW-GTR-694. Portland, OR; U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/pubs/pnw_gtr694.pdf

Abstract - Alaska has remained relatively unaffected by non-native plants; however, recently the state has started to experience an influx of invasive non-native plants that the rest of the U.S. underwent 60–100 years ago. With the increase in population, gardening, development, and commerce there have been more frequent introductions to Alaska. Many of these species, such as meadow hawkweed (*Hieracium caespitosum*), Canada thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea biebersteinii*), have only localized populations in Alaska. Other species such as reed canary grass (*Phalaris arundinacea*) and white sweetclover (*Melilotus officinalis*), both formerly used in roadside seed mixes, are now very widespread and are moving into riparian areas and wetlands. We review the available literature and Alaska's statewide invasive plant database (AKEPIC, Alaska Exotic Plant Clearinghouse) to summarize changes in Alaska's non-native flora over the last 65 years. We suggest that Alaska is not immune to invasion, but rather that the exponential increase in non-native plants experienced elsewhere is delayed by a half century. This review highlights the need for more intensive detection and rapid response work if Alaska is going to remain free of many of the invasive species problems that plague the contiguous U.S.

Langor, D.W., E.K. Cameron, C.J.K. MacQuarrie, A. McBeath, A.S. McClay, B. Peter, M. Pybus, T. Ramsfield, K.L. Ryall, T.A. Scarr, D. Yemshanow, I. DeMerchant, and R.G. Pohl. 2014. Non-native species in Canada's boreal zone: diversity, impacts, and risk. Environmental Reviews 22:372-420. http://www.nrcresearchpress.com/doi/pdf/10.1139/er-2013-0083

Lassuy, D.R., and P.N. Lewis. 2013. Invasive species: human-induced. Pp. 559-565 in Conservation of Arctic Flora and Fauna Arctic Council (eds.), Arctic biodiversity assessment: status and trends in Arctic biodiversity. Akureyri, Iceland; Conservation of Arctic Flora and Fauna. http://www.arcticbiodiversity.is

Abstract - As human society has become more mobile, the transfer of species beyond their native ranges has similarly increased. Human-induced biological invasions now occur around the world and are a leading cause in the loss of biodiversity. While only few invasions are currently known from the Arctic compared with lower latitudes, changes in climate and patterns of human use are likely to increase the susceptibility of Arctic ecosystems to invasion. Much of that increased risk of invasion may come from increased shipping, energy development, mineral exploration and associated shore-based developments such as ports, roads and pipelines.

Because future change will be best understood when measured against a credible baseline, much more work is needed to define the current status of native and invasive species populations in the Arctic. The development of cost-effective early detection monitoring networks will be a challenge, but can be informed by Traditional Ecological Knowledge and may benefit from engaging a network of citizen scientists. There also needs to be increased and targeted prevention efforts to limit the influx of non-native species (e.g. ballast water treatment and the effective cleaning and treatment of ship hulls and drilling rigs brought in from other marine ecosystems).

Marler, M. 1998. Exotic plant invasions of federal Wilderness areas: current status and future directions. Missoula, MT; Rocky Mountain Research Station, Aldo Leopold Wilderness Research Institute.

http://leopold.wilderness.net/unpublished/UNP106.pdf

Summary – I conducted a survey of Wilderness areas to provide an initial overview of plant invasions in the National Wilderness Preservation System in the continental US and Alaska. A total of 333 wilderness areas responded, and approximately 15% reported that exotic species were among their top 10 management concerns. Many wilderness areas are actively dealing with control of exotic pest plants, while others have prioritized prevention establishment. About 70% of responding wilderness areas do not monitor, inventory, or survey for exotic species in any way. The majority of wilderness areas reported that they have not been severely impacted by exotic plants, so it is important to emphasize prevention and early detection of exotic plant establishment.

Across all agencies, responses varied greatly between regions, with the highest priority given to exotic plants by agencies in the California Mediterranean region and the Rocky Mountain montane region. Wilderness areas managed by the National Park Service indicated greater overall awareness of exotic plants, and were far more likely to monitor or inventory wilderness areas for exotic plants.

The greatest need for most areas is increased funding, education and training in order to prevent further establishment of exotic plants. A range of natural disturbances facilitate exotic plant invasions, and it is therefore important to recognize that lack of, or low levels of, human disturbance does not preclude weed establishment.

It appears that without explicit goals and increased funding it is difficult for many wilderness area managers to prioritize exotic plant management. Most wilderness areas have never been inventoried for exotic plants and, in general, there is little information on the distribution of exotics in wilderness areas.

McClory, J., and T. Gotthardt. 2008. Non-native and invasive animals of Alaska: a comprehensive list and selected species status reports: Final report. Anchorage, AK; University of Alaska Anchorage, Alaska Natural Heritage Program. http://www.adfg.alaska.gov/static/species/nonnative/invasive/pdfs/invasivespp_report.pdf

Executive Summary - In recent years, a number of non-native animal species have been observed in Alaska, some of which have proven to be invasive. Since animal introductions to the state are still limited in distribution, and because protecting land not yet infested by non-natives is an efficient technique for the management of invasive species, we have the opportunity to preserve Alaska's immense natural resources with careful management of invasive animal threats. However, before management efforts towards invasive species can be successful, information must be gathered to identify which non-native animal species are present in the state, where they occur, and which species pose the greatest risk to native ecosystems. In an effort to provide managers with the most up-to-date information regarding invasive animal species in Alaska, we compiled a comprehensive list of non-native animals that have been documented in the state, and also developed a list of potential future invaders based on their occurrence in neighboring states and/or provinces. We collected published and unpublished information on a number of non-native animal species that are known to pose a high risk to native ecosystems, and summarized information on their biology, modes of dispersal, documented impacts, control options, and current and historic distribution.

A total of 116 non-native animal species (including fishes, amphibians, reptiles, birds, mammals, invertebrates, parasites and pathogens) were documented as present (either historically or currently) in the state, of which 20 were designated as highly invasive species. Status reports describing biology and invasive potential were developed for 14 of the highly invasive species and are included as an appendix to this report, along with maps of their

known current distribution in the state. An additional 41 species were identified as potential invaders based on their rapid spread in western North America and on their ability to disperse over large distances. Ten of the 41 potential invaders were identified as being highly invasive, and status reports were developed for 3 of those species.

The development of the first comprehensive list of non-native animals in Alaska summarizes necessary and preliminary information about the current status of these animals in the state. Information contained within the individual species status reports and associated distribution maps may be used to interpret a species' ability to spread into particular regions, and could be used in future mapping efforts to calculate rates of dispersal as well as enable prediction of future range expansions. As global climate change continues to warm the landscape, Alaska may become more susceptible to harmful invaders and the information compiled within this report could be useful in predicting and preventing animal invasions.

Millar, A.W., and G.M. Ruiz. 2014. Arctic shipping and marine invaders. Nature Climate Change 4:413-416. http://www.nature.com/nclimate/journal/v4/n6/pdf/nclimate2244.pdf

Introduction - With striking reductions in Arctic sea-ice coverage in recent years, a long-anticipated opportunity for modern interocean shortcuts is being realized. The first commercial bulk carrier loaded with British Columbian coal successfully transited the Northwest Passage in September 2013. Perhaps more importantly, ships in larger numbers are already navigating the icy waters of Norway and Russia through the Northeastern Passage, also known as the northern sea route (NSR) — a 3,000 mile passage along Russia's northern coast that connects the Barents and Bering seas. The Russian Federation's Northern Sea Route Administration, which issues permits, provides icebreaker escort and regulate s commercial ships traversing the NSR, is now open for business.

Among many potential environmental effects, the continued expansion of Arctic shipping will alter the risk of biological invasions in coastal ecosystems on both regional and global scales. Commercial ships are a dominant mechanism for the introduction of non-native marine species. A diverse range of organisms is unintentionally transferred in ballast tanks and on the hulls of ships. A major shift in trade-routes will alter the current landscape of marine invasion dynamics, affecting the transfer, establishment and potential consequences of invasions.

There are two categories of commercial Arctic shipping: (1) trans-Arctic voyages, whereby ships use the Arctic as a thoroughfare for interocean passage; (2) destination shipping that moves goods to and from the Arctic (for example, import of oil extraction equipment and export of liquefied natural gas; LNG). Increased opportunity for invasions of the Arctic are an important concern, but trans-Arctic shipping will also change global commerce patterns significantly, connecting world ports and their biota in unprecedented ways. The melting of Arctic sea ice is connecting the North Pacific and North Atlantic oceans for the first time in several million years. Although an ice-free Arctic provides a new interocean corridor for natural dispersal of marine biota across the region, it also represents a new route for long-distance transport of organisms by ships.

Revich, B.A., and M.A. Podolnaya. 2011. Thawing of permafrost may disturb historic cattle burial grounds in East Siberia. Global Health Action 4(1): doi:10.3402/gha.v4i0.8482 https://doi.org/10.3402/gha.v4i0.8482

Invertebrates

Bousquet, Y. 1991. Checklist of beetles of Canada and Alaska. Publication 1861/E. Ottawa, Canada; Agriculture Canada, Research Branch. http://esc-sec.ca/aafcmonographs/checklist_of_beetles_of_canada_and_alaska.pdf

Bousquet, Y., P. Bouchard, A.E. Davies, and D.S. Sikes. 2013. Checklist of beetles (Coleoptera) of Canada and Alaska. ZooKeys 360:1-44, doi:10.3897/zookeys.360.4742. http://www.pensoft.net/journals/zookeys/article/4742/checklist-of-beetles-coleoptera-of-canada-and-alaska-second-edition

Abstract - All 8237 species-group taxa of Coleoptera known to occur in Canada and Alaska are recorded by province/territory or state, along with their author(s) and year of publication, in a classification framework. Only presence of taxa in each Canadian province or territory and Alaska is noted. Labrador is considered a distinct geographical entity. Adventive and Holarctic species-group taxa are indicated. References to pertinent identification keys are given under the corresponding supraspecific taxa in the data archive.

Editors note – this is only the tabular presentation of a 402-page formatted version of the checklist, which includes an index; available via Pensoft Publishers.

Bright, D.E. 1976. The bark beetles of Canada and Alaska, Coleoptera: Scolytidae. Publication 1576. Ottawa, Canada; Canada Department of Agriculture, Biosystematics Research Branch. http://www.esc-sec.ca/aafcmonographs/insects_and_arachnids_part_2.pdf

Capinera, J.L. 2010. Insects and wildlife: arthropods and their relationships with wild vertebrate animals. Jersey City, NJ: Wiley-Blackwell.

Churchwell, R.T., S.J. Kendall, A.L. Blanchard, K.H. Dunton, and A.N. Powell. 2016. Natural disturbance shapes benthic intertidal macroinvertebrate communities of high latitude river deltas. Estuaries and Coasts 39(3):798-814. https://doi.org/10.1007/s12237-015-0028-2

Abstract - Unlike lower latitude coastlines, the estuarine nearshore zones of the Alaskan Beaufort Sea are icebound and frozen up to 9 months annually. This annual freezing event represents a dramatic physical disturbance to fauna living within intertidal sediments. The main objectives of this study were to describe the benthic communities of Beaufort Sea deltas, including temporal changes and trophic structure. Understanding benthic invertebrate communities provided a baseline for concurrent research on shorebird foraging ecology at these sites. We found that despite continuous year-to-year episodes of annual freezing, these estuarine deltas are populated by a range of invertebrates that represent both marine and freshwater assemblages. Freshwater organisms like Diptera and Oligochaeta not only survive this extreme event, but a marine invasion of infaunal organisms such as Amphipoda and Polychaeta rapidly recolonizes the delta mudflats following ice ablation. These delta sediments of sand, silt, and clay are fine in structure compared to sediments of other Beaufort Sea coastal intertidal habitats. The relatively depauperate invertebrate community that ultimately develops is composed of marine and freshwater benthic invertebrates. The composition of the infauna also reflects two strategies that make life on Beaufort Sea deltas possible: a migration of marine organisms from deeper lagoons

to the intertidal and freshwater biota that survive the 9-month ice-covered period in frozen sediments. Stable isotopic analyses reveal that both infaunal assemblages assimilate marine and terrestrial sources of organic carbon. These results provide some of the first quantitative information on the infaunal food resources of shallow arctic estuarine systems and the long-term persistence of these invertebrate assemblages. Our data help explain the presence of large numbers of shorebirds in these habitats during the brief summer open-water period and their trophic importance to migrating waterfowl and nearshore populations of estuarine fishes that are the basis of subsistence lifestyles by native inhabitants of the Beaufort Sea coast.Danks, H.V., and J.A. Downes. 1997. Insects of the Yukon. Biological Survey of Canada Monograph Series No. 2. Ottawa, Canada; Biological Survey of Canada (Terrestrial Arthropods). http://www.biology.ualberta.ca/bsc/english/yukon.htm

Preface – “The Yukon is an area of North America of key relevance in understanding the fauna of the continent, both in the Northwest and elsewhere. Unglaciated in Pleistocene time and hence a refugium for organisms, connected intermittently to Eurasia and its faunas while cut off by ice from the rest of the North American continent, and now with a relatively rich fauna for its latitude, the Yukon contains many taxa that can bring information to bear on important questions of evolution, dispersal and adaptation.

Consequently, the contents of this book will be of interest to a wide audience. Information here will appeal to zoologists, botanists, and others interested in biotas, especially in the North, whether their focus is on current biodiversity, on the historical development of faunas and ecosystems, or on adaptations to rigorous conditions.

The results reported stem chiefly from a concerted effort by many cooperators under the auspices of the Biological Survey of Canada (Terrestrial Arthropods), which many years ago recognized the importance of the region in the context of the Beringian refugium, and the fact that its insect fauna was very little known. Most of the chapters here deal in detail with particular groups of insects and arachnids, providing the basic information for further analysis and study. These taxonomically arranged chapters are introduced by an outline of the development of the work and its scientific importance, and overviews of the current and past environments of the region. A concluding chapter draws some general lessons from the detailed analyses provided by the core taxonomically arranged chapters.

Glesne, R.S., and S.J. Deschermeier. 1984. Abundance, distribution and diversity of aquatic macroinvertebrates on the North Slope of the Arctic National Wildlife Refuge, 1982 and 1983. Pp. 523-552 in G.W. Garner and P.E. Reynolds (eds.), Arctic National Wildlife Refuge coastal plain resource assessment: 1983 update report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Abstract – Quantitative aquatic microinvertebrate samples were collected from 46 sites in the vicinity of the 1002c study area, Arctic NWR, during the summers of 1982 and 1983. Density, biomass, number of taxa, diversity (H') and eveness (J') values were determined for macroinvertebrate communities from all stations. Mean values were compared for tundra, spring, and mountain stream types. Density of invertebrates ranged from 11 organisms/m^2 to 15,555 organisms/m^2. Mean density increased by nearly an order of magnitude between mountain and tundra streams and between tundra and spring streams. Species composition was dominated by taxa of Orthocladiinae, Simuliidae, Oligochaeta, and Baetidae. The majority of the taxa collected were representative of the collector-gatherer functional group. The scarcity of other functional groups was reflected in the generally low

diversity (H') values found in the study area. Highest diversity values were found in tundra streams. Low diversity values were found at spring stream sites, and were attributed to the high redundancy of chironomids in the invertebrate samples at these sites. Significant positive correlations ($P<0.01$, $r=0$) were found between density and biomass of organisms with alkalinity and conductivity values.

Holsten, E., P. Hennon, L. Trummer, J. Kruse, M. Schultz, and J. Lundquist. 2008. Insects and diseases of Alaskan forests. U.S. Dept. Agriculture, Forest Service Alaska Region Report No. R10-TP-140, Juneau, AK. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5315942.pdf

West, R.L., and E. Snyder-Conn. 1987. Effects of Prudhoe Bay pit fluids on water quality and macroinvertebrates of Arctic tundra ponds in Alaska. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service Biological Report 87(7). dtic.mil/cgi-bin/GetTRDoc?AD=ADA323422

Summary - Macroinvertebrates from tundra ponds have been shown to be an important food of many waterfowl and shorebirds nesting in Arctic tundra wetlands. Birds in the Prudhoe Bay area of Alaska are among those that rely on such resources. We attempted to determine if water quality or the macroinvertebrate community of these ponds was being adversely affected by oil field operations. In particular, we examined the impacts of direct and indirect discharges of reserve pit fluids into tundra ponds. Reserve pit fluids, including drill muds and other wastes from well drilling operations diluted by snowmelt, constitute a large waste stream produced by the oil production industry.

In June 1983, preliminary inspections revealed visible oil sheens at 52% of all reserve pits inspected and discharges of reserve pit fluids from 61% of these pits. Many of these discharges were directly to tundra wetlands, and others were to gravel roads and pads. Heavy metal concentrations were high in fluids from all six of the pits sampled and hydrocarbon concentrations were high in fluids from three.

One month after preliminary observations, we took additional grab samples of water for water quality, metal, and hydrocarbon analyses and sweep net samples of invertebrates at the six drill sites, including samples from a reserve pit on the drill site, from a pond adjacent to the reserve pit, and from a more distant pond with connections to the adjacent pond. Similar samples were collected from three control ponds.

We used Friedman's method of randomized blocks to examine differences between drill site locations and reserve pit, adjacent pond and distant pond treatments. Differences between treatments were statistically significant ($P \leq 0.05$) for all water quality and biological measures, and far exceeded the differences between drill sites. Stepwise discriminant analyses of water quality, contaminant, and biological variables not significantly affected by location indicated that reserve pits, receiving ponds, distant ponds, and control ponds could be readily distinguished from each other on the basis of water quality and biological variables.

However, location significantly affected most contaminant concentrations. Contaminants not affected by location (aluminum, arsenic, and aliphatic hydrocarbons) did not enable sufficient distinction between treatments. For the water quality characteristics, reserve pits and ponds were best separated by a primary discriminant function corresponding to a gradient in turbidity, and by a second discriminant function reflecting progressive increases in alkalinity from control ponds to distant ponds to receiving ponds. Among the biological variables, the total number of taxa was the biological measure first selected in the stepwise process; this variable alone was sufficient to distinguish among all treatments, accounting for about 89% of the variance between the treatment pits and ponds. Samples from all six reserve pits were devoid of invertebrates.

Comparisons of adjacent receiving ponds with control ponds by Kruskal-Wallis tests revealed the scope of effects of contaminants. Hardness, alkalinity, turbidity, chromium, barium, arsenic, and nickel were all elevated in receiving ponds ($P \leq 0.05$). Differences between distant ponds and control ponds were less pronounced, but alkalinity, chromium, and aliphatic hydrocarbons were higher, and the number of invertebrate taxa was lower in the distant ponds.

Results of simple linear regressions of chemical on biological data (pits excluded) were used to suggest water quality and contaminant variable indicative of adverse environmental impacts. Water quality characteristics that best predicted deteriorating biological conditions were alkalinity and hardness, and metals most indicative of biological change were arsenic and barium. In addition, chromium concentrations in reserve pits and ponds near drill sites may have exceeded chronic toxicity criteria for protection of aquatic life set by the EPA, and high concentrations of chromium had obviously dispersed into distant ponds. Measurement of these variables should assist in more effectively screening reserve pit fluids before discharging to the tundra.

Fish

Brown, R.J. 2008. Life history and demographic characteristics of Arctic Cisco, Dolly Varden, and other fish species in the Barter Island region of northern Alaska. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 101. https://www.fws.gov/alaska/fisheries/fish/Technical_Reports/t_2008_101.pdf

Abstract - Arctic cisco *Coregonus autumnalis* and Dolly Varden *Salvelinus malma* are major fishery resources for people in coastal regions of northern Alaska and Yukon Territories. Concerted attempts to document the presence and monitor the relative abundance of these species and others began in the 1970s in response to regional development activities associated with oil exploration and extraction. Numerous sampling projects have taken place in coastal lagoon systems from the Colville River in the west to the Mackenzie River in the east. The USFWS conducted an initial four year fyke net sampling program in the Barter Island region from 1988 to 1991 and repeated the sampling program 15 years later, from 2003 to 2005, to examine long-term trends in demographic composition, relative abundance, and body condition of Arctic cisco and Dolly Varden. The relative abundance of Arctic cisco varied widely among years primarily because of the tremendous variation in the number of age 0 fish moving west along the coast. The abundance of mature-size Arctic cisco, the primary demographic group harvested in coastal fisheries, remained relatively stable across years and between the early and late years of the project. Maturity indices, age, tagging, and relative abundance data suggested that Arctic cisco encountered in the Barter Island region come from overwintering habitats in both the Colville and Mackenzie River deltas. Immature Dolly Varden dominated the catch during all sampling years. With few exceptions, the relative abundance of mature Dolly Varden, the primary demographic group harvested in coastal fisheries, remained stable across years and between the early and late years of the

project. Catch rates for mature Dolly Varden declined earlier in the season than for immature fish, presumably because of time constraints associated with fall spawning in freshwater habitats. In general, body condition of Dolly Varden improved between early and late summer seasons, as expected. Information regarding other fish species, such as overwintering origins, length frequency data, or relative abundance, is presented with minimal discussion.

Brown, R.J., M.B. Loewen, and T.L. Tanner. 2014. Overwintering locations, migrations, and fidelity of radio-tagged Dolly Varden in the Hulahula River, Arctic National Wildlife Refuge, 2007–09. Arctic 67(2):149-158. http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/article/view/4379

Abstract - Essential overwintering habitats for anadromous Dolly Varden *Salvelinus malma* on Alaska's North Slope appear to be limited to a small number of perennial springs, primarily in eastern Brooks Range drainages. Because future petrochemical development in the region continues to be a possibility, and development would require large quantities of freshwater, we sought to identify and document the overwintering areas used by Dolly Varden in the Hulahula River, eastern Brooks Range. In August 2007, we implanted 52 Dolly Varden with multi-year radio transmitters at a known overwintering area in the lower Hulahula River. Other wintering areas were located during 11 aerial surveys conducted over the next 2.5 years. A stationary receiver located in the lower Hulahula River provided migration timing information. Radio-tagged Dolly Varden used four discrete areas with perennial springs for overwintering in the Hulahula River drainage. The springs, totaling approximately 12 km in stream length, were located between river km 40 and 105. Radio-tagged Dolly Varden migrated downstream on their way to the Beaufort Sea in early June. Most tagged fish known to have survived the summer at sea returned to the Hulahula River during late July and August, but seven fish overwintered in other North Slope drainages. Within the Hulahula River drainage, 15 fish overwintered in more than one area during the three winters of the project, but only the four identified perennial spring areas were used. These data clearly indicate that the perennial springs in the Hulahula River are essential overwintering habitats for Dolly Varden.

Burkart, G.A. 2007. Energy flow in Arctic lake food webs: the roles of glacial history, fish predators and benthic-pelagic linkages. Logan, UT: Utah State University, Department of Aquatic, Watershed and Earth Sciences, Ph.D. Dissertation.

Corning, R.V. 1990. Life history findings for Arctic Grayling (*Thymallus arcticus*) of the Tamayariak River drainage, Alaska. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch, Fisheries Management Services unpublished report.

Corning, R.V. 1990. Fish inventories of the Jago and Katakturuk River drainages, 1002 area of the Arctic National Wildlife Refuge. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch, Fisheries Management Services unpublished report.

Courtney, M.B., B. Scanlon, R.J. Brown, A.H. Rikardsen, C.P. Gallagher, and A.C. Seitz. 2017. Offshore ocean dispersal of adult Dolly Varden *Salvelinus malma* in the Beaufort Sea. Polar Biology https://doi.org/10.1007/s00300-017-2246-5

Abstract - While it is known that Dolly Varden *Salvelinus malma* occupies offshore waters of the Bering and Chukchi seas in Alaska, the general scientific consensus is that this species typically occupies nearshore waters of the Beaufort Sea during its summer feeding season. Because of the importance of offshore waters for many upper trophic level vertebrates in this region, we tested if Dolly Varden occupies this area as well. Therefore, we attached pop-up satellite archival tags (PSATs) to Dolly Varden in the Beaufort Sea. Ten PSATs released from the fish and floated to the surface on pre-programmed dates throughout the summer, and transmitted archived depth and temperature data to satellites, while providing tag end locations. PSATs documented offshore dispersal of up to 69 km from the coast by Dolly Varden during the summer. Tagged fish were surface oriented with mean depths of individuals ranging from 0.1 to 2.2 m (total depth range 0–18.8 m), and experienced an ambient thermal environment of mostly 2-8 °C. The findings of this study highlight the importance of the offshore waters of the Beaufort Sea for Dolly Varden. Such knowledge aids in understanding potential impacts of human activities and environmental change in the Arctic.

Craig, P., and L. Haldorson. 1986. Pacific salmon in the North American Arctic. Arctic 39(1):2-7. http://pubs.aina.ucalgary.ca/arctic/Arctic39-1-2.pdf

Abstract - All five North American Pacific salmon species occur in small numbers in arctic waters, but only pink and chum salmon appear to have viable populations north of Point Hope, Alaska. Pink salmon are the most common species and constitute 85% of salmon caught in biological surveys. Pink salmon apparently have small runs in eight arctic drainages, while chum salmon may have small runs in six. Arctic pink salmon are smaller in size than individuals to the south but have similar meristic characteristics. It is likely that minimal use of freshwater habitats by pink and chum salmon has allowed them to colonize characteristically cold arctic rivers.

Dunton K.H., T. Weingartner, and E.C. Carmack. 2006. The nearshore western Beaufort Sea ecosystem: circulation and importance of terrestrial carbon in arctic coastal food webs. Progress in Oceanography 71(2-4):362-378. https://doi.org/10.1016

Dunton K.H., S.V. Schonberg, and L.W. Cooper. 2012. Food web structure of the Alaskan nearshore shelf and estuarine lagoons of the Beaufort Sea. Estuaries and Coasts 35(2):416-435. https://doi.org/10.1007/s12237-012-9475-1

Abstract - The eastern Alaska Beaufort Sea coast is characterized by numerous shallow (2–5 m) estuarine lagoons, fed by streams and small rivers that drain northward from the Brooks Range through the arctic coastal plain, and bounded seaward by barrier islands and shoals. Millions of birds from six continents nest and forage during the summer period in this region using the river deltas, lagoons, and shoreline along with several species of anadromous and marine fish. We examined biogeochemical processes linking the benthic community to the overall food web structure of these poorly studied but pristine estuaries, which are largely covered by 1.8 m of ice for 10 months annually. In summer, these lagoons are relatively warm with brackish salinities (5–10°C, S = 10–25) compared to more open coastal waters (0–5°C, S > 27). The stable isotopic composition of organic materials in sediments (i.e., benthic particulate organic matter) and water column suspended particulate organic matter from both streams and lagoons are largely indistinguishable and reflect strong terrestrial contributions, based upon δ13C and δ15N values (−25.6‰ to −27.4‰ and 1.4‰ to 3.3‰, respectively). By comparison, shifts toward more heavy isotope-enriched organic materials reflecting marine influence are observed on the adjacent coastal shelf (−24.8‰ to −25.4‰ and 3.4‰ to 5.3‰, respectively). The isotopic composition of lagoon fauna is consistent with a food web dominated by omnivorous detritovores strongly dependent on microbial processing of terrestrial sources of carbon. Biomagnification of 15N in benthic organisms indicate that the benthic food web in lagoons support up to four trophic levels, with carnivorous gastropod predators and benthic fishes (δ15N values up to 14.4‰) at the apex.

Elliot, G. 1982. Final report on the evaluation of stream crossings and channel modifications on the fishery resources along the route of the trans-Alaskan pipeline. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Special Studies.

Elliot, G.V. 1989. Winter water availability on the 1002 area of the Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch, Alaska Fisheries Technical Report Number 3.

Elliot, G.V. 1990. Quantification and distribution of winter water within the lakes of the 1002 area, Arctic National Wildlife Refuge, 1989. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 7.

Elliot, G.V., and S.M. Lyons. 1990. Quantification and distribution of winter water within river systems of the 1002 area, Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch, Alaska Fisheries Technical Report Number 6.

Fruge, D.J., and D.E. Palmer. 1994. Fishery management plan Arctic National Wildlife Refuge FY 1994-1998. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Fishery Resource Office.

Groot, C., and L. Margolis. 1991. Pacific salmon life histories. Vancouver, B.C.: University of British Columbia Press.

Hale, S.S., T.E. McMahon, and P.C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: chum salmon. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Biological Report 82(10.108). https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-108.pdf

Hinzman, L., M.R. Lilly, D.L. Kane, D.D. Miller, B.K. Galloway, K.M. Hilton, and D.M. White. 2006. Physical and chemical implications of mid-winter pumping of tundra lakes - North Slope, Alaska. Fairbanks, AK: Water and Environmental Research Center, Report INE/WERC 06.15.

Hobbie, J.E. 1961. Summer temperatures in Lake Schrader, Alaska. Limnology and Oceanography 6:326-329.

Hobbie, J.E. 1964. Carbon 14 measurements of primary production on two Arctic Alaskan lakes. International Association of Theoretical and Applied Limnology Verhandlungen 15:360-364.

Hobbie, J.E. 1984. The ecology of tundra ponds of the Arctic coastal plain: a community profile. U.S. Department of the Interior, Fish and Wildlife Service FWS/OBS-83/25.

Editors Note – no author prepared abstract or summary.

Quotes – from Preface (Pp. iii).

The Arctic coastal plain is a flat or gently rolling area of tundra which covers the entire coastal region of northern Alaska. The grasses, sedges, and waterbodies are covered with ice, snow, and silence for 9 months of the year, but lakes, ponds, marshes, and birds abound for the brief summer. This entire region is almost pristine today, but only because the mountains of the Brooks Range isolated northern Alaska from the roads and development of the rest of the state. Before the recent oil boom, only a few Alaska Native villages and radar sites were present along the coast and the population was less than 3,000 people in an area the size of Lake Superior.

Changes have come with the development of oil fields a t Prudhoe Bay. An all-weather highway, completed in 1975, carries tractor- trailers to the Arctic Ocean and may soon be opened to the public. While only 2 oil spills of consequence have occurred since the trans-Alaska pipeline system (TAPS) began operation, many hectares of the coastal plain have been covered by roads, airfields, gravel drilling pads, and pipelines. The roads have changed drainage patterns in many places and created and destroyed wetlands. These changes will continue as new oilfields are sought and developed on the coastal plain and under the Arctic Ocean.

Ecological scientists have long been attracted to the Arctic both because of the excitement of exploration where wildlife is abundant and because of the opportunity to study environments unaffected by humans. Investigators have also used Arctic habitats to test hypotheses about general ecological principles and to analyze the effects of certain environmental factors that may vary together in more temperate regions. As a result of the scientific interest and of the presence of oil development there is a great deal known about the Arctic coastal plain.

This community profile synthesizes much of the information on the ecology of these coastal plain wetlands. It will provide background and information needed by government planners and environmental scientists whose decisions will influence the future of this vast region. In addition, it will provide students, scientists, and laymen a better understanding of how arctic ponds and wetlands function.

This profile emphasizes the environmental conditions and ecological interactions that produce these particular wetland communities. The communities are described here, but we now know enough about their ecology that the controls of processes and species can also be discussed. It is usually disruption of these controls, such as changing the water movement in a salt marsh or the nutrient cycle of a lake, that causes unplanned or unexpected changes.

The text includes descriptions of the communities as well as of ecological processes. An introductory description of the Arctic coastal plain is followed by a discussion of the types of wetland habitat found there. Next, the physical and chemical environment is described with special emphasis on the controlling influence of the permafrost and of the phosphorus cycle. The following chapter gives details of the plants and animals and of their seasonal abundance. After this, the food chains, the cycling of carbon, energy flow, and the controls acting on these wetland ecosystems are discussed. Finally, human effects on ponds, wetlands, and their processes are described.

Most of the detailed scientific studies of Arctic wetlands have dealt with small ponds in the coastal plain and, of necessity, so does this community profile. Although rivers and large shallow lakes are also important parts of the wetlands of the Arctic coastal plain, they are not discussed in this profile. This report is one in a series of community profile on important coastal ecological communities of the United States. Community profiles are designed to provide comprehensive reviews and syntheses of current research results and scientific literature and to assist Fish and Wildlife Service personnel and others making sound and informed decisions on issues affecting our nation's natural resources.

Quotes – from Chapter 6. Effects of Humans on Wetlands (Pp. 41-44).

6.1. Oil-spill Effects

The production of oil at Prudhoe Bay has stimulated research on effects of an oil spill on coastal plain wetlands. Because the intensively- studied ponds at Barrow could be used as controls, an experimental spill was made in a pond in Jul of 1970 and the recovery followed for 7 years (see Barsdate et al. 1980; Oil spill effects Pp. 388-406 in Limnology of tundra ponds, Barrow, Alaska; US/IBP Synthesis Series 13).

The spill was 4 barrels of crude oil or 1.6 l m^{-2}. The wind immediately moved the oil to the edge of the pond where most became trapped in the vegetation and litter. Some oil floated for about 30 d but by the end of the summer most of it had sunk. After several years at least 50% of the oil was still present, covered by debris and organic matter; it still welled up and created a scum when disturbed. After 5 years the oil remaining had virtually the same chemical composition as the oil in the fresh spill except for the loss of low molecular weight hydrocarbons.

The zooplankton community was the most strongly affected by the oil. A second test spill in 1975 revealed that fairy shrimp were after 1 d, *Daphnia* after 3 d, and *Heterocope* after 5 d. *Daphnia* and fairy shrimp did not return to the 1970-spill pond until 1976.

The phytoplankton community responded to the oil by a 50% reduction of primary productivity for several weeks followed by an apparently complete recovery. There were, however, other changes and the dominant nanoplankton algae, *Rhodomonas minuta*, was replaced by *Uroglena* sp.

The *Rhodomonas* did not return to this pond until 1976, the same year the *Daphnia* and fairy shrimp reappeared (Federle et al. 1979; The effect of Prudhoe Bay crude oil on primary production and zooplankton in Arctic tundra thaw ponds. Marine Environmental Research 2:3-18). Other tests showed that this replacement is caused by the removal of the zooplankton, not by the toxicity of the oil. The exact mechanism of this interaction is unknown but it could be grazing pressure or the enhancement of the nutrient cycling rate by the zooplankton.

The spills had little effect on the numbers and production of chironomids but one genus, Tanytarsus, was nearly eliminated from the ponds. Beetles, caddisflies, stoneflies, and snails were also drastically affected; most of these animals live only in the plant beds and may have become entrapped in the soil on plant stems. These insects were still absent 6 yr after the spill.

There is also information on effects of crude oil on Carex from the studies of Walker et al. (1982; Landsat-assisted environmental mapping in the Arctic National Wildlife Refuge, Alaska. USACE CRREL Report 82-37) at Prudhoe Bay. The plants in wet sites were less susceptible than those of drier sites and all plants were much more affected by refined oil (gasoline and diesel fuel) than by crude oil.

When an oil spill is relatively light, as in these experiments at Barrow, the best treatment of a spill would be to absorb the floating oil (e.g., with straw or plastic sponge absorbers), then to flood the marsh to float the oil away from littoral plants, and then to absorb the floating oil again. The biota of the pond will recover in a few years with this simple treatment. Drastic cleanup measures are likely to induce greater changes in the ecology of these coastal plain ponds.

6.2. Effects of Off-road Vehicles and Roads

Oil spills and physical destruction of wetlands are obvious and dramatic effects of human activity on the Arctic coastal plain. But there are also less obvious and subtle interactions as well and these produce serious local effects. The effect of various types of vehicles on the tundra surface illustrates the possible range of effects.

The smallest effect is produced by air cushion vehicles (ACVs). The sequence of events begins with removal of standing dead leaves and stems and ends with an increase in plant production (Figure 28). The change is well within the natural variation produced by lemming population highs.

A more-noticeable change is triggered by balloon-tired vehicles (Rolligons). These have extremely large tires with low bearing pressure, yet the resulting depression of vegetation reduces insulation and leads eventually to an effect on plant productivity that takes 5-15 yr to disappear (Figure 28).

The most severe effect is a result of vehicles with tires or tracks driving across the tundra. The organic layers overlying the mineral soil are compacted and the vegetation may be destroyed (Figure 28). Eventually, the ice in the permafrost may melt; the volume of soil decreases and a pond may form in the resulting depression. This thawing is termed a thermokarst phenomenon. When vehicle tracks cross ice wedges, these may melt and ponds several meters deep may form. On slopes, vehicle tracks intercept sheet flow and stream channels may form. It may take centuries or thousands of years to form stable new communities (Abele et al. 1978; Effects of low ground pressure vehicle traffic on tundra at Lonely, Alaska. USACE CRREL Report 78-16). While new ponds are formed in this manner, the conversion of shallow ponds and grass and sedge wetlands to muddy tracks and deep ponds is a net loss of wildfowl habitat and food.

A different series of events ensue when roads are built. The roads are usually built of gravel and are 2 m thick (Figure 8). In the climate of the Arctic coastal plain, the center of the gravel becomes frozen and the road acts as a dam to normal drainage unless many culverts are provided. Klinger et al. (1983; The effects of gravel roads on Alaskan Arctic coastal plain tundra. National Academy of Sciences Proceedings) identified snowbank formation, flooding, and road dust deposition as the main effects of roads on the tundra. For ponds, only flooding has been shown to have any significant effect during the few years of study; the main result of flooding is likely to be the replacement of numerous and diverse shallow ponds and wetlands by larger and deeper water bodies that are of lower value for breeding birds.

The future effects of humans on the ponds and other wetlands that make up the Arctic coastal plain will depend greatly upon the amount of planning and control exerted by various State, federal and local agencies. At the present, much of the coastal plain is under the jurisdiction of the federal government. The North Slope Borough and State of Alaska also

control large areas. Minimal change will occur if travel is restricted to roads and if roads are constructed with adequate culverts. The key to preservation of adequate and diverse habitat for wildfowl is the protection of the permafrost and its natural insulating layer of vegetation.

Hubert, W.A., R.S. Helzner, L.A. Lee, and P.C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: Arctic grayling riverine populations. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Biological Report 82(10.110). https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-110.pdf

Irvine, J.R., R.W. Macdonald, R.J. Brown, L. Godbout, J.D. Reist, and E.C. Carmack. 2009. Salmon in the Arctic and how they avoid lethal low temperatures. North Pacific Fish Commission Bulletin 5:39-50.

Abstract - With climate change, scientists and others are interested in the future of Pacific salmon in the Arctic. Chum, pink, sockeye, coho, and chinook salmon have been encountered in the Beaufort Sea, well within Canadian Arctic waters. Chum is the only salmon species regarded as natal to the Mackenzie River watershed, although both pink and chum salmon appear to be natal to Alaska's North Slope rivers. It is not possible to say whether apparent recent increases in the frequency of occurrence of salmonids in the Arctic is an effect of climate change, but it appears there are either increases in the survival of natal fish from the Mackenzie, or in the wandering of non-natal fish to the Mackenzie, or both. We propose three hypotheses to explain how chum salmon survive cold marine winter conditions, and thereby persist in the North American Arctic: (1) Bering Sea Refuge – young salmon migrate to the Bering Sea and Gulf of Alaska where they remain until they are ready to return to spawn; (2) Atlantic Layer Beaufort Refuge – salmon remain in the Beaufort Sea, wintering offshore deep under pack ice; and (3) Freshwater Beaufort Refuge – salmon remain in the Beaufort Sea region, wintering in the brackish, under-ice Mackenzie River plume or in fresh water adjacent to the Beaufort Sea. As a preliminary test of these hypotheses, we examined the strontium-to-calcium ratios (Sr:Ca) of otoliths from chum salmon from the Colville (Alaska's North Slope) and Tanana (Yukon River drainage) rivers. Yukon River chum salmon were assumed to reside in the Gulf of Alaska and the Bering Sea. Otolith Sr:Ca ratios were similar between rivers, implying that fish from each group lived in similar environments, but also exhibited significant fluctuations often associated with migrations between freshwater and marine environments. Age compositions and sizes of adult chum salmon from the upper Mackenzie River watershed did not differ from chum from a Yukon River tributary. We are not able to refute any of our hypotheses, but the most parsimonious explanation is that arctic chum salmon live in the North Pacific for most of their marine life, rather than in the Beaufort Sea region. Because of the long distance to migrate between the mouth of the Mackenzie and the North Pacific Ocean, we suggest salmon may spend their first winter deep within the Beaufort Sea (i.e., a combination of Hypotheses 1 and 2). Additional elemental and isotopic signature measurements will enable a more thorough testing of these hypotheses, allow us to understand how chum salmon survive cold winter conditions, and thereby better predict potential climate change effects on salmon in the Arctic.

Jarvela, L.E., and L.K. Thorsteinson. 1998. The epipelagic fish community of Beaufort Sea coastal waters, Alaska. Arctic 52(1):80-94. http://pubs.aina.ucalgary.ca/arctic/Arctic52-1-80.pdf

Abstract - A three-year study of epipelagic fishes inhabiting Beaufort Sea coastal waters in Alaska documented spatial and temporal patterns in fish distribution and abundance and examined their relationships to thermohaline features during summer. Significant interannual, seasonal, and geographical differences in surface water temperatures and salinities were observed. In 1990, sea ice was absent and marine conditions prevailed, whereas in 1988 and 1991, heavy pack ice was present and the dissolution of the brackish water mass along the coast proceeded more slowly. Arctic cod, capelin, and liparids were the most abundant marine fishes in the catches, while arctic cisco was the only abundant diadromous freshwater species. Age-0 arctic cod were exceptionally abundant and large in 1990, while age-0 capelin dominated in the other years. The alternating numerical dominances of arctic cod and age-0 capelin may represent differing species' responses to wind-driven oceanographic processes affecting growth and survival. The only captures of age-0 arctic cisco occurred during 1990. Catch patterns indicate they use a broad coastal migratory corridor and tolerate high salinities. As in the oceanographic data, geographical and temporal patterns were apparent in the fish catch data, but in most cases these patterns were not statistically testable because of excessive zero catches. The negative binomial distribution appeared to be a suitable statistical descriptor of the aggregated catch patterns for the more common species.

Liljedahl, A.K., J. Boike, R.P. Daanen, A.N. Fedorov, G.V. Frost, G. Grosse, L.D. Hinzman, Y. Iijma, J.C. Jorgenson, N. Matveyeva, and M. Necsoiu. 2016. Pan-Arctic ice-wedge degradation in warming permafrost and its influence on tundra hydrology. Nature Geoscience, 9(4):312-318. http://dx.doi.org/10.1038/ngeo2674

Abstract - Ice wedges are common features of the subsurface in permafrost regions. They develop by repeated frost cracking and ice vein growth over hundreds to thousands of years. Ice-wedge formation causes the archetypal polygonal patterns seen in tundra across the Arctic landscape. Here we use field and remote sensing observations to document polygon succession due to ice-wedge degradation and trough development in ten Arctic localities over sub-decadal timescales. Initial thaw drains polygon centers and forms disconnected troughs that hold isolated ponds. Continued ice-wedge melting leads to increased trough connectivity and an overall draining of the landscape. We find that melting at the tops of ice wedges over recent decades and subsequent decimeter-scale ground subsidence is a widespread Arctic phenomenon. Although permafrost temperatures have been increasing gradually, we find that ice-wedge degradation is occurring on sub-decadal timescales. Our hydrological model simulations show that advanced ice-wedge degradation can significantly alter the water balance of lowland tundra by reducing inundation and increasing runoff, in particular due to changes in snow distribution as troughs form. We predict that ice-wedge degradation and the hydrological changes associated with the resulting differential ground subsidence will expand and amplify in rapidly warming permafrost regions.

Lyons, S.M., and J.M. Trawicki. 1994. Water resource inventory and assessment, coastal plain, Arctic National Wildlife Refuge: 1987-1992 Final Report. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch WRB 94-3.

Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Fishes of Alaska. Bethesda, MD; American Fisheries Society.

Nolan, M., R. Churchill, J. Adams, J. McClelland, K.D. Tape, S. Kendall, A. Powell, K. Dunton, D. Payer, and P. Martin. 2011. Predicting the impact of glacier loss on fish, birds, floodplains, and estuaries in the Arctic National Wildlife Refuge. Pages 49-54 in C.N. Medley, G. Patterson, and M.J. Parker (eds.), Proceedings of the Fourth Interagency Conference on Research in the Watersheds. U.S. Department of the Interior, Geological Survey Scientific Investigations Report 2011-5169.

Palmer, D.E., and L.J. Dugan. 1990. Fish population characteristics of Arctic National Wildlife Refuge coastal waters, summer 1989. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Fishery Assistance Office.

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Pollard, D.D., and D.S. Segar. 1994. A description of the physical characteristics of nearshore and lagoonal waters in the eastern Beaufort Sea, 1990. Final report for Department of Commerce, NOAA/NOS, Ocean Resources Conservation and Assessment, and U.S. Fish and Wildlife Service. Anchorage, AK: University of Alaska, Environment and Natural Resources Institute.

Raleigh, R.F., and P.C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: pink salmon. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Biological Report 82(10.109). https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-109.pdf

Snyder-Conn, E., and M. Lubinski. 1993. Contaminant and water quality baseline data for the Arctic National Wildlife Refuge, Alaska, 1988-1989. Volume 3, Quality Assurance/Quality Control Statistics. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Northern Alaska Ecological Services Technical Report NAES-TR-93-03.

Trawicki, J.M., S.M. Lyons, and G.V. Elliot. 1991. Distribution and quantification of water within the 1002 Area, Arctic National Wildlife Refuge, Alaska. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fishery Technical Report Number 10.

Underwood, T.J., J.A. Gordon, M.J. Millard, L.A. Thorpe, and B.M. Osborne. 1995. Characteristics of selected fish populations of the Arctic National Wildlife Refuge coastal waters, final report, 1988-1991. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 28.

Underwood, T.J., M.J. Millard, and L.A. Thorpe. 1996. Relative abundance, length frequency, age, and maturity of Dolly Varden in nearshore waters of the Arctic National Wildlife Refuge, Alaska. Transactions of the American Fisheries Society 125(5):719-728. https://doi.org/10.1577/1548-8659(1996)125<0719:RALFAA>2.3.CO;2

Abstract - Uncertainty about the environmental effects of oil development prompted a study of Dolly Varden *Salvelinus malma* in the nearshore waters of the Arctic National Wildlife Refuge, Alaska. Abundance of fish less than 400 mm fork length (FL), as indexed by tyke net catch per unit effort (CPUE), was significantly different among years, with the highest daily catch rates occurring in 1991, a year of heavy pack ice and relatively cold water temperatures. The CPUE for fish 400 mm or greater did not differ significantly among years. Within each sampling year, both large and small fish appeared to be more abundant in nearshore waters earlier in the summer. Lengths ranged from 53-734 mm. Growth was greater early in the season and in the years 1989 and 1990, and site-specific temporal changes in distribution were reflected in analysis of length data. Individual fish were aged at 1-13 years. A gonadosomatic index indicated that sexually mature fish were greater than 400 mm FL. Wide summer dispersal makes Dolly Varden less vulnerable to local coastal

perturbations during the summer; however, vulnerability may be greater for stocks that must migrate seasonally through particular areas (e.g., a river mouth during fall migrations). The significant differences in local abundance patterns makes effective monitoring of the overall population size difficult. Monitoring spawners or overwintering fish in freshwater may be a more accurate means of assessing overall abundance trends.

Weller, M.W., and D.V. Derksen. 1979. The geomorphology of Teshekpuk Lake in relation to coastline configuration of Alaska's coastal plain. Arctic 32(2):152-160. http://pubs.aina.ucalgary.ca/arctic/Arctic32-2-152.pdf

Abstract - Observations on a drained and a partially drained lake basin adjacent to Teshekpuk Lake led to the conclusion that the drainage was a result of erosion produced by the moat-current phenomenon of Teshekpuk Lake. The processes of shoreline erosion and lake-capture seem to be responsible for the growth and configuration of Teshekpuk Lake. Similar phenomena between large lakes and the Beaufort Sea may also have influenced the shoreline configuration of vast coastal areas such as Admiralty Bay, Dease Inlet and Harrison Bay.

West, R.L., and D.J. Fruge. 1989. A review of coastal plain fish surveys and the results of 1986 fish surveys of selected coastal lakes and streams, Arctic National Wildlife Refuge, Alaska. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 4.

Abstract – A review of fish surveys of Beaufort Sea drainages, North Slope lakes and nearshore waters of the Arctic National Wildlife Refuge is presented. Also, fish surveys of 9 lakes and 6 streams within the coastal plain were conducted in early Jul 1986. Sample sites were selected based upon their proximity to potential oil and gas development, suitability as water sources, and potential to support fish populations. Significant fish populations were not discovered at any of the sites, although ninespine stickleback (*Pungitius pungitius*) were found in 3 lakes and 3 streams, and a single Arctic grayling (*Thymallus arcticus*) was captured in the Kataturuk River. The abundance and distribution of Arctic freshwater fishes in the Arctic Refuge coastal plain are probably limited primarily by lack of suitable overwintering habitat.

West, R.L., and M.W. Smith. 1992. Autumn migration and overwintering of Arctic Grayling in coastal streams of the Arctic National Wildlife Refuge, Alaska. Transactions of the American Fisheries Society 121(6):709-715. https://doi.org/10.1577/1548-8659(1992)121<0709:AMAOOA>2.3.CO;2

Abstract - During 1984 and 1985, 67 adult Arctic grayling *Thymallus arcticus* with surgically implanted radio transmitters were released at their summer feeding areas in three river systems of the Arctic NWR, Alaska. We tracked the fish from aircraft to determine patterns of autumn migration to overwintering locations. During August or September in each area, fish left the small tundra streams where they were tagged and migrated into larger streams. Migration rates peaked at 5-6 km/d about 1 September and averaged 1 km/d. Fish in two river systems moved into adjacent rivers after passage through estuarine waters. Migration distances from spawning or summer feeding areas to overwintering sites were as great as 101 km. Potential overwintering areas determined from transmitter relocations included deep pools, spring-fed areas, and lakes. Management problems associated with these extensive seasonal migrations may include the maintenance of the species migratory circuit in a region that may face future development.

Wilson, W., E. Buck, G. Player, and L. Dreyer. 1977. Winter water availability and use conflicts as related to fish and wildlife in Arctic Alaska: a synthesis of information. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services FWS/OBS-77/06.

Wiswar, D.W. 1991. Summer distribution of fishes in the Okpilak and Akutoktak Rivers, Arctic National Wildlife Refuge, Alaska, 1989. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 11.

Abstract – The summer distribution of Arctic fishes was investigated in the Okpilak and Akutoktak rivers during 3 sampling periods in the summer of 1989. Four sites in each mainstem and 5-6 tributary sites were sampled in Jul; one mainstem and one tributary site sere revisited in each river during early and late Aug. Arctic char (*Salvelinus alpinus*), Arctic grayling (*Thamallus arcticus*) and ninespine stickleback (*Pungitius pungitius*) were captured.

In the mainstem Okpilak River, juvenile Arctic char were captured from the mouth to about 50 km upstream in Jul and Aug and in the lower reaches of 2 tributaries. No adult or young-of-the-year Arctic char were captured. Adult Arctic grayling were captured at only a single mainstem and one tributary site. Juvenile Arctic grayling were captured at all mainstem and 2 tributary sites. Juvenile and adult Arctic grayling ranged in fork length (FL) from 71-393 mm. Young-of-the-year Arctic grayling were absent from the mainstem in Jul, but were captured in a tributary of the lower Okpilak River. Young-of-the-year were captured in the mainstem Okpilak River near the tributary in Aug.

In the Akutoktak River, juvenile Arctic char were absent in Jul but were captured in Aug, 16 km upstream from the confluence of the Okpilak River. No adult or young-of-the-year Arctic char were caught. Juvenile and adult Arctic grayling were distributed in the mainstem Akutoktak River up to about 40 km upstream in Jul, but were absent in late Aug. Juvenile and adult Arctic grayling ranged from 220-394 mm FL. Young-of-the-year Arctic grayling, first captured on 6 Jul, were still present in the mainstem Akutoktak River in late Aug. Fish were not captured nor observed in any of the 6 tributaries of the Akutoktak River surveyed.

In both rivers, mean length increase of young-of-the-year Arctic grayling was greater between Jul and early Aug than between early and late Aug. There was no significant difference ($P>0.05$) between the length-weight relationship of young-of-the-year between early and late Aug 1989. However, differences were significant ($P<0.001$) between Jul and Aug, and between the Okpilak and Akutoktak rivers.

Juvenile Arctic char used both rivers for summer rearing. Arctic grayling utilized the mainstem Okpilak River primarily as a migration corridor to spawning and overwintering areas, and as rearing habitat for young-of-the-year fish. The mainstem Akutoktak River was utilized by Arctic grayling for spawning and provided rearing habitat for all life history stages.

Wiswar, D.W. 1992. Summer distribution of arctic fishes in the Okpilak, Akutoktak, Katakturuk, and Jago rivers, Arctic National Wildlife Refuge, Alaska, 1990. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 17.

Wiswar, D.W. 1994. Summer Distribution of Arctic Fishes in the 1002 Area of the Arctic National Wildlife Refuge, Alaska, 1991 with emphasis on selected lakes, tundra streams, and the Sadlerochit River drainage. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 27.

Wiswar, D.W., R.L. West, and W.N. Winkleman. 1995. Fisheries investigation in Oruktalik Lagoon, Arctic Lagoon, Arctic National Wildlife Refuge, Alaska. 1986. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Fisheries Technical Report Number 30.

Birds: General (includes human-subsidized predators)

Alaska Checklist Committee. 2018. Checklist of Alaska birds, 24th edition—2018. Fairbanks, AK: University of Alaska, University of Alaska Museum Department of Ornithology. http://www.universityofalaskamuseumbirds.org/products/checklist.pdf

Bart, J., R.M. Platte, B.A. Andres, S. Brown, J.A. Johnson, and W. Larned. 2013. Importance of the National Petroleum Reserve-Alaska for aquatic birds. Conservation Biology 27:1304-1312. http://dx.doi.org/10.1111/cobi.12133

Abstract - We used data from aerial surveys (1992–2010) of >100,000 km^2 and ground surveys (1998–2004) of >150 km^2 to estimate the density and abundance of birds on the North Slope of Alaska. In the ground surveys, we used double sampling to estimate detection ratios. We used the aerial survey data to compare densities of birds and Arctic fox (*Vulpes lagopus*), the major nest predator of birds, on the North Slope, in Prudhoe Bay, and in nearby areas. We partitioned the Prudhoe Bay oil field into 2 × 2 km plots and determined the relation between density of aquatic birds and density of roads, buildings, and other infrastructure in these plots. Abundance and density (birds per square kilometer) of 3 groups of aquatic birds—waterfowl, loons, and grebes; shorebirds; and gulls, terns, and jaegers—were highest in the National Petroleum Reserve–Alaska (NPRA) and lowest in the Arctic National Wildlife Refuge. Six other major wetlands occur in the Arctic regions of Canada and Russia, but the largest population of aquatic birds was in the NPRA. Aquatic birds were concentrated in the northern part of the NPRA. For example, an area that covered 18% of the NPRA included 53% of its aquatic birds. The aerial surveys showed that bird density was not lower and fox density was not higher in Prudhoe Bay than in surrounding areas. Density of infrastructure did not significantly affect bird density for any group of species. Our results establish that the NPRA is one of the most important areas for aquatic birds in the Arctic. Our results and those of others also indicate that oil production, as practiced in Prudhoe Bay, does not necessarily lead to substantial declines in bird density or productivity in or near the developed areas.

Bentzen, R., S. Dinsmore, J. Liebezeit, M. Robards, B. Streever, and S. Zack. 2017. Assessing development impacts on Arctic nesting birds using real and artificial nests. Polar Biology 40(8):1527-1536. https://link.springer.com/article/10.1007%2Fs00300-017-2074-7

Abstract - Arctic Alaska is an important breeding ground for many migratory bird populations. A variety of factors associated with industrial development may impact nesting birds in this region, including increased nest predator populations associated with anthropogenic nesting and perching sites and the availability of anthropogenic food sources. We tested the indirect impact of oil development on nest survivorship in an artificial nest experiment at Prudhoe Bay, Alaska, 2012–2014, by establishing and monitoring 268 artificial shorebird nests and 221 artificial waterfowl nests and through monitoring of real shorebird nests (n = 186). Distance to infrastructure and roads, and area of infrastructure within 2 km^2 of the nest did not significantly affect nest survival of artificial or real nests. Artificial nest survival was higher at shorebird than waterfowl nests. Cameras deployed at a subset of artificial shorebird nests documented nest predation by Arctic fox (*Alopex lagopus*), red fox (*Vulpes vulpes*), Parasitic Jaegers (*Stercorarius parasiticus*), Pomarine Jaegers (*Stercorarius pomarinus*), Long-tailed Jaegers (*Stercorarius longicaudus*), Northern Harriers (*Circus cyaneus*), and Glaucous Gulls (*Larus hyperboreus*). The presence of a camera had a positive effect on artificial shorebird nest survival, possibly due to cameras being placed on progressively older nests throughout the season. In conclusion, we did not detect an effect from infrastructure on nest survival at the scale of the study, in either real or artificial nests. We suggest caution when using artificial nests for Arctic research, given differences in survival of real and artificial nests in this study, and potential differences in nest predators.

Cross-reference = human-subsidized predators.

Boarman, W.I. 2003. Managing a subsidized predator population: reducing Common Raven predation on desert tortoises. Environmental Management 32(2):205-217. http://www.werc.usgs.gov/sandiego/pdfs/boarman%202003%20env%20mngmt.pdf

Abstract - Human communities often are an inadvertent source of food, water, and other resources to native species of wildlife. Because these resources are more stable and predictable than those in a natural environment, animals that subsist on them are able to increase in numbers and expand their range, much to the detriment of their competitors and species they prey upon. In the Mojave Desert, common ravens (*Corvus corax*) have benefited from human-provided resources to increase in population size precipitously in recent years. This trend has caused concern because ravens prey on juvenile desert tortoises (*Gopherus agassizii*), a federally threatened species. In this paper, I discuss management strategies to reduce raven predation on desert tortoises. The recommendations fall into three categories: (1) managing raven populations by reducing access to anthropogenic resources; (2) removing offending ravens or other birds in specially targeted tortoise management zones; and (3) continuing research on raven ecology, raven behavior, and methods of reducing raven predation on tortoises. I also recommend approaching the problem within an adaptive management framework: management efforts should first be employed as scientific experiments - with replicates and controls - to yield an unbiased assessment of their effectiveness. Furthermore, these strategies should be implemented in concert with actions that reduce other causes of desert tortoise mortality to aid the long-term recovery of their populations. Overall, the approaches outlined in this paper are widely applicable to the management of subsidized predators, particularly where they present a threat to a declining species of prey.

Cross-reference = human-subsidized predators.

DeGraaf, R.M., N.G. Tilghman, and S.H. Anderson. 1985. Foraging guilds of North American birds. Environmental Management 9(6):493-536. https://link.springer.com/article/10.1007/BF01867324

Abstract - We propose a foraging guild classification for North American inland, coastal, and pelagic birds. This classification uses a 3-part identification for each guild: major food, feeding substrate, and foraging technique, to classify 672 species of birds in both the breeding and nonbreeding seasons. We have attempted to group species that use similar resources in similar ways. Researchers have identified foraging guilds generally by examining species distributions along one or more defined environmental axes. Such studies frequently result in species with several guild designations. While the continuance of

these studies is important, to accurately describe species' functional roles, managers need methods to consider many species simultaneously when trying to determine the impacts of habitat alteration. Thus, we present an avian foraging classification as a starting point for further discussion to aid those faced with the task of describing community effects of habitat change.

Derksen, D.V., T.C. Rothe, and W.D. Eldridge. 1981. Use of wetland habitats by birds in the National Petroleum Reserve – Alaska. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service Resource Publication 141.

Abstract - Distribution, abundance, and use of wetland habitats by migratory birds were studied at two interior and three outer Arctic coastal plain sites in the National Petroleum Reserve in Alaska (NPRA) in 1977 and 1978. Comparative data were collected in the same years from a Beaufort Sea coastal site near Prudhoe Bay.

Species composition of breeding birds varied between sites, especially between coastal areas and sites near foothills of the Brooks Range. Seasonal fluctuation in population densities were common with numbers greatest in June during breeding and August during migration. Population densities also differed between sites, perhaps due to variation in wetland composition and ratios of water cover to upland tundra.

Use of wetlands by loons, waterfowl, and shorebirds was quantified to assess relative values of seven classes of freshwater habitats. Wetlands with emergent *Arctophila fulva* were used most by these water birds. Breeding birds were especially dependent upon wetlands with emergent hydrophytes, although they used various types of wetlands during different activities and life stages. Most broods were found in wetlands with *A. fulva,* which afforded protective cover and substrate for aquatic invertebrates used as food by water birds. Wetlands and lakes without emergents were generally less attractive to breeding birds, but were especially important to molting geese.

Based on water bird distribution and densities and their dependence on Arctic Coastal Plain wetlands in NPRA, petroleum exploration and production activities onshore and in the Beaufort and Chukchi seas may have significant adverse effects if not closely regulated and prohibited in some areas.

Gabrielson, I. N., and F.C. Lincoln. 1959. The birds of Alaska. Harrisburg, PA, Stackpole; and Washington, D.C.; Wildlife Management Institute.

Johnson, S.R., and D.R. Herter. 1989. The birds of the Beaufort Sea. Anchorage, AK: BP Exploration (Alaska), Environmental and Regulatory Affairs.

Kirchhoff, M.D., and V. Padula. 2010. Audubon Alaska watchlist 2010 technical report. Anchorage, AK: Alaska Audubon Society.

Liebezeit, J.R., S.J. Kendall, S. Brown, C.B. Johnson, P. Martin, T.L. McDonald, D.C. Payer, C.L. Rea, B. Streever, A.M. Wildman, and S. Zack. 2009. Influence of human development and predators on nest survival of tundra birds, Arctic coastal plain, Alaska. Ecological Applications 19(6):1648-1644. http://onlinelibrary.wiley.com/doi/10.1890/08-1661.1/pdf

Executive Summary - Climate change is occurring at an accelerated rate in the Arctic compared to most other places on the earth. Temperature and moisture changes are leading to warming permafrost, increased coastal erosion, more frequent fires, and shrub

invasion, altering geomorphology, hydrology, and habitat structure. These rapid changes in habitats, especially those associated with hydrology, are ultimately influencing wildlife populations. Arctic Alaska harbors some of the most important breeding and staging grounds for millions of birds representing over 90 species. Many of these species are migratory, wintering at disparate sites across the planet, and some are already experiencing population declines and/or are species of conservation concern. As climate change has become a focal issue for agencies and other institutions in recent years, one of the recognized needs is the application of science-driven assessments to reconsider landscape management, wildlife research, and conservation priorities in this context. To help address these emerging needs the Wildlife Conservation Society conducted a climate change vulnerability assessment for arctic breeding birds to help guide climate-informed wildlife management in the region. The specific goals of this assessment were to: 1) provide a climate change vulnerability ranking for 54 Arctic Alaskan breeding bird species; 2) evaluate the relative contribution of specific sensitivity and exposure factors to individual species rankings; 3) consider how this assessment may be integrated with other approaches; and 4) appraise the effectiveness of the NatureServe Climate Change Vulnerability Index (CCVI) tool.

The CCVI tool was developed by NatureServe specifically to compare the added vulnerability posed by climate change to species in a region. We assessed vulnerability with reference to changes projected for 2050 and restricted in geographic scope to the Alaska portion of the Arctic LCC region. The CCVI is a spreadsheet based algorithm that integrates information on species sensitivity, direct exposure to projected atmospheric changes in climate, and indirect exposure factors. Direct exposure factors, temperature and moisture balance change, were incorporated as geospatial inputs. We ran the tool with data from five global circulation models, two emissions scenarios, and at two spatial resolutions. Indirect exposure factors included sea-level rise, dispersal relative to barriers, and human mitigation in response to climate change. Sensitivity factors (life history traits making a species more or less vulnerable) were scored by species experts on survey forms based on published literature and their personal knowledge.

The CCVI results ranked two species as highly vulnerable (Gyrfalcon, Common Eider), seven as moderately vulnerable (Brant, Steller's Eider, Pomarine Jaeger, Yellow-billed Loon, Buff-breasted Sandpiper, Red Phalarope, Ruddy Turnstone), and five as likely to increase (Savannah Sparrow, Lapland Longspur, White-crowned Sparrow, American Tree Sparrow, Common Redpoll). The assessment outcome suggests that the most important contributions to the climate change vulnerability for the 54 bird species include: 1) being specialists in at least one life history trait and/or having a strong coastal orientation; 2) the quality and nature of interactions with other species; 3) restrictions associated with physical habitat and diet; 4) dependence on other species to meet habitat needs; and 5) changes in disturbance regimes that would negatively affect the specie. Physiological hydrological niche (i.e., dependence on wetland habitats in the arctic) was thought to have the greatest potential to influence vulnerability; although its effect on outcomes was diminished by the way the tool applies exposure weights to sensitivity factors. Currently available projections for Arctic Alaska suggest negligible change in moisture balance driven by atmospheric demand.

There was insufficient information to address questions, both for particular sensitivity factors and for certain species or taxon groups. These and other information gaps highlight the need for more research or synthesis of existing data to fill this void. Key needs identified to better understand the climate change vulnerability of birds in Arctic Alaska include: 1) the

effects of temperature increases on surface hydrology, wetland availability, and vegetation change; 2) information on nearly all aspects of phenology and its relationship with and response to changing environmental conditions; 3) greater knowledge of the genetic diversity of species, its relationship to climatic gradients, and its role in climate change response.

Climate change vulnerability indices are one of several approaches to understanding the effects of climate change on species, each with its own limitations. While the CCVI tool does not examine statistical or mechanistic relationships between sensitivity and exposure factors and does not integrate climate stressors affecting migratory birds outside of their breeding grounds, this assessment represents a starting point to help prioritize management, conservation, and research efforts with respect to breeding birds in the Alaskan Arctic.

Cross-reference = human-subsidized predators.

Liebezeit, J.R., K.E.B. Gurney, M. Budde, S. Zack, and D. Ward. 2014. Phenological advancement in arctic bird species: relative importance of snow melt and ecological factors. Polar Biology 37(9):1309-1320. https://doi.org/10.1007/s00300-014-1522-x

Abstract - Previous studies have documented advancement in clutch initiation dates (CIDs) in response to climate change, most notably for temperate-breeding passerines. Despite accelerated climate change in the Arctic, few studies have examined nest phenology shifts in arctic breeding species. We investigated whether CIDs have advanced for the most abundant breeding shorebird and passerine species at a long-term monitoring site in arctic Alaska. We pooled data from three additional nearby sites to determine the explanatory power of snow melt and ecological variables (predator abundance, green-up) on changes in breeding phenology. As predicted, all species (semipalmated sandpiper, *Calidris pusilla*, pectoral sandpiper, *Calidris melanotos*, red-necked phalarope, *Phalaropus lobatus*, red phalarope, *Phalaropus fulicarius*, Lapland longspur, *Calcarius lapponicus*) exhibited advanced CIDs ranging from 0.40 to 0.80 days/year over 9 years. Timing of snow melt was the most important variable in explaining clutch initiation advancement (“climate/snow hypothesis”) for four of the five species, while green-up was a much less important explanatory factor. We found no evidence that high predator abundances led to earlier laying dates (“predator/re-nest hypothesis”). Our results support previous arctic studies in that climate change in the cryosphere will have a strong impact on nesting phenology although factors explaining changes in nest phenology are not necessarily uniform across the entire Arctic. Our results suggest some arctic-breeding shorebird and passerine species are altering their breeding phenology to initiate nesting earlier enabling them to, at least temporarily, avoid the negative consequences of a trophic mismatch.

Liebezeit, J., E. Rowland, M. Cross, and S. Zack. 2012. Assessing climate change vulnerability of breeding birds in Arctic Alaska: a report prepared for the Arctic Landscape Conservation Cooperative. Bozeman, MT; University of Montana, Wildlife Conservation Society, North America Program. https://s3.amazonaws.com/WCSResources/file_20130114_152335_Vulnerability_Assessment_report_WCS_final_LCmwM.pdf?AWSAccessKeyId=AKIAJ6EG375ZDL3DG3EA&Expires=1416602302&response-content-disposition=attachment%3B%20filename%3D%22Vulnerability_Assessment_report_WCS_final.pdf%22&response-content-type=application/pdf&Signature=TJYysEIBIxfB9kN6uEvrZ0jqPQA%3D

Martin, P.D., J.G. Kidd and D.C. Anthon. 1990. Migratory bird use of potential port sites on the Beaufort Sea coast of the Arctic NWR. Pp. 1-18 in T.R. McCabe (ed.), Terrestrial research: 1002 area - Arctic National Wildlife Refuge annual progress report 1988. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Arctic National Wildlife Refuge.

[see Willms and Crowley (1992)].

McNicholl, M.K. 1975. Larid tenacity and group adherence in relation to habitat. Auk 92(1):98-104. http://www.jstor.org/stable/4084420

Summary - Nest site tenacity appears to be strongly developed in larids in highly stable habitats. In highly unstable habitats, site tenacity is necessarily greatly reduced, and group adherence assists rapid pioneering of newly suitable habitat. In fluctuating marshes and prairie lakes, group adherence and reduced site tenacity allow rapid colonization of newly suitable habitat, while the maintenance of at least a weak form of site tenacity allows rapid recolonization of previously used sites.

Cross-reference = human-subsidized predators.

Moitoret, C., T.R. Walker, and P.D. Martin. 1996. Predevelopment surveys of nesting birds at two sites in the Kuparuk oilfield, Alaska, 1988-1992. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Northern Alaska Ecological Services Technical Report NAES-TR-96-02.

Newton, I. 2008. Migration ecology of birds. San Diego, CA; Academic Press.

Noel, L.E., S.R. Johnson, and W.J. Gazey. 2006. Oilfield development and Glaucous Gull (*Larus hyperboreus*) distribution and abundance in central Alaskan Beaufort Sea lagoons, 1970-2001. Arctic 59(1)65-78. http://pubs.aina.ucalgary.ca/arctic/Arctic59-1-65.pdf

Abstract - We evaluated aerial survey data for glaucous gulls (*Larus hyperboreus*) in central Alaskan Beaufort Sea lagoons near the Prudhoe Bay oilfields during June to September 1978-2001 for trends in numbers of glaucous gulls, associations with human activity, and confounding relationships with environmental variables. Most glaucous gulls were in barrier island and mainland shoreline habitats, and the total number of gulls per survey ranged from 50 to 1600. Seasonal variation in abundance was apparent, with the largest numbers of gulls consistently recorded during September surveys. Ice cover and wave height had a significant negative correlation with the linear density of glaucous gulls (gulls/km). There was no clear trend in abundance of gulls in the lagoons at Prudhoe Bay or obvious interaction with human activity (such as air traffic, boat traffic, or humans on land or water) in the survey area during the period of oilfield development (1978-2001). We compiled glaucous gull nest counts from 1970-2001 across barrier islands to evaluate trends in the number of nests and associations with other colonial nesting species. The mean number of active glaucous gull nests increased from 1970-74 (77.6 nests/yr) to 1975-1985 (154.4 nests/yr), but there was no evidence of a difference from 1970-1974 to 1987-2001 (153.0 nests/yr). However, the change in 1976 from aerial to ground-based nest surveys confounds comparison of the survey periods before this date (1970-1974) with those after it (1975-1985 and 1987-2001). A strong positive relationship between the number of glaucous gull nests and both common eider and snow goose nests suggests that common environmental variables may be regulating nesting for these species.

Cross-reference = human-subsidized predators.

Pitelka, F.A. 1974. An avifaunal review for the Barrow Region and North Slope of Arctic Alaska. Arctic and Alpine Research 6(2):161-184.

Abstract – The avifauna of the North Slope of Arctic Alaska, with particular reference to the Barrow Region, is reviewed on the basis of records published since Bailey (1948) and field experience in northern Alaska, mainly near Barrow, over a 23-year period (1951 to 1973). New records for the region and other parts of the North Slope are reported. Five species are added to the known avifauna of mainland North America. The species list for the Barrow Region now totals 151 (increase in 28 since 1948); that for the North Slope as a whole now totals 185 (increase of 48 since 1948). A systematic list is provided for the North Slope summarizing distributional status as known to date. The main features of species composition and seasonality of the Barrow Region avifauna are summarized and discussed. Distributional zonation of birds on the North Slope is examined briefly with regard to physiographic and biological criteria for the delineation of zones, and several problems revealed by bird data are discussed.

Rodrigues, R. 1994. Microhabitat variables influencing nest-site selection by tundra birds. Ecological Applications 4(1):110-116. http://www.jstor.org/stable/pdf/1942120.pdf?refreqid=excelsior%3A859566c12b4b48747524a5605efaa4cd

Abstract - Studies were performed to determine what types of microhabitat characteristics attract the most common bird species to nest at particular sites on tundra habitats in the Prudhoe Bay oil field. Microhabitat variables of 2 x 2 m plots centered on bird nests were measured and compared with those of plots centered on random points. Results indicated differences in amount of microrelief, graminoid and shrub/forb cover, roughness of topography, and presence of water among species. These differences have implications for management of abandoned gravel sites as oil production declines in the Prudhoe Bay oil field. The amount and variability of microrelief plays an important role in influencing nest-site selection. Birds do not require total coverage by graminoid and shrub/forb plant species at nest sites. Water plays an important role by influencing plant growth at disturbed gravel sites. Studies were performed to determine what types of microhabitat characteristics attract the most common bird species to nest at particular sites on tundra habitats in the Prudhoe Bay oil field. Microhabitat variables of 2 x 2 m plots centered on bird nests were measured and compared with those of plots centered on random points. Results indicated differences in amount of microrelief, graminoid and shrub/forb cover, roughness of topography, and presence of water among species. These differences have implications for management of abandoned gravel sites as oil production declines in the Prudhoe Bay oil field. The amount and variability of microrelief plays an important role in influencing nest-site selection. Birds do not require total coverage by graminoid and shrub/forb plant species at nest sites. Water plays an important role by influencing plant growth at disturbed gravel sites.

Schroeder, R.L. 1982. Habitat suitability index models: Yellow Warbler. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Office of Biological Services FWS/OBS-82/10.27. https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-027.pdf

Editor's Note – HSI developed for application within the entire breeding distribution of the Yellow Warbler. Due to the lack of vertical habitat structure, use caution for Arctic coastal plain applications with caveat that model components may prove useful for developing site-specific models. Model habitat requirements include (1) cover (optimal nesting habitats with emphasis on deciduous shrubland and/or deciduous scrub/shrub wetland) with adequate arthropod prey base; and (2) minimum habitat area (mean ca 0.15 ha, 0.37 ac).

Szaro, R.C. 1986. Guild management: an evaluation of avian guilds as a predictive tool. Environmental Management 10(5):681-688. https://link.springer.com/content/pdf/10.1007%2FBF01866772.pdf

Abstract - The use and applicability of the guild concept to management is evaluated and questioned. Ecological problems are never as simple as implied in using one or two guild axes. A close examination of bird communities in a ponderosa pine forest reveals little relationship between guilds or guild blocks and the responses exhibited by individual bird species or bird species groups. Response guilds changed from year to year without any obvious changes in vegetation. A three-year composite analysis shows a clearer picture of the responses of ponderosa pine forest birds to the overall interactions between structure, weather, competition, and so on. The six response groups in the composite analysis are species that (1) were absent in 1973 on most or all study plots and showed no preference for any forested site; (2) had their highest densities on the medium cut and light cut plots; (3) were absent in 1973 on most or all study plots and had their highest densities on the medium cut and light cut plots; (4) had their highest densities on the untreated, light cut, and medium cut plots; (5) had their highest densities on the untreated and light cut plots and were either absent or had greatly reduced densities on all other plots; and (6) were present only on the clearcut, except for the Rock Wren which was also on the medium cut and heavy cut plots. The overall correlation between species density and guild density was significantly higher for response guilds ($\alpha < 0.05$) than for any of the structural or functional guilds. The whole concept of guild management needs much more research and development before it can be recommended as a management tool.

Troy, D.M., and T.A. Carpenter. 1990. The fate of birds displaced by the Prudhoe Bay oil field: the distribution of nesting birds before and after P-pad construction. Anchorage, AK: Troy Ecological Research Associates for BP Exploration (Alaska) Inc.

Abstract – The inability to directly link habitat modification with effects on organisms frequently hampers assessment of environmental impacts. At Prudhoe Bay it is possible to document the spatial extent of tundra covered by gravel, and to estimate the amount of tundra altered by drainage modification, dusting, and other factors. It is also possible to describe local changes in abundance or distribution of the birds, mammals, and fish. While we have become better at describing the changed local abundance of species, the link between habitat modification and abundance at the population level has been elusive.

Tundra birds provide an opportunity to assess directly the relationship between habitat change and population level effects. Many species of birds exhibit site- tenacity; the tendency for individuals to return to the previous year's breeding location. Thus, we know with some degree of confidence where individuals of site-tenacious species of tundra birds should occur in successive years. We can take advantage of this trait by marking these birds and tracking them in subsequent years to monitor their response to development-induced habitat changes.

An opportunity to conduct such an experiment occurred during construction of P-Pad, in the southern part of the Prudhoe Bay oil field. In 1988, during the summer prior to construction, we located nest sites of birds breeding in the vicinity of the proposed facilities and marked the birds with colored leg bands. Based on previous studies on Alaska's North Slope and from the literature, Semipalmated Sandpiper, Dunlin, and Lapland Longspur were expected

to be site-tenacious; whereas, Pectoral Sandpipers and Buff-breasted Sandpipers were not. If habitat availability restricted their abundance, the individuals most affected (i.e., displaced) by the development would not be expected to nest following pad and road construction. If habitat availability was not limiting, these birds would be expected to resettle in adjacent, unaffected areas. The first breeding season following construction of the road and pad (1989), we returned to determine the nesting distribution of birds, and attempted to relocate the birds marked the preceding year.

Key findings were as follows:

- Some marked birds displaced by habitat alteration returned and nested in adjacent areas. These included Semipalmated Sandpiper, Dunlin, and Lapland Longspur.
- Nest success of displaced individuals was not reduced indicating that the new nest sites were in suitable habitats.
- The number of nests in the study area decreased from 1988 to 1989. Most of this was attributable to decreases in Pectoral Sandpiper and Lapland Longspur density. These decreases also occurred away from the oil field (in the Pt. McIntyre Reference Area); therefore they were unrelated to the presence of P-Pad.
- Several shorebirds, including Semipalmated Sandpiper and Dunlin, experienced natural increases in density. Thus, in addition to absorbing the displaced birds, there was sufficient habitat for density increases resulting from recruitment by these species.
- Four species not found nesting in 1988, nested on the study plot in 1989. Two of these species, Baird's Sandpiper and Snow Bunting, nested in altered habitats, and their colonization was probably attributable to the presence of the pad and road.
- Nesting attempts declined in areas adjacent to the road and pad. Nest densities of Semipalmated Sandpipers and Dunlin declined in this zone. Lapland Longspurs and especially Pectoral Sandpipers may also be avoiding this area, but their area-wide decrease in density complicated detection of this effect. Some avoidance of facilities had been previously documented for all of these species except Pectoral Sandpipers.
- As reported in past studies, the distribution of birds adjacent to the facilities differed from that predicted in the absence of gravel placement. Some species increased in density while some decreased. This study has documented that displaced individuals are not necessarily lost from the breeding population, but rather, that many resettle in suitable areas nearby.

Troy, D.M., and J.K. Wickliffe. 1990. Trends in bird use of the Pt. McIntyre Reference Area 1981-1989. Anchorage, AK: Troy Ecological Research Associates for BP Exploration (Alaska).

<u>Executive Summary</u> – Trends in bird use of a study area near Pt. MacIntyre, adjacent to Prudhoe Bay oil field but relatively isolated from oil field facilities, were studied during 7 summers between 1981 and 1989. The sampling has resulted in a time series of data showing natural variations in population trends of birds of the central Beaufort Sea coastal tundra. Results from this area serve as a reference for impact analysis studies conducted within the oil fields.

Attributes of interest for describing bird use were nest densities, timing of nest initiation, nest success, breeding season bird densities, and post-breeding season bird densities. Preliminary analyses of the effects of local environmental factors (snow cover, temperatures, wind speed) on birds were also conducted. Important density trends during 1988 and 1989 are identified and their relevance for interpreting results of impact analysis studies which occurred during these years are summarized.

Trends 1981-1989

Major interannual changes occurred in nest and bird density, and nest initiation dates and success. Indications are that:

- There are frequently large changes in density among years for the most numerous species.
- Changes in nest density and bird density are often unrelated, indicating that both measures are required to assess intra- and interannual variability in bird use of tundra areas.
- Trends in post-breeding season bird density are frequently unrelated to breeding season density, thus confirming that the coastal plain is used by birds other than local breeders.

Influence of Environmental Stress

Annual differences in wind conditions and snow cover appeared to influence some aspects of bird-nesting and density. Preliminary analyses revealed potentially important correlations between wind speed and nest success with the presence of nonbreeding birds, as well as between snow cover and the timing of nest initiation. Despite suspicions to the contrary, wind did not influence census results.

Bird Use 1988-1989

During 1988 and 1989, sampling of the Pt. MacIntyre Reference Area was conducted as part of the Bird Use of Disturbed Habitats (Peat Road) study to aid in the interpretation of results of that study and the Bird Displacement (P-Pad) study. Describing the status of birds relative to other years was one of the specific objectives of this report.

Notable changes in nesting densities occurred during the two years of interest. Pectoral Sandpiper nest density varied significantly among years; the high density in 1988 was a major component of this variability. Red-necked Phalarope and Lapland Longspur were also at their highest densities in 1988, although not statistically so. Overall, 1988 was a year of high use of the Pt. MacIntyre plots, primarily because of the high density of Pectoral Sandpipers and Lapland Longspurs. Use was markedly different in 1989. Longspur nest densities were significantly lower than other years, equaling 1987 as the lowest recorded for this area. Also low density, although not statistically verifiable, was Greater White-fronted Goose nesting; 1989 was the only year no nests were found on plots. During 1989, Semipalmated Sandpipers reached their highest density recorded in 7 years of study. Despite these increases, the marked relative decrease in Pectoral Sandpipers (from a high in 1988) and Lapland Longspur (to a low in 1989) resulted in 1989 being among the years of lowest nesting use of the Pt. MacIntyre plots.

Neither 1988 or 1989 were identified as being particularly early or late years for nest initiation. Nest success in 1988 was among the highest of the study years. The two most numerous site-tenacious shorebirds – Semipalmated Sandpiper and Dunlin – had their highest success this year. In contrast, 1989 nest successes were markedly lower. The two shorebirds that peaked in 1988 as well as Lapland Longspur, all experienced reductions in success to approximately half their 1988 values.

The year 1988 was not identified in the statistical tests as being particularly high or low for any of the species exhibiting among-year differences in bird densities. In contrast, 1989 was a year of marked change in density for several species. Four species had significant among-year differences in density because of changes in 1989. Buff-breasted Sandpiper and Lapland Longspur reached their lowest densities in 1989, while Pacific Loon and Red Phalarope densities were high. The most important change was in Lapland Longspur, as this is always the most numerous species on plots. The greater the 50% decrease in density from 1988 to 1989 resulted in a substantial reduction in bird use of the plots.

Verner, J. 1984. The guild concept applied to the management of bird populations. Environmental Management 8:1-14. http://link.springer.com/article/10.1007%2FBF01867868

Abstract - Alternative ways to apply the guild concept to wildlife management are evaluated here. I reject the idea that indicator species can be selected for each bird guild to reduce costs of environmental assessment and monitoring. Promise is seen, however, in the option of using whole guilds to indicate the capability of habitat zones to support populations of wildlife species. It may be adequate for most management purposes to delineate guilds only for species that use an environment for breeding, because transients and winter residents probably use the same zones of the habitat in the same ways. Potential guilds are identified by cells of a two-dimensional matrix, the axes identifying primary feeding and nesting zones. Some questions may be answered with guilds as delineated by all cells in the matrix. Alternatively, larger guilds can be formed by grouping all species in each column or row of the matrix to identify, for example, all species that depend on tree canopies for foraging, or tree boles for nesting. One can also consider separately the resident breeders, migrant breeders, and winter residents to obtain insights into whether observed changes in numbers of birds in a guild are a result of conditions locally or elsewhere. I conclude that the guild concept probably has a place in wildlife management, but much testing must be done before it is widely applied

Willms, M.A., and D.W. Crowley. 1992. Migratory bird use of potential port sites on the Beaufort Sea coast of the Arctic National Wildlife Refuge. Appendice A (pp. 379-407) in T.R. McCabe, D.B. Griffith, N.E. Walsh, and D.D. Young (eds.), Terrestrial research: 1002 area – Arctic National Wildlife Refuge, interim report 1988-1990. Fairbanks, AK: Alaska Fish and Wildlife Research Center and Arctic National Wildlife Refuge.

Introduction. The Secretary of the Interior recommended that Congress authorize leasing of the Arctic NWR (Refuge) coastal plain, known as the 1002 area, for oil development (here after *Coastal Plains Report*, Clough et al. 1987). If such authorization was made, and oil is subsequently found in economical quantities, there will arise a need by industry for port facilities on the Beaufort Sea. Camden Bay (Camden) and Pokok Bluffs (Pokok) were identified as potential port sites in the *Coastal Plains Report* (Clough et al. 1987). These two areas are unique to the coastal shoreline of the Refuge in that they lack a barrier islands/lagoon system. Because they possess relatively deep waters close to shore, the need for dredging would be reduced or eliminated.

Construction and operation of any port facility will impact birds [polar bear?] using the surrounding area (Barry and Spencer 1976; Barret 1979; Sopuck et al. 1979). Potential exploration for oil may impact migratory birds directly or through disturbance and pollution, or indirectly through habitat modifications or food chain perturbations. Migratory bird use along the Refuge coastal plain is generally understood from baseline studies (Garner and Reynolds 1986). However, in order to provide accurate predictions of potential port-site effects and to determine mitigation needs, more specific site information was required. We report on investigations of pre-construction use of littoral and nearshore marine habitats by birds and their prey along both Camden and Pokok. In addition, since previous studies have identified the barrier island/lagoon system as being extremely important for Long-tailed Ducks (*Clangula hyemalis*), eiders (*Somateria* spp.), loons (*Gavia* spp.), shorebirds, and several other bird species (Divoky 1978; Martin and Moitoret 1981; Johhson and Richardson 1981), we compared this habitat to the open sea coast.

Specific objectives of this study were to determine: (1) the current migratory bird use of both nearshore coastal waters and adjacent shoreline habitats a the two potential port sites; (2) the occurrence and relative abundance of aquatic and littoral invertebrate species used as food by key species of migratory birds; and, (3) pre-construction levels of industrial pollutants both in migratory birds as well as the surrounding marine and littoral substrates. However, due to delays in processing the invertebrate samples and in interpreting the pollutants data, results from these last two objectives are scheduled for completion in fall of 1991.

Management Implications. Several factors need to be considered when evaluating the susceptibility of migratory birds to potential oil development impacts. These include the species on-site residence time and abundance, regional migration corridors, dependence on coastal habitats for completion of annual life cycle, reaction to human activity, and the vulnerability of their preferred habitat to changes resulting from oil development activities.

Species with long residence times will receive more exposure to development activities than those which remain for only short periods of time. Species which migrate along the coast may be more impacted than those which also migrate out to sea or further inland. Species which are sensitive to the presence of humans or human activities will be more impacted than those with greater tolerance and adaptability. If a large proportion of a species

population annually use coastal habitats for completing critical biological events such as molting, pre-migratory fat accumulation, or nesting, they will more likely be impacted than those with less dependence on such areas. A species whose preferred habitats is highly sensitive to oil spills will be more impacted than those species using less sensitive habitats. Water-borne oil damage will have short-term impact on gravel beaches, but greater long-term effects on littoral wetlands (Connors et al. 1984). Because of the limited distribution of wetland habitat, losses due to development activities will be of greater significance than those on more abundant tundra habitats. Also, species which use highly specific habitats will be more likely to be impacted by their loss than those with more general habitat use patterns.

Based on the criteria above, species which appear most sensitive to development activities include: Long-tailed Duck, Brant, Common Eider, loons, shorebirds, and tundra swans. Species for which development activities will likely have the least impact include: Lapland Longspur, Snow Bunting, and ptarmigan (*Lagopus* spp.). Most other species, including White-Fronted Geese, Red-necked Phalaropes, Arctic Terns, Glaucous Gull, and Northern Pintails, will be somewhat intermediate in this respect.

When selecting a port site location, both wetland and lagoon barrier/island spit habitat should be avoided. These habitats received high use by almost every sensitive species listed above. This statement probably holds true not only for the Camden and Pokok area, but also the entire 1002 area. The east-central portion of Camden Bay and the northern portion of Pokok Bluff both consist of long sections of shoreline without intervening wetland habitat. Selection of these areas for the port site facility will likely have the least impact on the local avian community. Since the nearshore waters of Camden does not appear to be a major migration route for Brant, loons or Common Eiders, selection of this location may reduce potential impacts on these sensitive migratory species. Although high use of offshore waters (>200 m) in the northeast part of Camden by Long-tailed Duck has been documented on aerial surveys (Martin et al. 1989 – updated Kendall 2005; Dau and Larned 2008; Dau and Bollinger 2009), we observed only small portion of this flock in the final report.

Other more specific mitigation information may be needed once the exact site location has been selected by industry. It may be possible that further recommendations can be made regarding the construction and planning of this facility which will not only satisfy the needs of industry, but also wildlife.

Salient Literature.

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Connors, P.G., C.S. Connors, and K.G. Smith. 1984. Shorebird littoral zone ecology of the Alaskan Beaufort coast. Pp. 297-396 in Environmental assessment of the Alaska Continental Shelf. U.S. Department of Commerce, National Ocean and Atmospheric Agency NOAA/OCSEAP Final Report 23.

Dau, C.P., and W.W. Larned. 2008. Aerial population survey of Common Eiders and other waterbirds in nearshore waters and along barrier islands of the Arctic coastal plain of Alaska, 24-26 June 2008. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Migratory Bird Management unpublished report. https://www.fws.gov/alaska/mbsp/mbm/waterfowl/surveys/pdf/coei08rpt.pdf

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Garner, G.W., and P.E. Reynolds (eds.). 1986. Birds. Pp. 68-209 in Arctic National Wildlife Refuge coastal plain resource assessment: final report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Johhson and Richardson 1981

Kendall, S. 2005. Surveys of breeding birds on barrier islands in the Arctic National Wildlife Refuge, 2003-2004. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Arctic National Wildlife Refuge. https://catalog.data.gov/dataset/surveys-of-breeding-birds-on-barrier-islands-in-the-arctic-national-wildlife-refuge

Martin, P.D., and C.S. Moitoret 1981. Bird populations and habitat use, Canning River delta, Alaska. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service unpublished report.

Martin, P.D., J.G. Kidd, and D.C. Anthon. 1989. Migratory bird use of potential port sites on the Beaufort Sea coast of Arctic National Wildlife Refuge.

Sopuck, L.G., C.E. Tull, J.E. Green, and R.W. Salter. 1979. Impacts of development on wildlife – a view from the perspective of the Cold Lake Project: Edmonton, Alberta. Calgary, Alberta: prepared by Esso Resources Canada Limited for LGL Limited.

[see Martin et al. (1990)]

Willson, M.F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029. http://www.jstor.org/stable/1940352

Abstract - Bird species diversity was linearly correlated with foliage height diversity and curvilinearly with total percent vegetation cover. The addition of trees in a vegetational series has a disproportionate effect on the addition of species, primarily by the addition rather than the expansion of guilds. No basic relationship of species-packing within guilds is associated with bill or body size except frequently within two-member guilds. Estimated abundance and biomass of birds does not appear to be related to productivity of the habitats, in contrast to reports form the literature. Similarity of bird species composition is not related to similarity of foilage distribution, when like study areas are compared. Avifaunas of grasslands generally differed more among themselves than did those of forests. Bird species overlaps were correlated with foilage height overlaps only for part of the variational range for two- and three-layered habitats, and little if at all for grasslands. Width of @'habitat-niche@' is not related to numerical dominance, taxonomic or ecological categories. Because many of these results do not coincide with previous attempts at ecological generalization, great care in such attempts seems strongly indicated. Studies should be made of meticulously delineated subcommunities, resource measurement, and reproductive success, as well as events in the nonbreeding season.Bird species diversity was linearly correlated with foliage height diversity and curvilinearly with total percent vegetation cover. The addition of trees in a vegetational series has a disproportionate effect on the addition of species, primarily by the addition rather than the expansion of guilds. No basic relationship of species-packing within guilds is associated with bill or body size except frequently within two-member guilds. Estimated abundance and biomass of birds does not appear to be related to productivity of the habitats, in contrast to reports form the literature. Similarity of bird species composition is not related to similarity of foilage distribution, when like study areas are compared. Avifaunas of grasslands generally differed more among themselves than did those of forests. Bird species overlaps were correlated with foilage height overlaps only for part of the variational range for two- and three-layered habitats, and little if at all for grasslands. Width of “habitat-niche” is not related to numerical dominance, taxonomic or ecological categories.

Because many of these results do not coincide with previous attempts at ecological generalization, great care in such attempts seems strongly indicated. Studies should be made of meticulously delineated subcommunities, resource measurement, and reproductive success, as well as events in the nonbreeding season.

Birds: Raptors

Booms, T. L., T. J. Cade, and N. J. Clum. 2008. Gyrfalcon (*Falco rusticolus*), v.2.0. In Birds of North America, P.G. Rodewald (ed.). Ithaca, NY: Cornell Lab of Ornithology.

Kochert, M. N., K. Steenhof, C.L. McIntyre, and E.H. Craig. 2002. Golden Eagle (*Aquila chrysaetos*), v. 2.0. In Birds of North America, P.G. Rodewald (ed.), Ithaca, NY: Cornell Lab of Ornithology.

Mauer, F.J. 1985. Distribution and relative abundance of golden eagles in relation to the Porcupine Caribou Herd during calving and post-calving periods, 1984. Pp. 114-144 in G.W. Garner and P.E. Reynolds (eds.), Arctic National Wildlife Refuge coastal plain resource assessment: 1984 update report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Abstract – Distribution and abundance of Golden Eagles (*Aquila chrysaetos*) in relation to calving and post-calving activities of the Porcupine caribou (*Rangifer tarandus*) herd were investigated by compiling records of incidental observations made by various field personnel, and conducting aerial surveys. The status of Golden Eagle production at nest sites adjacent to caribou calving and post-calving areas was determined by aerial and ground methods. A total of 323 observations (428 eagles) were recorded between 3 May and 11 August 1984. The ratio of subadults to adults was 8:1 for those observations when age was determined (n=192). Eighty-eight percent of recorded observations were made in areas of current or recent caribou occupation. Golden Eagles were observed either feeding or perched at caribou calf carcasses on 23 (7.2%) occasions and were at adult caribou carcasses on 13 (4.0%) occasions. Necropsy investigations confirmed that predation by Golden Eagles was most probable cause of death in 6 of 25 calf carcasses examined. Concentrations of Golden Eagles in caribou areas occurred during the late calving (13-19 June) and post-calving (20-30 June) periods when 8.1 and 12.4 eagles sightings/24 h occurred. Systematic aerial transect surveys during the calving period did not identify significantly more eagles in areas occupied by caribou than unoccupied areas. Intensive aerial searches over post-calving concentrations of caribou recorded 5.0 eagles/h of flight time. Similar searches over areas of comparable habitat and terrain which were not occupied by caribou, yielded 0.0 eagles/h. Only 1 out of 12 Golden Eagle nest sites adjacent to caribou calving and post-calving areas produced young in 1984. Other Golden Eagle nests remote to the caribou areas were also generally unproductive in 1984.

Peterson, A. 1986. Habitiat suitability index models: Bald Eagle (breeding season). 1986. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Biological Report 82(10.126). https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-126.pdf

Platt, J.N. 1976. Gryfalcon nest site selection and winter activity in the western Canadian Arctic. Canadian Field Naturalist 90:338-345.

Abstract - A population of breeding Falco rusticolus was studied on a 2000 km^2 (772.2 mi^2) area in the central Arctic of the Northwest Territories. Each year 14-18 territories were occupied. Mean internest distance was 10.6 km (6.58 mi), yielding one of the highest recorded densities for the species. There was a tendency for regularity in spacing of territories. Most (85%) nests were abandoned stick nests of Common Raven *Corus corax* or Golden Eagle *Aquila chrysaetos*. Mean data of initiation of laying was 8 May. Mean size of clutch was 3.80 and of brood was 2.53. Mean productivity was 1.50 fledged young. A reduction of 48% from estimated number of eggs laid to number of fledglings was determined. Reproductive success declined with increased severity of spring weather, notably increased days and amount of precipitation.

Ritchie, R.J. 1991. Effects of oil development on providing nesting opportunities for Gyrfalcons and Rough-legged Hawks in northern Alaska. Condor 93(1):180-184. https://sora.unm.edu/sites/default/files/journals/condor/v093n01/p0180-p0184.pdf

Watson, J. 2010. The Golden Eagle. London: T&AD Poyser.

Watson, R.T., T.J. Cade, M. Fuller, G. Hunt, and E. Potapov. 2011. Gyrfalcons and ptarmigan in a changing world. Boise, ID: Peregrine Fund.

White, C.M. 1994. Gyrfalcon (*Falco rusticolus*). Pp. 274- in J. del Hoyo, A. Elliott, and J. Sargatal (eds.), Handbook of the birds of the world – Volume 2 New World vultures to guineafowl. Barcelona, Spain: Lynx Edicions. [updated 2018] https://www.hbw.com/node/53245

Young, D.D., Jr., C.L. McIntyre, P.J. Bente, T.R. McCabe, and R.E. Ambrose. 1995. Nesting by Golden Eagles on the North Slope of the Brooks Range in northeastern Alaska. Journal of Field Ornithology 66(3):373-379.

Abstract - Twenty-two Golden Eagle (*Aquila chrysaetos*) nesting territories and 31 occupied eagle nests were documented on the north slope of the Brooks Range in northeastern Alaska, 1988-1990, in an area previously thought to be marginal breeding habitat for eagles. The mean number of young/successful nest was 1.25 in 1988, 1.27 in 1989, and 1.13 in 1990; means did not differ significantly among years. Eighty percent (20/25) of the nestlings for which age was estimated were assumed to have successfully fledged. Nesting success was 79% (11/14) in 1989, the only year nesting success could be determined. Laying dates ranged from 23 March (1990) to 11 May (1989) with mean estimated laying dates differing significantly among years. Annual variation in nesting phenology coincided with annual differences in snow accumulations during spring. These results indicate that Golden Eagles consistently and successfully breed at the northern extent of their range in Alaska, although, productivity may be lower than that for eagles at more southern latitudes.

Birds: Shorebirds (limited to Charadriiformes)

Alaska Shorebird Group. 2008. Alaska Shorebird Conservation Plan. V.2. Anchorage, AK: Alaska Shorebird Group.
https://www.fws.gov/alaska/mbsp/mbm/shorebirds/pdf/ascp_nov2008.pdf
Executive Summary - Alaska's immense size and northerly position make it a critical region for breeding and migrating shorebirds. In fact, Alaska provides breeding habitat for more shorebird species than any other state in the U.S. Seventy-three species of shorebirds have occurred in Alaska; 37 of them, including several unique Beringian species and Old World subspecies, regularly breed in the region. Most of these species migrate south of the U.S.-Mexico border and one-third migrate to South America or Oceania. Concentrations of shorebirds at several coastal staging and migratory stopover sites exceed one million birds; on the Copper River Delta alone, five to eight million shorebirds stop to forage and rest each spring.

Shorebirds worldwide have suffered dramatic population declines in the last decade. Using the species prioritization process developed for the U.S. National Shorebird Plan, we incorporated new population estimates, updated threats, and identified 20 taxa of shorebirds of high conservation concern in Alaska. All species of concern tend to have small global population sizes or limited breeding distributions. Seasonal occurrence of priority species

was examined within the geographic context of Alaska's five Bird Conservation Regions (BCRs). Most priority species, particularly breeding species, occur in the Western Alaska and Arctic Coastal Plain BCRs. Southern regions of the Northwest Interior Forest and the Northern Pacific Rainforest BCRs are primarily used by shorebirds during migration and winter. The Aleutian/Bering Sea Islands BCR is also an important wintering area for shorebirds.

Around the world, loss of wetland habitat represents the greatest threat to shorebird populations. Nonbreeding and migratory stopover areas outside of Alaska that are important to the state's shorebirds are being altered by humans at an immense scale, primarily through drainage and reclamation of coastal wetlands. Critical shorebird habitats are further threatened worldwide by changes predicted to occur through ancillary effects of global climate change, particularly rising of sea level and drying of continental wetlands. Shorebird habitats in Alaska are still relatively intact, but interior wetlands important for breeding are already showing evidence of drying, and coastal areas are being altered by increasingly intense storms. Shorebird habitats in Alaska face other, more local threats, particularly from energy and mining development in the Cook Inlet, Northern Pacific Rainforest, and Arctic Coastal Plain regions.

The Alaska Shorebird Conservation Plan is one of eleven regional plans associated with the U.S. Shorebird Conservation Plan. This document is the second iteration for Alaska, and contains updated conservation objectives and priorities based on the latest information. Important changes in this version include updated species conservation scores, revised population estimates, updated descriptions of conservation threats in Alaska, and a new framework for building a conservation strategy within a landscape context. This document is formatted in two sections: Part I presents an overview of the conservation plan for Alaskan shorebirds, descriptions of priority species, and threats to shorebirds throughout Alaska; Part II describes a conservation strategy specific for each Bird Conservation Region in Alaska. There are four major components to the conservation strategy adopted in this plan: (i) research, (ii) population monitoring, (iii) habitat management, and (iv) education and outreach. The overall goal of this plan is to keep shorebirds and their habitats well distributed not only across the Alaska landscape, but also throughout regions used by these populations during other phases of their annual cycle. Updates to this plan can be found at http://alaska.fws.gov/mbsp/mbm/shorebirds/plans.htm

Andres, B.A., and R.E. Gill, Jr. 2000. A conservation plan for Alaska shorebirds. Anchorage, AK; U.S. Shorebird Conservation Plan, Alaska Shorebird Working Group.

Abstract - Because of its size and northerly position, Alaska provides breeding habitat for more shorebird species than any other state in the U.S. Of 71 species of shorebirds occurring in Alaska; 37 of them, including several unique Beringian species and Old World subspecies, regularly breed in the region. Most of these species migrate south of the US-Mexico border and a third migrate to South America or Oceania. Concentrations of shorebirds at several coastal staging and migratory stopover sites exceed one million birds; on the Copper River Delta alone, 5-8 million shorebirds stop to forage and rest each spring.

Using the species prioritization process developed for the US National Shorebird Plan (Brown et al. 2001), we identified 14 taxa of shorebirds as species of high concern in Alaska. All species of concern tend to have small global population sizes and/or limited breeding distributions. Seasonal occurrence of priority species was examined within the geographic context of Alaska's 6 Bird Conservation Regions (BCRs). Most priority species, particularly breeding species, occur in the Western Alaska BCR. Southern regions (Cook

Inlet and the Northern Pacific Rainforest BCRs) are primarily used by shorebirds during migration and winter. The Aleutian/Bering Sea Islands BCR is also an important wintering area for shorebirds.

The overall size of Alaska and its BCRs dictate that conservation considerations for shorebirds generally be framed within landscape contexts. Except for the Arctic Plains/Mountains and Cook Inlet, where habitat for breeding shorebirds is being lost, most other shorebird habitats in Alaska remain relatively intact. The main threats to shorebirds in Alaska come from drilling, transport, and refining of oil and natural gas, especially in the Cook Inlet, Northern Pacific Rainforest, and Arctic Plains/Mountains BCRs.

It is unlikely that at any time in the near future habitat will be deliberately manipulated to manage shorebirds in Alaska as it is elsewhere in the US and Canada. Thus, an overall conservation goal for shorebirds in Alaska is to keep species and their habitats well distributed across not only the Alaska landscape, but also regions used by these same populations during other phases of their annual cycles. This will be achieved through a subset of goals and objectives specific to several major components of the Alaska Shorebird Conservation Plan that focus on population and habitat, research, and education/outreach. Specific actions for each component will be formulated during the first year following adoption of the plan. Biological elements of the plan will be based on well-designed, cost-effective, and well-coordinated efforts.

Andres, B.A., J.A. Johnson, S.C. Brown, and R.B. Lanctot. 2012. Shorebirds breed at high densities in the Teshekpuk Lake Special Area, Alaska. Arctic 65(4):411-420. http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/article/view/4239/0

Abstract - On the Arctic Coastal Plain of the National Petroleum Reserve-Alaska (NPR-A), the Teshekpuk Lake Special Area (TLSA) was recognized to protect outstanding wildlife values. Although information has accumulated on the TLSA's value to caribou and waterfowl, its importance to breeding shorebirds remains largely unquantified. Therefore, we undertook a broad-scale ground study to estimate the population size and density of shorebirds breeding in the TLSA. From a series of plot surveys conducted from 2006 to 2008, we estimated a detection-adjusted total breeding population of more than 573 000 shorebirds and an overall density of 126 shorebirds/km2. Most shorebird species had their greatest densities on the Outer Coastal Plain or had approximately equal densities on Outer and Inner Coastal Plains; only two species had their greatest densities on the Inner Coastal Plain. The greatest densities of breeding shorebirds occurred immediately around Teshekpuk Lake. The TLSA supported more than 10% of the biogeographic populations of black-bellied plover (*Pluvialis squatarola*), semipalmated sandpiper (*Calidris pusilla*), and dunlin (*C. alpina*). Breeding shorebird density in the TLSA is one of the highest in the NPR-A, on Alaska's North Slope, and throughout the circumpolar Arctic. Our results, coupled with previous information on waterfowl and caribou, indicate that the area around Teshekpuk Lake and the recognized goose molting area northeast of the lake should be protected from oil and gas development.

Andres, B.A., P.A. Smith, R.I.G. Morrison, C.L. Gratto-Trevor, S.C. Brown, and C.A. Friis. 2013. Population estimates of North American shorebirds, 2012. Wader Study Group Bulletin 119(3):178-194. http://www.shorebirdplan.org/wp-content/uploads/2013/03/ShorePopulationAndresEtAl2012.pdf

Abstract - Because of its size and northerly position, Alaska provides breeding habitat for more shorebird species than any other state in the U.S. Of 71 species of shorebirds occurring in Alaska; 37 of them, including several unique Beringian species and Old World

subspecies, regularly breed in the region. Most of these species migrate south of the US-Mexico border and a third migrate to South America or Oceania. Concentrations of shorebirds at several coastal staging and migratory stopover sites exceed one million birds; on the Copper River Delta alone, 5-8 million shorebirds stop to forage and rest each spring.

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The overall size of Alaska and its BCRs dictate that conservation considerations for shorebirds generally be framed within landscape contexts. Except for the Arctic Plains/Mountains and Cook Inlet, where habitat for breeding shorebirds is being lost, most other shorebird habitats in Alaska remain relatively intact. The main threats to shorebirds in Alaska come from drilling, transport, and refining of oil and natural gas, especially in the Cook Inlet, Northern Pacific Rainforest, and Arctic Plains/Mountains BCRs.

It is unlikely that at any time in the near future habitat will be deliberately manipulated to manage shorebirds in Alaska as it is elsewhere in the US and Canada. Thus, an overall conservation goal for shorebirds in Alaska is to keep species and their habitats well distributed across not only the Alaska landscape, but also regions used by these same populations during other phases of their annual cycles. This will be achieved through a subset of goals and objectives specific to several major components of the Alaska Shorebird Conservation Plan that focus on population and habitat, research, and education/outreach. Specific actions for each component will be formulated during the first year following adoption of the plan. Biological elements of the plan will be based on well-designed, cost-effective, and well-coordinated efforts.

Bart, J., and V. Johnston. 2012. Arctic shorebirds in North America: a decade of monitoring. Studies in Avian Biology 44.

Brown, S., J.R. Bart, R.B. Lanctot, J.A. Johnson, S. Kendall, D. Payer, and J. Johnson. 2007. Shorebird abundance and distribution on the coastal plain of the Arctic National Wildlife Refuge. Condor 109(1):1-14. https://doi.org/10.1650/0010-5422(2007)109[1:SAADOT]2.0.CO;2

Abstract - The coastal plain of the Arctic National Wildlife Refuge hosts seven species of migratory shorebirds listed as highly imperiled or high priority by the U.S. Shorebird Conservation Plan and five species listed as Birds of Conservation Concern by the U.S. Fish and Wildlife Service. During the first comprehensive shorebird survey of the 674 000 ha "1002 Area" on the coastal plain, we recorded 14 species of breeding shorebirds at 197 rapidly surveyed plots during June 2002 and 2004. We also estimated detection ratios with a double counting technique, using data collected at 37 intensively studied plots located on the North Slope of Alaska and northern Canada. We stratified the study area by major habitat types, including wetlands, moist areas, uplands, and riparian areas, using previously classified Landsat imagery. We developed population estimates with confidence limits by species, and estimated the total number of shorebirds in the study area to be 230 000 (95% CI: 104 000-363 000), which exceeds the biological criterion for classification as both a

Western Hemisphere Shorebird Reserve Network Site of International Importance (100 000 birds) and a Ramsar Wetland of International Importance (20 000 birds), even when conservatively estimated. Species richness and the density of many species were highest in wetland or riparian habitats, which are clustered along the coast. The coastal plain of the Arctic NWR hosts seven species of migratory shorebirds listed as highly imperiled or high priority by the U.S. Shorebird Conservation Plan and five species listed as Birds of Conservation Concern by the U.S. Fish and Wildlife Service. During the first comprehensive shorebird survey of the 674,000 ha "1002 Area" on the coastal plain, we recorded 14 species of breeding shorebirds at 197 rapidly surveyed plots during June 2002 and 2004. We also estimated detection ratios with a double counting technique, using data collected at 37 intensively studied plots located on the North Slope of Alaska and northern Canada. We stratified the study area by major habitat types, including wetlands, moist areas, uplands, and riparian areas, using previously classified Landsat imagery. We developed population estimates with confidence limits by species, and estimated the total number of shorebirds in the study area to be 230,000 (95% CI: 104,000-363,000), which exceeds the biological criterion for classification as both a Western Hemisphere Shorebird Reserve Network Site of International Importance (100,000 birds) and a Ramsar Wetland of International Importance (20,000 birds), even when conservatively estimated. Species richness and the density of many species were highest in wetland or riparian habitats, which are clustered along the coast.

Brown, S., S. Kendall, R. Churchwell, A. Taylor, and A.-M. Benson. 2012. Relative shorebird densities at coastal sites in the Arctic National Wildlife Refuge. Waterbirds 35(4):546-554. http://www.jstor.org/stable/pdf/23326556.pdf?refreqid=excelsior:3bb2f4a31e62b82ab34a13352e3361b4

Abstract - In the first comprehensive survey of post-breeding shorebirds conducted along the remote deltaic mudflat habitats on the coastline of the Arctic National Wildlife Refuge, six species of shorebirds were documented aggregating prior to southbound migration. Energy reserves gained while foraging in these areas may be critical for southbound migration of long-distance migrant shorebirds, but these habitats are vulnerable to potential effects of oil and gas development and climate change. The study objective was to assess the relative density and species composition of shorebirds. Surveys were conducted at 13 major river deltas on the coast between late July and mid-August each year from 2006 to 2010. Double-observer methods were used in 2010 to estimate the detection rate in surveys of randomly-selected transect sections. Shorebird density varied significantly between years and among river deltas. Peak relative density estimates at three deltas, the Jago (247.8 birds/km^2), the Kongakut (100.6 birds/km^2) and the Hulahula (49.5 birds/km^2), were significantly higher than the estimate for the Canning (16.0 birds/km^2). Because shorebird density and abundance vary significantly among sites and years, and individuals likely move among multiple sites within a given year, shorebird conservation strategies for these habitats should consider them to be spatially and temporally interconnected. In the first comprehensive survey of post-breeding shorebirds conducted along the remote deltaic mudflat habitats on the coastline of the Arctic National Wildlife Refuge, six species of shorebirds were documented aggregating prior to southbound migration. Energy reserves gained while foraging in these areas may be critical for southbound migration of long-distance migrant shorebirds, but these habitats are vulnerable to potential effects of oil and gas development and climate change. The study objective was to assess the relative density and species composition of shorebirds. Surveys were conducted at 13 major river deltas on the coast between late July and mid-August each year from 2006 to 2010. Double-observer methods were used in 2010 to estimate the detection rate in surveys of randomly-selected transect sections. Shorebird density varied significantly between years and among river deltas. Peak relative density estimates at three deltas, the Jago (247.8 birds/km 2), the Kongakut (100.6 birds/km 2) and the Hulahula (49.5 birds/km 2), were significantly higher than the estimate for the Canning (16.0 birds/km 2). Because shorebird density and abundance vary significantly among sites and years, and individuals likely move among multiple sites within a given year, shorebird conservation strategies for these habitats should consider them to be spatially and temporally interconnected.

Brown, S., C. Gratto-Trevor, R. Porter, E.L. Weiser, D. Mizrahi, R. Bentzen, M. Boldenow, R. Clay, S. Freeman, M.-A. Giroux, E. Kwon, D.B. Lank, N. Lecomte, J. Liebezeit, V. Loverti, J. Rausch, B.K. Sandercock, S. Schulte, P. Smith, A. Taylor, B. Winn, S. Yezerinac, and R.B. Lanctot. 2017. Migratory connectivity of Semipalmated Sandpipers and implications for conservation. Condor 119: 207-224. https://doi.org/10.1650/CONDOR-16-55.1

Abstract - Semipalmated Sandpiper (*Calidris pusilla*) populations have undergone significant declines at core nonbreeding sites in northeastern South America. Breeding populations have also declined in the eastern North American Arctic, but appear to be stable or increasing in the central and western Arctic. To identify vulnerable populations and sites, we documented the migratory connectivity of Semipalmated Sandpipers using light-level geolocators, deploying 250 at 8 Arctic sites across the species' breeding range from 2011 to 2015, plus 87 at a single wintering site in northeastern Brazil in 2013 and 2014. We recovered 59 units and resighted 7 more (26% return rate) on the breeding grounds, but none at the nonbreeding site. We recovered only ~3% of units deployed in 2013 at eastern Arctic breeding sites, but recovered 33% of those deployed in 2015. Overall, birds with geolocators were 57% as likely to return as those carrying alphanumeric flags. Stopover durations at prairie sites (mean: 8.7 days southbound, 6.7 days northbound) were comparable with durations estimated by local banding studies, but geolocator-tagged birds had longer stopovers than previously estimated at James and Hudson Bay, the Bay of Fundy, and the Gulf of Mexico. Migration routes confirmed an eastern Arctic connection with northeastern South America. Birds from eastern Alaska, USA, and far western Canada wintered from Venezuela to French Guiana. Central Alaskan breeders wintered across a wider range from Ecuador to French Guiana. Birds that bred in western Alaska wintered mainly on the west coasts of Central America and northwestern South America, outside the nonbreeding region in which population declines have been observed. Birds that bred in the eastern Arctic and used the Atlantic Flyway wintered in the areas in South America where declines have been reported, whereas central Arctic–breeding populations were apparently stable. This suggests that declines may be occurring on the Atlantic Flyway and in the eastern Arctic region.

Bulla, M., M. Valcu, A.M. Dokter, A.G. Dondua, A. Kosztolanyi, A.L. Rutten, B. Helm, B.K. Sandercock, B. Casler, B.J. Ens, C.S. Spiegel, C.J. Hassell, C. Kupper, C. Minton, D. Burgas, D.B. Lank, D.C. Payer, E.Y. Loktionov, E. Nol, E. Kwon, F. Smith, H.R. Gates, H. Vitnerova, H. Pruter, J.A. Johnson, J.J. H. St Clair, J.-F. Lamarre, J. Rausch, J. Reneerkens, J.R. Conklin, J. Burger, J. Liebezeit, J. Bety, J.T. Coleman, J. Figuerola, J.C.E.W. Hooijmeijer, J.A. Alves, J.A.M. Smith, K. Weidinger, K. Koivula, K. Gosbell, K.-M. Exo, L. Niles, L. Koloski, L. McKinnon, L. Praus, M. Klaassen, M.-A. Giroux, M. Sladeček, M.L. Boldenow, M.I. Goldstein, M. Šalek, N. Senner, N. Ronka, N. Lecomte, O. Gilg, O. Vincze, O.W. Johnson, P.A. Smith, P.F. Woodard, P.S. Tomkovich, P.F. Battley, R. Bentzen, R.B. Lanctot, R. Porter, S.T. Saalfeld, S. Freeman, S.C. Brown, S. Yezerinac, T. Szekely, T. Montalvo, T. Piersma, V. Loverti, V.-M. Pakanen, W.Tijsen, and B. Kempenaers. 2016. Unexpected diversity in socially synchronized rhythms of shorebirds. Nature 540:109-113. http://dx.doi.org/10.1038/nature20563

Summary - The behavioral rhythms of organisms are thought to be under strong selection, influenced by the rhythmicity of the environment1–4. Such behavioral rhythms are well studied in isolated individuals under laboratory conditions1,5, but free-living individuals have to temporally synchronize their activities with those of others, including potential mates, competitors, prey and predators6–10. Individuals can temporally segregate their daily activities (for example, prey avoiding predators, subordinates avoiding dominants) or synchronize their activities (for example, group foraging, communal defense, pairs reproducing or caring for offspring) 6–9,11. The behavioral rhythms that emerge from such social synchronization and the underlying evolutionary and ecological drivers that shape them remain poorly understood5–7,9. Here we investigate these rhythms in the context of biparental care, a particularly sensitive phase of social synchronization12 where pair members potentially compromise their individual rhythms. Using data from 729 nests of 91 populations of 32 biparentally incubating shorebird species, where parents synchronize to achieve continuous coverage of developing eggs, we report remarkable within- and between-species diversity in incubation rhythms. Between species, the median length of one parent's incubation bout varied from 1–19 h, whereas period length—the time in which a parent's probability to incubate cycles once between its highest and lowest value-varied from 6-43 h. The length of incubation bouts was unrelated to variables reflecting energetic demands, but species relying on crypsis (the ability to avoid detection by other animals) had longer incubation bouts than those that are readily visible or who actively protect their nest against predators. Rhythms entrainable to the 24-h light–dark cycle were less prevalent at high latitudes and absent in 18 species. Our results indicate that even under similar environmental conditions and despite 24-h environmental cues, social synchronization can generate far more diverse behavioral rhythms than expected from studies of individuals in captivity. The risk of predation, not the risk of starvation, may be a key factor underlying the diversity in these rhythms.

Byrkjedal, I., and D.E. Thompson. 2002. Tundra plovers: the Eurasian, and American and Pacific Golden Plover. London, T & AD Poyser

Book Review by Jane Turpie [Wilson Bulletin 113(1):118-119]. Anyone who has spent time getting to know any of the *Pluvialis,* or "tundra," plovers may have marveled at their migratory feats, their handsome summer plumage, their subtle melodic whistles, or their intriguing foraging and territorial behavior. The authors of this book, who are clearly captivated by their subjects and well qualified for the task, delve into the lives of these birds in 14 chapters, covering numerous aspects from their origins and distribution to breeding biology and conservation. The book is not only a highly comprehensive review of our current understanding, but a comparative study of the four *Pluvialis* species, and poses many questions to tantalize the next generation of researchers. For instance, why has the Grey Plover (*Pluvialis squatarola*) retained its circumpolar distribution, whereas the "Goldies," together covering a similar range, have split into three separate species, and what dictates the subtle differences in their breeding distributions?

The introductory chapter sets the scene, not only describing the tundra breeding habitats and some of the nonbreeding habitats of these birds, but also giving some insight into the difficulties of studying these well-camouflaged birds during the breeding season. In the following chapters, the book puts the tundra plovers in the context of the rest of the plovers, explaining what sets them apart, gives a brief history of the taxonomy of the group, and argues their phylogeny. There are no surprises here, but the subject is well reviewed. Plumage and molts, and their interspecific and geographical variation, are described in intricate detail in a well-illustrated chapter. The difficult task of estimating the population size and status of these four species is convincingly tackled, giving rise to population estimates considerably higher than have been made in the past.

Three chapters are devoted to the breeding cycle of the tundra plovers, covering breeding schedules and nesting, social behavior and sex roles, and parental behavior. These chapters draw heavily on the experience of the authors, presenting much previously unpublished information, and are a truly worthwhile read. Of particular interest are the detailed accounts of displays and calls.

The post-breeding migrations of the plovers are tracked as they spread to their temperate and tropical nonbreeding grounds. Here, the authors have painstakingly analyzed ringing recoveries and thousands of museum records to compile illustrated accounts of the movements of these birds. In spite of their collective name, tundra plovers spend the greater part of their lives in a wide variety of terrestrial and coastal habitats away from their breeding grounds. Yet, the book reflects a relative scarcity of knowledge on their nonbreeding ecology, and perhaps a lack of firsthand experience on the part of the authors, who cover the subject in a single chapter. Even the chapter on diet, although comprehensively presented, has a distinctly north temperate bias which begs more research in the tropics.

One cannot view the ecology of these birds in isolation, as they share their breeding and nonbreeding grounds with numerous other shorebird species. Thus, the penultimate chapter aptly describes the relationships of the tundra plovers with other species, considering both the hazards of competition and the advantages of associations in terms of predator avoidance and finding food.

The final chapter considers the challenge of conserving such wide-ranging and often sparsely-distributed species. There have been major losses of the coastal and grassland habitats that constitute their nonbreeding grounds, and even remote breeding grounds are threatened by oil and gas exploration, mining, and grazing pressures. Recent progress in global conservation efforts is helping to curb this trend, but global warming has dire implications for these birds.

It is clear that this excellent account of the biology of the tundra plovers has been written with dedication. It is eminently readable, keeping the reader intrigued from beginning to end. Although much detailed information is presented within the main chapters, very technical information is relegated to a series of 14 appendices which provide a very useful scientific reference.

Connors, P.G., and R.W. Risebrough. 1979. Shorebird dependence on Arctic littoral habitats. Environmental Assessment of the Alaska Continental Shelf 1:271-329.

Connors, P.G., J.P. Meyers, and F.A. Pitelka. Seasonal habitat use by Alaskan shorebirds. Studies in Avian Biology 2:101-111.

Abstract - Shorebirds display a wide range in seasonal patterns of habitat use along the Arctic coast near Point Barrow, Alaska. Differences between species reflect habitat preferences, the timing of movements with respect to seasonal habitat availability, and whether the use is breeding, postbreeding, or migrational. During the breeding season (June and July), most activity is centered on the tundra, but by early August a marked coastal movement occurs, resulting in high densities of particular species in shoreline and adjacent

habitats. In August and September, widespread use of littoral habitats develops, especially for such species as Red Phalarope, Ruddy Turnstone, and Sanderling. In contrast, Golden Plovers and Pectoral Sandpipers restrict most of their activities to the tundra. Other species exhibit intermediate patterns of habitat use. These patterns determine the dependence of each species on arctic coastal habitats, and the susceptibility of each species to disturbances related to outer continental shelf oil development.

Cunningham, J.A., D.C. Kesler, and R.B. Lanctot. 2016. Habitat and social factors influence nest site selection in Arctic-breeding shorebirds. Auk 133(3):364-377. http://www.bioone.org/doi/full/10.1642/AUK-15-196.1

Abstract - Habitat selection theory suggests that shorebirds should choose nest sites that maximize survival and fitness. We investigated how habitat, and proximity to conspecific or heterospecific nesting birds, was related to nest-site selection in American Golden-Plovers (*Pluvialis dominica*), Dunlin (*Calidris alpina*), Long-billed Dowitchers (*Limnodromus scolopaceus*), Pectoral Sandpipers (*C. melanotos*), Red Phalaropes (*Phalaropus fulicarius*), and Semipalmated Sandpipers (*C. pusilla*) in Barrow, Alaska, USA, between 2005 and 2012. We used remote-sensing data to link habitat information to used and unused nest sites, and we measured distances from nests to other nearby nesting shorebird neighbors. Results from an information-theoretic approach to identify best-approximating models indicated that all species selected nest sites on the basis of both habitat and social cues. Macroscale tundra moisture level within 50 m of the nest, which was closely associated with vegetation community, was an informative variable for Dunlin, Long-billed Dowitcher, and Red Phalarope, which all selected wetter habitat. Enhanced tundra microrelief increased the probability of nest-site selection for American Golden-Plover, Long-billed Dowitcher, Pectoral Sandpiper, and Semipalmated Sandpiper. American Golden-Plover, Dunlin, Pectoral Sandpiper, and Semipalmated Sandpiper selected sites farther from conspecific nests than predicted by chance. Our results indicate that shorebirds select nest sites on the basis of habitat features, and that some are also influenced by proximity to other nesting shorebirds. These findings indicate that shorebirds select nests that are likely to aid incubation abilities, reduce predator detection of nesting birds, enhance detection of predators, enhance foraging, and reduce competition from conspecifics. The variable needs of the different Arctic-breeding shorebirds indicate that climate change will have both beneficial and harmful consequences. Our habitat models may be useful for predicting areas of high shorebird importance throughout the Arctic Coastal Plain, allowing mitigation of proposed anthropogenic developments.Kendall, S., D. Payer, S. Brown, and R. Churchwell. 2011. Impacts of climate change and development on shorebirds of the Arctic National Wildlife Refuge. Pp. 91-100 in R.T. Watson, T.J. Cade, M. Fuller, G. Hunt, and E. Potapov (eds.), Gyrfalcons and Ptarmigan in a Changing World. Boise, ID: The Peregrine Fund. http://dx.doi.org/10.4080/gpcw.2011.0109

Fernández, G., J.B. Buchanan, R.E. Gill, Jr., R. Lanctot, and N. Warnock. 2010. Conservation Plan for Dunlin with breeding populations in North America (*Calidris alpina arcticola, C. a. pacifica*, and *C. a. hudsonia*), Version 1.1. Manomet, MA: Manomet Center for Conservation Sciences. http://www.planetofbirds.com/ns/sap2/Dunlin.pdf

Executive Summary – The Dunlin (*Calidris alpina*) is one of the more abundant migratory shorebirds of the Northern Hemisphere, and has an almost circumpolar distribution of breeding populations. Unlike most other shorebirds, the Dunlin shows considerable phenotypic and genotypic variation over its range, with up to 11 subspecies recognized. Three subspecies are known to occur in North America: *C. a. arcticola*, *C. a. pacifica*, and *C.*

a. hudsonia, with population estimates of 750,000, 550,000, and 225,000, respectively. Despite their large population estimates, the US Shorebird Conservation Plan lists the Dunlin (*C. a. arcticola* and *C. a. pacifica*) as a Species of High Concern (Brown *et al.* 2001), while the Canadian Shorebird Conservation Plan considers it a Species of Moderate Concern with known or potential threats (Donaldson *et al.* 2000). The Dunlin warrants conservation planning due to 1) recent rates of habitat loss in the nonbreeding range where the species tends to aggregate; 2) gaps in knowledge regarding factors limiting the populations; 3) the species' vulnerability to a variety of impacts, given its strong tendency to aggregate; and 4) inadequate monitoring data for determining population trends, coupled with suspected declines in parts of its range.

C. a. arcticola breeds in northern Alaska (and possibly Canada), and spends the nonbreeding season distributed from Japan to the People's Republic of China. *C. a. pacifica* breeds in coastal western Alaska, and its primary nonbreeding distribution is the Pacific coast from southern British Columbia, Canada, to northwestern Mexico. *C. a. hudsonia* breeds in northern Canada and spends the nonbreeding season commonly on the Atlantic and Gulf coasts from Massachusetts to Mexico. All three subspecies use similar habitats during migration and nonbreeding. Dunlin are common at estuarine mudflats, but they can move among a variety of available habitats, from freshwater to brackish wetlands. Dunlin also are found in coastal and adjacent agricultural habitats, and some individuals spend part or all of the season inland in freshwater wetlands and agricultural habitats.

Each subspecies uses a substantial number of sites throughout its annual range, and some sites support very large numbers of birds. Although some of the most important sites are protected, many others are on unprotected lands. Important migratory and nonbreeding sites for *C. a. arcticola* include:

- Alaska, USA: Yukon-Kuskokwim Delta, Shishmaref Inlet, and Kasegaluk Lagoon (southward migration);
- People's Republic of China: Yancheng National Nature Reserve (migration), and Yalu Jiang National Nature Reserve (northward migration);
- Republic of Korea [South Korea]: Saemangeum Estuary, Mangyeung Gang Hagu, and Tongjin Gang Hagu (migration).

It is noteworthy that the nonbreeding range of *C. a. arcticola* overlaps that of three other Dunlin subspecies (*actites*, *sakhalina*, and *kistchinski*) in the East Asian-Australian Flyway. This mixing of subspecies has complicated and, to date, prevented the establishment of a reliable population estimate for and identification of important sites used by *C. a. arcticola* during the migration and nonbreeding periods.

Important migratory and nonbreeding sites [per country/state] for *C. a. pacifica* include:

- British Columbia, Canada: Mud Bay and Fraser River Delta (nonbreeding);
- Alaska, USA: Yukon-Kuskokwim Delta, Nelson Lagoon-Mud Bay, Egegik Bay, Port
- Heiden, and Shishmaref Inlet (southward migration), and Copper River Delta, Yakutat Foreland, and Cook Inlet (northward migration);
- Washington, USA: Grays Harbor, Willapa Bay, and Puget Sound (migration and nonbreeding), and coastal beaches adjacent to the latter two sites (migration and nonbreeding);

- Oregon, USA: Columbia River Estuary [shared with Washington] (nonbreeding and northward migration), and the Willamette Valley (nonbreeding);
- California, USA: Central Valley (migration and nonbreeding), Sacramento Valley (nonbreeding), and San Francisco Bay and Humboldt Bay (nonbreeding and northward migration);
- Baja California Sur, Mexico: Laguna Ojo de Liebre-Guerrero Negro (nonbreeding).

Important migratory and nonbreeding sites [per state] for *C. a. hudsonia* include:

- North Dakota, USA: Minnewaukan Flats–Devil's Lake (northward migration);
- Michigan, USA: Shiawassee National Wildlife Refuge (northward migration);
- Ohio, USA: Ottawa National Wildlife Refuge (northward migration).
- New Jersey, USA: Edwin B. Forsythe National Wildlife Refuge (southward migration);
- Virginia, USA: Chincoteague National Wildlife Refuge (southward migration);
- Texas, USA / Tamaulipas, Mexico: Laguna Madre (nonbreeding);

Conservation threats to the three subspecies and the proposed solutions are similar. At migratory and nonbreeding sites, potential or actual threats include habitat loss and degradation, human disturbance, oil spills, and contaminants. Sources of habitat alteration are related to reclamation of intertidal areas for food production, shrimp farms, changes in water hydrology (i.e., dams) and agricultural practices, restoration of salt marshes, and invasive species (e.g., *Spartina*). There are still major gaps in the underlying factors that have the greatest influence on Dunlin populations and demographic rates.

Overall, the highest-priority conservation action identified within each subspecies' range is habitat protection, particularly during migration and at nonbreeding sites. For *C. a. arcticola*, it is critical to evaluate and curtail changes in nonbreeding sites, especially in the Yangtze River floodplain and along the Fujian coast. For *C. a. pacifica*, it is critical to reconsider plans to restore salt pond habitat to tidal marsh habitat, especially in California; the needs of Dunlin should be carefully balanced with those for other species. The control of *Spartina* also is a high priority. Important sites should be properly recognized at local, regional and international scales, either as new protected areas or as Western Hemisphere Shorebird Reserve Network (WHSRN), Ramsar Convention, or Important Bird Area designations. An education and outreach program would be valuable to increase awareness of migratory shorebird ecology and the importance of protecting wetlands. The conservation-related research needs include studies on migratory connectivity, density-dependent effects of habitat loss, and factors affecting survival and population dynamics. The monitoring needs include an adequate population monitoring program(s) to determine population trends and counts of birds in natural and manmade habitats.Kwon, E. 2016. Effects of climate change on the breeding ecology and trophic interactions of Arctic-breeding shorebirds. Manhattan, KS: Kansas State University Ph.D. dissertation. http://krex.k-state.edu/dspace/handle/2097/20604

Gates, H.R., R.B. Lanctot, and A.N. Powell. 2013. High renesting rates in arctic-breeding Dunlin (*Calidris alpina*): a clutch-removal experiment. Auk 130(2):372-380. http://www.bioone.org/doi/full/10.1525/auk.2013.12052

Abstract - The propensity to replace a clutch is a complex component of avian reproduction and poorly understood. We experimentally removed clutches from an Arctic-breeding shorebird, the Dunlin (*Calidris alpina arcticola*), during early and late stages of incubation to

investigate replacement clutch rates, renesting interval, and mate and site fidelity between nesting attempts. In contrast to other Arctic studies, we documented renesting by radiotracking individuals to find replacement clutches. We also examined clutch size and mean egg volume to document changes in individual females' investment in initial and replacement clutches. Finally, we examined the influence of adult body mass, clutch volume, dates of clutch initiation and nest loss, and year on the propensity to renest. We found high (82–95%) and moderate (35–50%) rates of renesting for early and late incubation treatments. Renesting intervals averaged 4.7–6.8 days and were not different for clutches removed early or late in incubation. Most pairs remained together for renesting attempts. Larger females were more likely to replace a clutch; female body mass was the most important parameter predicting propensity to renest. Clutches lost later in the season were less likely to be replaced. We present evidence that renesting is more common in Arctic-breeding shorebirds than was previously thought, and suggest that renesting is constrained by energetic and temporal factors as well as mate availability. Obtaining rates of renesting in species breeding at different latitudes will help determine when this behavior is likely to occur; such information is necessary for demographic models that include individual and population-level fecundity estimates.

Kendall, S., D. Payer, S. Brown, and R. Churchwell. 2011. Impacts of climate change and development on shorebirds of the Arctic National Wildlife Refuge. Pp. 91-100 in R.T. Watson, T.J. Cade, M. Fuller, G. Hunt, and E. Potapov (eds.), Gyrfalcons and Ptarmigan in a Changing World. Boise, ID: The Peregrine Fund. http://dx.doi.org/10.4080/gpcw.2011.0109

Abstract - Impacts of climate change are amplified at high latitudes such as the Arctic Coastal Plain of Alaska. In addition, this region and adjacent offshore areas are experiencing rapid changes associated with oil and gas exploration and production. The Arctic National Wildlife Refuge's location in northeast Alaska makes it particularly vulnerable to these environmental perturbations. Recognizing this, we have implemented several collaborative investigations of at-risk bird populations and habitats since 2002. In this paper we focus on studies of shorebirds using tundra and coastal habitats. Objectives include: (1) identify important habitats for nesting and staging; (2) assess effects of development on nest predation and success rates; (3) examine post-breeding shorebird staging ecology; and (4) develop models using demographic and environmental data to evaluate causes of shorebird population declines. Evaluating impacts of changing environmental conditions on birds is an overarching objective of all studies. Initial results suggest that the impacts of development on nest success are small relative to natural variability, but could be important as additive stressors. We identified several high-use areas for post-breeding shorebirds, but also found considerable inter-annual and within-season variability in bird distribution. We are currently investigating factors associated with shorebird use of coastal habitats including availability of food resources. We recently initiated further studies on demographics of breeding shorebirds. Several years of data from multiple sites will be required to evaluate shorebird population dynamics in this highly variable and rapidly changing environment. Our studies will contribute to understanding population limitation and developing conservation actions for arctic shorebirds.

Kwon, E., E.L. Weiser, R.B. Lanctot, S. Brown, H.R. Gates, H.G. Gilchrist, S.J. Kendall, D.B. Lank, J.R. Liebezeit, L. McKinnon, E. Nol, D.C. Payer, J. Rausch, D.J. Rinella, S.T. Saalfeld, N.R. Senner, P.A. Smith, D. Ward, R.W. Wisseman, and B.K. Sandercock. *In review*. Geographic variation in the intensity of phenological mismatch between Arctic shorebirds and their invertebrate prey. Ecological Monographs.

Herzog, P., S.T. Saalfeld, and R.B. Lanctot. *In review*. Nest reuse in Arctic-breeding shorebirds: an analysis of potential benefits and factors affecting the occurrence of this rare behavior. Journal of Avian Biology.

Hupp, J.W., Ward, D.H., Hogrefe, K.R., Sedinger, J.G., Martin, P.D., Stickney, A., and Kendall, S., D. Payer, S. Brown, and R. Churchwell. 2011. Impacts of climate change and development on shorebirds of the Arctic National Wildlife Refuge. Pp. 91-100 in R.T. Watson, T.J. Cade, M. Fuller, G. Hunt, and E. Potapov (eds.), Gyrfalcons and Ptarmigan in a Changing World. Boise, ID: The Peregrine Fund. http://dx.doi.org/10.4080/gpcw.2011.0109

Johnson, O.W., and P.G. Connors. 2010. Pacific Golden-plover (*Pluvalis fulva*). Birds of North America No. 202, (A. Poole, ed.). Ithaca, NY; Cornell Lab of Ornithology.

Johnson, O.W., P.G. Connors, and P. Pyle. 2018. American Golden-Plover (*Pluvialis dominica*), v.3.0. In Birds of North America (P.G. Rodewald, ed.). Ithaca, NY: Cornell Lab of Ornithology. https://doi.org/10.2173/bna.amgplo.03

Johnson, O.W., P.G. Connors, and P. Pyle. 2018. Pacific Golden-Plover (*Pluvialis fulva*), v.3.0. In Birds of North America (P.G. Rodewald, ed.). Ithaca, NY: Cornell Lab of Ornithology. https://doi.org/10.2173/bna.pagplo.03

Johnson, J.A., R.B. Lanctot, B.A. Andres, J.R. Bart, S.C. Brown, S.J. Kendall, D.C. Payer. 2007. Distribution of breeding shorebirds on the Arctic Coastal Plain of Alaska. Arctic 60(3): 277-293. http://pubs.aina.ucalgary.ca/arctic/Arctic60-3-277.pdf

Abstract - Available information on the distribution of breeding shorebirds across the Arctic Coastal Plain of Alaska is dated, fragmented, and limited in scope. Herein, we describe the distribution of 19 shorebird species from data gathered at 407 study plots between 1998 and 2004. This information was collected using a single-visit rapid area search technique during territory establishment and early incubation periods, a time when social displays and vocalizations make the birds highly detectable. We describe the presence or absence of each species, as well as overall numbers of species, providing a regional perspective on shorebird distribution. We compare and contrast our shorebird distribution maps to those of prior studies and describe prominent patterns of shorebird distribution. Our examination of how shorebird distribution and numbers of species varied both latitudinally and longitudinally across the Arctic Coastal Plain of Alaska indicated that most shorebird species occur more frequently in the Beaufort Coastal Plain ecoregion (i.e., closer to the coast) than in the Brooks Foothills ecoregion (i.e., farther inland). Furthermore, the occurrence of several species indicated substantial longitudinal directionality. Species richness at surveyed sites was highest in the western portion of the Beaufort Coastal Plain ecoregion. The broad-scale distribution information we present here is valuable for evaluating potential effects of human development and climate change on Arctic-breeding shorebird populations.

Meehan, R.H. 1986. Impact of oilfield development on shorebirds, Prudhoe Bay, Alaska. Denver, CO: University of Colorado Ph.D. dissertation.

Saalfeld, S.T. and R.B. Lanctot. 2015. Conservative and opportunistic settlement strategies in Arctic-breeding shorebirds. Auk 132(1):212-234. http://www.bioone.org/doi/pdf/10.1642/AUK-13-193.1

Saalfeld, S.T., R.B. Lanctot, S.C. Brown, D.T. Saalfeld, J.A. Johnson, B.A. Andres, and J.R. Bart. 2013. Predicting breeding shorebird distributions on the Arctic Coastal Plain of Alaska. Ecosphere 4(1):16. http://dx.doi.org/10.1890/ES12-00292.1

Abstract - The Arctic Coastal Plain (ACP) of Alaska is an important region for millions of migrating and nesting shorebirds. However, this region is threatened by climate change and increased human development (e.g., oil and gas production) that have the potential to greatly impact shorebird populations and breeding habitat in the near future. Because historic data on shorebird distributions in the ACP are very coarse and incomplete, we sought to develop detailed, contemporary distribution maps so that the potential impacts of climate-mediated changes and development could be ascertained. To do this, we developed and mapped habitat suitability indices for eight species of shorebirds (Black-bellied Plover [*Pluvialis squatarola*], American Golden-Plover [*Pluvialis dominica*], Semipalmated Sandpiper [*Calidris pusilla*], Pectoral Sandpiper [*Calidris melanotos*], Dunlin [*Calidris alpina*], Long-billed Dowitcher [*Limnodromus scolopaceus*], Red-necked Phalarope [*Phalaropus lobatus*], and Red Phalarope [*Phalaropus fulicarius*]) that commonly breed within the ACP of Alaska. These habitat suitability models were based on 767 plots surveyed during nine years between 1998 and 2008 (surveys were not conducted in 2003 and 2005), using single-visit rapid area searches during territory establishment and incubation (8 June–1 July). Species-specific habitat suitability indices were developed and mapped using presence-only modeling techniques (partitioned Mahalanobis distance) and landscape environmental variables. For most species, habitat suitability increased at lower elevations (i.e., near the coast and river deltas) and decreased within upland habitats. Accuracy of models was high for all species, ranging from 65–98%. Our models predicted that the largest fraction of suitable habitat for the majority of species occurred within the National Petroleum Reserve-Alaska, with highly suitable habitat also occurring within coastal areas of the Arctic National Wildlife Refuge west to Prudhoe Bay.

Saalfeld, S.T., B.L. Hill, and R.B. Lanctot. 2013. Shorebird responses to construction and operation of a landfill on the Arctic coastal plain. Condor 115(4):816–829. https://doi.org/10.1525/cond.2013.120169

Abstract - Although much of the Arctic Coastal Plain has remained undeveloped, oil and gas industries, new and expanding villages, as well as tourism are likely to increase in the near future. One potential effect of increased human development is increased anthropogenic waste and the need to dispose of this waste in landfills. We investigated potential indirect effects of the North Slope Borough landfill on breeding shorebirds by examining changes in environmental conditions (predator densities and timing of snow melt) and measures of shorebird reproduction (nest-initiation dates, nest density, nest survival, and return rates) in relation to construction and deposition of waste in the landfill. This study included one year of pre-construction data (2004), three years when landfill roads and fences were being constructed (2005–2007), and five years when waste was being deposited (2008–2012). We monitored 364 shorebird nests within a 36-ha plot (approximately half of which was inside the landfill and half outside). Construction of a fence around the landfill reduced snow levels inside the landfill, leading to earlier snow melt and likely to shorebirds initiating nests earlier. Densities of avian predators increased following waste deposition, but nest densities, nest survival, and return rates were generally greater inside the landfill than outside in all years after landfill construction. Our results indicate that fences placed around landfills and procedures to reduce attraction of predators to landfills can minimize indirect negative effects of landfill construction and operation and even favor species breeding in the area.

Saalfeld, S.T., D.C. McEwen, D. Kesler, M.G. Butler, J. Cunningham, A. Doll, W. English, D. Gerik, K. Grond, P. Herzog, B. Hill, B. Lagassé, and R.B. Lanctot. *In review*. Phenological mismatch in Arctic-breeding birds: impact of earlier summers and unpredictable weather conditions on food availability and chick growth. Global Change Biology.

Troy, D.M. 2000. Shorebirds. Pp. 277-303 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Summary - Shorebirds or waders are small to medium-sized birds of the order Charadriiformes that frequently are associated with shorelines and wetlands. In northern Alaska, where shorebirds dominate the avifauna in number of individuals and species, two families regularly occur—the plovers (*Charadriidae*) and the sandpipers (*Scolopacidae*). Arctic shorebirds have attracted considerable study because of their abundance and diversity, their exceptional migrations, and their variety of mating systems. Northern Alaska has hosted considerable research on arctic shorebirds. Studies of shorebird foraging and breeding biology took place during the 1960s and 1970s in the western Arctic Coastal Plain (ACP), primarily in the Barrow area. In more recent years the major focus of shorebird study has been the oil-field region of the central ACP. Arctic-breeding shorebirds undertake some of the most extreme migrations of any birds, many traveling across continents during their annual movements. During the breeding season, most occur widely in arctic environments and have ranges extending into Canada and/or Russia. The only taxon whose breeding range is restricted to northern Alaska is the Dunlin *(Calidris alpina articola)*; other races of this species are found throughout the Arctic.

Responses to Habitat Change and Human Activity (Pp. 292-

Assessments of shorebird responses to habitat change and to human activity have been made mainly on the basis of changes in bird distribution and abundance. No studies of changes in behavioral patterns or activity budgets have been conducted. Changes to the environment as a result of oilfield development on the Arctic coastal plain (ACP) have been classified by Meehan (1986) as follows:

- Primary – the footprint of facilities such as roads and pads
- Secondary – alterations to areas adjacent to facilities because of drainage changes, fugitive dust, thermokarsting, and human activity (noise, traffic, etc.)
- Tertiary – regional impacts such as habitat fragmentation caused by influences of the oilfield facilities well beyond their extent

In the following sections I discuss the changes in shorebird distribution and abundance and the population-level implications of these changes.

Changes in Distribution and Abundance

Gravel placement on tundra, which is required to support many oilfield facilities, is the most pervasive type of primary habitat change in the oilfield region. It results in habitat loss for most shorebirds. A few species, notably Semipalmated Plover, that frequent natural gravel habitats such as river alluvium make use of gravel pads. Many species on occasion roost or display from the elevated gravel surfaces, but for most species gravel removes habitats used for nesting and foraging, and the birds that would have used the habitat in the absence of development as displaced. Gravel fill covers a few percent or less of the total area of oilfields (e.g., 2.3% of the intensively developed Prudhoe Bay Unit, BP Exploration Alaska 1989).

Secondary habitat changes associated with gravel placement have elicited the most questions and research on shorebird responses to oil development. How far from gravel roads and pads do changes in shorebird abundance extend? What are the most important factors responsible for these distributional changes?

That distributional changes occur near gravel fill is unambiguous. Connors and Risebrough (1979), the first investigators to sample shorebirds along roads in the oilfield area, found that shorebirds as a group were less numerous near roads than away from roads. More recent and intensive studies (Troy and Carpenter 1990; TERA 1993; Troy 1993) confirmed that most shorebirds exhibit distributions adjacent to roads that differ from expected distributions based on habitat availability or historic patterns.

A generalized patter of response

[…not complete…]

Weiser, E.L., S.C. Brown, R.B. Lanctot, H.R. Gates, K.F. Abraham, R.L Bentzen, J. Bêty, M.L. Boldenow, R.W. Brook, T.F. Donnelly, W.B. English, S.A. Flemming, S.E. Franks, H.G. Gilchrist, M.-A. Giroux, A. Johnson, S. Kendall, L.V. Kennedy, L. Koloski, E. Kwon, J.-F. Lamarre, D.B. Lank, C.J. Latty, N. Lecomte, J.R. Liebezeit, L. McKinnon, E. Nol, J. Perz, J. Rausch, M. Robards, S.T. Saalfeld, N.R. Senner, P.A. Smith, M. Soloviev, D. Solovyeva, D.H. Ward, P.F. Woodard, and B.K. Sandercock. 2018. Effects of environmental conditions on reproductive effort and nest success of Arctic-breeding shorebirds. Ibis. doi: 10.1111/ibi.12571 https://bksandercock.files.wordpress.com/2018/01/weiser2018ibis.pdf

Abstract - The Arctic is experiencing rapidly warming conditions, increasing predator abundance, and diminishing population cycles of keystone species such as lemmings. However, it is still not known how many Arctic animals will respond to a changing climate with altered trophic interactions. We studied clutch size, incubation duration and nest survival of 17 taxa of Arctic-breeding shorebirds at 16 field sites over 7 years. We predicted that physiological benefits of higher temperatures and earlier snowmelt would increase reproductive effort and nest survival, and we expected increasing predator abundance and decreasing abundance of alternative prey (arvicoline rodents) to have a negative effect on reproduction. Although we observed wide ranges of conditions during our study, we found no effects of covariates on reproductive traits in 12 of 17 taxa. In the remaining taxa, most relationships agreed with our predictions. Earlier snowmelt increased the probability of laying a full clutch from 0.61 to 0.91 for Western Sandpipers, and shortened incubation by 1.42 days for arcticola Dunlin and 0.77 days for Red Phalaropes. Higher temperatures increased the probability of a full clutch from 0.60 to 0.93 for Western Sandpipers and from 0.76 to 0.97 for Red-necked Phalaropes, and increased daily nest survival rates from 0.9634 to 0.9890 for Semipalmated Sandpipers and 0.9546 to 0.9880 for Western Sandpipers. Higher abundance of predators (foxes) reduced daily nest survival rates only in Western Sandpipers (0.9821–0.9031). In contrast to our predictions, the probability of a full clutch was lowest (0.83) for Semipalmated Sandpipers at moderate abundance of alternative prey, rather than low abundance (0.90). Our findings suggest that in the short-term, climate warming may have neutral or positive effects on the nesting cycle of most Arctic-breeding shorebirds.

White, C.M., and D.G. Roseneau. 1970. Observations on food, nesting, and winter populations of large North American falcons. Condor 72(1):113-115. http://www.jstor.org/stable/1366493

Birds: Waterfowl (not limited to Anseriformes)

Barry, B.T. 1967. Geese of the Anderson River Delta, Northwest Territories: concluding report. Inuvik, Northwest Territories: Canadian Wildlife Service.

Abstract – The Snow Goose (*Chen caerulescens*), Pacific Brant (*Branta bernicla*), and White-fronted goose (*Anser albifrons*) have adapted themselves to the arctic environment and to different habitat niches at the Anderson River, NWT. The nesting season along the shores of the Arctic Ocean is short, but the geese are well-adapted to it. They arrive on the nesting grounds able to nest as soon as snow conditions permit. They are already paired and have copulated. They are physiologically ready for an "average" season. In seasons later than average there is a reduction in the number of eggs laid. If conditions remain adverse for such a long time that the young would be unable to fly by fall freeze-up, the geese will not nest at all. Instead, they bypass the remaining events of the reproductive cycle and go into their annual molt early, and thus are strong flyers before fall freeze-up. As they are long-lived, they can recoup a reproductive failure in succeeding seasons.

Within the arctic environment these species of geese are adapted to microhabitats suited to their requirements for food, nesting sites, protection from predators and their general habits. These are found in zones as one either moves upstream in a river delta or from north to should in the arctic in general. The Pacific Brant requires low coastal or delta islands (possibly for protection from a potentially serious predator, the arctic fox) covered with turf (grass and sedge) which is its food and nest material. The Snow Goose is a colony nester, seeking protection in numbers. Snow geese require large flat areas where they can concentrate their nests, and yet safe from spring floods. Their food habits are more universal than those of brant, and this allows them to occupy a larger variety of vegetation zones. The White-fronted Goose is the most inland or southerly nester of the three species. White-fronted Geese scatter their nests widely in tundra scrub willow. As solitary nesters they keep family groups of prior seasons together to help distract mammalian predators from the nest. The White-fronted geese has excellent protective coloration and has evolved the habit of dispersal to escape predation.

Variable weather conditions and cyclic or unusual amounts of predation can cause large flock fluctuations in the numbers of geese in fall flocks. With our present knowledge and facilities it is possible to predict the trends of these population changes by early June of each nesting season.

Brackney, A.W. 1987. Effects of aircraft disturbance on the energetics of staging Lesser Snow Geese: a model. Pp. 1109-1136 in G.W. Garner and P.E. Reynolds (eds.), Arctic National Wildlife Refuge coastal plain resource assessment: 1985 update report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Abstract – Energetics of fall staging Snow Geese (*Chen caerulescens caerulescens*) on the coastal plain of the Arctic National Wildlife Refuge (ANWR) were examined in 1984-1985 with special emphasis on the effects of aircraft disturbance. A comprehensive model of energy intake and expenditure predicted a daily energy expenditure of 1623.5+ 19.9 kj/da (mean± Sd) by adult females and 1759.8+ 21.2 kj/da were expended by males. In juveniles, 1302.4+ 15.5 kj/da and 1361.4+ 16.2 kj/da were expended by males and females, respectively. While adult females expended 1156+ 215.7 kj/da and males 1220+ 167.7 kj/da on tissue gain, juvenile males and females expended only 570.8+ 156.5 and 627.9+ 148.5

kj/da, respectively. Simulated aircraft disturbance had little effect on daily energy expenditure or activity cost under the base model which assumed limited non-flight habituation. Without the inclusion of behavioral substitution for lost feeding time (compensation), the model predicted a 50% reduction in true metabolizable energy intake and fat gain at aircraft overflights of 25 and 38 per day in juveniles and adults, respectively. Within the base model, the loss of feeding time and reduced energy intake, rather than increased energy expenditure, was relatively more important in regard to the detrimental effects of aircraft disturbance. The ameliorating effects of high levels of compensation indicated that the behavior of the geese when then are not being disturbed may be the most critical determinant of impacts from aircraft overflights.

Brackney, A.W. and J.W. Hupp. 1993. Autumn diet of Snow Geese staging in northeastern Alaska. Journal of Wildlife Management 57(1):55-61. http://www.jstor.org/stable/3809000

Abstract - The coastal plain of the Arctic National Wildlife Refuge (ANWR) is used by lesser snow geese (Chen caerulescens caerulescens) in autumn for premigratory staging. To better understand the potential impacts of human disturbance on lesser snow geese, we investigated species composition of, and temporal and age-related variation in, their diet during staging. Depending on age and time of collection, between 35.2 and 94.1% of the diet (aggregate percent wet mass, $n = 75$) consisted of 2 species of plants; underground stems of tall cotton-grass (Eriophorum angustifolium), and aerial shoots of northern scouring-rush (Equisetum variegatum). The diet varied between August and September ($P = 0.0089$), morning and afternoon ($P < 0.0001$), but not between age classes ($P = 0.066$). Throughout staging, lesser snow geese consumed more tall cotton-grass during the afternoon than during the morning ($P < 0.05$). Tall cotton-grass was a larger component of the afternoon diet in September than in late August ($P < 0.05$). In September, lesser snow geese consumed more northern scouring-rush in the mornings than in the afternoon ($P < 0.05$). Nighttime freezing, interspecific differences in nutritional quality, and plant senescence likely constrained the diet of lesser snow geese to a small number of food items. Because alternative foods may not be available, human disturbance should be minimized in areas that provide these forage species. The coastal plain of the Arctic National Wildlife Refuge (ANWR) is used by lesser snow geese (Chen caerulescens caerulescens) in autumn for premigratory staging. To better understand the potential impacts of human disturbance on lesser snow geese, we investigated species composition of, and temporal and age-related variation in, their diet during staging. Depending on age and time of collection, between 35.2 and 94.1% of the diet (aggregate percent wet mass, $n = 75$) consisted of 2 species of plants; underground stems of tall cotton-grass (Eriophorum angustifolium), and aerial shoots of northern scouring-rush (Equisetum variegatum). The diet varied between August and September ($P = 0.0089$), morning and afternoon ($P < 0.0001$), but not between age classes ($P = 0.066$). Throughout staging, lesser snow geese consumed more tall cotton-grass during the afternoon than during the morning ($P < 0.05$). Tall cotton-grass was a larger component of the afternoon diet in September than in late August ($P < 0.05$). In September, lesser snow geese consumed more northern scouring-rush in the mornings than in the afternoon ($P < 0.05$). Nighttime freezing, interspecific differences in nutritional quality, and plant senescence likely constrained the diet of lesser snow geese to a small number of food items. Because alternative foods may not be available, human disturbance should be minimized in areas that provide these forage species.The coastal plain of the Arctic National Wildlife Refuge (ANWR) is used by Lesser Snow Geese (*Chen caerulescens caerulescens*) in autumn for premigratory staging. To better understand the potential impacts of human disturbance on Lesser Snow Geese, we investigated species composition of, and temporal and age-related variation in, their diet

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Derksen, D.V., K.S. Bollinger, D. Esler, K.C. Jensen, E.J. Taylor, M.W. Miller, and M.W. Weller. 1992. Effects of aircraft on behavior and ecology of molting Black Brant near Teshekpuk Lake, Alaska. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Waterfowl Management final unpublished report.

Derksen, D.V., W.D. Eldridge, and M.W. Weller. 1982. Habitat ecology of Pacific Brant and other geese moulting near Teshepuk Lake, Alaska. Wildfowl 33:39-57.

Abstract - Behaviour, habitat selection, and foods of moulting Pacific Black Brant *Branta bernicla nigricans* and Canada Geese *Branta canadensis* were studied in 1977 and 1978, together with more general observations of White-fronted Geese *Anser albifrons*, at two large freshwater lakes near the Beaufort Sea in arctic Alaska. Molting Brant and Canada Geese gathered in large flocks of up to 1,000 and 3,000, respectively, but flock size in White-fronted Geese was much smaller. Feeding flocks moved rapidly along shorelines and returned to the same sites every three to four days. All three species were highly social. Flocks responded to aircraft by moving from feeding or resting sites to the safety of open water or ice floes. Feeding dominated the 24-hour cycle and seemed most intense in morning and early evening hours. Brant and Canada Geese preferred moss zones immediately adjacent to open water compared to sedge zones more distant from the security of the lake. *Deschampsia* sp. and *Carex* sp. were the most important grass and sedge, respectively, found in Brant and Canada Geese droppings. Mosses were also found in droppings from both species at both sites, but percentages were considered abnormally high probably due to their tendency to fragment more readily than vascular plants. Grasses were higher in nitrogen and nonstructural carbohydrates than sedges. Percentage nitrogen, as well as phosphorous and potassium in above ground biomass declined from early July through early August and peaked as geese were in their second week of wing molt. Mosses had low values for all mineral and organic nutrients except calcium which was well above sedges and grasses. Vegetation cover and density were not significantly altered by flocks of grazing Brant and Canada Geese, but height and weight (biomass) of forage plants were significantly greater inside than outside exclosures. These data also demonstrated that molting geese grazed the moss zone more intensively than the sedge zone. Protection of the Cape Halkett peninsula from petroleum development is recommended because of the unique combination of large isolated lakes that afford protection to molting geese, and nutrient-rich food supplies that occur in abundant drained basins.

Derksen, D.V., M.V. Wellera, and W.D. Eldridge. 1979. Distributional ecology of geese molting near Teshepuk Lake, National Petroleum Reserve-Alaska. Pp. 189-207 in R.L. Jarvis and

J.C. Bartonek (eds.), Management and biology of Pacific Flyway geese. Corvallis, OR: Oregon State University Press.

Flint, P.L., E,J. Mallek, R.J. King, J.A. Schmutz, K.S. Bollinger, and D.V. Derksen. 2008. Changes in abundance and spatial distribution of geese molting near Teshekpuk Lake, Alaska: interspecific competition or ecological change? Polar Biology 31(5):549-556. https://doi.org/10.1007/s00300-007-0386-8

Abstract - Goose populations molting in the Teshekpuk Lake Special Area of the National Petroleum Reserve-Alaska have changed in size and distribution over the past 30 years. Black Brant (*Branta bernicla nigricans*) are relatively stable in numbers but are shifting from large, inland lakes to salt marshes. Concurrently, populations of Greater White-fronted Geese (*Anser albifrons frontalis*) have increased seven fold. Populations of Canada Geese (*Branta canadensis* and/or *B. hutchinsii*) are stable with little indication of distributional shifts. The Lesser Snow Goose (*Anser caerulescens caerulescens*) population is proportionally small, but increasing rapidly. Coastline erosion of the Beaufort Sea has altered tundra habitats by allowing saltwater intrusion, which has resulted in shifts in composition of forage plant species. We propose two alternative hypotheses for the observed shift in Black Brant distribution. Ecological change may have altered optimal foraging habitats for molting birds, or alternatively, interspecific competition between Black Brant and Greater White-fronted Geese may be excluding Black Brant from preferred habitats. Regardless of the causative mechanism, the observed shifts in species distributions are an important consideration for future resource planning.

Flint, P.L., J.A. Reed, J.C. Franson, T.E. Hollmen, J.B. Grand, M.D. Howell, R.B. Lanctot, D.L. Lacroix, and C.P. Dau. 2003. Monitoring Beaufort Sea waterfowl and marine birds. Anchorage, AK: U.S. Department of the Interior, Geological Survey, Alaska Science Center OCS Study MMS 2003-037.

Abstract - We present the results from four seasons of a multifaceted research program designed to assess the breeding ecology of Pacific Common Eiders (*Somateria mollissima vnigra*) and molting ecology of Long-tailed Ducks (*Clangula hyemalis*) along the Beaufort Sea coast of Alaska. An aerial survey component of this study was completed in 2000 and presented as a separate report (Fischer et al 2002). Our study area was split into an Industrial Area adjacent to current oilfield development to the west of Prudhoe Bay and an undeveloped Control Area around Flaxman Island.

Long-tailed Ducks congregate in the lagoon system of the Beaufort Sea for a postbreeding molt period from mid-July through mid-September. During this time the lagoons host 10-30,000 flightless Long-tailed Ducks. The combination of their large numbers, limited mobility, nutritional demands along with a declining population trend has led to concern for this species. In 1999 and 2000, we collected ducks through the molt period for a study of body condition, molt timing, and flight parameters. The dynamics of body composition during the molt period act to minimize the flightless period for Long-tailed Ducks. These ducks meet their nutritional demands by foraging during the molt period, but there is no indication that they are resource limited. Body condition was not affected by experimental boat disturbances or proximity to industrial development. During 2000-2002, we studied aspects of movement, site fidelity, habitat use, and foraging using radio telemetry. In general, Long-tailed Ducks forage in the lagoons by day and roost along the barrier islands at night. Movement patterns of Long-tailed Ducks among years and areas are highly variable with some individuals showing a great deal of mobility. We have not seen effects of disturbance (including underwater seismic gunning) on movement, habitat use, or foraging; rather

weather (esp., wind) appears to be the primary influence on these behaviors. To examine the role of disease and contaminants on Long-tailed Ducks, we have analyzed blood and cloacal samples taken from live ducks and tissue samples from carcasses. Blood levels of lead were low and there were no major differences in concentrations of trace elements between the Industrial and Control Areas. We identified an adenovirus outbreak as the cause of poor body condition and mortality of Long-tailed Ducks in the Control Area in 2000. Our data suggest that molting Long-tailed Ducks are more influenced by natural phenomena such as wind and disease than human disturbance.

There is concern for the Common Eiders of the Beaufort Sea due to recent dramatic population declines. Along the arctic coast of Alaska, the greatest concentration of breeding Common Eiders is in the central Beaufort Sea where they nest almost exclusively on barrier islands. We used aerial surveys and ground based nest monitoring to assess the breeding ecology of Common Eiders in our study areas. Both aerial surveys and ground based nest searches show a continued decline in nesting effort since 1999. This decline parallels increasingly late sea ice breakup and we believe that it is in part due to eiders forgoing nesting because of poor conditions on breeding grounds. All of our measures of productivity (nesting effort, clutch size, hatch success, and fledging success) are low and substantially below those of Pacific Common Eiders nesting on the Yukon-Kuskokwim Delta. Predation by Arctic Foxes and Glaucous Gulls is the greatest contributor to nest failure. Of 52 broods followed in 2000 and 2001, none were known to survive until fledging. A reovirus, similar to one responsible for a major die-off in Finland, was isolated from two duckling carcasses collected in 2000. Disease and predation may be responsible for poor duckling survival. Concentrations of lead and mercury in blood and eggs were lower than on the Yukon-Kuskokwim Delta. Our data do not show an effect of industrial development on Common Eiders, with the possible exception of an increased risk of predation for eiders breeding near the oilfields. With the breeding success that we have documented since 2000, this population will not persist on its own. We see three possible scenarios for this population: 1) the population may be declining rapidly, 2) the population is maintained by recruitment from other populations, or 3) the population is maintained by infrequent years of high recruitment. Regardless, there is cause for significant concern about the long-term viability of this population.

Flint, P.L., J.A. Reed, D.L. Lacroix, and R.B. Lanctot. 2016. Habitat use and foraging patterns of molting male Long-tailed Ducks in lagoons of the Central Beaufort Sea, Alaska. Arctic 69(1):19-28. http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/article/view/4544

Abstract - From mid-July through September, 10 000 to 30 000 Long-tailed Ducks (*Clangula hyemalis*) use the lagoon systems of the central Beaufort Sea for remigial molt. Little is known about their foraging behavior and patterns of habitat use during this flightless period. We used radio transmitters to track male Long-tailed Ducks through the molt period from 2000 to 2002 in three lagoons: one adjacent to industrial oil field development and activity and two in areas without industrial activity. We found that an index to time spent foraging generally increased through the molt period. Foraging, habitat use, and home range size showed similar patterns, but those patterns were highly variable among lagoons and across years. Even with continuous daylight during the study period, birds tended to use offshore areas during the day for feeding and roosted in protected nearshore waters at night. We suspect that variability in behaviors associated with foraging, habitat use, and home range size are likely influenced by availability of invertebrate prey. Proximity to oil field activity did not appear to affect foraging behaviors of molting Long-tailed Ducks.

Franson, J.C., T.E. Hollmén, P.L. Flint, J. B. Grand, and R.B. Lanctot. 2004. Contaminants in molting Long-tailed Ducks and nesting Common Eiders in the Beaufort Sea. Marine Pollution Bulletin 48:504-513. https://doi.org/10.1016/j.marpolbul.2003.08.027

Abstract - In 2000, we collected blood from long-tailed ducks (*Clangula hyemalis*) and blood and eggs from common eiders (*Somateria mollissima*) at near-shore islands in the vicinity of Prudhoe Bay, Alaska, and at a reference area east of Prudhoe Bay. Blood was analyzed for trace elements and egg contents were analyzed for trace elements, organochlorine pesticides, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons. Except for Se (mean=36.1 μg/g dry weight (dw) in common eiders and 48.8 μg/g dw in long-tailed ducks), concentrations of trace elements in blood were low and, although several trace elements differed between areas, they were not consistently higher at one location. In long-tailed ducks, Se in blood was positively correlated with activities of two serum enzymes, suggestive of an adverse effect of increasing Se levels on the liver. Although common eiders had high Se concentrations in their blood, Se residues in eggs were low (mean=2.28 μg/g dw). Strontium and Ni were higher in eggs near Prudhoe Bay than at the reference area, but none of the other trace elements or organic contaminants in eggs differed between locations. Concentrations of Ca, Sr, Mg, and Ni differed among eggs having no visible development, early-stage embryos, or late-stage embryos. Residues of 4,4′-DDE, *cis*-nonachlor, dieldrin, hexachlorobenzene, oxychlordane, and *trans*-nonachlor were found in 100% of the common eider eggs, but at low concentrations (means of 2.35–7.45 μg/kg wet weight (ww)). The mean total PCB concentration in eggs was 15.12 μg/kg ww. Of PAHs tested for, residues of 1- and 2-methylnaphthalene and naphthalene were found in 100% of the eggs, at mean concentrations of 0.36–0.89 μg/kg ww.

Fuller, T., D.P. Morton, and S. Sakar. 2008. Incorporating uncertainty about species' potential distributions under climate change into the selection of conservation areas with a case study from the arctic coastal plain of Alaska. Biological Conservation 141(6):1547-1559.

Abstract – This analysis presents a conservation planning framework for decisions under uncertainty and applies it to the Arctic Coastal Plain of Alaska. Uncertainty arises from variable distributional shifts of species' ranges due to climate change. The planning framework consists of a two-stage optimization model that selects a nominal conservation area network in the first stage and evaluates its performance under the climate scenarios in the second stage. The model is applied to eleven at-risk species in Alaska including the threatened Spectacled Eider and Steller's Eider sea ducks and the polar bear. The 109th United States Congress and 2008 federal budget proposed opening for oil and gas development the ''1002 Area'' of the Arctic National Wildlife Refuge, which intersects the Plain. This analysis finds that, if Arctic Alaska experiences 1.5°C of warming by 2040 (as predicted by the Intergovernmental Panel on Climate Change's A2 scenario), then potential habitat will decrease significantly for eight of these at-risk species, including the polar bear. This analysis also shows that there is synergism between oil and gas development and climate change. For instance, climate change accompanied by no development of the 1002 Area results in an increase of potential habitat for Steller's Eider. However, if development accompanies climate change, then there is a 20% decrease in that area. Further, this analysis quantifies the tradeoff between development and maintenance of suitable habitat for at-risk species.

Ganter, B., and F. Cooke. 1998. Colonial nesters in a deteriorating habitat: site fidelity and colony dynamics of Lesser Snow Geese. Auk 115(3):642-652.

Abstract - Birds that exhibit a high degree of natal and breeding philopatry and normally breed in stable environments may suffer costs of philopatry if their habitat deteriorates. Female Lesser Snow Geese (*Chen caerulescens caerulescens*) are highly site faithful; however, recent increases in numbers of breeding birds have resulted in widespread habitat destruction in some colonies. Using capture-recapture modeling techniques on multiple resightings of marked individuals, we examined whether breeding-site fidelity of adult Snow Geese has changed over time in a colony that has grown rapidly and in which habitat quality has declined severely during the past two decades. In addition, we examined the age structure of breeding birds to investigate natal-site fidelity to formerly central areas of the colony. Only slight changes in adult breeding-site fidelity were detected over 10-year periods, despite the deterioration of nesting and brood-rearing habitats in and near the investigated areas. However, increasing mean ages of breeding birds in formerly central areas of the colony indicated a lack of recruitment into those areas; young birds must have preferred to settle at the colony periphery even when vacant spaces in the center were available. Together with a small amount of movement by adult birds, the settlement pattern of young birds has led to a long-term shift in the colony location as a whole.

Hansen, H.A., P.E.K. Shepherd, J.G. King, and W.A. Troyer. 1971. The Trumpeter Swan in Alaska. Wildlife Monographs 26. http://www.jstor.org/stable/pdf/3830542.pdf?refreqid=excelsior%3Adcfa755ff6f26236484416273ed9ced9

Jensen, K.C. 1990. Responses of molting Pacific Black Brant to experimental aircraft disturbance in the Teshekpuk Lake Special Area, Alaska. College Station, TX: Texas A&M University Ph.D. dissertation.

Johnson, S.R. 2000a. Lesser Snow Goose. Pp. 233-257 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Johnson, S.R. 2000b. Pacific Eider. Pp. 259-275 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Kendall, S. 2005. Surveys of breeding birds on barrier islands in the Arctic National Wildlife Refuge, 2003-2004. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Arctic National Wildlife Refuge. https://catalog.data.gov/dataset/surveys-of-breeding-birds-on-barrier-islands-in-the-arctic-national-wildlife-refuge

Executive Summary - Coastal islands in Alaska's Beaufort and Chukchi Seas are used for nesting by several species of waterfowl and marine birds. Much of the northern coast of the Arctic National Wildlife Refuge is bounded by barrier islands. These islands are low elevation and have little or no vegetation, making them somewhat transient. They could be susceptible to increased rates of change due to rising sea levels and increased erosion associated with global climate change. This habitat could also be affected by disturbance and oil spills associated with offshore oil development in the Beaufort Sea. Birds nesting on the islands may be vulnerable to other types of human disturbance as well, including use of the islands for recreational purposes, subsistence fishing camps, and subsistence egg collection. In northern Alaska these islands are the primary breeding habitat for the Pacific race of Common Eiders *(Somatcria mollissima v-nigra*), and there is evidence of declines in the populations of this species that breed in northeast Alaska and northwest Canada. The causes of this decline are unknown and may occur outside of the bird's breeding areas. Two

of the other three eider species that breed in Alaska have declined to a level that they are now listed as threatened under the Endangered Species Act. It is therefore important to monitor and better understand the dynamics of Common Eider populations here.

Beginning in 1999, aerial surveys have been conducted annually to census birds breeding in coastal areas of Alaska's Chukchi and Beaufort Seas. Ground-based investigations of breeding birds have been done periodically since the 1970s on islands in the central Beaufort Sea. However, few ground-based surveys have been conducted on barrier islands on the Refuge. The only complete ground-based survey of the Refuge's islands was conducted in 1976. To help fill this data gap, we conducted surveys on the islands from Demarcation Bay to Barter Island in July of 2003 and from Barter Island to Brownlow Point in July 2004.

Consistent with previous surveys in this region and in the Central Beaufort Sea, Common Eiders were the most abundant bird nesting on the islands, accounting for 341 of 460 nests. We also found Long-tailed Duck *(Clangula hyemalis; n==6),* Glaucous Gull *(Larus hyperboreus; n=92),* Arctic Tern *(Sterna paradisaea;* n=20) and Black Guillemot (*Cepphus grylle; n*= 1) nests. Most eiders were incubating at discovery *(n*= 1 77), but 21 nests had hatched, and 119 had failed. Eiders were found on most islands, but there were concentrations of nests at both ends of Icy Reef, on Tapkaurak Spit, on Arey Island and on Collinson Point Island. Elevation of nests above sea level was 0 to 6 m and the distance from water was 0.5 to 200m. Eider nests were mostly located in driftwood. Gull and tern nests were mostly in open areas or areas with little driftwood.

The islands between Demarcation Bay and Brownlow Point had a much higher number of nesting birds in 2003-04 than had been found in 1976. The difference was most dramatic for Common Eiders, for which 14 active nests were found in 1976 versus 177 in 2003-04. This large increase in nesting birds is contrary to what would be expected based on population trends observed during migration surveys at Point Barrow. Since there is only one year of data and no other concurrent surveys for comparison, it is not possible to determine if 1 is representative of that earlier period. We did find consistency when comparing our data with estimates of birds breeding in the area from recent aerial surveys. The differences in the two time periods may be due to changes in habitat conditions such as ice cover in lagoons or the availability driftwood for nest sites. It is possible that conditions in 1976 were unfavorable for eiders to breed. This situation could occur during a cold summer with low lemming populations. Under these conditions, when Arctic foxes have limited food sources, they are more likely to access the barrier islands and negatively affect the birds breeding there.

We compared our results to ground surveys of breeding birds conducted on islands elsewhere in the Beaufort Sea between 1970 and 2001. Relative species abundance was similar and nest densities were within the temporal and spatial range of densities found elsewhere in the Beaufort Sea.

If we omit nests that had failed prior discovery, our results were consistent with results of annual aerial surveys in this region in 2003, but lower than the estimates from the 2004 aerial survey. The aerial surveys are probably sufficient to monitor trends in the number of eiders nesting on the islands. Periodic ground-based surveys should be conducted at 3 year intervals to collect data that cannot be collected during aerial surveys. This would include nest site-specific habitat data, nest status, other nest parameters, and data on species that are difficult to observe from aircraft, Arctic Terns. An added objective of future surveys

should be developing methods to characterize available nesting habitat on the islands and to monitor habitat changes.

Kertell, K. 2000. Pacific loon. Pp. 181-195 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

King, J.G. 1970. The swans and geese of Alaska's Arctic slope. Wildfowl 21:11-17.

Abstract - A mid-summer aerial search was made on the 23,000 square miles of waterfowl habitat on Alaska's Arctic slope. Observations included 159 ~~Whistling~~ Tundra Swan (*Olor columbianus*); 10,278 Canada Geese (*Branta canadensis*); 20,981 Black Brant (*B. nigricans*); 6,730 White-fronted Geese (*Anser albifrons*); and 458 Snow Geese (*Chen hyperborea*). A fairly concentrated molting area for geese was found near Cape Ralkett. Expanded population estimates are given. Discussion includes: better census methods, the relation of these birds to areas of greater nesting concentration; possibility for banding and other studies; and the possibility of increasing abundance of snow geese. It is concluded that this large block of low density habitat could be representative of a vast Arctic area of low production that may be of considerable importance to the species involved.

Korschgen, C.E., and R.B. Dahlgren. 1992. Human disturbances of waterfowl: causes, effects, and management. Fish and Wildlife Leaflet 13.2.15. Washington, D.C.; U.S. Fish and Wildlife Service.

Management Considerations - Fortunately, numbers of breeding waterfowl usually increase in response to reduction or elimination of human disturbances. For the benefit of waterfowl, the harm from human disturbances must be minimized or eliminated. Management alternatives that reduce human disturbances of waterfowl include:

1. increasing the quantity, quality, and distribution of foods to compensate for energetic costs from disturbances;

2. establishing screened buffer zones around important waterfowl roosting and feeding areas;

3. reducing the number of roads and access points to limit accessibility to habitats;

4. creating inviolate sanctuaries; and

5. reducing the sources of loud noises and rapid movements of vehicles and machines.

Disturbances occur chiefly during all critical parts of the annual cycle of waterfowl—nesting, brood rearing, migration, and wintering. Each part of the cycle is crucial to the breeding and survival of waterfowl populations. Common to all parts of the cycle is disturbance while feeding, which may increase flight time and decrease feeding time. Disturbances of nesting birds may cause abandonment of the nest, disruption of the pair bond, reduction in clutch size, increased egg mortality, abandonment of the nesting area, and increased predation of the nest. Disturbances during brood-rearing may cause exhaustion of young and an increase in losses from predation. These disturbances can be lessened or their effects mitigated on refuges or other areas managed for waterfowl. Because disturbances are sometimes caused by professional wildlife managers or researchers and private citizens,

creation of sanctuaries is often necessary at critical times and locations. Access to roads and trails can be limited for professionals and for bird-watchers. Activities of other users of wildlife, such as trappers and hunters, may have to be restricted in space and time; boating, angling, camping, and picnicking may be restricted similarly. Human disturbance often is increased by viewing platforms and waterfowl can be viewed at a closer distance if the platform is screened with vegetation and made more like a blind. Proper screens and appropriate control of noise let people really enjoy wildlife close at hand.

Structures such as pumping stations and maintenance buildings on wildlife areas should be screened and placed where necessary human visits cause the least disturbance of waterfowl. Disturbances, particularly at critical times of the year, can be reduced notably by restricting access of pedestrians, autos, and boats; by regulating activities such as farming, grazing, bait collecting, camping, hunting, fishing, and trapping; and by prohibiting the use of nets that can entrap diving ducks. Access by dogs and other pets should not be permitted in critical areas during the nesting and brood-rearing periods. Airboats, aircraft, and ATVs are often useful to managers of waterfowl and wetland, but their use must be carefully planned to minimize harm from sight or sound. Construction of dikes, canals, water control structures, roads, and similar structures and military uses of wetlands or refuge areas should be scheduled for non-critical times in the annual activity cycle of waterfowl.

Disturbance of feeding waterfowl can sometimes be mitigated by acquiring feeding areas on privately owned land to create a sanctuary or by practicing moist soil management and thus increasing the availability of highly nutritious foods in the refuge or wetland areas. With careful planning, deleterious effects of human disturbance on waterfowl can be mitigated or eliminated by creating sanctuaries in time and space.

Managers must aggressively protect waterfowl from any human disturbance that reduces productivity and health of populations. To accomplish this goal, managers must resolve conflicting interests between needs of the public and needs of wildlife and researchers must gather more data to provide a greater range of management options.

Lacroix, D., R.B. Lanctot, J.R. Reed, and T.L. McDonald. 2003. Effect of underwater seismic surveys on molting male Long-tailed Ducks in the Beaufort Sea, Alaska. Canadian Journal of Zoology 81(11):1862-1875. https://doi.org/10.1139/z03-185

Abstract - Large numbers of Long-tailed Ducks (*Clangula hyemalis*) (10,000-30,000) undergo a postnuptial wing molt along barrier islands of the Beaufort Sea, Alaska. To investigate the potential effects of underwater seismic activities on this species, we monitored the number and diving behavior of molting Long-tailed Ducks before, during, and after seismic activities in a seismic area and two control areas nearby between Jul and Sep 2001. Aerial surveys documented a decline in duck numbers in both seismic and control areas during the period of seismic activity. We used automated data-collection computers to monitor the presence and diving behavior of radio-equipped Long-tailed Ducks residing within 2.5 km of a series of computer setups located along the barrier islands and on the mainland. A statistical analysis based on a modified before–after control–impact approach found no difference in indices of site fidelity or diving intensity between the seismic area and two control areas. Thus, we found no effect of seismic activity on movements and diving behavior of molting Long-tailed Ducks. These results should be evaluated carefully, however, as logistical and ecological factors limited our ability to detect more subtle disturbance effects. We recommend additional studies on other bird species to fully understand the effects of underwater seismic testing.

Lysne, L.A., E.J. Mallek, and C.P. Dau. 2004. Near shore surveys of Alaska's Arctic coast, 1999-2003. Fairbanks, AK: Department of the Interior, Fish and Wildlife Service, Migratory Bird Management, Waterfowl Branch unpublished report. https://www.fws.gov/alaska/mbsp/mbm/waterfowl/surveys/pdf/NSSANC.pdf

Mallek E.J., R. Platte, and R. Stehn. 2005. Aerial breeding pair surveys of the Arctic coastal plain of Alaska – 2004. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service unpublished report.

Miller, M.W., K.C. Jensen, W.E. Grant, and M.W. Weller. 1994. A simulation model of helicopter disturbance of molting Pacific Black Brant. Ecological Modeling 73(3-4):293-309. https://doi.org/10.1016/0304-3800(94)90067-1

Abstract - We describe a simulation model designed to study the effects of helicopter disturbance on molting Pacific Black Brant near Teshekpuk Lake, Alaska. Locations of 18,118 brant were digitized into the model based on 10 years of population survey data. Bell 206 and Bell 412 helicopters were simulated flying across the molting grounds along two routes between two airfields. The model determined the behavioral and energetic response of birds encountered by the aircraft during an overflight. Altitude and frequency of overflights were held constant during a simulated 28-day molting period, but were varied among simulations. The model provided the degree of weight loss these birds experienced due to helicopter disturbance. The effects of overflights on brant were classified into five risk categories based on weight. For both routes, the number of flocks and birds in each category was determined for each altitude, aircraft type, and overflight frequency. Simulation results indicated that the model can be used to identify flight-line modifications that result in significantly decreased disturbance to the birds.

Monda, M.J. 1991. Reproductive ecology of Tundra Swans on the Arctic National Wildlife Refuge, Alaska. Moscow, ID: University of Idaho, Ph.D. dissertation.

Abstract – I studied Tundra Swan (*Cygnus columbianus*) reproductive ecology on the Arctic NWR, 1988-1990. These data represent the first comprehensive research on the summer ecology of Tundra Swans. During 3 field seasons I recorded data for 110 nests. Nest sites were frequently in aquatic-marsh and graminoid-marsh habitats, and seldom in upland and partially vegetated habitats. The 3-year average nesting success was 76%. Nest losses were attributed to avian predators and brown bear (*Ursus arctos*). Swans usually departed their nests when I was >500 m (1650 ft) away and did not return while I was within their view. Uncovered eggs were vulnerable to avian predation and thermal stress.

I created 16 artificial swan-nest mounds to investigate factors that contributed to nest mound permanency. Several plant species resprouted from sod used for mound construction and vegetal cover after 1 year was 28-66%. The presence of feces and prey remains indicated that these mounds were heavily used by many animals. A permafrost core was retained under the mounds throughout the summer. Swans may benefit from using old nests mounds by having nest sites that are above snow and melt water, requiring less time for nest reconstructions.

Broods frequently foraged in aquatic-marsh and saline-graminoid-shrub habitats, and rarely in graminoid-shrub, upland, and partially vegetated habitats. Brood-foraging habitats changed over time; young cygnets grazed in uplands while older broods foraged more in

wetlands. Wetlands that contained sheathed pondweed (*Potamogeton vaginatus*) were uncommon, but were used extensively by broods.

I conducted field experiments to evaluate effects of clipping and fertilization from swan feces on above-ground biomass production and plant-species composition. Swan feces did not have an overall effect or interact with clipping for any response variables. Clipping increased within-year biomass production, and increased total-stem densities. The effects caused by clipping differed among plant species: Hoppner sedge (*Carex subspathacea*) increased, tundra grass (*Dupontia fisheri*) did not change, and chickweed (*Sellaria humifusa*) decreased. Traditional use of foraging sites may enhance grazing lawns by increasing biomass production within years, and increasing plant species that were tolerant to grazing.

<u>Management Implications</u> – Human activities that disrupt the tight time schedule of breeding swans would likely hinder breeding success. Disturbance during incubation would be particularly harmful, because of their sensitivity at this time. Swans with broods were also sensitive to disturbance, but to a lesser degree due to the mobility of cygnets. Potential impacts could be minimized by restricting anthropogenic disturbances on nesting areas during incubation.

Populations of nest predators (Common Raven, gulls, and foxes) could increase if oil-production facilities practice "poor housekeeping" (Clough et al. 1987). Arctic foxes would benefit from construction activities, because they readily used culverts and other construction materials for den sites (Clough et al. 1987). I infrequently observed bears on swan nesting areas, which may have accounted for the rarity of nest predation by bears. However, coastal development could attract bears by improper garbage or food handling, and illegal feeding (Clough et al. 1987). An increased presence of bears on swan nesting areas could have a dramatic effect on swan production through increased nest predation. Nest predation by bears was associated with large population decline of Dusky Canada Geese (*Branta canadensis occidentalis*) that nested on the Copper River Delta, AK (Cornely et al. 1985).

Tundra Swans may be an integral part of the wildlife community on the Arctic NWR. Swans modify the habitat by creating nest mounds and modifying grazing lawns. These modifications, particularly the nest building, may enhance habitat for other wildlife species by providing structural diversity to a fairly uniform environment. Use of swan nests by other species was not uncommon. In addition swans are members of multispecies nesting association. Mutualistic interactions may be important in maintaining biological diversity of communities (Gilbert 1980). Maintaining Tundra Swans could be important for maintaining the biological integrity of this arctic ecosystem.

To accurately assess natural changes or environmental degradation on the arctic, many variables need to be carefully monitored. The Tundra Swan may be an excellent indicator species for arctic ecosystem health, and data on population dynamics can be collected easily and cost-effectively, relative to other more cryptic species.

<u>Conclusions</u>.

1. Swans were highly sensitive to human disturbance during incubation and an increase in human activities on the nesting ground would likely increase egg losses to avian predators.

2. Swans are an interactive member of the wildlife community at Arctic NWR. The form interspecific nesting associations with several species, many species use swan nest mounds (for observation perches, display sites, scent posts), and may enhance the habitat for other grazing species. Thus, impacts to swans may in turn influence other species.

3. Swans have specific habitat requirements at Arctic NWR, particularly during brood rearing. Protection of specific habitat types may be important for maintaining swan populations.

4. Swans use the same nesting territories for many years. Traditional use of territories may be important for swan productivity. Disturbance of traditionally used sites may impact swan populations.

5. At Arctic NWR, swans are limited by available time to successfully reproduce. Any activities that interfere with the efficient use of time by swans may impact the population.

Clough, N.K., P.C. Patton, and A. C. Christiansen. 1987. Arctic National Wildlife Refuge, Alaska, coastal plain resources assessment: report and recommendation to the Congress of the United States and legislative environmental impact statement. Vol. 1. Washington, D.C.; U.S. Dept. Interior; Fish and Wildlife Service, Geological Survey, and Bureau of Land Management.

Cornely, J.E., B.H. Cambell, and R.L. Jarvis. 1985. Productivity, mortality and population status of dusky Canada Geese. Transactions North American Wildlife and Natural Resources Conference 50:540-548.

Gilbert, L.E. 1980. Food web organization and conservation of neotropical diversity. Pp. 11-33. In M.E. Soule and B.A. Wilcox (eds.), Conservation biology: an evolutionary–ecological perspective. Sunderland, MA; Sinauer.

Monda, M.J., J.T. Ratti, and T.R. McCabe. 1994. Reproductive ecology of tundra swans on the Arctic National Wildlife Refuge, Alaska. Journal of Wildlife Management 58(4):757-773.

Abstract - Management of Tundra Swans (*Cygnus columbianus*) is hampered by a lack of information on their nesting and brood-rearing ecology. We studied tundra swan nesting and brood-rearing ecology on the Arctic NWR, AK, 1988-90. Nest success was 58% (n = 31) in 1988, 83% (n = 36) in 1989, 84% (n = 43) in 1990, and 76% (n = 110) for the 3 years. Nests were located predominately in marshes dominated by sheathed pondweed (*Potamogeton vaginatus*), mare's tail (*Hippuris vulgaris*), and Hoppner sedge (*Carex subspathacea*), or by pendent grass (*Arctophila fulva*), water sedge (*C. aquatilis*), and tall cotton grass (*Eriophorum angustifolium*). Nests were seldom located in upland or partially vegetated habitats and were near coastal lagoons or large coastal lakes. Incubating swans were easily disturbed by ground observers and left their nests when we were 500-2,000 m from the nest. Swans did not cover eggs with nest material prior to departure; thus, eggs were vulnerable to avain predation and thermal stress. Brood-foraging sites on the Kongakut Delta (n = 41) were frequently in aquatic-marsh (59%) and saline graminoid-shrub (29%) habitats, occasionally in graminoid-marsh (7%) and partially vegetated (5%) habitats, and absent from upland, graminoid-shrub-water sedge, and graminoid-shrub-cotton grass habitats. Brood-foraging sites on the Canning Delta (n = 35) were frequently in graminoid-marsh (46%), graminoid-shrub-water sedge (26%), and aquatic-marsh (23%) habitats, occasionally in graminoid-shrub-cotton grass (3%) and upland habitats (3%), and absent from saline graminoid-shrub and partially vegetated habitats. Young cygnets grazed in terrestrial habitats more frequently than older broods on the Kongakut (P = 0.003) and

Canning (P = 0.053) deltas. Wetlands with sheathed pondweed were uncommon but preferred by broods (P = 0.001). Using field experiments, we evaluated effects of swan grazing and fertilization from feces on aboveground biomass production and plant-species composition. Fertilization from swan feces did not have an overall effect (P = 0.991) or interact with clipping (simulated grazing with hand shears) (P = 0.881) for any response variable investigated. Clipping increased total vegetational biomass the year of clipping (P = 0.001), decreased biomass the year after clipping (P = 0.001), and increased total shoot densities (P = 0.017). Shoot densities after clipping increased for Hoppner sedge (P = 0.010), did not change for tundra grass (*Dupontia fischeri*) (P = 0.296), and decreased for chickweed (*Stellaria humifusa*) (P = 0.006). Traditional use of foraging sites may enhance grazing areas by increasing plant production the year of grazing and densities of plant species that tolerate grazing. Protection of aquatic-marsh, graminoid-marsh, and saline graminoid-shrub habitats, particularly those supporting sheathed pondweed and traditionally used nesting areas, is important for maintaining current swan populations on Arctic NWR.

Mosbech, A., and D. Boertmann. 1999. Distribution, abundance and reaction to aerial surveys of post-breeding King Eiders (*Somateria spectabilis*) in western Greenland. Arctic 52(2):188-203. http://arctic.journalhosting.ucalgary.ca/arctic/index.php/arctic/article/view/922/947

Abstract - Molting and post-breeding King Eiders in western Greenland were surveyed in late Aug and early Sep of 1993, 1994, and 1995. We counted all eiders observed during fixed-winged aircraft flights along coastlines and offshore transects. The coastline in the survey area is roughly 13 400 km long, and our flightlines totaled approximately 16,500 km. The areas optimal for the birds were covered fully several times; in less suitable areas, only a fraction of the coastline was covered. Using the largest count for coastlines covered more than once, we counted a total of 22,980 King Eiders. Large numbers of King Eiders were observed at a number of remote localities on the west coast of Disko Island and in southern Upernavik. At localities considered to have frequent human disturbance, few birds were observed. Highest densities were found along coasts with sandy or muddy areas at the shorelines. Overall we estimate that 30,000-40,000 King Eiders reside in the coastal zone of western Greenland in late Aug. Even allowing for a high turnover rate, as different individuals may occupy the molting areas during the extended period from Jul to Oct, this figure can account for only half of a 1950s estimate that 200,000 males and immatures were molting in western Greenland.

Nagy, S., N. Petkov, E. Rees, A. Solokha, G. Hilton, J. Beekman, and B. Nolet. 2012. International single species action plan for the conservation of the northwest European population of Bewick's Swan (*Cygnus columbianus bewickii*). Bonn, Germany: Wetlands International and The Wildfowl and Wetlands Trust (WWT), African-Eurasian Migratory Waterbirds (AEWA) Technical Series No. 44. http://www.unep-aewa.org/sites/default/files/publication/ts44_ssap_bewicks_swan.pdf

Executive Summary - The Tundra Swan (*Cygnus columbianus*), of which the Bewick's Swan (*Cygnus columbianus bewickii*) is the Palearctic subspecies, has a global conservation status of Least Concern (BirdLife International 2010). However, the status of the species is considered as Vulnerable in Europe (BirdLife International 2004). The species is included in Appendix II of the Convention on the Conservation of the European Wildlife and Natural Habitats (Bern Convention), in Appendix II of the Convention on Migratory Species (CMS or Bonn Convention). It is also listed in category A(3) c of the African Eurasian Waterbird Agreement and in Annex I of the EU Birds Directive.

Three populations of *C. c. bewickii* have been identified, based on their winter distribution: NW European (21,500 individuals), Caspian (c. 1,000 individuals) and East Asian (c. 92,000 individuals). This action plan deals only with the population that winters in NW Europe.

The population increased dramatically during the late 1980s and early 1990s, from c. 10,000 in the mid-70s to 25,800 birds in 1990 and 29,000 in 1995 (Beekman 1997). However, a steep decline has taken place since the mid-1990s (Beekman 1997, Delany et al. 1999, Delany & Scott 2006, Wetlands International 2008); the population was estimated at 21,500 birds in 2005, and numbers have continued declining since then (Rees & Beekman 2010). The reason for the population trends and particularly the recent decrease in numbers - whether this is due to conditions on the breeding grounds, staging areas or wintering sites, or to a combination of factors - is unclear.

The Bewick's Swan breeds adjacent to shallow lakes and pools on the Arctic tundra, particularly on sedgegrass and moss-lichen tundra dotted with numerous small lakes and pools, and also in some dry land areas with willow bushes. At the breeding grounds it feeds mostly on sedge and other herbs and berries, as well as on algae and *Potamogeton*. On migration the species requires a chain of stop-over sites including shallow coastal lakes with soft sediment and good water quality as well as flooded grasslands. In winter the species traditionally occupies shallow tidal waters, coastal lagoons, inland freshwater lakes and marshes and flooded pastures, where they mostly feed on the tubers and rhizomes of *Potamogeton* spp., on *Zostera* spp. and *Chara* spp., and also on grasses and herbs. From the 1970s onwards, an increasing proportion of the Northwest European population has fed on arable land during the winter.

The population of Bewick's Swan wintering in Northwest Europe is thought to be sensitive to the impacts of climate and land-use changes, chemical pollution and infectious disease. A number of factors are likely to contribute to the decline or fluctuation of the population, but habitat changes (likelihood of this driving the population trends = High) and illegal/accidental shooting (Medium; potentially High if shooting increases) as the most important existing threats.

The action plan aims to halt the ongoing decline in the short-term, and to maintain the population minimally at its 2000 level in the long-term. Essential actions include: (a) maintaining the protected status of the species across the range of the population; (b) maintaining and, if necessary, restoring suitable aquatic macrophyta availability at key stop-over and wintering sites, through managing water level and water quality; (c) preventing negative impacts of infrastructure and industrial development by avoiding key sites, or by mitigating any potential negative impacts in the absence of alternative locations; (d) developing and (where necessary) implementing emergency plans by companies involved into exploitation and transporting petrochemicals on the Bewick's Swan's flyway to reduce mortality in case of accidents; and (e) continuing the monitoring and research of population changes and demographic parameters. Additional actions considered to be of high priority included extending the coverage and enhancing the protection of areas important for breeding and molting; managing and protecting key feeding and roosting sites in line with species requirements; reducing or preventing disturbance at key sites through zoning (e.g. of recreational activities), compensatory payments and other site management measures; increased efforts to reduce illegal shooting; avoiding key sites and flight-lines during infrastructure development; and expanding dead bird surveillance to cover the entire flyway of the NW European Bewick's Swan population.

Oates, R.M., M. McWhorter, G. Muehlenhart, and C. Bitler. 1987. Distribution, abundance and productivity of fall staging Lesser Snow Geese on coastal habitats of northeast Alaska and northwest Canada. Pp. 349-366 in Pp. 1109-1136 in G.W. Garner and P.E. Reynolds (eds.), Arctic National Wildlife Refuge coastal plain resource assessment: 1985 update report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

Phillips, L.M., A.N. Powell, E.J. Taylor, and E.A. Rexstad. 2007. Use of the Beaufort Sea by King Eiders breeding on the North Slope of Alaska. Journal of Wildlife Management 71(6):1892-1898. http://www.jstor.org/stable/4496281

Abstract - We estimated areas used by King Eiders (*Somateria spectabilis*) in the Alaskan Beaufort Sea, how distributions of used areas varied, and characteristics that explained variation in the number of days spent at sea, to provide regulatory agencies with baseline data needed to minimize impacts of potential offshore oil development. We implanted 60 King Eiders with satellite transmitters at nesting areas on the North Slope of Alaska, USA, in 2002-2004. More than 80% of marked eiders spent >2 weeks staging offshore prior to beginning a postbreeding molt migration. During postbreeding staging and migration, male king eiders had much broader distributions in the Alaskan Beaufort Sea than female eiders, which were concentrated in Harrison and Smith Bays. Distribution did not vary by sex during spring migration in the year after marking. Shorter residence times of eiders and deeper water at locations used during spring migration suggest the Alaskan Beaufort Sea might not be as critical a staging area for king eiders during prebreeding as it is postbreeding. Residence time in the Beaufort Sea varied by sex, with female King Eiders spending more days at sea than males in spring and during postbreeding. We conclude the Alaskan Beaufort Sea is an important staging area for king eiders during postbreeding, and eider distribution should be considered by managers when mitigating for future offshore development. We recommend future studies examine the importance of spring staging areas outside the Alaskan Beaufort Sea.

Ritchie, R.J., and J.G. King. 2000. Tundra Swans. Pp. 197-220 in J.C. Truett and S.R. Johnson (eds.). The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Summary - A good baseline of information has been collected for Tundra Swans *(Cygnus c. columbianus)* on the Arctic Coastal Plain of Alaska, primarily in the oil-field region. The Tundra Swan is the most numerous and widely distributed North American swan, nesting primarily in tundra habitats within 200 km of the seacoast from north-central Canada to southwestern Alaska. Studies to date have allowed biologists to annually monitor distribution of breeding swans, swan population levels, and swan productivity. These studies have also assisted with the placement of oil-field facilities. Habitat use patterns during nesting and brood-rearing, the degree of late-season mortality, and the distribution and habitat requirements of non-breeding swans are less readily studied by aerial survey, and thus are less well known. Tundra Swans have benefited greatly from the attention they have received from the regulatory, development, and research communities on the North Slope of Alaska. Cooperation between public-resource agencies and oil companies has resulted in the development of protective strategies advantageous for swans, particularly for breeding pairs. Sound stewardship of this important continental migratory bird resource will depend on these conservation efforts continuing in the future.

Schmidt, J.H., M.S. Lindberg, D.S. Johnson, and J.A Schmutz. 2009. Environmental and human influences on Trumpeter Swans habitat occupancy in Alaska. Condor 111(2):266-275. http://www.bioone.org/doi/full/10.1525/cond.2009.080102

Abstract - Approximately 70-80% of the entire population of the Trumpeter Swan (*Cygnus buccinator*) depends for reproduction on wetlands in Alaska. This makes the identification of important habitat features and the effects of human interactions important for the species' long-term management. We analyzed the swan's habitat preferences in five areas throughout the state and found that swan broods occupied some wetland types, especially larger closed-basin wetlands such as lakes and ponds, at rates much higher than they occupied other wetland types, such as shrubby or forested wetlands. We also found a negative effect of transportation infrastructure on occupancy by broods in and around the Minto Flats State Game Refuge, Kenai NWR, and Tetlin NWR. This finding is of particular interest because much of the Minto Flats refuge has recently been licensed for oil and gas exploration and parts of the Kenai refuge have been developed in the past. We also investigated the potential effects of the shrinkage of closed-basin ponds on habitat occupancy by nesting Trumpeter Swans. We compared nesting swans' use of ponds with changes in the ponds' size and other characteristics from 1982 to 1996 and found no relationships between occupancy and changes in pond size. However, we believe that the recent and rapid growth of Trumpeter Swan populations in Alaska may become limited by available breeding habitat, and anthropogenic and climate-induced changes to the swan's breeding habitats have the potential to limit future production.

Schroeder, R.L. 1984. Habitat suitability index models: Black Brant. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Office of Biological Services FWS/OBS-82/10.63. https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-063.pdf

Abstract - A review and synthesis of existing information were used to develop a habitat suitability index model for wintering habitat of the Black Brant (*Branta bernicla nigracans*). The model consolidates habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) to 1.0 (optimum habitat). Habitat suitability index (HSI) models are designed to be used with Habitat Evaluation Procedures (HEP) previously developed by the FWS.

Editor's Note – HSI developed for applications in the Pacific coast wintering habitat of Black Brant, specifically estuarine area that occur in bays or other locations protected from the ocean. Use caution in Arctic applications but model components may prove useful for developing site-specific models. Model habitat requirements include (1) minimum habitat area; (2) food component; and, (3) human disturbance.

"Human disturbance is one of the major factors restricting the abundance of Black Brant (Einarsen 1965). This model assumes that all areas of human disturbance, including a buffer zone around the disturbance, will be unusable by Black Brant regardless of eelgrass quality. Different types of human activities cause different levels of disturbance in Black Brant. Sculling (refers to hunting brant in a boat capable of travel in very shallow waters), helicopter flights, and oyster and clamming activities are highly disruptive and it is assumed that brant will avoid all areas within 183 m (600 ft) of such disturbances. Hunting (other than sculling) and flight of fixed-wing aircraft are moderately disruptive, and it is assumed that brant will avoid areas within 137 m (450 ft) of such activities. All other activities, including general boating, swimming, fishing, and shoreline development, will cause low levels of disturbance, and brant will not use areas within 91 m (300 ft) of such disturbances."

“Overall food suitability is related to the percent coverage of useable eelgrass and the availability of isolated sandy beaches for obtaining grit. It is assumed that the percent coverage of useable eelgrass is the most important variable, and thus will have a stronger influence than the presence of grit on the overall food value.”

Sedinger, J.S., and A.A. Stickney. 2000. Black Brant. Pp. 221-232 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Summary - The Black Brant is one of three recognized subspecies of brant, the smallest-bodied of the goose species. Monogamous like other geese, Black Brant breed throughout a broad range centered on Bering Strait. Spring migrants generally arrive on Alaska's North Slope in late May to early June. Fall migrants leave in largest numbers from the third week in August into early September. Anthropogenic habitat change and human activity could influence brant in the oil fields in three ways—facilities and roads could directly eliminate nesting or brood-rearing habitat; brant could leave preferred habitat in response to human activities at facilities or on roads; and, humans could provide food for predators of brant, thereby increasing predator populations and their rates of predation on brant nests or goslings. The entire Pacific Black Brant population is managed as a single unit under guidelines established by the Pacific Flyway Technical Committee. Currently, the brant management plan calls for cessation of all harvest when the 3-year running average of the midwinter index falls below 120,000. Harvest is not to be reopened until the 3-year running average rises above 145,000. The current management plan is inadequate because the breeding population of brant is composed of many nearly independent breeding units, which ought to be managed individually.

Sousa, P.J. 1985. Habitat suitability index models: Gadwall (breeding). Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Office of Biological Services FWS/OBS-82/10.100. https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-100.pdf

Suchy, W.J., and S.H. Anderson. 1987. Habitat suitability index models: Northern Pintail. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Office of Biological Services FWS/OBS-82/10.145. https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-145.pdf

Editor’s Note – HSI developed for breeding Northern Pintails of the US Prairie Pothole Region (ND, SD, w MN, sandhills of NE) including Prairie Provinces of Canada, with possibly some broader applications. Use caution in Arctic applications but model components may prove useful for developing site-specific models. Model habitat requirements include (1) cover (herbaceous wetlands, both natural and constructed wetlands); (2) minimum habitat area; and, (3) pair habitat component (e.g., conditions described as optimum for pairs with 150 wetlands totaling 65 ha (160.6 ac) per 259-ha (639.9 ac) section, which equates to an average wetland size of 0.43 ha (1.06 ac). If it is assumed that a few large wetlands will be present, then most of the wetlands will be <0.4 ha (0.98 ac).

Truett, J.C., M.E. Miller, and K. Kertell. 1997. Effects of Arctic Alaska oil development on Brant and Snow Geese. Arctic 50(2):138-146.

Abstract - Black Brant (*Branta bernicla nigricans*) and Lesser Snow Geese (*Chen c. caerulescens*) breeding in and near arctic Alaska oil fields could be affected by oil

development actions such as releases of contaminants, alteration of tundra surfaces, creation of impoundments, and human activities. These actions could affect geese directly (e.g., through oil spills) or indirectly (e.g., by altering food supplies or predator populations). Studies to date indicate no changes in the distribution, abundance, or reproduction of these geese that clearly can be attributed to development; rather, their numbers and recruitment have responded in the oil fields, as elsewhere, mainly to weather and predation. When snowmelt in spring is later than usual, the birds postpone or forego nesting, with consequent diminishment in recruitment. Predation by arctic foxes (*Alopex lagopus*), glaucous gulls (*Larus hyperboreus*), and grizzly bears (*Ursus arctos*) sometimes causes substantial losses of eggs and young, and predation by ravens (*Corvus corax*) has also been observed. Development-related changes in weather (microclimate) and loss of feeding habitat have involved small percentages of the total areas traditionally used, and populations of the birds probably have not been affected by these changes. Some studies and observations suggest that development has elevated local populations of some predators, but whether the level of predation on geese has in consequence risen above that which would have occurred in the absence of development is unknown; further investigation of this mechanism of potential impact is recommended.

Mammals: General (includes human-subsidized predators)

Burgess, R.M. 2000. Arctic fox. Pp. 159-178 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Carreker, R.G. 1985. Habitat suitability index models: snowshoe hare. Fort Collins, CO; U.S. Department of the Interior, Fish and Wildlife Service Biological Report 82(10.101). https://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-101.pdf

Pitelka, F.A., and G.O. Batzli. 2006. Population cycles of lemmings near Barrow, Alaska: a historical review. Acta Theriologica 52(3):323-336. https://link.springer.com/article/10.1007/BF03194229

Abstract - Current hypotheses regarding the causes of population cycling of brown lemmings*Lemmus trimucronatus* (Richardson, 1828), developed during long-term studies from 1950–1974. We maintain that three factors largely determine the timing and amplitude of population cycles in brown lemmings. First, a basic interaction between lemmings and vegetation sets the stage because dense populations of lemmings severely damage the vegetation, at which point lemming populations decline and remain low until the vegetation recovers. Second, opportunistic predators, mainly jaegers and owls, assemble as the snow melts during peak years and drive already declining populations to extremely low densities. Weasels are effective predators under the snow, but they appear irregularly. If weasel populations increase early in the cycle, lemming populations that normally increase dramatically during the winter in a peak year can be decimated before the snow melts. Finally, both wet summers that result in extensive flooding of the preferred habits of lemmings and freezing rains or winter thaws that cause ice formation reduce food availability, disrupt the cycle and extend the period between peak densities. Numerous observations, experimental results and simulation models support these views. Similar results regarding the importance of the available food supply, particularly in winter, and of the predation regime also have been reported for arvicoline populations at lower latitudes.

Prost, S., R.P. Guralnick,, E. Waltari, V.B. Fedorov, E. Kuzmina, N. Smirnov, T. Van Kolfschoten, M. Hofreiter, and K. Vrieling. 2013. Losing ground: past history and future fate of Arctic small mammals in a climate change. Global Change Biology 19(6):1854-1864. https://doi.org/10.1111/gcb.12157

Abstract - According to the IPCC, the global average temperature is likely to increase by 1.4–5.8 °C over the period from 1990 to 2100. In Polar regions, the magnitude of such climatic changes is even larger than in temperate and tropical biomes. This amplified response is particularly worrisome given that the so-far moderate warming is already impacting Arctic ecosystems. Predicting species responses to rapid warming in the near future can be informed by investigating past responses, as, like the rest of the planet, the Arctic experienced recurrent cycles of temperature increase and decrease (glacial–interglacial changes) in the past. In this study, we compare the response of two important prey species of the Arctic ecosystem, the collared lemming and the narrow-skulled vole, to Late Quaternary climate change. Using ancient DNA and Ecological Niche Modeling (ENM), we show that the two species, which occupy similar, but not identical ecological niches, show markedly different responses to climatic and environmental changes within broadly similar habitats. We empirically demonstrate, utilizing coalescent model-testing approaches, that collared lemming populations decreased substantially after the Last Glacial Maximum; a result consistent with distributional loss over the same period based on ENM results. Given this strong association, we projected the current niche onto future climate conditions based on IPCC 4.0 scenarios, and forecast accelerating loss of habitat along southern range boundaries with likely associated demographic consequences. Narrow-skulled vole distribution and demography, by contrast, was only moderately impacted by past climatic changes, but predicted future changes may begin to affect their current western range boundaries. Our work, founded on multiple lines of evidence suggests a future of rapidly geographically shifting Arctic small mammal prey communities, some of whom are on the edge of existence, and whose fate may have ramifications for the whole Arctic food web and ecosystem.

MacDonald, S.O., and J.A. Cook. 2009. Recent mammals of Alaska. Fairbanks, AK; University of Alaska Press.

Tape, K.D., B. Jones, C. Arp, and I. Nitze. 2018. Tundra be damned: beaver colonization of the Arctic. Global Change Biology

Abstract – Increasing air temperatures are changing the Arctic tundra biome. Permafrost is thawing, snow duration is decreasing, shrub vegetation is proliferating, and boreal wildlife is encroaching. Here we present evidence of the recent range expansion of North American beaver (*Castor canadensis*) into the Arctic, and consider how this ecosystem engineer might reshape the landscape, biodiversity, and ecosystem processes. We developed a remote sensing approach that maps formation and disappearance of ponds associated with beaver activity. Since 1999, 56 new beaver pond complexes were identified, indicating that beavers are colonizing a predominantly tundra region (18,293 km^2) of northwest Alaska. It is unclear how improved tundra stream habitat, population rebound following over-trapping for furs, as well as effects on permafrost, stream ice regimes, and freshwater temperatures in the pond and downstream, likely creating new and more varied aquatic habitat, but specifically biological implications are unknown. Beavers create dynamic wetlands and are agents of disturbance that may enhance ecosystem responses to warming in the Arctic.

See related

Graells, G., D. Corcoran, and J.C. Aravena. 2015. Invasion of North American beaver (*Castor canadensis*) in the province of Magallanes, Southern Chile: a comparison between dating sites through interviews with the local community and dendrochronology. Rivista Chilena de Historia Natural 88:3 DOI 10.1186/s40693-015-0034-6

Taylor, T. 1979. Species list of Alaskan birds, mammals, freshwater and anadromous fish, amphibians, reptiles, and commercially important invertebrates. Juneau, AK; US Dept. Agriculture, Forest Service Alaska Regional Report Number 82.

Mammals: Caribou

Arctic Biological Assessment. 2010. Arctic biodiversity trends – 2010 selected indicators of trends. Helsinki: Conservation of Arctic Flora and Fauna, Arctic Biodiversity Assessment.

<u>Quotes</u> – from *Population/ecosystem status and trends*. Currently wild reindeer and caribou have declined by about 33% since populations peaked in the 1990s and early 2000s (3.8 million compared to 5.6 million) which followed almost universal increases in the 1970s and 1980s. The declines are likely natural cycles, driven by continental and perhaps global atmospheric changes in combination with changing harvest practices and industrial developments. Regionally, there is a tendency for herds to show a measure of synchrony in their phases of increase and decrease. For example, currently all 7 of the major migratory tundra herds in Canada's Northwest Territories and Nunavut are declining from highs in the late 1980s/early 1990s, with 4 of these herds having decreased by 75% or more in 2009 than in the 1990s. In neighboring Alaska, the 2 larger herds are declining including the well-known Porcupine herd, while 2 smaller coastal herds are still increasing from the 1970s.

More is known about the status of caribou in Alaska than elsewhere as monitoring is more frequent. Of Alaska's 24 southern and interior herds where trends are known, 16 are declining, 6 are stable, and 2 are increasing. In Nunavut, the status of the several smaller herds on the northeast mainland and Baffin Island is unknown as the herds are not monitored. East of Hudson Bay, close to 1 million caribou from 2 herds occupy the Ungava Peninsula. Over the last 20 years, total numbers for both herds have decreased. …

The major stressors contributing to recent declines vary between individual herds. Generally, *Rangifer* in the far north, notably the Peary caribou in Canada and the marine reindeer in Russia, have been impacted by severity of local weather, primarily fall to spring icing. For the migratory mainland herds, continental climate trends are implicated, with current climatic changes likely exacerbating natural cycles and forcing lower population troughs and/or slowing the recovery period for some herds. Increased human activity and industrial development are also implicated in the declines of many herds, particularly in the more southern ones. The small mountain herds in Norway, for example, are affected by habitat fragmentation resulting from hydroelectric projects, roads, and recreational activities. In Russia and western Alaska, the overlap between wild and domestic reindeer, with the subsequent loss of domestic stock, undoubtedly complicates or masks normal wild reindeer or caribou trends. For of all these herds, as population numbers decline, the impact of harvesting increases and in many cases may promote further declines and delay recovery.

Ballard, W.B., M.A. Cronin, and H.A. Whitlaw. 2000. Caribou and oil fields. Pp. 85-104 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA: Academic Press.

Summary - In Alaska, caribou are classified into geographically separate herds for management purposes. Before the discovery of oil at Prudhoe Bay in the late 1960s, only two arctic caribou herds were recognized in Alaska—the Western Arctic Caribou Herd (WACH) and the Porcupine Caribou Herd (PCH). Since the 1970s, caribou have increased throughout their range. As of 1997, among 31 currently recognized Alaskan caribou herds, 9 were increasing, 4 were either stable or increasing, 12 appeared stable, 2 were stable or declining, and 4 were declining. One of the caribou herds that have increased dramatically over the past 25 years is the Central Arctic Caribou Herd (CAH), which has a summer range that includes the oil fields on Alaska's Arctic Coastal Plain. Assessment of the effects of oil-field development on caribou and the resulting mitigation measures in the Prudhoe Bay region are important for predicting potential effects of development in other areas of the Arctic. From a management standpoint, impacts have been inconsequential because the herd has grown over the period of oil-field development and management objectives are being met.

Bergerud, A.T. 1974. Decline of caribou in North America following settlement. Journal of Wildlife Management 38(4):757-770.
http://www.jstor.org/stable/pdf/3800042.pdf?refreqid=excelsior:74b124d907bdc837d088350b01518e3b

Abstract - The numbers of caribou (*Rangifer tarandus*) in North America generally declined in the 1800s and early 1900s. Four hypotheses are discussed relative to this decline: (1) numbers decreased because of a shortage of lichen supplies caused by the destruction of lichen pastures by fire and logging; (2) population declined because of increased hunting mortality, augmented by increased natural predation of some herds by wolves (*Canis lupus*); (3) a combination of hypotheses I and II above; and (4) caribou declined in Alaska because of increased movement to marginal habitats with high numbers. This review supports hypothesis II; that numbers declined because of increased hunting mortality and natural predation of some herds, and argues that the range-destruction hypothesis has not been shown to be either a necessary or sufficient cause to explain the decline.

Bergerud, A.T. 1994. Evolving perspectives on caribou population dynamics, have we got it right yet? Rangifer Special Issue 9:95-116.
http://septentrio.uit.no/index.php/rangifer/article/view/1128

Abstract - The roles of food, weather and predation are compared between sedentary and migratory caribou herds. Sedentary herds disperse (space out) at calving time while the cows of migratory herds move in masse (space away) to calving grounds to reduce predation risk. The sedentary ecotype calves on ranges near open water if tree cover is present or in rugged topography in the absence of tree cover. The migratory ecotype aggregates on calving grounds located on alpine mountain plateaus or on the tundra north of the Arctic tree line. The two herds with the greatest densities in North America, the sedentary Slate Islands Herd and the migratory George River Herd both had changes in abundance that followed summer food problems. The hypothesis that winter lichen supplies determine abundance and set the carrying capacity is rejected. Lichens are not a necessary food for caribou. A review of the mortality of young calves documented in the past 30 years provides no support for the hypothesis that hypothermia is a common mortality problem.

Young calves documented can be born inviable at birth if their dams are severely malnourished. The migratory caribou in North America reached peak numbers in the 1980's after wolf populations were heavily harvested in the 1970's. The sedentary ecotype is frequently regulated by wolf predation that affects both recruitment (R) and the mortality of adults (M). The balance between R/M schedules commonly occurs when R (calves) represents, about 15% of the herd and when numbers (prorated to the area of the dispersed annual range) approximate 0.06 caribou/km^2. Population limitation of migratory herds by predation has occurred in the NWT and in several herds in Alaska but only when wolf densities were > 6.5/1000 km^2. Wolf predation halted the growth of the George River Herd in 1980 but then wolves contracted rabies and the herd again increased and degraded spring/summer ranges. The reduced summer phytomass resulted in lower birth rates and increased the vulnerability of calves and possibly adults to wolf predation. Stabilizing mechanisms for migratory herds include movements between herds above tree line and range contractions/expansions with resultant changes in demography. It is hypothesized that the most important ecological variable in all seasonal distributions of caribou is predation risk rather than to maximize forage supplies.

Bergerud, A.T., R.D. Jakimchuk, and D.A. Carruthers. 1984. The buffalo of the north: caribou (*Rangifer tarandus*) and human developments. Arcric 37(1):7-23.

Abstract - The demography, movement, and behavior patterns of eight caribou populations (Kaminuriak, Nelchina, Central Arctic, Fortymile, Porcupine, British Columbia, Newfoundland, and Snøhetta) exposed to industrial activities or transportation corridors are reviewed. Behavior patterns of caribou encountering transportation corridors are explainable in terms of adaptive responses to natural environmental features. There is no evidence that disturbance activities or habitat alteration have affected productivity. Transportation corridors have adversely affected caribou numbers by facilitating access by hunters. There are no examples where physical features of corridors or associated disturbances have affected numbers or productivity. Caribou apparently have a high degree of resilience to human disturbance, and seasonal movement patterns and extent of range occupancy appear to be a function of population size rather than of extrinsic disturbance. The carrying capacity of the habitat is based on the space caribou need to interact successfully with their natural predators. Caribou must not be prevented from crossing transportation corridors by the construction of physical barriers, by firing lines created by hunting activity along a corridor, or by intense harassment - a loss in usable space will ultimately result in reduced abundance.

Cameron, R.D., K.R. Whitten, and W.T. Smith. 1983. Responses of caribou to petroleum-related development on Alaska’s Arctic slope. Juneau, AK: Alaska Department of Fish and Game, Progress Report Federal Aid in Wildlife Restoration Project W-21-2 and W-22-1, Job 3.18R.

Summary - Results of aerial surveys in 1981 indicated good overwinter survival of the 1980 cohort of the Central Arctic Herd (CAH) and high initial production/over-summer survival of the 1981 cohort. Comparison of regional estimates of calf percentage with those obtained during surveys along the Dalton Highway/Trans-Alaska Pipeline indicated continued avoidance of the corridor by cow/calf pairs.

The rationale, objectives, and experimental design of a new collaring program are outlined in detail. Between June and November 1981, 23 radio-collared cows were monitored to determine the 1st-year movements of their offspring; these same calves will be collared as

short yearlings and monitored similarly for up to 3 years. It is noteworthy that during this 6-month period only 4 collared individuals crossed the pipeline corridor.

Because of mild weather and lack of snow cover in 1981, virtually all calving occurred on the coastal plain; initial calf production was high, 8 5 calves/100 cows. Two distinct high-density calving areas for the CAR were identified, one north of the Kuparuk Development Area (KDA) and another on the Canning River delta.

Of 10,901 caribou classified during road surveys along the West Sak Road (WSR) in summer 1981, 18% were calves, substantially lower than the estimate of 27% calves for the region west of the Kuparuk River. Caribou were most numerous along the initial and terminal portions of the WSR; the corresponding calf percentages, however, differed appreciably. The local decline in calf representation and other changes/inconsistencies in caribou distribution within the KDA may be a result of increasing traffic and construction activity. A provisional analysis, using a disturbance index, indicates that cows with calves are underrepresented near areas of heavy local disturbance; this avoidance response appears to be attenuated by insect harassment.

Present land use policies for the central Arctic Coastal Plain do not adequately address problems associated with industrial development on caribou calving grounds, insect relief habitat, and within movement zones. An analysis of existing and possible future conflicts between petroleum development and caribou is presented, together with some general recommendations for minimizing those conflicts. In the long term, we believe that planning of surface uses and selective subsurface leasing is the only rational approach to protecting caribou habitat on the Arctic Slope.

Recommendations

The authors, with assistance from staff of the Divisions of Game and Habitat, are in the process of preparing a Department issue paper on "Caribou and Petroleum Development" (Appendix E) • The draft document presents an analysis of the various concerns related to existing and probable future conflicts based on a review of relevant literature and theoretical considerations regarding the habitat requirements of caribou. Although the focus is on the calving and summer ranges of the CAH, the other Arctic herds are considered in the context of overall development on the Arctic Slope. Also included is a description of the present scope of petroleum development on State land and, more importantly, the potential for massive future development considering the large tracts of State and Federal land identified as having oil and gas potential.

Foremost among the recommendations is a plea for interagency surface use planning of the Arctic Slope to ensure that adequate and appropriate habitats remain available. Limits on the total amount of regional development should be firmly established, principally on the basis of management goals for the various caribou herds (i.e., optimal size, primary use, etc.). Protection of special use areas (e.g., calving grounds, movement corridors, insect relief habitat) should receive particular attention. This comprehensive plan would be implemented through a strategic leasing program followed by careful preplanning of individual production units, each with a set of broad development standards and lessee responsibilities.

Crucial to the ultimate success of development planning is a continuing program of basic and applied research on the behavior and habitat requirements of caribou, together with a mechanism for input to, and revision of, various policy guidelines. The overall effectiveness of any planning system requires formal interagency recognition, but with sufficient flexibility to be refined on the basis of new knowledge.

An established planning framework should greatly simplify and facilitate the routine permitting process. Given a set of development guidelines that are established prior to unitization, site-specific mitigation (e.g., road/pipeline routing and design, facilities placement, construction scheduling, traffic regulation, etc.) need involve little more than direct application through various permits and strict enforcement of the appropriate stipulations. Previously established principles of development, together with specific limitations, should leave few actions subject to industry or agency interpretation.

In direct contrast to these proposed policy changes, present and renewable subsurface leases on State lands are extremely vague in terms of habitat protection. As industry is neither bound by specific formal agreement nor inclined toward voluntary self-regulation of its activities, the present course and character of oilfield development will likely prevail in these areas. Unfortunately, technical needs, procedural philosophies, and economic pressures are frequently inconsistent with what we perceive as adequate protection of caribou and caribou habitat. Thus, with no legal or official policy base, the only regulatory option is a site-specific, case-by-case approach to mitigation; that is, reaction to individual proposals rather than implementation and enforcement of an operating framework that is formulated and accepted before the fact.

The present inefficient, and largely ineffective, approach to mitigation is exacerbated by a tendency for the burden of proof to be placed squarely on the permitting agencies rather than on the lessee. It is incongruous, to say the least, that accountability be greater for a defending agency than for the development aggressor. Renewable resource agencies are inclined to err on the conservative side, and this cautious approach to permitting is apparently unpalatable to both industry and the State land managers. Also, on most environmental issues, the Department of Fish and Game is little more than advisory to the Department of Natural Resources, lacking the authority to insist on protective measures. In practice, however, the Habitat Division, recognizing its weak position, frequently settles for unacceptable compromises before the fact rather than forcing the issue and thereby risking a complete loss of mitigation.

Because of the Department's present inability to influence oilfield planning, and despite the inadequacies of the permitting system, advisory input to permit stipulations appears to be the only regulatory option on State lands. In an attempt to inform industry of Department views on various permitting issues and to standardize stipulations pertaining to caribou (and other species) on the central Arctic Slope, staff from the Division of Habitat drafted a "North Slope Lands Guideline Document" (excerpts, Appendix F). While this document has never been used staff as an internal reference. Seaman et al. (1981) prepared a comprehensive analysis of the coastal habitats between the Colville and Kuparuk Rivers and cited this same set of recommendations. By and large, we support the intent and substance of these guidelines. The reader is referred to these documents for specific operating principles and stipulations.

The central Arctic coastal plain (i.e., between the Colville and Canning Rivers) coincides very closely with land ownership by the State. The overwhelming majority of calving and summer range of the CAR is within this area, particularly that portion of State lands within about 50 km of the Arctic coast. Because of the magnitude of ongoing and probable future development in this region, conflicts during calving and midsummer continue to be of primary concern (see Appendix E). The following is an overview of what we perceive as chronic, recurrent problems resulting from ill-conceived development procedures and/or agency ineffectiveness. Discussion of the nature and status of each broad issue is followed by some general suggestions aimed at resolution. Admittedly, these problems will be difficult to resolve without a comprehensive planning approach, as discussed above, but should certainly be addressed by appropriate action within the existing permitting structure.

1. Oilfield Design and Development Procedures

We have repeatedly recommended that the routing of various roads and pipelines, as well as the siting of various temporary and permanent facilities, be such that total disturbance is minimized. This applies not only to individual processing/ support facilities, discrete complexes, and oilfield units, but also to contiguous and proximate production areas, irrespective of unit boundaries.

Few attempts have been made to achieve this goal. The progress of oilfield development to date demonstrates clearly that many actions are solely for the sake of convenience. Unit operators continue to request and receive permits for redundant access, new airports, additional docks, luxurious living accommodations, and temporary camps/equipment storage areas, to cite just a few examples. Similarly, surface leasing to commercial interests frequently results in additional unnecessary sources of disturbance in adjacent areas; specific examples are the recent proliferation of storage sites south of Deadhorse airport and tentative approval for a North Slope Borough "industrial park" in the Kuparuk area.

The proposed placement of any permanent road or processing/support facility should receive more careful scrutiny. The nature and extent of any potential conflict with caribou should be examined in the context of both present and future development in the area. Except in rare cases, permit applications for establishing temporary camp or storage facilities outside of existing complexes should be denied. Further, it should be the responsibility of the applicant to provide evidence for the necessity of each proposed action by assessing the alternatives. Claims of economic advantage may not, and simple convenience should not, be sufficient.

2. Linear Structures

Roads and pipelines should be designed and routed so as to maximize caribou passage. An essential element of the planning process is early implementation of an industry-funded field surveillance program to establish preferred routes of caribou movement through each area in question. Every attempt should be made to preserve these natural movement zones.

Unfortunately, the practical question of optimal pipeline design and caribou crossing success remains open, despite an assortment of useful studies conducted over the past decade. As an absolute minimum requirement, elevated pipe should be such that physical passage is assured; most caribou, considering maximum stage of antler development, can physically pass beneath a pipeline with a 150 cm (ca. 5 ft) surface-to-pipe clearance. However, special crossing provisions (e.g., buried sections, ramps, greater clearances} may be required, particularly in major movement zones and in areas where drifting snow would otherwise restrict passage.

To ensure the effectiveness of special crossing structures, it is essential that the location of existing and proposed structures/disturbances be considered in the planning process. It makes little sense to modify pipeline design in total ignorance of subsequent actions that might nullify or seriously compromise those efforts. One glaring example is the construction of an extremely expensive buried crossing in the TAP (just south of Pump Station l}, only to have a well pad appear in the immediate vicinity a few years later. There are numerous other instances where some reasonable foresight would have greatly improved both economic efficiency and mitigative effectiveness.

Mitigation may also involve strategic placement of roads and other facilities. Simply meeting the minimum criteria for physical passage of caribou has, in a number of instances, proven inadequate because of complications resulting from the presence of other adverse stimuli. Nearby roads and processing/support facilities, traffic and construction activity (see 3, below} as well as the overall character of proximal development (see 1, above} can greatly influence accommodation, irrespective of local road or pipeline design. Curatolo et al. (1982) tentatively concluded that in areas where the Kuparuk Pipeline was separated from the WSR, pipeline crossing success did not improve at clearances above 150 cm; accordingly, preliminary recommendations were for spatial separation of the pipeline and road/traffic stimuli. We agree that, although crossing success can be reduced by the presence of additional disturbance stimuli, separation of linear structures is not acceptable as a universal solution. Advantages associated with the spatial separation of stimuli must be weighed against the possibility that caribou will perceive the same stimuli collectively as a single, larger complex; that is, the association of individual stimuli such that the overall negative effect is greater than the sum of the various components. The relative desirability of a corridor vs. a network effect must be determined on a case-by-case basis, in recognition of the probable tradeoffs involved. As an example, although diverting the Kuparuk Pipeline south to a separate river crossing apparently increases crossing success of the pipeline itself, repeated encounters of the 2 separate linear structures by resident caribou may ultimately result in decreased use of the movement corridor in general. Most importantly, construction of any additional crossings may create an increasing network effect, with virtual abandonment as a possible consequence.

3. Activity

Numerous reports confirm the importance of movement stimuli as a source of disturbance to caribou (see Appendix E). Many such studies have been conducted in the Prudhoe/Kuparuk area, focusing on the responses of caribou to petroleum-related activity during spring and summer. Based on these findings and additional theoretical considerations, industry has been encouraged to restrict traffic and construction activity during calving and in midsummer (Appendix F). Unfortunately, these periods of concern coincide with the most active portion of the summer construction season. Consequently, agency attempts to restrict traffic in areas outside the established PBC have been largely unsuccessful. Industry argues that any limits on ground transportation would hinder the construction process, implying that all traffic is essential development-related activity. The fact of the matter is that considerable unproductive "touring" does occur in remote areas, not to mention totally unnecessary traffic resulting from improper planning (see below).

When approached about the possibility of traffic control through the use of security check stations, industry representatives typically argue that such measures would be unreasonably expensive and/or that they lack the authority to restrict surface travel on public lands. With respect to the latter claim, it is indeed ironic that established security systems within the PBC exercise a measure of control that is well beyond a simple checkpoint function, presuming authority reserved for law enforcement officers. More to the point, if a rudimentary security system is indeed within the legal privileges of a subsurface lessee, the checkpoint system should be designed to efficiently protect both wildlife resources and corporate interests. This issue has philosophical, legal, and biological ramifications and should be resolved promptly.

Additional unproductive traffic and construction activity also result from engineering errors in facilities design. Specifically, since 1978, many bridges and culverts along the WSR have been of insufficient size to accommodate water from spring runoff and summer storms. As a result, major road repairs and culvert/bridge replacement have become annual summer exercises. It is only recently that most of these water crossings have been finally replaced with what, hopefully, will prove to be adequate structures. Under-designing of culverts and bridges, whether intentional or otherwise, is inexcusable. In many instances, the necessary repairs and reconstruction activity are in direct conflict with caribou, which tend to preferentially occupy, and move along, riparian systems.

Related practices with similar consequences involve the aforementioned propensity for nonessential construction. Hence, optional/redundant roads, new transportation facilities, local commercialization, and storage pads all necessitate a concomitant increase in demands on everything from gravel resources to sewage disposal. Aside from an undesirable proliferation of permanent facilities within an oilfield, the intensity of activity must also increase correspondingly. In short, any construction project, however minor in its physical characteristics, must also be viewed in terms of its indirect impact on a variety of support requirements and, ultimately, the net disturbance increment. All construction proposals require closer examination as to need, feasibility, soundness of design, and environmental tradeoffs.

To reemphasize, given the present leasing policy and permitting structure on State lands, we believe that the only rational approach to maintaining caribou habitat is a careful reexamination of current development practices. Actions that can be confirmed as procedural essentials should be streamlined, while those which are superfluous should be abandoned. In the long term, and particularly in a regional context, strategic land use planning at the leasing and unitization stages is the most viable approach to reconciling conflicts between caribou and industrial development.

Cameron, R.D., K.R. Whitten, W.T. Smith, and D.D. Roby. 1979. Caribou distribution and group composition associated with construction of the trans-Alaska pipeline. Canadian Field-Naturalist 93(2):155-162.

Abstract – Caribou surveys were conducted periodically along the Trans-Alaska Pipeline haul road on the central Arctic Slope between June and November 1975. Mean calf percentage observed in summer was approximately one-third lower than that obtained from concurrent aerial surveys of both the pipeline corridor and adjacent areas; however, fall means were identical. In both summer and early fall, mean latitudes calculated for groups with and without calves along the haul road were more southerly than for the corresponding group types observed through aerial survey. A more detailed regional comparison of survey data revealed corridor-related abnormalities in caribou distribution and group composition. No caribou, or relatively low numbers, were observed in the northernmost segment of the pipeline corridor near Prudhoe Bay, and calf percentages in summer were consistently lower for each of four arbitrarily established regions of the haul road than expected on the basis of aerial survey results; fall calf percentages did not differ appreciably. Mean group size was generally lower along the haul road than for comparable areas to the cast and west.

Responses of caribou to the pipeline corridor in general, and of cows and calves in particular, are discussed in relation to inherent avoidance tendencies as modified seasonally by terrain, group dominance, and human activity.

Cameron, R.D., D.J. Reed, J.R. Dau, and W.T. Smith. 1992. Redistribution of calving caribou in response to oil field development on the Arctic Slope of Alaska. Arctic 45(4):338-342. http://pubs.aina.ucalgary.ca/arctic/Arctic45-4-338.pdf

Abstract - Aerial surveys were conducted annually in June 1978-87 near Prudhoe Bay, Alaska, to determine changes in the distribution of calving caribou *(Rangifer tarandus granfi)* that accompanied petroleum-related development. With construction of an oil field access road through a calving concentration area, mean caribou density (no./km^2) decreased from 1.41 to 0.31 $(P = 0.05)$ within 1 km and increased from 1.41 to 4.53 $(P = 0.04)$ 5-6 km from the road. Concurrently, relative caribou use of the adjacent area declined $(P < 0.02)$, apparently in response to increasing surface development. We suggest that perturbed distribution associated with roads reduced the capacity of the nearby area to sustain parturient females and that insufficient spacing of roads may have depressed overall calving activity. Use of traditional calving grounds and of certain areas therein appears to favor calf survival, principally through lower predation risk and improved foraging conditions. Given the possible loss of those habitats through displacement and the crucial importance of the reproductive process, a cautious approach to petroleum development on the Arctic Slope is warranted.

Cameron, R.D., W.T. Smith, R.G. White, and B. Griffith. 2005. Central Arctic caribou and petroleum development: distributional, nutritional, and reproductive implications. Arctic 58(1):1-9. http://pubs.aina.ucalgary.ca/arctic/Arctic58-1-1.pdf

Abstract - We synthesize findings from cooperative research on effects of petroleum development on caribou (*Rangifer tarandus granti*) of the Central Arctic Herd (CAH). The CAH increased from about 6000 animals in 1978 to 23000 in 1992, declined to 18,000 by 1995, and again increased to 27 000 by 2000. Net calf production was consistent with changes in herd size. In the Kuparuk Development Area (KDA), west of Prudhoe Bay, abundance of calving caribou was less than expected within 4 km of roads and declined exponentially with road density. With increasing infrastructure, high-density calving shifted from the KDA to inland areas with lower forage biomass. During July and early August, caribou were relatively unsuccessful in crossing road/pipeline corridors in the KDA, particularly when in large, insect-harassed aggregations; and both abundance and movements of females were lower in the oil field complex at Prudhoe Bay than in other areas along the Arctic coast. Female caribou exposed to petroleum development west of the Sagavanirktok River may have consumed less forage during the calving period and experienced lower energy balance during the midsummer insect season than those under disturbance-free conditions east of the river. The probable consequences were poorer body condition at breeding and lower parturition rates for western females than for eastern females (e.g., 1988–94: 64% vs. 83% parturient, respectively; $p = 0.003$), which depressed the productivity of the herd. Assessments of cumulative effects of petroleum development on caribou must incorporate the complex interactions with a variable natural environment.

Cronin, M.A., H.A. Whitlaw, and W.B. Ballard. 2000. Northern Alaska oil fields and caribou. Caribou (Rangifer tarandus) are a prominent factor in regulating and managing oil and gas exploration and development in Alaska. Concerns that the oil fields in the Prudhoe Bay region of northern Alaska have negatively affected the distribution and productivity of the

Central Arctic caribou herd (CAH) have been expressed in scientific literature and management documents such as environmental impact statements. The number of CAH caribou in the western summer range that includes the oil fields declined by more than 50% between 1992 and 1995 but then almost doubled between 1995 and 1997. Numbers of caribou in the eastern portion of the range, without oil fields, showed opposite trends during these time intervals. The changes in numbers of caribou in areas with and without oil fields are probably due to movements between summer ranges rather than oil-field impacts. Although there may be some disturbance of animals in the oil fields, population-level impacts apparently have not occurred. The number of caribou in the CAH has increased from approximately 5,000 to approximately 20,000 since oil-field development began, and the management objectives for the CAH have been met despite development of the largest oil and gas fields in the United States. Managers and regulators should acknowledge that coexistence of caribou with oil and gas development demonstrates the success of mitigation, regulation, and management efforts. These successes should be cited and incorporated in planning efforts for future oil development and in public management documents such as environmental impact statements (EIS). Management documents can be considered as scientific and objective only if all available information is included, regardless of whether the information has negative or positive connotations for developments. Wildlife Society Bulletin 28(4):919-922. http://www.jstor.org/stable/3783848

Abstract - Caribou (*Rangifer tarandus*) are a prominent factor in regulating and managing oil and gas exploration and development in Alaska. Concerns that the oil fields in the Prudhoe Bay region of northern Alaska have negatively affected the distribution and productivity of the Central Arctic caribou herd (CAH) have been expressed in scientific literature and management documents such as environmental impact statements. The number of CAH caribou in the western summer range that includes the oil fields declined by more than 50% between 1992 and 1995 but then almost doubled between 1995 and 1997. Numbers of caribou in the eastern portion of the range, without oil fields, showed opposite trends during these time intervals. The changes in numbers of caribou in areas with and without oil fields are probably due to movements between summer ranges rather than oil-field impacts. Although there may be some disturbance of animals in the oil fields, population-level impacts apparently have not occurred. The number of caribou in the CAH has increased from approximately 5,000 to approximately 20,000 since oil-field development began, and the management objectives for the CAH have been met despite development of the largest oil and gas fields in the United States. Managers and regulators should acknowledge that coexistence of caribou with oil and gas development demonstrates the success of mitigation, regulation, and management efforts. These successes should be cited and incorporated in planning efforts for future oil development and in public management documents such as environmental impact statements (EIS). Management documents can be considered as scientific and objective only if all available information is included, regardless of whether the information has negative or positive connotations for developments. 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Dau, J., and R.D. Cameron. 1992. Effects of a road system on caribou distribution during calving. Rangifer Special Issue 1:95-101.

Abstract - In winter 1981-1982, a 29-km road system was built in a high-use caribou (*Rangifer tarandus granti*) calving area near Milne Point, Alaska. Aerial surveys of this area were conducted annually during the calving period for 4 years before and 4 years after road construction. Effects of the road system on the distribution of caribou were investigated by comparing survey data obtained during these two periods. The 41 400-ha study area was partitioned into 40 quadrats; after construction (1982 - 85), significantly fewer caribou were observed within quadrats encompassing the present road system than before construction (1978 - 81). The area within 6 km of the road system was stratified into six 1-km intervals, and differences in the distribution of caribou among those strata were examined using linear regression analysis. **After construction, the density of maternal females was positively correlated with distance, whereas no such relationship was apparent before construction.** Density of non-maternal adults was unrelated to distance during both periods. The results suggest that a local displacement of maternal caribou has occurred in response to roads and associated human activity.

Elison, G.W., A.G. Rappoport, and G.M. Reid. 1986. Report of the caribou impact analysis workshop, Arctic National Wildlife Refuge November 19-20, 1985. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Arctic National Wildlife Refuge.

Abstract – Fourteen caribou biologists met to discuss the potential effects on caribou of petroleum development on the coastal plain of the Arctic National Wildlife Refuge. The biologists analyzed a hypothetical development scenario which was representative of the type of petroleum development which may occur on the coastal plain. The group expected the development would produce a negative effect on coastal plain caribou on the magnitude of that effect. Greatest concern focused on displacement from traditional calving areas, followed by displacement from, or inhibited access to, habitat used for relief from insect harassment. Many other aspects of caribou biology and effects of petroleum development were also discussed. Mitigation measures associated with petroleum development were also discussed. Mitigation measures focused on reducing disturbance and impacts of the infrastructure associated with petroleum development. Potential mitigation included permanently closing the core of traditional calving area to development; limiting area access to essential personnel only; closing the development to all hunting; designing pipelines to facilitate caribou passage; consolidating facilities; and, implementing time and area closures to minimize disturbances to caribou during their critical life stages. The group was concerned that the scenario did not consider the cumulative effects of potential petroleum development offshore or on adjacent State and private lands.

Points of General Consensus (Pp. 18ff)

1. Definitions of terms …revised definition of effects (Table 2).

   Major – a widespread, long-term change in habitat availability or quality which would likely modify natural abundance or distribution of species using the coastal plain. That modification will be persist at least as long as the modifying influences exist.

Moderate – a widespread, short-term change in habitat availability or quality which would likely modify natural abundance or distribution of species using the coastal plain; or local modification in habitat availability or quality which would likely modify natural abundance or distribution at least as long as modifying influence exist.

Minor – short-term, local change of species abundance, distribution, habitat availability or habitat quality.

Negligible – little or no change in population, habitat availability or habitat quality.

2. The circular and often daily movements of caribou to and from coastal plain biting-insect relief habitats were discussed. A majority of the biologists believed that a 5-8 km (3-5 mi) wide non-development buffer zone should be maintained along the coast to facilitate caribou movements and access to biting-insect relief habitat.

3. Maternal cows at calving and immediately thereafter in company with calves are the segment of the population which is most vulnerable to disturbance. Based upon the given development scenario, it is that portion of which the Porcupine caribou herd (PCH) which will encounter development in the 1002 area.

4. Roads will eventually become public, based upon experiences in Canada and with TAPS, regardless of the original intent.

5. Public access to the 1002 area will increase.

6. Disturbance caused by air traffic is generally less of a problem than disturbance by surface traffic.

7. Road kills and other human-caused accidents will occur but will have minor effect on the caribou population.

8. Oil and gas development on adjacent private and State lands or offshore will compound the ability to predict [incremental] effects of development on the 1002 area.

<u>Summary</u> (Pp. 21)

Workshop participants believed there would be a moderate or major decline or displacement of the PHC as a result of the amount of development presented in the scenario. If the area of historic, concentrated calving identified in Figure 2 is closed to leasing and surface occupation, the negative effects, e.g., displacement due to disturbance would be substantially reduced. To further reduce disturbance effects to caribou, prohibiting all hunting around the developed area, restrictions on personnel access, traffic controls and other measures are recommended. Past experience with the central Arctic herd (CAH) and the relatively brief period the PCH uses the 1002 area suggest there will be a low degree of habituation, particularly maternal cows, to the presence of development.

Barriers to free movement of caribou through development areas ca be reduced by placing ramps over pipelines, controlling traffic, and limiting human access. Based upon past experience with TAPS and developments in Canada, project roads will eventually become public and use of those roads will increase regardless of the original intent. A final recommendation was to maintain a non-development buffer zone of 5-8 km (3-5 mi) wide along the coast to facilitate free movement of caribou and access to biting-insect relief habitat.

Cumulative effects of development on all lands and waters within the PCH and CAH ranges must be considered to realistically assess impacts to caribou.

Hansen, B.B., R. Aanes, I. Herfindal, J. Kohler, and B.E. Seather. 2011. Climate, icing, and wild arctic reindeer: past relationships and future prospects. Ecology 92(10):1917-1923.

Abstract - Across the Arctic, heavy rain-on-snow (ROS) is an “extreme” climatic event that is expected to become increasingly frequent with global warming. This has potentially large ecosystem implications through changes in snowpack properties and ground-icing, which can block the access to herbivores' winter food and thereby suppress their population growth rates. However, the supporting empirical evidence for this is still limited. We monitored late winter snowpack properties to examine the causes and consequences of ground-icing in a Svalbard reindeer (*Rangifer tarandus platyrhynchus*) metapopulation. In this high-arctic area, heavy ROS occurred annually, and ground-ice covered from 25% to 96% of low-altitude habitat in the sampling period (2000–2010). The extent of ground-icing increased with the annual number of days with heavy ROS (≥10 mm) and had a strong negative effect on reindeer population growth rates. Our results have important implications as a downscaled climate projection (2021–2050) suggests a substantial future increase in ROS and icing. The present study is the first to demonstrate empirically that warmer and wetter winter climate influences large herbivore population dynamics by generating ice-locked pastures. This may serve as an early warning of the importance of changes in winter climate and extreme weather events in arctic ecosystems.

Joly, K., D.R. Klein, D.L. Verbyla, T.S. Rupp, and F.S. Chapin III. 2011. Linkages between large-scale climate patterns and the dynamics of Arctic caribou populations. Ecography 34:345-352.

Abstract - Recent research has linked climate warming to global declines in caribou and reindeer (both *Rangifer tarandus*) populations. We hypothesize large-scale climate patterns are a contributing factor explaining why these declines are not universal. To test our hypothesis for such relationships among Alaska caribou herds, we calculated the population growth rate and percent change of four arctic herds using existing population estimates, and explored associations with indices of the Arctic Oscillation (AO) and the Pacific Decadal Oscillation (PDO). The AO, which more strongly affects eastern Alaska, was negatively associated with the population trends of the Porcupine Caribou Herd and Central Arctic Herd, the easternmost of the herds. We hypothesize that either increased snowfall or suboptimal growing conditions for summer forage plants could explain this negative relationship. Intensity of the PDO, which has greatest effects in western Alaska, was negatively associated with the growth rate of the Teshekpuk Caribou Herd in northwestern Alaska, but the Western Arctic Herd in western Alaska displayed the opposite trend. We suggest that the contrasting patterns of association relate to the spatial variability of the effects of the PDO on western and northwestern Alaska. Although predation and winter range quality have often been considered the primary causes of population variation, our results show that large-scale climate patterns may play an important role in caribou population dynamics in arctic Alaska. Our findings reveal that climate warming has not acted uniformly to reduce caribou populations globally. Further research should focus on the relative importance of mechanisms by which climate indices influence caribou population dynamics.

Joly, K., R. Jandt, C.R. Meyers, and M.J. Cole. 2007. Changes in vegetative cover on Western Arctic Herd winter range from 1981 to 2005: potential effects of grazing and climate change. Rangifer Special Issue 17:199-207.

Abstract - The population of the Western Arctic Herd, estimated at 490,000 caribou (*Rangifer tarandus granti*) in 2003, is at its highest level in 30 years. Twenty permanent range transects were established in the winter range of the Western Arctic Herd in 1981 to assess the impacts of grazing. These transects were revisited in 1995 and 1996 (1995/96). Only 18 of transects were re-located, so an additional 7 transects were established in 1996. In 2005, all 25 remaining transects were revisited. Lichen coverage dropped by a relative 45.1% between 1981 and 1995/96 and by an additional relative 25.6% between 1995/96 and 2005. There was a significant decline in primary forage lichens between 1995/96 and 2005. Caribou use was greater in areas with high lichen abundance. Graminoid cover increased by a relative 118.4% from 1981 to 1995-1996, and again by a relative 26.1% from 1995/96 to 2005. Shrub cover increased during the study, whereas forb cover declined. The decline in lichen abundance on the winter range of the Western Arctic Herd over 24 years is an index of caribou habitat condition. The observed changes in vegetation cover can be attributed to caribou grazing, fire, and possibly global climate change. Continued declines in lichen cover could lead to population declines within the herd, range shifts, or both.

Klein, D.R. 1987. Caribou: Alaska's wilderness nomads. Pp. 191-207 in H. Kallman, C.P. Agee, W.R. Goforth, J.P. Linduska, S.R. Hillerbrand, N. Rollison, W.J. Savannah, W.T. Nebel, S.A. Exum, and G. Gallo (eds.), Restoring America's wildlife 1937-1987: the first 50 years of the Federal Aid in Wildlife Restoration (Pittman-Robertson) Act. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service.

Quotes – "When the future of caribou is viewed within the context of present-day Alaska, with the prospect of continued widespread energy development, changing land status, changing rural lifestyles, and an increasing human population, there is clearly cause for concern. The habitat of caribou in Alaska, at least up to now, has remained virtually intact, and past population declines have been reversed. But it is not at all clear whether extensive tracts of unaltered land can be maintained for caribou in the future. Caribou are "wilderness species" that require large expanses of unaltered natural habitat, free of obstructions to their movements and without excessive human disturbance."

Editor note – see Vors and Boyce 2009; Arctic Biological Assessment 2010.

Murphy, S.M., and B.E. Lawhead. 2000. Caribou. Pp. 59-84 in J.C. Truett and S.R. Johnson (eds.), The natural history of an arctic oil field: development and the biota. San Diego, CA; Academic Press.

Summary - Barren-ground caribou *(Rangifer tarandus)* are an important component of the arctic landscape in Alaska because of their high value to subsistence and sport hunters, indigenous Native cultures, the general public, and the functioning of terrestrial ecosystems. For many people, caribou also have come to symbolize the wilderness character of the Arctic, and the well-being of their populations often is regarded as an indicator of the health of arctic ecosystems. Thus, maintaining viable, healthy herds is a priority issue, and caribou figure prominently in land use decisions in arctic Alaska. This chapter presents an overview of the population status, life history, distribution, abundance, and responses to human activities of caribou in arctic Alaska, emphasizing the Central Arctic Herd (CAH).

Nelleman, C., and R.D. Cameron. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic 49(1):23-28.

Abstract - We investigated terrain preferences of caribou (*Rangifer tarandus granti*) in an oilfield region near Prudhoe Bay, AK. Under disturbance-free conditions, the distribution of calving caribou determined by aerial transect surveys was correlated with indices of terrain ruggedness based on map contours. Caribou preferred quadrats dominated by fine-textured rugged terrain, particularly when present in large clusters, and avoided quadrats with flatter terrain. Displacement of maternal females from a zone within 4 km of roads and production-related facilities reduced use of rugged terrain types in that zone by 52%; the remaining preferred terrain was scattered and less accessible. This reduction was accompanied by a 43% increase in caribou use of rugged terrain 4-10 km from surface development. Given that terrain ruggedness is positively correlated with forage quality and biomass availability, combined underuse and overuse of these important habitats may compromise summer nutrition of lactating female caribou, thereby depressing body condition and, hence, subsequent reproductive success.

Putkonen, J., and G. Roe. 2003. Rain-on-snow events impact soil temperatures and affect ungulate survival. Geophysical Research Letters 30(4):37-40.

Abstract - Field data from Spitsbergen and numerical modeling reveal that rain-on-snow (ROS) events can substantially increase sub-snowpack soil temperatures. However, ROS events have not previously been accounted for in high latitude soil thermal analyses. Furthermore such events can result in widespread die-offs of ungulates due to soil surface icing. The occurrence of Spitsbergen ROS events is controlled by the North Atlantic Oscillation. Globally, atmospheric reanalysis data show that significant ROS events occur predominantly over northern maritime climates, covering 8.4×10^6 km^2. Under a standard climate change scenario, a global climate model predicts a 40% increase in the ROS area by 2080–2089.

Reimers, E., and J.E. Colman. 2006. Reindeer and caribou (*Rangifer tarandus*) response towards human activities. Rangifer 26(2):55-71.

Abstract - We address the question of how human activities and infrastructure influence reindeer/caribou's (*Rangifer tarandus)* behavior and habitat use and review studies based on current methodologies. Anthropogenic activities have a direct effect on *Rangifer* behavior through the senses hearing, sight and smell, and all of these are important tools for behavioral risk assessment. Short term indirect responses, such as habituation, sensitization, avoidance, and displacement, develop through neutral, positive or negative associations towards stimulus in terms of *Rangifer* ability to experience, learn, and remember. Long term behavioral responses develop through interaction with predators and, for reindeer, also domestication. **A survey of the literature dealing with behavioral studies reveals that although *Rangifer* in most cases retreat from anthropogenic activities, comfort distances (i.e. distances beyond which animal behavior or activity are not influenced) are relatively short**. In most cases, energetic implications appear moderate and small compared to other natural, biotic influences such as disturbance (and death) caused by insect and/or predator harassment. Unless obstructing access, physical constructions of various kinds apparently have limited effects on *Rangifer* behavior or habitat use. On the other hand, constructions that do obstruct or limit access and recreational or other motorized and non-motorized activities appear to have stronger impacts on avoidance and redistribution of *Rangifer*. Behavioral effects that might decrease

survival and reproduction include retreat from favorable habitat near disturbance sources and reduction of time spent feeding with resulting energy depletion over time. *Rangifer* habitat use, habitat avoidance, and feeding preferences are governed by a complexity of natural interacting factors. Domestication, habituation and sensitization are essential in shaping *Rangifer* adaptability, and should be included in future studies on reindeer and caribou responses towards various anthropogenic activities. Although cumulative effects from human activities are likely, it remains difficult to separate these from natural variations in *Rangifer* habitat use and demography. Habitat avoidance towards various human infrastructures and activities is reported, but most studies reporting relatively far (4-25 km) avoidance distances relied on measurements of range properties and animal distribution recorded on 1-2 days annually in winter to induce a potential response from the animals and lack important environmental variables and/or alternative hypotheses. This methodology should be improved in order to enable identification of correlation versus causation. Studies relying on animal behavior measurements can more correctly identify and test responses to various stimuli while also controlling for degree of domestication and other various environmental variables, but only in a limited time and spatial scale. Furthermore, such studies may not necessarily capture potential population consequences from disturbances. Thus, there are important weaknesses in the two leading methodologies (measuring animal behavior and indirectly mapping regional/population movements and habitat use through measurements of range properties). To best study *Rangifer's* responses towards anthropogenic infrastructure and activities, we propose that the two methodologies be combined and supplied with modern GPS/telemetry.

Smith, W.T., and R.D. Cameron. 1983. Responses of caribou to industrial development on Alaska's Arctic Slope. Acta Zoologica Fennica 175:43-45.

Speed, J.D.M., E.J. Cooper, I.S. Jonsdottir, R. van der Wal, and S.J. Woodin. 2010. Plant community properties predict vegetation resilience to herbivore disturbance in the Arctic. Journal of Ecology 98:1002-1013. http://www.jstor.org/stable/pdf/40929049.pdf?refreqid=search%3A655e535e58c755e5b6ae67c0a2afe749

Abstract [herbivory equate to industrial disturbance as stressor]

1. Understanding the impact of disturbance on vegetation and the resilience of plant communities to disturbance is imperative to ecological theory and environmental management. In this study predictors of community resilience to a simulated natural disturbance are investigated. Responses to disturbance are examined at the community, plant functional type and species level. 2. Field experiments were set up in seven tundra plant communities, simulating disturbance based on the impact of grubbing by an increasing herbivore population of pink-footed geese (Anser brachyrhynchus). The short-term resilience of communities was assessed by comparing community dissimilarity between control plots and plots subject to three disturbance intensities based on the foraging impact of these geese. Potential for long-term recovery was evaluated across different disturbance patch sizes. 3. Resilience to disturbance varied between communities; those with higher moss cover and higher soil moisture, such as wetlands and mires, were most resilient to disturbance. 4. The wetter communities demonstrated greater long-term recovery potential following disturbance. In wetland communities, vegetative recovery of vascular plants and moss was greater in smaller disturbed patches and at the edges of patches. 5. The response of vegetation to disturbance varied with intensity of disturbance, plant community and plant species. The use of functional type classifications only partially explained the

variation in species responses to disturbance across communities, thus their use in predicting community changes was limited. 6. Synthesis. The impact of disturbance is shown to be plant-community specific and related to the initial abiotic and biotic properties of the community. By showing that resilience is partly predictable, the identification of disturbance-susceptible communities is possible, which is of relevance for ecosystem management.1. Understanding the impact of disturbance on vegetation and the resilience of plant communities to disturbance is imperative to ecological theory and environmental management. In this study predictors of community resilience to a simulated natural disturbance are investigated. Responses to disturbance are examined at the community, plant functional type and species level.

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6. Synthesis. The impact of disturbance is shown to be plant-community specific and related to the initial abiotic and biotic properties of the community. By showing that resilience is partly predictable, the identification of disturbance-susceptible communities is possible, which is of relevance for ecosystem management.

Stein, A., L.E. Loe, A. Mysterud, T. Sverinsen, J. Kohler, and R. Langvatin. 2010. Icing events trigger range displacement in high-Arctic ungulate. Ecology 91(3):915-920.

Abstract - Despite numerous studies of how climate change may affect life history of mammals, few have documented the direct impact of climate on behavior. The Arctic is currently warming, and rain-on-snow and thaw-freeze events leading to ice formation on the ground may increase both in frequency and spatial extent. This is in turn expected to be critical for the winter survival of arctic herbivores. Svalbard reindeer (*Rangifer tarandus plathyrynchus*) have small home ranges and may therefore be vulnerable to local "locked pasture" events (ice layers limit access to plant forage) due to ground-ice formation. When pastures are "locked," Svalbard reindeer are faced with the decision of staying and live off a diminishing fat store, or trying to escape beyond the unknown spatial borders of the ice. We demonstrate that Svalbard reindeer do the latter, as icing events cause an immediate increase in range displacement between 5-day observations. Population-level responses of previous icing events may therefore not accurately predict future responses if the spatial

extent of icing increases. The impact of single events may be more severe if it exceeds the maximum movement distances, so that the spatial displacement strategy reported here no longer buffers climate effects.

Valkenburg, P., D.G. Kelleyhouse, J.L. Davis, and J.M. Ver Hoef. 1994. Case history of the Fortymile caribou herd, 1920-1990. Rangifer 14(1):11-22. http://septentrio.uit.no/index.php/rangifer/article/view/1128

Abstract - Early this century, the Fortymile caribou herd was the largest in Alaska and one of the largest in the world. Since the 1940s the herd has remained relatively small, fluctuating between 6,000-8,000 and about 50,000. To determine possible limiting factors, we reviewed historical fluctuations in herd since and harvest, historical data on wolf numbers and summer and winter weather. The major decline in herd size from 1963 to 1973 was accompanied by high wolf numbers, some years of unfavorable winter and summer weather, and some years of high harvests. From 1974 to 1990 the Fortymile herd failed to recover as well as the adjacent Nelchina herd and provided less than one-fourth the harvest despite favorable winter conditions in both areas. Two notable differences between these herds were that (1) wolves were less strongly limited within the range of the Fortymile herd, and (2) moose as alternate prey for wolves remained more abundant within the range of the Nelchina herd.

Vistnes, I., and C. Nellemann. 2001. Avoidance of cabins, roads, and power lines by reindeer during calving. Journal of Wildlife Management 65(4):915-925.

Abstract - We investigated possible avoidance behavior of calving semi-domesticated reindeer (*Rangifer tarandus tarandus*) near recreational cabins, roads, and power transmission lines in Repparfjord Valley, northern Norway. The distribution, sex, and general age composition of the reindeer were mapped during the 1998 and 1999 calving seasons (n = 776 and n = 678, respectively) using systematic snowmobile and ski surveys. Mean reindeer density within preferred habitat was 78% lower in the area 4 km from the resort (1.47 vs. 6.68 reindeer/km2, respectively). Mean reindeer density by the power line corridor without traffic was 73% lower in the area 4 km from the power line for comparable habitat. Areas <4 km from anthropogenic structures were avoided despite low levels of human traffic and a high proportion of preferred habitat. Within snow-free sites available for grazing, no significant differences occurred in phenological development of cotton-grass (*Eriophorum* spp.), in live:dead ratio of plant material, or in graminoid biomass with distance to the tourist resort. Almost 74% of all available forage was located within the avoided 0-4-km zones from the resort or the separate power line. Our results suggest that power lines, even without human traffic, may result in substantial reductions in the use of foraging areas. The combined actions of power lines, roads, and cabins may increase potential avoidance, thereby increasing the use of remaining undisturbed grazing grounds. Possible increased competition for high-quality forage may affect lactation, body condition, and, hence, reproductive success in the long term.

Vistnes, I., and C. Nellemann. 2007. Impacts of human activity on reindeer and caribou: the matter of spatial and temporal scales. Rangifer Report No. 12:47-56.

Abstract - The impacts of human activity and infrastructure development on reindeer and caribou (*Rangifer tarandus*) have been studied for decades and have resulted in numerous debates among scientists, developers and indigenous people affected. Herein, we discuss the development within this field of research in the context of choice of spatial and temporal scale and concurrent trends in wildlife disturbance studies. Before the 1980s, the vast majority of *Rangifer* disturbance studies were behavioral studies of individual animals exposed directly to potential disturbance sources. Most of these local studies reported few and short-term impacts on *Rangifer*. Around the mid-1980s focus shifted to regional scale landscape ecology studies, reporting that reindeer and caribou reduced the use of areas within 5 km from infrastructure and human activity by 50-95%, depending on type of disturbance, landscape, season, sensitivity of herds, and sex and age distribution of animals. In most cases where avoidance was documented a smaller fraction of the animals, typically bulls, were still observed closer to infrastructure or human activity. Local-scale behavioral studies of individual animals may provide complementary information, but will alone seriously underestimate potential regional impacts. Of 85 studies reviewed, 83% of the regional studies concluded that the impacts of human activity were significant, while only 13% of the local studies did the same. Traditional ecological knowledge may further increase our understanding of disturbance effects.

Vistnes, I., C. Nellemann, P. Jordhoy, and O. Strand. 2001. Wild reindeer: impacts of progressive infrastructure development on distribution and range use. Polar Biology 24(7):531-537.

Abstract - We investigated the distribution of wild reindeer (*Rangifer tarandus tarandus)* from aerial surveys in 1986–1998 in 622 contiguous 4-km^2 grid squares in relation to density of power lines, roads and ski trails in the Nordfjella region, south-central Norway. Density of reindeer was significantly lower in developed quadrats compared to undeveloped quadrats and decreased with increasing density of development. No reindeer were observed in areas exceeding 1.3 km/km^2 of linear structures and only 1.1% of the reindeer were observed in areas exceeding 0.8 km/km^2 of linear structures, an area constituting 17% of the study area. The results imply that development, and also the degree of development, affect the availability of range for wild reindeer. Furthermore, the results suggest that reindeer may abandon areas once disturbance exceeds a critical level. We conclude that there is a need for cumulative impact assessments of the overall development in Norwegian mountain regions, to preserve the last remaining wild reindeer populations in Europe.

Vistnes, I., C. Nellemann, P. Jordhoy, and O. Strand. 2004. Effects of infrastructure on migration and range use of wild reindeer. Journal of Wildlife Management 68(1):101-108.

Abstract - We investigated possible avoidance behavior of calving semi-domesticated reindeer (*Rangifer tarandus tarandus*) near recreational cabins, roads, and power transmission lines in Repparfjord Valley, northern Norway. The distribution, sex, and general age composition of the reindeer were mapped during the 1998 and 1999 calving seasons (n = 776 and n = 678, respectively) using systematic snowmobile and ski surveys. Mean reindeer density within preferred habitat was 78% lower in the area 4 km from the resort (1.47 vs. 6.68 reindeer/km2, respectively). Mean reindeer density by the power line corridor without traffic was 73% lower in the area 4 km from the power line for comparable habitat. Areas <4 km from anthropogenic structures were avoided despite low levels of human traffic and a high proportion of preferred habitat. Within snow-free sites available for grazing, no significant differences occurred in phenological development of cotton-grass (*Eriophorum* spp.), in live:dead ratio of plant material, or in graminoid biomass with distance to the tourist resort. Almost 74% of all available forage was located within the avoided 0-4-km zones from the resort or the separate power line. Our results suggest that power lines, even without human traffic, may result in substantial reductions in the use of foraging areas. The

combined actions of power lines, roads, and cabins may increase potential avoidance, thereby increasing the use of remaining undisturbed grazing grounds. Possible increased competition for high-quality forage may affect lactation, body condition, and, hence, reproductive success in the long term.

Vors, L.S., and M.S. Boyce. 2009. Global declines of caribou and reindeer. Global Change Biology 15:2626-2633.

Abstract – Caribou and reindeer herds are declining across their circumpolar range, coincident with increasing arctic temperatures and precipitation, and anthropogenic landscape change. Here, we examine the mechanisms by which climate warming and anthropogenic landscape change influence caribou and reindeer population dynamics, namely changes in phenology, spatiotemporal changes in species overlap, and increased frequency of extreme weather events, and demonstrate that many caribou and reindeer herds show demographic signals consistent with these changes. While many caribou and reindeer populations historically fluctuated, the current, synchronous population declines emphasize the species' vulnerability to global change. Loss of caribou and reindeer will have significant, negative socioeconomic consequences for northern indigenous cultures.

Webster, L. 1997. The effects of human related harassment on caribou (*Rangifer tarandus*). Williams Lake, B.C.; Ministry of Environment.

Introduction - The expansion of human settlements and land developments have accelerated the decline of caribou numbers across the northern hemisphere, but the degree to which specific activities influence caribou population dynamics are still in dispute. **Predation, hunting, habitat destruction or any combination of these factors may limit caribou populations**. This review focuses on the effects of harassment resulting from human interactions with caribou and caribou habitat, but also examines disturbance impacts on other ungulate species.

In most cases, direct links between caribou declines and human activities or land uses are as yet unresolved and difficult to isolate, but some immediate and long term impacts of harassment to individual animals have been studied. For the purpose of this literature review the term “harassment” defines a specific human activity resulting in the altering of an animal’s behavior that could potentially increase energy expended or risk of injury to the animal. The effects of pedestrian approaches, habitat alteration (logging, road and seismic development and mining) and vehicular stimuli (all-terrain vehicles, snow machines, aircraft and automobiles) on ungulates will be summarized, with special attention to caribou (*Rangifer tarandus*).

Geist (1975) states that during harassment, the regulatory systems require additional energy that would normally be allocated to growth, maintenance or reproduction and that excitation temporarily doubles the energy required for maintenance by increasing metabolism by about 25%. Severe or repeated human harassment could therefore result in reduced growth rates, poor body condition and decreased reproductive rates, that may in turn increase adult and calf mortality.

Caribou are most sensitive to harassment during the calving and rutting periods. During the calving period Mountain and Woodland maternal caribou that depend on limited alpine habitat to space themselves from predators and conspecifics are particularly sensitive to additional stress, and may suffer the most serious consequence if displaced. Disturbance during the fall rut often results in extremely elevated stress levels. Depending on the level of ungulate response human-related harassment may result in anything from a slight increase in vigilance to panicked flight, with equally variable consequences for the animal (Schideler et al 1986, Jakimchuck 1980).

Summary - The ability of caribou to habituate to human presence in their home range appears to depend on the degree of previous harassment and hunter presence. In areas where man is not associated with danger, animals may quickly habituate to human disturbance and thus become more prone to poaching and hunting, or in the case of roads and vehicles, road kill; all of which result in increased mortality rate. Where caribou have been hunted or chased (passively or actively) herds are more likely to experience additional stress from associating man with danger, and are especially sensitive during the calving and rut periods. Harassment of unhabituated caribou to human disturbance may have immediate impacts as well as long term effects.

Where humans or their machines are perceived as a threat, caribou often experience increased stress levels and subsequently expend more energy attempting to avoid the disturbance. Flight is the most common response for unhabituated animals that perceive humans as predators. This flight response uses up vital body reserves, increases the chance of physical injury or death during stampedes and may cause herd fragmentation. Utilization of essential body fat and protein, especially during harsh climatic conditions, can lead to increased cow/calf mortality, and may effectively reduce productivity of the herd.

Long term displacement from home range (especially during calving period) may result in increased mortality, decreased reproductive success, increased predation, altered habitat use and decreased caribou densities. Human activities within caribou range which do not necessarily destroy caribou habitat may still result in a functional loss of usable space by the disturbance and resulting displacement. The relatively isolated areas caribou live in may make them more responsive to human disturbance, eliciting high stress responses. **Human activities such as hiking, snowmobiling, low altitude flights and ATV use, which briefly stress caribou are likely to have significant negative effects if animals are displaced out of their preferred habitat**. Displacement to poorer habitat where adequate forage may not be available or predators exist in greater numbers could potentially result in caribou population declines.

Habitat alteration resulting from human activity is not the focus of this report, but is directly linked to harassment since it has been shown to alter caribou behavior and increase risk of injury to the animal. Land clearing practices reduce available cover and forage, increase hunter visibility, and may create winter barriers to caribou movement, while roads and trails increase hunter success rates and provide improved travel corridors for wolves. Increased hunter and predator access and decreased habitat quality and availability may result in higher caribou mortality rates and/or displacement from traditional home ranges.

The concept of caribou harassment is extremely complex, as responses to different activities and developments are dependent on numerous factors which may be encountered in various combinations and intensities. Whether animals are habituated to human presence or not, the majority of studies reviewed in this paper conclude that the net effect on individually harassed caribou is negative. In order to draw conclusions at the population level, more study is required and researchers must consider the variation in responses between individuals and from herd to herd make generalizations difficult and sometimes unreliable.

Management of caribou populations with respect to human related harassment must address both the maintenance of suitable habitat and regulation of hunter harvest.

Recommendations

Do not attempt to habituate animals to human related disturbance.

Limit general flight altitudes in caribou habitat to above 300m.

Restrict recreational access to alpine areas during calving (mid-May to July).

Zone snowmobile and ATV use away from core caribou winter range particularly where terrestrial lichen is essential to caribou winter survival.

Limit snowmobile and ATV use in areas that may stress animals.

Promote further study concerning long term effects of human related harassment.

Minimize visibility of area surrounding active roads to screen animals from vehicular disturbance and reduce hunter success.

Caribou population surveys should be scheduled to avoid peak calving and rutting periods.

Population surveys should be planned with the objective of minimizing the duration of disturbance to each encountered group while maximizing the aircraft's altitude but still allowing animals to be classified.

When animals are encountered in rough terrain where there is a high risk of injury if chased, or in dense cover where extra time is required to classify all animals, discretion should be used to minimize disturbance, and as a result, likely all animals will not be classified.

Wolfe, S.A., B. Griffith, and C.A. Gray Wolf. 2000. Response of reindeer and caribou to human activities. Polar Research 19(1):63-73.

Abstract - Petroleum and mineral exploration and extraction, hydroelectric development, atmospheric transport of contaminants, timber harvesting and tourism are increasing worldwide, especially in the Arctic. This development may adversely affect populations of reindeer/caribou (*Rangifer tarandus*) which are the basis of subsistence economies for northern indigenous peoples. Our purpose is to present a survey of the literature that has investigated the response of reindeer/caribou to human activities. Individuals and groups of reindeer/caribou: (1) move away from point sources of disturbance; (2) increase activity and energy expenditure near disturbance; (3) delay crossing or fail to cross linear structures; (4) shift away from areas of extensive and intensive development; and, (5) are killed by collisions with vehicles and by hunting along roads. **Cows and calves during the calving season are the most easily disturbed group**. Bulls in general and all reindeer/caribou during insect harassment are least likely to avoid development areas. Estimation of the proportion of a population that is exposed to disturbance and the implications of this exposure to annual energy budgets, survival and productivity of reindeer/caribou has received little attention. Future advances in understanding the implications of human disturbance to reindeer/caribou will require cumulative effects assessment at annual, population and regional scales. Although some level of cumulative effect is likely, clear separation of cumulative effects of development from natural variation in caribou habitat use and demography will be difficult.

Introduction (quote, without citations) - Caribou and reindeer are the most important subsistence and cultural resources for indigenous Arctic dwelling peoples and are the subject of intense interest by people who view the Arctic as one of the last remaining wilderness regions. The welfare of Arctic reindeer/caribou populations is a function of husbandry practices, climatic effects on habitats and anthropogenic forces within herd ranges. Advances in operation technology and discoveries of substantial reserves of petroleum and minerals in the Arctic have facilitated industrial development in the circumpolar region in the latter half of the 20th century. Because many Arctic reindeer/caribou populations have had limited exposure to modern industrial development, there are potential implications of this development for reindeer/caribou movements, distribution and populations.

Sustainable development requires an understanding of the effects of development on wildlife populations and habitats. During the past 30 years many studies have investigated reindeer/caribou responses to human activities. This work has been periodically reviewed and synthesized but not all of these reviews are readily available. Our purpose in this paper is to survey the existing literature on the response of reindeer/caribou to human activities.

Wilson, R., A. Bartsch, K. Joly, J. Reynolds, A. Orlando, and W. Loya. 2012. Summary of winter thaw-freeze events detected by satellite in national wildlife refuges on the Alaska Peninsula, 2001-2008.

Mammals: Polar Bear - General

DeMaster, D.P., and I. Stirling. 1981. *Ursus maritimus*. Mammalian Species No. 145:1-7.

Garshelis, D.L. 2009. Family Ursidae (Bears). Pp. 448-497 in D.E. Wilson and R.A. Mittermeier (eds.), Handbook of the mammals of the world. Vol. 1. Carnivores. Barcelona: Lynx Edicions.

Herreman, J., and E. Peacock. 2013. Polar bear use of a persistent food subsidy: insights from non-invasive genetic sampling in Alaska. Ursus 24:148-163.

Abstract - Remains of bowhead whales (*Balaena mysticetus*) harvested by Iñupiat whalers are deposited in bone piles along the coast of Alaska and have become persistent and reliable food sources for polar bears (*Ursus maritimus*). The importance of bone piles to individuals and the population, the patterns of use, and the number, sex, and age of bears using these resources are poorly understood. We implemented barbed-wire hair snaring to obtain genetic identities from bears using the Point Barrow bone pile in winter 2010–11. Eighty-three percent of genotyped samples produced individual and sex identification. We identified 97 bears from 200 samples. Using genetic mark–recapture techniques, we estimated that 228 bears used the bone pile during November to February, which would represent approximately 15% of the Southern Beaufort Sea polar bear subpopulation, if all bears were from this subpopulation. We found that polar bears of all age and sex classes simultaneously used the bone pile. More males than females used the bone pile, and males predominated in February, likely because 1/3 of adult females would be denning during this period. On average, bears spent 10 days at the bone pile (median = 5 days); the probability that an individual bear remained at the bone pile from week to week was 63% for females

and 45% for males. Most bears in the sample were detected visiting the bone pile once or twice. We found some evidence of matrilineal fidelity to the bone pile, but the group of animals visiting the bone pile did not differ genetically from the Southern Beaufort Sea subpopulation, nor did patterns of relatedness. We demonstrate that bowhead whale bone piles may be an influential food subsidy for polar bears in the Barrow region in autumn and winter for all sex and age classes.

Kurten, B. 1964. The evolution of the polar bear *Ursus maritimus* Phipps. Acta Zoologica Fennica 108:1-26.

Quote - Although the Polar Bear uses its swimming powers to move about in quest of its prey, the actual hunting always takes place on the ice or the ground, so that no radical change in the limbs would be expected; and they are in fact very little modified from the Brown Bear type.

Summary - This paper lists known fossil and subfossil material of the Polar Bear, *Ursus maritimus,* and describes new finds. The Late Pleistocene Polar Bear, *U. maritimus tyrannus,* new subspecies, was markedly larger than the living. As late as in Yoldia times, the Polar Bear P^4 was on an average more *arctos*-like than at present, indicating that evolution within the species has continued in the Postglacial. M^2 shows evidence of secondary reduction from an original condition resembling that in the Brown Bears. Allometric growth patterns in the Polar Bear skull may in several instances be matched by allometries found in early Middle Pleistocene (especially Mindel) Brown and Cave Bears, suggesting that the ancestry of the Polar Bear was close to this stock.

Mclellan, B., and D.C. Reiner. 1994. A review of bear evolution. International Conference on Bear Research and Management 9(1):85-96.

Abstract - Ursidae is a young family, evolving from early canids during the late Oligocene and early Miocene, about 20-25 million years ago. The family has frequently been divided into subfamilies. Although debated, these often include: (1) Hemicyoninae, (2) Agriotheriinae, (3) Tremarctinae,(4) Ursinae, and (5) Ailuropodidae. Based on scattered literature published over the past century, we trace the evolutionary lineage of the various genera and species found in these subfamilies; most are extinct, 8 species remain. Many if not most of the relationships have been disputed for many years and we may be far from the definitive history. Speculated causes of extinction usually involved climate change and competition. Primitive man may have been the major competitor of some extinct species and modem man is definitely a major influence on bear evolution today.

Stewart, B.S. 2014. Family Phocidae (Earless Seals). Pp. 120-183 in D.E. Wilson and R.A. Mittermeier (eds.), Handbook of the mammals of the world. Vol. 4. Sea mammals. Barcelona: Lynx Edicions.

Watts, P.D., and P.S. Ratson. 1989. Tour operator avoidance of deterrent use and harassment of polar bears. Pp. 189-193 in M. Bromley, M. (ed.), Bear–People Conflicts, Proceedings of a Symposium on Management Strategies. Northwest Territories Department of Renewable Resources, Yellowknife.

Watts, P.D., K.L. Ferguson, and B.A. Draper. 1991. Energetic output of subadult polar bears (*Ursus maritimus*): resting, disturbance and locomotion. Comparative Biochemistry and Physiology A., Comparative Physiology 98:191-193.

Mammals: Polar Bear - Status (past, present, future)

Amstrup, S.C., I. Stirling, and J.W. Lentfer. 1986. Past and present status of polar bears in Alaska. Wildlife Society Bulletin 14:241-254.

Summary and Conclusion - Four independent procedures for estimating population size suggested the number of polar bears in Alaska in 1984 was similar to the number in 1956, and that polar bears have probably never been more numerous in most Alaskan waters than 1 bear/137-240 km^2. Independently, each of these estimators is weak because of sample size limitations, possible violation of assumptions, or large variances. However, we believe the degree of agreement between them is significant.

Numbers of polar bears in Alaska apparently declined by the end of the trophy hunting period in 1972. Some recovery occurred during the mid- and late 1970s, and numbers appear to have been relatively stable since then.

Radio-tracking data suggest that polar bears occupying the area between Point Barrow, Alaska, and Cape Bathurst, Northwest Territories, Canada, are members of the same population. Mark-recapture data suggest the size of this population is 1,300-2,500 bears (Table 1). Limited information from the Chukchi Sea suggests winter-spring densities are similar to those in the Beaufort Sea. Densities of bears in the Bering Strait region may be higher in late winter and early spring, but are highly variable seasonally and dependent entirely on the conditions and motion of the ice.

We are concerned about the future of polar bears in the Beaufort Sea for several reasons. First, our estimates suggest stability in recent years, but the population is small. A small, isolated population with low reproductive potential is vulnerable to natural and human-caused perturbations. Second, despite many years of study, our knowledge of polar bear population dynamics is rudimentary. We cannot rule out the possibility that our assessment of stability was in error, and with a small population there is little latitude for error. Also, hydrocarbon exploration and development have allowed unprecedented increases in human numbers in coastal areas of the Beaufort Sea, and habitat is changing at an accelerating rate. As a result, opportunities for encounters between polar bears and humans are increasing. There is potential for a change in philosophy among increasingly numerous and mobile local people, a change in value of polar bear parts (e.g., hides, gall bladders), or development-related phenomena (such as an oil spill) to increase the human-caused mortalities of polar bears in the Beaufort Sea. The Beau- fort Sea population can sustain little if any increase in mortalities of females. Because we currently have no regulatory ability to protect females and young in Alaska, this potential for adverse change cannot be overlooked.

Notwithstanding the above conclusions, the harvest of polar bears in Alaska has a long history, and polar bears must be recognized as a valuable renewable resource. During the period of trophy hunting, 75% of the polar bear harvest was males, demonstrating that a managed hunt can protect females and concentrate on males. Airborne hunters could observe several bears in a brief time period, and were highly selective of animals they harvested. Present-day hunting from the ground is more limited in that regard; however, 3 simple regulations could again protect most females and their young. Immature polar bears accompany their mothers until the age of 2.5 (Lentfer et al. 1980). Therefore females are

encumbered by cubs during most of their adult lives. Single adult females are usually pregnant and will occupy maternity dens during December-April, at which time they emerge with new cubs (S.C. Amstrup, unpubl. data). Thus, if it were unlawful to harvest females accompanied by their young, most adult females would be protected. Further, most sin- gle females could be protected if it were unlawful to remove bears from dens, and if polar bear hunting was disallowed before 15 December (by which time most single females would be in dens). Reducing the losses of females to hunting would decrease the vulnerability of the population to both natural and human-caused perturbations. Also, because large numbers of adult males may suppress growth rates in bear populations (Kemp 1976, McCullough 1981, Young and Ruff 1982, Larsen 1985), a harvest concentrating on males may have some compensatory benefits, including the possibility of an increased take.

FWS (U.S. Fish and Wildlife Service). 1982. Arctic National Wildlife Refuge coastal plain resource assessment: initial report baseline study of the fish, wildlife, and their habitats. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

FWS (U.S. Fish and Wildlife Service). 1983. 50 CFR Part 37 - Geological and geophysical exploration of the coastal plain, Arctic National Wildlife Refuge, Alaska: final rule. Federal Register 48(76):16838-16872.

FWS (Fish and Wildlife Service). 1988a. Arctic National Wildlife Refuge comprehensive conservation plan, environmental impact statement, wilderness review, and wild river plans: final. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

FWS (Fish and Wildlife Service). 1988b. Record of decision: Arctic National Wildlife Refuge comprehensive conservation plan, environmental impact statement, wilderness review, and wild river plans. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

FWS (Fish and Wildlife Service). 1990. Management of oil and gas activity on the 1002 area of the Arctic National Wildlife Refuge. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

~~FWS (Fish and Wildlife Service). 1994. Water resource inventory and assessment, Arctic National Wildlife Refuge 1987-1992: final report. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Water Resources Branch.~~

FWS (Fish and Wildlife Service). 1999. Guide to management of Alaska's land mammals. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Office of Subsistence Management.

FWS (Fish and Wildlife Service). 2008. Birds of conservation concern 2008. Washington, D.C., U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Species.

FWS (Fish and Wildlife Service). 2008. Endangered and threatened wildlife and plants; Determination of threatened status for the polar bear (*Ursus maritimus*) throughout its range; final rule. Federal Register 73(95):28212-28303.

FWS (Fish and Wildlife Service). 2008. Endangered and threatened wildlife and plants; special rule for the polar bear [final]. Federal Register 73(242):76249-76269.

FWS (Fish and Wildlife Service). 2009. Endangered and threatened wildlife and plants; designation of critical habitat for the polar bear (*Ursus maritimus*) in the United States. Federal Register 74(208):56058-56086.

FWS (Fish and Wildlife Service). 2009. Endangered and threatened wildlife and plants; designation of critical habitat for the polar bear (*Ursus maritimus*) in the United States. Federal Register 74:56058-56086.

FWS (Fish and Wildlife Service). 2010. Polar bear (*Ursus maritimus*): Chukchi/Bering Seas Stock. Final Polar Bear Stock Assessment Report. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region, Marine Mammals Management.

FWS (Fish and Wildlife Service). 2013. Endangered and threatened wildlife and plants; special rule for the polar bear under Section 4(d) of the Endangered Species Act. Federal Register 78(34):11766-11788.

FWS (Fish and Wildlife Service). 2016a. Polar bear conservation management plan. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Alaska Region.

FWS (Fish and Wildlife Service). 2016b. Marine mammals; incidental take during specified activities: final rule. Federal Register 81(151):52276-52320.

FWS (Fish and Wildlife Service). 2016c. Finding of no significant impact and environmental assessment for a final rule to authorize the incidental take of small numbers of polar bear (*Ursus maritimus*) and Pacific walrus (*Odebenus rosmarus divergens*) during oil and gas activities in the Beaufort Sea and adjacent coastal Alaska. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service, Marine Mammals Office.

FWS (Fish and Wildlife Service). 2016d. Biological Opinion for polar bears and conference opinion for Pacific walrus on the proposed issuance of 2016-2021 Beaufort Sea incidental take regulations. Fairbanks, AK: U.S. Department of the Interior, Fish and Wildlife Service, Fairbanks Field Office.

Mammals: Polar Bear – Habitat/Climate Change Factors

Bergen, S., G.M. Durner, D.C. Douglas, and S.C. Amstrup. 2007. Predicting movements of female polar bears between summer sea ice foraging habitats and terrestrial denning habitats of Alaska in the 21st century: proposed methodology and pilot assessment. Reston, VA: U.S. Department of the Interior, Geological Survey Science Strategy to support U.S. Fish and Wildlife Service polar bear listing decision.

Abstract - Polar bears (*Ursus maritimus*) require the relative warmth and stability afforded by snow dens for successful reproduction. Pregnant bears must travel from foraging habitats on the sea ice to land in autumn to establish winter dens. Data of sea ice extent and composition from satellite-acquired passive microwave (PMW) imagery show a reduction in summer sea ice extent throughout the Arctic from 1979-2006. Additionally, General Circulation Models (GCM) predicted that Arctic sea ice extent will continue to diminish throughout the 21st century. Greater energetic demands will be placed on pregnant polar bears in the future if they travel greater distances from summer forage habitats to traditional denning habitats on land. We developed an approach for estimating how much these distances may change by modeling autumn movement paths of polar bears using the observational PMW record of sea ice distribution and sea ice projections of 5 GCMs during

the 21st century. Over the 1979-2006 PMW record, polar bears returning to Alaska to den have experienced an annual increase in travel of > 6 km/year—an increase of >168 km over the 28 year period. Based on GCM sea ice projections during 2001-2060, the average increase in the distance required to reach traditional Alaskan denning regions was estimated to increase > 16 km/year. Distances traveled, and therefore, energetic demands, will likely vary among the different circumpolar sub-populations of polar bears.

Durner, G.M., and T.C. Atwood. 2018. A comparison of photograph-interpreted and IfSAR-derived maps of polar bear denning habitat for the 1002 area of the Arctic National Wildlife Refuge, Alaska. U.S. Department of the Interior, Geological Survey Open-file Report 2018-108. doi:10.3133/ofr21081083

Abstract - Polar bears (*Ursus maritimus*) in Alaska use the Arctic National Wildlife Refuge (ANWR) for maternal denning. Pregnant bears den in snow banks for more than 3 months in winter during which they give birth to and nurture young. Denning is one of the most vulnerable times in polar bear life history as the family group cannot simply walk away from a disturbance without jeopardizing survival of newly born cubs. The ANWR includes the “1002 Area”, a region recently opened for oil and gas exploration by the U.S. Department of the Interior (DOI). As a part of its mission, the DOI “… protects and manages the Nation's natural resources …” and is therefore responsible for conserving polar bears and encouraging development of energy potential. Because future industrial activities could overlap habitats used by denning polar bears, identifying these habitats can inform the decisions of resource managers tasked to develop resources and protect polar bears. To help inform these efforts, we qualitatively compared the distribution of denning habitat identified by two different methods: previously published habitat from manual interpretation of aerial photographs, and habitat derived by computer interrogation of interferometric synthetic aperture radar (IfSAR) digital terrain models (DTM). Because photograph-interpreted methods depicted denning habitat as a line and IfSAR-derived methods depicted habitat as a polygon, we assessed agreement between the two methods with distance measurements. We found that 77.5 percent of IfSAR-derived denning habitat (79.6 km^2; 1.2 percent of the 6,837.0 km^2 1002 Area) was within 600 m of photograph-interpreted habitat (3,026.9 km), including 53.9 percent within 200 m. This distribution differed from that of randomly distributed points, as only 49.4 percent of these occurred within 600 m of photograph-interpreted habitat, including 18.3 percent within 200 m. Both methods appear to identify the major physiographic features that polar bears might select for denning. IfSAR-derived methods identified habitat at greater frequency beyond major landscape features such as coastal bluffs, river banks and lakeshores, were more likely to identify isolated pockets of putative denning habitat, and were easier to implement than deriving habitat from photograph-interpretive efforts. However, previous research suggests that photograph-interpretation methods may identify denning habitat more correctly than computer interrogation of IfSAR DTMs. Future work should quantify the distribution of IfSAR-derived denning habitat relative to actual landscape features and polar bear maternal dens in the 1002 Area, and investigate the feasibility of habitat identification from finer grained DTMs.

Durner, G.M., and T.C. Atwood. 2018. Data used to compare photo-interpreted and IfSAR-derived maps of polar bear denning habitat for the 1002 area of the Arctic National Wildlife Refuge, Alaska, 2006-2016. U.S. Department of the Interior, Geological Survey data release https://doi.org/10.5066/F7DJ5DXT

Summary – These are data that characterize the distribution of polar bear denning habitat in the 1002 area of the Arctic National Wildlife Refuge, Alaska. They were generated to compare the efficacy of two different techniques: (1) from a previously published study

(Durner et al. 2006) that used manual interpretation of aerial photos and (2) from computer interrogation of the interferometric synthetic aperture radar (IfSAR) digital derived terrain model (DTM) tiles used to generate the raster shapfiles. The IfSAR DTM are available for purchase through Internet Technologies, Inc., and are not provided in the data release.

Durner, G.M., S.C. Amstrup and K. Ambrosius. 2006. Polar bear maternal den habitat on the Arctic National Wildlife Refuge, Alaska. Arctic 59:31-36.

Abstract - Polar bears (*Ursus maritimus*) give birth during mid-winter in dens of ice and snow. Denning polar bears subjected to human disturbances may abandon dens before their altricial young can survive the rigors of the Arctic winter. Because the Arctic coastal plain of Alaska is an area of high petroleum potential and contains existing and planned oil field developments, the distribution of polar bear dens on the plain is of interest to land managers. Therefore, as part of a study of denning habitats along the entire Arctic coast of Alaska, we examined high-resolution aerial photographs (n = 1655) of the 7994 km^2 coastal plain included in the Arctic NWR and mapped 3621 km^2 of bank habitat suitable for denning by polar bears. Such habitats were distributed uniformly and comprised 0.29% (23.2 km^2) of the coastal plain between the Canning River and the Canadian border. Ground-truth sampling suggested that we had correctly identified 91.5% of bank denning habitats on the ANWR coastal plain. Knowledge of the distribution of these habitats will help facilitate informed management of human activities and minimize disruption of polar bears in maternal dens.

Durner, G.M., D.C. Douglas, R.M. Neilson, S.C. Amstrup, and T.L. McDonald. 2007. Predicting the future distribution of polar bear habitat in the polar basin from resource selection functions applied to 21st century general circulation model projections. Reston, VA: U.S. Department of the Interior, Geological Survey Science Strategy to support U.S. Fish and Wildlife Service polar bear listing decision.

Abstract - Predictions of polar bear (*Ursus maritimus*) habitat distribution in the Arctic polar basin during the 21st century were developed to help understand the likely consequences of anticipated sea ice reductions on polar bear populations. We used location data from satellite-collared polar bears and environmental data (e.g., bathymetry, coastlines, and sea ice) collected between1985–1995 to build habitat-use models called Resource Selection Functions (RSF). The RSFs described habitats polar bears preferred in each of four seasons: summer (ice minimum), autumn (growth), winter (ice maximum) and spring (melt). When applied to the model source data and to independent data (1996–2006), the RSFs consistently identified habitats most frequently used by polar bears. We applied the RSFs to monthly maps of 21st century sea ice concentration predicted by 10 general circulation models (GCM) described in the International Panel of Climate Change Fourth Assessment Report. The 10 GCMs we used had high concordance between their simulations of 20th century summer sea ice extent and the actual ice extent derived from passive microwave satellite observations. Predictions of the amount and rate of change in polar bear habitat varied among GCMs, but all GCMs predicted net habitat losses in the polar basin during the 21st century. Projected losses in the highest-valued RSF habitat (optimal habitat) were greatest in the peripheral seas of the polar basin, especially the Chukchi Sea and Barents Sea. Losses were least in high-latitude regions where RSFs predicted an initial increase in optimal habitat followed by a modest decline. The largest seasonal reductions in habitat were predicted for spring and summer. Average area of optimal polar bear habitat during summer in the polar basin declined from an observed 1.0 million km^2 in 1985–1995 (baseline) to a projected multi-model average of 0.58 million km^2 in 2045–2054 (-42% change), 0.36 million km^2 in 2070–2079 (-64% change), and 0.32 million km^2 in 2090–2099

(-68% change). After summer melt, most regions of the polar basin were projected to refreeze throughout the 21st century, so winter losses of polar bear habitat were more modest; from 1.7 million km2 in 1985–1995 to 1.4 million km^2 in 2090–2099 (-17% change). Simulated and projected rates of habitat loss during the late-20th and early-21st centuries by many GCMs tended to be less than observed rates of loss during the past 2 decades. Hence, we consider habitat losses based on GCM multi-model averages to be conservative. Although less available habitat will likely reduce polar bear populations, exact relationships between habitat losses and population demographics remain unknown. Density effects may become important because polar bears that make long distance annual migrations from traditional winter ranges to remnant high-latitude summer sea ice will enter regions already occupied by polar bears. Declines and large seasonal swings in habitat availability and distribution may impose greater impacts on pregnant females seeking denning habitat or leaving dens with cubs than on other sex and age groups. Despite annual replenishment of most winter habitats, large retreats of summer habitat may ultimately preclude bears from seasonally returning to their traditional winter ranges.

Durner, G.M., A.S. Fischbach, S.C. Amstrup, and D.C. Douglas. 2010. Catalogue of polar bear (*Ursus maritimus*) maternal den locations in the Beaufort Sea and neighboring regions, Alaska, 1910-2010. U.S. Department of the Interior, Geological Data Series 568.

Abstract - This report presents data on the approximate locations and methods of discovery of 392 polar bear (*Ursus maritimus*) maternal dens found in the Beaufort Sea and neighboring regions between 1910 and 2010 that are archived by the USGS Alaska Science Center, Anchorage, AK. A description of data collection methods, biases associated with collection method, primary time periods, and spatial resolution are provided. Polar bears in the Beaufort Sea and nearby regions den on both the sea ice and on land. Standardized VHF surveys and satellite radio telemetry data provide a general understanding of where polar bears have denned in this region over the past 3 decades. Den observations made during other research activities and anecdotal reports from other government agencies, coastal residents, and industry personnel also are reported. Data on past polar bear maternal den locations are provided to inform the public and to provide information for natural resource agencies in planning activities to avoid or minimize interference with polar bear maternity dens.

Fuller, T., D.P. Morton, and S. Sarkar. 2008. Incorporating uncertainty about species' potential distributions under climate change into the selection of conservation areas with a case study from the Arctic coastal plain of Alaska. Biological Conservation 141(6):1547-1559.

Abstract - This analysis presents a conservation planning framework for decisions under uncertainty and applies it to the Arctic Coastal Plain of Alaska. Uncertainty arises from variable distributional shifts of species' ranges due to climate change. The planning framework consists of a two-stage optimization model that selects a nominal conservation area network in the first stage and evaluates its performance under the climate scenarios in the second stage. The model is applied to eleven at-risk species in Alaska including the threatened Spectacled Eider and Steller's Eider sea ducks and the polar bear. The 109th United States Congress and 2008 federal budget proposed opening for oil and gas development the "1002 Area" of the Arctic National Wildlife Refuge, which intersects the Plain. This analysis finds that, if Arctic Alaska experiences 1.5 °C of warming by 2040 (as predicted by the Intergovernmental Panel on Climate Change's A2 scenario), then potential habitat will decrease significantly for eight of these at-risk species, including the polar bear. This analysis also shows that there is synergism between oil and gas development and climate change. For instance, climate change accompanied by no development of the 1002

Area results in an increase of potential habitat for Steller's Eider. However, if development accompanies climate change, then there is a 20% decrease in that area. Further, this analysis quantifies the tradeoff between development and maintenance of suitable habitat for at-risk species.

Molnar, P.K., A.E. Derocher, G.W. Thiemann, and M.A. Lewis. 2010. Predicting survival, reproduction and abundance of polar bears under climate change. Biological Conservation 143:1612-1622.

Abstract - Polar bear (*Ursus maritimus*) populations are predicted to be negatively affected by climate warming, but the timeframe and manner in which change to polar bear populations will occur remains unclear. Predictions incorporating climate change effects are necessary for proactive population management, the setting of optimal harvest quotas, and conservation status decisions. Such predictions are difficult to obtain from historic data directly because past and predicted environmental conditions differ substantially. Here, we explore how models can be used to predict polar bear population responses under climate change. We suggest the development of mechanistic models aimed at predicting reproduction and survival as a function of the environment. Such models can often be developed, parameterized, and tested under current environmental conditions. Model predictions for reproduction and survival under future conditions could then be input into demographic projection models to improve abundance predictions under climate change. We illustrate the approach using two examples. First, using an individual-based dynamic energy budget model, we estimate that 3–6% of adult males in Western Hudson Bay would die of starvation before the end of a 120 day summer fasting period but 28–48% would die if climate warming increases the fasting period to 180 days. Expected changes in survival are non-linear (sigmoid) as a function of fasting period length. Second, we use an encounter rate model to predict changes in female mating probability under sea ice area declines and declines in mate-searching efficiency due to habitat fragmentation. The model predicts that mating success will decline non-linearly if searching efficiency declines faster than habitat area, and increase non-linearly otherwise. Specifically for the Lancaster Sound population, we predict that female mating success would decline from 99% to 91% if searching efficiency declined twice as fast as sea ice area, and to 72% if searching efficiency declined four times as fast as area. Sea ice is a complex and dynamic habitat that is rapidly changing. Failure to incorporate climate change effects into population projections can result in flawed conservation assessments and management decisions.

Olson, J.W. 2015. Maternal denning phenology and substrate selection of polar bears (*Ursus maritimus*) in the southern Beaufort and Chukchi Seas. M.S. thesis. Provo, UT: Brigham Young University, Department of Plant and Wildlife Sciences.

Abstract - Loss of sea ice due to global warming may affect the phenology and distribution of polar bear denning by altering access to denning habitats. We examined trends in the selection of maternal denning substrate (land versus sea-ice denning) in the southern Beaufort Sea (SB), addressing the potential influence of summer land-use and fall sea-ice conditions on substrate selection. We developed an algorithm based on statistical process control methods to remotely identify denning bears and estimate denning phenology from temperature sensor data collected on collars deployed 1985–2013 in the SB and Chukchi Sea (CS). We evaluated cub survival relative to den entrance, emergence, and duration, and examined differences in the phenology of land and sea-ice dens. Land denning in the SB was more common during years when ice retreated farther from the coast and off of the continental shelf in September. All SB bears that occupied land prior to denning

subsequently denned on land; however, only 29% of denning bears that summered on sea ice denned on land. Den entrance and duration in the SB and CS were similar, although CS bears emerged later. Land dens were occupied longer than those on ice. Bears later observed with cubs remained in dens 23 days longer and emerged from denning 17 days later on average than bears that denned but were subsequently observed without cubs, suggesting that den exit dates are related to cub survival. The increase in land-based denning in the SB when sea ice retreated farther from shore, along with the positive correlation between fall land-use and land denning, suggest that further sea-ice declines may result in continued increases of onshore denning. Growing numbers of denning females along the coast may increase the potential for human-bear interactions.

Regehr, E.V., S.C. Amstrup, and I. Stirling. 2006. Polar bear population status in the southern Beaufort Sea. U.S. Department of the Interior, Geological Survey Open-File Report 1337.

Abstract - Polar bears depend entirely on sea ice for survival. In recent years, a warming climate has caused major changes in the Arctic sea ice environment, leading to concerns regarding the status of polar bear populations. Here we present findings from long-term studies of polar bears in the southern Beaufort Sea (SBS) region of the U.S. and Canada, which are relevant to these concerns. We applied open population capture-recapture models to data collected from 2001-2006, and estimated there were 1,526 (95% CI = 1,211; 1,841) polar bears in the SBS region in 2006. The number of polar bears in this region was previously estimated to be approximately 1,800. Because precision of earlier estimates was low, our current estimate of population size and the earlier ones cannot be statistically differentiated. For the 2001–2006 period, the best fitting capture-recapture model provided estimates of total apparent survival of 0.43 for cubs of the year (COYs), and 0.92 for all polar bears older than COYs. Because the survival rates for older polar bears included multiple sex and age strata, they could not be compared to previous estimates. Survival rates for COYs, however, were significantly lower than estimates derived in earlier studies ($P = 0.03$). The lower survival of COYs was corroborated by a comparison of the number of COYs per adult female for periods before (1967–89) and after (1990–2006) the winter of 1989–90, when warming temperatures and altered atmospheric circulation caused an abrupt change in sea ice conditions in the Arctic basin. In the latter period, there were significantly more COYs per adult female in the spring ($P = 0.02$), and significantly fewer COYs per adult female in the autumn ($P < 0.001$). Apparently, cub production was higher in the latter period, but fewer cubs survived beyond the first 6 months of life. Parallel with declining survival, skull measurements suggested that COYs captured from 1990 to 2006 were smaller than those captured before 1990. Similarly, both skull measurements and body weights suggested that adult males captured from 1990 to 2006 were smaller than those captured before 1990. The smaller stature of males was especially notable because it corresponded with a higher mean age of adult males. Male polar bears continue to grow into their teens, and if adequately nourished, the older males captured in the latter period should have been larger than those captured earlier. In western Hudson Bay, Canada, a significant decline in population size was preceded by observed declines in cub survival and physical stature. The evidence of declining recruitment and body size reported here, therefore, suggests vigilance regarding the future of polar bears in the SBS region.

Regehr, E.V., R.R. Wilson, K.D. Rode, M.C. Runge. 2015. Resilience and risk - A demographic model to inform conservation planning for polar bears. U.S. Department of the Interior, Geological Survey Open-File Report 2015-1029.

Abstract - Climate change is having widespread ecological effects, including loss of Arctic sea ice. This has led to listing of the polar bear (*Ursus maritimus*) and other ice-dependent

marine mammals under the U.S. Endangered Species Act (ESA). Methods are needed to evaluate the effects of climate change on population persistence to inform recovery planning for listed species. For polar bears, this includes understanding interactions between climate and secondary factors, such as subsistence harvest, which provide economic, nutritional, or cultural value to humans.

We developed a matrix-based demographic model for polar bears that can be used for population viability analysis and to evaluate the effects of human-caused removals. This model includes density-dependence (the potential for a declining environmental carrying capacity), density-independent limitation, and sex- and age-specific harvest vulnerabilities. We estimated values of adult female survival (0.93–0.96), recruitment (number of yearling cubs per adult female; 0.1–0.3), and carrying capacity (>250 animals) that must be maintained for a hypothetical population to achieve a 90-percent probability of persistence over 100 years.

We also developed a state-dependent management framework, based on harvest theory and the potential biological removal method, by linking the demographic model to simulated population assessments. This framework can be used to estimate the maximum sustainable rate of human-caused removals, including subsistence harvest, which maintains a population at its maximum net productivity level. The framework also can be used to calculate a recommended sustainable harvest rate, which generally is lower than the maximum sustainable rate and depends on management objectives, the precision and frequency of population data, and risk tolerance. The historical standard 4.5-percent harvest rate for polar bears, at a 2:1 male-to-female ratio, is reasonable under many biological and management conditions, although lower or higher rates may be appropriate in some cases.

Our modeling results suggest that harvest of polar bears is unlikely to accelerate population declines that result from declining carrying capacity caused by sea-ice loss, provided that several conditions are met: (1) the sustainable harvest rate reflects the population's intrinsic growth rate, and the corresponding harvest level is obtained by applying this rate to an estimate of population size; (2) the sustainable harvest rate reflects the quality of population data (e.g., lower harvest when data are poor); and (3) the level of human-caused removals can be adjusted. Finally, our results suggest that stopgap measures (e.g., further reduction or cessation of harvest when the population size is less than a critical threshold) may be necessary to minimize the incremental risk associated with harvest, if environmental conditions are deteriorating rapidly. We suggest that the demographic model and approaches presented here can serve as a template for conservation planning for polar bears and other species facing similar challenges.

Rode, K.D., J. Olson, D. Eggett, D.C. Douglas, G.M. Durner, T.C. Atwood, E.V. Regehr, R.R. Wilson, T. Smith, and M. St. Martin. In press. Denning phenology and polar bear reproductive success in a changing climate. Journal of Mammalogy.

Rode, K.D., S.C. Amstrup, and E.V. Regehr. 2010. Reduced body size and cub recruitment in polar bears associated with sea ice decline. Ecological Applications. 20:768-782.

Abstract - Rates of reproduction and survival are dependent upon adequate body size and condition of individuals. Declines in size and condition have provided early indicators of population decline in polar bears (*Ursus maritimus*) near the southern extreme of their range. We tested whether patterns in body size, condition, and cub recruitment of polar bears in the southern Beaufort Sea of Alaska were related to the availability of preferred sea ice habitats and whether these measures and habitat availability exhibited trends over time, between 1982 and 2006. The mean skull size and body length of all polar bears over three years of age declined over time, corresponding with long-term declines in the spatial and temporal availability of sea ice habitat. Body size of young, growing bears declined over time and was smaller after years when sea ice availability was reduced. Reduced litter mass and numbers of yearlings per female following years with lower availability of optimal sea ice habitat, suggest reduced reproductive output and juvenile survival. These results, based on analysis of a long-term data set, suggest that declining sea ice is associated with nutritional limitations that reduced body size and reproduction in this population.

Rode, K.D., E.V. Regehr, D.C. Douglas, G.M. Durner, A.E. Derocher, G.W. Thiemann, and S.M. Budge. 2014. Variation in the response of an Arctic top predator experiencing habitat loss: feeding and reproductive ecology of two polar bear populations. Global Change Biology 20:76-88.

Abstract - Polar bears (*Ursus maritimus*) have experienced substantial changes in the seasonal availability of sea ice habitat in parts of their range, including the Beaufort, Chukchi, and Bering Seas. In this study, we compared the body size, condition, and recruitment of polar bears captured in the Chukchi and Bering Seas (CS) between two periods (1986–1994 and 2008–2011) when declines in sea ice habitat occurred. In addition, we compared metrics for the CS population 2008–2011 with those of the adjacent southern Beaufort Sea (SB) population where loss in sea ice habitat has been associated with declines in body condition, size, recruitment, and survival. We evaluated how variation in body condition and recruitment were related to feeding ecology. Comparing habitat conditions between populations, there were twice as many reduced ice days over continental shelf waters per year during 2008–2011 in the SB than in the CS. CS polar bears were larger and in better condition, and appeared to have higher reproduction than SB bears. Although SB and CS bears had similar diets, twice as many bears were fasting in spring in the SB than in the CS. Between 1986–1994 and 2008–2011, body size, condition, and recruitment indices in the CS were not reduced despite a 44-day increase in the number of reduced ice days. Bears in the CS exhibited large body size, good body condition, and high indices of recruitment compared to most other populations measured to date. Higher biological productivity and prey availability in the CS relative to the SB, and a shorter recent history of reduced sea ice habitat, may explain the maintenance of condition and recruitment of CS bears. Geographic differences in the response of polar bears to climate change are relevant to range-wide forecasts for this and other ice-dependent species.

Rode, K.D., C.T. Robbins, L. Nelson, and S.C. Amstrup. 2015. Can polar bears use terrestrial foods to offset lost ice-based hunting opportunities?. Frontiers in Ecology and the Environment 13:138-145.

Rode, K.D., R.R. Wilson, D.C. Douglas, V. Muhlenbruch, T.C. Atwood, E.V. Regehr, E. Richardson, N. Pilfold, A. Derocher, G. Durner, I. Stirling, S. Amstrup, M. St. Martin, A.Pagano, E. Peacock, and K. Simac. In press. Spring fasting behavior among polar bears provides and index of ecosystem productivity. Global Change Biology.

Wilson, R.R., E.V. Regehr, M. St. Martin, T.C. Atwood, L. Peacock, S. Miller, and G. Divoky. 2017. Onshore ecology of polar bears in relation to sea-ice loss with implications for the management of conflict with humans. Biological Conservation 214:288-294.

Mammals: Polar Bear/Grizzly Bear - Disturbances

Amstrup, S.C. 1993. Human disturbances of denning polar bears in Alaska. Arctic 46:246-250.

<u>Abstract</u> - Polar bears (*Ursus maritimus*) give birth in dens of snow and ice. The altricial neonates cannot leave the den for >2 months post-partum and are potentially vulnerable to disturbances near dens. The coastal plain (1002) area of Alaska's Arctic National Wildlife Refuge (ANWR) lies in a region of known polar bear denning and also may contain >9 billion barrels of recoverable oil. Polar bears in dens could be affected in many ways by hydrocarbon development, but neither the distribution of dens nor the sensitivity of bears in dens has been known. I documented the distribution of dens on ANWR between 1981 and 1992 and observed responses of bears in dens to various anthropogenic disturbances. Of 44 dens located by radiotelemetry on the mainland coast of Alaska and Canada, 20 (45%) were on ANWR and 15 (34%) were within the 1002 area. Thus, development of ANWR will increase the potential that denning polar bears are disturbed by human activities. However, perturbations resulting from capture, marking, and radiotracking maternal bears did not affect litter sizes or stature of cubs produced. Likewise, 10 of 12 denned polar bears tolerated exposure to exceptional levels of activity. This tolerance and the fact that investment in the denning effort increases through the winter indicated that spatial and temporal restrictions on developments could prevent the potential for many disruptions of denned bears from being realized.

Anderson, M. 2013. Polar bears (*Ursus maritimus*) in the Barents Sea area: population biology and linkages to sea ice change, human disturbance and pollution. Ph.D. dissertation. University of Tromso, Faculty of Biosciences, Fisheries and Economics, Department of Arctic and Marine Biology.

<u>Summary</u> - Polar bears in the Barents Sea population have been protected from hunting in Russia since 1956 and following the signing of the international Polar Bear Agreement in 1973 in Norway. This thesis seeks to summarize current knowledge on key population biology issues four decades after the Norwegian protection and almost six after the Russian. Further, it discusses threats that have developed in the decades following protection against human harvesting. It concludes with a discussion of the effect of multiple stressors on the population, and some thoughts on future research, monitoring and management.

Polar bears in Svalbard and the Barents Sea area have been studied during the last 40 years with the aim of gaining knowledge regarding population biology and to evaluate potential sources of impact on the population from anthropogenic activity and changes to their habitat. The initial threat to polar bears in the region was unquestionably overharvest. Polar bear numbers were reduced quite drastically and hunting was clearly not sustainable. After the harvesting was stopped, the population grew in size to an estimated 2650 (1900-3600) in 2004. We believe that population recovery led to a wider distribution of maternity denning in the Svalbard Archipelago, compared to the period just after the protection of the population in 1973. However, during recent decades, the population has faced challenges from a variety of new anthropogenic impacts. The population has been exposed to a range of pollutants and an increasing level of human presence and activity within their range. Contaminants are bioaccumulated through the trophic levels in the marine food web, culminating in this top predator that consumes primarily ringed, bearded and harp seals. Females with small cubs use the land-fast sea ice for hunting, and are vulnerable to human disturbance. Changes in sea ice conditions also affect polar bears in the region, and reduced access to denning areas on the eastern islands of Svalbard is currently a concern. A decrease in spring land-fast ice close to important denning areas could negatively affect the survival of cubs.

Research and monitoring provides advice to management bodies both locally and globally. Information on the presence of toxic compounds in High Arctic systems has resulted in progress in recent decades in having better control of harmful substances and in some cases international bans on their production and use. This has resulted in declining contaminant burdens in polar bears. Unfortunately, new harmful substances are finding their way to the Arctic, while others, such as radionuclides, are stored locally (within Russian Territories) in large quantities, representing potential sources of pollution. The protection of important habitats locally with restrictions on motorized traffic may help reduce negative impacts from human activity on polar bears in the region. The fate of polar bears with regard to climate change is uncertain, but significant negative effects have been documented and these impacts are expected to increase in the coming decades. Relevant research and monitoring of polar bears is essential for future management of the species. The arctic environment should be managed in such a way that the combined effects of stressors on polar bear populations are minimized.

Anderson, M., and J. Aars. 2008. Short-term behavioural response of polar bears (*Ursus maritimus*) to snowmobile disturbance. Polar Biology 31:501-507.

Abstract - In this study the distance, at which polar bears detected and actively responded to approaching snowmobiles was measured and the behavioural response was recorded. The study was performed on Svalbard, an arctic island where human traffic has increased substantially in recent years. Fieldwork was conducted in April and/or May during the years 2003–2005. Polar bears were observed on ice with telescopes and binoculars. Undisturbed polar bears were observed continuously and their behaviours recorded, during the time when two snowmobiles moved toward the bear(s). Distances between the bear, the observer, and the approaching snowmobiles were measured using GPS positions taken on the track towards the bear. Data on the behavioural response of 20 encounters with bears were collected. On average, bears were alerted to the snowmobiles at 1,164 m. Mean distance at which the locomotive response occurred was 843 m, and there was a statistical significant difference in distance between sex and age classes [326 m (95% CI = 138–496 m) for adult males; 1,534 m (95% CI = 508–2,768 m) for adult females with cubs; 164 m (95% CI = 49–543 m) for two adult females without cubs; and 1,160 m (95% CI = 375–1,353 m) for single medium sized bears]. The responses of the polar bears to the snowmobiles were categorized according to intensity and persistence of reactions. Females with cubs and single medium sized bears tended to show more intense responses than adult males and lone adult females. Wind direction affects sound and odour transmission, and although an effect on response distance was not found, the response intensity was affected by wind direction. We conclude that female polar bears with small cubs in particular may have a greater risk to be disturbed, since they react at greater distances with amplified reactions; thus, users of snowmobiles should take particular care in areas where females with cubs are present.

Atwood, T.C., B.G. Marcot, D.C. Douglas, S.C. Amstrup, K.D. Rode, G.M. Durner, J.F. Bromaghin. 2015. Evaluating and ranking threats to the long-term persistence of polar bears. USGS Open-File Report 2014-1254.

Abstract - The polar bear (*Ursus maritimus*) was listed as a globally threatened species under the Endangered Species Act (ESA) in 2008, mostly due to the significant threat to their future population viability from rapidly declining Arctic sea ice. A core mandate of the ESA is the development of a recovery plan that identifies steps to maintain viable populations of a listed species. A substantive evaluation of the relative influence of putative

threats to population persistence is helpful to recovery planning. Because management actions must often be taken in the face of substantial information gaps, a formalized evaluation hypothesizing potential stressors and their relationships with population persistence can improve identification of relevant conservation actions. To this end, we updated a Bayesian network model previously used to forecast the future status of polar bears worldwide. We used new information on actual and predicted sea ice loss and polar bear responses to evaluate the relative influence of plausible threats and their mitigation through management actions on the persistence of polar bears in four ecoregions. We found that polar bear outcomes worsened over time through the end of the century under both stabilized and unabated greenhouse gas (GHG) emission pathways. Under the unabated pathway (i.e., RCP 8.5), the time it took for polar bear populations in two of four ecoregions to reach a dominant probability of greatly decreased was hastened by about 25 years. Under the stabilized GHG emission pathway (i.e., RCP 4.5), where GHG emissions peak around the year 2040, the polar bear population in the Archipelago Ecoregion of High Arctic Canada never reached a dominant probability of greatly decreased, reinforcing earlier suggestions of this ecoregion's potential to serve as a long-term refugium. The most influential drivers of adverse polar bear outcomes were declines to overall sea ice conditions and to the marine prey base. Improved sea ice conditions substantively lowered the probability of a decreased or greatly decreased outcome, while an elevated marine prey base was slightly less influential in lowering the probability of a decreased or greatly decreased outcome. Stressors associated with *in situ* human activities exerted considerably less influence on population outcomes. Reduced mortality from hunting and defense of life and property interactions resulted in modest declines in the probability of a decreased or greatly decreased population outcome. Minimizing other stressors such as trans-Arctic shipping, oil and gas exploration, and point-source pollution had negligible effects on polar bear outcomes, but that could be attributed to uncertainties in the ecological relevance of those specific stressors. Our findings suggest adverse consequences of loss of sea ice habitat become more pronounced as the summer ice-free period lengthens beyond 4 months, which could occur in portions of the Arctic by the middle of this century under the unabated pathway. The long-term persistence of polar bears may be achieved through ameliorating the loss of sea ice habitat, which will likely require stabilizing CO2 emissions at or below the ceiling represented by RCP 4.5. Management of other stressors may serve to slow the transition of polar bear populations to progressively worsened outcomes, and improve the prospects of persistence, pending GHG mitigation.

Atwood, T.C., E. Peacock, M.A. McKinney, K. Lillie, R.R. Wilson, D.C. Douglas, S. Miller, and P. Terletzky. 2016. Rapid environmental change drives increased land use by an Arctic marine predator. PLoS One 11:e0155932.

<u>Abstract</u> - In the Arctic Ocean's southern Beaufort Sea, the length of the sea ice melt season (i.e., period between the onset of sea ice break-up in summer and freeze-up in fall) has increased substantially since the late 1990s. Historically, polar bears (*Ursus maritimus*) of the SB have mostly remained on the sea ice year-round (except for those that came ashore to den), but recent changes in the extent and phenology of sea ice habitat have coincided with evidence that use of terrestrial habitat is increasing. We characterized the spatial behavior of polar bears spending summer and fall on land along Alaska's north coast to better understand the nexus between rapid environmental change and increased use of terrestrial habitat. We found that the percentage of radiocollared adult females from the SB subpopulation coming ashore has tripled over 15 years. Moreover, we detected trends of earlier arrival on shore, increased length of stay, and later departure back to sea ice, all of which were related to declines in the availability of sea ice habitat over the continental shelf

and changes to sea ice phenology. Since the late 1990s, the mean duration of the open-water season in the SB increased by 36 days, and the mean length of stay on shore increased by 31 days. While on shore, the distribution of polar bears was influenced by the availability of scavenge subsidies in the form of subsistence-harvested bowhead whale (*Balaena mysticetus*) remains aggregated at sites along the coast. The declining spatio-temporal availability of sea ice habitat and increased availability of human-provisioned resources are likely to result in increased use of land. Increased residency on land is cause for concern given that, while there, bears may be exposed to a greater array of risk factors including those associated with increased human activities.

Blix, A.S. and J.W. Lentfer. 1992. Noise and vibration levels in artificial polar bear dens as related to selected petroleum exploration and developmental activities. Arctic 45(1):20-24.

Abstract - The noise and vibration levels resulting from seismic testing, drilling and transport were measured in artificial polar bear dens at Prudhoe Bay, Alaska. It was concluded that the dry and wind-beaten arctic snow muffles both sound and vibrations extremely well and it seems unlikely that polar bears in their dens will be disturbed by the type of petroleum-related activities measured here, providing those activities do not take place within 100 m of the den.

Dyck, M.G., 2001. Effects of tundra vehicle activity on polar bears (*Ursus maritimus*) at Churchill, Manitoba. Winnepeg: University of Manitoba, Master's thesis.

[editor note – may be integrated into published article 2004].

Dyck, M.G., R.K. Baydack. 2004. Vigilance behaviour of polar bears (*Ursus maritimus*) in the context of wildlife-viewing activities at Churchill, Manitoba, Canada. Biological Conservation 116(3):343-350.

Abstract - Viewing of polar bears (*Ursus maritimus*) from tundra vehicles has been offered at Churchill, Manitoba since the early 1980s. This form of wildlife viewing has provided a unique and safe way for tourists to learn about polar bears. However, these activities have largely been carried out without examining possible effects on polar bear behavior. We studied vigilance behavior (a scanning of the immediate vicinity and beyond) of resting polar bears to evaluate impacts from tundra vehicle activity. Focal animal sampling was used to examine whether a difference in vigilance behavior existed when vehicles were present. We recorded the numbers of head-ups, vigilance bout length, and between-bout intervals for polar bears. In general, the frequency of head-ups increased, and the between-bout intervals decreased for male bears, when vehicles were present. Female bears behaved opposite to males. The vigilance bout lengths did not differ significantly between vehicle presence and absence. Vigilance behavior of male bears was not magnified with increasing numbers of vehicles; therefore the threshold is one vehicle. We suggest that manipulative studies be conducted to examine how distances between vehicles and bears, tundra vehicle activity in the immediate vicinity of a bear during viewing, and noise of tourists affect increased vigilance.

Ferguson, S.H., M.K. Taylor, and F. Messier. 2000. Influence of sea ice dynamics on habitat selection by polar bears. Ecology 81(4):761-772.

Abstract - Polar bears live in high-latitude environments characterized by cyclic variation in form and extent of sea ice. From 1991 to 1995, we used radio telemetry and monthly satellite images to compare patterns of ice selection by 110 female polar bears, relative to

two geographic regions and four seasons. We hypothesized that extreme seasonal changes in ice characteristics in the Baffin Bay region, including a period of open water, may limit polar bear density despite supporting greater prey density than the Archipelago region, where ice is present year-round. Using cyclic time series analysis to model seasonal variation, we found differences in level, amplitude, and phase between sea ice characteristics and habitat selection by polar bears of the Arctic Archipelago and Baffin Bay regions. Polar bears not only followed seasonal changes, but they anticipated seasonal fluctuations, e.g., polar bears were found close to ice edges in spring in advance of the peak availability of edges. Also, seasonal selection of sea ice by polar bears was generally of a larger amplitude than cycles in ice and is best explained by intensive use of specific ice types in spring and summer, and sparse use during the remaining year. During spring and summer, Archipelago bears used landfast ice more intensively, whereas Baffin bears used moving ice, defined as thick first-year ice found in large floes. Both ice types likely represent areas where most seal pupping occurred in spring for each region. Bears from both regions selected first-year ice in winter when new ice was forming and multiyear ice in autumn when maximum ice melt had occurred. Overall, polar bear selection of ice habitat was similar between regions despite major differences in seasonal ice characteristics. Polar bear density may not directly relate to prey density, due to the limited ability of bears to track the extreme seasonal fluctuations in ice extent found in more productive environments.

Ferguson, S.H., M.K. Taylor, A. Rosing-Asvid, E.W. Born, and F. Messier. 2000. Relationships between denning of polar bears and condition of sea ice. Journal of Mammalogy 81(4)1118-1127.

Abstract - We examined shelter and maternity dens used by 97 adult female polar bears (*Ursus maritimus*) in relation to conditions of sea ice. Obligate use of maternity dens for pregnancy, birth, and lactation varied little with latitude or area. In contrast, timing of facultative use of shelter dens switched from autumn in the southern area (<70°N) to winter in the northern area (>75°N). For the southern area, 13 of 16 female polar bears used shelter dens in autumn versus winter (median dates of entry and exit, 11 September and 2 November; total = 56 days), whereas in the northern area, 11 of 17 bears used shelter dens in winter versus autumn (median dates, 24 December and 2 March; total = 65 days). Difference in facultative use of shelter dens was associated with conditions of sea ice. Southern regions had no sea ice when polar bears used shelter dens. In contrast, northern areas had more constant ice conditions that included presence of ice throughout the year. Southern regions seem to have greater primary productivity and more seals as a result of a pronounced seasonal cycle of annual ice. Polar bears in northern areas responded to the more constant ice conditions and less productive environment with use of shelter dens during the period with lowest seal accessibility.

Fischbach, A.S., S.C. Amstrup, and D.C. Douglas. 2007. Landward and eastward shift in Alaskan polar bear denning associated with recent sea ice changes. Polar Biology 30(11):1395-1405.

Abstract - Polar bears *(Ursus maritimus)* in the northern Alaska region den in coastal areas and on offshore drifting ice. We evaluated changes in the distribution of polar bear maternal dens between 1985 and 2005, using satellite telemetry. We determined the distribution of maternal dens occupied by 89 satellite-collared female polar bears between 137°W and 167°W longitude. The proportion of dens on pack ice declined from 62% in 1985–1994 to 37% in 1998–2004 (P = 0.044) and among pack ice dens fewer occurred in the western Beaufort Sea after 1998. We evaluated whether hunting, attraction to bowhead whale remains, or changes in sea ice could explain changes in den distribution. We concluded

that denning distribution changed in response to reductions in stable old ice, increases in unconsolidated ice, and lengthening of the melt season. In consort, these changes have likely reduced the availability and quality of pack ice denning habitat. Further declines in sea ice availability are predicted. Therefore, we expect the proportion of polar bears denning in coastal areas will continue to increase, until such time as the autumn ice retreats far enough from shore that it precludes offshore pregnant females from reaching the Alaska coast in advance of denning.

Linnell, J.D., J.E. Swenson, R. Andersen, and B. Barnes. 2000. How vulnerable are denning bears to disturbance? Wildlife Society Bulletin 28(2):400-413.

Abstract - When exposed to human disturbance, most large carnivores are able to move away from the source with little energetic cost. Bears represent an exception in that during winter, most individuals spend several months in an energy-saving state of hibernation in a den. This implies that **disturbance of denning bears has the potential to have a large energetic cost**, although data on the subject are rather diffuse. We reviewed the literature on densite selection, denning physiology, and responses to disturbance for the brown bear (*Ursus arctos*), black bear (*U. americanus*), and polar bear (*U. maritimus*). Generally, bears select dens one to 2 km from human activity (roads, habitation, industrial activity) and seemed to tolerate most activities that occurred more than one km from the den. Activity closer than one km and especially within 200 m caused variable responses. Some bears tolerate disturbance even inside the den, but **bears will abandon dens in response to activity within this zone, especially early in the denning period**. Den abandonment by brown and black bear females with cubs of the year can lead to increased cub mortality. Specific excavated or ground dens are rarely reused, whereas natural caves or hollow trees are reused with varying frequency. There is often some distance between an individual bear's consecutive dens. This indicates that loss of a single denning area following human disturbance will not always lead to deleterious effects, if alternative denning areas are available within the home range.

Mattson, D.J. 1990. Human impacts of bear habitat use. Bears: their biology and management 8:33-56.

Abstract - Human effects on bear habitat use are mediated through food biomass changes, bear tolerance of humans and their impacts, and human tolerance of bears. Large-scale changes in bear food biomass have been caused by conversion of wildlands and waterways to intensive human use, and by the introduction of exotic pathogens. Bears consume virtually all human foods that have been established in former wildlands, but bear use has been limited by access. Air pollution has also affected bear food biomass on a small scale and is likely to have major future impacts on bear habitat through climatic warming. Major changes in disturbance cycles and landscape mosaics wrought by humans have further altered temporal and spatial pulses of bear food production. These changes have brought short-term benefits in places, but have also added long-term stresses to most bear populations. Although bears tend to avoid humans, they will also use exotic and native foods in close proximity to humans. Sub-adult males and adult females are more often impelled to forage closer to humans because of their energetic predicament and because more secure sites are often preempted by adult males. Although male bears are typically responsible for most livestock predation, adult females and sub-adult males are more likely to be habituated to humans because they tend to forage closer to humans. Elimination of human-habituated bears predictably reduces effective carrying capacity and is more likely to be a factor in preserving bear populations where humans are present in moderate-to-high densities. If humans desire to preserve viable bear populations, they will either have to accept increased risk of injury associated with preserving habituated animals, or continue to crop habituated bears while at the same time preserving large tracts of wildlands free from significant human intrusion.

McLellan, B.N, and D.M. Shackleton. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25(2):451-460.

Abstract - Roads are an integral part of the development of resource-extraction industries. We wanted to know whether grizzly bears were displaced by these roads from adjacent habitats. Over 7 years, twenty-seven grizzly bears were captured and radio-collared in 264 km^2 of the Rocky Mountains, containing active tree-felling and petrocarbon developments. (2) Most bears used habitats within 100 m of roads less than expected. This is equivalent to a habitat loss of 8.7%. This is significant because many habitats close to roads contain important bear foods. Avoidance of roads was independent of traffic volume, suggesting that even a few vehicles can displace bears. (3) Roads and nearby areas were used at night but avoided in the day. Yearlings and females with cubs used habitats near roads more than other bears. These areas may have been relatively secure because they were avoided by potentially aggressive adult males. (4) Limited data indicated minimal demographic effects during our study, but roads increased access for legal and illegal hunters, the major source of adult grizzly mortality. (5) When roads are developed for resource industries in grizzly bear habitat, the bear population becomes highly vulnerable unless vehicle access and people with firearms are controlled.

McLellan, B.N., and D.M. Shackleton. 1989. Immediate reactions of grizzly bears to human activities. Wildlife Society Bulletin 17(3):269-274.

Management Implications - Because grizzly bears in open habitats responded more strongly to ground-based human activities than did bears in cover, high human-use areas such as roads should be constructed away from open areas to reduce disturbance. Timber companies should always leave visual cover between haul roads and cutting units when practical and close spur roads to cutting units once post-logging treatments are complete. Conversely, where strong reactions of bears to humans are desired, such as at industrial camps or settlements, removing cover by clearing adjacent timber may be beneficial.

Bears become habituated to human activities, particularly moving vehicles, and habituated bears are more vulnerable to both legal and illegal harvest. Therefore, we recommend that roads be closed whenever possible to reduce habituation and deaths of grizzly bears.

Grizzly bears in this study responded more strongly to people on foot in remote areas than to any other stimulus. Areas with known seasonal concentrations of bears could be closed to hikers to protect both bears and people.

Summary – We studied reactions of grizzly bears to human activities between 1979 and 1986 in the North Fork of the Flathead River drainage of southeastern British Columbia and northern Montana. Reactions of bears were measured primarily by radio telemetry rather than by direct observations to reduce recording biases caused by cover or bear behavior. Bears responded more strongly to ground-based human activities, such as people on foot or moving vehicles, when in the open than when in cover. Cover had less effect on their response to fixed-wing aircraft. Bears generally dis- played stronger reactions to human activities, other than to people on foot, that occurred <76 m than farther away. The strongest response of bears was to people on foot, and these reactions were most extreme in areas of low human use.

Reynolds, P.E., H.V. Reynolds, and E.H. Follmann. 1986. Responses of grizzly bears to seismic surveys in northern Alaska. International Conference on Bear Research and Management 6:169-175.

Abstract - Responses of denning grizzly bears (*Ursus arctos*) to noise associated with winter seismic surveys and small fixed-wing aircraft were studied on the north slope of Alaska during the years 1978-1981. Changes in signal amplitude and collar temperature were monitored in 4 bears denned near seismic lines. Heart rates monitored by implanted transmitters, were measured in 1 of these bears and in a 2nd bear not subjected to seismic exploration activities. None of the bears left their dens as a result of seismic exploration activities. In undisturbed midwinter conditions, heart rates of 2 denned bears ranged 12- 26 beats/min, but rose to 30-50 beats/min for brief periods at least once or twice in 24 hours. Signal amplitudes and collar temperatures, monitored in 1 bear, did not vary. During 3 days when seismic crews were working near 1 den, changes in signal amplitude and collar temperatures, accompanied by increases in heart rate to a maximum of 64 beats/min, indicated that the bear moved several times. Heart rates of 2 bears recorded during midwinter overflights were the same as those measured in midwinter from the ground in undisturbed conditions. About the time of emergence, heart rates were higher than those recorded in midwinter and during undisturbed resting behavior in mid-June.

Mammals – Small (non-predator)

Batzli, G.O. 1975. The role of small mammals in Arctic ecosystems. Pp. 243-268 in F.B. Golley, K. Petrusewicz, and L. Ryszkowski, Small mammals and their productivity and population dynamics. New York, NY: Cambridge University Press, International Biological Programme 5.

Summary and Conclusions – It is clear from the discussions above that small mammals, particularly microtine rodents, play a pivotal role in tundra ecosystems. Whereas peak microtine populations in temperate grasslands may only consume 1-35% of available food during a particular season, lemmings may consume nearly all of their accessible forage (50-90%).

The effects on the vegetation, microtopography and soil are striking. Productivity of vegetation and nutrient concentrations in both vegetation and soil fluctuate in rhythm with microtine cycles, and these fluctuations appear to be caused by microtine grazing. This may be the only case of herbivore control of nutrient flux through a terrestrial ecosystem. In addition, changes in topography (formation of hummocks) and vegetational composition (reduction of mosses and lichens) seem to be associated with small mammal activity.

Reproductive activity and density of predator populations also cycle in response to microtine density. Indirect effects may be felt by other tundra inhabitants, particularly breeding birds, when predators shift their diet following a microtine decline.

A word of caution must be added. The distribution and population dynamics of small mammals in the Arctic is relatively poorly known. While the conclusions I have drawn certainly apply to low coastal tundra which support high densities of lemmings, their application in other types of tundra may be debated.

Robinson, B.G., A. Franke, and A.E. Derocher. 2014. The influence of weather and lemmings on spatiotemporal variation in the abundance of multiple avian guilds in the Arctic. PLoS ONE 9(7): e101495. doi:10.1371/journal.pone.0101495.

Abstract - Climate change is occurring more rapidly in the Arctic than other places in the world, which is likely to alter the distribution and abundance of migratory birds breeding there. A warming climate can provide benefits to birds by decreasing spring snow cover, but increases in the frequency of summer rainstorms, another product of climate change, may reduce foraging opportunities for insectivorous birds. Cyclic lemming populations in the Arctic also influence bird abundance because Arctic foxes begin consuming bird eggs when lemmings decline. The complex interaction between summer temperature, precipitation, and the lemming cycle hinder our ability to predict how Arctic-breeding birds will respond to climate change. The main objective of this study was to investigate the relationship between annual variation in weather, spring snow cover, lemming abundance and spatiotemporal variation in the abundance of multiple avian guilds in a tundra ecosystem in central Nunavut, Canada: songbirds, shorebirds, gulls, loons, and geese. We spatially stratified our study area based on vegetation productivity, terrain ruggedness, and freshwater abundance, and conducted distance sampling to estimate strata-specific densities of each guild during the summers of 2010–2012. We also monitored temperature, rainfall, spring snow cover, and lemming abundance each year. Spatial variation in bird abundance matched what was expected based on previous ecological knowledge, but weather and lemming abundance also significantly influenced the abundance of some guilds. In particular, songbirds were less abundant during the cool, wet summer with moderate snow cover, and shorebirds and gulls declined with lemming abundance. The abundance of geese did not vary over time, possibly because benefits created by moderate spring snow cover were offset by increased fox predation when lemmings were scarce. Our study provides an example of a simple way to monitor the correlation between weather, spring snow cover, lemming abundance, and spatiotemporal variations in Arctic-breeding birds.

Therrien, J.-F., F. Gauthier, E. Korpimaki, and J. Bety. 2014. Predation pressure by avian predators suggests summer limitation of small-mammal populations in the Canadian Arctic. Ecology 95(1):56-67.

Abstract - Predation has been suggested to be especially important in simple food webs and less productive ecosystems such as the arctic tundra, but very few data are available to evaluate this hypothesis. We examined the hypothesis that avian predators could drive the population dynamics of two cyclic lemming species in the Canadian Arctic. A dense and diverse suite of predatory birds, including the Snowy Owl (*Bubo scandiacus*), the Rough-legged Hawk (*Buteo lagopus*), and the Long-tailed Jaeger (*Stercorarius longicaudus*), inhabits the arctic tundra and prey on collared (*Dicrostonyx groenlandicus*) and brown (*Lemmus trimucronatus*) lemmings during the snow-free period. We evaluated the predation pressure exerted by these predators by combining their numerical (variation in breeding and fledgling numbers) and functional (variation in diet and daily consumption rates) responses to variations in lemming densities over the 2004–2010 period. Breeding density and number of fledglings produced by the three main avian predators increased sharply without delay in response to increasing lemming densities. The proportion of collared lemmings in the diet of those predators was high at low lemming density (both species) but decreased as lemming density increased. However, we found little evidence that their daily consumption rates vary in relation to changes in lemming density. Total consumption rate by avian predators initially increased more rapidly for collared lemming but eventually leveled off at a much higher value for brown lemmings, the most abundant species at our site. The combined daily predation rate of avian predators exceeded the maximum daily potential growth rates of both lemming species except at the highest recorded densities for brown lemmings. We thus show, for the first time, that predation pressure exerted without delay by avian predators can

limit populations of coexisting lemming species during the snow-free period, and thus, that predation could play a role in the cyclic dynamic of these species in the tundra.

Yoccoz, N.G., and R.A. Ims. 1999. Demography of small mammals in cold regions: the importance of environmental variability. Ecological Bulletins 47:137-144.

Abstract - Environmental variability in arctic and alpine regions is large, and consists of predictable (seasonality) as well as less predictable components (e.g., between-years variability). We compare demography of alpine and arctic microtines based on two long-term studies in the French Alps (snow vole, *Chionomys nivalis*) and at Svalbard (sibling vole, *Microtus rossiaemeridionalis*) as, well as data from a short-term study on the common vole, *M. arvalis*, in the Alps. While the length of the vegetation period is of the same order of magnitude (3-4 mo in the Alps, 3 mo at Svalbard), the population dynamics and demography of the snow vole and of the sibling vole population are strikingly different. The alpine snow vole population is very stable, with little variability in survival and reproduction between years, particularly so during the winter. The sibling vole Svalbard population is highly fluctuating, with low variability in summer demographic rates and large variability in winter population rate of change. These different patterns of variability in the dynamics and demography of small mammals are related to the climatic patterns in both areas, particularly the pronounced seasonal fluctuations in climatic variability at Svalbard, and the somewhat constant level of climatic variability in the Alps. We argue that such patterns may be of general relevance to arctic environments on one hand and alpine environments at middle latitudes on the other hand. We further discuss the possible consequences of changes in variability patterns on the demography of small mammals.

HOLDING AREA

CSE (Council of Science Editors). 2014. Scientific style and format: the CSE manual for authors, editors, and publishers. Chicago, IL: University of Chicago Press. https://www.councilscienceeditors.org

Coastal plain 1002 area, Arctic NWR, oil & gas program environmental effects summary.

- identify the desired functional landscape with a historic range of variability (HRV), or alternatively, future desired condition (FDC) sequentially & collectively through all phases of oil & gas program: seismic exploration, development, production, transportation, & oilfield abandonment. Note cumulative effects considers all phases of oil & gas program.
- account for projected milder climate regimes, e.g., annual mean high & low temperatures; longer frost-free growing season; fewer days below freezing; changes in precipitation & transpiration; etc.
- scenario planning that will most likely entail: (1) rapid & continuing change (disruptive, punctuated); (2) sequential & measured change (steady state); (3) refugia (no change from present); or, combinations of these.
- industry & land management BMPs/ROPs work only at the broadest level & only if monitored & enforced

subject (overlap will need to be addressed, with final categorical definitions)	environmental effects context and intensity								
	direct short-term	**direct long-term**	**indirect short-term**	**indirect long-term**	**cumulative - a** climate change	**cumulative - b** industry incremental	**cumulative collective**	**connected resources, factors, or other considerations**	**unavoidable adverse effects** (aka BLM residual effects)
soils, permafrost & wetlands									
permafrost					yes	incremental	yes	climate change; *uncertainty*;	incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
thermokarst & ponding					yes	incremental	yes	climate change; *uncertainty*; restoration & rehabilitation	
soil temperature					yes	incremental	yes	climate change; *uncertainty*; biotic communities & vegetation	
soil compaction					yes	yes	yes	industry activity; *uncertainty*; biotic communities & vegetation; ecosystem resilience; available snow depth; restoration & rehabilitation	
freeze-thaw/rain-on-snow events					yes	no	yes	climate change; caribou foraging; storm events	
biotic communities & vegetation									
invasive species (all taxa: nonvascular & vascular plants, invertebrates, vertebrates, pathogens)	yes	yes	Yes	yes	yes	yes [any BMPs need to be adaptive, continuously reviewed & updated]	yes	surface disturbance type; ecosystem resilience; small mammal herbivory; BMPs effective only if enforced; effective EDRR; restoration & rehabilitation	> any invasive species pioneering & establishment directly connected with industry that cannot be contained or controlled via BMP/ROP or mitigation > incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
coastal resources & processes									
erosion, mass wasting					yes	incremental	yes	climate change; storm events; permafrost; hydrological cycle change	
sea level rise					yes	no	yes	climate change; coastal erosion; coastline wildlife movement corridors	
declining sea ice					yes	no	yes	polar bear & seals; marine forage fish	
water resources (quality & quantity)									
freshwater								climate change; erosion, mass wasting; recharge - glacial meltwater, precipitation, groundwater	
running waters								industry activity;	
water quality (turbidity, bank stability, sedimentation, nutrient recharge, temperature, O_2)									
water quantity -									
ponds & lakes									
water quality (saltwater intrusion, temperature change with withdrawal, O_2, sedimentation, nutrient recharge)									
water quantity -									
groundwater					yes	incremental	yes	industry activity;	
water quality -									
water quantity -									
gravel & substrate (incl within & independent of primary channels)					unlikely	yes	yes	industry activity; invasive species	
brackish & marine								sea level rise,	incremental-incremental may positively affect overwinter habitat for fisheries through creation of new deep water pools of abandoned gravel quarries
sedimentation, nutrient recharge								freshwater plumes from river discharge, spring runoff events	

climate (based on HRV, present & projected trends)									
biotic community shifts (new seral or climax – new community equilibrium)					yes	incremental	yes	climate change; ecosystem resilience; invasive species; *uncertainty*	
shrub - grass/forb encroachment					yes	incremental	yes	climate change; ecosystem resilience; invasive species	
new spp assemblages: displacement or replacement					yes	unlikely	yes	climate change; ecosystem resilience; *uncertainty*	
phenological mismatch					yes	no	yes	climate change; shorebirds & insectivorous spp; foraging spp (caribou, sheep, muskox); *uncertainty*	
modified hydrological cycles – continental air mass (i.e., less precipitation/snowfall)					yes	no	yes	climate change;	
ecosystem process & functions (drivers & stressors)					yes	unlikely	yes	climate change; *uncertainty*	
disturbance regime					yes	incremental	yes	climate change; ecosystem resilience; *uncertainty*	
ecosystem resilience					yes	incremental	yes	climate change; *uncertainty*	
fire regime					yes	unlikely	yes	climate change; ecosystem resilience; invasive species	
storm events								climate change; hydrological cycle; temperature regime	
modified temperature regimes ($\bar{x}$ seasonal high/low temperatures) – continental air mass								climate change; *uncertainty*	
rain-on-snow events					yes	no	yes	climate change; *uncertainty*; forage availability for caribou, sheep, muskox	
beaver expansion into tundra (other boreal species?)					yes	unlikely	yes	climate change; *uncertainty*; vegetation change; thermokarst; water temperature change; alteration of ecosystem resilience	consequences of beaver habitat alteration may affect industry capacity; affect native species/habitat natural disturbance regimes
industry-based effects									
oil & gas exploration	yes		yes		yes	incremental	yes	current industry standard: winter activity period only; 10 Dec-1 May annually, with staging activities beyond this window undefined; no surface occupation; ecosystem resilience; invasive species	
oil & gas development	yes	yes	yes	yes	yes	incremental	yes	current industry standard: surface occupation; ecosystem resilience; invasive species	
gravel & substrate									incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
oil & gas production	yes	yes	yes	yes	yes	incremental	yes	current industry standard: surface occupation; ecosystem resilience; invasive species	
gravel & substrate									incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
oil & gas transportation	yes	yes	yes	yes	yes	incremental	yes	current industry standard: surface occupation; ecosystem resilience; invasive species	
gravel & substrate									incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
oil & gas restoration & rehabilitation		yes		yes				current industry standard: frequently unsuccessful; *uncertainty*; climate change may make restoration problematic; ecosystem resilience; invasive species	see below oilfield abandonment; restoration & rehabilitation
infrastructure development (roads or other ROWs, communication towers, fiber optics, waste sites, etc)					yes	incremental	yes	current industry standard: surface occupation	incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
increased human access					na	incremental	yes	some predictable, other increased activity uncertain	
other extraction development (locatable, leasable, salable; rare earths or precious minerals)	yes	yes	Yes	yes	na	incremental	yes	some predictable, others uncertain – market-economy driven: communications, fiber optics, public access, hunting pressure, staging area build-up, increased traffic (air, land, sea) …	
industrial solid waste stream management									
industrial wastewater treatment incl reinjection									
effluent wastes with 1º & 2º treatment									
air quality									
ambient levels	--	--	--	--	--	--	--		

oil & gas exploration	yes	no	unlikely	no	no	unlikely	unlikely		
oil & gas development, production, transportation		yes	yes	yes	no	incremental	yes		
contaminants & spill contingency								linked with subsistence resource use	
incident control & containment; preset staging of equipment					no	yes	yes	magnitude, duration-exposure, frequency, agent	
absorption, inhalation, ingestion of toxins or contaminants					no	yes	yes		
clean-up (standards & procedures)					no	yes	yes		
acoustic environment									
ambient levels	--	--	--	--	no	--	--		
thresholds of disturbance (spp tolerance & adaptability)					no	yes	yes		
fisheries								linked with climate change; subsistence resource use	
existing/projected overwinter habitat								climate change	incremental-industrial may positively affect overwinter habitat for fisheries through creation of new deep water pools of abandoned gravel quarries
anadromous spp									
fish passage (incl arthropod movement)									
birds								all: linked with climate change; industry activity; *uncertainty*; subsistence resource use	
raptors (emphasis Gyrfalcon, Golden Eagle, Bald Eagle breeding events)					yes		yes		
resident spp					yes		yes		
migratory birds (emphasis on breeding events)					yes		yes		
eiders (Common Eider; King Eider; Spectacled Eider-listed; Steller's Eider-listed)					yes	incremental	yes		
waterfowl/water birds (Yellow-billed Loon; Snow Goose; Brant; Tundra Swan – waterfowl for consistency with historic evaluations)					yes	incremental	yes		
shorebirds (tundra plovers, Dunlin, Semipalmated Sandpiper)					yes	incremental	yes		
land birds (tundra ptarmigan; Smith's Longspur, Horned Lark-American Pipit for ease of monitoring)					yes	incremental	yes		
caribou (Central Arctic & Porcupine herds)								all: linked with climate change; *uncertainty*; subsistence resource use; international considerations	
movement corridors					yes	incremental	yes		
wintering habitat					yes	incremental	yes		
calving habitat – productivity/survivorship (incl plant phenology, nutrition value lactating ♀♀)					yes	incremental	yes		
habitat forage quality					yes	incremental	yes		
insect-relief habitat					yes	incremental	yes		
predation (wolf, Golden Eagle)					unlikely	unlikely	unlikely	calf survival	
industry/human disturbance/displacement [population-level effects]					no	yes	yes	industry activity;	incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
other wildlife issues								all: linked with climate change; *uncertainty*; subsistence resource use	
human-subsidized predators (fox, raven, gull, etc)					no	yes	yes	industry activity; climate change; alternative prey resources; lemming population fluctuations; waterfowl & shorebirds;	incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
population outbreaks/irruptions									
disease vectoring/pathogen outbreaks									
Dall sheep									

muskox									
furbearers									
small mammal herbivory; population fluctuations; & effect on human-subsidized predators as alternative food resource					yes	incremental	yes	industry activity; climate change; *uncertainty*; nutrient availability; human-subsidized predators; shorebirds/waterfowl; caribou foraging	
polar bear								linked with climate change; *uncertainty*; international considerations	
denning habitat					yes	incremental	yes		
food & habitat resources					yes	incremental	yes		
coastal corridor & coastal area to denning site movement					yes	incremental	yes		
disturbance/avoidance					no	yes	yes	industry activity type	
incidental take & harassment [population-level effects]					no	yes	yes	industry activity type; *uncertainty*;	iIncremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
bowhead whale, ringed & bearded seals								linked with climate change; *uncertainty*; subsistence resource use	
disturbance/avoidance					no	yes	yes		
cultural resources (archaeological, historical, cultural sites or affinity)									
concentrated sites or districts					na	??			
inadvertent discovery(s)					na	yes			
paleontological resources									
concentrated sites or districts					na	??			
inadvertent discovery(s)					na	yes			
human dimensions									
- national interest									
- local interest									
- international (Arctic Council; community of practice)									
- historical background	--	--	--	--	--	--	--		
- public use (access to resources)									
- subsistence use					yes	incremental	yes		
- visitor use									
- socioeconomics									
- public health					yes	incremental	yes	pathogen & disease vectoring; emerging epizootics linked with climate change; industry work schedules & personnel rollover	
- tourism									
wilderness value									
wilderness characteristics					unlikely	yes	yes		incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
oilfield abandonment; restoration & rehabilitation								linked with climate change; *uncertainty*; subsistence resource use; human dimensions; wilderness values	
climate change preclusion to restoration of original state					yes	incremental	yes		> partial or incomplete restoration & rehabilitation; preclusions due to climate change > incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
invasive species displacement/replacement					yes	incremental	yes		incremental-industrial most likely irreversible & irretrievable commitment of resources due to climate change factors
notes 1 May 2018 jwm ♀♂ x̄									