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PEND OREILLE RIVER FISHERY/ROTOVATION STUDY

by
Randy Coots
Barbara Carey

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Surface Water Investigations Section
Olympia, Washington 98504-8711

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ABSTRACT

The Washington State Department of Ecology conducted a survey on the Pend Oreille River to compare fish communities from a naturally weeded (non-rotovated) and trail-rotovated habitat. Differences could not be determined do to low numbers of fish. Water quality data from non-rotovated, trail-rotovated, totally rotovated and open water habitats were compared. Conductivity was higher and total P lower at totally rotovated and open water habitats versus non-rotovated and trail-rotovated habitats. Surface total P was significantly lower at the non-rotovated habitat. Plant biomass and taxonomic identification were determined from macrophyte samples. *Potamogeton zosteriformis, Myriophyllum spicatum* and *Elodea canadensis* dominated the plant community. Recommendations for future work are included.

1.0 INTRODUCTION

Eurasian water milfoil (*Myriophyllum spicatum*) has become a significant problem for environmental managers of the Pend Oreille River. It chokes shorelines and embayments along the river, interfering with recreation and other uses. This results in economic loss. Citizen concerns have grown over the water quality and recreational impacts on the river. A recent water quality study (Pelletier and Coots, 1990) indicated the proliferation of milfoil was a product of substrate nutrients as opposed to water column concentrations, so eradication by nutrient load reduction seems unlikely. Management strategies need to be tested to optimize the water resource and maximize the fishery while at the same time enhancing recreational benefits.

Rotovation has become the preferred method of managing milfoil in the Pend Oreille River. Questions regarding rotovation techniques versus fisheries resources need to be evaluated while at the same time allowing recreational use of littoral regions. Researchers on the Potomac River near Alexandria, Virginia (Kilgore *et al.*, 1989) sampled fish from three relative densities of aquatic plants. They collected nearly six times more fish (98,000 fish/hectare) with popnets in areas with intermediate plant densities of several co-dominant plant species, compared to areas with dense *Hydrilla sp.* (18,000 fish/hectare). Their findings suggest fish diversity (abundance, size and species richness) is greater in more diverse river habitats than in either dense macrophyte beds or areas with no plants.

2.0 OBJECTIVES

- Evaluate fish communities in two types of river habitat:
  a. Average density weed beds with milfoil present or dominant.
  b. Average density weed beds with similar amounts of milfoil through which trails were rotovated.

- Characterize water quality in the above two habitats plus completely rotovated and open-water sites.

3.0 METHODS

3.1 FISH SAMPLING

Popnet and electroshocking activities were led by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) and supported by Ecology and University of Idaho personnel. Fish were sampled the evenings of August 15 and 16 using modified popnets (Kilgore, *et al.*, 1989) and electroshocking at two premarked habitats. Each habitat area was roughly 1.25 acres; one was naturally weeded (non-rotovated) and the other trail-rotovated. These locations are shown on Figure 1. The trail habitat was rotovated three

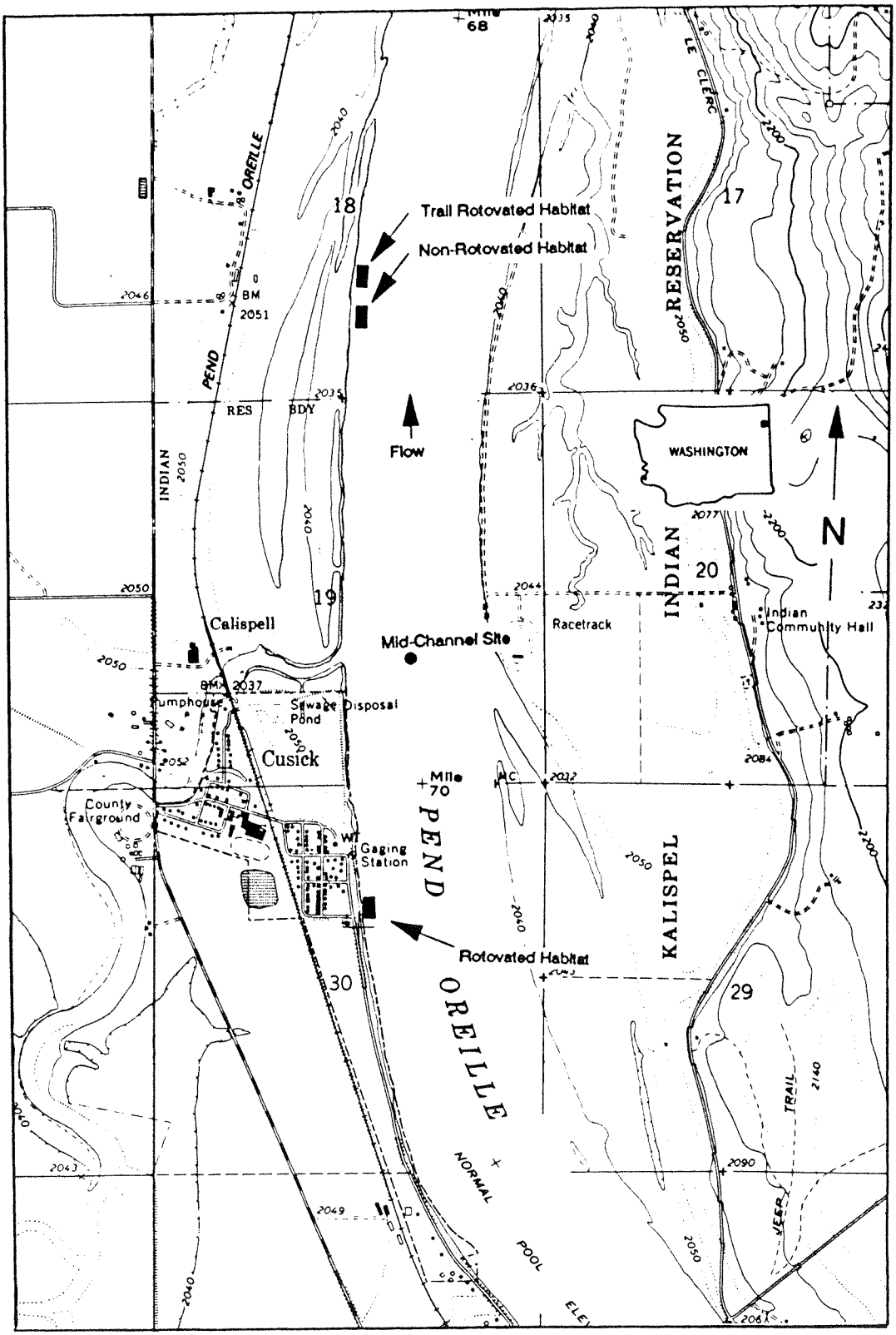

Figure 1. Habitat and Water Quality Sampling Locations.

weeks prior to sampling by the Pend Oreille County Planning Department's "Aquamog" rotovator. Survey design called for strip rotovation in alternating lanes with a naturally weeded strip then a totally rotovated strip, of the same size, then naturally weeded and so on, to maximize habitat diversity. Site preparation to this detail was precluded by limits on rotovator control imposed by sediment disturbance, wind and current. Figure 2 shows the trail-rotovated habitat; a trail about one-third the width of the test plot was rotovated. The trail was cut parallel to the shore. Popnets were used to sample fish inside the non-rotovated and trail-rotovated habitats at depths ranging from three to ten feet. Electroshocking was conducted along plant bed edges to increase capture efficiency of more mobile adult fish. Both techniques were employed to maximize the capture of all sizes and species.

Six popnets were set at each site on successive afternoons, two each in three, seven and nine feet of water. Fish sampling began approximately one hour after sunset. One popnet from the 9-foot depth at each habitat failed to release, resulting in a total sample number of five per site. A ten-foot seine was used to remove fish from the popnets. Electroshocking within popnets was necessary to ensure collection of all fish because of low seine recoveries.

All popnet samples were analyzed for species, size and fish density. Popnet data is expressed as mean fish density per 100 square feet.

Three electroshocking transects were used per habitat to collect fish along the plant bed edges. Approximately 250 seconds of shocking were used per transect. Electroshocking data is expressed as catch-per-unit-effort (CPUE).

3.2 WATER QUALITY SAMPLING

Representative water quality parameters (Table 1) were sampled at four sites: the two habitats previously described; a habitat rotovated the year before; and an open water site (Figure 1). Surface and bottom grab samples were collected early morning and mid-afternoon using a Van Dorn sampler and analyzed for total P, soluble reactive P (SRP), nitrate+nitrite N, ammonia N and turbidity. Field measurements included temperature, pH, conductivity and dissolved oxygen.

Samples for laboratory analysis were placed on ice and shipped by bus to the Ecology/EPA Environmental Laboratory in Manchester, Washington. Laboratory staff then transported the samples to AmTest Inc. of Redmond, Washington, for analysis. Sample containers, processing, and analysis conformed to EPA (1983) and APHA *et al.* (1985).

Table 1. Summary of Sampling and Analytical Methods for the Pend Oreille River Survey, August 1989.

Parameter	Analytical Method	Method Reference*
Temperature	Mercury Thermometer	--
pH	Field Probe	SM 423
Sp. Conductance	Field Probe	SM 205
Dissolved Oxygen	Azide Modification	SM 421B
Turbidity	Nephelometer	SM 214A
Total P	Ascorbic Acid, Persulfate Digestion	EPA 365.3
SRP	Ascorbic Acid	EPA 365.3
Nitrate+Nitrite-N	Cadmium Reduction	EPA 353.2
Ammonia-N	Phenate	EPA 350.1
Plant Biomass	Muffle Furnace	SM 1004 D

* SM: Standard Methods for the Examination of Water and Wastewater, 16th ed., APHA-AWWA-WPCF, 1985.

EPA: Methods for the Chemical Analysis of Water and Wastes. EPA 600/4-79-020. 1983.

3.3 PLANT BIOMASS

A total of 30 aquatic plant samples were collected during peak biomass (August) from the previously rotovated, trail-rotovated and non-rotovated habitats. Water depth ranged from five to 12 feet. A scuba diver collected all plants within a one-foot^2 frame from ten randomly selected sites within each habitat type. Grids showing locations of samples within habitats are featured in Figure 2.

The diver broke the plants off at the sediment-water interface. Whole plants were then placed in a bucket, brought to the surface, bagged, labeled and put on ice. Samples were analyzed for dry weight and ash-free dry weight (Table 1). Two samples from each habitat were also sorted by species. Dry weight and ash-free dry weight were determined by species. WATER Environmental Services, Inc., Bainbridge Island, Washington, analyzed the samples.

3.4 STATISTICAL METHODS

Appendix A gives the methods and results of statistical comparisons. Systat and Sygraph software were used for all graphical and statistical analyses. If necessary, data were transformed to approximately normal distributions. Differences between populations were determined using analysis of variance (ANOVA). Data which could not be transformed to a normal distribution were analyzed using Kruskal-Wallis or Mann-Whitney U tests, which are nonparametric equivalents of ANOVA and the two sample t-test, respectively. Tests for statistically significant differences were based on the confidence level of $P = 0.05$. Values below analytical detection limits were assumed to equal one-half the detection limit.

4.0 RESULTS AND DISCUSSION

4.1 FISH

Table 2 shows the results from fish collection. Eleven species with a total of 198 fish were collected by popnets and electroshocking. Five species accounted for 88% of the total catch. Pumpkinseed sunfish were most abundant, followed by yellow perch, largescale sucker, tench and largemouth bass.

There was no statistically significant difference between the non-rotovated and trail-rotovated habitats for popnet total fish density. Six species were collected in popnets with the majority being juvenile (Kilgore, 1989). Abundance, size and species richness were similar between the two popnet habitats. One exception was an adult largescale sucker found in the trail habitat. Another exception were tench the most abundant small fish, found only in the non-rotovated habitat. It appears this species uses the dense aquatic plant beds as a rearing area.

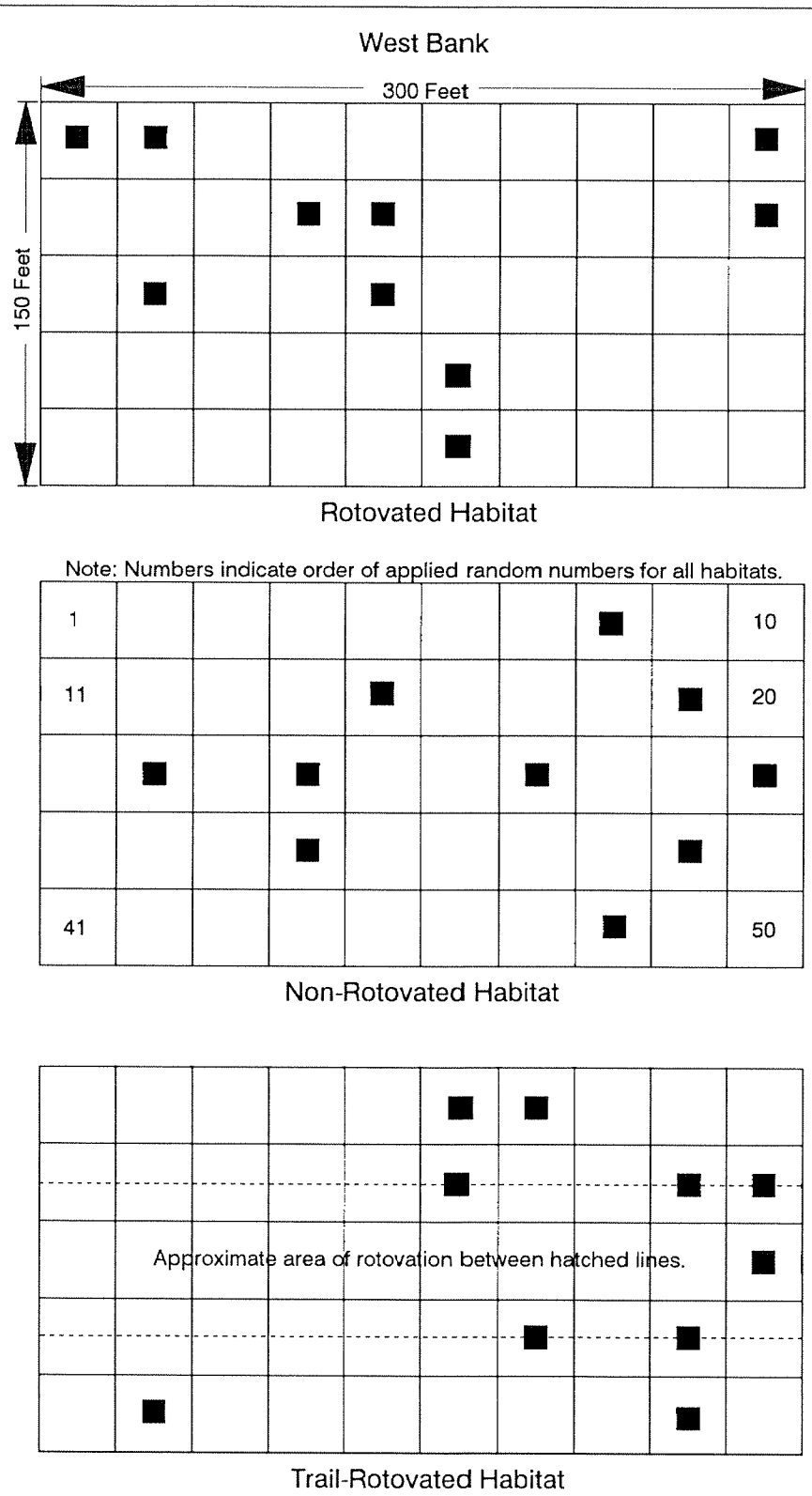

Figure 2. Aquatic Plant Sample Locations By Habitat for the Pend Oreille River Survey of August 9, 1989

Table 2. Results of Fish Collected in the Pend Oreille River and their Abundance in Trail-Rotovated and Non-Rotovated Habitats, August 15-16, 1989.

Species	Total Number Collected	Range of Total Length(mm)	Fish Density			
			Trail-Rotovated		Non-Rotovated	
			PN(1)	ES(2)	PN	ES
Salmonidae						
Mountain whitefish (*Prosopium williamsoni*)	4	254	0	0.3 ± 0.6	0	0.3 ± 0.6
Cyprinidae						
Peamouth (*Mylocheilus caurinus*)	1	-	0	0.3 ± 0.6	0	0
Northern squawfish (*Ptychocheilus oregonensis*)	5	40-304	0	0.7 ± 0.6	0	0.3 ± 0.6
Tench (*Tinca tinca*)	20	30-310	0	0.3 ± 0.6	2.0 ± 2.3	0.3 ± 0.6
Catostomidae						
Longnose sucker (*Catostomus catostomus*)	2	381-609	0	0	0	1.3 ± 0.6
Largescale sucker (*Catostomus macrocheilus*)	25	360-620	0.2 ± 0.4	4.0 ± 1.7	0	5.0 ± 1.0
Ictaluridae						
Brown bullhead (*Ictalurus nebulosus*)	3	140-220	0	0.7 ± 0.6	0	0
Centrarchidae						
Largemouth bass (*Micropterus salmoides*)	12	50-180	0	0.2 ± 0.4	0.2 ± 0.4	1.0 ± 0.0
Pumpkinseed (*Lepomis gibbosus*)	74	30-127	3.0 ± 1.2	3.7 ± 0.6	3.8 ± 2.8	2.7 ± 1.1
Black crappie (*Pomoxis nigromaculatus*)	9	95-152	0.2 ± 0.4	0.3 ± 0.6	0	1.7 ± 1.1
Percidae						
Yellow perch (*Perca flavescens*)	43	101-127	0.6 ± 0.5	2.0 ± 1.0	0	1.7 ± 0.6
Total number of fish	198	-	4.0 ± 1.7	13.0 ± 2.0	6.2 ± 4.8	14.7 ± 2.1

1) Densities in popnets (PN) expressed as number of fish/100 square feet (n=5). Values are mean ± 1 standard deviation.
2) Densities collected by electroshocking (ES) expressed as number of fish/250 seconds of shocking (n=3). Values are mean ± 1 standard deviation.

Electroshocking yielded 11 fish species. Community structure and CPUE was similar between trail-rotovated and non-rotovated habitats. Data from electroshocking were not used in subsequent analyses because electroshocking was done along plant bed edges only.

Fish sampling in the Pend Oreille River by popnets was found to be more difficult than in southern United States (U.S.) waterbodies. This was related to the lower numbers of fish present, greater plant density or possibly the predominant plant species, milfoil. Kilgore (personal communication, 1990) has collected greater than 50 fish/100 ft^2 in southern U.S. waterbodies. He has reported popnet surveys successfully sampling fish in the Potomac with plant biomass of 400 to greater than 1000 g/m^2 (Kilgore *et al.*, 1989), while this survey measured mean plant biomass at 2000 g/m^2 from the non-rotovated and 2600 g/m^2 from the trail-rotovated habitats.

This study found popnet fish densities from 4 to 6 fish/100 ft^2. Similar fish densities have been reported by Barber *et al.*, (1988). The Upper Columbia United Tribes (UCUT) Fisheries Center at Eastern Washington University conducted an assessment of fishery improvement opportunities in the Pend Oreille River. Fish were collected by beach seine from a littoral area of the mainstem one mile north of Cusick. Popnet density estimates were similar to beach seine estimates. They collected roughly 6 fish/100 ft^2 although methods, depth and location relative to plant beds differed.

The UCUT Fisheries Center has been conducting fishery surveys on the Pend Oreille for the past five years. UCUTS's Allen Scholz (personal communication) has suggested use of macrophyte beds by fish may be a function of flow. During high flows, fish may use the macrophytes to conserve energy by holding in the downstream fringes of the beds where velocity is reduced by the plants. During low flow, utilization of the macrophyte areas by fish may be less.

University of Idaho researchers (David Bennett, personal communication) have subsequently used popnets with success in eastern Washington's Long Lake. *Brasenia sp.*, a small water lily, was the dominant plant species. They collected 30 to 40 fish/100 ft^2. They also compared collection by popnet to localized rotenone application and found popnets to be more efficient in determining fish abundance and composition.

The physical character of milfoil and substrate modifications resulting from reduced velocity, sedimentation and decomposing plant fragments may render milfoil beds unattractive to fish populations. A study on Lake Opinicon, Ontario, comparing pre-milfoil to five years after colonization (Keast, 1984), found milfoil had a limited effect on fish density but some effects on distribution of various species. Significantly fewer prey invertebrates were found in milfoil stands compared to native macrophyte stands. He found three to six times more pumpkinseed, yellow perch and bluegill feeding in *Potamogeton spp.* stands than in milfoil, and fish collection was poorest in milfoil areas

during full plant growth. Keast reported juvenile *Lepomids* used milfoil as a rearing habitat, which was consistent with this study.

It may be that popnet efficiency in milfoil is low due to a restricted rise of the nets from entangled growth, or that the abundance of fish in milfoil during low flow and high plant biomass is less, or a combination of both. Either situation leaves the results of this fishery survey in question. Data from this survey should be viewed as a baseline for fish collection in macrophyte beds of the Pend Oreille. Additional studies using modified popnets in Pend Oreille milfoil beds are needed before any definite conclusions can be drawn from the fishery data generated from this study. However, popnets remain a promising tool in fish collection within macrophyte beds where other techniques are limited.

4.2 WATER QUALITY

The results of water quality analyses are presented in Appendix B and summarized in Table 3. River discharge was lower than normal during water quality sampling, averaging 13,800 cfs at Newport. For comparison, the August mean daily flow at Newport is 15,000 cfs (Williams and Pearson, 1985). Water temperatures ranged from 20.3 to 22.9 degrees C. The pH ranged from a low of 8.0 to a high of 9.6. Conductivity ranged from 135 to 159 umhos/cm, while dissolved oxygen fluctuated from 5.9 to 10.6 mg/L. Statistical comparison of habitats indicate they were similar for mean temperature, pH and dissolved oxygen. Conductivity in the rotovated and the open water habitats were significantly higher than the non-rotovated and trail-rotovated habitats (Figure 3).

Figure 3 illustrates conductivity values for the rotovated, non-rotovated, trail-rotovated and open water habitats using a notched box and whisker plot. A descriptive example of this type of plot is included in Figure 3. It displays the interquartile range of a ranked data set with the lower 25 percentile, median and upper 75 percentile values represented by the horizontal lines of the box respectively, while the extended vertical lines above and below the box are the maximum and minimum range. The notches radiating from the median correspond to its 95 percentile confidence intervals. Notches extending beyond the 25th and 75th percentiles of the data set give the box a folded appearance. If the notches of two boxes overlap, it indicates that medians are not significantly different. Conversely, if the notches do not overlap, medians are significantly different. Asterisks identify data outliers that are greater than 1.5 times the interquartile range.

Total P concentrations ranged from undetected at <5 μg P/L to 73 μg P/L, while SRP ranged from 1 to 6 μg P/L. Nitrate+nitrite N was generally undetected at <10 μg N/L. Ammonia N had only 8 of 36 values above the minimum detection of 5 μg N/L, with a maximum of 18 μg N/L.

Table 3. Summary of Water Quality Analysis from the Pend Oreille River Survey, August 1989.

Parameter	Units	Rotovated Mean	Rotovated S.D.	Non-Rotovated Mean	Non-Rotovated S.D.	Trailed* Mean	Trailed* S.D.	Open Water Mean	Open Water S.D.
Temperature	deg C	21.4	± 0.9	21.6	± 1.0	21.6	± 1.0	21.4	± 0.9
pH	Std Units	8.53	± 0.5	8.73	± 0.7	8.80	± 0.5	8.92	± 0.2
Conductivity (@ 25°C)	umho/cm	156	± 2.1	141	± 2.9	142	± 3.8	157	± 1.9
Dissolved Oxygen	mg/L	8.0	± 0.5	7.9	± 1.8	7.9	± 1.5	8.2	± 0.3
Turbidity**	NTU	1.2	± 0.8	2.6	± 2.5	1.6	± 1.3	0.4	± 0.07
Total P	ug P/L	5	± 2.7	32	± 24	15	± 7.3	<5	
SRP***	ug P/L	2	± 1.2	4	± 1.7	3	± 1.6	2	± 0.8
Nitrate+Nitrite N	ug N/L	<10		<10		<10		<10	
Ammonia N	ug N/L	<5		7	± 5.2	<5		<5	
Sample Size		8		8		16		4	

* Mean of 16 samples; 8 from the non-rotovated portion and 8 from the trailed portion.
** Turbidity sample sizes were 4, 2, 8, and 2, respectively (2 data outliers were rejected due to sampling error).
*** Soluble reactive phosphorus.

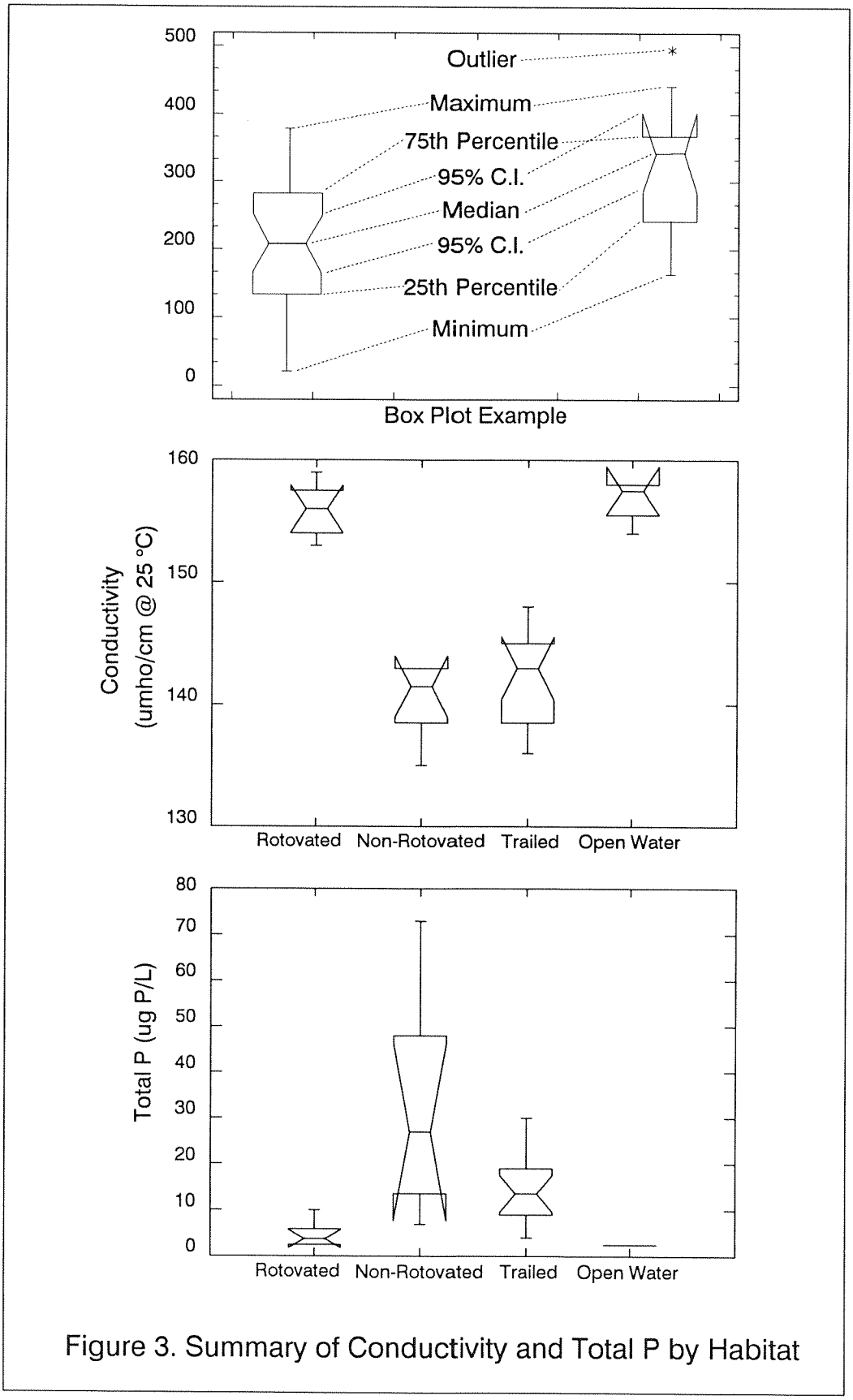

Figure 3. Summary of Conductivity and Total P by Habitat

Comparisons of mean nutrient concentrations by habitat indicate no significant differences for SRP and nitrate+nitrite N. The non-rotovated habitat had a significantly higher ammonia N than the rotovated or trail habitats, although results for ammonia N were generally below detection except from the non-rotovated site. The source of ammonia N in the non-rotovated habitat is likely anaerobic decomposition of sedimented plant fragments.

The non-rotovated and trail-rotovated habitat had significantly higher total P than the rotovated and open water habitats (Figure 3). The source of higher total P in the non-rotovated and trail-rotovated habitats may be a result of secretion of P by macrophyte shoots and/or decay of plant tissue. Shoot senescence may be a primary P source during the height of the growing season (Smith and Adams, 1986). Another P source within the macrophyte beds may be the metabolic processing of particulate P by epiphytes. Carignan and Kalff (1982) reported the P contribution by littoral epiphytes was greater than the contribution by shoot secretion and about the same as the contribution by shoot senescence.

There appears to be an inverse relationship between mean total P and conductivity within habitats (Figure 3). This may be explained by photosynthetic processes increasing pH leading to the formation of calcium carbonate, which co-precipitates phosphate (Otsuki and Wetzel, 1972). The removal of a major cation (Ca^{++}) thereby lowers the conductivity.

Large increases in pH can also result in aerobic release of sediment phosphorus by competition between hydroxyl ions and phosphate ions bonding on iron-hydroxyphosphate complexes at the sediment-water interface (Stumm and Morgan, 1981). Also, anomalous total P concentrations could have resulted from disturbance in dense weed beds during sample collection.

Mean surface P concentrations were compared to mean bottom concentrations within habitats (Figure 4). Surface total P was significantly lower than bottom concentrations at the non-rotovated habitat. This may be due to increased sedimentation of plankton, senescing plant fragments, precipitation of complex formations of major cations with phosphate anions (Wetzel, 1983) and/or solubilization of sediment phosphorus. Another source of P loading to bottom waters may be metabolic processing of particulate P by epiphytes associated with lower-stature macrophytes. In addition, agitation of macrophyte foliage during bottom sampling may have led to anomalous P concentrations, as discussed earlier.

Pooled surface and bottom data show significantly higher afternoon values for temperature, pH and dissolved oxygen from the rotovated, non-rotovated and trail-rotovated habitats (Figure 5). Additionally, results for temperature, afternoon pH and

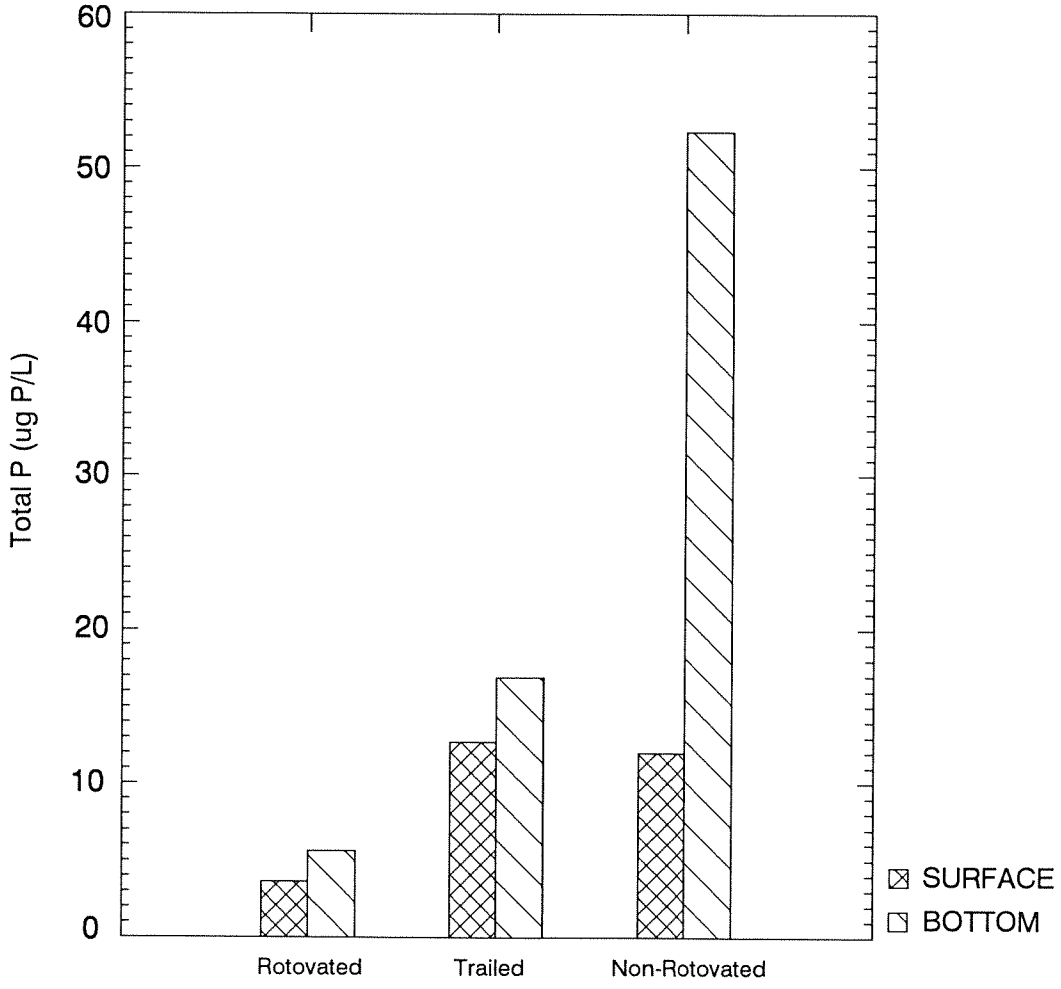

Figure 4. Mean Surface and Bottom Comparison by Habitat for Total P

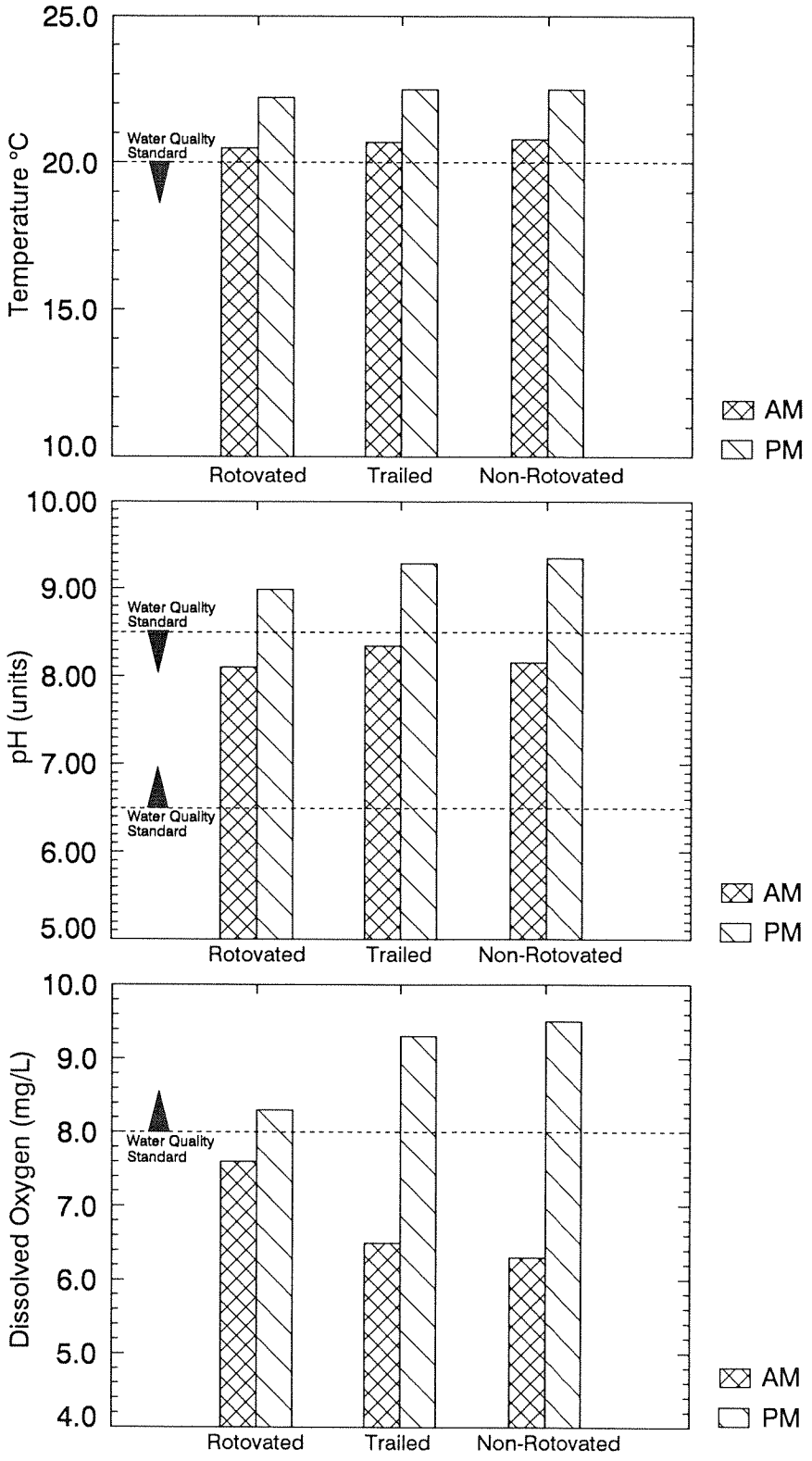

Figure 5. Diurnal Variation of Temperature, pH and Dissolved Oxygen Within Habitats From Pooled Data

morning dissolved oxygen were consistently beyond established water quality standards. The values for pH and dissolved oxygen are a by-product of photosynthesis, while higher temperature is due to solar warming.

Water quality data from the present study was generally comparable to August 1988 data (Pelletier and Coots, 1990), considering differences in sampling methods, locations and seasonal variation. Ammonia N, nitrate+nitrite N, SRP, temperature and pH were similar between the two years, as was total P, except for high values for bottom samples from the trail and non-rotovated habitats. Dissolved oxygen was slightly higher in August 1988 compared to August 1989. Conductivity in 1989 was about the same as in 1988 in rotovated and open water sites, and higher than trail and non-rotovated sites.

4.3 PLANT BIOMASS

Aquatic plant biomass results are contained in Table 4. Plant biomass varied between habitat types. Mean dry weight of plant biomass for the non-rotovated habitat was 1965 ± 1311 g/m^2, while the trailed habitat had 2638 ± 1758 g/m^2. The higher mean biomass density from the trail habitat was surprising but not significantly different what with sample to sample variation and predetermined random sample locations corresponding more to weeded areas of the habitat rather than the rotovated areas. Biomass results indicate only two of the ten samples were within the trailed portion.

Mean dry weight of plant biomass for the rotovated habitat was 997 ± 491 g/m^2, which was also higher than expected and reflects rapid recolonization over the previous year (Gibbons, personal communication).

Figure 6 shows mean plant biomass for dry weight and ash-free dry weight. Ash-free dry weight is a measure of the organic content of the plants, whereas dry weight is total organic plus inorganic content.

A total of six subsamples (two per habitat) from the 30 biomass samples were separated by species. There were five species identified from the subsamples. Based on dry weight of subsamples separated by species, total percent species composition for all sites were *Potamogeton zosteriformis* (51%), *Myriophyllum spicatum* (27%), *Elodea canadensis* (15%), *Ceratophyllum demersum* (6%) and *Myriophyllum exalbescens* (<1%). Earlier macrophyte composition and density work (WATER, 1986, 1987, 1988) in the vicinity of this survey found agreement in species composition, but biomass densities were much greater and *Potamogeton spp.* was much more dominant in this survey. Milfoil prevalence was lower than expected given that habitat selection was biased toward areas where milfoil appeared dominant. In fact, results indicate milfoil was only dominant at the surface, not below the canopy.

Table 4. Results of Aquatic Plant Biomass from Pend Oreille River Samples Collected August 8, 1989.

Sample Location(1)	Species(2)	Dry Wt (g/m^2)	AFDW(3) (g/m^2)	Notes(4)
Roto 1		1403.44		(MS<1%,CD,HD,EC,R)
Roto 2		449.73		(PZ,HD,EC,MEx,R)
Roto 10		1375.78		(MS<1%,PZ,PP,HD,EC70%,MEx)
Roto 14	MEx	26.16	19.10	
Roto 14	MS	53.61	41.38	
Roto 14	CD	65.12	55.71	
Roto 14	PZ	139.72	120.95	
Roto 14	EC	1423.25	1167.07	
Roto 15		1261.36		(MS<1%,PZ,HD,EC,MEx)
Roto 20		1392.47		(PZ,HD,EC,MEx,R)
Roto 22	MS	39.18	28.43	
Roto 22	CD	23.79	20.02	
Roto 22	EC	17.01	12.44	
Roto 22	PZ+HD	167.60	129.89	
Roto 22	MEx	20.45	12.27	
Roto 25		1084.50		(CD,PZ,EC,MEx)
Roto 36		695.37		(MS<1%,CD,HD,EC)
Roto 46		331.32		(HD+PR95%,EC)
Trail 6		2823.36		(MS99%,CD,PZ,HD)
Trail 7	EC	8.40	6.02	
Trail 7	CD	271.69	207.45	
Trail 7	PZ	2965.23	2624.63	
Trail 16	MS	1177.61	1065.20	
Trail 16	PZ+HD	211.63	191.20	
Trail 19		6530.36		(MS5%,PZ)
Trail 20		2414.42		(MS<1%,,CD,PZ)
Trail 30		280.52		(MS20%,CD,PZ)
Trail 37		803.77		(MS90%,CD,HD)
Trail 39		2948.44		(MS10%,PZ)
Trail 42		4476.86		(MS99%,PN)
Trail 49		1472.01		(MS99%,PZ)
Weeds 8		1698.28		(MS,CD,PZ95%)
Weeds 15	CD	13.99	10.67	
Weeds 15	MS	10.66	8.03	
Weeds 15	PZ	1040.69	898.48	

Table 4. (continued)

Sample Location(1)	Species(2)	Dry Wt (g/m^2)	AFDW(3) (g/m^2)	Notes(4)
Weeds 19		1753.61		(MS90%,CD,PZ)
Weeds 22		157.48		(MS,CD,PZ90%)
Weeds 24		1773.95		(MS90%,CD,PZ)
Weeds 27	PZ	462.43	417.68	
Weeds 27	MS	1390.64	1171.06	
Weeds 27	CD	218.95	179.92	
Weeds 30		4471.04		(MS20%,CD,PZ)
Weeds 34		4050.27		(MS,CD,PZ)
Weeds 39		2154.57		(MS60%,CD)
Weeds 48		453.93		(MS95%,CD)

1) Location of samples within each habitat are identified on the random number grid in Figure 2.
2) Legend of taxanomic identification:
   - CD = *Ceratophyllum demersum*
   - EC = *Elodea canadensis*
   - PZ = *Potamogeton zosteriformis*
   - MEx = *Myriophyllum exalbescens*
   - MS = *Myriophyllum spicatum*
   - HD = *Heteranthera dubia (tenta)*
   - PP = *Potamogeton pectinatus*
   - PN = *Potamogeton nodosus*
   - PR = *Potamogeton richardsonii*
   - R = *Ranunculus sp.*
3) AFDW = ash-free dry weight.
4) Visual estimates of sample species composition are by volume.

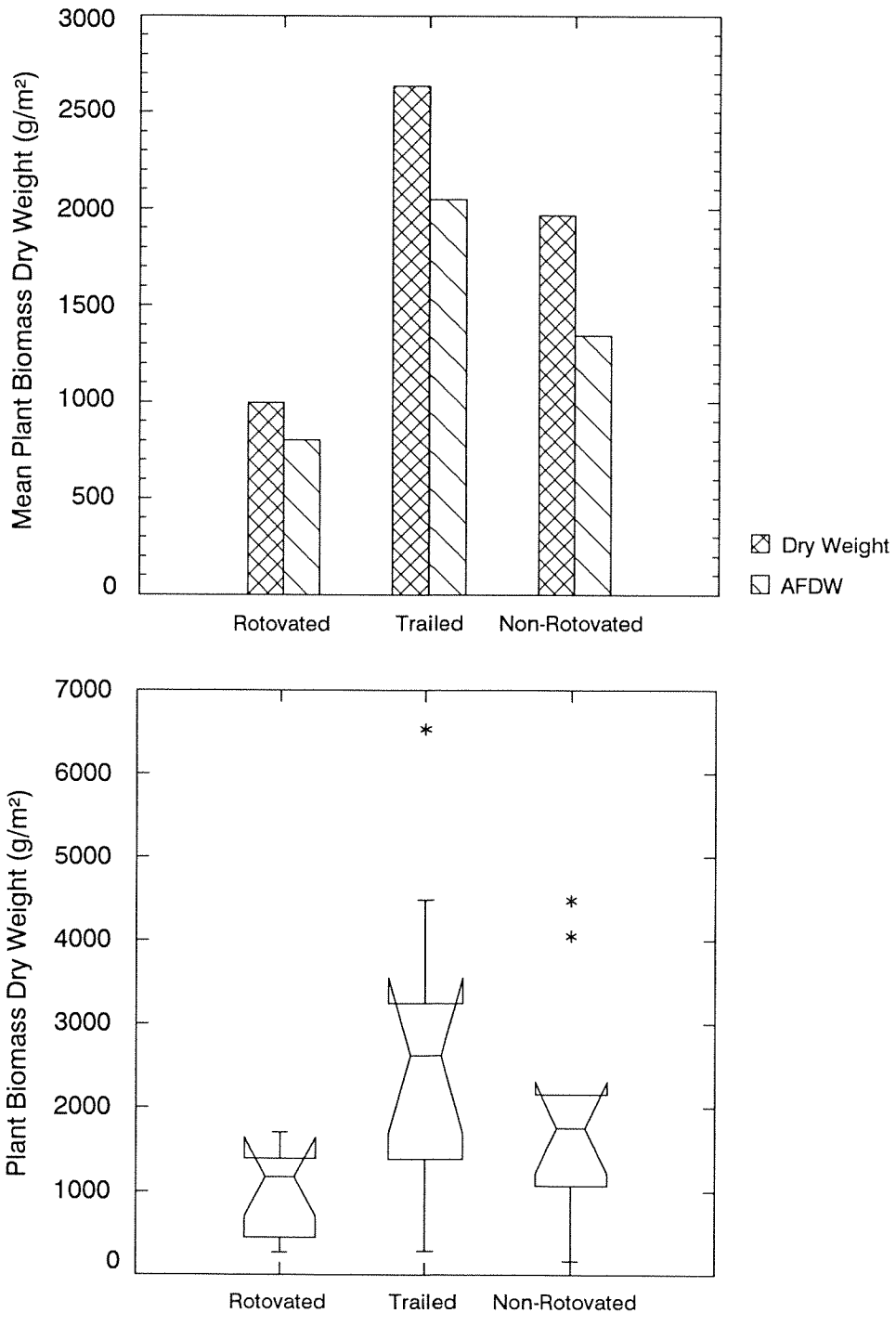

Figure 6. Summary of Aquatic Plant Biomass by Habitat

There were 10 species identified from all 30 biomass samples (Table 4). Based on dry weight of subsamples, the non-rotovated habitat was dominated by *Potamogeton zosteriformis* (48%) and *Myriophyllum spicatum* (45%). *Potamogeton zosteriformis* (69%) dominated the trail habitat, however percentages of *Potamogeton sp.* may have been biased because the rotovated strip occured at water depths generally occupied by milfoil. *Elodea canadensis* (73%) dominated the rotovated habitat. WATER (1988) identified *Myriophyllum exalbescens* as the dominant plant species in this same area in 1988. This high percentage of *Elodea sp.* in the habitat rotovated the year before may reflect short-term depression of *Myriophyllum spp.* by growth of other opportunistic plant species (e.g., *Elodea spp.*, *Potamogeton spp.*). Following rotovation in Lake Osoyoos, Washington, Gibbons *et al.* (1987) reported a short-term suppression in milfoil growth compared to a reference site. She also noted that Canadian researchers observed enhanced growth by non-target plant species following rotovation.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

- This survey was unable to effectively compare fish communities in the two habitat types due to low numbers of fish collected. High plant biomass and low numbers of fish made weedbed sampling in the Pend Oreille a difficult task. Popnets have been shown to be an effective tool for fish sampling in macrophyte beds, although other surveys have not reported plant biomass densities as great.

- There was no statistically significant difference between the non-rotovated and trail-rotovated habitats for total fish density; however, judgement on the lack of difference should be withheld pending future studies of popnet efficiency in dense macrophyte beds by other investigators.

- Morning dissolved oxygen was consistently below and afternoon pH consistently above established water quality standards in the rotovated, trailed and non-rotovated habitats. Morning and afternoon temperatures also exceeded standards.

- There appears to be an inverse relationship between mean total P and conductivity when non-rotovated and trail-rotovated habitats are compared to rotovated and open-water habitats. This is probably due to photosynthetic processes within macrophyte beds.

- Temperature, pH and dissolved oxygen from the rotovated, non-rotovated and trail-rotovated habitats were significantly higher in the afternoon. Higher afternoon values for pH and dissolved oxygen are a by-product of photosynthesis, while higher temperatures are a result of solar warming.

- Based on dry weight of subsamples, the non-rotovated habitat was dominated by *Potamogeton zosteriformis* (48%) and *Myriophyllum spicatum* (45%); the trail-rotovated habitat was dominated by *Potamogeton zosteriformis* (69%), possibly due to bias in the method of rotovation; and the rotovated habitat was dominated by *Elodea canadensis* (73%), which is an opportunistic species in rotovated beds.

- Based on subsamples separated by species, total percent composition for all sites was *Potamogeton zosteriformis* (51%), *Myriophyllum spicatum* (27%), *Elodea canadensis* (15%), *Ceratophyllum demersum* (6%) and *Myriophyllum exalbescens* (<1%).

5.2 RECOMMENDATIONS

- Future popnet sampling efforts in the Pend Oreille need to intensify sampling beyond that of this survey to obtain adequate sample sizes. Divers may be needed to assess in-situ effectiveness of popnets. It may be that further modifications are needed in popnet design or seining methods for use in dense milfoil beds. Increased flotation in the upper frame and additional weight in the lower frame may be needed to overcome gear entanglement in milfoil.

- Multiple sampling techniques are probably needed to characterize the species, sizes and distribution of fish associated with macrophyte beds dominated by milfoil.

- To maximize the use of the rotovator, trail-rotovation should be used rather than total clearing of areas, except where total rotovation is necessary (e.g., swimming areas, boat launches, highly visible areas, etc.). Trail-rotovation will improve the localized water quality associated with weedbeds, increase areal coverage and create boating channels for littoral access.

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APPENDICES

Appendix A. Summary of Statistical Comparisons.

Habitat	Treatments	Parameter	Sample Size Per Treatment	Transformation	Statistical Test	P Value
All Sites*	Habitat (4)	Temperature	8,8,16,4**	None	Kruskal-Wallis	P = 0.68
All Sites	Habitat (4)	pH	8,8,16,4	None	Kruskal-Wallis	P = 0.31
All Sites	Habitat (4)	Conductivity	8,8,16,4	Log 10	ANOVA	P < 0.01 ~
All Sites	Habitat (4)	Dissolved Oxygen	8,8,16,4	None	ANOVA	P = 0.98
All Sites	Habitat (4)	Total P	8,8,16,4	Log 10	ANOVA	P < 0.01 ~
All Sites	Habitat (4)	SRP	6,6,12,4	None	ANOVA	P = 0.21
All Sites	Habitat (4)	Ammonia N	8,8,16,4	None	Kruskal-Wallis	P = 0.025 ~
Non-Roto/Roto	Habitat (2)	Conductivity	8,8	Log 10	ANOVA	P < 0.01 ~
Non-Roto/Trail	Habitat (2)	Conductivity	8,16	Log 10	ANOVA	P = 0.19
Non-Roto/Mid	Habitat (2)	Conductivity	8,4	Log 10	ANOVA	P < 0.01 ~
Roto/Mid	Habitat (2)	Conductivity	8,4	Log 10	ANOVA	P = 0.68
Roto/Trail	Habitat (2)	Conductivity	8,16	Log 10	ANOVA	P < 0.01 ~
Trail/Mid	Habitat (2)	Conductivity	16,4	Log 10	ANOVA	P < 0.01 ~
Non-Roto/Roto	Habitat (2)	Total P	8,8	Log 10	ANOVA	P < 0.01 ~
Non-Roto/Trail	Habitat (2)	Total P	8,16	Log 10	ANOVA	P = 0.023 ~
Non-Roto/Mid	Habitat (2)	Total P	8,4	Log 10	ANOVA	P < 0.01 ~
Roto/Mid	Habitat (2)	Total P	8,4	Log 10	ANOVA	P = 0.20
Roto/Trail	Habitat (2)	Total P	8,16	Log 10	ANOVA	P < 0.01 ~
Trail/Mid	Habitat (2)	Total P	16,4	Log 10	ANOVA	P < 0.01 ~
Non-Roto/Roto	Habitat (2)	Ammonia N	8,8	None	Mann-Whitney U	P = 0.030 ~
Non-Roto/Trail	Habitat (2)	Ammonia N	8,16	None	Mann-Whitney U	P = 0.024 ~
Roto/Trail	Habitat (2)	Ammonia N	8,16	None	Mann-Whitney U	P = 0.92
Rotovated	Depth (2)	Temperature	4,4	None	Mann-Whitney U	P = 0.38
Rotovated	Depth (2)	pH	4,4	None	Mann-Whitney U	P = 0.77
Rotovated	Depth (2)	Conductivity	4,4	None	Mann-Whitney U	P = 0.24
Rotovated	Depth (2)	Dissolved Oxygen	4,4	None	Mann-Whitney U	P = 0.77
Non-Rotovated	Depth (2)	Temperature	4,4	None	Mann-Whitney U	P = 1.00
Non-Rotovated	Depth (2)	pH	4,4	None	Mann-Whitney U	P = 0.56
Non-Rotovated	Depth (2)	Conductivity	4,4	None	Mann-Whitney U	P = 0.77
Non-Rotovated	Depth (2)	Dissolved Oxygen	4,4	None	Mann-Whitney U	P = 0.24

Appendix A. (Continued).

Habitat	Treatments	Parameter	Sample Size Per Treatment	Transformation	Statistical Test	P Value
Trailed	Depth (2)	Temperature	8,8	None	Mann-Whitney U	P = 0.29
Trailed	Depth (2)	pH	8,8	None	Mann-Whitney U	P = 0.53
Trailed	Depth (2)	Conductivity	8,8	None	Mann-Whitney U	P = 0.92
Trailed	Depth (2)	Dissolved Oxygen	8,8	None	Mann-Whitney U	P = 0.96
Mid-Channel	Depth (2)	Temperature	2,2	None	Mann-Whitney U	P = 0.44
Mid-Channel	Depth (2)	pH	2,2	None	Mann-Whitney U	P = 1.00
Mid-Channel	Depth (2)	Conductivity	2,2	None	Mann-Whitney U	P = 0.68
Mid-Channel	Depth (2)	Dissolved Oxygen	2,2	None	Mann-Whitney U	P = 1.00
Rotovated	Depth (2)	Total P	4,4	None	Mann-Whitney U	P = 0.28
Rotovated	Depth (2)	SRP	3,3	None	Mann-Whitney U	P = 0.50
Rotovated	Depth (2)	Ammonia N	4,4	None	Mann-Whitney U	P = 0.32
Non-Rotovated	Depth (2)	Total P	4,4	None	Mann-Whitney U	P = 0.02~
Non-Rotovated	Depth (2)	SRP	3,3	None	Mann-Whitney U	P = 0.077
Non-Rotovated	Depth (2)	Ammonia N	4,4	None	Mann-Whitney U	P = 0.018~
Trailed	Depth (2)	Total P	8,8	None	Mann-Whitney U	P = 0.27
Trailed	Depth (2)	SRP	6,6	None	Mann-Whitney U	P = 0.57
Trailed	Depth (2)	Ammonia N	8,8	None	Mann-Whitney U	P = 0.93
Mid-Channel	Depth (2)	Total P	2,2	None	Mann-Whitney U	No Variance°
Mid-Channel	Depth (2)	SRP	2,2	None	Mann-Whitney U	No Variance°
Mid-Channel	Depth (2)	Ammonia N	2,2	None	Mann-Whitney U	No Variance°
Rotovated	Diurnal (2)	Temperature	4,4	None	Mann-Whitney U	P = 0.018~
Rotovated	Diurnal (2)	pH	4,4	None	Mann-Whitney U	P = 0.021~
Rotovated	Diurnal (2)	Conductivity	4,4	None	Mann-Whitney U	P = 0.028~
Rotovated	Diurnal (2)	Dissolved Oxygen	4,4	None	Mann-Whitney U	P = 0.018~
Non-Rotovated	Diurnal (2)	Temperature	4,4	None	Mann-Whitney U	P = 0.020~
Non-Rotovated	Diurnal (2)	pH	4,4	None	Mann-Whitney U	P = 0.021~
Non-Rotovated	Diurnal (2)	Conductivity	4,4	None	Mann-Whitney U	P = 0.018~
Non-Rotovated	Diurnal (2)	Dissolved Oxygen	4,4	None	Mann-Whitney U	P = 0.020~

Appendix A. (Continued).

Habitat	Treatments	Parameter	Sample Size Per Treatment	Transformation	Statistical Test	P Value
Trailed	Diurnal (2)	Temperature	8,8	None	Mann-Whitney U	P = 0.001 ~
Trailed	Diurnal (2)	pH	8,8	None	Mann-Whitney U	P = 0.001 ~
Trailed	Diurnal (2)	Conductivity	8,8	None	Mann-Whitney U	P = 0.83
Trailed	Diurnal (2)	Dissolved Oxygen	8,8	None	Mann-Whitney U	P = 0.001 ~
Mid-Channel	Diurnal (2)	Temperature	2,2	None	Mann-Whitney U	P = 0.12
Mid-Channel	Diurnal (2)	pH	2,2	None	Mann-Whitney U	P = 0.12
Mid-Channel	Diurnal (2)	Conductivity	2,2	None	Mann-Whitney U	P = 0.68
Mid-Channel	Diurnal (2)	Dissolved Oxygen	2,2	None	Mann-Whitney U	P = 0.12
Rotovated	Diurnal (2)	Total P	4,4	None	Mann-Whitney U	P = 0.12
Rotovated	Diurnal (2)	SRP	3,3	None	Mann-Whitney U	P = 0.057
Rotovated	Diurnal (2)	Ammonia N	4,4	None	Mann-Whitney U	P = 0.32
Non-Rotovated	Diurnal (2)	Total P	4,4	None	Mann-Whitney U	P = 0.88
Non-Rotovated	Diurnal (2)	SRP	3,3	None	Mann-Whitney U	P = 0.64
Non-Rotovated	Diurnal (2)	Ammonia N	4,4	None	Mann-Whitney U	P = 0.55
Trailed	Diurnal (2)	Total P	8,8	None	Mann-Whitney U	P = 0.92
Trailed	Diurnal (2)	SRP	6,6	None	Mann-Whitney U	P = 0.86
Trailed	Diurnal (2)	Ammonia N	8,8	None	Mann-Whitney U	P = 0.14
Mid-Channel	Diurnal (2)	Total P	2,2	None	Mann-Whitney U	No Variance°
Mid-Channel	Diurnal (2)	SRP	2,2	None	Mann-Whitney U	P = 1.00
Mid-Channel	Diurnal (2)	Ammonia N	2,2	None	Mann-Whitney U	No Variance°
All Sites @	Habitat (3)	Plant Biomass	10,10,10	Square Root	ANOVA	P = 0.048 ~
Non-Roto/Trail	Habitat (2)	Plant Biomass	10,10	Square Root	ANOVA	P = 0.33
Non-Roto/Roto	Habitat (2)	Plant Biomass	10,10	Square Root	ANOVA	P = 0.12
Trail/Roto	Habitat (2)	Plant Biomass	10,10	Square Root	ANOVA	P = 0.015 ~
Non-Roto/Trail	Habitat (2)	Fish	11,6	None	Mann-Whitney U	P = 0.98
Non-Roto/Trail	Habitat (2)	Fish/Popnet	5,5	None	Mann-Whitney U	P = 0.78
Non-Roto/Trail	Habitat (2)	Fish/Electrofish	3,3	None	Mann-Whitney U	P = 0.76

* Rotovated, non-rotovated, trail-rotovated and mid-channel.
** Rotovated, non-rotovated, trail-rotovated and mid-channel, respectively.
~ Exceeds confidence level of P = 0.05 for statistical difference.
° All reported values for this parameter were below the detection limit.
@ Rotovated, non-rotovated and trail-rotovated habitats.

Appendix B1. Water Quality in the Pend Oreille River on August 9-10, 1989.

Sample Station	Time	Temperature (Degree C)	pH (units)	Conductivity (umho/cm 25°C)	D.O. (mg/L)	Turbidity (NTU)
R1-S-AM	0630	20.5*	8.24	153	7.6*	0.80
R1-B-AM	0637	20.5*	8.09	156	7.6*	0.60
R1-S-PM	1250	22.5*	8.96*	157	8.1	--
R1-B-PM	1254	21.7*	8.87*	159	8.0	--
R2-S-AM	0645	20.7*	8.03	154	7.5*	0.80
R2-B-AM	0650	20.5*	8.05	154	7.6*	2.40
R2-S-PM	1304	22.7*	9.15*	156	8.6	--
R2-B-PM	1307	21.9*	8.97*	158	8.7	--
W1-S-AM	0700	20.7*	8.24	143	6.4*	0.80
W1-B-AM	0707	20.8*	8.23	142	6.2*	17■
W1-S-PM	1310	22.9*	9.30*	141	10.0	--
W1-B-PM	1315	22.2*	9.15*	139	8.1	--
W2-S-AM	0715	20.6*	8.10	143	6.8*	4.3
W2-B-AM	0720	21.1*	8.06	143	5.9*	26■
W2-S-PM	1322	22.9*	9.62*	135	10.0	--
W2-B-PM	1330	22.0*	9.35*	138	9.8	--
TR1-S-AM	0745	20.6*	8.35	143	6.3*	1.60
TR1-B-AM	0750	20.6*	8.29	143	6.8*	0.90
TR1-S-PM	1350	22.6*	9.23*	139	9.0	--
TR1-B-PM	1355	22.2*	9.19*	137	9.0	--
TR2-S-AM	0730	20.7*	8.25	145	6.3*	0.60
TR2-B-AM	0735	20.7*	8.27	148	6.7*	4.60
TR2-S-PM	1340	22.9*	9.49*	144	10.6	--
TR2-B-PM	1345	22.0*	9.09*	148	8.6	--
TR3-S-AM	0800	20.9*	8.34	141	6.4*	0.90
TR3-B-AM	0810	20.3*	8.36	144	6.4*	1.10
TR3-S-PM	1400	22.4*	9.30*	145	9.4	--
TR3-B-PM	1405	22.3*	9.07*	145	8.4	--
TR4-S-AM	0815	20.7*	8.47	143	6.6*	1.60
TR4-B-AM	0820	20.8*	8.45	136	6.6*	1.40
TR4-S-PM	1410	22.8*	9.53*	138	10.1	--
TR4-B-PM	1415	22.4*	9.39*	138	9.1	--
01-S-AM	0830	20.7*	8.71*	154	7.8*	0.50
01-B-AM	0837	20.6*	8.79*	158	8.1	0.40
01-S-PM	1420	22.2*	9.09*	158	8.5	--
01-B-PM	1425	22.1*	9.08*	157	8.4	--

* Indicates exceedance of Water Quality Standards.

■ Elevated turbidity values a result of sampling error.

FOOTNOTE: Sample stations starting with the letter "R" indicate samples from the rotovated habitat; stations starting with "W" indicate samples from the non-rotovated habitat; stations starting with "TR" are samples from the trailed habitat; stations starting with "O" are from a mid-channel open-water habitat. The "S" and "B" identifiers denote surface and bottom, respectively.

Appendix B2. Nutrients in the Pend Oreille River on August 9-10, 1989.

Sample Station	Time	Total P (ug P/L)	SRP (ug P/L)	Nitrate/Nitrite (ug N/L)	Ammonia (ug N/L)
R1-S-AM	0630	7	4	10 U	5 U
R1-B-AM	0637	5	3	10 U	5 U
R1-S-PM	1250	5 U	1	10 U	5 U
R1-B-PM	1254	5	1	10 U	5 U
R2-S-AM	0645	5 U	3	10 U	5 U
R2-B-AM	0650	10	2	10 U	5 U
R2-S-PM	1304	5 U	--	10 U	5
R2-B-PM	1307	5 U	--	10 U	5 U
W1-S-AM	0700	7	4	10 U	5 U
W1-B-AM	0707	42	6	10 U	7
W1-S-PM	1310	14	1	10 U	5 U
W1-B-PM	1315	54	5	10 U	9
W2-S-AM	0715	14	3	10 U	5
W2-B-AM	0720	73	4	19	18
W2-S-PM	1322	13	--	10 U	5 U
W2-B-PM	1330	40	--	10 U	6
TR1-S-AM	0745	11	3	10 U	5 U
TR1-B-AM	0750	10	2	10 U	5 U
TR1-S-PM	1350	13	4	10 U	5 U
TR1-B-PM	1355	16	2	12	5 U
TR2-S-AM	0730	23	1	10 U	5 U
TR2-B-AM	0735	17	2	10 U	5 U
TR2-S-PM	1340	8 U	1	10 U	5 U
TR2-B-PM	1345	30	4	10 U	9
TR3-S-AM	0800	8	2	10 U	5 U
TR3-B-AM	0810	8	3	10 U	5 U
TR3-S-PM	1400	8	--	10 U	15
TR3-B-PM	1405	11	--	10 U	5 U
TR4-S-AM	0815	21	5	10 U	5 U
TR4-B-AM	0820	16	6	10 U	5 U
TR4-S-PM	1410	14	--	10 U	5 U
TR4-B-PM	1415	27	--	10 U	5 U
01-S-AM	0830	5 U	3	10 U	5 U
01-B-AM	0837	5 U	1	23	5 U
01-S-PM	1420	5 U	2	10 U	5 U
01-B-PM	1425	5 U	2	10 U	5 U

DATA QUALIFIER: U = concentration is below detection limit shown.

FOOTNOTE: Sample stations starting with the letter "R" indicate the rotovated habitat; stations starting with "W" indicate the non-rotovated habitat; stations starting with "TR" are from the trailed habitat; stations starting with "O" are from a mid-channel open-water habitat. The "S" and "B" identifiers denote surface and bottom, respectively.