



Inventory and Mapping of Aquatic Plants at Lake Roosevelt National Recreation Area

Natural Resource Report NPS/UCBN/NRTR-8008/076



ON THE COVER

Aquatic plant bed in Lake Roosevelt National Recreation Area

Image source: Ray Dashiell, National Park Service

Inventory and Mapping of Aquatic Plants at Lake Roosevelt National Recreation Area

Natural Resource Report NPS/MWR/HTLN/NRTR—2008/076

Mark Sytsma and Rich Miller
Portland State University
Center for Lakes and Reservoirs
PO Box 751
Portland, Oregon 97207

January 2008

U.S. Department of the Interior
National Park Service, Natural Resource Program Center
Fort Collins, Colorado

The Natural Resource Publication series addresses natural resource topics that are of interest and applicability to a broad readership in the National Park Service and to others in the management of natural resources, including the scientific community, the public, and the NPS conservation and environmental constituencies. Manuscripts are peer-reviewed to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and is designed and published in a professional manner.

The Natural Resources Technical Reports series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service's mission. The reports provide contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations. Current examples of such reports include the results of research that addresses natural resource management issues; natural resource inventory and monitoring activities; resource assessment reports; scientific literature reviews; and peer reviewed proceedings of technical workshops, conferences, or symposia.

Views, statements, findings, conclusions, recommendations and data in this report are solely those of the author(s) and do not necessarily reflect views and policies of the U.S. Department of the Interior, NPS. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

Printed copies of reports in these series may be produced in a limited quantity and they are only available as long as the supply lasts. This report is also available from the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM>) on the Internet or by sending a request to the address on the back cover.

Please cite this publication as:

Sytsma, M. and R. Miller 2008. Inventory and Mapping of Aquatic Plants at Lake Roosevelt National Recreation Area. Natural Resource Technical Report NPS/UCBN/NRTR-2008/076. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures	iv
Tables	v
Introduction.....	1
Methods	1
Site Selection and Treatment Plot Description.....	1
Sampling Strategy and Data Management.....	4
Results	6
Discussion.....	8
Recommendations	11
Literature Cited	13

Figures

Page

Figure 1. Location of Lake Roosevelt macrophyte treatment plots in the mainstem Columbia River reservoir (East and West Hanson Harbor) and the Spokane River arm (Porcupine Bay, Riverview Courts, and Moccasin Bay).....	2
Figure 2. USGS reservoir elevation data, aquatic vegetation growth zone, and treatment and sampling periods.	3
Figure 3. Random sampling points in aquatic macrophyte treatment plots.....	5
Figure 4. Wet macrophyte weight per sample at control plot sites in the Aquatic Vegetation Growth Zone (1260-1280 ft elevation).....	7
Figure 5. Wet weight of macrophytes by depth for samples collected from Spokane arm (left) and mainstem (right) reservoir sites.	7
Figure 6. Macrophyte biomass (left) and occurrence (right) at Spokane River arm reservoir sites..	9
Figure 7. Macrophyte biomass (left) and occurrence (right) at Columbia River mainstem reservoir sites.	10
Figure 8. Macrophyte species composition by site and treatment.....	11

Tables

Page

Table 1. Lake Roosevelt aquatic plant treatment location, size, and timing.....	3
Table 2. Percent abundance and corresponding assignments to NPS abundance categories of macrophytes species encountered in the AVGZ (1260 to 1280 ft elevation) during August 2007.	6
Table 3. Q values for Dunn’s multiple comparison test of wet weight per sample between control plots.	7

Introduction

Lake Roosevelt is a large reservoir in northeast Washington State formed by the Grand Coulee Dam. The reservoir, which inundates portions of the Columbia River, the Spokane River, and other rivers and streams, is the focus of the Lake Roosevelt National Recreation Area (LARO) that is managed by the National Park Service. LARO encompasses 100,390 acres (40,625 ha) and includes significant cultural and recreational resources. The surface area, volume, and shoreline length of Lake Roosevelt at full pool is 82,691 acres (33,490 ha), 9.41×10^{10} acre-ft (1.16×10^{10} m³) (Nigro et. al. 1981), and 630 miles (1014 km) (www.lrf.org/AboutLR/ALR-FastFacts.html accessed 28 January 2008), respectively; thus, the reservoir provides a significant aquatic resource for fish and wildlife as well as recreation in the region.

Invasive plants are a high-priority “vital sign” of LARO ecosystem health (Garret et. al. 2007). In recent years, LARO staff noted an increase in the density of submersed aquatic plants (macrophytes), including *Myriophyllum spicatum* (Eurasian watermilfoil), in the lake. *M. spicatum* is a highly invasive weed that forms dense surface mats that interfere with boating and angling and degrade water quality. In an effort to reduce recreational impacts of aquatic plants LARO staff established test plots of nonchemical methods of control during the drawdown period in the spring of 2007.

The National Park Service contracted Portland State University Center for Lakes and Reservoirs to accomplish two main objectives: 1) document the effects of nonchemical control measures of submersed aquatic plants in the reservoir, and 2) describe the composition of the aquatic plant community at selected locations in LARO.

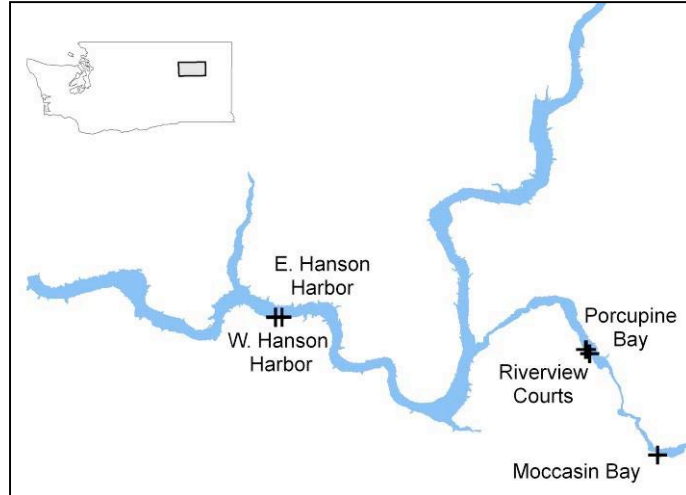
Methods

Site Selection and Treatment Plot Description

Macrophyte treatment plots were placed at five sites in LARO (Figure 1). Three sites were located in the Spokane River arm of the reservoir (Porcupine Bay, Moccasin Bay, and Riverview Courts) and two in the Columbia River mainstem of the reservoir (East and West Hanson Harbor). Sites were chosen by resource management staff at LARO based on:

- the potential of submersed aquatic plants to impede visitor use and safety
- high numbers of plants inventoried by LARO staff during the 2005 and 2006 seasons
- comments on problematic areas by park visitors, and
- ease of access during treatment and monitoring periods.

Figure 1. Location of Lake Roosevelt macrophyte treatment plots in the mainstem Columbia River reservoir (East and West Hanson Harbor) and the Spokane River arm (Porcupine Bay, Riverview Courts, and Moccasin Bay).



Treatments were administered to de-watered areas during low-water elevations in the spring (Table 1). Treatments included:

- cultivation
- application of forced heat
- solarization through application of black plastic
- solarization through application of clear plastic
- placement of a benthic barrier within the bathing zone at Porcupine Bay, and
- no-treatment control

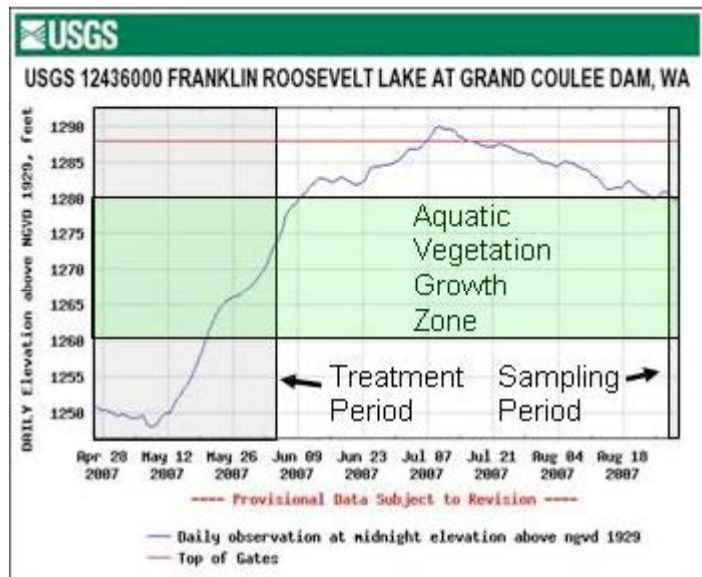
Cultivation involved pulling a rototiller behind a tractor to uproot plants to a depth of approximately four inches. The forced-heat treatment involved pumping steam beneath tarps on the soil surface for two to three hours to heat the soil to a depth of two to four inches. The gas permeable AquaScreen-brand benthic barrier was applied in the swimming area of Porcupine Bay. It is commonly used to remove or prevent submersed plant growth in small areas around docks and swimming beaches. Solarization involved placing heavy black or clear plastic on the soil surface for approximately one month. The purpose of the plastic was to kill any vegetation underneath through trapping heat. Black plastic and control treatment plots were placed at all sites while other treatments were placed at a subset of the sites.

Table 1. Lake Roosevelt aquatic plant treatment location, size, and timing.

Site	Treatment	Area (m ²)	Treatment Period	Sampling Date
East Hanson Harbor	Control	711	Control	8/29/07
East Hanson Harbor	Black Plastic	372	4/27/07 - 5/24/07	8/29/07
West Hanson Harbor	Control	665	Control	8/29/07
West Hanson Harbor	Black Plastic	329	4/27/07 - 5/24/07	8/29/07
West Hanson Harbor	Cultivation	265	5/08/07	8/29/07
West Hanson Harbor	Forced Heat	44	5/25/07	8/29/07
Porcupine Bay	Control	929	Control	8/28/07
Porcupine Bay	Black Plastic	401	4/26/07 - 5/24/07	8/28/07
Porcupine Bay	Clear Plastic	126	4/26/07 - 5/24/07	Not sampled
Porcupine Bay	Cultivation	1080	5/08/07	8/27/07
Porcupine Bay	Forced Heat	111	5/07/07	Not sampled
Porcupine Bay	Benthic Barrier	222	5/22/07 up to 7 yr	Not sampled
Riverview Court	Control	921	Control	8/27/07
Riverview Court	Black Plastic	702	5/01/07 - 5/24/07	8/27/07
Moccasin Bay	Control	986	Control	8/28/07
Moccasin Bay	Black Plastic	1455	4/26/07 - 5/24/07	8/28/07
Moccasin Bay	Homeowner Black Plastic	877	5/06/07 - 6/04/07	8/28/07
Moccasin Bay	Forced Heat	186	5/09/07	Not sampled

All treatment plots were located within the depth range identified by LARO staff as the aquatic vegetation growth zone (AVGZ) (Figure 2). This zone corresponded to an elevation range from 1260 ft (384 m) to 1280 ft (390 m) above sea level, the range at which water depth is shallow enough for light to reach the sediment, yet deep enough to remain watered during the growing season. LARO staff created control plots during the treatment, however, PSU established control plots that spanned the AVGZ depth strata. In addition, PSU sampled a strata 10 feet (3.05 m) deeper than the maximum depth of the AVGZ to characterize any low-light, deep water communities. The area of control plots created by PSU was the same at all sites to standardize the sampling area used for aquatic plant characterization. The LARO-staff created control plots were not sampled.

Figure 2. USGS reservoir elevation data, aquatic vegetation growth zone, and treatment and sampling periods.



Sampling Strategy and Data Management

Treatment and PSU-established control plots were sampled from August 27 to August 29, 2007 (Figure 3). Sampling of the plots was stratified by depth because depth is a fundamental factor in structuring the submersed plant community. Depth was stratified into the upper AVGZ: 1280 to 1270 ft (390.1 to 387.1 m); the lower AVGZ: 1270 to 1260 ft (390.1 to 384 m); and the 1260 to 1250 ft (384 to 381 m) strata. These elevation ranges corresponded to depth ranges of 0 to 10 ft, 10 to 20 ft, and 20 to 30 ft at a water surface elevation of 1280 ft. Only the control plots were within the 20 to 30-ft strata. The water surface elevation at Grand Coulee Dam was 1280.80 ft on August 27, 1280.21 on August 28, and 1279.58 on August 29 (<http://waterdata.usgs.gov/nwis>, accessed on 1/14/08).

Ten random sampling points were identified within each sampling strata of the black plastic, cultivation and control treatments using the Hawth Analysis Tools for ArcGIS (Beyer 2004). Points within 1 m of plot edges were excluded to avoid edge effects. Sampling points were also constrained to be greater than 9.8 to 16.4 ft (3 to 5 m) apart depending upon plot size. The constraint on proximity was required due to the resolution of the GPS and the difficulty of holding a position in the wind and current. The heat-treatment plot at West Hanson Harbor was small (10 x 40 ft) so samples were collected at ten haphazard points.

Following navigation to each sampling point using GPS, samples were collected by vertical insertion of a double-sided thatch rack attached to an extendable pole. The rake sampled an area of approximately 1.23 ft² (0.114 m²). Plants collected on the tines of the rake following retrieval with a twisting action were put in labeled plastic bags and stored on ice. Samples were weighed to the nearest tenth of a gram after removal of sediment and excess water by spinning the sample in a mesh bag. Samples were then sorted, identified to species, and percent of total biomass of each species within each sample was estimated. All data were recorded in waterproof field notebooks. All sample processing was completed within 24 hours of collection.

Samples were not collected from the Porcupine Bay heat treatment because the plot was above the 1280 foot elevation and therefore dewatered. Similarly much of the Porcupine Bay cultivation, clear plastic and black plastic plots were dewatered. Ten samples were collected from the cultivation plot; seven were collected from the black plastic plot; and none were collected from the clear plastic plot. Dewatering also affected four of the East Hanson Harbor control plot points, four West Hanson Harbor control plot points, and two of the Moccasin Bay black plastic points. Alternate samples were collected at points just off shore within these plots. Samples were not collected from the Moccasin Bay heat treatment because the location of the plot corners was not provided prior to the sampling event. The Porcupine Bay benthic barrier plot was not sampled because the barrier was disturbed prior to the sampling event.

The nonparametric Dunn's multiple comparison test was used to identify difference in biomass of control plots at the sampling sites.

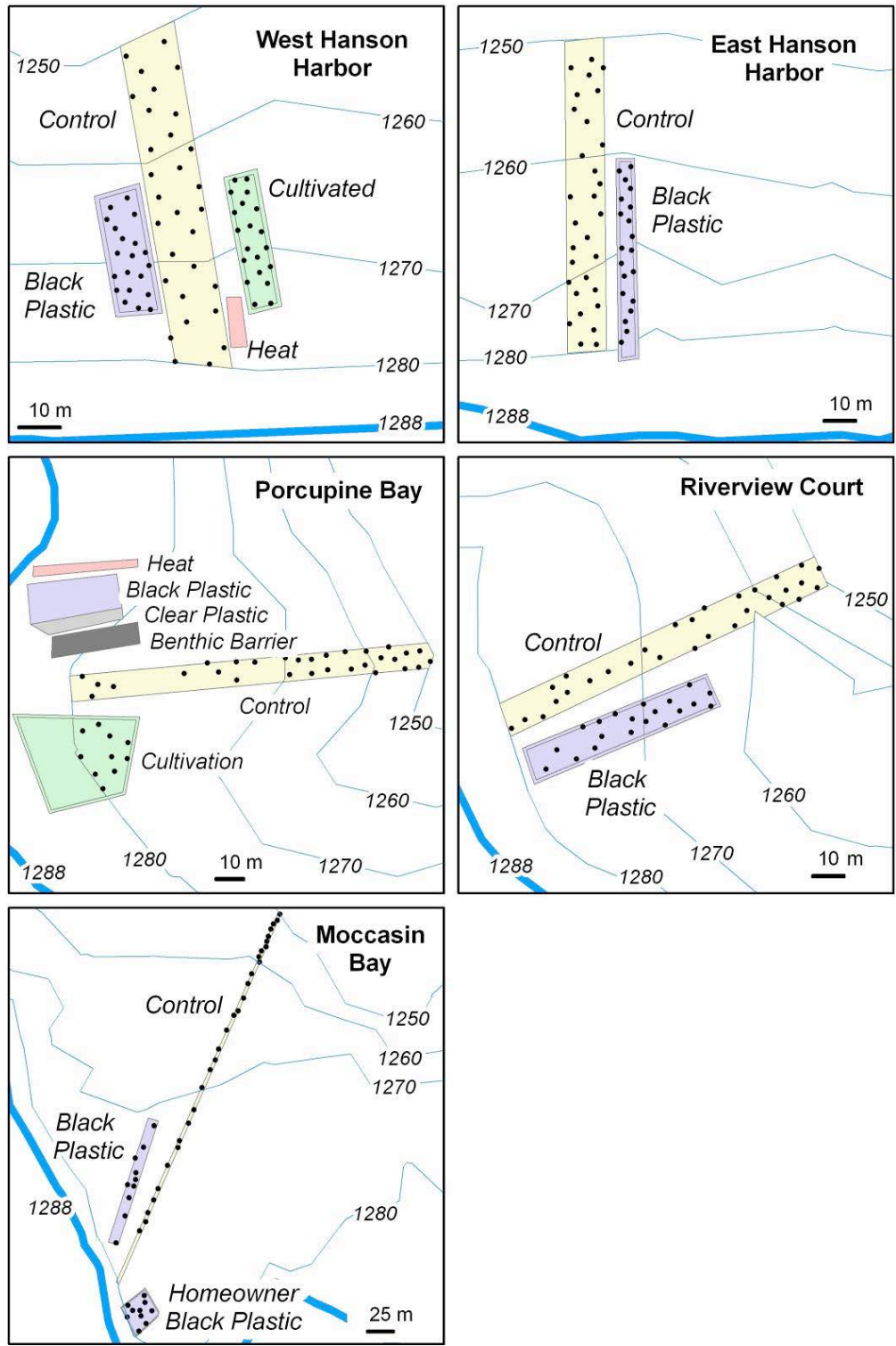


Figure 3. Random sampling points in aquatic macrophyte treatment plots. Contour elevations are in 10-foot intervals. Reservoir surface elevation ranged from 1280.8 ft to 1279.58 ft during sampling. Full pool elevation is 1288 ft.

Results

Eleven submersed aquatic plant species and one macroalgae species were encountered in the LARO plots (Table 2). One non-native species was encountered, *Myriophyllum spicatum*, and was classified as uncommon as it was present in only three percent of the samples collected.

Potamogeton richardsonii, *Najas flexilis*, *Potamogeton pusillus*, and *Potamogeton illinoensis* were the most common species present in the samples.

Table 2. Percent abundance and corresponding assignments to NPS abundance categories of macrophytes species encountered in the AVGZ (1260 to 1280 ft elevation) during August 2007.

Species	Percent of samples with species present	Abundance Category
<i>Potamogeton richardsonii</i> (Richardson's pondweed)	32	Abundant
<i>Najas flexilis</i> (Water naiad)	28	Abundant
<i>Potamogeton pusillus</i> (Narrow-leaved pondweed)	23	Abundant
<i>Potamogeton illinoensis</i> (Illinois pondweed)	22	Abundant
<i>Stuckenia pectinata</i> (Sago pondweed)	14	Common
<i>Ranunculus aquatilis</i> (Water buttercup)	7	Common
<i>Potamogeton sp.</i> (Narrow-leaved pondweed)	4	Uncommon
<i>Potamogeton sp.*</i> (Hybrid pondweed)	3	Uncommon
<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)	3	Uncommon
<i>Nitella sp.</i> (a macroalgae species)	2	Uncommon
<i>Elodea canadensis</i> (Canadian pondweed)	0.9	Rare
<i>Potamogeton epihydrus</i> (Ribbon-leaved pondweed)	0.5	Rare
Any species	58	-

*possible *P. richardsonii* x *P. praelongus* hybrid

Biomass of aquatic macrophytes in the control plots was highly variable (Figure 4). Porcupine Bay had the highest median biomass but it also had the highest variation. Biomass at the Hanson Harbor sites in the Columbia River was generally lower than at the sites located in the Spokane Arm, however, the difference was statistically significant only in comparison with the Porcupine Bay site (Table 3). No plants were detected growing on sediments at any site below an elevation of 1263.1 ft (385.0 m) or 17.7 ft (5.4 m) below the water surface elevation on the sampling date. Ninety-two percent of the total biomass was in samples collected from elevations greater 1268 ft (386.5 m). There was no clear effect of depth on sample biomass across the AVGZ at depths less than the maximum depth of colonization (Figure 3).

Figure 4. Wet macrophyte weight per sample at control plot sites in the Aquatic Vegetation Growth Zone (1260-1280 ft elevation). Boxes are the 25th to 75th percentile interquartile ranges of non-outlier samples, whiskers are ranges of non-outlier samples, horizontal lines are medians of non-outlier samples, circles are outliers between 1.5 and 3 box lengths outside the interquartile ranges, and asterisks are outliers greater than 3 box lengths outside the interquartile ranges.

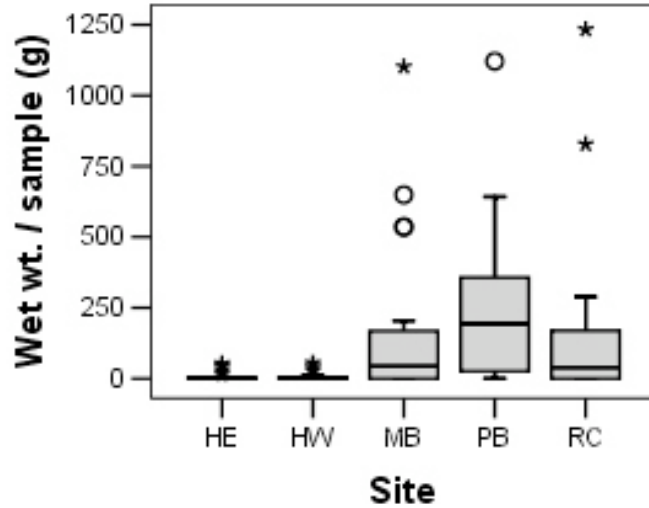


Table 3. Q values for Dunn's multiple comparison test of wet weight per sample between control plots. Only sites within the littoral zone were included in comparisons. Pairwise comparisons with Q values greater than 2.807 are significantly different at the 95% confidence level and are marked with asterisks.

	HE	HW	MB	PB	RC
HE	-	0.18	2.63	3.78*	2.52
HW	-	-	2.44	3.63*	2.34
MB	-	-	-	1.64	0.10
PB	-	-	-	-	1.72
RC	-	-	-	-	-

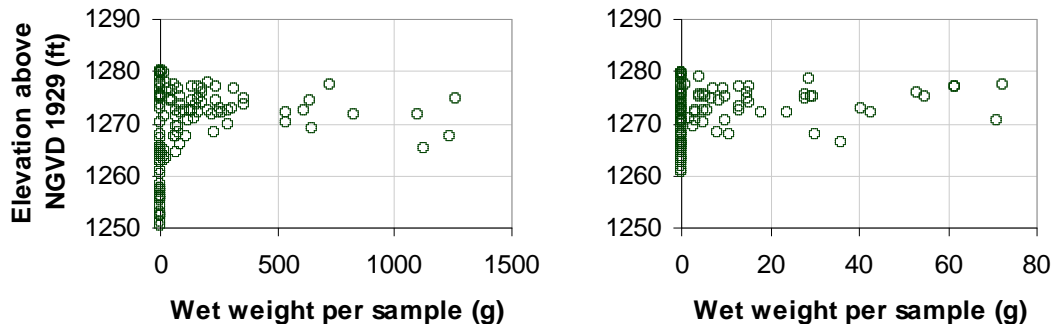


Figure 5. Wet weight of macrophytes by depth for samples collected from Spokane arm (left) and mainstem (right) reservoir sites. Note the different biomass scales.

The nonchemical treatments did not consistently impact biomass or species composition (Figures 6, 7, 8). The apparent reduction in biomass and the proportion of sampling locations with plants in the black plastic treatment in Porcupine Bay could be attributed to disturbance of the plot by swimmers. Rototilling may have enhanced habitat quality for *Ranunculus aquatilis* in Porcupine Bay but a similar effect was not seen in the rototilled plot at West Hanson Harbor. Rototilling appeared to have a negative impact on *Stuckenia pectinata* in West Hanson Harbor. The East

Hanson Harbor site contained a plant that appeared to be a hybrid between *P. richardsonii* and *P. praelongus* that was not present in any other sampling location.

Discussion

The most striking difference between macrophyte plots in LARO was the low macrophyte biomass at the Hanson Harbor sites compared to the Spokane Arm sites. The difference in biomass may be attributed to differences in sediment and water column chemistry. Sediments in the Hanson Harbor sites contained more gravel and less fine material than the Spokane Arm sites. Nutrient availability may limit biomass at Hanson Harbor. Aquatic macrophytes obtain most of the N and P required for growth from the sediments, and the gravelly sediments at Hanson Harbor are likely to contain lower N and P concentrations than the sediments in the Spokane Arm.

Potamogeton richardsonii, a native species, was the most common species encountered in AVGV of LARO in 2007. It comprised a major portion of the community biomass at all sites. *Potamogeton illinoiensis* was abundant at the Moccasin Bay and Hanson Harbor sites. *Stuckenia pectinata* was only abundant in the Moccasin Bay and Hanson Harbor sites.

The nonchemical control methods applied at LARO in 2007 did not have a consistent impact on macrophyte biomass or community composition. Cultivation appeared to enhance *R. aquatilis* at Porcupine Bay but not at Hanson Harbor, although the differences in sediment type and overall productivity between the two sites may have confounded the effect. Rototilling seemed to reduce *S. pectinata* in West Hanson Harbor. Given the high variability in biomass within and between sites, more replication of treatment plots would have aided in interpretation of the results.

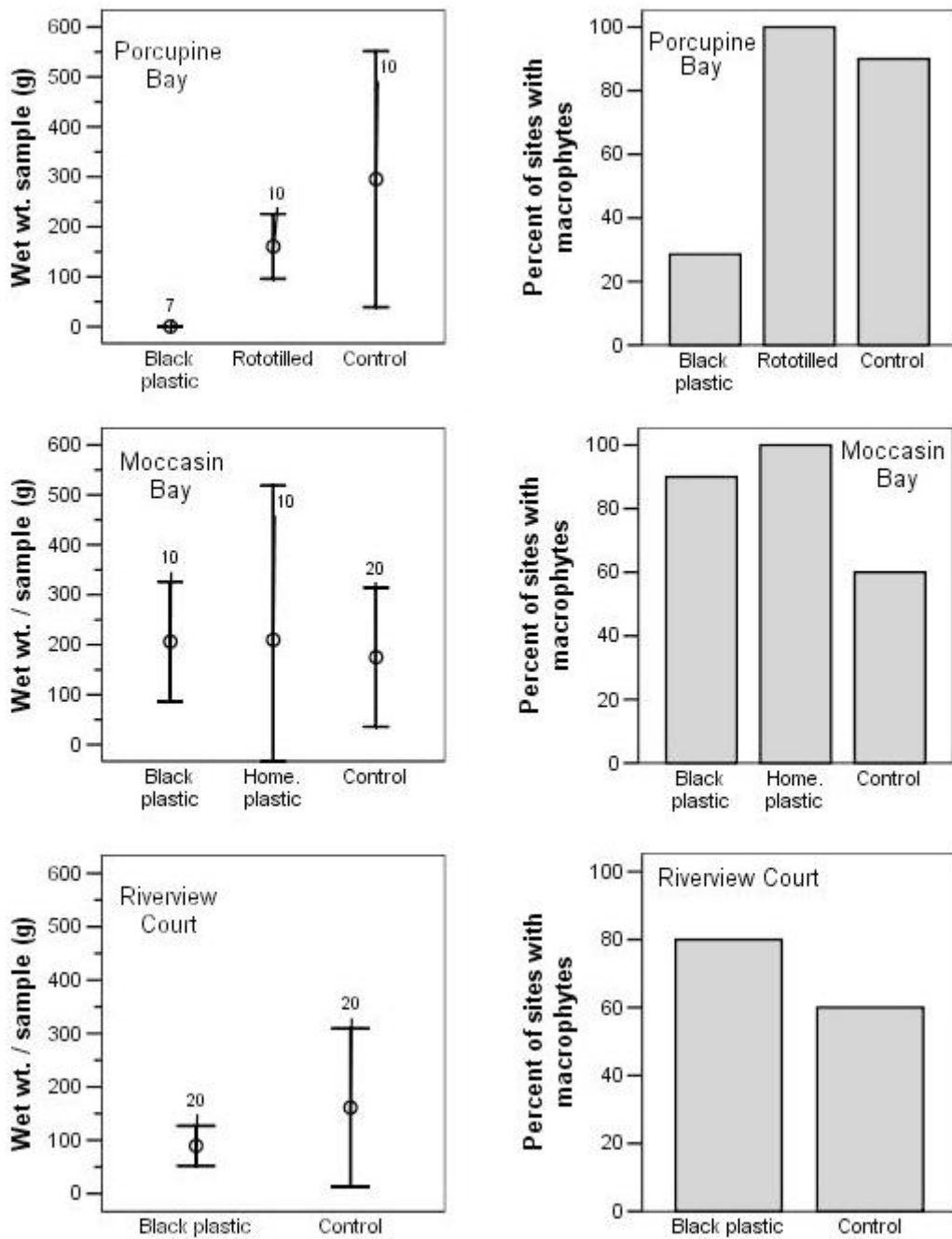


Figure 6. Macrophyte biomass (left) and occurrence (right) at Spokane River arm reservoir sites. Circles are mean wet weights per sample, whiskers are 95% confidence intervals, and numbers above whiskers are sample counts.

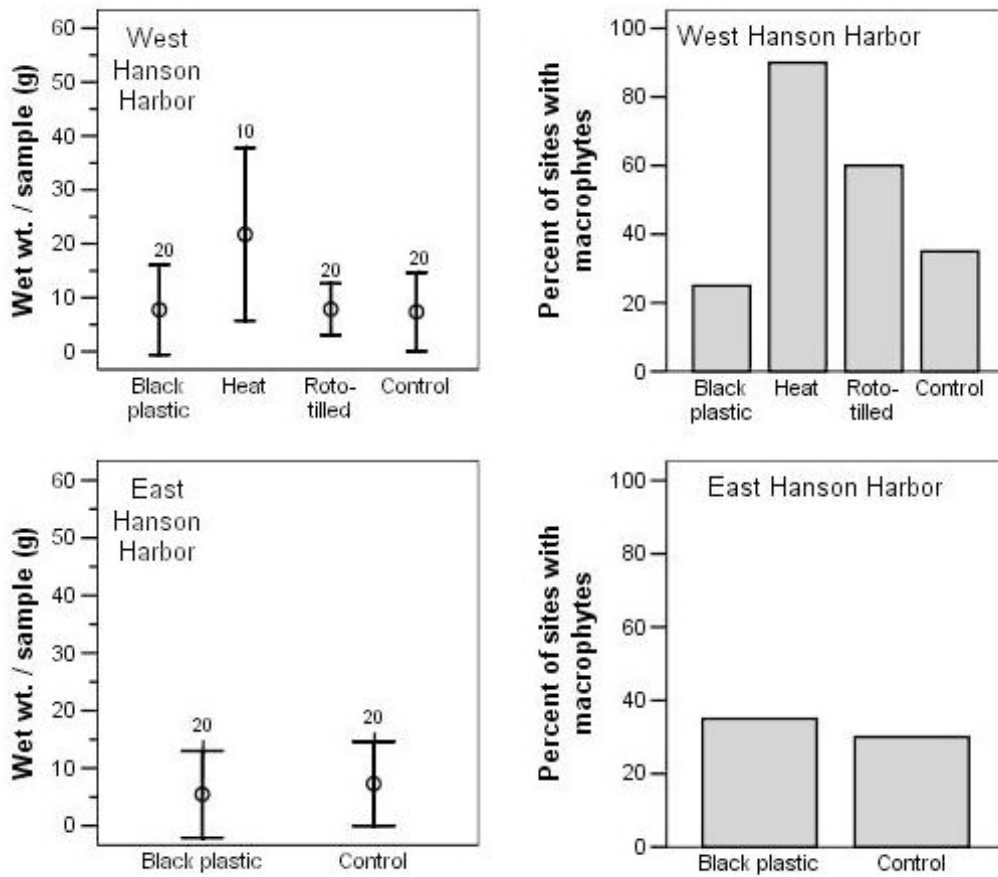


Figure 7. Macrophyte biomass (left) and occurrence (right) at Columbia River mainstem reservoir sites. Circles are mean wet weights per sample, whiskers are 95% confidence intervals, and numbers above whiskers are sample counts.

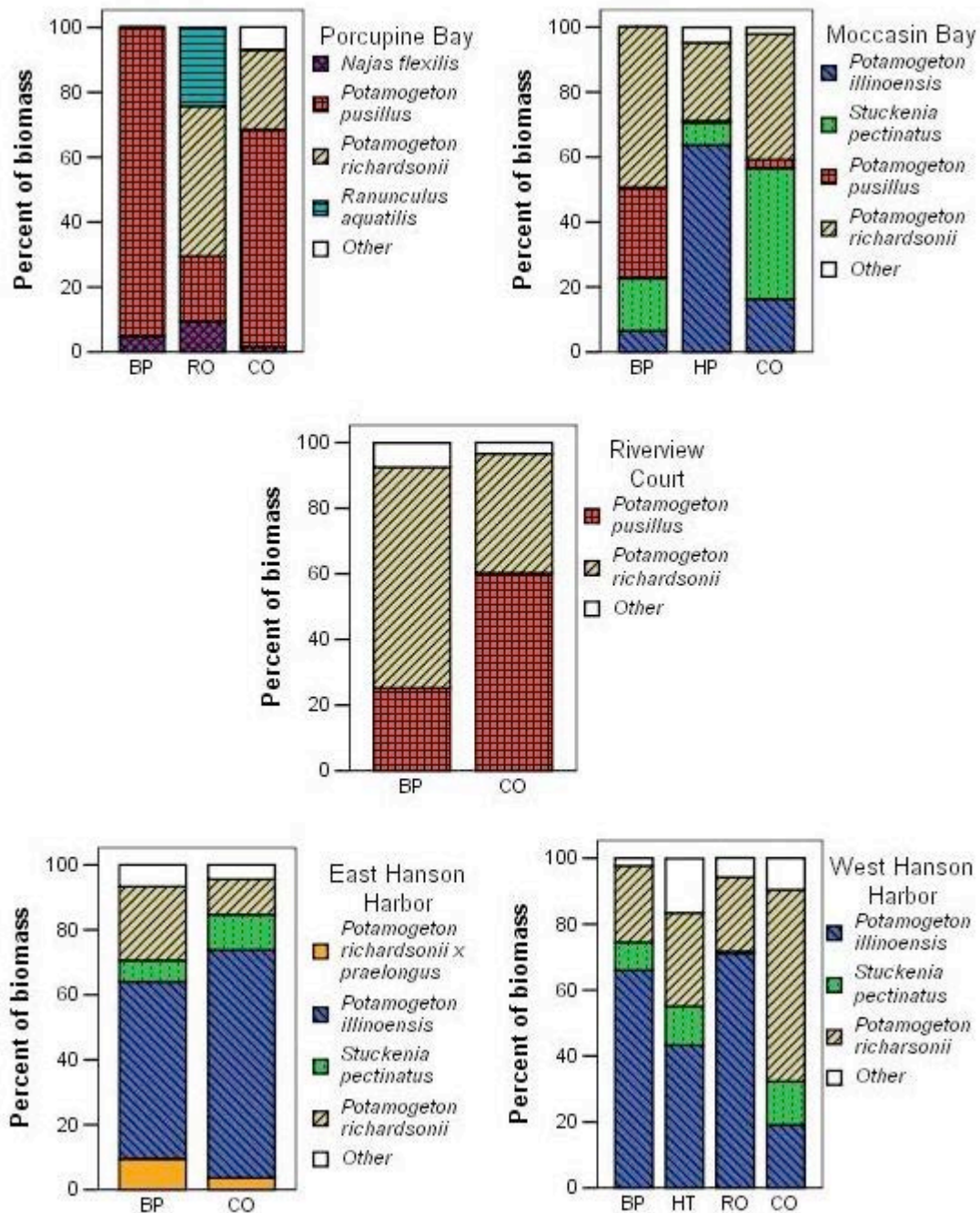


Figure 8. Macrophyte species composition by site and treatment.

Recommendations

Additional tests of methods to manage plant biomass during the drawdown period are recommended for 2008. Amendment of sediments with organic matter during winter drawdown was effective in reducing biomass of aquatic plants in irrigation canals the following summer (Sytsma and Parker 1999). Fluridone is an aquatic herbicide labeled for sediment application in

canals during drawdown. We recommend testing of sediment amendment and fluridone in LARO in 2008. Testing could be done at a single site where a large, relatively uniform bed of macrophytes provides an opportunity for replication of treatments and minimizes variation introduced by differences between locations in LARO.

We recommend testing the efficacy of fluridone applied at a rate of 2 lb a.i./acre. Fluridone would be applied to 5, 50 ft x 50 ft plots during drawdown. An Experimental Use Permit from EPA may be required for this use of fluridone.

Wheat straw should be used in the sediment amendment experiment because of its local availability. Straw should be chopped and incorporated into the sediment with a rototiller. Treatments should include cultivation only, cultivation + 125 lbs straw, and cultivation + 250 lbs straw. Each treatment should be replicated 5 times in 50 x 50 ft. plots.

Five control plots would also be established for comparison with the fluridone, organic matter, and cultivation treatment plots. Treatment and control plots would be randomly assigned to the 50 x 50 ft plots. The 25 experimental plots should be established as soon as possible during the spring drawdown period. Plots should not be contiguous; they should be separated from each other by a minimum of 25 ft. All treatments (control, cultivation, cultivation+125 lb. straw, cultivation + 250 lb straw, 2 lb fluridone/acre) should be randomly assigned to the plots.

Fluridone concentration and organic matter concentration in the respective treatment and control plots should be determined prior to rewatering by collecting two cores from each plot. Fluridone analysis can be conducted by SePRO corporation (Tyler Koschnik, SePRO Corp., personal communication). Sediment organic matter content should be determined by loss on ignition.

In late summer 2008 the plots should be sampled for biomass using a random, point-sampling procedure as was used in 2007. In addition, cores should be collected for determination of organic matter and fluridone concentration in the sediments, as was done in the spring prior to rewatering.

Literature Cited

- Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at <http://www.spataleecology.com/htools>.
- Garrett, L.K., T.J. Rodhouse, G.H. Dicus, C.C. Caudill, and M.R. Shardlow. 2007. Upper Columbia Basin Network Vital Signs Monitoring Plan. Natural Resource Report NPS/UCBN/NRR-2007/002. National Park Service, Fort Collins, Colorado.
- Nigro, A. A., T. T. Terrell and L. G. Beckman. 1981. Assessment of the Limnology and Fisheries of Lake F. D. Roosevelt. Annual Report. 1981. Prepared by U. S. Fish and Wildlife Service, Seattle National Fisheries Research Center, Grand Coulee Substation, for U. S. Bureau of Reclamation. 97 pp.
- Sytsma, M.D. and M. Parker. 1999. Aquatic Vegetation Management in Irrigation Canals. Prepared for Oregon Department of Agriculture and the US Environmental Protection Agency. Center for Lakes and Reservoirs, Portland State University. 51 pp.
- Wheater, P. and P.A. Cook. 2000. Using statistics to understand the environment. Routledge, London, 246 pp.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS D-128, January 2008

**National Park Service
U.S. Department of the Interior**



Natural Resource Program Center

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nps.gov

EXPERIENCE YOUR AMERICA™