Integrated Pest Management Plan for Eradicating Elodea from the Kenai Peninsula

Working Draft 2020

Prepared by
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KENAI PENINSULA - CWMA
Cooperative Weed
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Table of Contents

I. Summary

Elodea, the first submersed freshwater invasive plant to establish in Alaska, has the potential to spread throughout Kenai Peninsula waterways, affecting ecological and economic values. This document outlines an integrated pest management approach to achieve the goal of making and keeping the Kenai Peninsula free of Elodea. To date, six infestations have been found on the peninsula since Elodea was first detected in September 2012, and five have been successfully eradicated: Beck, Daniels, Hilda-Seppu, Sports and Stormy Lakes). Elodea was discovered in Sandpiper Lake in fall 2019 and an eradication effort at Sandpiper Lake will begin in 2020. Our treatments have focused on applying pelleted and/or liquid fluridone, a selective systemic herbicide, for up to three years to ensure eradication from all five waterbodies. We have used diquat twice, a nonselective contact herbicide, to both prevent further spread of Elodea in a partially-treated lake (Daniels Lake), and to reduce the risk of spreading Elodea to other lakes (Sports Lake). Much of our success to date is attributable to our rapid management response after detection of Elodea. Combined with outreach, institutional/agency support, and monitoring for both efficacy (short term) and early detection of novel infestations (long term), we believe it is possible to eradicate Elodea populations from, and to keep new infestations off, the Kenai Peninsula. The outcome will ultimately be determined by successful eradication elsewhere in the state, particularly from the neighboring Mat-Su and Anchorage areas, where floatplane traffic keeps the peninsula vulnerable to re-infestation.

II. Issue/Problem Statement

Elodea is the first submersed freshwater invasive plant to establish in Alaska. It is a particularly injurious perennial plant. Outside its native range in North America, and elsewhere in Europe, New Zealand, Australia, and Africa, it has compromised water quality, grown so abundantly that boat traffic is hindered, reduced dissolved oxygen, and severely impacted native fisheries. Elodea is also insidious, in that a small plant fragment can infest a waterbody because it reproduces vegetatively; additionally, Elodea is somewhat tolerant of freezing, drying, and brackish water. Although probably introduced to Alaska via dumped aquaria (Bowmer et al. 1995) and discarded commercial lab kits, Elodea is now being moved around the state by floatplanes and motorboats. If it establishes throughout Alaska, Elodea is likely to cost $100 million per year in lost revenue to the commercial sockeye (*Oncorhynchus nerka*) fisheries (Schwoerer 2017). Early to recognize this threat, the Alaska Department of Natural Resources (DNR) issued a statewide quarantine in March 2014 for both *Elodea canadensis* and *E. nuttallii* (and their hybrids), in addition to three other aquatic invasive plant species.

Elodea was first detected on the Kenai Peninsula in Stormy Lake in September 2012, ironically during rotenone treatment of another aquatic invasive species, northern pike (*Esox lucius*). An Alaska Department of Fish and Game (ADF&G) fisheries biologist subsequently found a single Elodea fragment in Daniels Lake during a “windshield” survey of nearby lakes in October before they froze. In February 2013, KP-CWMA partners surveyed the spatial extent of Elodea in Daniels Lake by sampling through the ice in preparation for the first public meeting with landowners later that month. In March 2013, KP-CWMA partners held their first meeting of this technical working group to manage Elodea. Permit applications for herbicide use (diquat, fluridone) were submitted to the Alaska Department of

Environmental Conservation (DEC) by May 2013, and a presentation to the Kenai Peninsula Borough Assembly resulted in the first dedicated funds of $40,000 by June. A summer 2013 survey of 68 widely-distributed lakes on the Kenai Peninsula detected Elodea in a third waterbody (Beck Lake) close to the other two infested lakes, but also confirmed that it was restricted to two watersheds near Nikiski.

An Environmental Assessment was approved in August 2013 and the first draft of this IPM plan was completed in December 2013. The second face-to-face meeting of the Elodea working group was held in March 2014 and a second public meeting with landowners held in April 2014. In May 2014, immediately after winter lake ice melted, pre-treatment surveys of Elodea populations in the three infested lakes were conducted. By early June 2014, one and a half years after initial detection of Elodea on the Kenai Peninsula, members of this working group applied the first of several herbicide treatments to Beck, Daniels and Stormy Lakes. The last Elodea detected in any of these three treated lakes was in September 2015 (Schwoerer and Morton 2018).

This accomplishment of detecting and eradicating Elodea infestations from three waterbodies in three years is extraordinary, especially considering that our working group was first in applying aquatic herbicides in Alaska. The learning curve was steep, as our group had to learn the technical aspects of applying both liquid and pelleted aquatic herbicides, pioneer the federal (USFWS), state (DEC, DNR, ADF&G) and local Kenai Peninsula Borough permitting processes, and face public skepticism about both the efficacy and safety of using aquatic herbicides (Sethi et al. 2017).

Elodea infestations have since been found in two other waterbodies on the Kenai Peninsula in 2017, one accidentally in Sports Lake, Soldotna, and the other during surveys of two connected waterbodies, Seppu and Hilda Lakes, near Nikiski. In both instances, Elodea was treated that year and, by the end of 2019, both lakes are already considered eradicated. But elsewhere in Alaska, Elodea has continued to spread down the Chena, Nenana and Tanana Rivers towards the Yukon River; spread among multiple lakes and streams in the Copper River Delta; and spread to multiple waterbodies in the Mat-Su and Anchorage areas despite early treatment successes in the latter.

The Early Detection and Rapid Response (EDRR) demonstrated by KP-CWMA partners continues to be a successful model for others in Alaska to follow (Schwoerer and Morton 2018). Our approach integrates herbicide use for eradication (fluridone) and risk reduction (diquat bromide), monitoring for both treatment efficacy and early detection of novel infestations elsewhere on the peninsula, regular public outreach to both inform and sustain support, and continued organizational and agency engagement. This IPM approach, first outlined in December 2013 (version 1.0), was last revised in June 2014 (version 4.1) just before application of the first herbicide treatments on the Kenai Peninsula. Here, this document (version 5.0) is significantly revised to include detailed information on application equipment and survey methodology, treatment results, and lessons learned. It is intended to be the working plan for KP-CWMA partners to continue eradicating new Elodea populations from, and keeping new infestations off, the Kenai Peninsula.

III. Status of Elodea

Taxonomy and life history

Elodea is a submersed aquatic plant within the Hydrocharitaceae or waterleaf family. Five distinct species of Elodea are recognized, all native to the New World (Bowmen et al. 1995, Cook and Urmi-König 1985). *Elodea canadensis* or Canadian waterweed is native to temperate North America, originally distributed from 35°—55°N primarily in the Great Lakes region. The native range of *E. nuttallii* (Nuttall's waterweed) tends to overlap with *E. canadensis,* but the former is more prevalent further south. *Elodea bifoliata* occurs primarily in temperate western North America. *Elodea potamogeton* and *E. callitrichoides* are both native to South America.

Elodea canadensis aggressively invaded European waterways in the 19th century after it was first recorded in 1876 in an Irish pond (Josefsson 2011). Although much of Europe has seen a population decline, invasion continues at high rates in Scandinavia, northern Europe, parts of Asia and Africa, Australia, and New Zealand (Josefsson 2011, Bowmen et al. 1995). *Elodea nuttallii* was recorded as early as 1914 in Great Britain, although specimens were often incorrectly identified. This species has been observed to displace *E. canadensis* in Europe, possibly due to its ability to tolerate more turbid and nutrient-rich or polluted waters (Josefsson 2011, Bowmen et al. 1995). *Elodea callitrichoides* was introduced to Europe in 1958 (Josefsson 2011).

Where Elodea has been introduced outside its native range, Elodea has generally responded by a fairly explosive growth period of 5—6 years (Sand-Jensen 2000, Mjelde et al. 2012) followed by a declining (Nichols 1994) or sometimes a stable (Mjelde et al. 2012) population. Rapid growth may be initiated in areas where the sediment is iron rich; growth is terminated when iron reserves are depleted (Spicer and Catling 1988) or when the decaying biomass depletes the oxygen and lowers the pH, thereby weakening the carbon fixation and photosynthesis efficiencies of Elodea (Lehtonen 2000).

Elodea grows in still or slow-moving neutral or alkaline waters (pH 6.5—10) with reduced iron and bicarbonate available as carbon sources. Elodea is tolerant of cold water and can survive freezing, with documented rapid invasion as far north as northern Finland (Heikkinen et al. 2009, Sand-Jensen 2000) and Norway (Rorslett et al. 1986). Elodea has high light requirements and occurs primarily in clear waterbodies with low or slight current. Elodea is not able to use the C4 photosynthetic pathway like many aquatic invaders, but is a facultative HCO_3^- species (Raghavendra and Sage 2011). In alkaline conditions, Elodea is able to use bicarbonate as a carbon source either directly or by converting bicarbonate into carbon dioxide via acidification of the cell walls (Bowmen et al. 1995). Elodea, when biomass levels are high, can cause primary productivity to decline (Rorslett et al. 1986).

Perhaps the best case study of how non-native Elodea invades and colonizes a lake is Steinsfjord in Norway (Mjelde et al. 2012). Steinsfjord is a 3,400-acre lake (average depth = 32 feet) at the same latitude as the Kenai Peninsula. *Elodea canadensis*, introduced to Norway in 1925, subsequently invaded the watercourse upstream from Steinsfjord in the early 1960s. It was first detected in Steinsfjord in 1978; by 1982, Elodea occupied 72% of sites sampled in the 0—6 m depth and its spatial coverage peaked two years later. Elodea strands reached the lake surface through at least 1985–87, but then began to die-back. However, Elodea continued to expand its distribution into greater depths even as Elodea dominated the submersed vegetation community through at least 2004. Other native species that were sympatric with Elodea in 1979–1980 either shifted to deeper or shallow water, or had declined to the point that they were almost extirpated mainly through depletion of free CO_2 in the water column and/or of nutrient content in the sediment.

Plants are dioecious with separate male and female plants. Flowering is uncommon, with few records of viable seed (Bowmen et al. 1995). Reproduction is primarily vegetative. Elodea readily breaks into transportable fragments that can root in sediments. Fragments can spread in water and by birds such as geese and swans, although these propagules do not withstand drying (Barnes et al. 2013, Sand-Jensen 2000).

Distribution

Alaska

Elodea is considered not native to Alaska based on limited distribution, sparse herbarium records, and published literature on aquatic invasives that identifies Elodea as non-native within the state (Wurtz et al. 2013). The only known locations of Elodea in Alaska prior to 2010 were Eyak Lake near Cordova in 1982 and Chena Slough near Fairbanks in 2009. Extensive floristic surveys across Alaska have been conducted over the past century. The University of Alaska Fairbanks herbarium (ALA) includes over 1,500 aquatic plant specimens entered in the Arctos database, only two of which are Elodea (specimens from Eyak Lake and Chena Slough)(Wurtz et al. 2013). Elodea has since been found widely distributed in waterbodies on the Copper River delta, has spread to Alexander and Sucker Lakes in the Mat-Su since 2014, and has continued dispersing downstream from Chena Slough to Chena River to Totchaket Slough on the Nenana River and, as of 2018, to the Tanana River near Manley Hot Springs. In Anchorage, Elodea was initially found in Sand Lake in 2011, and it has been subsequently eradicated from there, Delong, and Little Campbell Lakes; however, it continues to fester in a ditch near Potter Marsh and was recently found in Jewell Lake in 2018. Here on the Kenai Peninsula, Elodea has been eradicated from Beck, Daniels and Stormy Lakes, and appears to be eradicated from Sports, Seppu and Hilda Lakes; at this time, there are no other known infestations on the peninsula.

To date, morphological and genetic identification of Alaskan specimens have indicated *E. canadensis*, *E. nuttallii* or their hybrid (Kate Mohatt, unpublished data). Genetic analysis indicates that *Elodea nuttallii* occurs in Fairbanks, *E. canadensis* in Anchorage and Cordova, and their hybrid in the Nikiski lakes. The hybrid is common in the commercial aquarium trade (Lars Anderson, pers. comm), lending support to the idea that these populations arose from independent aquarium dumps. *Elodea canadensis* X *nuttallii* hybrids are known to be fertile and to produce viable seeds (cited in Cook and Urmi-König 1985).

Elodea canadensis distribution in North America includes northern portions of the contiguous U.S. and southern Canada, excepting southern Alberta and southwestern Saskatchewan. Distribution is highest in parts of Quebec, the St. Lawrence Valley, the Great Lakes region, southern British Columbia, and the Pacific West Coast. *Elodea nuttallii* distribution is similar but is more common further south (Bowmen et al. 1995, Catling and Wojtas 1985). Elodea species are absent from northern Canada including the Yukon and northern British Columbia, displaying a sizeable gap in distribution between recent discoveries of Elodea in Alaska and the previously known northernmost locations in North America. The Electronic Atlas of the Flora of British Columbia (http://linnet.geog.ubc.ca/Atlas/Atlas.aspx?sciname=Elodea%20canadensis) indicates that *E. canadensis* is infrequent north of 51°N but it does occur as far north as 59°N, approximately 615 miles from Cordova, 800 miles from Kenai-Soldotna, and 725 miles from Fairbanks, but on the east side of the Coastal Range.

Elodea nuttallii is very similar to *E. canadensis* but has shorter and narrower leaves that are bent and folded along the midrib. *Elodea nuttallii* is generally smaller and paler green with more branches than *E. canadensis*. Characteristics often overlap making the species difficult to distinguish. Hybrids with intermediate characteristics occur naturally between the two species (Catling and Wojtas 1985, Cook and Urmi-König 1985). Taxonomic overlap due to hybridization is only further confused when parent stocks are introduced outside their native ranges; e.g., growth forms (phenotypes) of *E. nuttallii* can vary considerably in terms of leaf morphology and lateral shoot number (Thiebaut and Di Nino 2009).

The life history traits of these two species are similar in some respects (Barrat-Segretain et al. 2002). Both species are resistant to varying water current rates and have high regeneration (regrowth into viable plants) and colonization ability by fragments (establishment in sediment). In experimental tests, both species were shown to withstand strong current and survive long distance dispersal, increasing invasion capabilities (Barrat-Segretain et al. 2002). Both species grow in water temperatures of 10°—25°C. Few invertebrate species find either species to be palatable.

There are some critical differences between the two species that may affect their hybrid. Both species prefer depths ≤ 3 m, but will eventually spread to 5—6 m with some evidence that *E. nuttallii* can go deeper. *Elodea canadensis* prefers mesotrophic lakes whereas *E. nuttallii* prefers eutrophic lakes and can tolerate higher levels of pollution (oligo-mesoprobic). Both species are salt intolerant but to varying degrees: ≤ 0.25% for *E. canadensi*s (Sand-Jensen 2000) and ≤ 1.4% for *E. nuttallii* (CAPM 2004); for comparative purposes, ocean water is typically 3.5% salt.

Suitable habitat for Elodea may increase in response to global warming. Predictive bioclimatic models suggest that Elodea will continue to aggressively colonize even further north in Europe (Heikkinen et al. 2008). *Elodea canadensis* shows high competitive ability compared to other invasive aquatic species including Brazilian waterweed (*Egeria densa*) and oxygen weed (*Lagarosiphon major*) in a variety of low to high temperature conditions and varied light availability (Riis et al. 2012).

Elodea is commonly used as an aquarium plant and is readily available in pet stores. Elodea is also used in college and high school biology labs for experiments in plant cellular structure, living protoplasm, respiration, photosynthesis and other physiological processes (Catling and Wojtas 1985). The introduction to Chena Slough is likely the result of an aquarium dump at a point at Plack and Repp Roads near Fairbanks, as the population is dense below this point, but nonexistent above (Wurtz et al. 2013). Here on the Kenai Peninsula, ground zero was Beck Lake based on the abundance and distribution of Elodea before herbicide treatments. A tropical fish shop near the intersection of Halbouty and Dragonfly Roads, near Beck Lake, reportedly went out of business in the late-1990s and this is likely when Elodea was initially introduced.

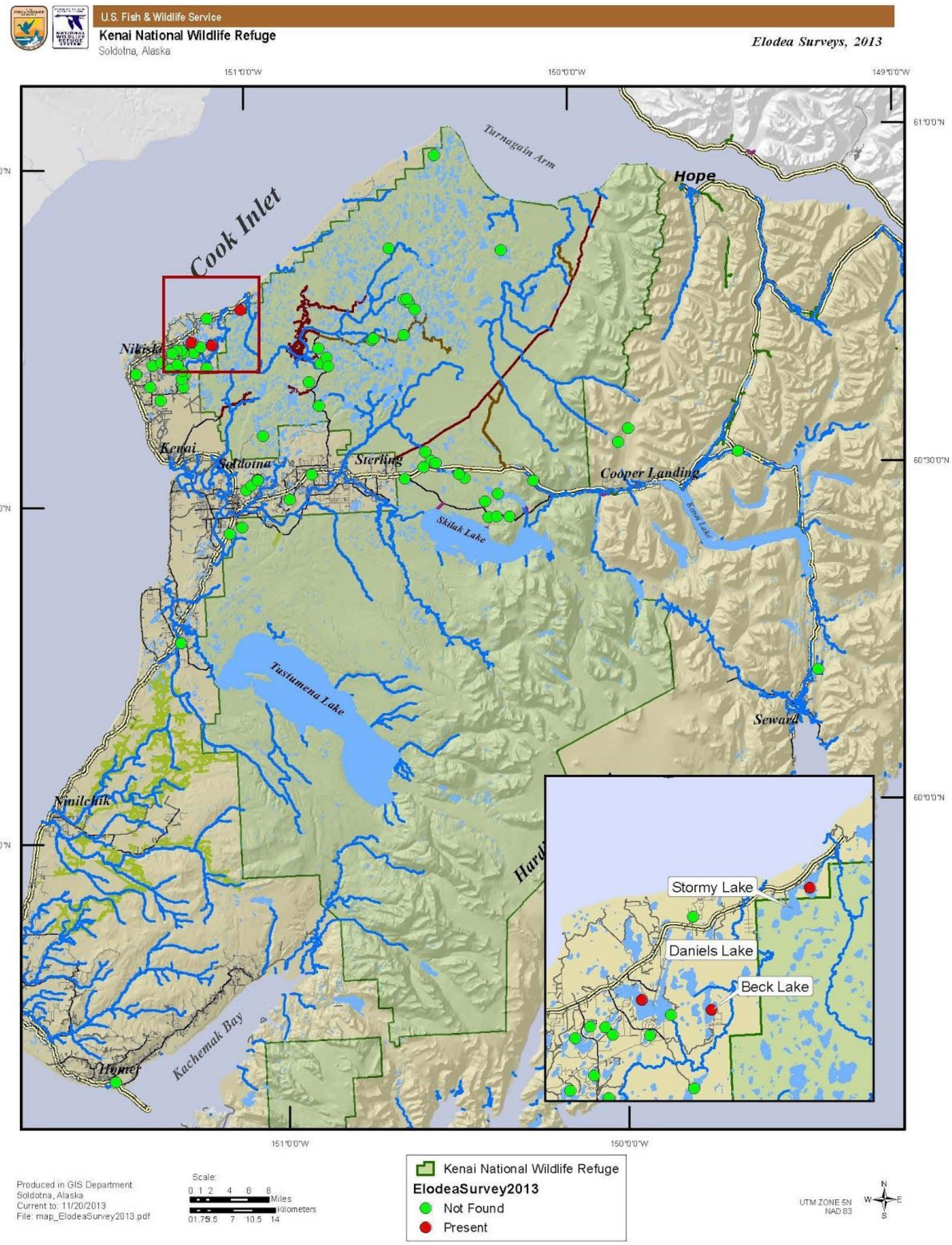


Figure 1. Elodea occurs in Beck, Daniels and Stormy Lakes. It was not found in 65 at-risk lakes on the Kenai Peninsula surveyed in summer 2013 including Afonasi, Arc, Barabara, Barbara, Barr, Bear, Bernice, Big Merganser, Bishop, Bottenintnin, Breeze, Cabin, Cecille, Dolly Varden, Douglas, Duck, East Mackey, Engineer, Forest, Georgine (Georgina), Headquarters, Hidden, Imeri, Island, Jean, Johnson, Kelly, Kivi, Lily, Little Merganser, Longmere, Lower Ohmer, Lure, Marie, McLain, Mosquito, Paddle, Parsons, Peterson, Pond, Portage, Pot, Rainbow (Rainbow Trout), Rock, Salamatof, Scout, Spirit (Elephant), Sport, Tern, Thetis, Timberlost, Tirmore, Union, Upper Ohmer, Vogel, Watson, Weed, West Mackey, and Wik.

Kenai Peninsula

Elodea was detected in Stormy Lake (400 acres) in September 2012, Daniels Lake (620 acres) in October 2012, Beck Lake (200 acres) in August 2013, Sports Lake (70 acres) in February 2017, Seppu (12 acres) and Hilda Lakes (43 acres) in July 2017, and Sandpiper Lake (74 acres) in September 2019. Four watersheds are involved: Stormy Lake flows into the mouth of the Swanson River; Seppu and Hilda Lakes (essentially one waterbody) flow into Beck Lake, which in turn flows into Bishop Creek (Figure 2); Daniels Lake flows into Bishop Creek; Sports Lake drains into the Kenai River (Figure 1); and Sandpiper Lake flows through Vogel Lake to Miller Creek Neither the Swanson River nor Bishop Creek are known to have Elodea. The Swanson River is not likely a concern because Stormy Lake drains into the tidally-influenced portion of the latter (and Elodea is salt intolerant). However, outflows from both Daniels and Beck Lakes clearly put Bishop Creek at risk; Elodea has not yet been detected there despite annual canoe surveys, the most recent in August 2019. Hilda Lake flows into Seppu Lake, which flows into Beck Lake, but a long-abandoned, silted-in and vegetated beaver dam serves as an effective barrier between the lakes. Two nets were installed in the outflow from Seppu Lake by Cook Inlet Aquaculture staff in August 2017; no Elodea (and, in fact, very little debris) has been intercepted to date. However, beaver, moose and a pair of breeding trumpeter swans may still be possible vectors. Surveys of Vogel Lake and North Vogel Lake in September 2019 failed to detect Elodea, so it appears that Elodea has not dispersed downstream from Sandpiper Lake.

The infestation in Seppu and Hilda Lakes was well established, and believed to have been present in 2013 (despite a rapid survey there that year) when Elodea was detected in Beck Lake. Thus Elodea in Beck, Daniels, Stormy and Seppu/Hilda Lakes, all close to one another north of Nikiski, likely originated from an initial aquarium dump in the late 1990s (see above), and was dispersed by trailered boat, floatplane, waterfowl, beaver or moose. Indeed, the life form of Elodea from all four lakes was superficially similar. Genetic analysis of specimens from Stormy, Daniels and Beck Lakes indicate a hybrid between *E. canadensis* and *E. nuttallii* (Dr. Donald H. Les, University of Connecticut, pers. comm.), consistent with another genetic analysis of specimens collected statewide that included Stormy Lake (Kate Mohatt, unpublished data).

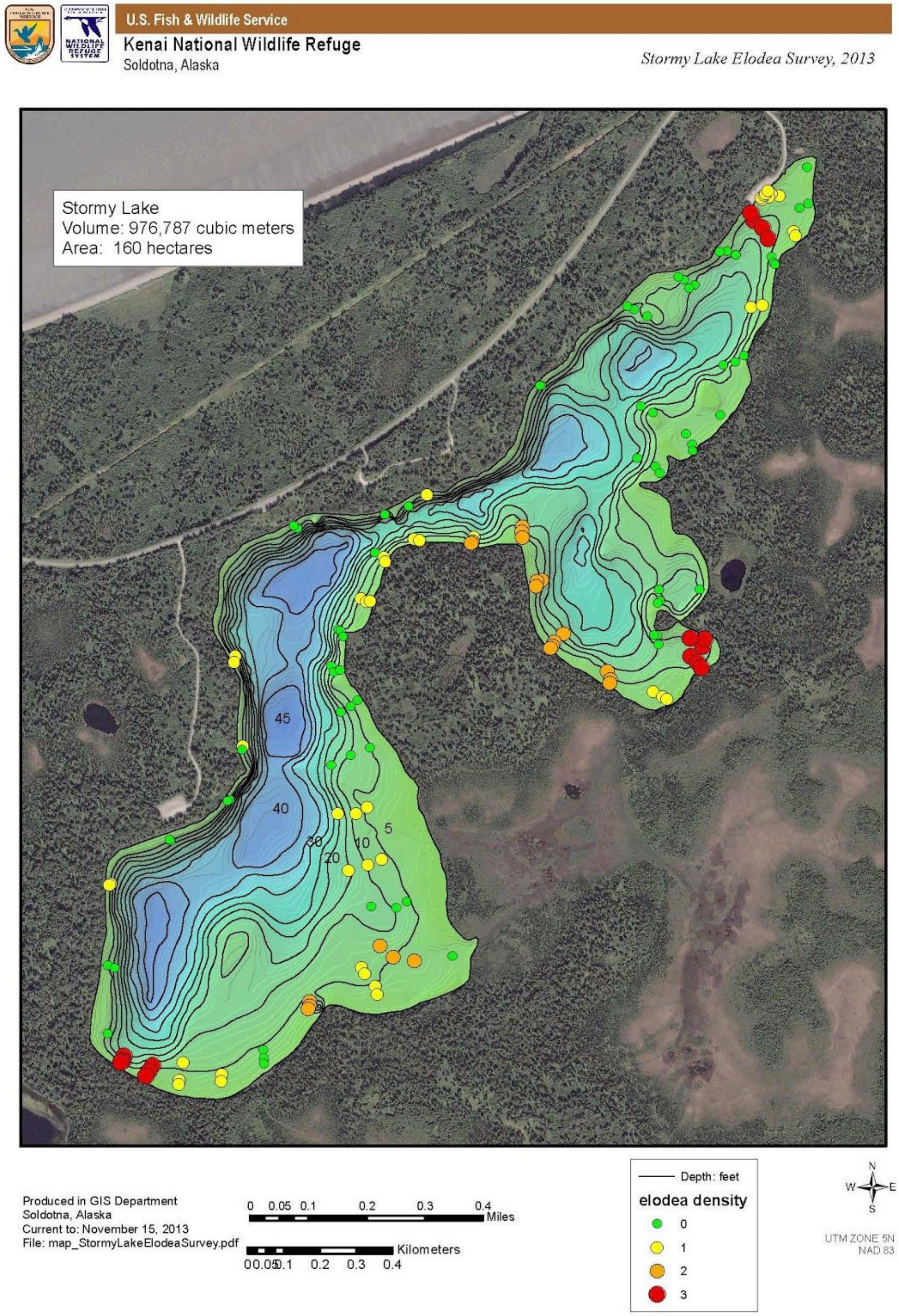
Elodea was first detected in Sports Lake in February 2017 when an ADF&G fisheries biologist was augering holes in the ice in preparation for a youth fishing derby. This Elodea, however, was more robust, with larger leaves and longer strands than Elodea from the Nikiski lakes, and its population growth was explosive (similar to what occurred in Alexander Lake in the MatSu between 2014 and 2016). Although genetic analysis was never conducted on specimens from this lake, the evidence suggests it was likely independently introduced from an Anchorage or MatSu waterbody by one of four floatplanes owned by Sports Lake residents.

Neither Elodea nor other exotic submersed freshwater plants were known to occur on the Kenai Peninsula until very recently. Pfauth and Systsma (2005) did not detect Elodea in Vogel, Johnson and Longmere Lakes as part of a larger regional survey of exotic aquatic plants in 2005. However, in September 2012, Elodea was incidentally found while Stormy Lake was being treated with rotenone for northern pike. Shortly thereafter, ADF&G staff surveyed the distribution of Elodea in Stormy Lake, detecting it at ~ 20% of 150 rake throws, mostly at 7-9 foot depths. In October 2012, ADF&G and

USFWS staff found a single strand of Elodea in Daniels Lake during windshield surveys of nine other lakes: Salamatof, Longmere, Island, Sport, Scout, West Mackey, East Mackey, Wik and Daniels. In February 2013, Daniels Lake was surveyed by augering through the ice at 25 sites (3 holes per site) distributed systematically around the 10-mile perimeter; Elodea was detected at 2 sites adjacent to each other on the southern shore. In May 2013, immediately after ice-out, a more comprehensive survey by boat confirmed that Daniels Lake was in the early stages of infestation with Elodea distribution restricted to five areas along the shoreline (Figure 5).

With the recognition that a strategic approach to Elodea management could not be determined without a more comprehensive understanding of its distribution on the Kenai Peninsula, USFWS staff surveyed 65 lakes on the western peninsula during summer 2013, from Tern Lake in the east to Johnson Lake in the south to Vogel Lake in the north (Figure 1). In addition to surveying Bishop Creek and 13 other lakes (Barbara, Barr, Bishop, Cecille, Douglas, Duck, Georgine [Georgina], Kivi, Marie, Parsons, Timberlost, Tirmore and Wik) in that watershed, waterbodies targeted elsewhere were those exposed to likely routes of infection: public boat launches, multiple private homes, road accessible or floatplane charters. Other agencies surveyed Beluga Lake in Homer, Trout and Juneau Lakes on Chugach National Forest, and Bear Lake near Seward. Elodea was found in only one additional lake, the 200-acre Beck Lake in the Bishop Creek watershed (Figures 2, 4). Significantly, no other nonnative submersed aquatic plant was detected. Thirty-four species were identified (Table 1), of which 14 were pondweeds of the genus Potamogeton, including *P. robbinsii*, a species considered rare in Alaska.

Since 2013, surveys have been conducted by CWMA partners, particularly the Kenai Watershed Forum, on lakes around the Kenai Peninsula. Several high-risk lakes have been surveyed twice in intervening years. To date, over 150 waterbodies have been surveyed by floatplane, motorboat or canoe with no additional detections other than Seppu and Hilda Lakes in 2017. At this time, the five known populations of Elodea on the Kenai Peninsula (Beck, Daniels, Seppu/Hilda, Sports, Stormy) have been eradicated.


U.S. Fish & Wildlife Service
Kenai National Wildlife Refuge
Soldotna, Alaska
Stormy Lake Elodea Survey, 2013
Stormy Lake
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Area: 160 hectares
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40
30
20
10
5
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Soldotna, Alaska
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Kilometers
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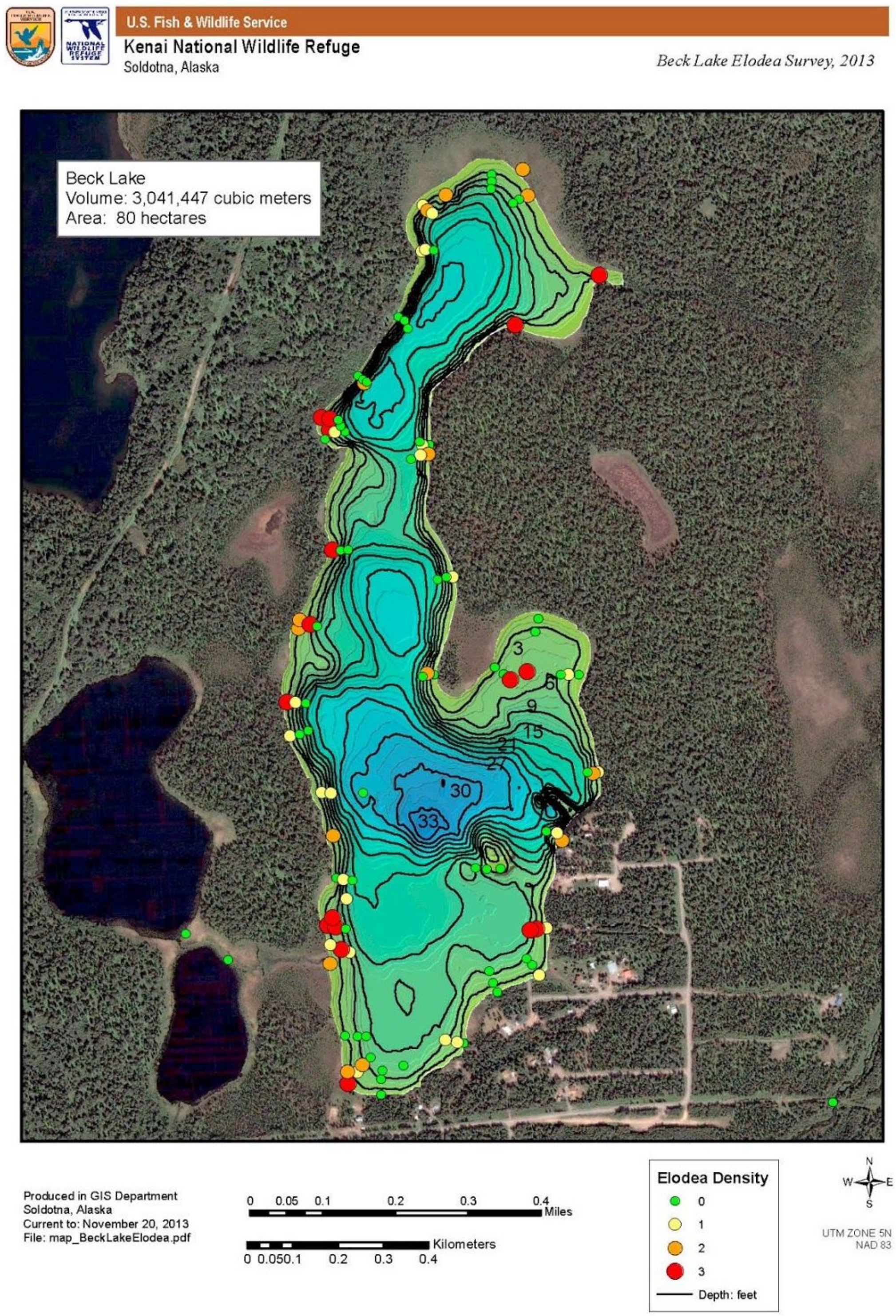
2
3
UTM ZONE 5N
NAD 83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Kenai National Wildlife Refuge
Soldotna, Alaska
Beck Lake Elodea Survey, 2013
Beck Lake
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Area: 80 hectares
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9
15
21
27
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33
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0 0.050.1 0.2 0.3 0.4 Kilometers
Elodea Density
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2
3
Depth: feet
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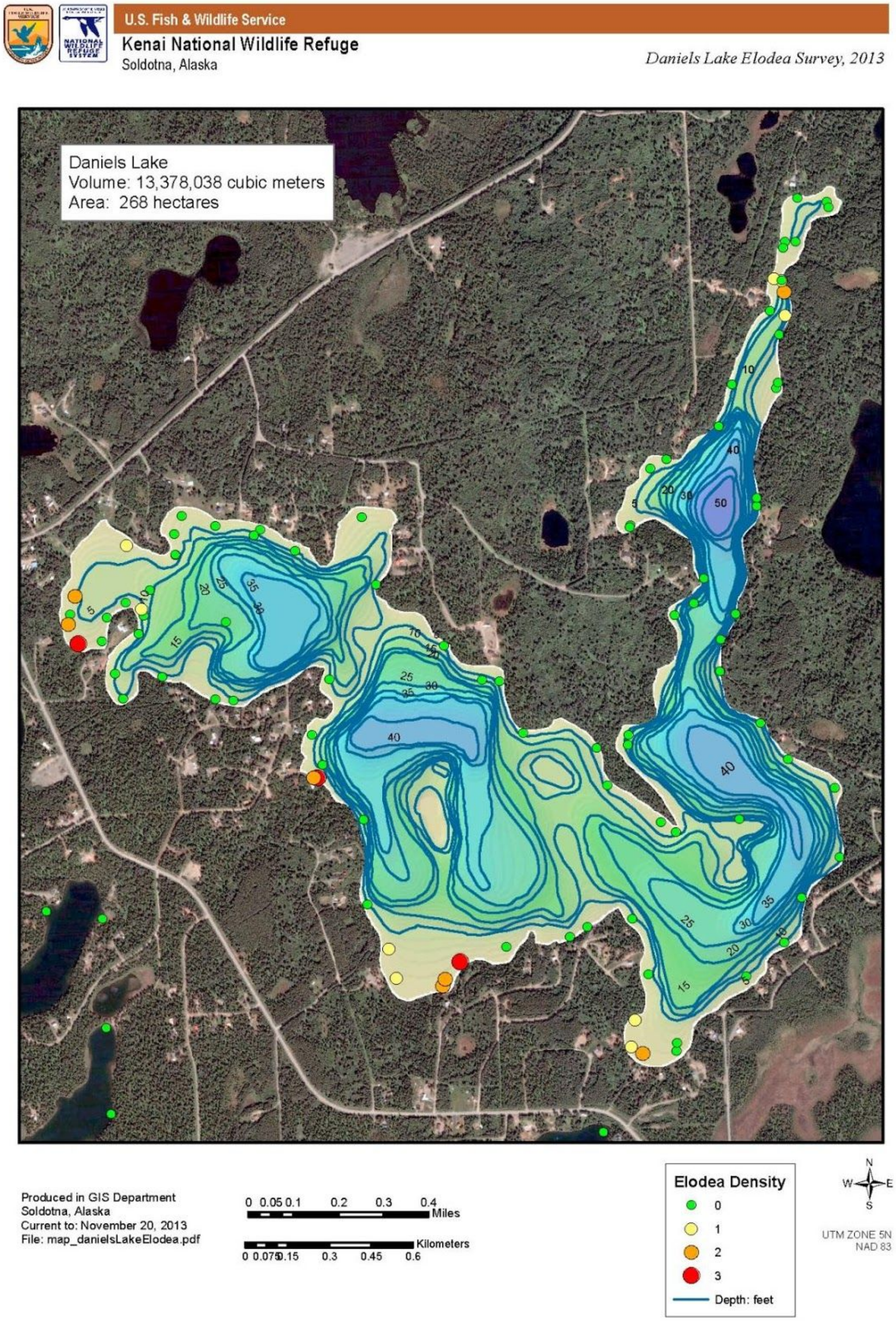
S
UTM ZONE 5N
NAD 83


U.S. Fish & Wildlife Service
Kenai National Wildlife Refuge
Soldotna, Alaska
Daniels Lake Elodea Survey, 2013
Daniels Lake
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Area: 268 hectares
Produced in GIS Department
Soldotna, Alaska
Current to: November 20, 2013
File: map_danielsLakeElodea.pdf
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0 0.075 0.15 0.3 0.45 0.6 Kilometers
Elodea Density
0
1
2
3
Depth: feet
N
W
E
S
UTM ZONE 5N
NAD 83

Ecological and economic effects of Elodea

Elodea is a particularly injurious aquatic perennial. In most places where Elodea has been introduced outside its species-specific native ranges, it has compromised water quality (Mjelde et al. 2012), grown so abundantly that boat traffic is hindered, and reduced dissolved oxygen (Buscemi 1958, Lehtonen 2000), all of which have the potential to severely impact native fisheries. Elodea is also insidious, in that only a plant fragment is needed to infest a water body because it reproduces vegetatively. The connected waterways of the Kenai Lowlands, adjacent to Stormy, Daniels and Beck Lakes, could potentially support large infestations of Elodea if plant fragments had been transported to new locations. Inflow and outflow of the known infested lakes were a concern as plant fragments may spread to adjacent water bodies, and from there remote lakes in the Kenai Lowlands. Likely initial vectors on the Kenai Peninsula were aquaria and discarded commercial lab kits. However, as Elodea becomes more established in other parts of Alaska, motorboats, anchors, fishing gear, and float planes become the greater risk.

Elodea represents an enormous economic and ecological threat to aquatic and fisheries resources of the Kenai Peninsula. All five anadromous salmon species spawn and rear young in freshwater habitats associated with the extensive glacial and non-glacial river systems on the peninsula. Gross earnings of all commercial fisheries and specifically for salmon in the Kenai Peninsula Borough were $108 million and $52 million, respectively, in 2008. Elodea has the potential to severely degrade the quality of lakes, wetlands, and slow-flowing streams used specifically by coho, chinook and sockeye fry. Rainbow trout and steelhead habitats are also vulnerable to degradation by Elodea, particularly when infestations become so dense as to create anoxic conditions. Elodea, along with other non-native aquatic plants, has affected Chinook salmon spawning rates by reducing spawning habitat in California (Merz et al. 2008). If Elodea were to spread statewide in Alaska, it would likely cost at least $100 million per year (and as much as $500 million annually) in lost economic opportunity to the commercial sockeye fisheries and recreational floatplane pilots (Schwoerer 2017).

Elodea can develop into dense, monospecific stands that prevent light from reaching other species. These dense stands limit water movement as well. Many stands experience 5—6 year growth cycles, possibly related to iron availability and depletion cycle, then collapse and cause oxygen depletion with massive amounts of decaying vegetation (Josefsson 2011). Chemical composition, pH, and oxygen level are all affected by Elodea infestation, thereby affecting fish, amphibian, and invertebrate populations in the waterbody. Elodea can impede recreational activities such as fishing, boating, and swimming Elodea can clog water intake pipes at hydropower and industrial plants, or even cause scrape damage to boats in calcium encrusted stands (Josefsson 2011). However, in rare cases, submersed aquatic vegetation communities with a mixture of non-native and native species may remain stable or even have natives increase over time, and waterfowl communities may show positive response to invaded waters (Rybicki and Landwehr 2007).

Elodea and other aquatic invasive species can reduce property values for landowners on infested lakes. Policies with successful invasion prevention have significant benefits to lakefront properties and community members. A study in New Hampshire determined 21—43% decline in property values by the presence and increase in variable milfoil, which can clog waterbodies, crowd out native aquatic species, and reduce recreational activities like boating and swimming (Halstead et al. 2003). In a study in Wisconsin on 170 lakes infested with Eurasian watermilfoil, property values were reduced by 8—13%, and spread rate increased due to the number of lakes infested (Horsch and Lewis 2009). A similar study in Vermont also with Eurasian watermilfoil showed a 1—6% decline in property values (Zhang and Boyle 2010).

Jurisdictional issues

Stormy Lake is within the Swanson River watershed. Stormy Lake drains into the Swanson River within Captain Cook State Park (Alaska Department of Natural Resources), one mile upstream from its mouth. Daniels and Beck Lakes are within the Bishop Creek watershed. Bishop Creek originates in Parson Lake, flows for 1.4 miles through Bishop Lake and then continues for 15.5 miles to the Cook Inlet. Timberlost, Daniels, Beck and several smaller lakes drain into Bishop Creek as it flows to the sea. The lower portion of Bishop Creek passes in and out of the Kenai National Wildlife Refuge before flowing under the Spur Highway at MP36 and then into the Cook Inlet; the mouth is within Captain Cook State Park, 2 miles south of the Swanson River. All three lakes are natural.

Stormy Lake is located in T8N, R10W (Sections 15,20,21,36, 37; Seward Meridian, Kenai Peninsula)(Figure 2). It is 0.3 miles east of Cook Inlet, 8.5 miles northeast of Nikiski and just off the Kenai Spur Highway. The land surrounding the lake is publicly managed by Captain Cook State Park and Kenai National Wildlife Refuge. A public boat launch is maintained by the Alaska Department of Natural Resources at MP38 of the Kenai Spur Highway. Stormy Lake drains into the tidal-influenced zone of the Swanson River via a 0.75-mile outlet steam at ~2 cubic feet per second (cfs).

Daniels Lake is located in T8N, R11W (Sections 33, 34, 35) and T7N, R11W (Sections 2, 3)(Figure 4). It is 2.2 miles south of the Cook Inlet shore and 2 miles northeast of Nikiski; access is south of the Kenai Spur Highway at MP30 (Halibouty Road). Daniels Lake is primarily surrounded by private lands with 153 parcels, although there are State (Alaska Mental Health Trust Authority, Alaska Department of Natural Resources), Kenai Peninsula Borough, and Cook Inlet Region Inc. (CIRI) parcels. The outflow from Daniels Lake is ~ 3 cfs and flows for 1.7 miles before draining into Bishop Creek 12.3 miles from the Cook Inlet.

Beck Lake is located in T8N, R11W (Section 36) and T7N, R11W (Section 1)(Figure 3). It is 2.7 miles south of the Cook Inlet shore, 4.6 miles east of Nikiski and south of the Kenai Spur Highway. The southeast shoreline of Beck Lake is within private land ownership (21 parcels), but the Kenai Peninsula Borough, Alaska Mental Health Trust Authority, and CIRI have significant holdings. Beck Lake is drained via a 0.6-mile outflow into Bishop Creek, 4 miles downstream from Daniels Lake.

In addition to multiple land ownerships, state management of Elodea is complicated because aquatic invasive plants are under the jurisdiction of the AK Department of Natural Resources, fisheries resources are managed by AK Department of Fish and Game, and herbicides are permitted by AK Department of Environmental Conservation. It is appropriate that the interagency Kenai Peninsula Cooperative Weed Management Area develop this integrated pest management plan for responding to Elodea.

IV. Management

Goals and objectives

The management goal is to eradicate Elodea from, and to prevent its reintroduction, to the Kenai Peninsula.

At this time, the five known populations of Elodea on the Kenai Peninsula (Beck, Daniels, Seppu/Hilda, Sports, Stormy Lakes) have been eradicated. Consequently, the short-term objectives (2019-2024) that this plan addresses are

1) to continue EDRR for Elodea in other lakes on the Kenai Peninsula including possible re-introduction to the five previously-treated lakes.

The long-term objective that this plan acknowledges but does not address in full is

2) to eradicate new infestations on the Kenai Peninsula; and
3) to prevent the reintroduction of Elodea (and the introduction of other submersed freshwater invasive plants) to the Kenai Peninsula .

Treatments considered for eradication

Elodea is difficult and expensive to eradicate. The only economical, safe and effective methods for managing Elodea are draining and drying the channel or waterbody, application of herbicides, or introducing herbaceous fish (grass carp) (Josefsson 2011, Bowmen et al. 1995). Covering methods, such as tarping the sediment or covering live plants, may be effective in small, shallow areas (CAPM 2004). Mechanical methods, such as cutting, draglines or suction dredging, are not effective as they fragment the plant and cause it to spread to new areas. However, we did rake Elodea in one instance during treatments on the Kenai Peninsula. In early May 2017, shortly after ice-out, green Elodea strands rafted up along an accessible shoreline on Sports Lake after a storm event. Leveraging this unusual opportunity, we raked up and discarded this significant biomass before applying herbicide (Figure _).

The only realistic option for treating large and deep waterbodies such as Daniels, Beck and Stormy Lakes are herbicides. Herbicides can be lethal to Elodea, but may require a long contact time and/or multiple applications for effective control and certainly for eradication, while often imposing significant nontarget effects. Elodea responds to a limited number of herbicides including fluridone, diquat, terbutryne, copper sulphates or chelates of copper (which also inhibits algal growth), and paraquat (Bowmen et al. 1995). The most effective herbicides have been found to be fluridone and diquat; both chemicals are rated E for Excellent, with success rates exceeding 95% for potential control of Elodea species (DiTomaso et al. 2013). However, fluridone is a selective systemic herbicide that is ultimately lethal to the entire plant and can result in eradication, whereas diquat is a nonselective, quick-acting contact herbicide that kills only the above ground biomass and does not result in eradication.

Figure 6. KP-CWMA partners rake up Elodea strands rafted up along the shoreline near the public boat launch at Sports Lake in May 2017, shortly after ice-out. This was an unusual opportunity to significantly reduce biomass before applying herbicide.

We have used fluridone pellets in all five successfully eradicated lakes to date on the Kenai Peninsula. Liquid fluridone (Sonar Genesis) is sometimes also applied initially to increase uptake early in the treatment. We have also used diquat in Daniels Lake to prevent it transitioning from a partial-lake to a whole-lake treatment, and in Sports Lake to minimize the risk of spread to other lakes by boat or floatplane.

Fluridone

Fluridone (Sonar™) has been used successfully to manage Elodea in the Lower 48 (Dr. Lars. Anderson, UC-Davis, pers. comm). Fluridone is a selective systemic aquatic herbicide which inhibits the formation of carotene, a plant pigment, causing the rapid degradation of chlorophyll by sunlight, which then prevents the formation of carbohydrates necessary to sustain the plant. Adequate concentrations must be maintained (albeit at very low concentrations) in the treated area for 45-90 days after the initial application, which is determined through periodic water monitoring.

Fluridone is a tan to off-white odorless crystalline solid, chemically formulated as 1-methyl-3-phenyl-5-[3-(trifluromethyl)phenyl]-4(1*H*)-pyridinone, and applied as either a pellet or liquid (Bartels et al. 1978, McCowen et al. 1979). Sonar by SePRO Corporation is a commercially available herbicide used to selectively manage undesirable aquatic vegetation in freshwater ponds, lakes, reservoirs, rivers, and canals. Sonar is currently approved for use by the Alaska Department of

Environmental Conservation in five different formulations: two aqueous suspensions known as Sonar AS (USEPA Registration Number 67690-4) and Sonar Genesis (USEPA Registration Number 67690-54), and three time-released pellet forms known as Sonar Q (USEPA Registration Number 67690-3), Sonar PR Precision Release (USEPA Registration Number 67690-12), and SonarONE (USEPA Registration Number 67690-45).

Fluridone may be applied to an entire water body (whole-lake) or on smaller infestations within a water body (partial-lake). In the former case, fluridone is generally applied as a liquid by boat through surface or underwater drip equipment depending on the size and distribution of necessary treatment areas. In the latter case, Fluridone is typically applied as time-release pellets. A targeted, partial-lake treatment will result in less herbicide to the lake, reduced treatment costs, and fewer non-target impacts. In both cases, application will take place under appropriate conditions for boating, avoiding conditions of high wind, water flow, or wave action. The herbicide will be applied following all directions on the EPA approved label and will not exceed the maximum cumulative concentration (150 ppb).

Complete eradication with fluridone products generally require treatment of 45—90 days per growing season for two or more growing seasons. The ideal time for treatment is shortly after ice out (late May, early June) when plant biomass is low, turbidity is low, water volume is low, and the plant is actively growing, but before a thermocline is established in the lake (typically mid- to late-June) that can inhibit a uniform distribution of fluridone in the water column.

However, fluridone can be applied at any time that Elodea is photosynthesizing, which appears to be year-round. Unlike most other native submersed aquatic plants, Elodea does not completely senesce. In February 2013, when a joint USFWS-ADFG crew sampled Elodea through two feet of ice and snow cover in Stormy and Daniels Lakes, it was obvious that Elodea was green, vibrant and photosynthesizing under the ice (Figure 6). Pedlow et al. (2006) effectively treated watermilfoil in a Michigan lake with a whole-lake treatment of low-dosage fluridone, first applied in October and subsequently boosted in November, with herbicide residuals maintained through the winter. Despite relatively low uptake by plants during this time, this disadvantage may be offset by low water volume, minimal mixing (no wind due to ice cover), and reduced concerns about potential impacts to anadromous fish and human health.

Fluridone effect on Elodea

Fluridone is a slow-acting systemic herbicide used to control Elodea, hydrilla, Eurasian watermilfoil and other underwater plants. Like other systemic herbicides, fluridone is absorbed from water by plant shoots and from the hydrosoil by the roots of aquatic vascular plants (Marquis et al. 1981, Westerdahl and Getsinger 1988). The susceptibility of a plant to fluridone is associated with its uptake rate and rate of translocation. Fluridone interferes with the synthesis of RNA, proteins, and carotenoid pigments in plants, and disrupts photosynthesis of targeted plants. Production of carotene is inhibited, preventing carbohydrate formulation necessary to sustain the plant. Fluridone symptoms on submersed aquatic plants appear as progressive albescence of young leaves followed by leaf necrosis, initially appearing 3—6 days after application (McCowen et al. 1979), but requiring 45—90 days for optimal lethality. Eventually, aquatic plants gradually sink to the bottom and the amount of open water increases (McCowen et al. 1979). Fluridone does not affect water quality parameters such as pH, dissolved oxygen, color, dissolved solids, hardness, nitrate nitrogen, total phosphates, and turbidity (McCowen et al. 1979).

Although fluridone is considered to be a broad spectrum herbicide, when used at very low concentrations, it can be used to selectively remove Elodea, which is considered highly susceptible to the effects of fluridone (McCorkelle et al. 1992). Some native aquatic plants, especially emergent plants, are minimally affected by low concentrations of fluridone (NYSFOLA 2009). At higher concentrations, fluridone controls a broad spectrum of annual grass and broadleaf weeds, but not algae (Bartels et al. 1978, Berard et al. 1978, McCowen et al. 1979, Marquis et al. 1981). Fluridone has been field tested on a variety of invasive or non-native aquatic plants including salvinia (*Salvinia* spp.), bladderwort (*Utriculata* spp.), Eurasian watermilfoil (*Myriophyllum spicatum*), coontail (*Ceratophyllum demersum*), pondweeds (*Potamogeton* spp.), cattail (*Typha* spp.), horsetail (*Equisetum* spp.), duckweed (*Lemna* spp.), fanwort (*Cabomba caroliniana*), vallisneria (*Vallisneria* spp.), water hyacinth (*Eichornia crassipes*), hydrilla (*Hydrilla* spp.) and Elodea (*Elodea* spp.)(McCowen et al. 1979). Because fluridone does not work on algae, ponds or waterbodies with high algal concentrations should not be treated with this herbicide as the algal coating on Elodea can prevent herbicide absorption. Field tests in mixed invasive and native submersed aquatic vegetation showed reduction in invasive populations with native plant cover retention of approximately 70% (Madsen et al. 2002). Treatments of Michigan lakes resulted in drastic reductions in invasive Eurasian watermilfoil, increases in native submersed aquatic vegetation, and increases in size and abundance of native fish populations (Schneider 2000).

Fluridone is removed from treated water by degradation from sunlight (photolysis), adsorption to sediments, and absorption by plants. In partially-treated water bodies, dilution reduces the level of the herbicide more rapidly following application. In field studies, fluridone (various formulations) decreased logarithmically with time after treatment and approached zero detectable presence 64—69 days after treatment (Langeland and Warner 1986). In other studies, fluridone levels decreased rapidly to a value below detection limits after 60 days in various parts of the water column, with a half-life $\leq$ 7—21 days (Kamarianos eta al. 1989, Osborne et al. 1989, Muir et al. 1980, McCowen et al. 1979). Fluridone can persist in hydrosoils (sediments) with a half-life exceeding one year (Muir et al. 1980). High lake turbidity also increased the half-life to $\geq$ 50 days in Waneta Lake in New York, and resulted in measurable fluridone concentrations several months after the initial treatment (Kishbaugh 2011).

Fluridone can persist for months (over the winter) in the water column when applied in autumn due to lower water temperatures and low light levels. This attribute has resulted in fluridone applications in the fall in the Midwest where lakes freeze (WADOE 2000).

One of the primary reasons we believe treatments on the Kenai Peninsula have been so successful is because we have maintained lethal fluridone concentrations (4-10 ppb) in these waterbodies for more than two consecutive years, not seasons. Additionally, the absence of a seed bank (because all reproduction to date has been asexual) means that only the standing stock of Elodea needs to be killed.

Fluridone effects on non-target animals (including humans)

Any pesticide approved by the U.S. Environmental Protection Agency (USEPA) has undergone extensive testing to determine toxicity level through acute (high doses for short periods of time) and chronic (long term exposure) studies on animals (USEPA 1986). Sonar has been tested in both acute and chronic studies, as well as studies to examine genetic, cancer, and reproductive effects. Sonar was not shown to result in the development of tumors, adverse reproductive effects or offspring development, or genetic damage. Sonar has been tested extensively on target aquatic invasive plants, as well as in long-term residue monitoring studies in treated waters. Sonar is labeled with the signal world “caution” by the USEPA on the label, indicating a level of toxicity lesser than those labeled with either “danger” (more toxic) or “poison” (most toxic).

The USEPA has approved Sonar’s application in water used for drinking as long as residue levels do not exceed 0.15 parts per million (ppm) or 150 parts per billion (ppb) (USEPA 1986). For comparative purposes, 150 ppb is well below the 560 ppb set by USEPA as the MCL (maximum contaminant level). One ppm can be considered equivalent to approximately one second in twelve days or one foot in two hundred miles. Sonar applications can be made within one-fourth mile (1,320 feet) of a potable water intake. Human contact to fluridone may be through swimming in treated waters, drinking water from treated waters, by consuming fish from treated waters, or by consuming meat, poultry, eggs, or milk from livestock that were provided water from treated waters. Stormy and Daniels Lake have no commercial agricultural use, so exposure through livestock is unlikely. There are no USEPA restrictions on the use of fluridone-treated water for swimming or fishing when used according to label directions (USEPA 1986).

The maximum non-toxic dose is characterized by the “no-observed-effect-level” or NOEL for pesticides. The dietary NOEL for fluridone (the highest dose at which no adverse effects were observed in laboratory test animals fed Sonar) is approximately 8 milligrams of Sonar per kilogram of body weight per day (8mg/kg/day). A 70-kg (150 lb.) adult would have to drink over 1,000 gallons of water containing the maximum legal allowable concentration of Sonar in potable water (15 ppm) for a significant portion of their lifetime to receive an equivalent dose. A 20-kg (40 lb.) child would have to drink approximately 285 gallons of Sonar treated water every day to receive a NOEL- equivalent dose. The risk therefore is negligible even if a human were to accidentally ingest water directly after Sonar treatment. As Sonar is only applied intermittently and in limited areas, and because it disappears from the environment, continuous exposure over a lifetime for humans, mammals, and other animals is improbable.
Fluridone has been tested for acute and chronic toxicity, as well as reproductive effects, on mammals (rats, mice, guinea pigs, rabbits, dogs), birds (bobwhite quail, mallard duck), insects (honey bee,

amphipods, daphnids, midge, chironomid), earthworms, fish (fathead minnows, catfish, mosquitofish, rainbow trout), and other aquatic animals (Hamelink et al. 2009, Kamarianos et al. 1989, Muir et al. 1982, McCowen et al. 1979).

Exposure of test animals dermally (skin contact) has shown minimal toxicity to mammals by acute, concentrated contact. Chronic dermal exposure in mammals showed no signs of toxicity and slight skin irritation. Mammals were shown to excrete fluridone metabolites within 72 hours of varying doses of up to 1400 ppm/day (McCowen et al. 1979). A dietary NOEL was established for birds that may feed on aquatic plants or insects in treated waters. The risk to birds via diet was considered negligible. The acute median lethal concentrations of fluridone were 4.3 +/- 3.7 mg/L for invertebrates and 10.4 +/- 3.9 mg/L for fish. Fish in treated ponds have shown no fluridone metabolites after treatment (Kamarianos et al. 1989). Chronic studies showed no effects on daphnids, midge larvae, fathead minnows, or channel catfish and rapid rates of metabolic excretion (Hamelink et al. 2009, Muir et al. 1982). Insects that fed on bottom sediment had higher rates of fluridone intake and persistence than others (Muir et al. 1982). Honeybees and earthworms were not considered particularly sensitive to fluridone, even when directly dusted or placed in treated soil.

Fluridone has low bioaccumulation potential in fish, bird, or mammal tissues. Irrigation of crops using water treated with fluridone lead to only trace amounts detected in forage crops. Livestock consumption of Sonar-treated water resulted in negligible levels of Sonar in lean meat and milk. Sonar manufacturer recommendations indicate the livestock can be watered immediately from Sonar-treated water. The tolerance for milk is the same as for water (0.15 ppm).

<u>Fluridone effects on non-target vegetation</u>
At the low concentrations applied (≤ 10 ppb) fluridone is expected to be only lethal to Elodea. The aquatic plant community is expected to shift back to one comprised entirely of native species if eradication is successful. Early on, there may be a period when Elodea is decaying that light and dissolved oxygen may be temporarily reduced. As the plant continues to decay, water clarity and dissolved oxygen as well as nutrient levels are expected to return to normal water quality levels. Indeed, Sethi et al. (2017) showed there were no systemic effects of fluridone on macrophytes (as well as zooplankton and measures of water quality) in Beck and Stormy Lakes when compared to nearby untreated control lakes, other than early onset of senescence in *Nuphar* spp. However, continued vegetation surveys indicate that the native *Myriophyllum sibiricum* (Table 1) may have been eradicated from these treated lakes. FasTEST assays indicate average fluridone concentrations in the water column only fell below lethal levels in 2017, so we remain hopeful that the native milfoil will recover from an existing seed bank; if not, milfoil can be re-introduced from populations in nearby lakes.

Similarly, Madsen et al. (2002) evaluated nontarget plant effects in three lakes in southern Michigan that were treated with low-dosages of fluridone (Sonar AS®) to control Eurasian watermilfoil. Despite achieving >93% reduction in the frequency of watermilfoil, native plant cover (composed mostly of *Ceratophyllum demersum, Chara* spp., *Heteranthera dubi, Potamogeton* spp., and *Vallisneria americana*) was maintained at >70% in the year of treatment and 1-year post treatment. Floating leaf plants (such as yellow pond lily) exhibiting chlorosis (due to lack of chlorophyll) usually recover within the year of treatment or become re-established within the following year (Kenaga 1992).

Table 1. Native freshwater plant species found in the three lakes on the Kenai Peninsula infested with *Elodea* sp.

Scientific Name	Common Name	Beck Lake	Stormy Lake	Daniels Lake
Calla palustris	wild calla	X		
Callitriche hermaphroditica L.	northern water starwort	X		
Eleocharis palustris	common spikerush	X		
Elodea canadensis x nuttallii	waterweed hybrid	X	X	X
Equisetum fluviatile	water horsetail	X		
Fontinalis antipyretica	common water moss	X	X	X
Hippuris vulgaris	common mare's-tail	X		
Myriophyllum sibiricum	shortspike watermilfoil	X	X	X
Nuphar lutea	yellow pond lily	X	X	X
Potamogeton spp. (P. epihydrous, P. friessii, P. gramineus, P. praelongus, P. pusillus, P. richardsonii)	pondweeds	X	X	X
Ranunculus aqualtilis	water crowfoot		X	
Schoenoplectus tabernaemontani	bulrush		X	
Sparganium angustifolium	marrowleaf burreed	X	X	X
Sparganium natans	small bur-reed	X	X	X
Utricularia intermedia	flatleaf bladderwort	X	X	X

Diquat effects on non-target native vegetation

Treatment with diquat may affect non-target native species as it is a nonselective contact herbicide. However, since only parts of the lake will be treated, propagules of native aquatic plants are expected to recolonize any areas where Elodea has been eliminated. Reduction of biomass using diquat may create a more favorable environment in which native plants can compete with Elodea, or may have no effect on native plant populations in the short term (Rybicki and Landwehr 2007). Also, in the two lakes in which diquat has been used on the Kenai Peninsula (Daniels, Sports), both were treated shortly after ice-out (when native flora is just starting to grow but Elodea is already green) to ensure that Elodea was targeted.

Minimal trampling of shoreline vegetation is expected from field operations. In previous treatments, we staged activities from existing boat launches and adjacent gravel or paved parking. Our experience to date shows some dieback of emergent vegetation due to herbicide use and the physical damage caused by boat application, but full recovery post-treatment.

Diquat (in combination with fluridone)

Growth suppression of Elodea infestations in the nearshore littoral zone (<10’ depth) may be accomplished with diquat bromide (diquat), sold as Reward™, to minimize plant fragmentation and decrease the likelihood of further spread within infested lakes and to lakes elsewhere on the peninsula. In combination with fluridone, we specifically applied diquat to the five infested areas within Daniels Lake to prevent further spread within that lake. Diquat is a nonselective, contact algicide, defoliant, desiccant and herbicide that is best applied when plant biomass and turbidity are low. Although diquat has a maximum application rate of 2 gallons of Reward™ per surface acre, we have only applied it at half that rate with great success after ice-out when Elodea represents most (if not all) of the green biomass.

Reward Landscape and Aquatic Herbicide (USEPA Registration No. 100-1091) contains the active ingredient diquat dibromide and is currently approved for use by the Alaska Department of Environmental Conservation. Diquat is formulated as 6,7-dihydrodipyrido (1,2-a: 2',1'-c) pyrazinediium dibromide (Cochrane at al. 1994). It is a general use herbicide typically used to control broadleaf and grassy weeds in non-crop and aquatic areas (USEPA 2002). It is an organic solid of colorless or yellow crystals, or dark red-brown in water solution, and is highly soluble in water. In the presence of strong oxidizers, diquat may pose a fire and explosion hazard. Diquat is a quick-acting herbicide, causing injury only to the parts of the plant to which it is applied (Hayes and Laws 1990). Diquat is absorbed by plant leaves where it interferes with cell respiration and prevents uptake of oxygen.

Diquat is considered a moderately toxic material, labeled with the USEPA signal word “warning” (USEPA 2002). Diquat exhibits low acute toxicity via oral and inhalation exposure, but has moderate to severe acute toxicity by dermal exposure. Humans drinking water containing diquat in excess of the maximum contaminant level (MCL) over many years could get cataracts. Diquat can cause eye irritation, and can cause serious burns and scarring of the cornea (Sax 1984). Diquat may be harmful to the gastrointestinal tract, kidneys, and liver of mammals, causing severe congestion and ulceration of stomach and gastrointestinal tract (Gosselin et al. 1984).

Diquat is not known to cause genetic changes and is therefore not considered a mutagen in acute tests with mice. Diquat does not cause tumors in rat studies both acute and chronic. Tests have been conducted on mice, rats, guinea pigs, rabbits, dogs, and cows (Cochrane et al. 1994, Hayes and Law 1990). Diquat causes cataracts in dogs and rats, and developmental effects in rats and rabbits (Cochrane et al. 1994). Oral diquat doses are metabolized mainly in the intestines with excretion in feces, in tests with rats, hens, and cattle. Minute traces (0.004—0.015% of oral doses) of diquat were found in cow milk, and cows are considered sensitive to diquat exposure. Diquat is considered moderately-toxic to practically-nontoxic to birds, depending on the species. In mallards, acute toxicity (LD50 or lethal dose fifty in which half of the subjects are killed with that dose) was 564 mg/kg. For domestic hens, oral LD50 was 200-400 mg/kg, for rats 120/mg/L, for mice 233 mg/kg, and 188 mg/L in rabbits. Chronic exposure at the 4-week no-observed-effect-level (NOEL) for increased relative liver weight in rats from dietary exposure to diquat was 7.2 mg/kg-day (Cochrane et al. 1994).

Diquat is slightly toxic to fish. The LC50 (lethal concentration fifty, in which half of the experimental subjects are killed when exposed to that concentration) was 12.3 ppm for rainbow trout and 28.5 in Chinook (king) salmon at eight hours, and 16 ppm at 96 hours for northern pike and 20.4 ppm for fingerling trout. Some species of fish may be harmed but not killed by sublethal levels of diquat, including suffering respiratory stress (yellow perch) (Bimber et al. 1976). There is no bioconcentration of diquat in fish. Diquat is toxic to aquatic invertebrates, which display varying levels of sensitivity. Diquat has shown to be 300 more times toxic to amphipods than mayfly, with caddisfly, damselfly, and dragonfly less sensitive in that order (Nicholson and Clerman 1974, Wilson and Bond 1969).
The Maximum Contaminant Level (MCL) is 0.02 milligrams per liter (mg/L) or 20 ppb for diquat (USEPA 2002). Diquat residue studies suggest that diquat is not persistent in water, as it binds to suspended particles in the water, which are then taken up by plants. The half-life is less than 48 hours in water. Affected plants decompose and release diquat, which is then degraded by microbes, photodegraded by sunlight (within 1 to 3 weeks), or adsorbed to sediment particles. Adsorbed sediment diquat is also degraded by microbial activity, although diquat has been found in the bottom soil of pools and ponds four years after application. Adsorption rates are highest in loam, sandy clay loam, and sandy loam (Cochrane et al. 1994). Granular activated carbon can be used to remove diquat to below MCL.

At its maximum application rate of 2 gallons per surface acre, The Reward® label for Landscape and Aquatic Herbicide specifies the following water use restrictions after treatment: 0 days for fishing and swimming, 1 day for consumption by livestock and domestic animals, 3 days for drinking, and 5 days for irrigating food crops and production ornamentals. The Restricted Entry Interval for this product is 24 hours. However, to date, in the two instances in which diquat has been used on the Kenai Peninsula, it was applied at the rate of 1 gallon per surface acre and only over areas in which we had mapped Elodea.

The one-time use of diquat, in combination with multiple applications of fluridone, is an excellent cocktail for minimizing the risk of further spread of Elodea because it is so effective in a short period. Managing dispersal risk is at least as important as the actual treatment to eradicate elodea from an infested water body. Consider that Elodea appears to have been introduced to Alexander Lake in the MatSu by a floatplane from Sand Lake in Anchorage, even as the latter was being treated with fluridone. Recent introductions of Elodea (e.g., Alexander Lake, Sports Lake) by floatplane from locally adapted populations (as opposed to an aquarium dump) have been viral in their response, infesting most of the waterbody in just two years. Consequently, diquat should be considered in any newly infested waterbody with obvious vectors such as public boat launches, resident floatplanes, high migratory bird use or high-volume water flow.

Lake-specific prescriptions

Lake-specific prescriptions are outside the scope of this IPM plan. However, the following prescriptions for Beck, Daniels and Stormy Lakes are offered as real examples to help plan treatments for new infestations that may occur on the Kenai Peninsula in the future.

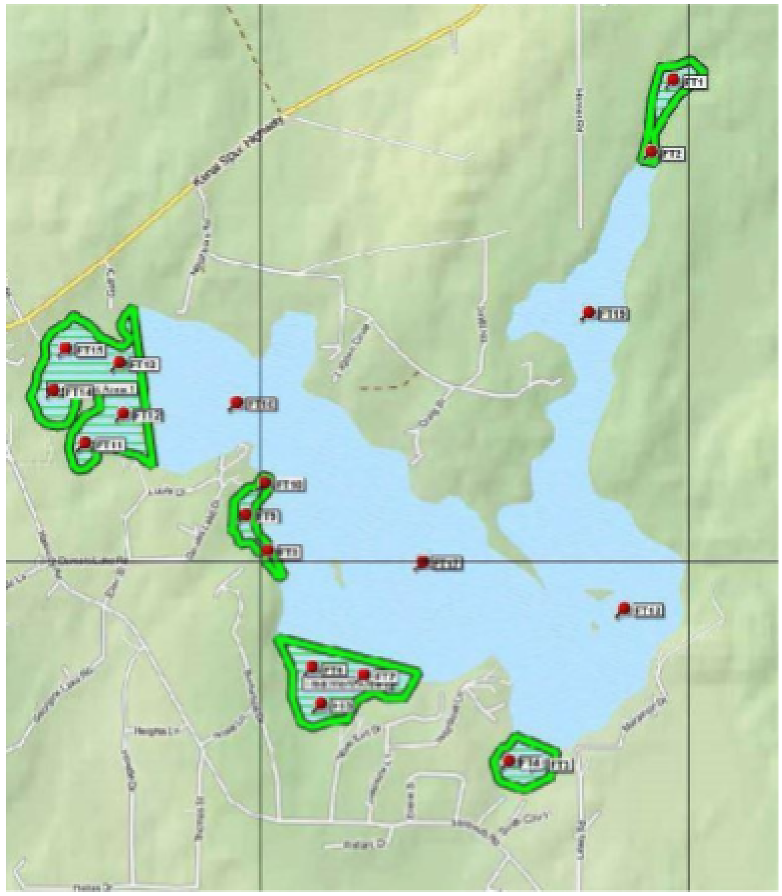

Figure 8. Five treatment areas and their 18 FasTEST sample sites for determining fluridone concentrations within Daniels Lake.

Based on initial surveys of elodea distribution in the three lakes (Figures 2–4), we aimed to begin a partial-lake treatment of Daniels Lake and whole-lake treatments of Beck and Stormy Lakes with fluridone after ice-out in 2014. Based on our knowledge of water quality parameters and Elodea distributions, SonarONE® (pellet) and Sonar Genesis® (liquid) were quickly deemed the preferred products for treating Stormy, Daniels and Beck Lakes. The SonarONE formulation does not require mixing and is applied directly as pellets. The Sonar Genesis formulation does not require pre-mixing; however, water is drawn into the hose during application as a carrier (4 gallons of water per gallon of Sonar Genesis).

As the goal was eradication, not simply control, four treatments over three years were planned, although even at the onset we recognized that all four may not be needed pending our post-treatment assessment of herbicide efficacy after the second year (third treatment). For Beck and Stormy Lakes, which are whole-lake treatments, we applied an initial treatment of Sonar Genesis (8 ppb) to ensure a rapid uptake in the spring 2014, followed by a second treatment with SonarONE (6 ppb) in spring 2014 to ensure that concentrations remained at lethal dosages over the summer; a late season (before ice) boost of SonarONE maintained fluridone concentrations through winter 2014-15. Spring treatments of SonarONE were proposed in 2015 (8 ppb) and 2016 (6 ppb)(Tables 2, 3), but the third treatment was applied in October 2015 instead. No treatment was necessary spring of 2016.

For Daniels Lake, which is a partial-lake treatment, all four treatments were with the pelleted SonarONE to minimize dilution, but the concentration needed to be higher to maintain lethal concentrations.

Consequently, the initial treatments of the five different infestations (108.5 acres total) varied from 60—90 ppb, with subsequent treatments varying from 30—45 ppb (Table 4). In addition, we applied diquat dibromide (Reward®) immediately before the first application of fluridone in spring 2014 with the goal of preventing further spread of the infestation in Daniels Lake. It was applied at half the recommended rate; i.e., 1 gallon per surface acre mixed with 50 gallons of water as a carrier.

In addition, we worked with SePRO Corporation (http://www.sepro.com/default.php) to further optimize treatment concentrations based on laboratory studies conducted in Colorado and North Carolina on Elodea samples taken from Stormy and Beck Lakes. Lastly, if Elodea had been detected in out-flowing streams below either of the two lakes, a one-time application of fluridone in pelleted form at a rate of 5—8 ppb was planned.

Outcome

The first two treatments in 2014 went as planned. However, based on mean fluridone concentrations in the water columns, fluridone was never re-applied in Beck Lake, and spot-treated twice in Daniels Lake and once in Stormy Lake in 2015; no fluridone was applied in any of the lakes in 2016. Nonetheless, concentrations remained in the lethal range (≥ 4 ppb) in all three lakes for over 2 years (through spring 2016). This long residency time could be due to underestimation of the flow rate, but we believe it is more likely due to the cold-water temperatures and relatively low UV radiation in Alaska, both of which reduce the degradation rate of fluridone. Similarly, mean fluridone concentrations in the sediment of all three lakes (based on Eckman dredge samples) averaged 13.9 ppm in 2015 but declined to ≤ 5 ppb during the subsequent three years post treatment (2016–19). Fluridone binds tightly to clay particles and is not biologically active so it decays slowly over time by microbial action. Diquat is even more tightly bound and could not even be successfully measured in samples sent to a commercial analytical lab.

Table 2. Prescribed whole-lake treatments of Beck Lake with liquid (Sonar Genesis®) and pelleted (SonarONE°) fluridone formulations in 2014-16.

BECK LAKE (196.8 acres, mean depth = 12.5 ft, volume = 2,466 acre-ft)								
TREATMENT		**PRESCRIPTION**						**OST**
o.	arget Date	Sonar Genesis®			SonarONE®			
		pb	gal	$	pb	bs	$	
	014	8	107	27,400	6	799	22,400	$49,800
	014				4	533	14,950	$14,900
	015				8	1065	29,900	$29,900
	016				6	799	22,400	$22,400
			107			**3196**		**$117,000**

Table 3. Prescribed whole-lake treatments of Stormy Lake with liquid (Sonar Genesis®) and pelleted (SonarONE°) formulations of fluridone in 2014-16.

STORMY LAKE (395.1 acres, mean depth = 17.6 ft, volume = 6,936 acre-ft)								
TREATMENT		**PRESCRIPTION**						**OST**
o.	arget Date	Sonar Genesis®			SonarONE®			
		pb	gal	$	pb	bs	$	
	June 2014	8	300	77,000	6	2247	63,000	$140,000
	Sept 2014				4	1498	42,000	$42,000
	June 2015				8	2996	84,000	$84,000
	June 2016				6	2247	63,000	$63,000
			300			**8989**		**$329,000**

Table 4. Prescribed partial-lake treatments of Daniels Lake with pelleted (SonarONE®) formulation of fluridone in 2014-16. In addition, a one-time treatment of diquat bromide (Reward®) will be applied in June 2014 to prevent Elodea from continuing to spread in Daniels Lake.

PARTIAL LAKE TREATMENTS					**SonarONE® PRESCRIPTIONS**								
					June 2014		Sept 2014		June 2015		June 2016		**Σ**
Treatment Area	Acres	Depth (ft)	Mean volume (ac-ft)	% lake volume	ppb	lbs	ppb	lbs	ppb	lbs	ppb	lbs	
1	52.1	8	416.8	3.8	60	1350	30	675	30	675	30	675	3375
2	29.1	5	145.5	1.3	60	471	30	236	30	236	30	236	1179
3	10.1	4	40.4	0.4	90	196	45	98	45	98	45	98	490
4	9.2	3	27.6	0.3	90	134	45	67	45	67	45	67	335
5	8.0	8	64.0	0.6	90	311	45	156	45	156	45	156	779
TOTAL PRODUCT (lbs)						2,462		1,232		1,232		1,232	**6,158**
COST						$69,100		$34,500		$34,500		$34,500	**$172,600**
Theoretical lake-wide concentration (ppb)						4.21		2.10		2.10		2.10	
Theoretical in-water concentration (ppb)						2.52		1.26		1.26		1.26	

Preventing spread from the three infested lakes

A key measure in preventing Elodea spread is to inform the media, schools, and public about the risk associated with dispersal and spread. Restriction of movement of boats, fishing gear, or other vectors between waters could help in preventing spread, along with disinfection of gear (Josefsson 2011).

Outreach with private landowners

Private landowners with property affected by the infestations at Stormy, Daniels, and Beck Lakes will be kept informed during planning and field implementation. We held one well-attended public meeting at the Nikiski Community Recreation Center in February 2013. There were additional public meetings to gather input from, and provide information to, the relevant landowners and any concerned citizens. The Alaska Department of Natural Resources worked with property owners on Daniels and Beck Lakes to prevent contact during and after the treatment period. As a precaution, signage discouraging human contact with treated waters was posted until all waters were determined to be safe for human contact.

Stormy Lake closure

The Alaska Department of Natural Resources, Division of Parks and Recreation, administers public access including the boat launch to Stormy Lake. In summer 2013, the Stormy Lake boat launch was closed to prevent Elodea from being spread to other waterbodies. The Division collaborated with the KP-CWMA to temporarily close the Stormy Lake public boat launch during the treatment preparation, application, and follow-up (up to 14 days total), and then for the multiple seasons to prevent spread of Elodea to new areas. Contact with treated waters was discouraged after treatment using appropriate signage and public notices. Stormy Lake was reopened to the public in June 2016.

Nets at lake outlets

Escaped Elodea fragments from the outlets of Beck, Daniels, and Stormy Lakes clearly threatened Bishop Creek and, to a much lesser extent, the Swanson River (the latter is within the brackish tidal zone). Particularly during herbicide application, increased motor-boat activity in shallow waters will almost certainly fragment and uproot Elodea. The Alaska Department of Fish and Game has maintained staggered fyke net panels at the Stormy Lake outlet that allows for fish passage while successfully intercepting Elodea fragments. We used staggered fyke nets or suspended nets on floating booms to intercept Elodea fragments dispersing from Daniels and Beck Lakes as well (Figure 8). During and for 10 days post-treatment, the nets completely blocked the outlet to prevent Elodea escaping but also fish passage; at all other times during 2014-16, staggered fyke net panels were kept in place but open for fish passage. The Cook Inlet Aquaculture Association brokered the necessary landowner agreements and permits, installed and maintain the fyke nets.

Preventing reintroduction to the Kenai Peninsula

Outreach to KPB public, schools and aquaria retailers

- Media Outlets – CWMA representatives will engage T.V., radio, and print news outlets in conversation that supports reporting on the Elodea eradication project on the Kenai Peninsula.
- Information about the Elodea eradication project, the environmental assessment, the prescribed herbicides, and any other relevant public information will be accessible on the CWMA website (www.kenaiweeds.org) on a dedicated Elodea page. Partners and community websites with any interest will be encouraged to link to the CWMA website for more information.
- An accessible publication will be developed and produced to explain Elodea and the eradication process. This publication will be available to members of the public.
- CWMA representatives will contact pet shop supply businesses to discuss the use of Elodea as an aquarium plant in our area and seek to educate them on the importance of offering a suitable substitution and discontinuing their use of Elodea.
- CWMA representatives will contact float plane operators in the Southcentral region to educate them on the risks and impact of Elodea and how to recognize the plant. They will be encouraged to collect samples that look suspicious and contact a CWMA representative to provide positive identification of the plant.
- CWMA representatives will contact school science teachers and educate them on the risks of utilizing Elodea as a classroom aid. Science teachers will be encouraged to utilize alternative plants for those lesson objectives, as well as an educational component discussing the invasive potential of Elodea. CWMA representatives will provide material as necessary and guest speakers when feasible.

V. Monitoring

Maintaining fluridone concentrations

The treatment goal is to maintain a lethal dosage in the eradication zone for 45—90 days. To ensure that concentrations are maintained, surface water samples are collected from 2—6 sites in the target area. For the whole lake treatments of Stormy and Beck Lakes, water samples were collected at 2, 4, 8, 12, and 16 week intervals from six sites in each of the lakes (Table 5). In the case of Daniels Lake, more sites were sampled, proportional to the volume of each of the five application areas (Figure 7), because of the increased concern about dilution in a partial-lake treatment. Consequently, 19 sites were sampled, including 4 nontarget sites to measure whole-lake concentrations over the same intervals as Stormy and Beck Lakes. These 31 sites were sampled regularly during the treatment window. Additionally, we continued to sample in June and September post-treatment through 2019 (or until fluridone was undetectable (< 1 ppb). All water samples were collected using FasTEST protocols (Appendix 1) established by, and sent by overnight delivery to SePRO Corporation's analytical laboratory in Carmel, IN for immunoassay following the techniques described by Netherland et al. (2002).

Table SEQ Table * ARABIC 5. Sites for monitoring fluridone concentrations in target areas at 2, 4, 8, 12 and 16 week intervals after treatment in Daniels, Beck and Stormy Lakes.

4

Daniels Lake	2	X	X				60.7489173	-151.169602
Daniels Lake	3	X	X	X	X	X	60.7255421	-151.1783782
Daniels Lake	4	X	X				60.7256261	-151.1806742
Daniels Lake	5	X	X				60.727812	-151.1953083
Daniels Lake	6	X	X	X	X	X	60.7291887	-151.1959735
Daniels Lake	7	X	X				60.728905	-151.1919609
Daniels Lake	8	X	X				60.7336754	-151.1994711
Daniels Lake	9	X	X	X	X	X	60.7350518	-151.2011555
Daniels Lake	10	X	X				60.7362653	-151.199675
Daniels Lake	11	X	X				60.7377676	-151.2136654
Daniels Lake	12	X	X	X	X	X	60.7389127	-151.2107042
Daniels Lake	13	X	X				60.7408561	-151.2110261
Daniels Lake	14	X	X				60.7397951	-151.2160472
Daniels Lake	15	X	X	X	X	X	60.7413813	-151.2151459
Daniels Lake	16	X	X				60.733263	-151.1874602
Daniels Lake	17	X	X	X	X	X	60.7314558	-151.1717532
Daniels Lake	18	X	X				60.742802	-151.1744997
Daniels Lake	19	X	X				60.7393565	-151.2018797
Beck Lake	1	X	X	X	X	X	60.7408472	-151.1300189
Beck Lake	2	X	X				60.7378211	-151.1344396
Beck Lake	3	X	X	X	X	X	60.7336602	-151.1353409
Beck Lake	4	X	X				60.7325465	-151.128903
Beck Lake	5	X	X				60.7300037	-151.1332379
Beck Lake	6	X	X	X	X	X	60.7263682	-151.134783
Stormy Lake	1	X	X				60.7874167	-151.0327008
Stormy Lake	2	X	X	X	X	X	60.7840311	-151.0400868
Stormy Lake	3	X	X				60.7797427	-151.0402846
Stormy Lake	4	X	X	X	X	X	60.7794847	-151.0560459
Stormy Lake	5	X	X				60.7716495	-151.0532762
Stormy Lake	6	X	X	X	X	X	60.7696181	-151.0627725
	Total Samples	**31**	**31**	**13**	**13**	**13**		
	Grand Total	**101**						

Figure 10. Sample bottles are provided by SePRO Corporation for monitoring fluridone concentrations in the water column. They are pre-labeled with a Sharpie, and collection sites are pre-determined. Following FasTEST protocols, the bottle cap is removed, the bottle filled, and then recapped, all events occurring underwater at arm's length. The filled bottle is kept on ice in a cooler while in the field until transferred to a freezer. Frozen samples are shipped overnight in Styrofoam fish boxes with gel packs to the analytical lab in Indiana.

Efficacy and nontarget effects of fluridone treatments

The shoreline (perimeter) of treated lakes is divided into 50 equal segments within a GIS. While in the field, a sampling site is subjectively selected within each segment to best capture the highest Elodea abundance or, if no Elodea can be found, then select the midpoint; record the location with a GPS. Each site is sampled from a motorboat or canoe perpendicular to the shoreline, with one throw shoreward and one throw lakeward so as to represent an environmental gradient. The occurrence and relative abundance of Elodea is recorded on each side by the following code: 0 = no Elodea; 1 = one or two tines with Elodea; 2 = ≤ 50% of tines with Elodea; 3 = > 50% of tines with Elodea. Water depth is also recorded at each point using the throw rope as a measuring device. For assessing the efficacy of treatments, the preferred sampling times are soon after ice-out (May/June) or just before herbicide application, and late in the season before ice-in (September). Sites should continue to be re-sampled twice per year until all sites have no Elodea present.

At each sampling location, water quality data is be collected including temperature, pH, dissolved oxygen, specific conductivity, turbidity, and alkalinity. Data is collected throughout the water column at each location using a Quanta Hydrolab™. Water transparency is measured using a secchi disc.

An Ekman dredge is used to collect bottom sediment from sample sites; sediments are screened to extract any macro-invertebrates. Kick nets are also used to collect invertebrates along vegetated shorelines at sample locations. Attempts are made to visually locate and collect freshwater mussels and snails. All specimen samples collected are preserved in 90% ETOH, labeled with the date, collector initials and site location then archived for later quantification and identification to family.

Figure 11. Throw rakes were constructed by welding two field rake heads together with a center D ring. A 1.5-ft medium-weight chain is used as a leader to ensure the rake drags on the lake bottom while being retrieved.

Effects on fish will be inferred indirectly from the water quality data. Results of each parameter will be compared with fish life-stage needs to ensure fish needs are being met.

Long-term monitoring for early detection on the Kenai Peninsula

The eventual desired outcome is the successful eradication of Elodea from all waterbodies on the Kenai Peninsula. This outcome will be determined by annual surveys of these waterbodies both during treatment and for at least three years post-treatment. In addition, at-risk lakes (those that have public boat launches, charter floatplane services, high private floatplane use, or high recreational use) on the Kenai Peninsula will be selected for annual or biannual monitoring as early warning indicators of Elodea being transported to the peninsula by boat or floatplane from other infested areas in mainland Alaska. For future long-term monitoring, we will investigate the possibility of eDNA to detect Elodea species in lakes.

VI. Field Implementation for future infestations

Materials and equipment will be transported to the site by truck. Mixing and loading of herbicide will only occur within treatment areas. Herbicide dispersal will be directly into the lake by DEC-certified applicators from outboard motorboats. Boats will be equipped with apparatus to deliver either liquid (Sonar Genesis, Diquat) or pellet (SonarONE) herbicide to the water body to be treated. Regardless of formulations, applications will take place under appropriate conditions for boating, avoiding conditions of high wind, water flow, or wave action. The herbicide will be applied following all directions on the EPA approved label and will not exceed the maximum cumulative concentration of 150 ppb. During treatment, signage will be placed at all access locations in compliance with all applicable legal requirements related to the fluridone or diquat treatment. All residents of the infested lake(s) will be notified directly in compliance with all applicable legal requirements related to treatments.

Liquid formulations

The first application of fluridone in Beck and Stormy Lakes in 2014 included Sonar Genesis, a liquid formulation intended for rapid uptake by Elodea. We also treated Daniels Lake in spring 2014 with diquat, a liquid contact herbicide, to help ensure that Elodea did not continue to spread in Daniels Lake. Both products are liquid herbicides and are be mixed with water in an onboard 30-50 gallon mixing tank, using a small electric transfer pump to draw lake water. A second electric pump will be used to apply mixed product through a hose assembly that bifurcates to two nozzles, one in each corner of the boat's stern. Sonar Genesis is a low volume application (1 gal product per 4 gal water) that simply needs to be well distributed in the water column, whereas Diquat is a high volume application (2 gal product per 50 gal water) that needs to be applied as close to the vegetation stratum as possible. If the former is applied later in the summer after a thermocline is established, one may need a boom system that can be extended into the water column (Figure 11). Table 6 provides an example of how Sonar Genesis was calibrated for application, in this case, in Beck Lake.

Application routes will be determined based on swath width (width of application dispersal; typically 60-ft wide swaths) and then programmed into onboard GPS equipment to be followed by the operator of the application vessel. The speed of the boat (typically 4 mph) will be set to cover the given route in the amount of time calculated to deliver the prescribed volume of herbicide.

Table 6. Example of how Sonar Genesis was calibrated for application in Beck Lake.

Lake Size	196.8	
Application rate: Sonar Genesis (ppb)	8	
Gallons of Sonar Genesis	107	
	0.54369	
Gallons per acre product	9	
Tank Gallons (1 part Sonar:4 parts water)	535	16.2 acres covered per tank
	2.71849	
Gallons per acre tank mix	6	12.2 tanks to cover Beck lake
Swatch width example (feet)	20	
Boat Speed (mph)	8	
Boat Speed feet per minute	704	
	0.32323	
Acres/minute = swath X speed (ft/min) /43560	2	
gallons tank mix needed per minute	1	
gallons tank mix per nozzle (2 nozzzles)/minute	0.5	
Tank Size (gallons)	50	
Minutes per tank	50	

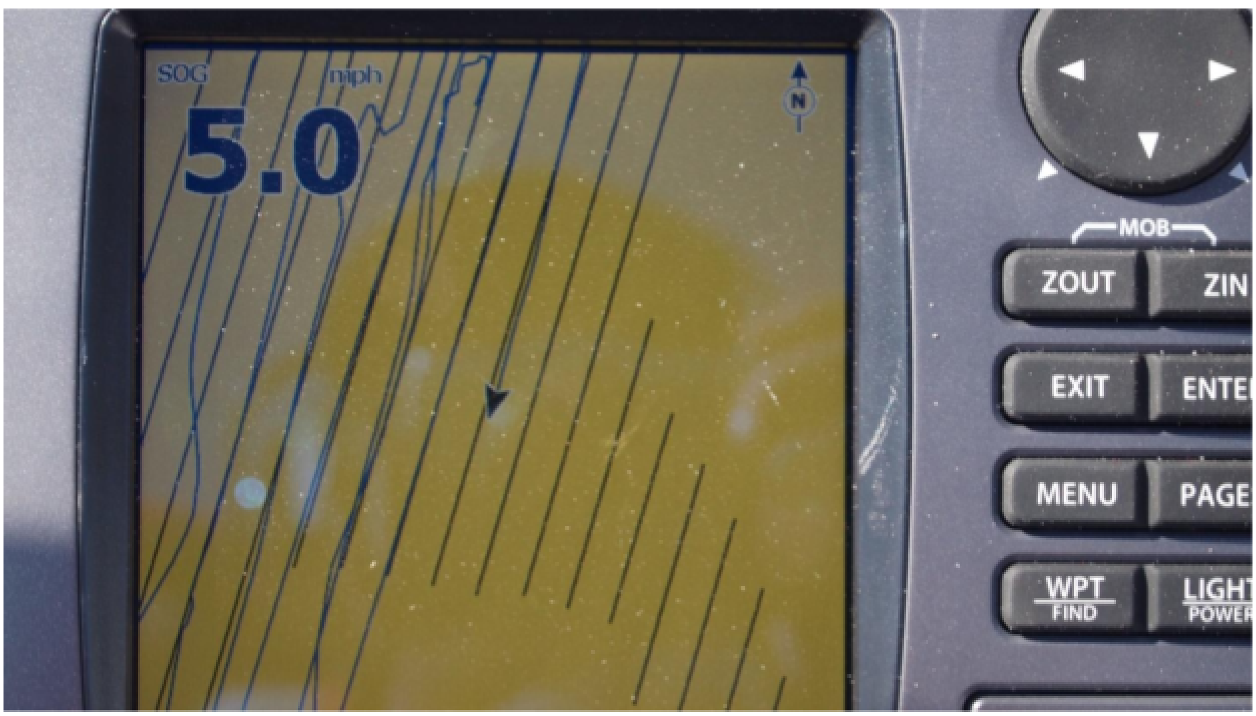

Figure 1 SEQ Figure * ARABIC 1. Application routes are uploaded into an onboard GPS and tracked in real time during application to ensure herbicides are well distributed over the waterbody. Vessel speed is also monitored to ensure correct rates of application. In deep sections of a waterbody (e.g., Beck Lake) or in partially-treated lakes (e.g., Daniels Lake), herbicide may not be applied and so the transects will be discontinuous as shown in the lower, middle section of the GPS screen.

Figure14. A 12-volt dual electric pump system with 30-gallon tank is used with PVC trailing hoses to apply liquid fluridone (Sonar Genesis®) or diquat (Littora®, Reward®) at or below the water surface. The pump system is mounted on a white cutting board and hung by chain from the center console. The 30-gal tank in the foreground is used to mix herbicide with water drawn directly from the lake with an electric transfer pump. The mixed product is then forced, with a second electric pump, through a PVC hose (lower right) that splits into two hoses that trail on either side of the boat's stern.

Pelleted formulation

SonarONE will be applied using the Vortex TR-A (http://www.vortexspreader.com/tra.php), a forced-air 2-stroke blower system mounted to a motorboat. These are not heavy units only weighing 95 lbs. empty that can hold up to 250 lbs of pelleted fluridone in the hopper and can put out ≤ 15 lbs of product per minute. Each TR-A delivery system (at least two) will be calibrated independently by using SePRO training pellets (clay blanks), which are the same weight and size as SonarONE. The critical parameter to estimate, as each TR-A is slightly different, is the throughput in minutes. Pass 20 lbs of training pellets through each system twice with the system wide open to estimate the number of minutes required to deliver all 20 lbs; the average of the two trials will be used as a calibration value. In a GIS, determine the area to be treated, application swath width, and the total number of minutes needed to deliver the prescribed pounds of product so that one can estimate boat speed. Use onboard GPS to navigate swath paths and ensure appropriate speed is maintained.

Prescriptions shown in Tables 3, 4 and 5 are based on the following calculations:

Beck Lake – 196.8 acres X 12.53 feet mean depth = 2,466 acre-feet
2,466 acre-feet X 8 ppb X 0.0054 (label constant) = 107 gallons (106.53) Sonar Genesis
2,466 acre-feet X 6 ppb X 0.054 (label constant) = 799 (798.98) pounds of SonarOne

Stormy Lake – 395.1 acres X 17.6 (17.55) feet mean depth = 6,936 acre-feet
6,936 acre-feet X 8 ppb X 0.0054 (label constant) = 300 gallons Sonar Genesis
6,936 acre-feet X 8 ppb X .054 (label constant) = 2,247 pounds of SonarOne

Daniels Lake – Area 1: 416.8 acre-feet X 60 ppb X 0.54 (label constant) = 1,350 pounds of SonarOne
Area 2: 145.5 acre-feet X 60 ppb X 0.054 (label constant) = 471 pounds of SonarOne
Area 3: 40.4 acre-feet X 90 ppb X 0.054 (label constant) = 196 pounds of SonarOne
Area 4: 27.6 acre-feet X 90 ppb X 0.054 (label constant) = 134 pounds of SonarOne
Area 5: 64 acre-feet X 90 ppb X 0.054 (label constant) = 311 pounds of SonarOne

Prescribed fluridone concentrations need to be maintained in the water column for 45—90 days. If average fluridone concentrations fall below the target amount for two consecutive samples (based on FasTEST results; Appendix 1), then supplemental fluridone will be added. For example, if the average concentration of fluridone from the six sites in Beck Lake based on the average of the 1st and 2nd samples is 5 ppb when the target is 6 ppb, the following calculations are used to calculate the amount of SonarONE that needs to be added to increase the total concentration by 1 ppb:

2,466 acre-feet X 1 ppb X 0.054 (label constant) = 133 pounds of SonarOne

Under no circumstance will cumulative applications exceed 150 ppb per year per lake.

Figure 15. The Vortex TR Aquatic™ is used to blow pelleted formulations of fluridone (SonarONE®) at known rates; calibration is based on application swath width, vessel speed, and throughput of the blower assembly. The blower is gasoline-powered but the electric agitator runs off a 12-volt deep cycle battery. The unit remains bolted to the pallet for easy placement in the boat, in this case a Hewescraft.


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Storage and handling of herbicides

Materials and equipment would be transported to the site by truck. Pesticide dispersal will be directly into the lake by DEC-certified applicators from outboard motorboats. Boats would be equipped with gas-powered pumping systems that would mix lake water with Sonar (if applied in liquid form) and sprayed on the lake surface. Alternatively, pelleted formulations will be distributed on the lake surface by an electric disk-driven spreader or a high-velocity blower applicator; in either case, the application rate will be calibrated. The target concentration for fluridone will be formulated by calculating area of infestation, volume of water in infested areas, and desired persistence time but is generally expected to be in the range of 5-15 ppb, with no single application exceeding 90 ppb and the sum of all applications in a given season not to exceed 150 ppb. For complete eradication, both lakes will have to be treated for at least two seasons. Pesticide containers will be triple rinsed within the application area with the rinsate applied to the treated waters. Spill kits will be present on each boat and additional spill response supplies will be on-hand at the staging area (e.g., boat launch).

Figure 17. A spill kit placed on-site at the Stormy Lake boat launch during herbicide treatments in 2014.

Applicators of Sonar will experience risks from exposure. Applicators must avoid breathing spray mist, or any contact with skin, eyes, or clothing. They must wash thoroughly with soap and water after handling and should wash exposed clothing before reuse. Sonar used according to label instructions minimizes risk to applicators. A fluridone Material Data Safety Sheet (MSDS) is available in Appendix 2, and a Sonar AS label is available in Appendix 3.

Applicators of Reward will experience risks from exposure. Applicators must avoid breathing spray mist, or any contact with skin, eyes, or clothing. They must wash thoroughly with soap and water after handling and should wash exposed clothing before reuse. Reward used according to label instructions minimizes risk to applicators. Applicators must wear protective clothing when handing the concentrated produce to reduce skin exposure. Splashes should be immediately washed from eyes and skin. Applicators should avoid drift contact to skin or eyes. Breathing diquat spray or mist should also be avoided, and respiratory equipment is recommended. A diquat Material Data Safety Sheet (MSDS) is available in Appendix 4, and a Reward label is available in Appendix 5.

Permits and Certifications Required

The following permits and approvals will need to be obtained prior to herbicide use:
Federal: NEPA, USFWS Pesticide Use Permit
State: DEC, DNR (Division of Mining), ADF&G (Division of Habitat)
Alaska Pollution Discharge Elimination System (APDES) Permit

VIII. Administrative Record For Beck, Daniels and Stormy Lakes

Sep 2012	Elodea detected in Stormy Lake
Oct 2012	Elodea detected in Daniels Lake
Feb 2013	1st public landowner meeting in Nikiski Preliminary survey of Daniels Lake
Mar 2013	1st face-to-face meeting of Elodea technical working group
Apr 2013	DEC permit application submitted for diquat Live Elodea samples sent to SePRO
May 2013	DEC permit application submitted for fluridone Enhanced survey of Daniels Lake Presentation/petition to KPB Assembly Stormy Lake closed to public waterboat and aircraft use
Jun 2013	Began surveys of other lakes on the Kenai Peninsula ($55K) DEC permit to apply diquat approved (#13-AQU-01) APDES approved for Stormy, Daniels Lakes (AKG870000) $40K received from KBP
July 2013	Elodea detected in Beck Lake
Aug 2013	EA approved (AK-DNR/USFWS)
Sep 2013	Complete survey of 65 other lakes on the Kenai Peninsula
Dec 2013	First draft of IPM completed
Jan 2014	$40K received from National Fish & Wildlife Foundation
Feb 2014	DEC permit application for fluridone formally resubmitted APDES modification to include Beck Lake approved (AKG870001)
Mar 2014	2nd face-to-face meeting of Elodea technical working group
Apr 2014	DEC permit to apply fluridone approved (#14-AQU-01) 2nd public landowner meeting in Nikiski 2-hr special session at KP-CWMA annual conference $155K (2 grants) received from USFWS

May 2014 Pre-treatment surveys to monitor treatment efficacy (50 sites per lake)
Pre-treatment surveys of water quality and non-target effects
$120K received from KP Fish Habitat Partnership
$400K received from State of Alaska (through KPB)
Supplemental EA approved (to include Beck Lake)
USFWS Pesticide Use Permits approved
Nets installed at outlets of Daniels and Beck Lakes (CIAA)

Jun 2014 1st herbicide treatments (Beck, Daniels Lake)

Jul 2014 KPB Ordinance 2014-19-05 for Elodea Eradication project enacted
1st herbicide treatment (Stormy Lake)

Sep 2014 Post-treatment surveys of Elodea populations

Oct 2014 Post-treat surveys of Elodea populations on Stormy, Beck, and Daniels Lakes

Feb 2015 FasTEST samples of fluridone concentrations in water column

Mar 2015 $90K received from USFWS

May 2015 Post-treatment survey of Elodea populations
FasTEST samples of fluridone concentrations in water column

Jun 2015 Two public meetings in Nikiski and Anchorage
FasTEST samples of fluridone concentrations in water column
15-DC-085 amended (#1) to treat "other necessary areas" that threaten peninsula lakes

Jul 2015 Lake Hood treated
2nd treatment of Daniels Lake

Aug 2015 FasTEST subsamples of fluridone concentrations in water column
1st grid-based survey (100 sites/lake) of native vegetation response in Beck and Daniels Lake

Sep 2015 FasTEST samples of fluridone concentrations in water column
Post-treatment survey of Elodea populations
First sediment samples for diquat/fluridone residues in three lakes

Oct 2015 3rd treatment of Daniels Lake, 2nd treatment of Stormy Lake
Presentation at CNIPM Statewide Invasive Species Workshop
Nov 2015 Presentation to National Park Service resource managers in Anchorage
Presentation to KPB Assembly

May 2016 Post-treatment survey of 50 sites in each of Beck, Daniels, Stormy
FasTEST samples of fluridone concentrations in water column of 3 lakes

Jun 2016	Newspaper article written in Peninsula Clarion Stormy Lake re-opened for public use of watercraft and aircraft
July 2016	Grid-based survey of native aquatic vegetation response on all 3 lakes
Aug 2016	Presentation to course participants in "Field Techniques for Invasive Plant Management" taught by National Conservation Training Center, Shepherdstown, WV
Sep 2016	Post-treatment survey of Elodea populations in 3 lakes FasTEST samples of fluridone concentrations in water column 2nd sediment samples for fluridone residues in 3 lakes Presentation to Arctic Invasive Alien Species (ARIAS) Steering Committee 170 20-lb containers of Sonar ONE (fluridone) transferred to the AK Division of Agriculture to treat Alexander Lake
Feb 2017	Elodea discovered in Sports Lake, Soldotna, AK
Mar 2017	KENWR staff conduct through-the-ice survey of Sports Lake, detecting Elodea at 6/28 sites; interagency meetings to discuss steps to move forward with public engagement and proposed treatments
Apr 2017	Alaska DNR formally submits a Pesticide Use Permit based to Alaska DEC, and draft Supplemental Environmental Assessment submitted to the USFWS for review. A public meeting to discuss the proposed management held at CIAA
May 2017	During week of 5/1/17, ice on Sports Lake went out, ADFG installs cable across boat launch with signage; shipment of fluridone and diquat received by KENWR; DNR receives DEC permit exemption and approved Notice of Intent (NPDES); Homer SWCD receives ADFG habitat permit. Also conducted survey of 50 systematically-distributed points along shoreline with rakes; Elodea detected at 16/50 sites. Staff from KENWR, AK-DNR and KWF apply first treatments of diquat and fluridone in Sports Lake
Jun 2017	Water samples (3 weeks post-application) indicate 2.5 –3.1 ppb; follow-up sampling indicates mean fluridone only 3.9 ppb
Jul 2017	Elodea occurs at 1/25 sites sampled by rake on Sports Lake; more SonarONE applied to ensure concentrations > 4 ppb; ADF&G re-opens public boat launch during week of July 10th; Elodea detected in Hilda-Seppu Lakes near Nikiski
Aug 2017	Two nets installed between Hilda-Seppu and Beck Lakes by CIAA; DEC grants DNR permit exemption
Sep 2017	KWF receives ADFG habitat permit for Hilda-Seppu Lakes; Homer SWCD receives DNR ML&W permit; KENWR detects elodea at 22/50 sites surveyed; first treatments of Sonar Genesis and Sonar ONE applied

Oct 2017 KENWR staff collect water samples from Hilda-Seppu and Sports Lakes

Nov 2017 KENWR staff apply more SonarOne in Hilda-Seppu before ice-in

May 2018 Fluridone concentrations in Hilda-Seppu and Sports Lakes still in lethal zone

Jun 2018 Rake surveys indicate no Elodea in Beck, Daniels, Stormy and Sports Lakes; 25/25 sites in Hilda-Seppu Lake has Elodea

Jul 2018 Sports Lake retreated with SonarONE

Aug 2018 Fluridone in Hilda-Seppu Lakes 5.6 ppb

Sep 2018 Elodea in Hilda-Seppu Lakes decreases to 9/50 sites sampled; Sonar ONE added to Hilda-Seppu Lakes

May 2019 Rake surveys indicate no Elodea in Sports Lake and 1/50 with Elodea in Hilda-Seppu Lake; FasTEST indicates fluridone 3.6 ppb in Sports Lake and 5.3 in Hilda-Seppu Lake

Jul 2019 Close out KPB $400K grant; fluridone in Hilda-Seppu Lake 4.6 ppb

Sep 2019 160 lbs. of SePRO SonarONE were added to Hilda-Seppu Lake before ice-in (Bowser 2019).

Sep 2020 ADFG staff discover Elodea in Sandpiper Lake in the Miller Creek drainage.

Sep 2020 Rake surveys in Vogel Lake and North Vogel Lake (downstream of Sandpiper Lake) indicate absence of Elodea in these lakes. (Bowser 2019)

IX. Literature Cited

Anderson, N.H., and J.B. Wallace. 1984. Habitat, life history, and behavioral adaptations of aquatic insects. Pages 38-58 in R.W. Merrit and K.W. Cummins (eds.). An Introduction to the Aquatic Insects of North America. 2nd ed. Kendall/Hunt Publishing, Dubuque, Iowa.

Barnes, M., C. L. Jerde, D. Keller, W. L. Chadderton, J. G. Howeth and D. M. Lodge. 2013. Viability of aquatic plant fragments following desiccation. Invasive Plant Science and Management. In Press.

Bartels, P. and C. Watson. 1978. Inhibition of carotenoid synthesis by fluridone and norflurazon. Weed Science. 26(2):198-203.

Barrat-Segretain, M., A. Elger, P. Sagnes and S. Puijalon. 2002. Comparison of three life-history traits of invasive *Elodea canadensis* Michx. and *Elodea nuttallii* (Planch.) H. St. John. Aquatic Botany 74:299-313.

Berard, D., D. Rainey and C. Lin. 1978. Absorption, translocation, and metabolism of fluridone in selected crop species. Weed Science. 26(3):252-254.

Bimber, K. L., R. W. Boenig and M. L. Sharma. 1976. Respiratory stress in yellow perch induced by subtoxic concentrations of diquat. Ohio Journal of Science 76(2):87-90.

Boulton, A.J., C.G. Peterson, N.B. Grimm and S.G. Fisher. 1992. Stability of an Aquatic macroinvertebrate community in a multiyear hydrologic disturbance regime. Ecology 73(6):2192-2207.

Bowmer, K. H., S. W. L. Jacobs and G. R. and Sainty. 1995. Identification, biology and management of *Elodeacanadensis*, Hydrocharitaceae. Journal of Aquatic Plant Management 33:13-19.

Bowser, M.L. 2019. Work Journal 2019. U.S. Fish & Wildlife Service, Kenai National Wildlife Refuge. Soldotna, Alaska. http://dx.doi.org/10.7299/X7RB74XZ.

Buscemi, P.A. 1958. Littoral oxygen depletion produced by a cover of *Elodea canadens*is. Oikos, 9: 239--245.

Catlin, P. M. and W. Wojtas. 1985. The waterweeds (*Elodea* and *Egeria*, Hydrocharitaceae) in Canada. Canadian Journal of Botany 64:1525-1541.

Centre for Aquatic Plant Management (CAPM). 2004. Information Sheet 25: *Elodea nuttallii*, Nuttall's Pondweed.http://www.nercwallingford. ac.uk/research/capm/pdf%20files/25%20Elodea%20nuttallii.pdf. Access Date: 04/25/2013.

Cochran, R. C. (principal) et al. 1994. Diquat dibromide risk characterization document. Medical Toxicology and Worker Health and Safety Branches, Department of Pesticide Regulation, California Environmental Protection Agency.

Cook, C. D. K. and K. Urmi-Konig. 1985. A revision of the genus *Elodea* (Hydrocharitaceae). Aquatic Botany 21:111-156.
DiTomaso, J. M., G. B. Kyser et al. 2013. Weed control in Natural Areas in the Western United States. Weed Research and Information Center, University of California. 554 pp.
Finlayson, B., R. Schnick, D. Skaar, J. Anderson, L Demong. W. Horton and J. Steinkjer. 2010. Planning and standard operating procedures for the use of rotenone in fish management-rotenone SOP manual. American Fisheries Society, Bethesda, Maryland.

Gosselin, R. E., et al. 1984. Clinical toxicology of commercial products. Fifth edition. Baltimore, MD: Williams and Wilkins.

Halstead, J. M., J. Michaud and S. Hallas-Burt. 2003. Hedonic analysis of effects of a nonnative invader (*Myriophyllum heterophyllum*) on New Hampshire (USA) lakefront properties. Environmental Management 32(3):391-398.

Hamelink, J., D. Buckler, F. Mayer, D. Palawski and H. Sanders. 1986. Toxicity of fluridone to aquatic invertebrates and fish. Environmental Toxicology and Chemistry. 5:87-94.

Hauxwell, J., S. Knight, K. Wagner, A. Mikulyuk, M. Nault, M. Porzky and S. Chase. 2010. Recommended baseline monitoring of aquatic plants in Wisconsin: sampling design, field and laboratory procedures, data entry and analysis, and applications. Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010. Madison, WI, USA.

Hayes, W.J. and E.R. Laws (ed.). 1990. Handbook of Pesticide Toxicology, Vol. 3, Classes of Pesticides. Academic Press, Inc., NY.

Heikkinen, R. K., N. Leikola, S. Fronzek, R. Lampinen, and H. Toivonen. 2009. Predicting distribution patterns and recent northward range shift of an invasive aquatic plant: *Elodea canadensis* in Europe. BioRisk 2:1-32.

Horsch, E. J. and D. J. Lewis. 2009. The effects of aquatic invasive species on property values: evidence from a quasi-experiment. Land Economics 85(3):391-409.

Josefsson, M. 2011. Invasive Species Fact Sheet. *Elodea canadensis, Elodea nuttallii and Elodea callitrichoides.* From: Online Database of the European Network on Invasive Alien Species (NOBANIS), www.nobanis.org, Access Date: 4/24/2013.

Langeland, K. and J. Warner. 1986. Persistence of diquat, endothall, and fluridone in ponds. Journal of Aquatic Plant Management. 24:43-46.

Kamarianos, A., J. Altiparmakis, X. Karamanlis, D. Kufidis, T. Kousouris, G. Fotis, and S. Kilikidis. 1989. Experimental evaluation of fluridone effectiveness on fish productive aquatic ecosystems. Journal of Aquatic Plant Management 27:24-26.

Kenaga, D. 1992. The impact of the herbicide Sonar on the aquatic plant community in 21 Michigan lakes. Michigan DNR publication.

Lehtonen, J. 2000. Vesirutto ja karvalehti täyttävät ajoittain Littoistenjärven. Aurora 1: 29-31.

Madsen, J.D. 1999. Point intercept and line intercept methods for aquatic plant management. Aquatic plant control technical note MI-02. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Madsen, J. D., K. D. Getsinger, R. M. Stewart and C. S. Owens. 2002. Whole lake fluridone treatments for selective control of Eurasian watermilfoil: II. Impacts on submersed plant communities. Lake and Reservoir Management 18(3):191-200.

Marquis, L., R. Comes and C. Yang. 1981. Absorption and translocation of fluridone and glyphosate in submersed vascular plants. Weed Science. 29(2):229-236.

Matthaei, C.D., U. Uehlinger, E. I. Meyer and A. Frutiger. 1996. Recolonization by benthic invertebrates after experimental disturbance in a Swiss pre-alpine river. Freshwater Biology 35 (2):233-248.

McCorkelle, G., G.R. Sainty and K.H. Bowmer. 1992a. Evaluation of Sonar (Fluridone) for aquatic plant management in Australia. Final report for Dow Elanco Australia Ltd, Consultancy Report No 92/2. CSIRO Division of Water Resources, Griffith NSW. 58pp.

McCowen, M., C. Young, S. West, S. Parka and W. Arnold. 1979. Fluridone, a new herbicide for aquatic plant management. Journal of Aquatic Plant Management 17:27-30.

Merz, J. E., J. R. Smith, M. L. Workman, J. D. Setka, and B. Mulchaey. 2008. Aquatic macrophyte encroachment in Chinook salmon spawning beds: lessons learned from gravel enhancement monitoring in the Lower Mokelumne River, California. North American Journal of Fisheries Management 28:1568-1577.

Mohatt, K.

Muir, D., N. Grift, A. Blouw and W. Lockhart. 1980. Persistence of fluridone in small ponds. Journal of Environmental Quality 9(1):151-156.

Muir, D., N. Grift, B. Townsend, D. Metner, and W. Lockhart. 1982. Comparison of the uptake and bioconcentration of fluridone and terbutryn by rainbow trout and *Chrironomus tentans* in sediment and water systems. Archives of Environmental Contamination and Toxicology 11:595-602.

Netherland, M. D., D. R., A. G. Staddon and K. D. Getsinger. 2002. Comparison of immunoassay and HPLC for analyzing fluridone concentrations: New applications for immunoassay techniques. J. Lake Reserv. Manage.18(1):75-80.

Nicholson, S. A. and R. J. Clerman. 1974. Toxicity of diquat to the custracean amphipod *Hyalella* from

Chautauqua Lake. Environmental Letters 7(4):215-227.

Osborne, J., S. West, R. Cooper, and D. Schmitz. 1989. Fluridone and N-methylformamide residue determinations in ponds. Journal of Aquatic Plant Management 27:74-78.

Pedlow, C. L., E. D. Dibble, and K. D. Getsinger. 2006. Littoral habitat heterogeneity and shifts in plant composition relative to a fall whole-lake fluridone application in Perch Lake, Michigan. J. Aquat. Plant ManaPennack, 1989. Freshwater Invertebrates of the United States , John Willey and Sons and Company, New York.

Pfauth, M. and Sytsma, M. 2005. Alaska Aquatic Plant Survey Report. Center for Lakes and Reservoirs, Portland State University, Portland, OR.

Raghavendra, A. S. and R. F. Sage (eds). 2011. Advances in Photosynthesis and Respiration, Volume 32. C4 Photosynthesis and Related CO2 Concentrating Mechanisms. Springer, The Netherlands.

Riis, T., B. Olesen, J. S. Clayton, C. Lambertini, H. Brix, and B. K. Sorrell. 2012. Growth and morphology in relation to temperature and light availability during the establishment of three invasive aquatic plant species. Aquatic Botany 102:56-64.

Rorslett, B., D. Berge and S. W. Johansen. 1986. Lake enrichment by submersed macrophytes: a Norwegian whole-lake experience with *Elodea canadensis*. Aquatic Botany 26:325-340.

Rybicki, N. B. and J. M. Landwehr. 2007. Long-term changes in abundance and diversity of macrophyte and waterfowl populations in an estuary with exotic macrophytes and improving water quality. Limnology and Oceanography 52(3): 1195-1207.

Sand-Jensen, K. 2000. An introduced vascular plant - the Canadian waterweed (*Elodea canadensis*). Pp. 96-100 in: Weidema, I. (ed.). Introduced species in the Nordic countries. Norden (The Nordic Council), Copenhagen, Denmark.

Sax, N. I. 1984. Dangerous properties of industrial materials. Sixth edition. NY.: VanNostrand Reinhold Company.

Schneider, J. C. 2000. Evaluation of the effects of the herbicide Sonar on sport fish populations in Michigan lakes. Michigan Department of Natural Resources, Fisheries Technical Report No. 2000-2. 35 pp.

Schwoerer, T., and J.M. Morton. 2018. Human dimensions of aquatic invasive species in Alaska: Lessons learned while integrating economics, management and biology to incentivize early detection and rapid response. Chapter 1 in *Alaska: Economic, Environmental, and Social Issues*, T. Lewis (ed.), Nova Science Publishers, Inc., NY. ISBN: 978-1-53613-437-7.

Sethi, S.A., M.P. Carey, J.M. Morton, E. Guerron-Orejuela, R. Decino, M. Willete, J. Boersman, J. Jablonski, and C. Anderson. 2017. Rapid response for invasive waterweeds at the arctic invasion front: Assessment of collateral impacts from herbicide treatments. Biological Conservation 212:300–309.

Thiebaut, G. and F. Di Nino. 2009. Morphological variations of natural populations of an aquatic macrophyte Elodea nuttallii in their native and in their introduced ranges. Aquatic Invasions 4(2):311-320.

U. S. Environmental Protection Agency (USEPA). 2002. Tolerance Reassessment Progress and Risk Management Decision (TRED) for Diquat Dibromide. http://www.epa.gov/oppsrrd1/reregistration/REDs/factsheets/diquat_tred_fs.htm.

U. S. Environmental Protection Agency (USEPA). 1986. Pesticide Fact Sheet: Fluridone. No. 81, 5 pp.
Van Patten, D. 2005. Soil survey of western Kenai Peninsula Area, Alaska. National Cooperative Soil Survey. Available at: http://soildatamart.nrcs.usda.gov/Manuscripts/AK652/0/WesternKenai_manu.pdf.

Wilson, D. C. and C. E. Bond. 1969. The effects of the herbicides diquat and dichlobenil (Casoron) on pond invertebrates. Part I. Acute toxicity. Transactions of the American Fisheries Society 98(3):438-443.

Wurtz, T. L., N. Lisuzzo, A. Batten and A. Larsen. 2013. Request for analysis of native status of Elodea in Alaska. Internal letter dated April 8th. USDA Forest Service, Alaska Region State and Private Forestry, Forest Health Protection, Fairbanks, AK.

Zhang, C. and K. J. Boyle. 2010. The effect of an aquatic invasive species (Eurasian watermilfoil) on lakefront property values. Ecological Economics 70:394-404.ge. 44:26-31.

APPENDICES

APPENDIX 1. FasTEST Forms and Sampling Protocols for Monitoring Fluridone Concentrations

APPENDIX 2. Fluridone Material Data Safety Sheet (MSDS)

APPENDIX 3. SonarONE and Sonar Genesis AS labels

APPENDIX 4. Diquat Material Data Safety Sheet (MSDS)

APPENDIX 5. Reward (diquat dibromide) label

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FasTEST® Monitoring

Chain of Custody

Company Name:* ____ Contact Person:* ____

Billing Address:* ____

Telephone:* ____ E-mail Address:* ____

*Required fields

Project/Reference Name: ____

SePRO Aquatic Specialist Name: ____

Sampler: ____

Number of samples to be analyzed: ____

Will water from treatment site be used for irrigation or potable purposes? If so, please describe: ____

Check Payment Method: ☐ PO Number ____ ☐ VISA ☐ MasterCard Card No. ____ CCV Code: ____ Expiration Date: ____

☐ Check here if you would like us to keep this credit card information on file for future lab analysis orders.

(To establish a secure credit card file for future billing, please contact the SePRO Accounting Department at 317-580-8291).

Draw a map of water body or enclose a copy of a prepared map identifying the following:

- Sample locations by Sample Numbers as listed on the *other side of this form.*
- Treatment area, if not the whole lake.
- Irrigation or potable water intake locations

Field Notes:

Direct all inquiries about your sampling and FasTEST results to your SePRO Aquatic Specialist.

Ship samples to:
SePRO SRTC
Attn: Haywood Perry
16013 Watson Seed Farm Road
Whitakers, NC 27891-9114
E-mail: haywoodp@sepro.com
Tel: (252) 437-3282

SRTC

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Water Body Name: ____ Water Body Size (acres): ____ State: ____

Depth Average and Depth Collected (feet): ____ Target Plant Species: ____

Formulations Applied (Place an "X" in the boxes of analysis desired) — One form for each water body and formulation

Sonar® (fluridone) ☐ A.S. ☐ PR ☐ Q ☐ SRP ☐ One ☐ Genesis | Renovate® (triclopyr) ☐ 3 ☐ OTF | Renovate® MAX G (triclopyr & 2,4-d) ☐ | Sculpin® G (2,4-d) ☐

Galleon® (penoxsulam) ☐ | Nautique® (copper) ☐ | Komeen® (copper) ☐ | SeClear® (copper) ☐ | K-Tea® (copper) ☐ | Captain® (copper) ☐ | Captain® XTR (copper) ☐

Habitat® (imazapyr) ☐ | Clearcast® (imazamox) ☐ | Oasis® (topramezone) ☐

Client Sample Site I.D. (Required field)	Date(s) Treated	Date Sample Collected (Required field)	Application Rate(s)	Treated Area (In Acres)	Sample Location – Identify sites on map (GPS coordinates preferred)	Lab Use Only - Notes
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						

FasTEST results will be reported 48 hours from receipt of samples by laboratory. Inaccurate or incomplete information on this form may delay analysis and reporting.

Shipped by: ____ Date/Time: ____

To be filled out by laboratory

Received by: ____ Date/Time: ____

FasTEST analysis is performed using SePRO proprietary methods via HPLC and/or ICP. FasTEST, Sonar, Sculpin, Nautique, SeClear, K-Tea, Komeen and Captain are trademarks of SePRO Corporation. Habitat, Clearcast and Oasis are registered trademarks of BASF Corporation. Renovate is a registered trademark of Dow AgroSciences LLC. ©Copyright 2013 SePRO Corporation. Revised F040.02

APPENDIX 1. FasTEST Forms and Sampling Protocols for Monitoring Fluridone Concentrations

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Sampling Collection Procedures for FasTEST*

FasTEST provides rapid and accurate analysis of aquatic herbicide concentrations in water. FasTEST assay services are available for monitoring the following SePRO aquatic products: Sonar*, Renovate® 3, Renovate® OTF, Renovate® MAX G, Galleon* SC, Sculpin* G, Captain*, K-Tea*, SeClear*, Komeen*, Nautique*, Clearcast®, Habitat®, Oasis® and Littora*. It is extremely important to maintain a contamination free environment during water sample collection. Do not collect water samples from a boat that was used to apply the SePRO aquatic product you are monitoring. All equipment and clothes used during sampling should be completely free of the aquatic herbicide.

Follow these collection steps in sequence

1. **Complete FasTEST Chain of Custody (COC) and enclose with sample(s). This is included with sampling bottles, or may be downloaded from the SePRO website. Appropriate billing information MUST be completed before analysis.**
2. Draw a map, or attach a map, of the water body and location of each water collection on accompanying Chain of Custody. Number each sample location and transfer to page one of the Chain of Custody.
3. Complete accompanying sample water bottle labels and affix labels to sample bottles. Number each sample water bottle with corresponding sample location number from COC form. Include date and name of water body on label.
4. At the collection site, remove the bottle cap from the designated bottle, triple rinse the bottle with water from this site and submerge the bottle upside down until elbow deep. Should your program require sampling at depth, utilize the proper device to collect water from the target depth or depths. ***Note: For Littora (diquat) sample collection and analysis, contact the SRTC lab (srtclab@sepro.com) to receive preserved bottles and specific sample collection protocols.***
5. Turn the bottle upright and allow filling as you slowly bring the bottle toward the surface.
6. When the bottle is full, yet still underwater at the targeted collection depth; screw the cap back on the bottle. It is recommended to secure cap with tape to prevent the cap loosening during shipment.
7. Place the sample bottle(s) in a cooler and close the lid to prevent exposure to sunlight.
8. Refrigerate samples if they will not be shipped within 24-hours of collection to keep samples cool until shipment. Do not ship samples collected on a Friday, refrigerate and ship Monday.
9. Do not ship samples in loose ice.
10. We request that samples are overnighted and ice packs are used when outdoor temperatures reach 90 plus degrees. Shipping via FedEx is recommended. Note, shipments by U.S. mail typically require additional time in transit to the SRTC.
11. Ship samples to: **SePRO Research & Technology Campus**
    Attn: Haywood Perry
    16013 Watson Seed Farm Road
    Whitakers, NC 27891-9114
    E-mail: haywoodp@sepro.com
    Tel: (252) 437-3282
12. If you have questions pertaining to sample collection, please contact your SePRO Aquatic Specialist. If you need to order FasTEST sample bottles, please contact the SRTC at **(252) 437-3282** or by e-mail **srtclab@sepro.com**. COC forms are available on our web site **www.sepro.com** (Professional Aquatic Products/Laboratory Services).

FAQs

Q. Why ship Chain of Custody (COC) in a plastic bag?

A. When the Chain of Custody is not protected from moisture, it may become wet and thus very difficult to read…if we can't read or salvage the COC, the sample cannot be analysed until we establish where the sample originated. This may result in later turnaround than our 48-hour policy for water analysis.

Q. Why ship overnight?

A. Shipping overnight ensures that your watersample is not left in an environment (such as the back of a delivery truck or warehouse) in which external factors may affect sample integrity.

Q. Why ship samples on ice?

A. We know that water samples maintain their integrity if kept on ice or in a cold environment; we do not know the same about samples that arrive warm or hot, this leaves the potential for skewed results.

Q. Why send water samples in an opaque Nalgene® bottle?

A. The herbicides we test for are broken down by photolysis (absorption of light), so translucent bottles may promote additional breakdown before analysis is complete.

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