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Aquatic Invasive Plant Baseline Surveys in Kenai Peninsula Water bodies, Alaska, 2013

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Cheryl A. Anderson

Abstract

Alteration and loss of aquatic habitats by invasive plants is a serious concern with potential ecological, economic, and social consequences. Invasive aquatic plants can degrade water quality, fish and wildlife habitat, and ultimately, property values. The Kenai Fish and Wildlife Field Office established baseline data on plant communities for water bodies of concern on the Kenai Peninsula, focusing on the presence or absence of waterweed (*Elodea* spp.). Eighteen lakes were surveyed between July 1, 2013, and September 24, 2013. Of the lakes surveyed, waterweed was only observed in one lake (Beck Lake) and was later identified as a hybrid, *Elodea canadensis* x *nuttallii*. There were 57 different plant species encountered during the surveys and 52 of those were of herbarium quality and mounted for preservation. Our survey of Beck Lake was used to guide development of a treatment plan for waterweed using herbicides in 2014. Additional lakes in the central Kenai Peninsula should be surveyed for early detection and rapid response.

Introduction

Alteration and loss of aquatic habitats by invasive plants is a serious concern with potential ecological, economic, and social consequences. Invasive plants can severely and permanently damage ecosystems by outcompeting native species, thus reducing abundance and altering ecosystem processes (Vitousek et al. 1996). Invasive aquatic plants can degrade water quality, fish and wildlife habitat (Kerr et al. 2005), and ultimately, property values (Olden and Tamayo 2014). They can also decrease the aesthetics of a water body and detrimentally affect commercial and sport fishing, recreational boating, and pose threats to human health and safety.

The cost of controlling or eradicating invasive species in the United States ranges from thousands to billions of dollars annually. This cost does not reflect the value of ecosystem health or the aesthetics of nature, which can consequently influence tourism and recreational revenue. For example, many of the states bordering the Gulf of Mexico have been severely impacted by invasive aquatic plants such as common water hyacinth *Eichhornia crassipes*, waterthyme (hydrilla) *Hydrilla verticillata* (Rockwell 2003), and Eurasian watermilfoil *Myriophyllum spicatum* (Aiken et al. 1979). The Great Lakes ecosystem significantly changed due to aquatic invasive animals and plants such as Sea Lamprey *Petromyzon marinus*, Alewife *Alosa pseudoharengus*, Zebra Mussels *Dreissena polymorpha*, reed canarygrass *Phalaris arundinacea*, and purple loosestrife *Lythrum salicaria* (Mills et al. 1993). The people that depend on these waters have been impacted both economically and socially.

In comparison, Alaska is generally in the early stages of invasion by aquatic invasive plants and has the unique opportunity to address early infestations before they become a bigger and more costly problem. Management strategies in Alaska that focus on early detection and rapid response (EDRR) can prevent new infestations. By utilizing EDRR, Alaska can help prevent the introduction of new invasive populations, eradicate incipient populations, and contain populations that are established but geographically isolated (Slemmons 2007, unpublished).

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Humans are the primary means of dispersal of invasive aquatic plants. For example, unintentional transportation between lakes from trailered boats is a known pathway of new infestations (Johnson et al 2001, Pfauth and Sytsma 2005). In Alaska, dispersal of aquatic plants via floatplanes flying between urban and remote water bodies within the state poses a threat for potential introductions into otherwise pristine areas (Pfauth and Sytsma 2005). Lastly, intentional introduction by humans releasing aquarium plants into natural systems is another pathway by which invasive aquatic plant species can be introduced (Kay and Hoyle 2001; Padilla and Williams 2004).

Waterweed *Elodea* spp. is the first submerged aquatic invasive plant to become established in Alaska. Prior to 2010, waterweed had only been confirmed in Cordova. However, in 2009 waterweed was discovered in Fairbanks, in 2010 in Anchorage, and more recently on the Kenai Peninsula (Stormy and Daniels lakes in 2012), evidence that this aquatic invasive plant is being introduced into multiple regions in Alaska. Waterweed can survive in lakes, ponds, streams, sloughs, and rivers and is easily dispersed by water currents or human disturbance such as boats or floatplanes (Johnson et al. 2001). Waterweed reproduces by fragmentation or specialized buds. Once these fragments are established, they rapidly colonize areas forming dense monoculture stands, choking out native vegetation, resulting in severe ecological consequences for native species and substantial economic costs to control or eradicate (Barrat-Segretain et al. 2002). These traits combined with waterweed's ability to survive freezing within ice, are why it is extremely invasive and poses a major threat to aquatic habitats in Alaska.

Early detection of invasive aquatic plants and rapid response are important to controlling infestations and greatly increases the likelihood of successful eradication (Pfauth and Sytsma 2005). Collecting baseline information of the plant communities in lakes and ponds is an essential component in effective management of aquatic invasive species and early detection of new invaders.

The Kenai Peninsula Fish Habitat Partnership, through its strategic planning process, ranked injurious aquatic invasive species as one of four major threats to freshwater systems. Baseline surveys of Kenai Peninsula lakes are necessary to determine the extent of waterweed infestations on the Kenai Peninsula and to make informed decisions regarding EDRR. In addition, baseline surveys will be used to foster public awareness and stewardship of Kenai Peninsula water bodies and their habitats.

Objectives for the project were:

1) Establish baseline data on plant communities for water bodies on the Kenai Peninsula, focusing on the presence or absence of waterweed *Elodea* spp.; and

2) Collect voucher specimens of all plant species encountered within a water body.

Study Area

The Kenai Peninsula is located in Southcentral Alaska approximately 162 km south of Anchorage. It is about 137 km long and 62 km wide. The Kenai Peninsula encompasses a vast network of rivers, lakes, and wetlands (Figure 1) and baseline surveys were concentrated within the central portion near the communities of Kenai, Soldotna, Sterling, and Nikiski.

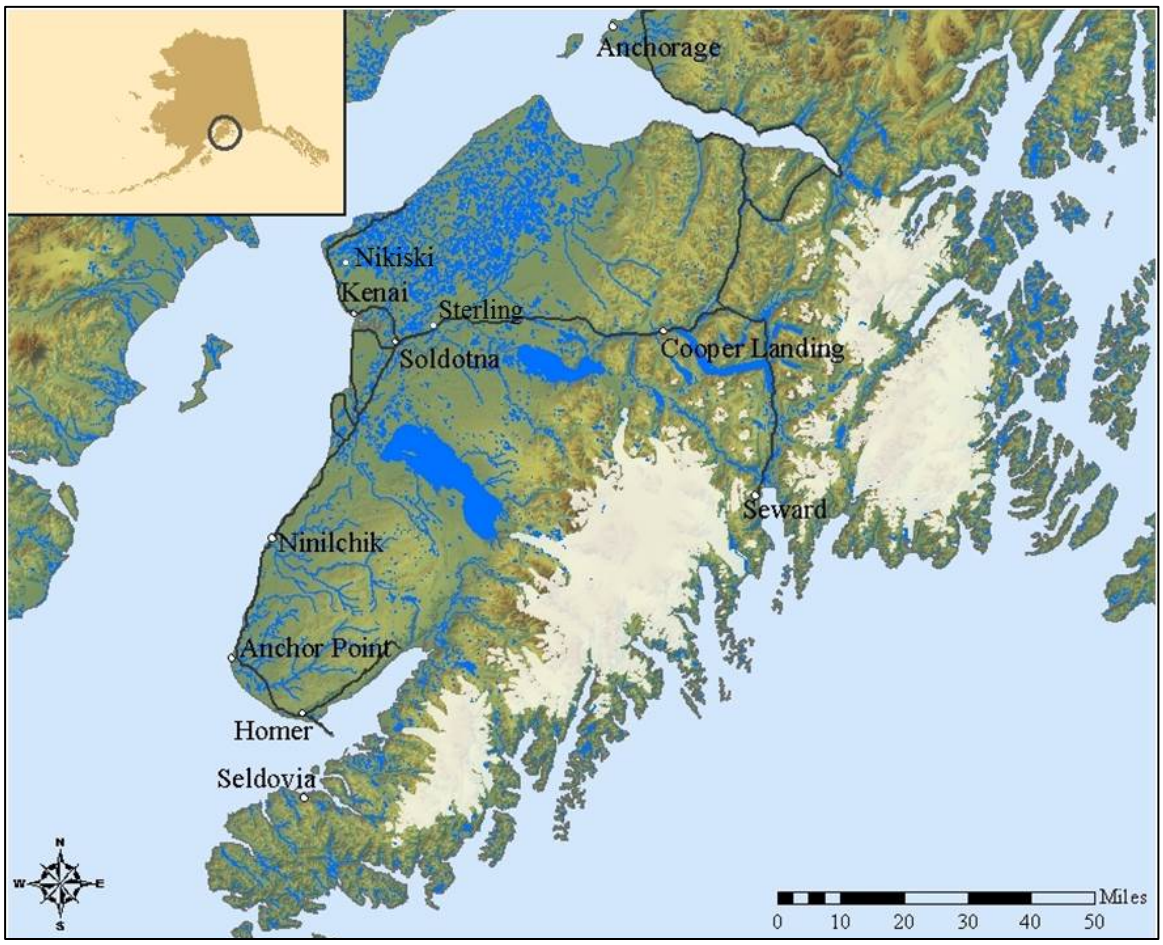

FIGURE 1.—Map of baseline survey sampling area, central Kenai Peninsula, Alaska.

Methods

A subset of Kenai Peninsula lakes were selected for surveys using a Geographic Information System (GIS) based prioritization tool developed by the Kenai National Wildlife Refuge (KNWR) and the Kenai Peninsula Cooperative Weed Management Area (Slemmons 2007, unpublished). The tool was modified to include parameters specific to waterweed and invasion vulnerability of the lakes (Table 1) and was used to develop a prioritized list of lakes prior to the field season. A detailed description of the prioritization tool is described in Slemmons (2007, unpublished).

Presence or absence of waterweed was surveyed in a modified systematic sampling procedure around the lake perimeter in the littoral zone. This method is a relatively quick and effective

TABLE 1.—Parameters used in the prioritization model for selecting lakes to sample for waterweed *Elodea* spp.

Vector	Physical Attribute	Sampling Ease
Proximity to Known Infestations	Connectivity-Open/Closed System	Proximity to Roads
Float Plane Access	Ownership/Density of Ownership	Access - Public Boat Launch
Boat Use/Access	Depth/Bathymetry	
Proximity to Schools (0.3 km)		

way of quantifying the distribution and frequency of aquatic vegetation and allows for tracking aquatic species changes within a lake over time.

Lake surveys were conducted by making a complete circuit around the lake perimeter in the littoral zone by a two person team in a canoe. One person recorded data while a second person collected aquatic plant samples. Clear shallow areas were scanned for invasive aquatic plants while wearing polarized sunglasses to reduce glare and using a viewing tube to aid in discerning between plant species. In deeper areas, a sampling rake was thrown overboard to bring plants up from the bottom of the lake. Extra care was taken in sampling public access areas or other frequently used areas such as boat launches where invasive species could likely be first introduced in a water body and at inflow and outflow areas where plant fragments may accumulate. A one (1) was recorded if waterweed was present and a zero (0) was recorded if it was absent. All plant species encountered within the lake were recorded or collected and placed in sealable plastic bags for subsequent identification. Underwater pictures of aquatic plants were taken as needed to aid in plant identification. Lakes that had waterweed were sampled more extensively to aid in planning for future control or eradication efforts.

Along with species observed at each sample location, latitude and longitude were determined using a handheld global positioning system unit using the North American 1983 datum, and water depth was measured to the nearest 0.2 m using the anchor line. Major substrate types (cobble, gravel, sand, sediment) and their combinations were observed and recorded. Light conditions (sunny, cloudy or overcast) and lake water conditions (flat, ripples, waves or whitecaps) were recorded for each lake and visibility depth was recorded using a Secchi disk in the deepest part of the lake following procedures described in Hamilton and Bergersen (1984). Surface water temperature (^{o}C) was recorded at each sample location.

All plant species encountered within the lake were collected at least once and specimens were pressed, dried and mounted for herbarium preservation. Plant specimens were identified to species using a dichotomous key (Hultén 1968) and current taxonomic nomenclature was verified using the U.S. Department of Agriculture Plants Database (USDA and NRCS 2014). A

KNWR ecologist verified any questionable specimens. The herbarium specimens serve as a permanent record of the plant communities in Central Kenai Peninsula lakes and can be used to document and compare changes in the aquatic plant community over time, which can indicate changes in lake productivity. Mounted herbarium specimens are housed at the Kenai Fish and Wildlife Field Office and at KNWR.

Every precaution was taken to ensure that invasive species were not transported from one water body to the next. All visible mud and plant debris were removed from canoes, vehicles, equipment and gear before leaving a water body and wading shoes and waders were cleaned, scrubbed and thoroughly dried upon returning to the office.

Data Analysis

The sum of all native and invasive species present per lake gives an estimate of species richness within each water body. Results of native or invasive plant distribution will be used to monitor the plant community for changes in species composition over time and to compare with other water bodies on the Kenai Peninsula.

Results

Eighteen lakes were surveyed between July 1, 2013, and September 24, 2013 (Table 2). Salamatof Lake was only partially surveyed due to high winds before freeze up. Waterweed was only observed in Beck Lake (Figure 2) and was later identified as a hybrid, *Elodea canadensis* x *nuttallii*. There were two shoreline non-native species also discovered during the surveys. Reed canarygrass, an invasive perennial grass, was found along lake margins at Cabin and Island lakes, and curly dock *Rumex crispus*, a tall grass-like weed, was found along lake margins at Bishop, Cabin and Duck lakes. Various terrestrial non-native species were also observed and recorded at several lakes.

There were 57 different plant species encountered during the surveys and 52 of those were of herbarium quality and mounted for preservation. Sweetgale *Myrica gale*, Rocky Mountain pond-lily *Nuphar lutea*, and grasses *Poa* spp. were the most abundant species encountered among all 18 lakes (Table 3). The lakes with the greatest species richness were Beck (28 species), Parson's (27 species), and Duck (24 species) lakes. These lakes also had predominately sand/sediment or sediment substrates. Douglas, Kivi and Wik lakes all had the least species richness with eight species each. Douglas and Wik lakes had predominately sand/sediment substrates and Kivi Lake had predominately a cobble/sediment substrate. Sixteen plant species, including waterweed, were each found in only one of the 18 lakes sampled. Shoreline plants made up the largest group encountered with a total of 34 different species and submersed plants were next with 15 different species (Table 4).

The most predominate lake substrate categories were sand/sediment, gravel/sediment and sediment (Table 5). Duck and Georgine lakes had only one substrate category (sediment and cobble/sediment, respectively). Average surface water temperatures were warmest in July and August (18 ^{o}C) and began to drop off considerably in September (Figure 3). Greatest water clarity and Secchi depths were observed at Wik Lake (7.16 m), Island Lake (6.10 m), and Georgine Lake (5.79 m), with the lowest Secchi depths at Duck Lake (1.37 m) and Bishop Lake (1.43 m; Figure 4; Table 6).

TABLE 2.—Lakes surveyed for presence of waterweed *Elodea* spp. on the Kenai Peninsula, Alaska in 2013.

Sample Date	Lake Surveyed	Waterweed Present
10-Jul	Beck	Y
16-Jul	Wik	N
18-Jul	Island	N
22-Jul	Tirmore	N
23-Jul	Douglas	N
24-Jul	Johnson	N
25-Jul	Cabin	N
29-Jul	Duck	N
1-Aug	Georgine	N
1-Aug	Kivi	N
7-Aug	Parsons	N
8-Aug	Bishop	N
8-Aug	Marie	N
15-Aug	East Mackey	N
19-Aug	Barr	N
20-Aug	West Mackey	N
12-Sep	Union	N
23-Sep	Salamatof[a]	N

[a]Salamatof Lake was a partial survey.

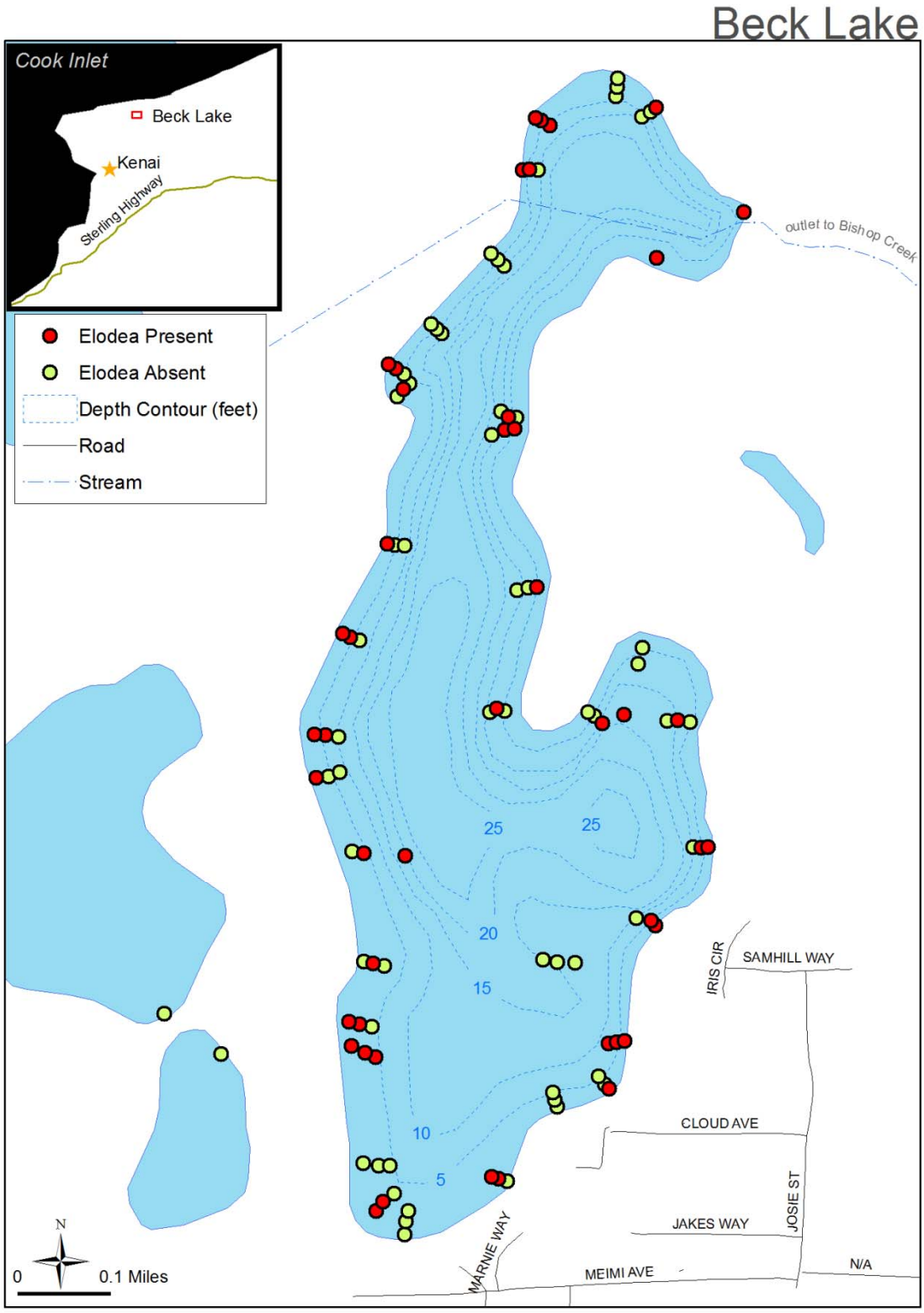

FIGURE 2.—Map showing sampling locations and density of waterweed *Elodea* spp. in Beck Lake, Nikiski, Alaska in 2013.

TABLE 3.—Plant species encountered in each lake surveyed on the Kenai Peninsula in 2013.

	Lake								
Genus Species	Barr	Beck	Bishop	Cabin	Douglas	Duck	East Mackey	Georgine	Island
Calamagrostis canadensis			x		x				x
Calla palustris		x				x			
Callitriche hermaphroditica		x							
Carex aquatilis			x			x		x	x
Carex lasiocarpa									
Carex mackenziei						x			
Carex spp.		x	x	x	x	x		x	x
Carex utriculata								x	x
Ceratophyllum demersum		x	x			x			
Chara spp.									x
Cicuta virosa	x	x	x	x		x	x	x	x
Comarum palustre	x	x	x	x		x	x	x	x
Eleocharis palustris	x	x		x	x	x	x	x	
Elodea canadensis x nuttallii[a]		x							
Epilobium ciliatum						x			
Equisetum fluviatile		x	x		x	x	x		
Eriophorum angustifolium		x							
Fontinalis antipyretica	x	x		x					
Galium trifidum									
Glyceria borealis								x	
Hippuris vulgaris		x	x			x			x
Isoetes tenella		x							
Lathyrus palustris									
Lemna minor			x			x			
Lemna trisulca						x			
Lysimachia thyrsiflora							x		
Menyanthes trifoliata		x	x				x	x	
Mimulus guttatus						x			
Myrica gale	x	x	x	x	x	x	x	x	x
Myriophyllum sibiricum		x				x			x
Nuphar lutea	x	x	x	x	x	x	x	x	x
Nymphaea tetragona			x						x
Phalaris arundinacea[a]				x					x
Poa spp.	x	x	x	x	x	x	x	x	x
Polygonum amphibium				x					x
Potamogeton epihydrous	x	x		x			x		
Potamogeton friesii		x	x			x			

TABLE 3.—Continued.

	Lake Name								
Genus Species	Barr	Beck	Bishop	Cabin	Douglas	Duck	East Mackey	Georgine	Island
Potamogeton gramineus	x	x						x	x
Potamogeton natans	x		x						x
Potamogeton praelongus		x	x			x			
Potamogeton pusillus		x				x			
Potamogeton richardsonii		x	x						x
Potamogeton zosteriformis			x						
Ranunculus aquatilis		x							
Rumex crispus[a]			x			x			
Salix alexensis				x					
Sanguisorba canadensis									
Scheuchzeria palustris									
Schoenoplectus tabernaemontani									
Scirpus microcarpus						x			
Scirpus spp.									x
Sparganium angustifolium	x	x	x	x	x			x	
Sparganium natans	x	x		x		x			
Spiraea stevenii							x		
Stuckenia pectinata	x								
Utricularia intermedia		x							
Utricularia macrorhiza									
Total Species Per Lake	13	28	21	14	8	24	11	13	19

TABLE 3.—Continued.

	Lake								
Genus Species	Johnson	Kivi	Marie	Parson's	Salamatof[b]	Tirmore	Union	West Mackey	Wik
Calamagrostis canadensis				x	x		x	x	
Calla palustris								x	
Callitriche hermaphroditica				x			x		
Carex aquatilis				x	x	x	x		x
Carex lasiocarpa						x			
Carex mackenziei	x			x					
Carex spp.	x	x	x	x		x			x
Carex utriculata						x			
Ceratophyllum demersum									
Chara spp.	x					x	x		
Cicuta virosa		x	x	x	x	x	x	x	x
Comarum palustre	x		x	x	x	x	x	x	x
Eleocharis palustris	x	x	x	x	x	x	x	x	
Elodea canadensis x nuttallii[a]									
Epilobium ciliatum									
Equisetum fluviatile	x				x	x	x	x	
Eriophorum angustifolium	x			x	x				
Fontinalis antipyretica	x						x		
Galium trifidum				x					
Glyceria borealis									
Hippuris vulgaris									
Isoetes tenella									
Lathyrus palustris				x					
Lemna minor				x					
Lemna trisulca									
Lysimachia thyrsiflora									
Menyanthes trifoliata	x			x			x	x	
Mimulus guttatus									
Myrica gale	x	x	x	x	x	x	x	x	x
Myriophyllum sibiricum	x			x	x			x	
Nuphar lutea	x	x	x	x	x	x	x	x	x
Nymphaea tetragona	x			x					
Phalaris arundinacea[a]									
Poa spp.	x	x	x	x	x	x	x	x	x
Polygonum amphibium						x			
Potamogeton epihydrous						x	x	x	x

TABLE 3.—Continued.

	Lake								
Genus Species	Johnson	Kivi	Marie	Parson's	Salamatof[b]	Tirmore	Union	West Mackey	Wik
Potamogeton friesii				xx					
Potamogeton gramineus						x	x	x	
Potamogeton natans		x	x				x	x	
Potamogeton praelongus				x	x				
Potamogeton pusillus				x				x	
Potamogeton richardsonii	x			x				x	
Potamogeton zosteriformis	x			x				x	
Ranunculus aquatilis					x				
Rumex crispus[a]				x					
Salix alexensis									
Sanguisorba canadensis				x					
Scheuchzeria palustris								x	
Schoenoplectus tabernaemontani	x								
Scirpus microcarpus									
Scirpus spp.									
Sparganium angustifolium	x	x	x				x	x	
Sparganium natans	x			x			x	x	
Spiraea stevenii				x	x				
Stuckenia pectinata	x								
Utricularia intermedia								x	
Utricularia macrorhiza	x						x	x	
Total Species Per Lake	21	8	9	27	14	15	19	22	8

[a]Denotes a nonnative or invasive species in Alaska.
[b]Salamatof Lake was a partial survey.

TABLE 4.—Categories of plants encountered during Kenai Peninsula lakes surveys, 2013.

Genus Species	Common Name
Shoreline Plants	
Calamagrostis canadensis	Bluejoint
Calla palustris	Water arum
Carex aquatilis	Water sedge
Carex lasiocarpa	Woollyfruit sedge
Carex mackenziei	Mackenzie's sedge
Carex spp.	Sedges
Carex utriculata	Northwest Territory sedge
Cicuta virosa	Mackenzie's water hemlock
Comarum palustre	Purple marshlocks
Eleocharis palustris	Common spikerush
Epilobium ciliatum	Fringed willowherb
Equisetum fluviatile	Water horsetail
Eriophorum angustifolium	Tall cottongrass
Galium trifidum	Threepetal bedstraw
Glyceria borealis	Small floating mannagrass
Hippuris vulgaris	Common mare's-tail
Lathyrus palustris	Marsh pea
Lysimachia thyrsiflora	Tufted loosestrife
Menyanthes trifoliata	Buckbean
Mimulus guttatus	Seep monkeyflower
Myrica gale	Sweetgale
Phalaris arundinacea[a]	Reed canarygrass
Poa spp.	Grasses
Polygonum amphibium	Water knotweed
Rumex crispus[a]	Curly dock
Salix alexensis	Flatleaf willow
Sanguisorba canadensis	Canadian burnet
Scheuchzeria palustris	Rannoch-rush
Schoenoplectus tabernaemontani	Softstem bulrush
Scirpus microcarpus	Panicled bulrush
Scirpus spp.	Bulrushes
Sparganium angustifolium	Narrowleaf bur-reed
Sparganium natans	Small bur-reed
Spiraea stevenii	Beauverd spirea

TABLE 4.—Continued.

Genus Species	Common Name
Floating Leaved Rooted Plants	
Nuphar lutea	Rocky Mountain pond-lily
Nymphaea tetragona	Pygmy waterlily
Potamogeton epihydrous	Ribbonleaf pondweed
Potamogeton gramineus	Variableleaf pondweed
Potamogeton natans	Floating pondweed
Macroscopic Algae	
Chara spp.	Muskgrass
Aquatic Moss	
Fontinalis antipyretica	Antifever fontinalis moss
Free Floating Plants	
Lemna minor	Common duckweed
Submersed Plants	
Callitriche hermaphroditica	Northern water-starwort
Ceratophyllum demersum	Coon's tail
Elodea canadensis x nuttallii[a]	Waterweed (hybrid)
Isoetes tenella	Spiny-spore quillwort
Lemna trisulca	Star duckweed
Myriophyllum sibiricum	Shortspike watermilfoil
Potamogeton friesii	Fries' pondweed
Potamogeton praelongus	Whitestem pondweed
Potamogeton pusillus	Small pondweed
Potamogeton richardsonii	Richardson's pondweed
Potamogeton zosteriformis	Flatstem pondweed
Ranunculus aquatilis	White water crowfoot
Stuckenia pectinata	Sago pondweed
Utricularia intermedia	Flatleaf bladderwort
Utricularia macrorhiza	Common bladderwort

[a]Denotes a non-native or invasive species in Alaska.

TABLE 5.—Percentage of substrate types observed in Kenai Peninsula lakes surveyed in 2013.

	Substrate Type (%)					
Lake	Cobble	Cobble/ Sediment	Gravel/ Sediment	Sand/ Sediment	Sediment	# Sample Points
Barr	43	43	14			7
Beck	1	1		92	6	116
Bishop		18	55	18	9	11
Cabin			25		75	12
Douglas	18		9	73		11
Duck					100	9
East Mackey		19	75		6	16
Georgine		100				6
Island	20	20	10	50		10
Johnson		14		86		7
Kivi	40	60				5
Marie			17	66	17	6
Parsons		18	18		64	11
Salamatof[a]	100					3
Tirmore	13	13	25	50		8
Union			11	78	11	9
West Mackey			83		17	12
Wik	6	12	18	59	6	17

[a]Salamatof Lake was a partial survey.

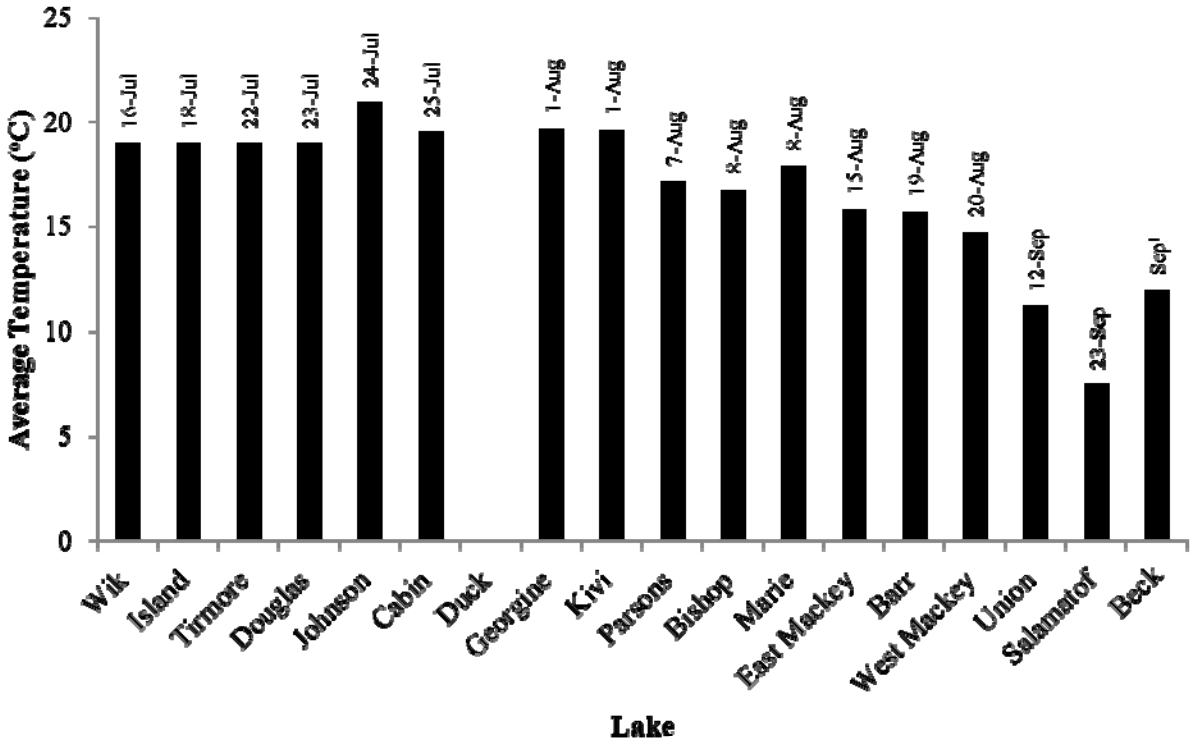

FIGURE 3.—Average surface water temperature (°C) and sample date of lakes surveyed in 2013. Average water temperatures were not collected for Duck Lake. [1]Beck Lake was sampled September 4, 16, 19–20, 2013; water temperature was averaged over all dates in September.

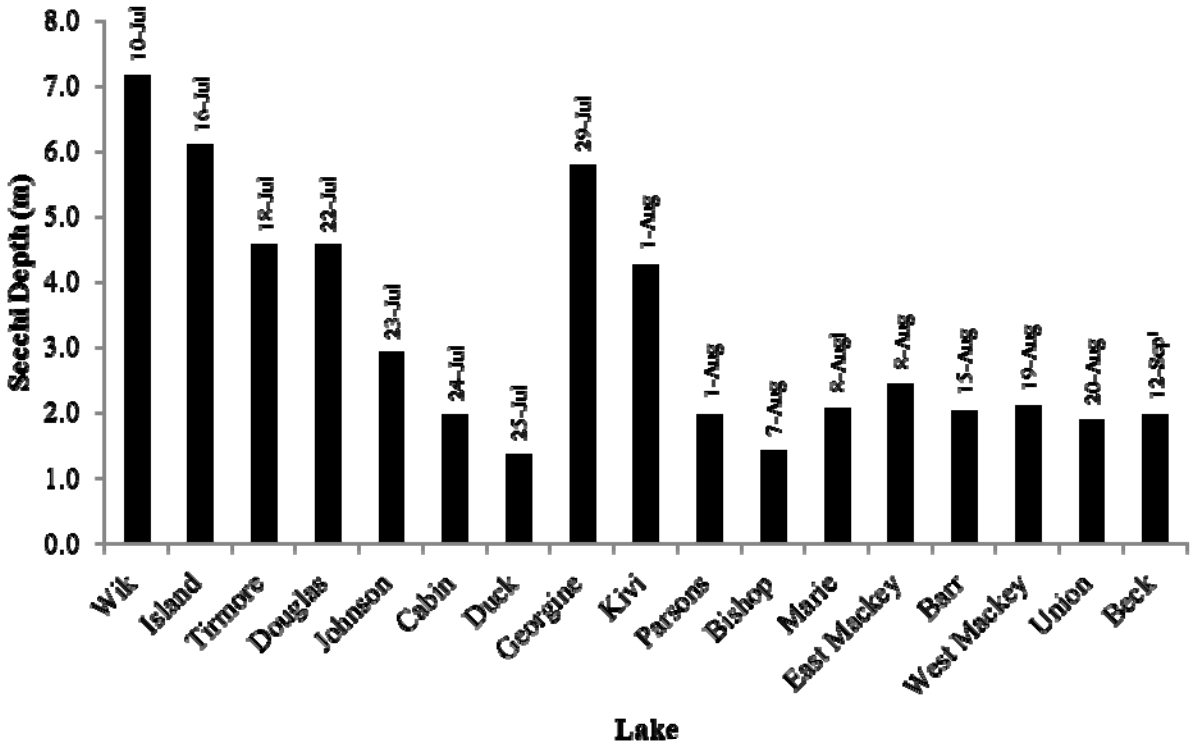

FIGURE 4.—Secchi depth (m) and sample date of lakes surveyed in 2013. [1]Beck Lake was sampled September 4, 16, 19–20, 2013; Secchi depth was averaged over all dates in September.

Table 6.—Average surface water temperature (°C), Secchi depth (m) and sample date of lakes surveyed in 2013. Average water temperatures were not collected for Duck Lake. Beck Lake was sampled September 4, 16, 19–20, 2013; Secchi depth was averaged over all dates in September

Lake	Date	Average Water Temperature (°C)	Secchi Depth (m)
Wik	16-Jul	19	2.59
Island	18-Jul	19	7.16
Tirmore	22-Jul	19	6.10
Douglas	23-Jul	19	4.57
Johnson	24-Jul	21	4.57
Cabin	25-Jul	20	2.93
Duck[1]	29-Jul		1.98
Georgine	1-Aug	20	1.37
Kivi	1-Aug	20	5.79
Parsons	7-Aug	17	4.27
Bishop	8-Aug	17	1.98
Marie	8-Aug	18	1.43
East Mackey	15-Aug	16	2.07
Barr	19-Aug	16	2.44
West Mackey	20-Aug	15	2.04
Union	12-Sep	11	2.10
Salamatof	23-Sep	8	1.89
Beck[2]	Sep	12	1.98

[1]Water temperature data were not collected for Duck Lake.
[2]Beck Lake was sampled September 4, 16, 19–20, 2013; water temperature and Secchi depth were averaged over all dates in September.

Discussion

All of the waterweed in Stormy, Daniels, and Beck lakes was identified as *Elodea canadensis* x *nuttallii* and all three lakes are located near the town of Nikiski. Because we did not find wild populations of both waterweeds together on the Kenai Peninsula, the most likely pathway for introduction to the Kenai Peninsula was from the disposal of aquaria. We speculate that waterweed was dumped into Beck Lake in the late 1990s, when an aquarium supply owner, located near Beck Lake went out of business, and the waterweed spread to Stormy and Daniels lakes by boat, float plane or waterfowl. The waterweed in Beck Lake was extensive and we could not determine the location of introduction (Figure 2). The highest density of waterweed was found near the outlet to Bishop Creek where winds likely dispersed and accumulated fragments. Beck Lake was the first lake we surveyed and the only lake with waterweed present, therefore we only surveyed it briefly the first time, once waterweed was found. We returned September 4, 16, 19, and 20 to survey it more thoroughly using a modified systematic sampling procedure to map locations and density of waterweed.

Beck Lake had the greatest species richness observed. This was likely because we sampled it on five separate occasions. Lakes that had the most species present were also the lakes with either sand/sediment or sediment substrates except for Wik and Douglas lakes, which had only eight plant species each and predominately consisted of sand/sediment substrate. We encountered predominately shoreline plant species at Douglas and Wik lakes; therefore some other factor, such as water chemistry may be contributing to less plant species richness in these lakes. We did not find waterweed in lakes that had predominately cobble or gravel substrate, which is counterintuitive for an aquarium species. It makes sense that fewer plant species would be found in lakes with cobble or gravel type substrates because vegetation would have a harder time establishing a root system unless the gravel/cobble had a fair amount of sediment beneath. Waterweed may be able to survive in gravel substrates (i.e., aquaria), but it can likely (from our observations) thrive in substrates consisting predominately of sediment.

Duck Lake was densely vegetated with shortspike watermilfoil *Myriophyllum sibiricum* and coon's tail *Ceratophyllum demersum* making navigation challenging in some locations. A resident of the lake sprayed the Rocky Mountain pond-lily in the lake with an herbicide two years prior to our survey, and the roots, which are large and extensive, were still dying off resulting in a decaying stench in the lake. Of all the lakes surveyed, Duck Lake was the most vegetated and was likely in a later successional stage, slowly progressing into a wetland.

Plant species encountered during our surveys were a good representation of most species present, although our surveys were by no means extensive enough to detect all species within a lake. However, we greatly increased our documentation of plant species in Kenai Peninsula lakes and likely documented most of the common species within each lake.

Average water temperatures appeared to be relatively warm (19–21 ^{o}C) in July and early August and we observed many dead small fish (salmonids and other species) in several lakes. A combination of warmer temperatures and lower oxygen levels may have stressed fish if these conditions persisted for an extended period.

Greatest water clarity and Secchi depths were observed at Wik, Island, and Georgine lakes, with the lowest Secchi depths at Duck Lake and Bishop Lake. Wik Lake along with Douglas Lake had the lowest plant species density, which may have aided in increased Secchi depths. Secchi

depths in Beck Lake decreased from the first sampling in July to the last sampling in September. As water temperatures drop, plants begin senescing and lakes become less stratified, and we would expect a decline in water clarity.

Conclusions

Our surveys showed that Beck Lake was extensively infested with waterweed and would likely require a whole lake herbicide treatment for eradication.

Additional lakes in the central Kenai Peninsula should be surveyed in the future and the lakes that we surveyed should be surveyed again in three to five years to ensure EDRR to any new infestations.

If funding does not allow for all lakes to be resurveyed, lakes with predominately sediment substrates should be given priority over lakes with predominately cobble or gravel substrates.

Education is crucial to the prevention of unintentional and intentional introductions of invasive aquatic plants in Alaska. We recommend collaborating with partners to effectively get the message out to a broad audience.

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