Early Detection of Zebra and Quagga Mussels in Alaska

for

Alaska Department of Fish & Game

prepared by

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INTRODUCTION

Dreissenid mussels (zebra, *Dreissena polymorpha,* and quagga, *D. rostriformis bugensis*) were introduced to North America's Great Lakes in the mid 1980s, brought over from the Black Sea region in the ballast water of ships. Soon after introduction, they spread rapidly throughout the Great Lakes region, where they form massive colonies, with densities of up to 75,000 organisms/ft^2. Where they have been introduced, dreissenid mussels have disrupted food chains, degraded water quality, and outcompeted native species. In 2007, they were detected in Lake Mead on the Nevada Arizona border, over 1200 miles from the nearest known infestation at the time. Since then, they have spread to dozens of waterbodies in several western states (Figure 1). Motorboats are the primary suspected vector for the spread of dreissenids, as they are trailered from infested waterbodies to previously unaffected lakes (Lucy et al. 1999; Johnson et al. 2001).

Many efforts have been underway to slow the spread of dreissenids in western states. The Quagga-Zebra Mussel Action Plan for Western U.S. Waters (QZAP) is coordinated by the Aquatic Nuisance Species (ANS) Task Force—an intergovernmental organization for the prevention and control of ANS. QZAP outlines the highest priority actions that are needed to prevent and control the spread of dreissenids throughout the Western U.S., focusing on prevention, early detection (ED), and rapid response (RR). Many western states have active prevention and EDRR programs that include inspection stations, where boats and trailers are inspected and if mussels are found, the boat and trailer are decontaminated; early detection monitoring in waterbodies that have been determined to be susceptible to invasion and are likely to support introduced dreissenids; and rapid response plans to address unwanted mussel infestations soon after they are detected. In the past few years, dozens of boats harboring live dreissenid mussels have been intercepted and decontaminated in western states as a result of these efforts (Idaho DOA 2012; AP 2012).

Aside from a cursory effort in 2004, in association with a native freshwater mussel survey (Smith et al. 2005), this project was the first attempt at early detection monitoring for dreissenids in Alaska waters. The purpose of this project was to identify and prioritize waterbodies that are susceptible to dreissenid introduction and establishment, and to implement an ED program for those waterbodies most at risk. Since newly introduced populations of mussels are difficult to detect (due to low numbers, clumped distribution, and difficulty to observe underwater habitat) early detection efforts should focus on waterbodies that are at a high risk for introduction and establishment (Wells et al. 2010).

METHODS

Identifying at risk waterbodies

We evaluated the relative risk of introduction and establishment of dreissenid mussels in Alaskan lakes based on a number of factors. Since the primary vectors for introduction of dreissenids are motorboats transported from an infested lake, only lakes with public boat launches were considered for initial assessment. Other important factors included the lake's distance from the nearest known infestation, and recreational fishing data. Since the Alaska Highway is the primary road access to the state, lakes were considered less susceptible to invasion the further they were from the Alaska/Canada border. Recreational fishing data were obtained from Statewide Harvest Surveys conducted by the Alaska Department of Fish & Game, averaged from 2006-2010, since recreational boat user data were not available.

Risk of dreissenid establishment was evaluated based on water chemistry data. Dreissenid growth and development are limited by dissolved calcium concentrations and pH. In general, veliger survival, shell growth, and adult survival all increase with increasing calcium concentrations (Hincks and Mackie 1997;

McMahon 1996). The literature suggests a lower calcium threshold of 9-12 µg/L for dreissenid survival, although results vary with life stage, pH levels and other factors (Wells et al. 2010). McMahon (1996) found that veligers in North America survive in waters with pH levels between 7.4 and 9.4. Since most Alaskan lakes fall within this pH range, we chose to use available calcium data to evaluate risk of establishment, and used lower thresholds to account for a general lack of data, temporal and spatial variation not accounted for in existing data, and recommendations to use lower thresholds (Jesse Schultz, Washington Dept. of Fish & Wildlife, personal communication, August 2012).

We developed a dreissenid risk matrix for Alaska lakes incorporating: presence of public boat launch(es), recreational angler days, calcium concentrations, and proximity to know infestation and vector data (Table 1). Boat launch information was obtained primarily from the Alaska Department of Fish & Game's lake fishing website (ADF&G 2012), and verified in the field. Multiple data sources were queried to compile calcium concentrations for Alaska lakes. The USGS National Water Information System (NWIS) database (http://waterdata.usgs.gov) was the primary source for calcium data; additional data was obtained from the USEPA STORET database (http://www.epa.gov/store/dbtop.html), the Alaska Department of Environmental Conservation, and Dr. Michael A. Bell, from the University of Utah, who has collected calcium data for southcentral Alaska lakes in association with his stickleback research. For lakes where calcium data were unavailable, we assumed that calcium concentrations were high enough to facilitate dreissenid growth. We used fishing data from user surveys conducted by ADF&G between 2006 and 2010 as a proxy for recreational use, since consistent boater information for Alaska lakes is not available. The nearest known confirmed dreissenid infestations are currently over 2000 road miles away via the Alaska Highway, in the Red River at Kidder Dam in southeastern South Dakota (Zebra mussels) and the Rye Patch Reservoir in northern Nevada (Quagga mussels) (USGS 2012). We assumed that dreissenids coming into the state were most likely to come via the Alaska Highway, and considered distance from the Alaska-Canada border in determining the proximity to known infestation ranking.

Risk scores were weighted so that only lakes with public boat access scored in the moderate to high risk categories, since we considered trailered boats from infested lakes to Alaska lakes as the only vector of transport in this study. Risk scores could change with new information concerning risks of transport from other sources (eg. float planes) or more comprehensive water chemistry data. Lakes with the highest priority scores can be found in Table 3.

Field and Lab Data Collection

Lakes with the highest risk priority rankings were visited August 30 through September 14, 2013 (Table 2, Figure 2). Field data was collected out of a small motorized inflatable water craft launched from a public boat launch at each lake (Figure 3). We chose an index site in a relatively deep part of the lake based on bathymetry maps provided by the ADF&G, and anchored the boat. At each index site we: measured and recorded depth using a weighted measuring tape; recorded latitude and longitude in decimal degrees using a Garmin eTrex Legend GPS; measured and recorded secchi depths, at point of disappearance and point of reappearance; collected and filtered (0.45µm) a 10ml water sample for calcium analysis into a clean polyethylene centrifuge tube and placed on ice; and measured and recorded water temperature, dissolved oxygen, specific conductance, and pH at the surface and at 1 meter depth intervals down to a maximum of 5 meters using a calibrated Hydrolab 5a minisonde. Calcium samples were delivered to the Applied Science, Engineering, & Technology (ASET) Laboratory at the University of Alaska Anchorage (UAA) on September 17, 2013, where they were analyzed using inductively coupled plasma mass spectrometry (ICP-MS).

At each lake, a minimum of five vertical plankton tows were collected at random locations (including the index site), close to the public boat launch(es), and composited into a single sample. At smaller lakes (eg <500 acres), tows were spread evenly throughout the lake. In lakes with more than one public boat launch, two or more composited samples were collected. Samples were collected using protocols provided by EcoAnalysts, Inc. (Wells 2009). After each plankton tow, the inside of the net was rinsed down to the collection cup with deionized water; the composited sample was poured into a 500ml sample bottle, preserved with 50-70% ethanol, and buffered with a teaspoon of baking soda. Each sample bottle was clearly labeled with site and waterbody name, date, and number of tows. Samples were shipped to EcoAnalysts, Inc. on September 17, 2013, where they were analyzed for the presence of dreissenid veligers using Cross Polarized Light Microscopy (CPLM). Frischer et al. (2011) found that veliger detection in plankton samples using CPLM was more reliable than Image Flow Cytometry and environmental DNA at this time.

RESULTS AND DISCUSSION

All but one lake that had a moderate or high risk ranking (i.e. $\geq$12) was sampled in 2012. We did not sample Lower Bonnie Lake due to a warning sign that was posted on its access road. We also sampled 5 lakes that had low rankings, due to easy access and/or a lack of historic calcium data. Water chemistry and plankton tow data can be found in Table 4.

No dreissenid veligers were found in any of the 32 plankton samples collected. A Unionid glochidia from Lucile Lake was the only mussel larva found in the lab analysis; we observed several *Anodonta sp.* adults in Lucile Lake on our sampling visit. The glochidia measured 324 microns, much larger than dreissenid veligers which range from 90-130 microns.

A water sample for calcium analysis was collected from Mirror Lake, near Eagle River, since we could find no calcium data for this lake, and a relatively high calcium concentration of 27.6 µg/L moved this lake to a moderate priority ranking. We did not visit/sample four other lakes that were low priorities based on our ranking matrix for a variety of access issues, including poor signage and poor road/boat launch conditions (Table 4).

AS previously mentioned, only lakes with public boat launches had a greater than “very low” risk ranking, and were therefore sampled for this survey. Of lakes with improved public boat launches, only Sport Lake, Island Lake, Douglas Lake, Tustamena Lake, Johnson Lake, and Stormy Lake (from the Kenai Peninsula), and Rocky Lake, Prator Lake, Benka Lake, and Christiansen Lake (from the Mat-Su Borough) scored a “low” (or lower) risk ranking, due mainly to historic calcium concentrations below 7mg/L. Another two dozen lakes on the Kenai Peninsula and in the Mat-Su Borough have primitive public boat launches (ADF&G, 2012) and did not score above a “low” risk ranking.

We gained more clarity for the risk of dreissenid establishment in the sampled lakes from the 2012 water chemistry data. Calcium concentrations in 2012 ranged from a low of 7.2 mg/L in Round Tangle Lake to a high of 38.1 mg/L in Clearwater Lake. Mean pH ranged from 7.5 in Kenai Lake to 9.1 in Lucile Lake, thus indicating that all lakes sampled had pH levels conducive for dreissenid growth and development (Table 4, McMahon 1996). Calcium concentrations, however, were more variable, and can be used to help refine the risk priority rankings (Table 4). Since calcium concentrations can vary spatially and temporally, we recommend that additional calcium data be collected at these lakes before moving them to a lower or higher risk category. Calcium results from the 2012 sampling efforts were used to refine the priority ranking scores (Table 3).

Recreational use data, especially boater data, is lacking for Alaska lakes, so we used fishing survey data from ADF&G to help determine the risk of introduction. Many public boat launches are located at state or federal recreation sites which have staff on site. We recommend that boater user surveys be conducted at these sites to attain data that would more appropriately inform this risk. Since introduction could occur from boats harboring dreissenids both owned by people living outside Alaska, and Alaskan boat owners returning from visits outside the state, all boaters at high risk lakes should be surveyed.

In this initial early detection monitoring effort, we assumed the primary vector for transport to be by boats transported from an infested lake to an Alaska lake. In future monitoring efforts, more scrutiny should be given to the potential transport of dreissenids to Alaska via floatplanes. Floatplanes landing in infested lakes could potentially carry dreissenid veligers in the ballast water of their floats. Although it is standard operating procedure to pump out ballast water before take-off (John Pratt, Alaska Seaplane Pilots Association, personal communication, August 2012), there are no regulations requiring such action.

ED monitoring for introduced dreissenids provides many challenges. Dreissenids can be transported at any life stage, and therefore may only be present as veligers in some invaded lakes. When sampling for veligers in the water column, they are easy to miss, especially at low densities. Looking for adults is also difficult, as they are small and difficult to see with the unaided eye. Dreissenids cannot tolerate sub-freezing temperatures, so they would not be able to survive in shallow water where they could be seen, since water in the littoral zone freezes to the bottom in winter in most Alaskan lakes. Dredging for adults in deeper water and the use of artificial substrate should be considered in addition to examination of plankton in subsequent ED monitoring efforts. Monitoring for a variety of dreissenid life stages could reduce the probability of false negatives (Wells et al. 2010), even though sampling for veligers is much more likely to detect early invasions (Holser 2011).

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Figure 1. USGS Zebra and Quagga Mussel Sightings in North America, March 12, 2009.

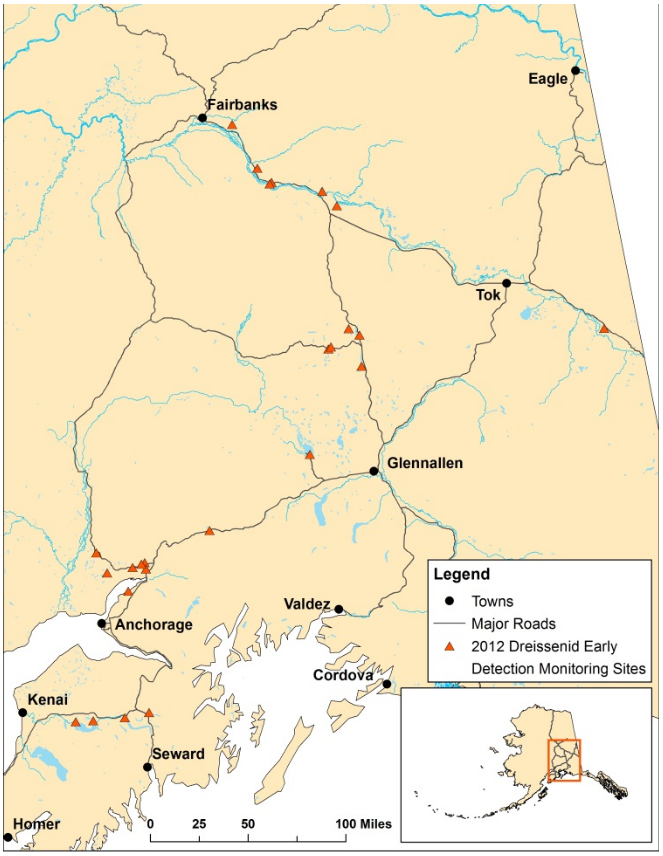

Figure 2. Map of dreissenid early detection monitoring sites in Alaska lakes, 2012.


Figure 3: Dreiessenid early detection monitoring in Long Lake, Alaska.

Table 1: Risk ranking scoring matrix for dreissenid introduction/establishment into Alaskan lakes.

Ranking	Ca^{2+}	Ca^{+2} Score[a]	Proximity	Prox. Score	Boat launch	BL Score	Non-resident Fishing Days	Resident Fishing Days	FD Score (whichever is greater)	Total
High	>25	4	Alaska Hwy	4	2 or more improved	8	>500	>5000	4	>15
Moderate	12-25	3	Richardson Hwy, Tok Cutoff	3	1 improved	6	350-500	3000-5000	3	12-15
Low	9-12	2	Glenn & Parks Hwys	2	primative	4	200-350	1000-3000	2	10-11
Very Low	7-9	1	MOA, Seward, & Sterling Hwys	1	no boat ramp; stocked	2	50-200	200-1000	1	8-9
None	<7	0	Not Road Accessible	0	no boat ramp; not stocked	0	<50	<200	0	<8

[a] lakes with no calcium data = 2

Table 2. Alaska lake dreissenid monitoring locations.

Name	Latitude at Index Site (WGS84)	Longitude at Index Site (WGS84)	2012 Sample date
Beach Lake	61.4056	-149.5570	30 Aug.
Big Lake (North)	61.5502	-149.8629	7 Sept.
Big Lake (South)	61.5353	-149.8499	7 Sept.
Big Lake (East)	61.5386	-149.8443	7 Sept.
Birch Lake	64.3135	-146.6533	10 Sept.
Chena Lake	64.7689	-147.2214	9 Sept.
Chisholm (Lost) Lake	64.3025	-146.6872	10 Sept.
Clearwater Lake	64.0855	-145.6027	10 Sept.
Cottonwood Lake	61.5982	-149.3245	4 Sept.
Deadman Lake	62.8841	-141.5504	11 Sept.
Fielding Lake (Mid)	63.1741	-145.6638	12 Sept.
Fielding Lake (NE)	63.1315	-145.6425	12 Sept.
Finger Lake	61.6069	-149.2709	4 Sept.
Harding Lake	64.4281	-146.8673	9 Sept.
Hidden Lake	60.4696	-150.2089	1 Sept.
Junction (Loberg) Lake	61.5589	-149.2590	4 Sept.
Kenai Lake (Quartz)	60.4791	-149.7320	31 Aug.
Kenai Lake (Primrose)	60.3405	-149.3631	31 Aug.
Lake Louise (1)	62.2903	-146.5246	13 Sept.
Lake Louise (2)	62.2845	-146.5257	13 Sept.
Long Lake	61.8054	-148.2226	14 Sept.
Lucile Lake	61.5776	-149.4634	30 Aug.
Nancy Lake	61.7033	-150.0101	8 Sept.
Paxson Lake	62.8881	-145.5323	12 Sept.
Quartz Lake	64.2032	-145.8159	10 Sept.
Round Tangle Lake (Main)	63.0570	-145.9888	13 Sept.
Round Tangle Lake (West)	63.0580	-146.0007	13 Sept.
Skilak Lake (Lower)	60.4691	-150.4721	1 Sept.
Skilak Lake (Upper)	60.4357	-150.3229	1 Sept.
Summit Lake (near Paxson)	63.1188	-145.5009	12 Sept.
Upper Tangle Lakes	63.0439	-146.0336	13 Sept.
Upper Trail Lake	60.5037	-149.3661	31 Aug.

Table 3: Priority scores for Dreissenid monitoring for Alaska Lakes.

Name	Proximity to known infestations/ vectors	Prox. to vector score	Historic Ca^{+2} (ppm)	Ca^{+2} score	Comments	Pub. Boat Launch?	Boat Ramp score	Mean Res Fishing Days	Mean NonRes Fishing Days	Mean total Fishing Days	FD Score	Total Score	Revised Score
Quartz Lake	Richardson Hwy	3	29	4	stocked	yes	6	6092	264	6356	4	17	17
Big Lake	Parks Hwy	2	16	3		yes (2+)	8	4995	203	5198	4	17	17
Finger Lake	Parks Hwy	2	26	4	stocked	yes	6	5605	155	5760	4	16	16
Birch Lake	Richardson Hwy	3	13	3	stocked	yes	6	5385	211	5596	4	16	16
Upper Tangle Lakes	Richardson Hwy	3	12.1	3		yes	6	3726	695	4421	4	16	14[a]
Lake Louise	Glenn Hwy	2	NA	2		yes (2)	8	4371	263	4634	3	15	16
Chena Lake	Richardson Hwy	3	NA	2	stocked	yes; ele motors	4	8443	397	8840	4	14	16[a]
Skilak Lake	Sterling Hwy	1	NA	2		yes (2)	8	895	408	1303	3	14	14
Long Lake (near Sutton)	Glenn Hwy	2	25	4	stocked	yes	6	1467	103	1570	2	14	13[a]
Paxson Lake	Richardson Hwy	3	13	3		yes	6	1065	217	1282	2	14	14
Deadman Lake	Alaska Hwy	4	13	3		yes	6	103	59	162	1	14	14
Nancy Lake	Parks Hwy	2	13	3		yes	6	2362	225	2587	2	13	13
Summit Lake (near Paxson)	Richardson Hwy	3	13	3		yes	6	711	142	853	1	13	12[a]
Fielding Lake	Richardson Hwy	3	11	2		yes	6	946	129	1075	2	13	14[a]
Clearwater Lake	Richardson Hwy	3	32	4		yes	6	33	0	33	0	13	13
Hidden Lake (KNWR)	Sterling Hwy	1	24	3		yes	6	2206	178	2384	2	12	12
Kenai Lake	Sterling Hwy	1	NA	2		yes (4+)	8	537	190	727	1	12	12
Beach Lake	Glenn Hwy	2	NA	2	stocked	yes	6	1874	80	1954	2	12	12
Lower Bonnie Lake	Glenn Hwy	2	18	3		yes	6	431	44	475	1	12	11[b]
Chisholm (Lost) Lake	Richardson Hwy	3	10	2	stocked	yes	6	170	43	213	1	12	13[a]
Harding Lake	Richardson Hwy	3	8.5	1	stocked	yes	6	1458	56	1514	2	12	12
Knik Lake	Parks Hwy	2	26	4	stocked	yes; primative	4	656	22	678	1	11	10[b]
Junction (Loberg) Lake	Parks Hwy	2	31	4	stocked	yes; primative	4	244	0	244	1	11	11
Lucile Lake	Parks Hwy	2	15	3	stocked	yes; primative	4	977	89	1066	2	11	11
Cottonwood Lake	Parks Hwy	2	28	4		yes; primative	4	752	130	882	1	11	11
Lynx Lake	Parks Hwy	2	NA	2		yes	6	455	0	455	1	11	10[b]
Round Tangle Lake	Richardson Hwy	3	9.5	2		yes	6	0	14	14	0	11	10[b]
Bearcub Lake	Tok Cuttoff	3	NA	2	stocked	yes	6	0	0	0	0	11	10[b]
Upper Trail Lake	Seward Hwy	1	NA	2		yes	6	82	137	219	1	10	10
Mirror Lake	Glenn Hwy	2	NA	2	stocked	yes; primative	4	2459	114	2573	2	10	12[a]

[a] adjusted for 2012 Ca^{+2} data
[b] adjusted for access difficulty

Table 4: 2012 water quality and plankton tow data collected for dreissenid monitoring in Alaska lakes.

Name	Sample date (2012)	Mean Dis. Oxygen (mg/L)	Mean Specific Cond. (µs/cm)	Mean Water Temp (°C)	Mean pH	Mean Secchi depth (m)	No. of vertical tows	Total tow length (m)	Total Tow volume (m^3)	Ca^{+2} (mg/L)
Quartz Lake	9/10	8.9	527	11	8.5	2.8	6	42	2.97	25.7
Big Lake (North)	9/7	9.9	163	12.8	7.7	3.25	5	28.5	2.01	20.9
Big Lake (South)	9/7	10.0	159	13.4	7.8	4.95	5	26	1.84	21.0
Big Lake (East)	9/7						5	26	1.84	
Finger Lake	9/4	9.5	277	13.8	8	4	5	21.5	1.52	30.2
Birch Lake	9/10	9.2	133	11.2	7.8	4.05	5	25.5	1.80	14.8
Upper Tangle Lakes	9/13	10.8	72	5.6	7.6	4.55	5	56	3.96	9.0
Chena Lake	9/9	9.2[b]	253	12.4	7.7	5.45	5	30	2.12	34.5
Skilak Lake (Upper)	9/1	12.0	70	8.8	7.6	1.1	12	118	8.34	9.7
Skilak Lake (Lower)	9/1	11.9	72	9.5	7.7	1.95	14	65.5	4.63	9.9
Long Lake (near Sutton)	9/14	10.3	499	10.8	8.5	10.5	5	45	3.18	22.1
Paxson Lake	9/12	10.4	124	8.8	8.2	3.9	5	35.5	2.51	15.1
Deadman Lake	9/11	8.8	162	9.9	7.7	2.15	5	20	1.41	21.6
Nancy Lake	9/8	9.6	116	11.8	7.7	2.9	5	42.5	3.00	13.3
Lake Louise (1)	9/13	10.3	156	9.4	8	6.05	6	39	2.76	17.7
Lake Louise (2)	9/13						6	26.5	1.87	
Summit Lake (near Paxson)	9/12	10.6	88	7.5	7.9	>6.6	12	40	2.83	11.8
Fielding Lake (Middle)	9/12	10.2	137	8	7.9	3.6	5	54	3.82	14.6
Fielding Lake (NE)	9/12						5	42	2.97	
Clearwater Lake	9/10	12.7	293	4.2	7.9	N/A	2[a]	25	1.77	38.1
Hidden Lake (KNWR)	9/1	10.4	153	13.6	8.1	9.6	6	77	5.44	21.9
Kenai Lake (Primrose)	8/31	12.2	77	8.2	7.6	0.85	10	80	5.65	10.9
Kenai Lake (Quartz)	8/31	12.0	83	9	7.5	1.7	11	70.5	4.98	12.3
Beach Lake	8/30	10.0	93	16.4	8.3	1.15	5	10.5	0.74	10.1
Lower Bonnie Lake	Not sampled due to warning sign posted on the turn off the Glenn Highway									
Chisholm (Lost) Lake	9/10	9.7	116	11.2	7.8	4.35	5	31.5	2.23	12.3
Harding Lake	9/9	10.4	82	12.4	7.9	9.05	7	35.5	2.51	7.9
Knik Lake	Not sampled due to poor condition of boat launch									
Junction (Loberg) Lake	9/4	9.5	373	14	8	7.25	5	29.5	2.08	37.3
Lucile Lake	8/30	11.0	243	15.3	9.1	5	7	13.5	0.95	21.0
Cottonwood Lake	9/4	9.9	205	13.4	8.1	3.15	5	28.5	2.01	27.8
Lynx Lake	Not sampled due to poor condition of Lynx Lake Road									
Round Tangle Lake (Main)	9/13	10.3	65	7.2	7.8	2.95	5	54.5	3.85	7.2
Round Tangle Lake (West)	9/13						5	13	0.92	
Bearcub Lake	Not sampled due to poor signage off the Tok Cutoff Highway									
Upper Trail Lake	8/31	12.0	78	8.2	7.6	0.5	9	48	3.39	11.6
Mirror Lake	Not sampled due to low preliminary priority score									27.6

[a]Horizontal tows due to shallow depth.
[b]1.0 mg/L @ 5 meters depth