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Aquatic Invasive Species Surveys of Upper Klamath Lake, Fourmile Lake, and Lake of the Woods, OR During 2012

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Report to the Bureau of Land Management

By
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Table of Contents

Cover photo: the rare native submersed aquatic plant swaying bulrush (*Schoenoplectus subterminalis*) with emergents flower at Lake of the Woods, Oregon. Photo by Rich Miller.

Abstract

Three lakes located within the Klamath River Basin in Oregon (Upper Klamath Lake, Fourmile Lake, and Lake of the Woods) were surveyed for aquatic invasive species during the summer of 2012. Specimens were collected using plant rakes, benthic dredges, plankton nets, and crayfish traps. No invasive aquatic plants, gastropods, snails, bivalves or crayfish were detected in the lakes.

Introduction

Aquatic invasive species (AIS) pose a significant ecological and economic threat to the waters of the Pacific Northwest (Sanderson et al. 2009). Aquatic plants species such as hydrilla (*Hydrilla verticillata*) and invertebrate species such as zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*) are a few of the high risk, high impact AIS that are not present in Oregon. Early detection of new introductions increases the probability of successful management and decreases the associated costs (Rejmánek and Pitcairn 2003).

The Center for Lakes and Reservoirs at Portland State University (CLR) conducted early detection AIS surveys at three large lakes in the Klamath Basin for aquatic plants, crayfish, gastropods, adult bivalves, and planktonic bivalves during the summer of 2012. The lakes surveyed included Upper Klamath Lake, a very large, shallow lake used for irrigation and recreation; Lake of the Woods, a popular recreation lake surrounded by vacation homes, camps, and resorts; and Fourmile Lake, a popular recreation lake with minimal development in the watershed (Figure 1; Table 1) (Johnson et al. 1985).

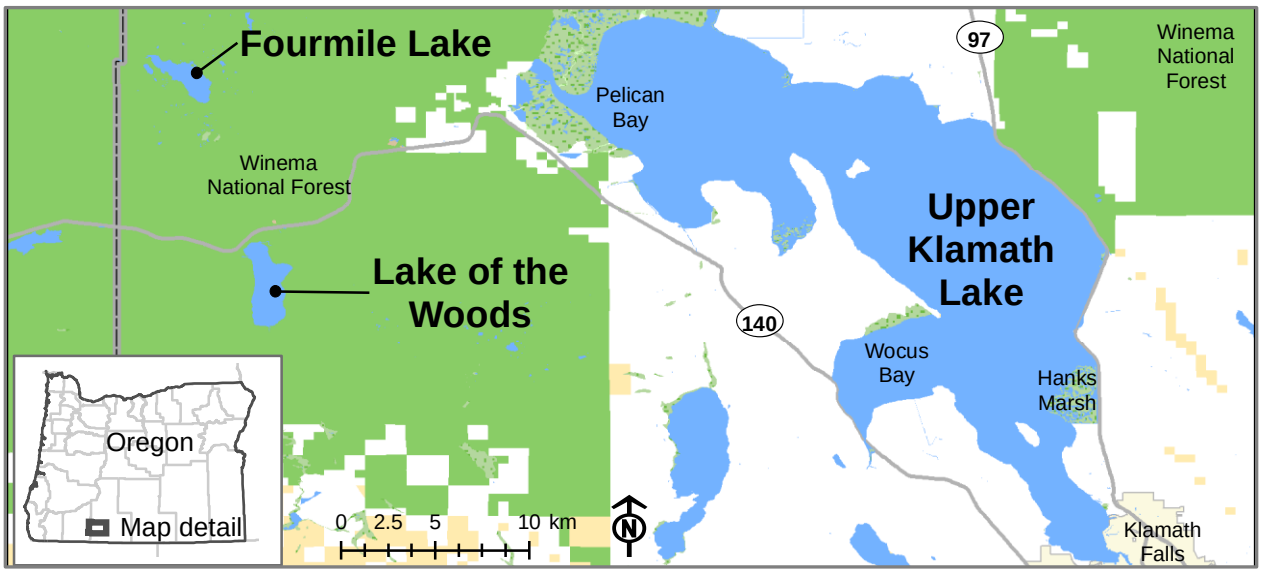

Figure 1. Location of AIS survey lakes: Upper Klamath Lake, Lake of the Woods, and Fourmile Lake.

Table 1. Location and morphometric statistics of surveyed lakes.

Waterbody	Longitude	Latitude	Elev. (m)	Area (acres)	Max. depth (m)	Mean depth (m)
Upper Klamath Lake	-121.882	42.393	1,262	61,653	15.2	4.2
Lake of the Woods	-122.216	42.367	1,509	1,145	16.8	8.1
Fourmile Lake	-122.256	42.467	1,751	763	53.3	16.7

Methods

Aquatic Plants

Aquatic plant species composition was assessed at approximately 50 sampling sites in each lake. Sites were haphazardly distributed to span the geographic and the different habitat types within each lake, e.g. protected and shorelines, shallow and deepwater littoral zones. Samples were collected from a boat with a double-sided thatch rake attached to a graduated pole. The graduated pole was lowered vertically to the sediment surface, rotated 180 degrees, and attached material was retrieved. The total area sampled was approximately 0.15 m^2 for each pole sample. At shoreline sites, emergent species were visually scanned with a focus on Oregon Department of Agriculture class "A" and "B" designated noxious weeds such as purple loostrife (*Lythrum salicaria*) and yellow flag iris (*Iris pseudacorus*) (2012). GPS location, sample depth, and preliminary species identifications were noted on field datasheets. Voucher specimens were placed in labeled plastic bags and placed on ice for verification. Field identifications were verified using Crow and Hellquist (2000; 2006), Hamel and Parsons (2001), and Brayshaw (2001). Selected specimens were pressed for archive at the Portland State University herbarium.

Bivalve Veligers

Samples for the detection of zebra mussel (*Dreissena polymorpha*) and quagga mussel (*Dreissena rostriformis bugensis*) veligers were collected and inspected according to Wells and Sytsma (2011). Samples were collected from a boat at a minimum of ten sites distributed throughout Lake of the Woods and Fourmile Lake. Veliger samples were collected from two sites in Upper Klamath Lake to supplement samples collected by CLR at 24 sites during July of 2012. Vertical, oblique, or horizontal tows were collected depending on the depth at each site. Tows were collected with a decontaminated 20-cm diameter, 64-µm mesh plankton net with a removable cod-end piece. The multiple tow samples were composited into a single 500-mL HDPE bottle. Total sample volume of approximately 125 mL was preserved by adding 95% ethanol to a final concentration of approximately 70% ethanol. Samples were inspected for veligers at the Portland State University using cross-polarized light microscopy.

Gastropods and Adult Bivalves

Gastropods and adult bivalves were collected using three methods: sediment dredging, SAV sampling, and shallow water observations. Sediment dredge samples (225 cm^2 sample area) were collected at 10 sites within each impoundment using a Petit Ponar dredge. SAV samples were collected with either a Petit Ponar dredge or a rake as described in the Aquatic Plants Methods section above. Sediment and SAV samples were rinsed onto a 250-µm mesh screen

and inspected for suspected invasive snails and bivalves. For the shallow water observations, rocks and woody debris were inspected every few meters along 30-m transects near the shore of primary access points. Suspected invasive species, in particular specimens that resemble big-eared radix snails (*Radix auricularia*), New Zealand mudsnails *(Potamopyrgus antipodarum*), or Chinese mystery snails (*Cipangopaludina chinensis*) were placed in labeled vials and preserved in ethanol. AIS identifications were verified by Robyn Draheim at Portland State University.

Crayfish

Crayfish surveys were conducted based on the protocols outlined by Larson and Tait (2011). Briefly, modified Gee minnow traps were placed at five sites at least 10-m apart in each of the lakes. Traps were baited with dry dog food and deployed from late evening to early morning in shallow areas (< 2 m). Trap locations, deployment length, deployment depth, substrate type, and numbers and species of crayfish trapped were recorded on field data sheets. Crayfish encountered during aquatic plant and benthic surveys were collected if captured. Specimens were photographed and preserved in ethanol.

Water Quality

Temperature, dissolved oxygen, pH and specific conductivity were measured near the deepest location in Lake of the Woods and Fourmile Lake using a Eureka Manta^{TM} water quality multiprobe. Water quality parameters were not measured in Upper Klamath Lake since the lake is routinely monitored by the USGS and the BOR (Wood 2013). Accuracy of specific conductivity and pH sensors was assured by calibration at the start of each sampling day using NIST certified 500 µS/cm, pH-7, and pH-10 standards. At each lake, accuracy of dissolved oxygen was assured by calibration to 100% saturation based on in situ barometric pressure measurements. Accuracy of temperature probes was assured through factory calibration. Measurements were conducted at 0.1 m, 1 m, and at 1 m depth increments thereafter to within 1 m of the sediment. Probes were held at each depth for at least one minute for equilibration with conditions at each depth. Precision was assessed by repeating the one or two meter measurements after profiles were completed.

Water transparency was measured by observing the depth of disappearance of a 20 cm Secchi disk lowered off the shaded side of the boat. All water quality measurements were recorded on waterproof field datasheets.

Results

Fourmile Lake

Aquatic plants. Aquatic plants were surveyed at 45 locations in Fourmile Lake on August 14 and 15, 2012 (Figure 2). Plants were present at only 51% of the sites and densities were low where present. None of the species collected were known AIS (Table 2). Of the ten submersed or floating leaf taxa, five were identified to species, four were identified to genus and one was identified to family. These specimens could not be identified to species due to a lack of mature morphological characteristics species. Identification of these unknown species, however, was

narrowed down to likely natives. The shoreline plants collected did not include any ODA listed species.

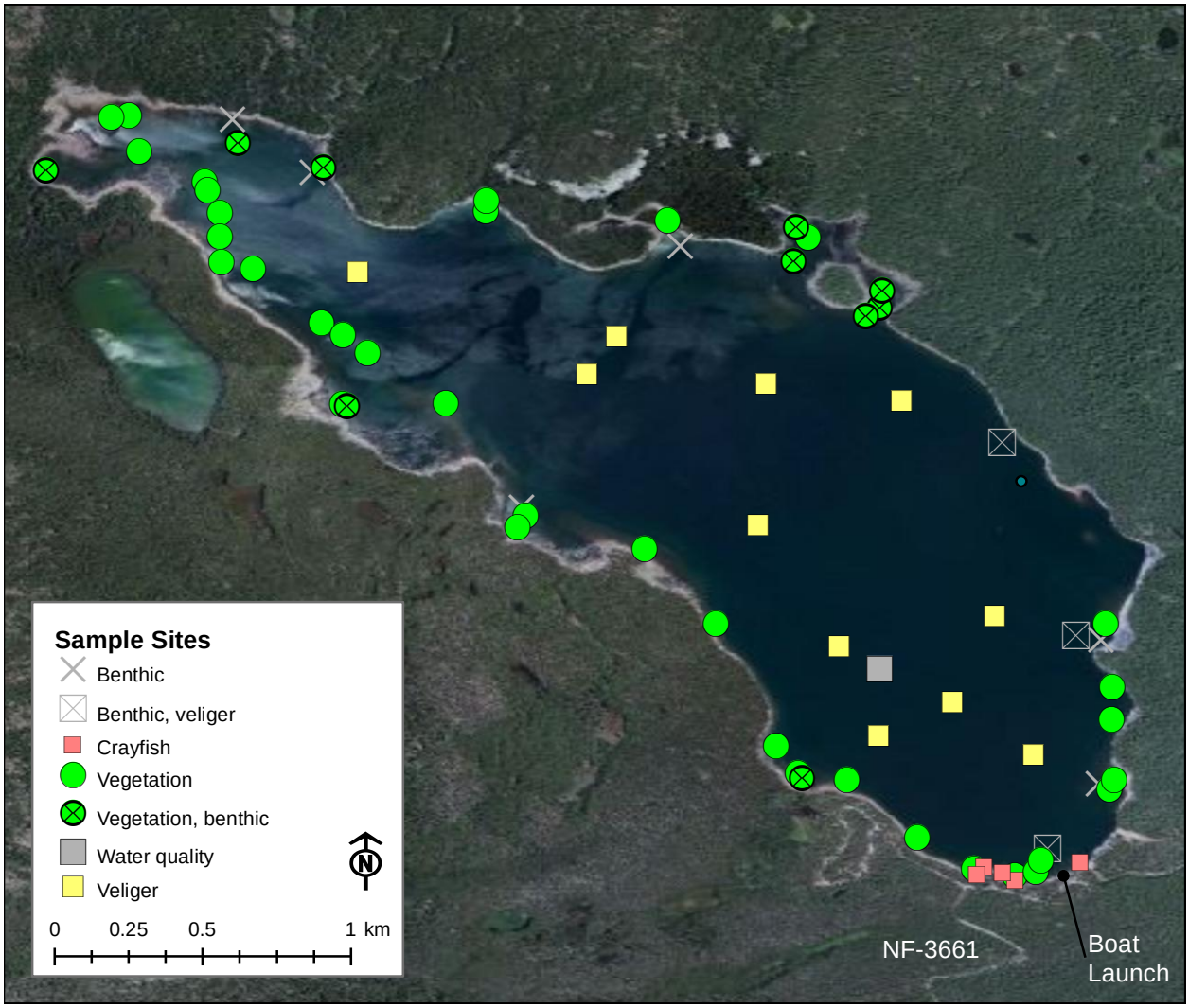

Figure 2. Fourmile Lake sampling sites.

Gastropods and adult bivalves. Twenty-one benthic or vegetation samples were sieved for gastropods and adult bivalves (Figure 2). Native pea clams *(Sphaeriidae sp.*), also known as fingernail clams, were the only specimens detected.

Bivalve velgers. Veliger tows were collected at ten sites throughout Fourmile Lake (Figure 2) and composited into two sample bottles. A total of approximately 30 m^3 of water was sampled. No bivalve veligers were detected in the samples.

Crayfish. No crayfish were collected with the traps deployed at five sites in Fourmile Lake (Figure 2).

Water quality. Fourmile Lake was isothermal at approximately 20˚C down to a depth of 9 m (Table 3). Dissolved oxygen concentrations were at saturation and pH was slightly basic in the isothermal layer. A metalimnetic maximum in pH and dissolved oxygen saturation indicated higher algal production at the thermocline and dissolved oxygen concentrations remained near

saturation to 25 m. Specific conductivity was consistently low throughout the water column. Secchi disk transparency was very deep at 13.3 m (43.5 ft) at 2:10 pm.

Table 2. Fourmile Lake aquatic vegetation collected August 14, 2012.

Species name	Growth form	% presence (45 sites)	Status	Notes
Poacea sp.	floating leaf	36	Likely native	Likely *Glyceria borealis*
Eleocharis acicularis	submersed	27	Native	
Sparganium sp.	emergent	18	Likely native	Likely *Sparganium natans*
Utricularia vulgaris ssp. macrorhiza	submersed	18	Native	
Carex sp.	emergent	9	Unknown	Not a shoreline survey target AIS sp.
Nitella sp.	submersed	7	Likely native	Non-native *Nitella sp.* have not been recorded in the PNW
Eleocharis sp.	emergent	4	Unknown	Not a shoreline survey target AIS sp.
Isoetes sp.	submersed	4	Likely native	Non-native *Isoetes sp.* have not been recorded in the PNW
Callitriche heterophylla	submersed	2	Native	
Sagittaria sp.	submersed	2	Unknown	Fleshy rosette of leaves in deep water, no flowers or floating leaves
Potamogeton natans	floating leaf	2	Native	
Potamogeton pusillus	submersed	2	Native	
Rananculus flammula var. reptans	submersed	2	Native	

Table 3. Water quality profile of Fourmile Lake measured on August 14, 2012.

Depth (m)	Temp. (˚C)	Sp. Cond. (µS/cm)	pH (S.U.)	D.O. (mg/l)	D.O. (% sat.)
0.1	20.3	13	7.53	7.39	101
1.0	20.3	13	7.51	7.35	100
2.0	20.3	13	7.48	7.34	100
3.0	20.0	13	7.48	7.35	100
4.0	19.9	13	7.46	7.37	100
5.0	19.9	13	7.45	7.37	100
6.0	19.5	13	7.44	7.41	100
7.0	19.2	13	7.45	7.47	100
8.0	18.9	13	7.44	7.55	101
9.0	18.3	13	7.44	7.75	102
10.0	16.0	13	7.48	8.90	110
11.0	13.5	13	7.51	9.70	115
12.0	10.6	13	7.57	10.50	117
13.0	9.7	13	7.60	10.66	116
14.0	8.8	13	7.61	10.82	115
15.0	8.4	13	7.60	10.81	114
20.0	7.5	13	7.57	10.53	108
25.0	7.1	13	7.50	10.03	102

Lake of the Woods

Aquatic plants. Aquatic plants were surveyed at 50 locations in Lake of the Woods on August 16 and 17, 2012 (Figure 3). Plants were present at 90% of the sites surveyed, were abundant at most sites, and very diverse. Twenty-three species were collected, 20 of which were submersed or floating leaf species, and none were known AIS (Table 4). Seven of the submersed and floating leaf specimens could not be identified to species due to a lack of mature morphological characteristics. Identification of six of the seven unknown species, however, was narrowed down to likely natives. One small submersed plant collected from moderate depths at several sites at very low densities was tentatively identified as an unknown *Myriophyllum* species; however, the species did not fit any of the available taxonomic keys. Follow-up collections and submittal for genetic identification is recommended. Shoreline emergent plants collected did not include any ODA listed species.

Two of the plant species collected from Lake of the Woods are included on the Oregon Biodiversity Information Center's list of rare, threatened and endangered species of Oregon (Obic 2010). Both species, water clubrush (*Schoenoplectus suberminalis*) and lesser bladderwort (*Utricularia minor*) are listed as imperiled in Oregon "because of rarity or because other factors demonstrably make it very vulnerable to extinction." OBIC notes that at a global scale, *S. subterminalis* is "not rare and apparently secure, but with cause for long-term concern." *U. minor* is listed as widespread globally and not rare.

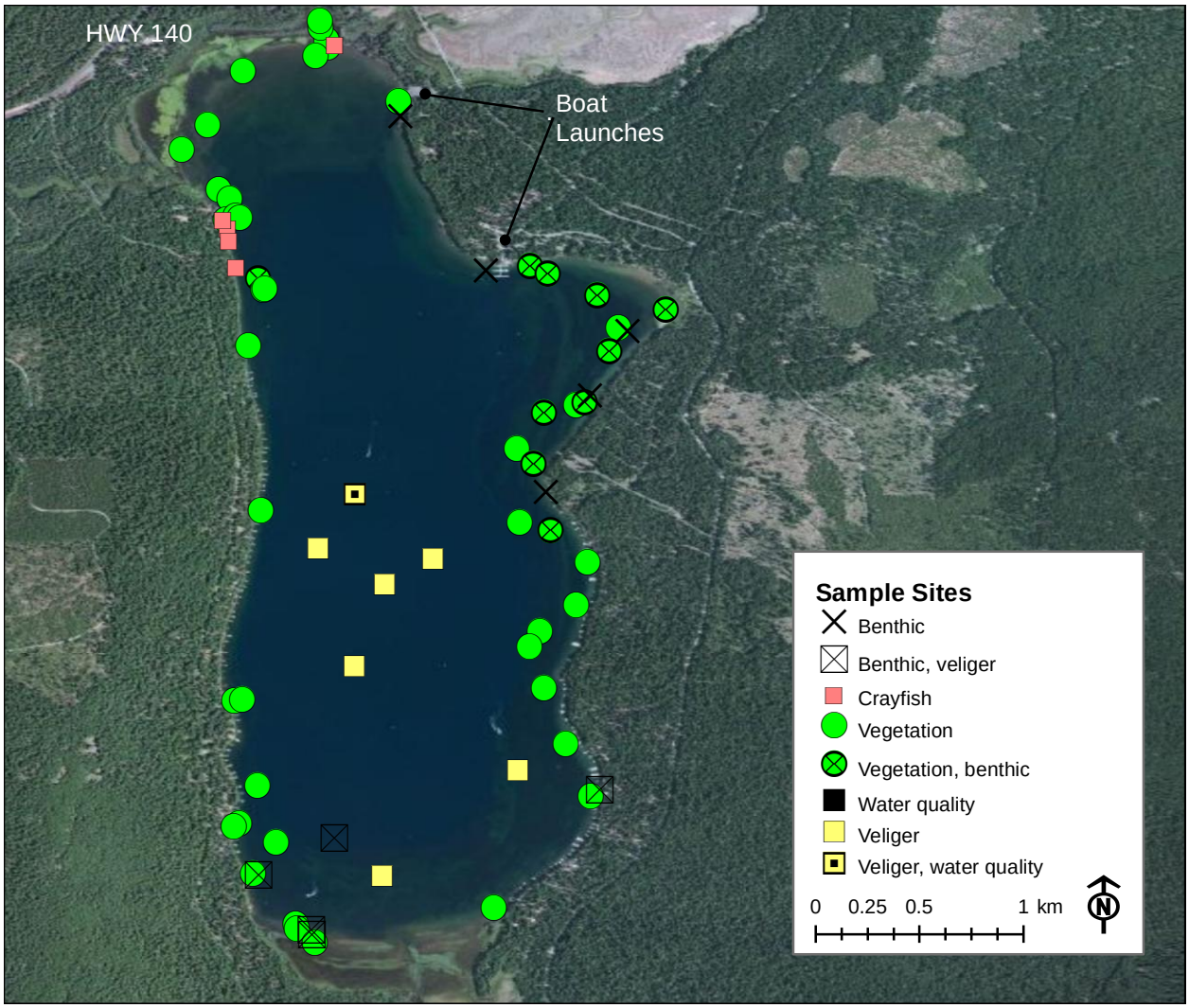

Figure 3. Lake of the Woods sample sites.

Gastropods and adult bivalves. Twenty benthic or vegetation samples were sieved for gastropods and adult bivalves in Lake of the Woods (Figure 3). A single bladder snail species (*Physidae sp.*) was collected from one site. No other species were detected.

Bivalve velgers. Fifteen bivalve veliger tows were collected from 12 Lake of the Woods sites (Figure 3) and composited into three sample bottles. A total of approximately 22 m^3 of water was sampled. No bivalve veligers were detected in the concentrated samples.

Crayfish. No crayfish were collected with the traps deployed at five sites in Lake of the Woods (Figure 3). One signal crayfish (*Pacifastacus leniusculus*), a native species, was collected by hand near the Lake of the Woods Resort boat launch at the north end of the lake.

Water quality. Lake of the Woods temperatures were isothermal at approximately 23˚C down to a depth of 6 m (

Table 5). Dissolved oxygen concentrations were at saturation and pH was slightly basic in the isothermal layer. A metalimnetic maximum in dissolved oxygen saturation indicated higher algal and macrophyte production at the thermocline. Oxygen concentrations dropped considerably in the hypolimnion and were nearly anoxic at 16 m. Specific conductivity was low throughout the water column. Secchi disk transparency was 8.4 m (28 ft) at 10:50 am.

Table 4. Lake of the Woods aquatic vegetation collected August 16 through 17, 2012.

Species	Growth form	% presence (50 sites)	Status	Notes
Potamogeton amplifolius	submersed	58	Native	
Potamogeton robbinsii	submersed	34	Native	
Potamogeton gramineus	floating leaf	30	Native	
Nitella sp.	submersed	22	Likely native	Non-native *Nitella sp.* have not been recorded in the PNW
Eleocharis acicularis	submersed	22	Native	
Elodea canadensis	submersed	22	Native	
Brasenia schreberi	floating leaf	22	Native	
Sagittaria sp.	floating leaf	16	Unknown	small floating leaves, fleshy rosette of leaves in deep water, no flowers
Isoetes sp.	submersed	16	Likely native	Non-native *Isoetes sp.* have not been recorded in the PNW
Najas flexilis	submersed	12	Native	
Utricularia vulgaris ssp. macrorhiza	submersed	12	Native	
Nuphar polysepala	floating leaf	10	Native	
Sparganium sp.	floating leaf	8	Likely native	Possibly *S. natans*
Ranunculus flammula var. reptans	submersed	8	Native	
Schoenoplectus subterminalis	floating leaf	8	Native	Rare species (OBIC 2010)
Carex sp.	emergent	6	Likely native	Not a shoreline survey target AIS sp.
Small spiky green plant	submersed	6	Unknown	Possibly *Myriophyllum sp.*
Scirpus sp.	emergent	6	Likely native	Not a shoreline survey target AIS sp.
Eleocharis sp.	emergent	4	Likely native	Not a shoreline survey target AIS sp.
Utricularia intermedia	submersed	4	Native	
Poacea sp.	floating leaf	2	Likely native	Possibly *Glyceria borealis*
Utricularia minor	submersed	2	Native	Rare species (OBIC 2010)
Lemna sp.	floating leaf	2	Likely native	Probably *Lemna minor*

Table 5. Water quality profile measured in Lake of the Woods on August 17, 2012.

Depth (m)	Temp. (˚C)	Sp. Cond. (µS/cm)	pH (S.U.)	D.O. (mg/l)	D.O. (% sat.)
0.1	22.8	29	7.68	7.26	100.8
1.0	22.8	29	7.65	7.26	100.8
2.0	22.7	29	7.67	7.30	101.4
3.0	22.6	29	7.68	7.35	101.7
4.0	22.5	29	7.68	7.35	101.8
5.0	22.5	29	7.68	7.37	101.8
6.0	22.3	29	7.68	7.42	102.0
7.0	21.2	28	7.69	7.65	102.9
8.0	19.4	27	7.75	8.58	111.8
9.0	17.4	27	7.76	9.37	116.6
10.0	12.7	26	7.73	10.43	117.5
11.0	10.7	26	7.68	10.54	112.9
12.0	9.8	26	7.44	8.34	87.3
13.0	9.0	26	7.11	5.60	57.5
14.0	8.6	27	6.87	3.83	39.1
15.0	8.4	28	6.70	1.84	18.7
16.0	8.2	31	6.62	0.78	7.9

Upper Klamath Lake

Aquatic plants. Aquatic plants were surveyed at 51 locations in Upper Klamath Lake on August 15 and 16, 2012 (Figure 4). Plants were present at 92% of the sites surveyed and density varied considerably across sites. Twenty two species were collected, 18 of which were submersed or floating leaf species, and none were known AIS (Table 6). Three of the submersed and floating leaf specimens could not be identified to species due to a lack of mature morphological characteristics. Identification unknown species, however, was narrowed down to a selection of native species. The shoreline emergent plants collected did not include any ODA listed species.

Gastropods and adult bivalves. Seventeen benthic or vegetation samples were sieved for gastropods and adult bivalves in Upper Klamath Lake (Figure 4). No suspected AIS were collected. A high diversity of gastropods (relative to the other survey lakes) was collected including bladder snails (family *Physidae*), ramshorn snails (family *Planorbidae*) and gilled snails (sub class *Prosobranchia*). At least one pea clam species (*Sphaeriidae sp.*) was also collected.

Bivalve velgers. Two bivalve veliger tows were collected from Upper Klamath Lake and composited into one sample bottle on August 15, 2012 (Figure 4). CLR staff collected an additional 38 tows from 24 sites in Upper Klamath Lake on July 24, 2012 (Steve Wells, CLR, unpublished data). No bivalve veligers were detected in any of the samples.

Crayfish. No crayfish were collected with the traps deployed at five sites in Upper Klamath Lake (Figure 4).

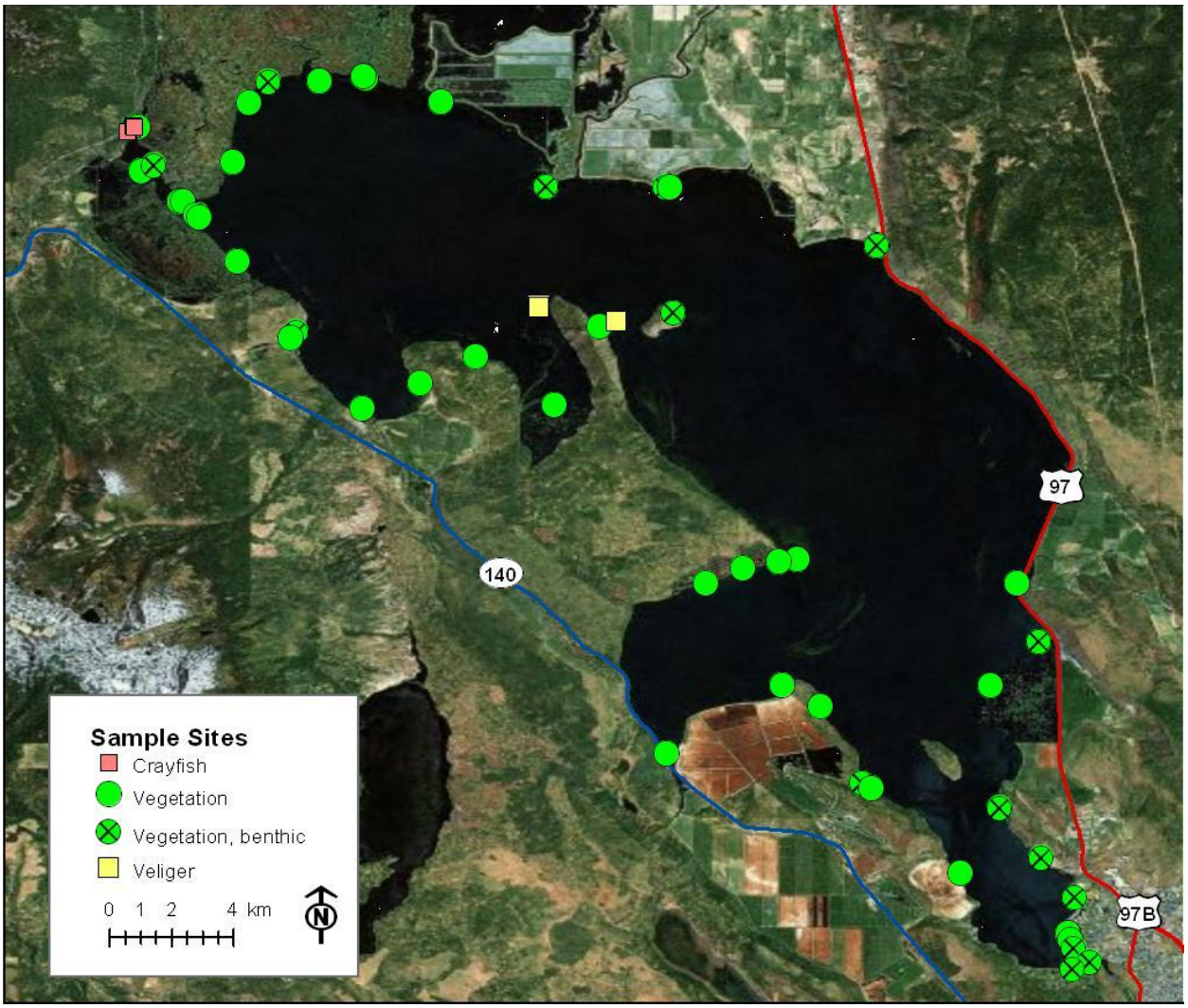

Figure 4. Upper Klamath Lake sampling sites.

Table 6. Aquatic plants collected from Upper Klamath Lake on August 15 and 16, 2012.

Species	Growth form	% presence (51 sites)	Status	Notes
Schoenoplectus tabernaemontani	emergent	51	Native	
Potamogeton richardsonii	submersed	33	Native	
Potamogeton pusillus	submersed	27	Native	
Elodea canadensis	submersed	24	Native	
Typha latifolia	emergent	14	Native	
Myriophyllum sibiricum	submersed	14	Native	
Nuphar polysepala	floating leaf	10	Native	
Ceratophyllum demersum	submersed	10	Native	
Sagittaria sp.	emergent	6	Likely native	Probably *S. cuneata*
Lemna sp.	floating	6	Likely native	Probably *L. minor*
Ranunculus aquatilis var. diffusus	submersed	6	Native	
Fontinalis antipyretica	submersed	6	Native	
Utricularia vulgaris ssp. macrorhiza	submersed	4	Native	
Chara sp.	submersed	4	Likely native	Non-native *Chara sp.* have not been recorded in the PNW
Potamogeton crispus	submersed	4	Native	
Spirodela polyrrhiza	floating	4	Native	
Eleocharis acicularis	submersed	2	Native	
Potamogeton natans	floating leaf	2	Native	
Lemna trisulca	floating	2	Native	
Hipparus vulgaris	emergent	2	Native	
Stuckenia pectinata	submersed	2	Native	
Potamogeton sp.	submersed	2	Native	*P. pusillus* or *P. foliosus*

Discussion

No AIS plants were detected in the three lakes, which is somewhat surprising due to the presence of several invasive aquatic plants in other lakes in southwest Oregon. For instance, curly leaf pondweed (*Potamogeton crispus*) and an invasive watermilfoil hybrid (*Myriophyllum spicatum x sibiricum*) are abundant in Howard Prairie Lake which is located just 12 miles southwest of Lake of the Woods (Sytsma et al. 2011). The *M. spicatum x sibiricum* hybrid is especially threatening since it may be even more invasive and less sensitive to herbicides than the invasive, non-hybrid *M. spicatum* (Larue et al. 2012).

Several plant specimens were not identified to species. Most of the specimens, however, belong to genera (e.g. *Chara sp*., *Nitella sp*., and *Isoetes sp*.) that do not have AIS species in the Pacific Northwest. Others are emergent shoreline species (e.g. *Carex sp.*) rather than the submerged species this survey was focused on or any of the ODA class "A" or "B" designated noxious weeds.

The submersed rosette-leaf forming *Sagittaria sp.* encountered in relatively deep waters of Lake of the Woods and Fourmile Lake should be monitored for flowers to aid in identification to species. The specimens encountered did not fit any of the available keys, however, *Sagittaria sp.* are notoriously plastic in their morphological features. The small stature *Myriophyllum sp.* collected from Lake of the Woods also failed to fit into any of the available keys. Fresh new specimens should be collected and submitted for genetic identification.

AIS invertebrates are also present in nearby lakes but were also not detected in the three lakes sampled. Big-eared radix snails (*Radix auricularia*) are in several waterbodies in the Umpqua National Forest (Kipp et al. 2013) and New Zealand mudsnails are present in the Rogue River downstream of Medford (Benson 2011). Zebra mussels (*Dreissena polymorpha*) are present in central California (Benson et al. 2013a) and quagga mussels (*Dreissena bugensis*) are present southern Nevada and California (Benson et al. 2013b), but have not been detected in the Northwest (Steve Wells, Portland State University, personal communication).

Invasive crayfish are present in several nearby waterbodies (Pearl et al. 2011) including ringed crayfish (*Orconectes neglectus*) in Little Hyatt Reservoir which is less than 20 miles southwest of Lake of the Woods (Center for Lakes and Reservoirs, unpublished data). Detection probabilities are low, however, at population densities that are common in other Northwest lakes (Larson and Olden 2012).

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