Research Technical Completion Report

PERIPHYTON DEVELOPMENT OF INSHORE AREAS ON PEND OREILLE LAKE, NORTHERN IDAHO

by

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U.S. Geological Survey
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ABSTRACT

Sixteen sites were established at south, mid, and north lake areas on Pend Oreille Lake, Idaho in 1989. Information on inshore water chemistry, bacteria, physical/chemical conditions, and productivity of attached benthic algae and aquatic macrophytes was gathered. Sites were sampled in July, August, and September 1989. Mean inshore total phosphorus was greater near developed areas than undeveloped areas all three months. Highest fecal coliform counts were seen in August at Bayview (south lake) (50/100ml) and Trestle Creek (10/100ml), two developed sites. Conversely, fecal streptococci counts were highest at Warren Island (>100/100ml) and Talache (72/100ml), two relatively undeveloped sites. Maximum summer transparencies were found in mid and south lake areas, up to 11.1 m. Shallow north bays had the lowest transparency readings with a minimum of 0.35 m. Mean chlorophyll *a* values from attached algae correlated with level of shoreline development or higher values at more developed sites and lower values at less developed sites. Total (Aug.+Sept.) mean chlorophyll *a* on artificial substrate was 4.3 mg/m^2 for developed sites vs 2.1 mg/m^2 at undeveloped sites. August and September aquatic macrophyte data show highest production 3.0 to 4.9 m deep, with a rapid decline from 4.9 to 6.7 m. Production was found to be at or near zero from 6.7 to 10.1 m deep.

INTRODUCTION

In a large, deep lake such as Pend Oreille with a low littoral to pelagic ratio, littoral production does not play a large role in overall productivity. Productivity response in shallow, light-rich shoreline areas from shoreline nutrient sources should reflect early lake response, and therefore, imminent changes in trophic status more quickly than would pelagic waters. Most of the previous limnological work on Pend Oreille Lake has been done in pelagic waters. Given that changes in trophic status would first show up in littoral areas (compared to the relatively slow changes in the dynamics of pelagic areas), shoreline monitoring should provide valuable refinement to in-depth limnological study of Pend Oreille Lake.

Work was begun the summer of 1989 to gather information on productivity (periphyton and aquatic macrophyte), water chemistry, bacteria, and physical/chemical conditions at shoreline sites around Pend Oreille Lake. This work complements concurrent pelagic limnological studies being conducted by the U.S. Geological Survey, Boise.

APPROACH

In mid-July 1989, sixteen sites were established around Pend Oreille Lake (Figure 1). Sites were selected as representative of embayments (developed vs relatively undeveloped) and open-lake shore habitat. At each site, water samples

LAKE PEND OREILLE, IDAHO

PERIPHYTON SITES - 1989

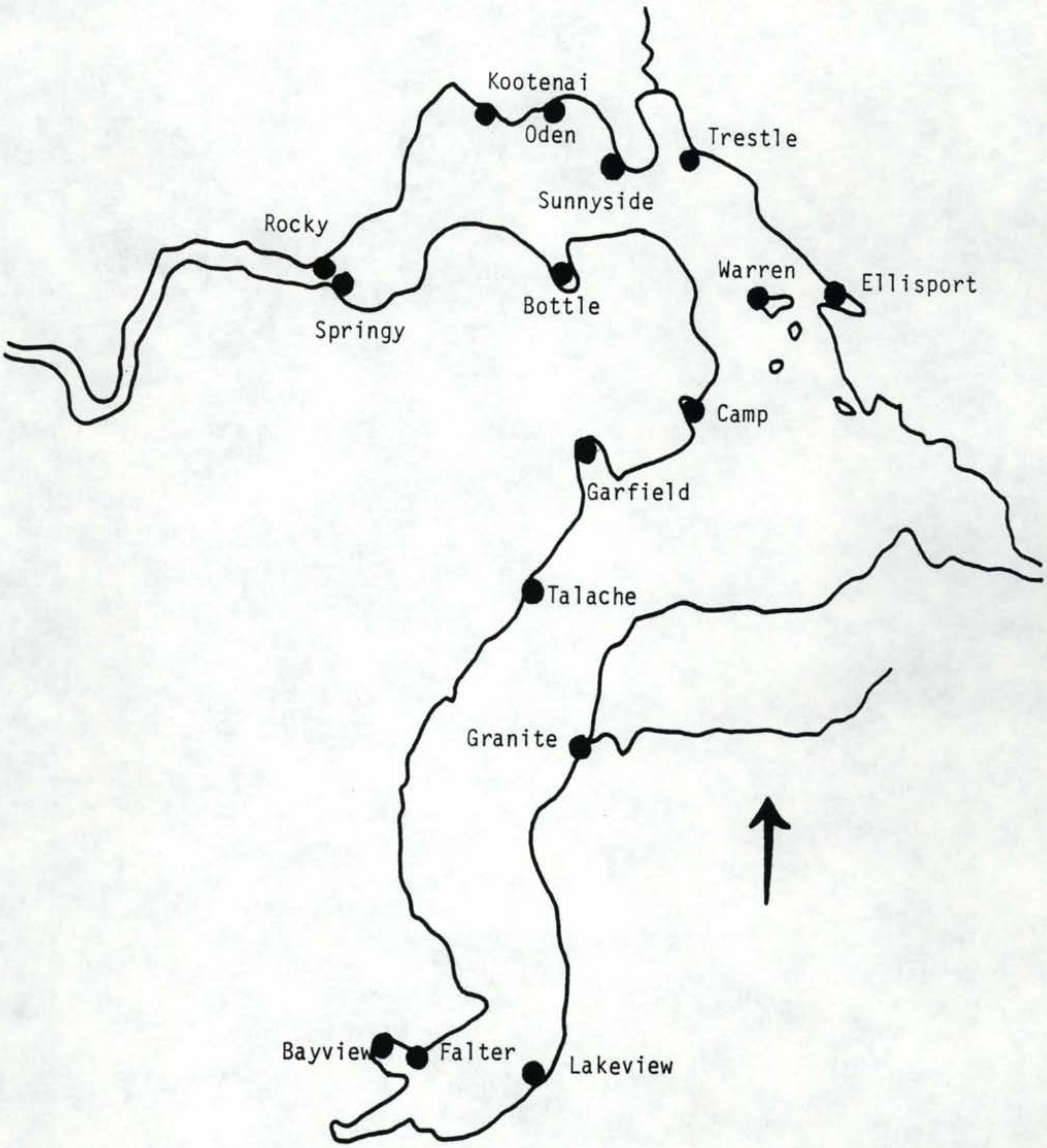

Figure 1. Periphyton sites on Pend Oreille Lake, 1989.

were collected for nutrient and bacteria analysis, physical/chemical field data was recorded, and artificial substrates (unglazed tiles) were placed on the bottom at 1 m depths.

Thirty days later, in mid-August 1989, sites were revisited. Water samples were again collected for nutrient and bacterial analysis, and physical data were recorded. Periphyton samples were collected from both artificial and natural substrates, with six replicates per substrate type per site. In mid-August, aquatic macrophytes were additionally sampled at eight sites in North bay areas and the outlet arm of the lake by SCUBA sampling. Nine sites were reset with tiles for a second 30-day period, mid-August to mid-September.

In mid-September, the nine periphyton sites were revisited and physical data and water samples for nutrient and bacterial analysis were again collected. Periphyton was collected as six replicates per substrate type per site. Aquatic macrophytes were also sampled in mid-September at nine sites in the outlet arm and north lake bay areas by Peterson dredge. Diver observations support our conclusion that Peterson dredging provided a more valid and representative macrophyte sample where weed densities were very high.

RESULTS

Differences between chlorophyll *a* values as a function of length of time artificial substrate was seasoned before being placed was addressed. No significant difference was found between tiles that had seasoned 30 days vs tiles that had seasoned 1-4 days ($p<.01$).

July nutrient data indicate nutrient levels to be higher near developed areas than undeveloped areas (Table 1). Mean total phosphorus for developed sites was 0.010 mg/l vs 0.008 mg/l for undeveloped sites. August data reinforced this finding with mean total phosphorus being 0.009 mg/l adjacent to developed areas vs 0.006 mg/l at undeveloped sites.

Bacteria data (Table 2) show August to be the month of highest fecal coliform counts. Highest counts were found at Bayview and Trestle Creek followed by Springy point (below Sandpoint STP discharge) and Sunnyside. Fecal streptococci counts for August had highest counts occurring at two of the least developed sites, Warren Island and Talache (Table 2), both open lake, relatively undeveloped sites.

Field chemistry data (Table 3) indicate wide variation in water transparency throughout the lake. The south lake basin remains clear in early summer while northern and mid- areas show more turbidity as a result of inflows to the lake and wind action stirring bottom sediments in the very shallow bays of the north. Maximal summer transparencies are in the mid to southern portions (up to 11.1 m) with northern bays again very turbid from wind action (down to 0.35 m transparency).

Monochromatic chlorophyll *a* analysis of periphyton showed mean natural substrate values to be 390% and 350% higher than mean artificial substrate values in August and September respectively (Figures 2 and 3). Analysis of mean

Table 1. Pend Oreille Lake Water Chemistry Data 1989.

Site	*T. NH3*	*Dis. NH3*	*T.Kjdl. N*	*Dis.Kjdl. N*	*T. NO2&NO3*	*Dis. NO2&NO3*	*T. Phos.*	*Ortho. P*	*T. Alky.*	*pH*
mid-July										
Springy	0.006	0.038	0.14	0.16	<.001	0.021	0.012	0.012	71	8.3
Rocky	0.021	0.037	0.07	<.05	0.008	0.049	0.007	<.001	71	8.2
Kootenai	0.04	0.124	0.14	0.16	0.012	0.049	0.02	<.002	72	8.1
Sunnyside	0.007	0.034	0.07	0.12	0.011	0.016	0.008	<.002	73	8.2
Bottle Bay	0.003	0.021	0.11	0.09	<.001	0.027	0.006	<.002	69	8.2
Oden	0.005	0.026	<.05	0.09	<.001	0.015	0.01	<.002	73	8.4
Trestle	0.016	0.045	0.08	0.16	0.009	0.036	0.009	<.002	68	8.2
Ellisport Bay	0.021	0.018	0.11	0.18	0.01	0.012	0.01	0.001	72	8.1
Warren Island	0.014	0.017	0.1	<.05	0.001	0.02	0.008	<.001	73	8
Camp Bay	0.007	0.018	0.09	0.25	0.005	0.027	0.008	0.001	69	8
Garfield	0.042	0.053	0.16	0.11	0.008	0.043	0.007	0.001	68	8.1
Granite	0.013	0.012	0.13	0.11	0.009	0.009	0.009	<.001	75	8.2
Talache	0.013	0.019	0.1	0.12	<.001	0.023	0.009	0.001	72	8.3
Lakeview	0.013	0.042	0.06	0.11	0.007	0.024	0.008	<.001	73	8.2
Falter	0.021	0.032	0.07	<.05	0.008	0.036	0.005	<.001	74	8.2
Bayview	0.013	0.034	0.2	0.16	0.011	0.016	0.007	<.001	73	8.4
mid-August										
Springy	0.024	0.012	0.08	0.05	<.001	0.003	0.008	<.001	77	8.1
Rocky	0.049	0.032	0.09	0.08	0.005	0.008	0.01	<.001	74	8.2
Kootenai	0.015	0.009	0.05	0.06	<.001	0.005	0.012	0.001	75	8.2
Sunnyside	0.02	0.012	<.05	<.05	<.001	0.005	0.007	0.001	75	8.3
Bottle Bay	0.061	0.113	0.05	<.05	0.032	0.057	0.007	0.001	77	8.3
Oden	0.015	0.014	0.07	0.06	<.001	0.003	0.009	0.002	77	8.3
Trestle	0.044	0.024	0.23	0.1	<.001	0.008	0.014	0.001	77	8.2
Ellisport Bay	0.047	0.044	0.09	0.11	0.003	0.004	0.006	0.001	80	8.2
Warren Island	0.054	0.055	0.1	0.12	0.009	0.015	0.009	0.001	78	8.1
Camp Bay	0.068	0.047	0.12	0.1	0.003	0.012	0.007	<.001	80	8.1
Garfield	0.089	0.087	0.1	0.12	0.018	0.014	0.007	0.001	75	8.1
Granite	0.042	0.038	0.09	0.09	<.001	0.003	0.005	<.001	78	8.2
Talache	0.046	0.032	0.08	0.17	0.003	0.003	0.005	0.001	74	8
Lakeview	0.044	0.049	0.08	0.06	0.004	0.006	0.006	0.001	77	8.4
Falter	0.027	0.041	<.05	<.05	<.001	0.005	0.007	0.001	77	8.3
Bayview	0.07	0.041	0.08	0.06	0.01	0.005	0.006	0.001	75	7.9
mid-September										
Springy	0.003	0.037	0.1	0.11	0.002	0.014	0.01	0.001	81	8.4
Kootenai	0.013	0.106	0.14	0.12	0.001	0.036	0.019	0.004	83	8.4
Sunnyside	0.015	0.046	0.12	0.17	0.004	0.007	0.011	<.001	81	8.4
Bottle Bay	0.013	0.063	0.11	0.17	0.004	0.014	0.006	<.001	82	8.3
Oden	0.051	0.05	0.1	0.1	0.061	0.008	0.008	0.001	81	8.4
Lakeview	0.044	0.049	0.08	0.06	0.004	0.006	0.006	0.001	77	8.4
Falter	0.007	0.094	0.13	0.19	0.001	0.016	0.005	<.001	78	8.3
Bayview	0.152	0.03	0.09	0.18	0.033	0.014	0.006	<.001	81	8.3

Table 2. Pend Oreille Lake Fecal Coliform/Fecal Strep Density Counts 1989

Site	Fecal Coliform (#/100ml)			Fecal Strep (#/100ml)		
	July	Aug.	Sept.	July	Aug .	Sept.
Rocky	1	3	*	22	2	*
Springy	4	7	4	45	10	1
Kootenai	8	1	4	>100	<1	41
Sunnyside	1	5	7	28	5	37
Bottle Bay	4	1	4	2	1	4
Oden	4	1	1	25	7	7
Trestle	2	10	2	6	16	4
Ellisport Bay	10	1	*	90	2	*
Warren Island	<1	3	*	62	>100	*
Camp Bay	<1	1	*	1	1	*
Granite	<1	2	*	53	13	*
Garfield	<1	4	*	>100	15	*
Talache	<1	2	*	5	72	*
Lakeview	<1	2	4	76	2	4
Falter	1	3	4	21	2	1
Bayview	1	50	4	34	8	8

*Sites not sampled mid-September

Table 3. Pend Oreille Lake Field Chemistry Data,1989

Site	CO2 mg/l	EC umho	Temp C	DO mg/l	Secchi m
			mid July		
Springy	0	125	19	9.1	3.9
Rocky	0	125	18	9.2	3.4
Kootenai	1	129	16	9.2	0.35
Sunnyside	0	123	17	6.5	7
Bottle Bay	0	129	20.5	7	5.4
Oden	0	123	17.2	9.7	2
Ellisport Bay	0.6	123	15.6	6.95	6.5
Warren Island	0	123	14.2	5	6
Camp Bay	0.7	122	21.2	9.5	6.2
Garfield	0.5	115	19	10.1	6.8
Granite	0	119	16	9.6	7.1
Talache	0	130	19	9	6.8
Lakeview	0	110	17	9.2	7.5
Falter	1.5	109	16.8	9	7.1
Bayview	0.5	108	17.3	8	6.5
			mid August		
Springy	0.5	127	19.8	8.6	---
Rocky	0	124	19.8	8.2	6.6
Kootenai	0	127	21.5	7.6	1.1
Sunnyside	0	126	21.5	7.75	7.2
Bottle Bay	0.5	124	22	7.65	7.7
Oden	0	127	21.4	8.3	3
Ellisport Bay	2	135	21	7.8	8.5
Warren Island	2.5	136	22	8.4	10
Camp Bay	2	128	21.3	7.7	8.2
Garfield	2	134	20.8	7.9	8.4
Granite	4	134	21	8.2	11.1
Talache	2	131	21.1	8.1	9.55
Lakeview	1.5	130	20.2	7.8	9.5
Falter	1.3	135	19.6	7.85	7.5
Bayview	1	127	19.5	7.8	8
			mid September		
Springy	5	159	17	9.3	5.5
Kootenai	5	129	18.3	8.7	0.45
Sunnyside	3	160	17.9	8.4	bottom4.7
Bottle Bay	5	123	17	8.8	7.5
Trestle	6	138	17.5	8.05	8.5
Lakeview	5	129	16.7	8.85	10.5
Falter	3	133	17	8.45	11
Bayview	4	121	16.5	8.6	10.5

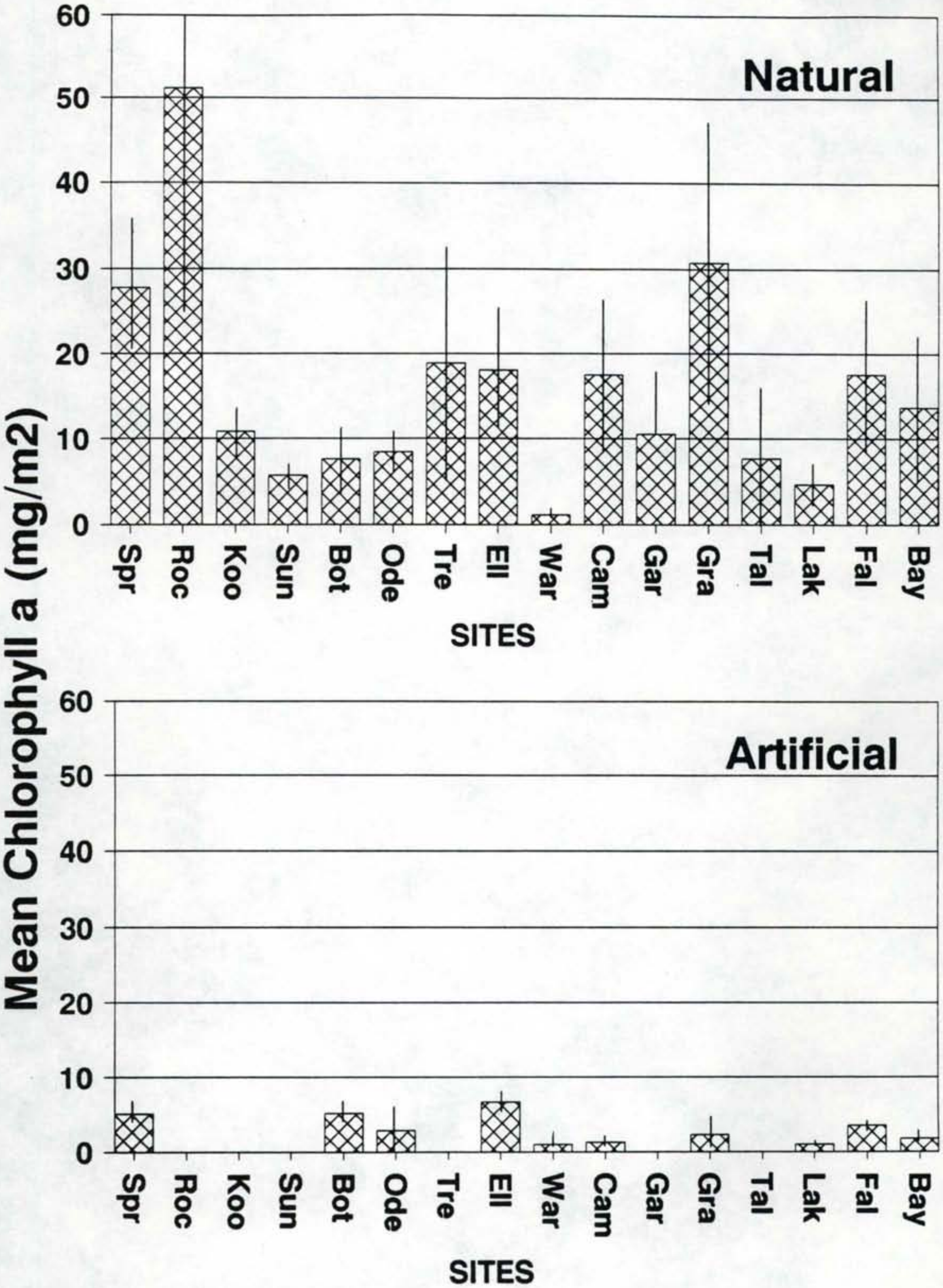

Figure 2. Mean monochromatic chlorophyll a on natural and artificial substrates in Pend Oreille Lake, August, 1989.

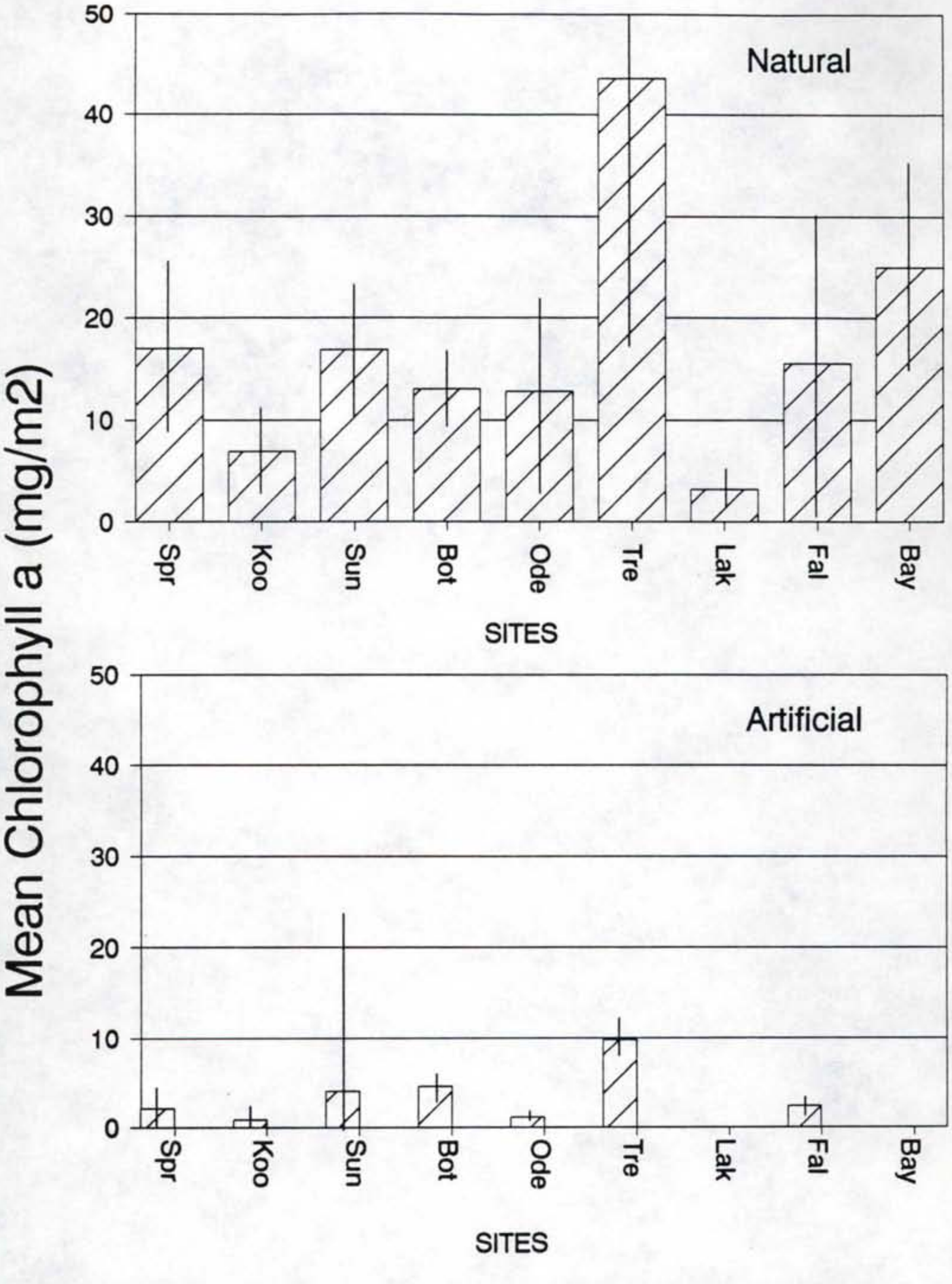

Figure 3. Mean monochromatic Chlorophyll a on natural and and artificial substrates in Pend Oreille Lake, September, 1989.

chlorophyll *a* values showed between-site variation that tended to correlate with level of shoreline development, i.e. highly developed sites had greater within-site variation. With the exception of artificial substrates in September, sites judged to be developed had higher mean values than those judged moderately developed, which in turn had mean values greater than "undeveloped" sites (Figures 4, 5, 6, and 7). Total (August and September) means show developed areas with 21.4 mg/m^2 chlorophyll *a* on natural substrate and 4.3 mg/m^2 on artificial substrate. Moderately developed sites had 14.3 mg/m^2 and 3.4 mg/m^2 chlorophyll a vs 10.0 mg/m^2 and 2.1 mg/m^2 chlorophyll *a* on natural and artificial substrates, respectively, at undeveloped sites. August monochromatic chlorophyll *a* values are comparable to those found in July-August 1986. Chlorophyll *a* values for 1989 natural substrate at sites Falter Talache and Garfield were 17.6, 7.7, and 10.6, respectively, compared to 26.6, 7.0, 16.0, for the same sites in 1986. Natural trichromatic values though, differ by a factor of four (Table 4). The recent literature generally supports the use of monochromatic techniques over trichromatic because of the correction for inactive or dead chlorophyll in the monochromatic technique.

August aquatic macrophyte data show biomass, an indicator of standing crop, and ash free oven dried weight (AFODW) peaking at 3.0-4.9 m deep and then declining with increasing depth (Figures 8 & 9). Results of Duncan's new multiple range test (D.M.R.) on August data correspond with this, showing significant differences between depths of 1.4 to 1.8 m and 3.0 to 5.2 m (Table 5).

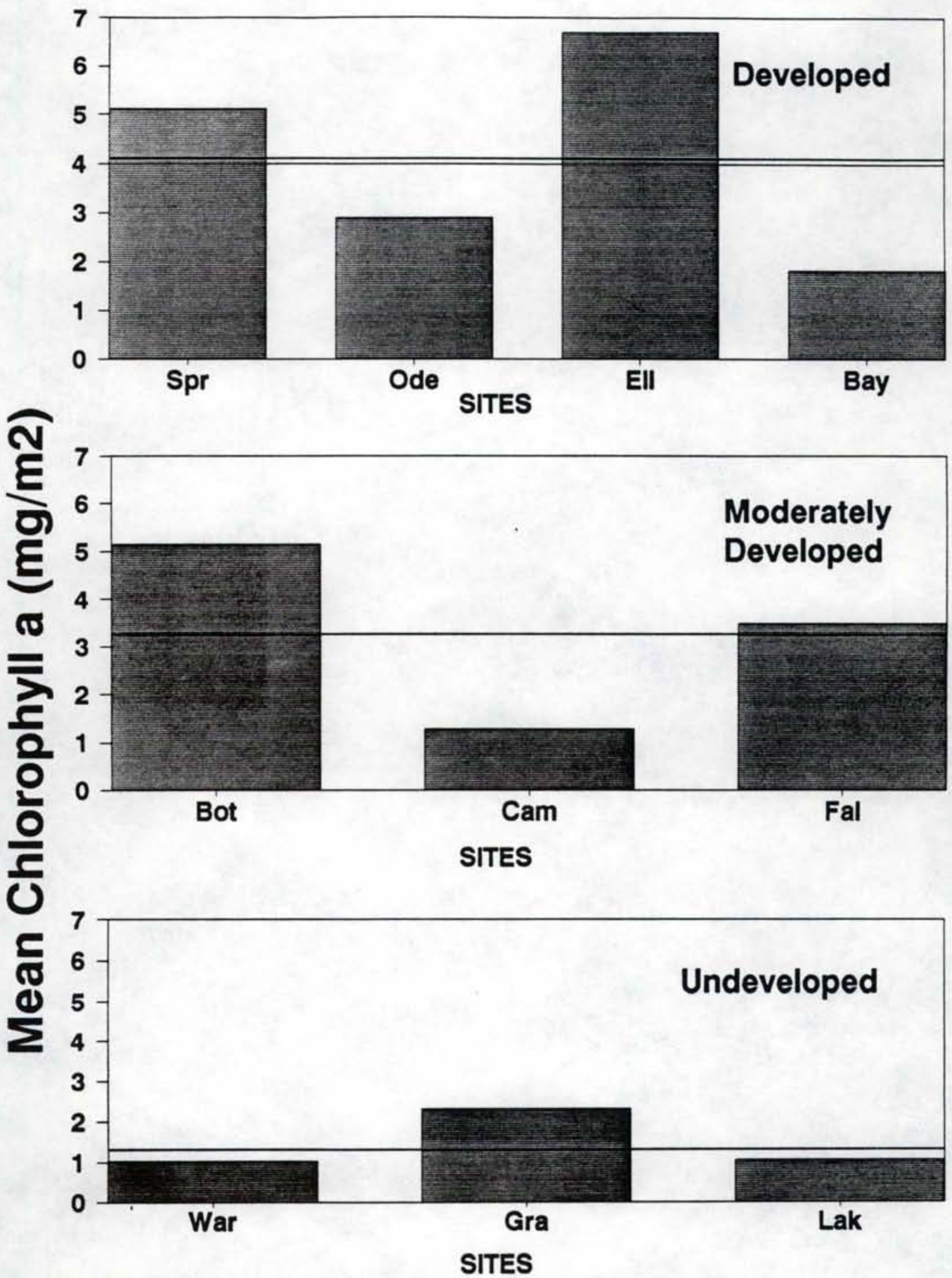

Figure 4. Mean monochromatic Chlorophyll a on artificial substrates in Pend Oreille Lake, August, 1989. Site development compared.

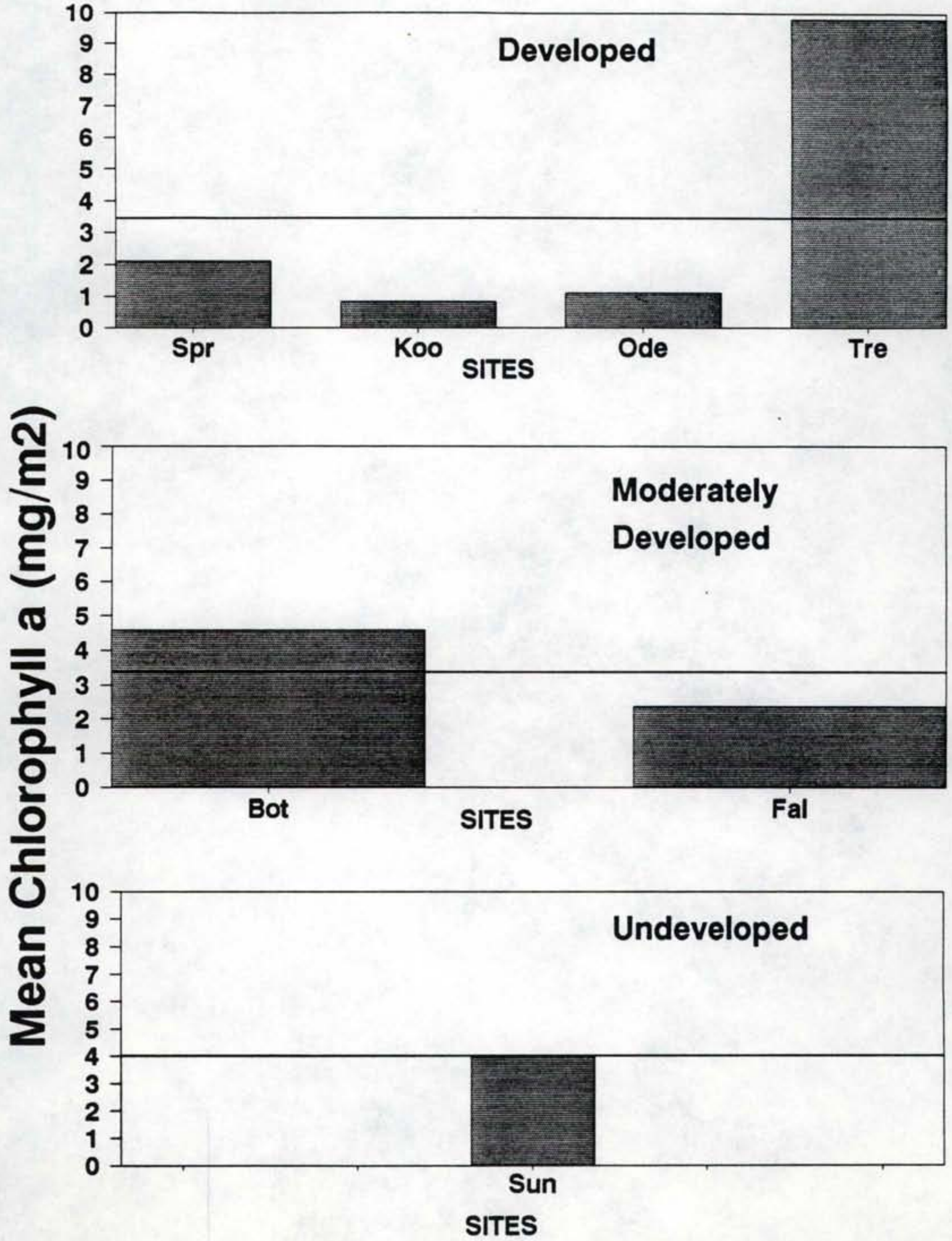

Figure 5. Mean monochromatic chlorophyll a on artificial substrates in Pend Oreille Lake, September, 1989. Site development compared.

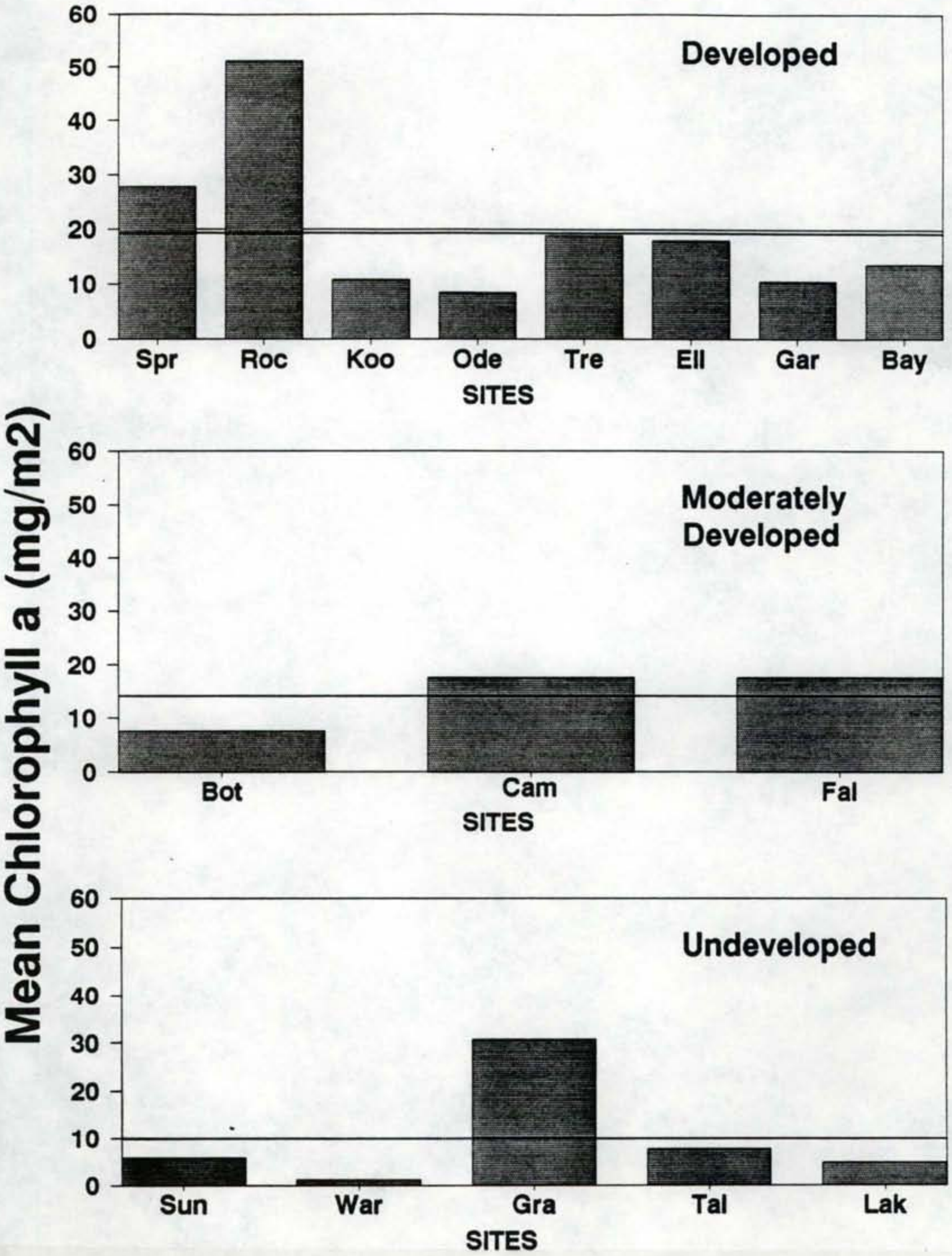

Figure 6. Mean monochromatic chlorophyll a on natural substrates in Pend Oreille Lake, August, 1989. Site development compared.

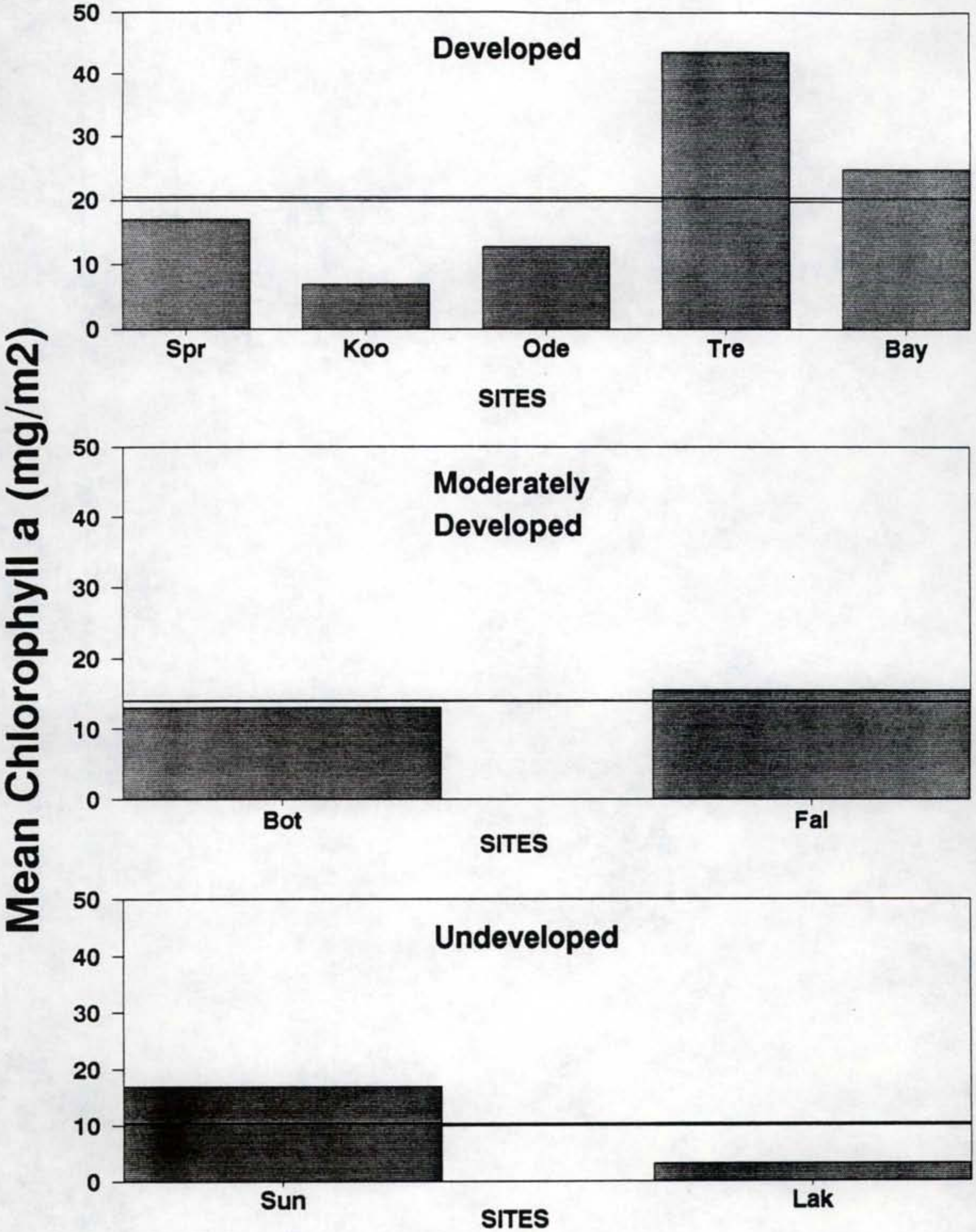

Figure 7. Mean monochromatic chlorophyll a on natural substrates in Pend Oreille Lake, September, 1989. Site development compared.

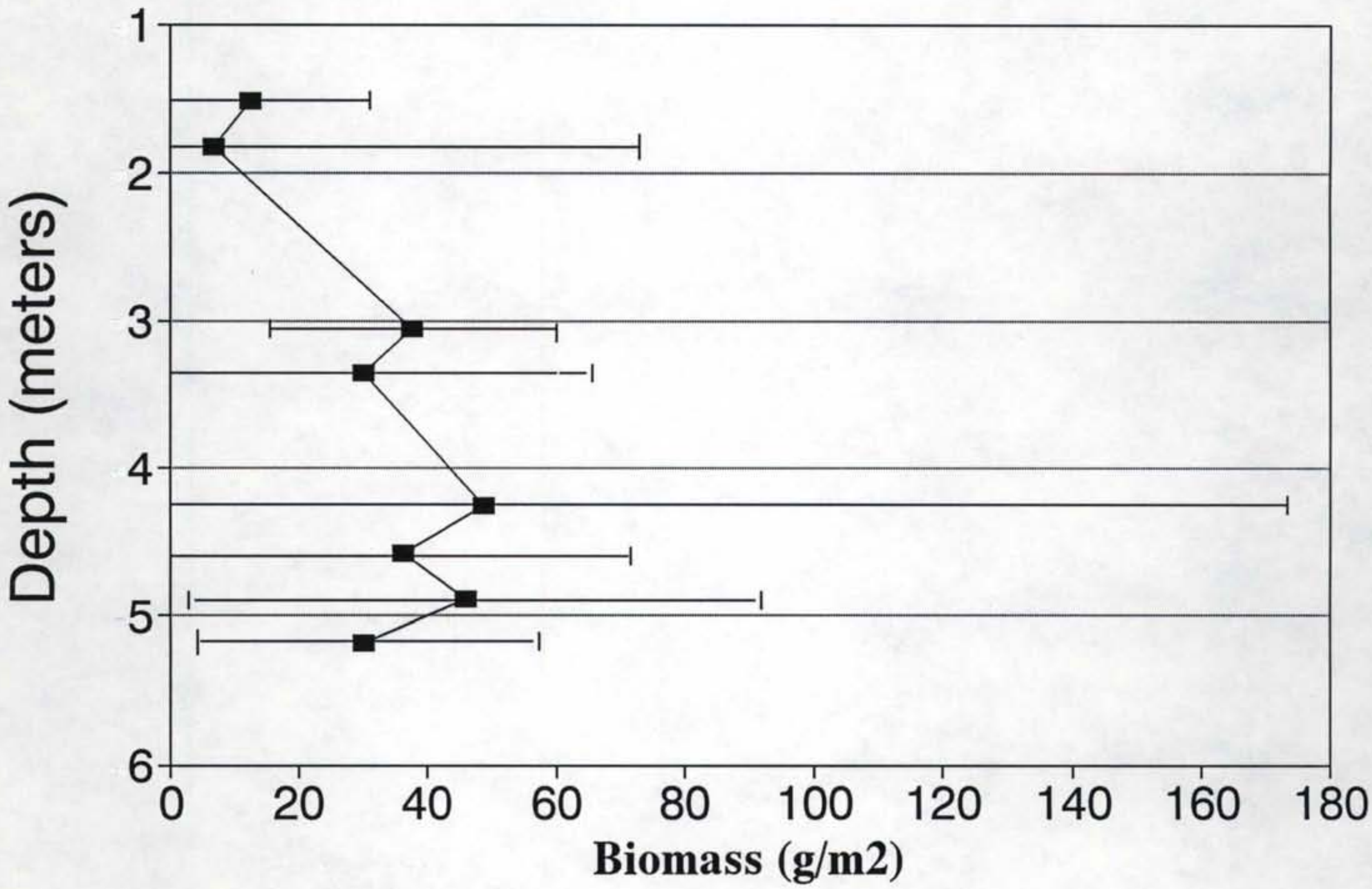

Figure 8. Aquatic Macrophyte biomass relationship to depth, POL, Aug. 1989.
(with 90% confidence intervals)

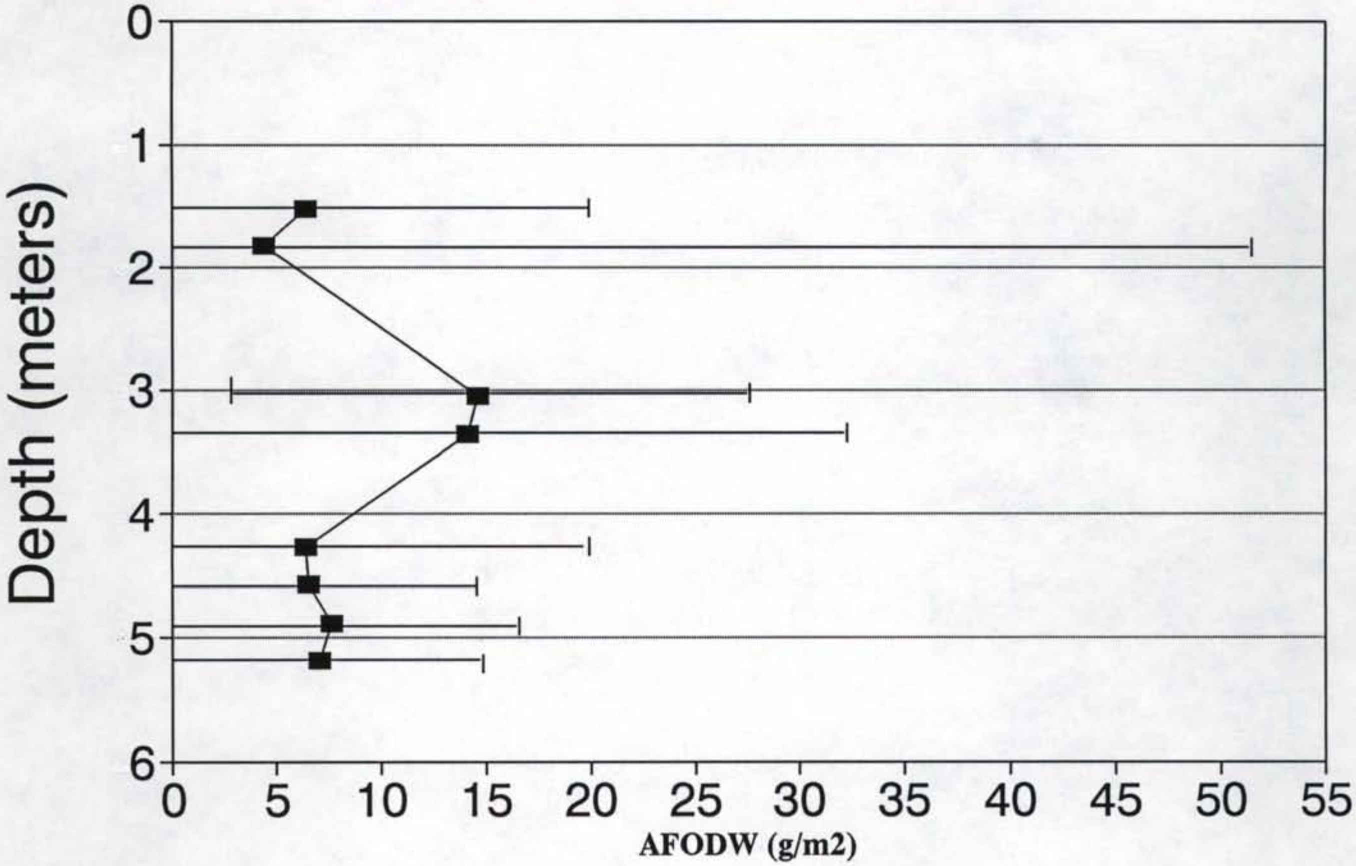

Figure 9. Aquatic Macrophyte AFODW relationship to depth, POL, Aug. 1989. (with 90% confidence intervals)

Table 4. Lakewide means of chlorophyll a on natural & artificial substrates, Pend Oreille Lake, 1989

	Natural (mg/m2)		*Artificial (mg/m2)*
	Aug-89		
Trichromatic Chlorophyll a	4.62		5.26
Monochromatic Chlorophyll a	15.96		3.25
	Sep-89		
Trichromatic Chlorophyll a	4.58		6.45
Monochromatic Chlorophyll a	17.23		3.82
	July-Aug 86 (Kann and Falter 1986)		
		0.5m	1.5m
Trichromatic Chlorophyll a	17.96	5.27	2.06
Monochromatic Chlorophyll a	18.31	5.06	2.25

Table 5. Results of Duncan's New Multiple Range (D.M.R.) Test performed on August aquatic macrophyte dry & AFODW means, contrasted by depth. Depths connected by an unbroken vertical line are not significantly different at P</=0.05.

Dry Weight

Depth (feet)	n	Mean g/m2	D.M.R.
14	4	48.76	
16	5	56.04	
10	11	37.50	
15	6	36.21	
11	10	29.97	
17	6	29.96	
5	3	12.50	
6	2	6.93	

Ash Free Oven Dried Weight (AFODW)

Depth (feet)	n	Mean g/m2	D.M.R.
10	11	14.66	
11	10	14.1	
16	5	7.62	
17	6	7.01	
15	6	6.51	
5	3	6.38	
14	4	6.35	
6	2	4.35	

September sampling was expanded to 9.1 m deep and the biomass/AFODW to depth relationship was very similar to that of August. The expanded sampling showed low plant production at 1.2 to 3.0 m deep, highest production at 3.0 to 4.9 m, and then a rapid decline in production after 4.6 m with no plant growth past 6.7 m deep (Figures 10 & 11). Duncan's new multiple range test backs up the sampling data and shows both shallow (<3.0 m) and deeper (>4.9 m) depths to be significantly different from mid-depths (3.3-4.9 m) (Table 6). Dominant aquatic macrophyte species found to date in Pend Oreille Lake are water-milfoil *(Myriophyllum spicatum* var *exalbescens)*, muskgrass *(Chara vulgaris,* and *Chara fragilis)*, waterweed *(Elodea canadensis)*, water-buttercup *(Ranunculus spp.)*, and pondweed *(Potamogeton richardsonii)*.

CONCLUSIONS

1. August was the month of highest fecal coliform counts while July was the month of highest fecal streptococcus counts. Fecal coliform counts were highest at Bayview and Trestle with 50/ml and 10/ml, respectively.

2. SCUBA and dredging appear to be comparable macrophyte sampling techniques for biomass estimation.

3. Periphyton differences between sites were far more discriminating as indicators of site enrichment than were water chemistry parameters. Chlorophyll *a* values between sites differed by up to 25 x while water chemistry parameters differed by up to 3 x.

4. Mean chlorophyll *a* on natural substrate in August was 390% greater than on artificial substrate. Within-site variability was greater on natural substrate.

5. Highest chlorophyll *a* on both artificial and natural substrate was at north-lake and at developed sites. Highest artificial substrate chlorophyll a was at Ellisport, concurring with data from the 1986 and 1988 inshore studies.

6. Mean chlorophyll *a* on natural and artificial substrate in developed areas was twice that found in undeveloped and is correlated to inshore water enrichment.

7. Water chemistry indicates Pend Oreille Lake to be meso-oligotrophic......Inshore periphyton, however, shows localized advanced eutrophication. One site (Rocky point downstream of Sandpoint) developed

levels of chlorophyll *a* (25 mg/m^2) comparable to areas of eutrophic Lake Saimaa (Finland) polluted with pulping effluent.

8. Natural substrate better expresses site growth potential, i.e. extrapolatable to the entire lake. Artificial substrate offers a better experimental tool to assess site eutrophication.

9. Periphyton growths in Pend Oreille Lake in the summer of 1989 were comparable to growths measured in 1986.

10. Aquatic macrophyte growth is low in shallow depths (1.2-3.0m) peaks in mid-depths (3.0-4.9 m) and declines rapidly to virtually no production after 6.7 m. 11. Aquatic macrophytes most commonly found in north bays were *Myriophyllum spicatum* var *exalbescens, Chara sp.*, and *Potamogeton sp.* Outlet Arm macrophyte communities were also dominated by these three as well as *Elodea canadensis.*

12. Our data indicate that periphyton monitoring can be a valuable indicator to detect changes in lake trophic status before obvious deterioration in pelagic (open water) areas.

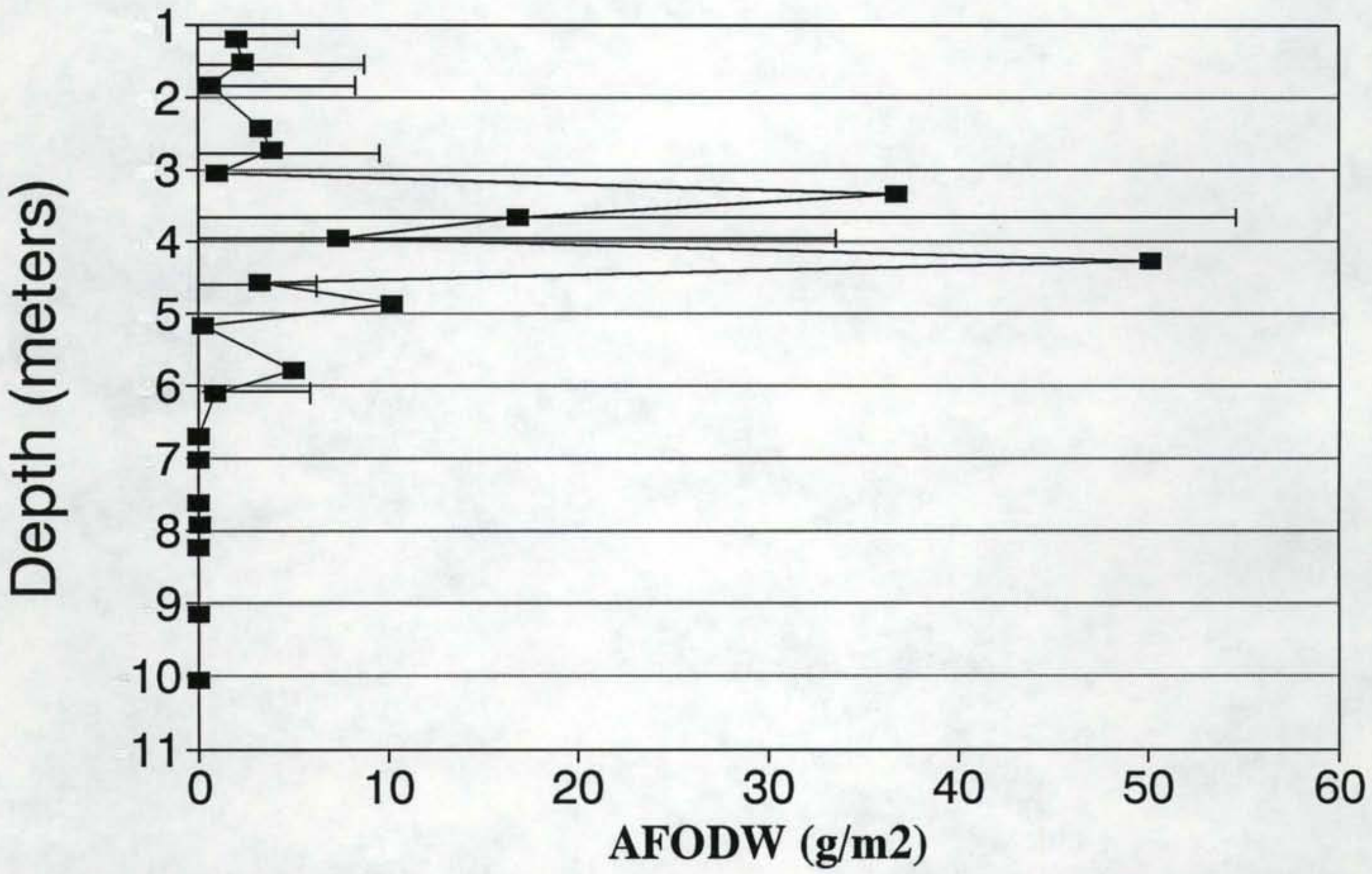

Figure 10. Aquatic Macrophyte biomass relationship to depth, POL, Sept. 1989.

(with 90% confidence intervals)

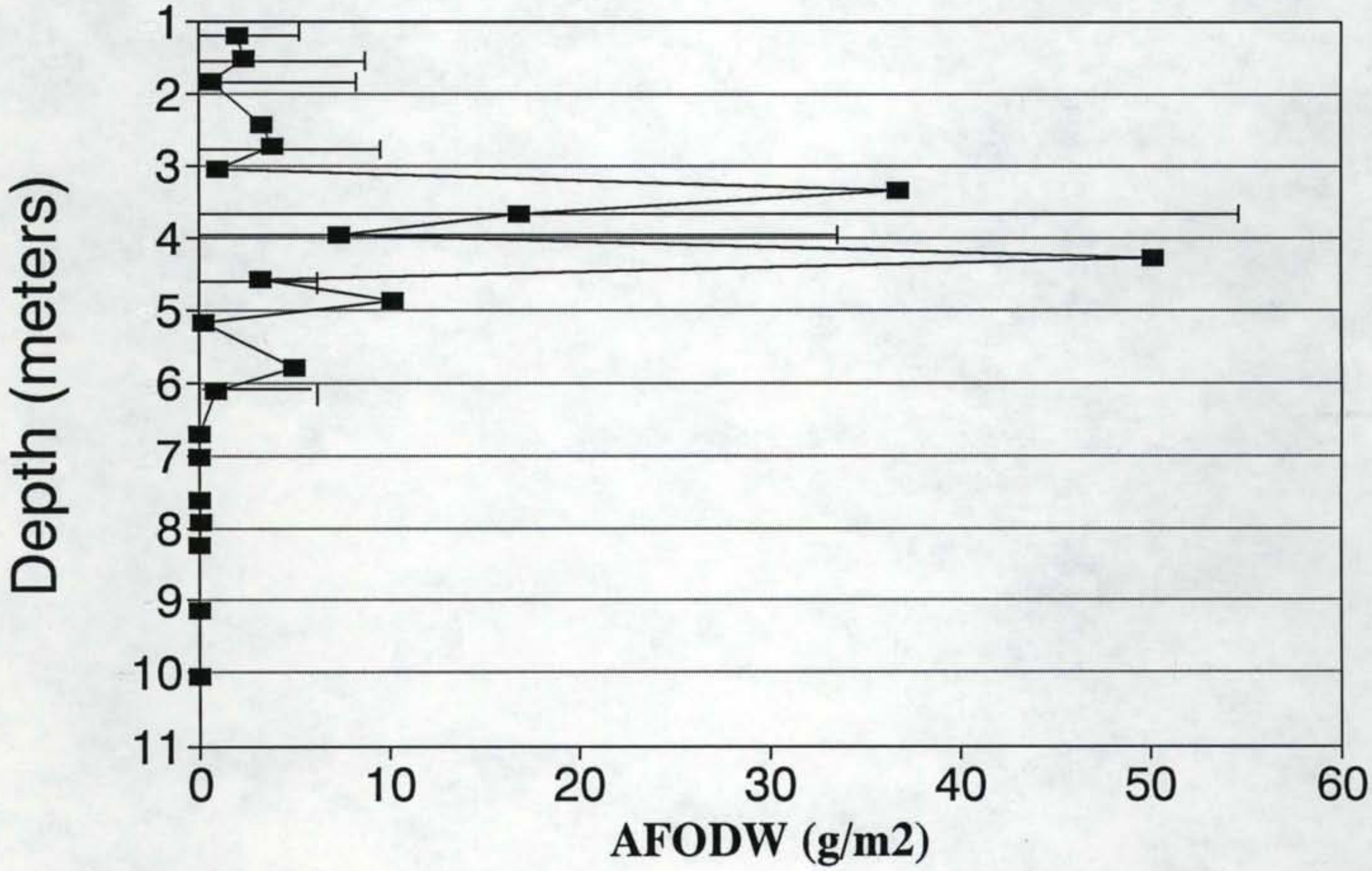

Figure 11. Aquatic Macrophyte AFODW relationship to depth, POL, Sept. 1989.
(with 90% confidence intervals)

Table 6. Results of Duncan's New Multiple Range (D.M.R.) Test performed on September aquatic macrophyte dry & AFODW means, contrasted by depth. Depths connected by an unbroken vertical line are not significantly different at P</=0.05.

Dry Weight

Depth (feet)	n	Mean g/m2	D.M.R.
11	1	168.56	
12	3	123.98	
14	1	73.39	
5	3	48.55	
16	1	34.97	
13	4	34.60	
8	1	20.77	
15	3	12.28	
20	2	11.90	
9	4	9.77	
10	3	5.25	
19	1	3.70	
4	3	3.13	
17	1	2.51	
6	2	2.29	
26	2	0.35	
22	3	0.00	
23	1	0.00	
25	1	0.00	
27	1	0.00	
30	1	0.00	
33	1	0.00	

Ash Free Oven Dried Weight (AFODW)

Depth (feet)	n	Mean g/m2	D.M.R.
14	1	50.14	
11	1	36.78	
12	3	16.88	
16	1	10.16	
13	4	7.39	
19	1	5.01	
9	4	3.87	
8	1	3.30	
15	3	3.26	
5	3	2.37	
4	3	2.02	
10	3	1.03	
20	2	0.93	
6	2	0.69	
17	1	0.27	
26	2	0.12	
22	3	0.00	
23	1	0.00	
25	1	0.00	
27	1	0.00	
30	1	0.00	
33	1	0.00	