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RECENT PALEOLIMNOLOGY OF SMITH AND BYBEE LAKES, OREGON

A Report to

METRO

by

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EXECUTIVE SUMMARY

Sediment cores were collected from Smith and Bybee Lakes in July 1994 to provide information on the pre-development and more recent limnology of the lakes. The 40 cm cores were measured for water content, loss-on-ignition (LOI), and diatom remains. The age of the sediment was evaluated using ^{210}Pb and ^{137}Cs isotopes. The sediment from both lakes had low water content (37-72%) and low organic matter content based on LOI (3-8%). The total ^{210}Pb activity in Smith Lake ranged from 0.85 pCi/g at 21 cm to 1.26 pCi/g at the surface. Similar ^{210}Pb values were measured in Bybee Lake sediments (0.83 to 0.90 pCi/g). No ^{137}Cs was detected in a core from Smith Lake. The analyses indicate that the sediment in the lakes are pre-20th century. Diatoms were abundant in sediments from both lakes. The dominant surface diatom taxa in Smith Lake were *Aulacoseira* spp., *Cyclostephanos dubia, Fragilaria pinnata*, and *Nitzschia* spp. The diatom community exhibited only modest changes in the sediments.

The sediment analyses show that Smith and Bybee Lakes historically were subject to significant hydrologic forces including floods from the Columbia River and, perhaps more importantly, tidal fluctuations. With the completion of dams on the Columbia and Willamette Rivers and the installation of the control gate on the Columbia Slough in 1982, the lakes have been transformed from depositional/erosional environments to depositional environments. The current management strategy favors long-term retention and accumulation of nutrients and sediments in excess of the historical patterns.

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I. INTRODUCTION

Smith and Bybee Lakes are adjacent lakes located in Portland, OR. The lakes have a combined surface area of about 425 ha and are contained within the 810 ha Smith and Bybee Lakes Natural Area (Table 1). The lakes and surrounding area provide important wildlife habitat and environmental amenities for the urban community. Metro Regional Parks and Greenspaces manages the lakes and natural area. Metro was awarded a Clean Lakes grant through the Department of Environmental Quality (DEQ) to conduct a Phase I diagnostic and feasibility study of the lakes. The first year of study involved characterization of lake water quality and hydrodynamic modeling. The second year of study includes an analysis of nonpoint source loading and a paleolimnological reconstruction of the lakes. The purpose of this report is to present the findings of the paleolimnological investigations under the second year of the diagnostic and feasibility study. The information contained in this report is intended to assist with decisions regarding appropriate actions for restoring the lakes to their natural condition.

II. STUDY AREA

Smith and Bybee Lakes are shallow basins that are joined through a common channel and have an historical connection to the Columbia Slough (Figures 1 and 2). The present watershed area is about 650 ha and the contributing area includes a portion of St. John's Landfill. The landfill is in the process of being closed, although discharge from the landfill continues to enter the lake via two storm water inlets. Two additional storm water inlets drain industrial land from other portions of the watershed.

The lakes are situated in the floodplain and historically this area was inundated by floods from the Columbia and Willamette Rivers. The last major flood occurred in 1948. Since then, numerous dams have been built on the Columbia and Willamette Rivers, thus reducing the magnitude of peak discharge. A surface connection to the Columbia River was eliminated in

Table 1. Physical and Chemical Characteristics of Smith and Bybee Lakes.[a]

	Smith (n=19)	Bybee (n=21)
Surface Area (ha)	242.8 (293)[b]	101.2 (132)[b]
Watershed Area (ha)[b]	(650)[b], total	
Depth, m (max)	2.0	2.3
(mean)	0.3	0.3
Elevation (m)	2.7 (3.17)[b]	2.7 (3.17)[b]
Conductivity		
median	216	219
$\overline{x}$	216	211
Alkalinity (mg/L)	69	65
pH[b]		
median	7.7	7.69
$\overline{x}$	7.97	7.97
Total Phosphorus (μg/L)[b]		
median	150	180
$\overline{x}$	250	239
Secchi (m)		
$\overline{x}$	0.4	0.4

[a] Source: Johnson et al. 1985
[b] Metro, unpublished data, 1992-1993

1980 as a consequence of industrial development. The remaining connection to the Willamette and Columbia Rivers through the Columbia Slough was modified with a flow control structure in 1982. This control structure eliminated the effect of tidal fluctuations and maintained the stage at a static level (Johnson et al. 1985).

III. METHODS

The lakes were sampled on three occasions in 1994: January 27, July 8, and July 19. During January, we used a mini-Glew 2.5 cm diameter corer to explore variability in sediments in Smith and Bybee Lakes. The corer was capable of collecting sediment samples up to 25 cm

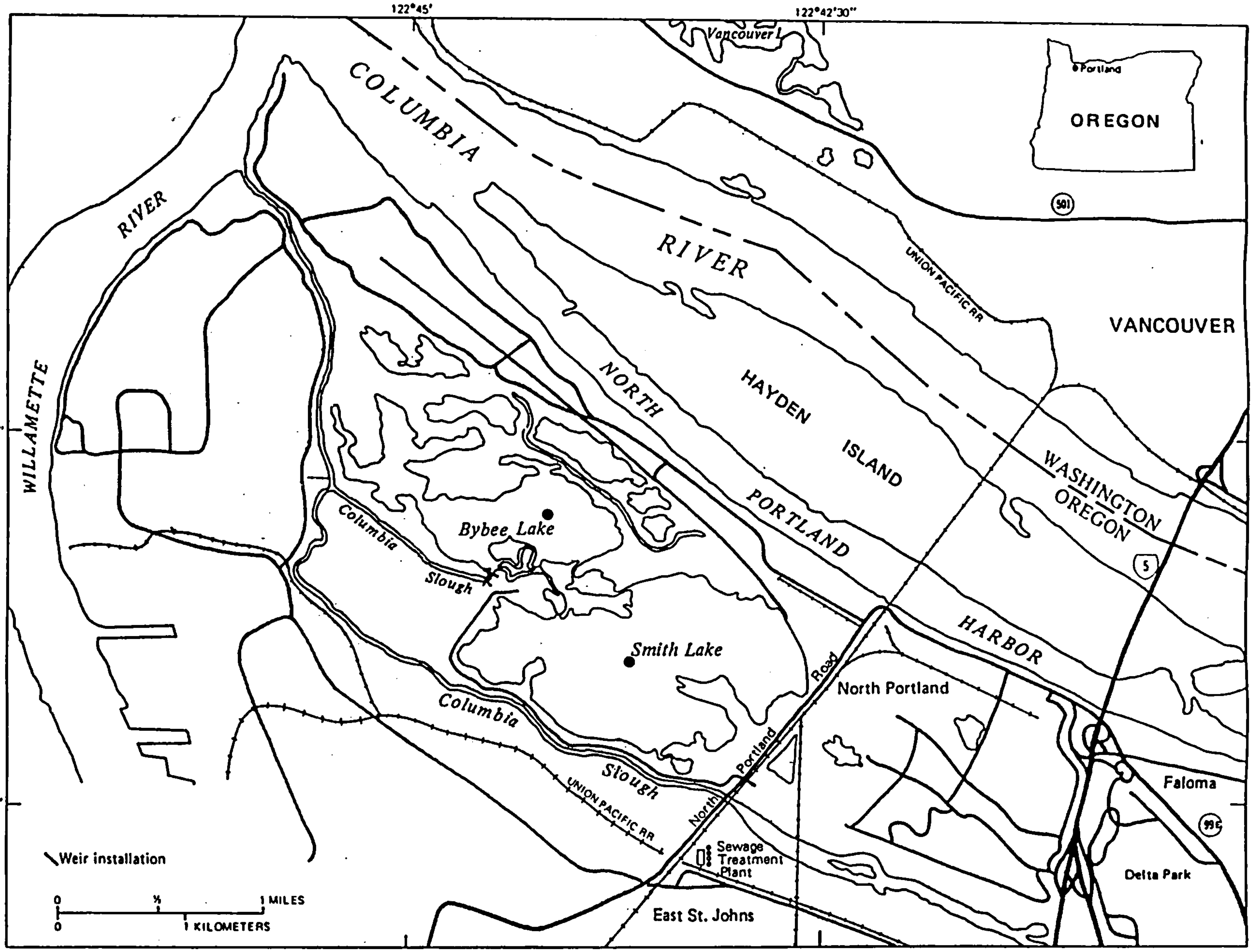

Figure 1. Smith and Bybee Lakes showing location of sampling sites (•) (modified from Clifton 1983).

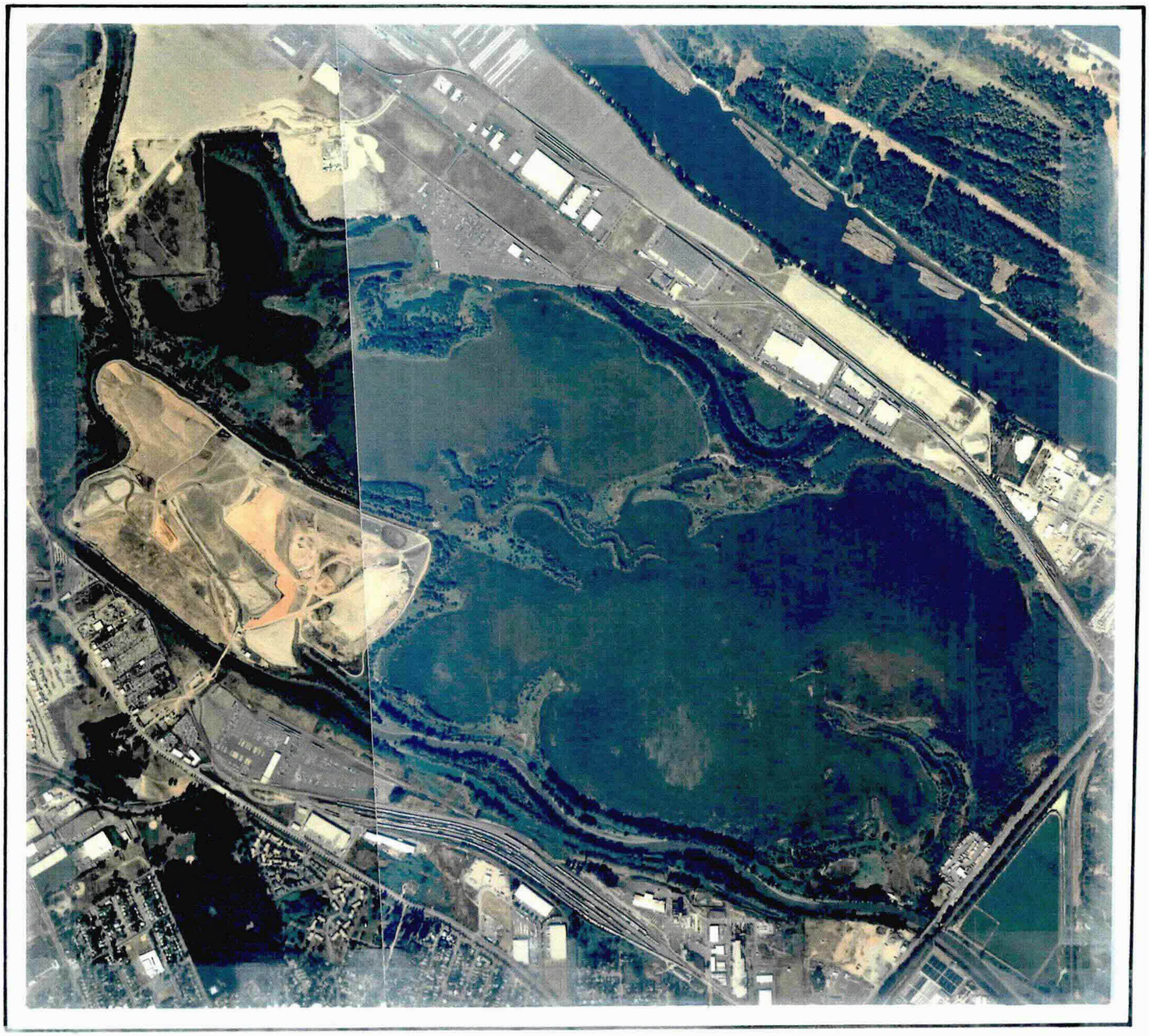

Figure 2. Smith and Bybee Lakes, Oregon, September 13, 1993. Copyright WAC Corp., 1993.

depth. The reconnaissance showed that within the deeper areas of the lake, there appeared to be relatively little spatial heterogeneity in surficial sediment composition. At the candidate coring site in Smith Lake, we collected a 36-cm sediment sample using a 5 cm-diameter piston corer. This core was sectioned on-site and analyzed for percent water and loss-on-ignition. Subsamples of the sediment were retained for microscopic examination.

The lake was revisited on July 8 for collection of sediment using a large-diameter (10-cm) corer equipped with a sphincter closure device. The corer was unable to function properly in these very dense sediments. We returned to the lake on July 19 and collected water samples which were preserved with Lugol's solution. Samples of the dominant submerged macrophyte, curly-leaf pondweed (*Potomogeton crispus*), also were collected and stored in ethanol. During the July 19 sampling trip, three sediment cores were collected from Smith Lake and two cores from Bybee Lake (Figure 1).

Sediment samples were obtained with a 5-cm diameter piston corer with a core length of 1.0 m (cf. Mudroch and MacKnight 1991). The corer was placed above the sediment and the cylinder was manually forced into the sediments until resistance prevented further penetration of the sediments. Sediment cores of about 40 cm depth were collected. Each core was inspected immediately for signs of disturbance at the top caused by the frequently-observed failure to capture the topmost sediment and for possible loss of sediment from the bottom of the core during core extraction. All cores were judged to be sound on both the top and bottom. Successful cores were taken to the lakeshore where they were inspected again. All sectioned sediment material was placed in Whirlpac® and ICHEM® containers, stored in coolers, and placed in a cold room at the laboratory maintained at about 13°C. Subsamples from all sectioned materials were analyzed for percent water content (% H_2O) and loss on ignition (LOI) at 550°C (Dean 1974).

In addition to % H_2O and LOI, subsamples of the sediment were analyzed for lead-210 (^{210}Pb), cesium-137 (^{137}Cs), and diatom species composition. Excess ^{210}Pb activity was measured to determine age and sediment accumulation rates for the past 150 years. ^{210}Pb activity was inferred through measurement of its granddaughter product polonium-210 (^{210}Po), with ^{208}Po added as an internal yield tracer. The polonium isotopes were distilled from 0.2-1.3 g of dry sediment at 550° C, following pretreatment with concentrated HCl, and plated directly (without HNO_3 oxidation) onto silver planchettes from a 0.5 N HCl solution (modified from Eakins and Morrison 1978). Activity was measured for 1-6 x 10^5 s with Si-depleted surface barrier detectors and an Ortec Adcam® alpha spectroscopy system. Unsupported ^{210}Pb was calculated by subtracting supported activity from the total activity measured at each level; supported ^{210}Pb was estimated from the asymptotic activity at depth (the mean of the lowermost samples in a core).

Samples were processed using standard techniques developed for diatoms and siliceous microfossils in general. Diatom microfossils were extracted from the sediments using a modified version (Renberg 1990) of standard diatom protocols (Battarbee 1986, Douglas and Smol 1993). Briefly, this entails placing a small amount of sediment (0.5 g) in a glass 20 ml scintillation vial and oxidizing the sediments with a strong acid (50:50 H_2SO_4:HNO_3) to remove organic material. Approximately 15 ml of acid were added to the sediment. The reaction was accelerated by placing the vials in a boiling water bath for one hour. The spent acid was then removed by aspiration and distilled water (15 ml) was added. The sample was allowed to settle for 24 hours and this wash step was repeated five times. The treated sediments were mounted on glass slides using high refractive media (Hyrax or Naphrax).

Diatoms were identified and enumerated under oil immersion at 600 X and 1000 X magnification, using an Olympus BH-2 series microscope. Because of the nature of the sedimentation in these lakes as revealed by isotopic dating of the cores, only scans of the samples were done and relative abundances of taxa were completed in only one section of sediment. Several standard references were used in taxonomic identifications (Patrick and Reimer 1966, 1975; Hustedt 1930; Krammer and Lange-Bertalot 1986-1991) as well as some regional studies on diatoms (e.g., Czarnecki and Blinn 1978, Wujek and Rupp 1980).

An initial examination of several "exploratory" sediment samples (0-1 cm, 5-6 cm, 16-18 cm, and 34-36 cm) from Smith/Bybee Lakes revealed that diatoms were abundant throughout these core depths.

Two cores, one from each of the lakes, were examined (S-01 and B-01). Sediment samples from the following depths were cleaned and mounted for examination under the light microscope: top ten centimeters of the core at one centimeter intervals; the remainder of the core every second centimeter to a depth of 22 cm, and the bottom 23 cm sample.

One periphyton and one plankton sample each from Smith Lake and Bybee Lake were cleaned using the methods described above and examined in order to determine the diatom communities present in each habitat.

IV. RESULTS

A. Water and Organic Content

The results of the exploratory core collected from Smith Lake in January 1994, shown in Figure 3, indicate that the sediments have low water content and low LOI compared to other shallow, productive lakes. However, the core showed patterns in the sediment profile for percent water and LOI that suggested changes in sediment accumulation.

Several sediment cores were collected from the lakes in July. These cores form the basis for the analysis in the remainder of the report. The percent water and LOI data for cores from Smith and Bybee Lakes collected in July are similar to the Smith core collected in January (Figures 4 and 5). Sediments from both lakes have low water content and low organic matter. Smith Lake sediments decrease in water content from 70% at the surface to 40% at 40 cm. Bybee Lake sediments also show a decrease in water content, but increase at 40 cm. The magnitude of change in water content throughout the length of these two cores is comparable to other productive lakes in the region (Meyerhoff 1977; Eilers et al. 1994, 1995), although the water content would be expected to be greater than 90% at the surface, decreasing to perhaps 70%

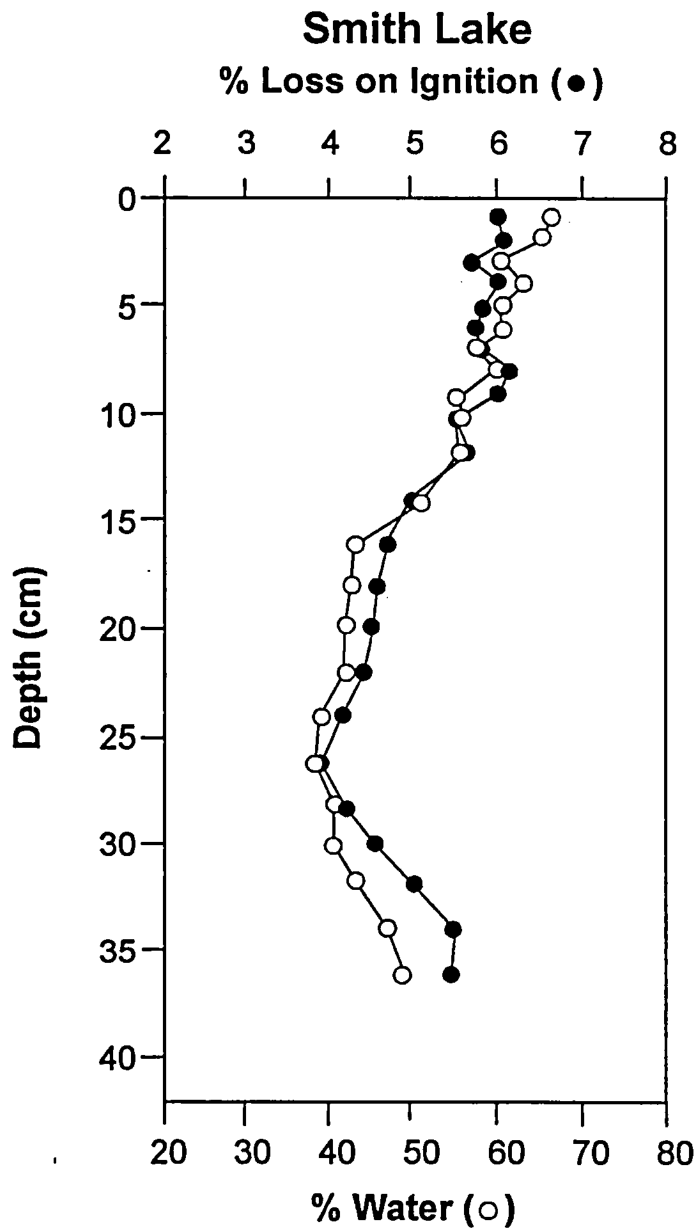

Figure 3. Percent water (○) and organic matter (as % loss on ignition, LOI[●]) for Smith Lake based on an exploratory core collected January, 1994.

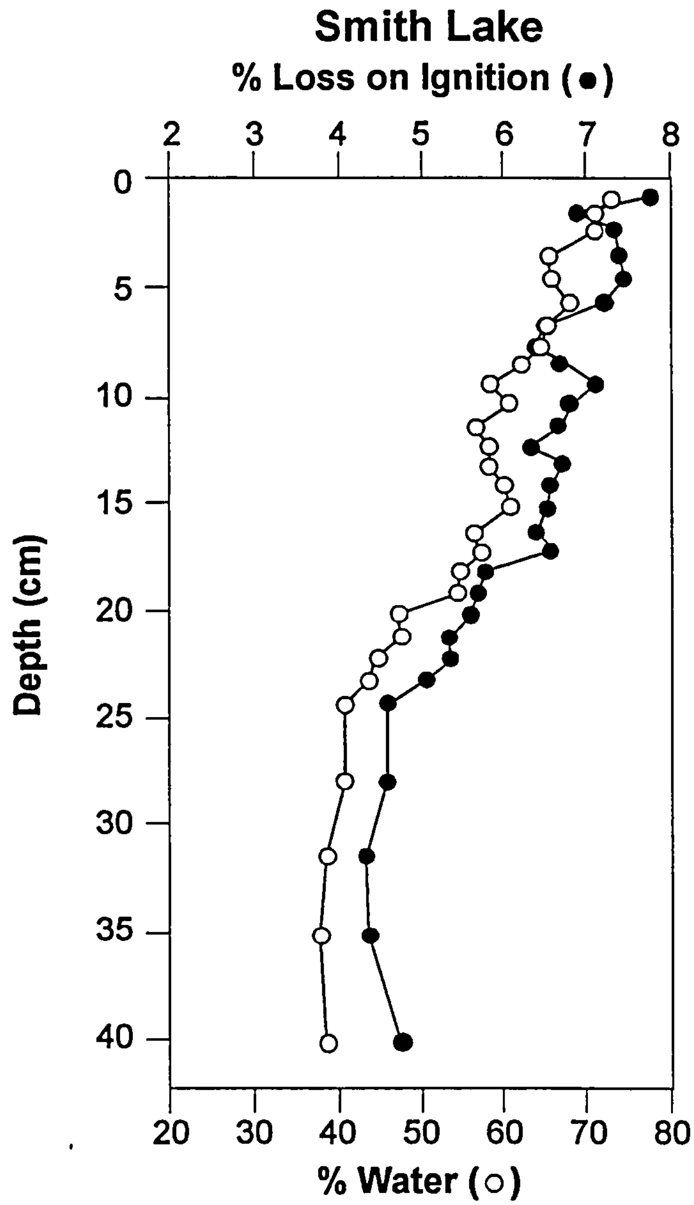

Figure 4. Percent water (o) and organic matter (as % loss on ignition, LOI[•]) for Smith Lake based on an exploratory core collected July, 1994.

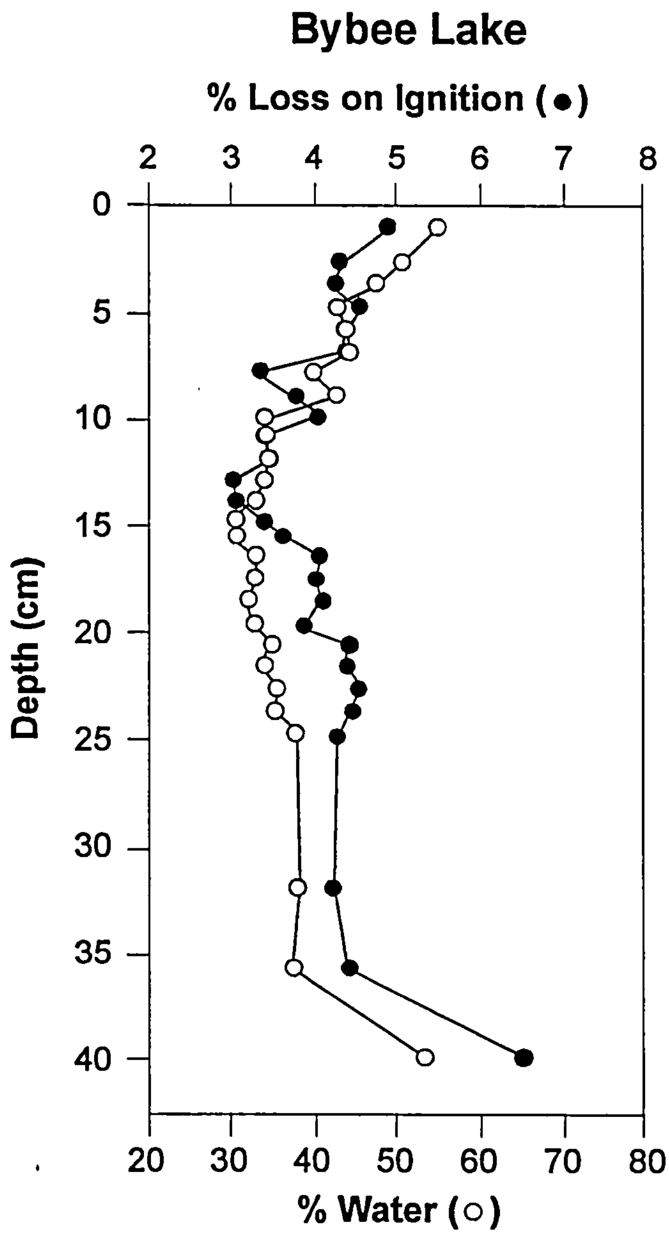

Figure 5. Percent water (o) and organic matter (as % loss on ignition, LOI[●]) for Bybee Lake based on an exploratory core collected July, 1994.

at the base of the core. Figure 6 shows the water content for the upper 40 cm in Devils Lake and Lake Lytle, two other shallow productive lakes in Oregon. Even the minimum values in the Devils and Lytle cores (150 cm) generally exceed the surface water content of the surface sediments in Smith and Bybee Lakes. The LOI values show patterns similar to the water content in both lakes, with values of less than 8% at the surface of Smith Lake decreasing to about 4% at 40 cm. Bybee Lake shows values of almost 5% at the surface, decreasing to less than 3% mid-core and sharply increasing at the base. These LOI values are lower by a factor of 3 to 5 than other productive lakes in Oregon (Meyerhoff 1977; Eilers et al. 1994, 1995). Figure 7 presents LOI values for the same lakes presented in Figure 6. Again, the LOI content in surface sediments of Devils and Lytle Lakes greatly exceeds the values in Smith and Bybee Lake surface sediments. Although the maximum depth in Devils Lake (5.8 m) is greater than in Smith-Bybee, the depth of Lake Lytle (2 m) is similar to the study lakes.

B. Sediment Dating

Determining the age of the sediments is critical to understanding the chronology of lake changes and measuring the sedimentation rate. The age of sediments is normally determined according to the C.R.S. (constant rate of supply) model (Appleby and Oldfield 1978) with confidence intervals calculated by first-order error analysis of counting uncertainty (Binford 1990).

The results of the ^{210}Pb activity measurements on the Smith and Bybee Lake sediments show that activity levels are only slightly greater than background values (Figure 8; Tables 2 and 3). Lead-210 is a natural radioactive isotope that has a radioactive half-life of 25 years. Consequently, sediments deposited in the last 75 years would be expected to exhibit much greater ^{210}Pb activity than shown here. These data were judged to be insufficient for determining the age of the lake sediments. These low and undifferentiated ^{210}Pb values could only be explained under one of three scenarios: (1) the sedimentation rate is so rapid that it effectively

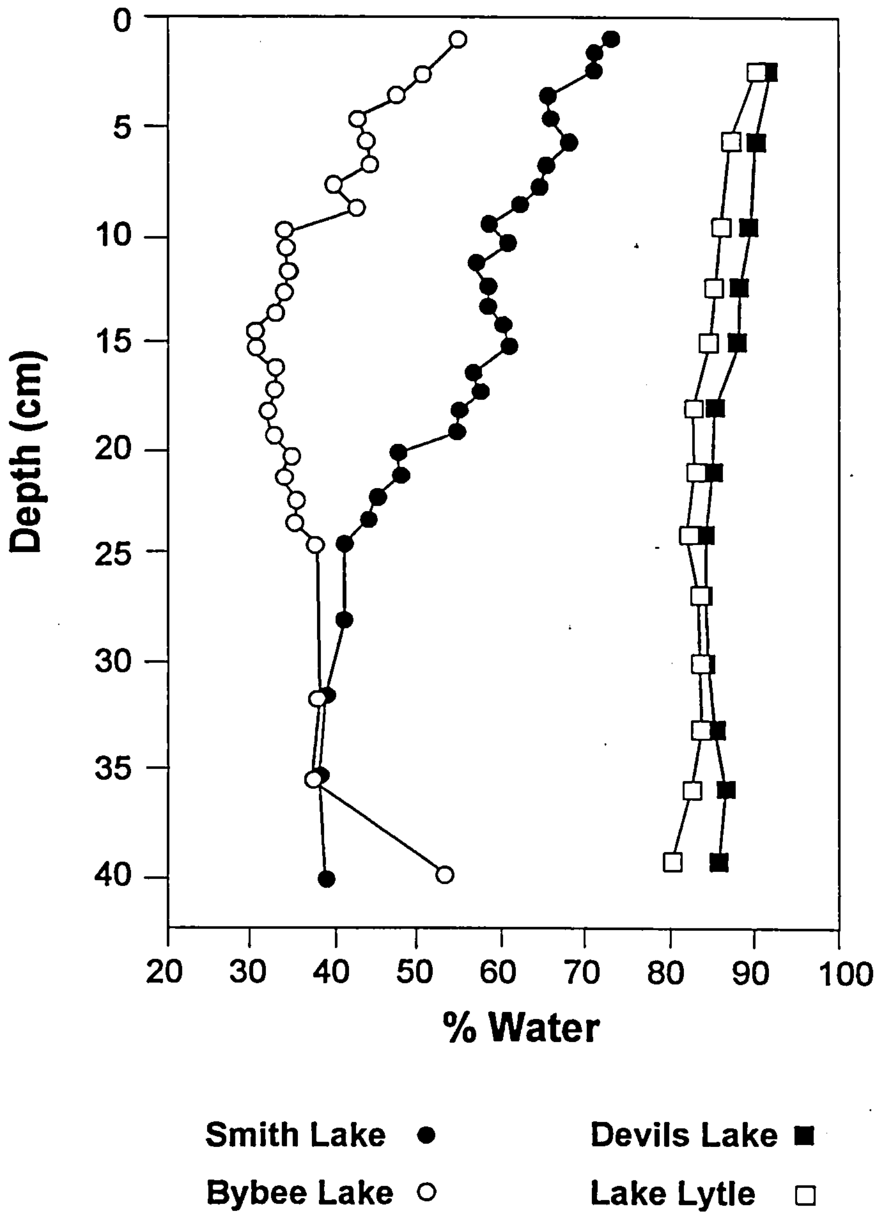

Figure 6. Percent water content for the upper 40 cm of Smith Lake (●), Bybee Lake (○), Devils Lake (■), and Lake Lytle (□). Data from Devils Lake are derived from Eilers et al. 1994. Data from Lake Lytle are derived from Eilers et al. 1995.

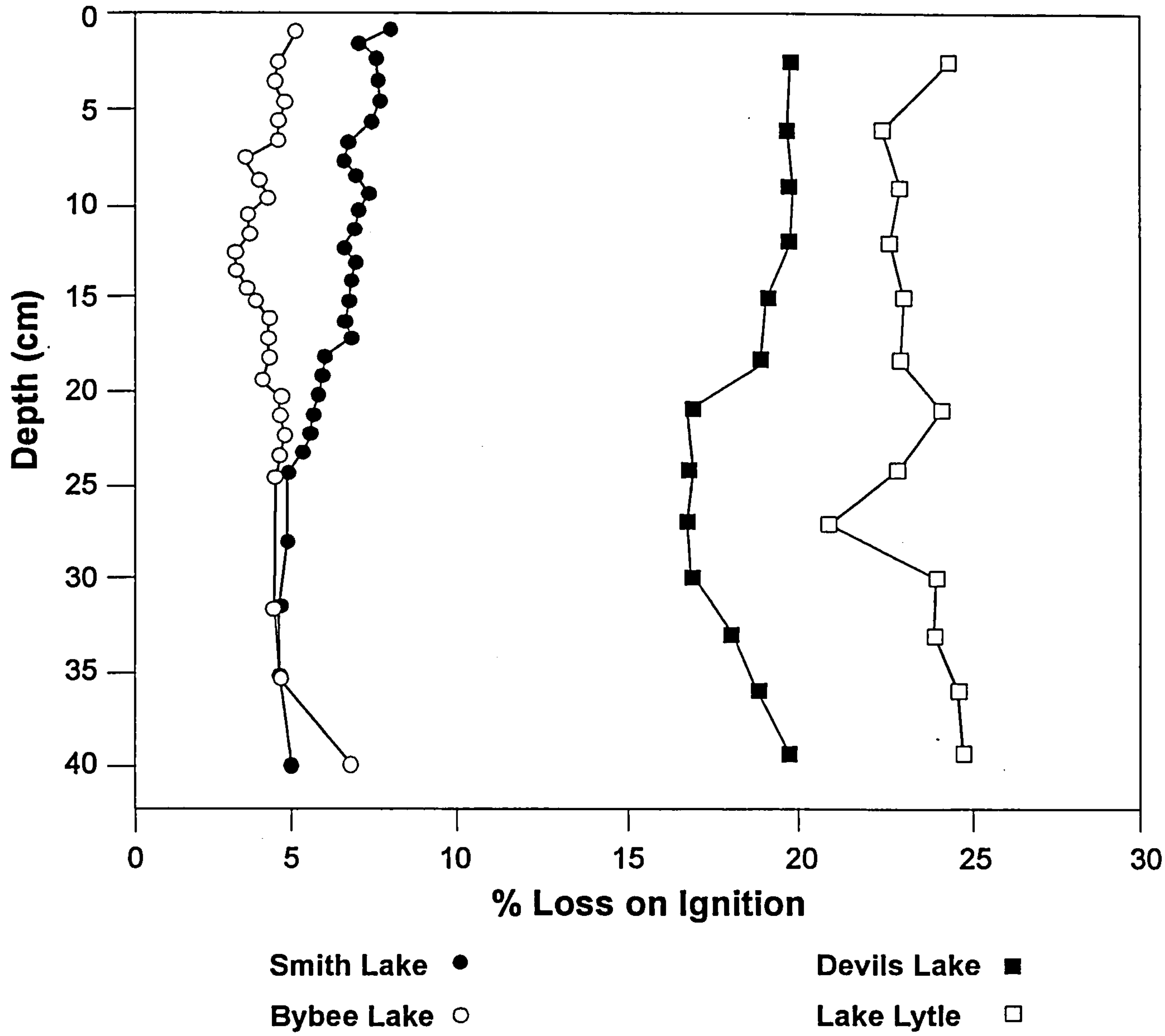

Figure 7. Loss on ignition (%) for the upper 40 cm of Smith Lake (●), Bybee Lake (○), Devils Lake (■), and Lake Lytle (□). Data from Devils Lake are derived from Eilers et al. 1994. Data from Lake Lytle are derived from Eilers et al. 1995.

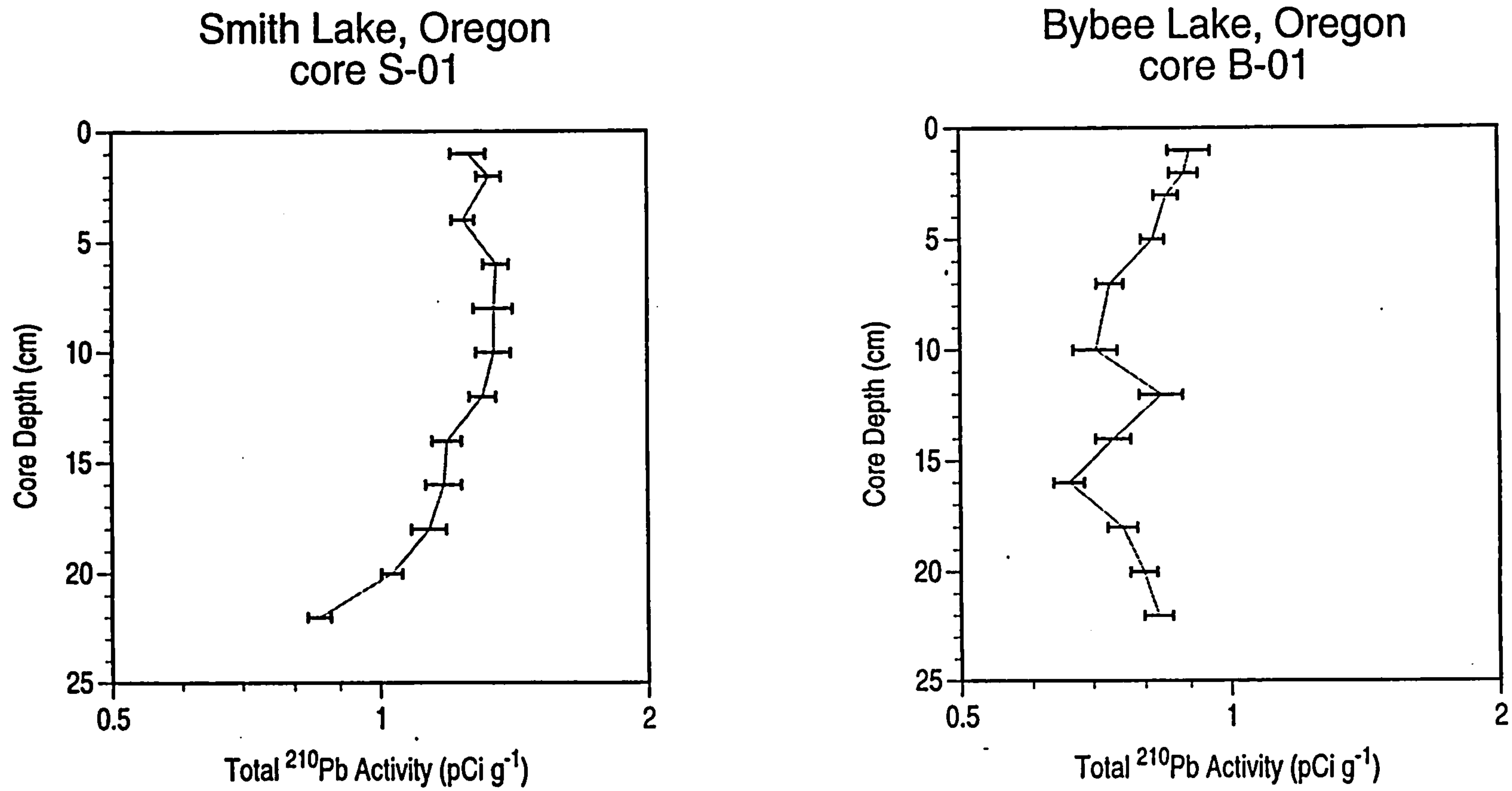

Figure 8. Total ^{210}Pb activity for surface sediments (a) Smith Lake and (b) Bybee Lake.

Table 2. ^{210}Pb activity and raw counts for sediment samples in Smith Lake. The code # represents the depth of the top of each sediment interval in centimeters.

Code #	1st 208 Ch	Nth 208 Ch	1st 210 Ch	Nth 210 Ch	208 Counts	210 Counts	210 Act. (pCi/g)	Δ210 Act. (±s.d.)	Plat. Effic. (%)	Series #
0	275	300	318	343	928	1016	1.26	0.0576	36	1
1	250	267	284	301	2256	2016	1.3284	0.0408	38	2
3	248	266	281	299	2379	2171	1.2422	0.037	40	3
5	266	284	297	315	1924	1810	1.3526	0.0444	32	4
7	371	385	406	420	967	687	1.3438	0.0675	16	5
9	250	268	283	301	965	1078	1.3442	0.0598	38	6
11	247	268	280	301	1710	1699	1.3064	0.0449	45	7
13	274	300	318	344	1371	1485	1.1904	0.0449	36	8
15	277	300	321	344	810	1115	1.1808	0.0548	35	9
17	276	301	320	345	932	1039	1.1355	0.0515	44	10
19	276	297	320	341	2523	2905	1.0311	0.0282	39	11
21	277	301	321	345	2289	2298	0.8543	0.0254	36	12

Table 3. ^{210}Pb activity and raw counts for sediment samples in Bybee Lake. The code # represents the depth of the top of each sediment interval in centimeters.

Code #	1st 208 Ch	Nth 208 Ch	1st 210 Ch	Nth 210 Ch	208 Counts	210 Counts	210 Act. (pCi/g)	Δ210 Act. (±s.d.)	Plat. Effic. (%)	Series #
0	247	267	280	300	783	592	0.9027	0.0493	43	1
1	261	284	306	329	2078	1121	0.8894	0.033	35	2
3	283	302	328	347	2478	1890	0.8489	0.026	42	3
5	277	296	320	339	2538	1991	0.8199	0.0247	43	4
7	276	299	320	343	2210	1381	0.7339	0.0253	37	5
9	272	300	316	344	623	652	0.7075	0.0399	44	6
11	277	297	320	340	523	859	0.8379	0.0467	37	7
13	277	297	320	340	894	1077	0.7393	0.0336	42	8
15	279	301	323	345	1309	1430	0.6599	0.0254	39	9
17	250	267	284	301	1390	1475	0.7572	0.0284	42	10
19	249	267	283	301	1517	1798	0.7995	0.0279	46	11
21	267	284	298	315	1343	1697	0.8303	0.0304	41	12

dilutes the ^{210}Pb activity, (2) no modern sediments are present, or (3) the sediments are well mixed to at least 20 cm.

Subsamples of other Smith Lake cores were analyzed for ^{137}Cs using α-spectrometric methodology (EML 1992) to further explain the results from the ^{210}Pb dating. Cesium-137 is a major fission product of above ground nuclear testing which began in 1954. ^{137}Cs has a half-life of 30 years and, regardless of the sedimentation rate or degree of sediment disturbance, sediment accumulated since the mid 1950's will show measurable ^{137}Cs. The results from these analyses showed no ^{137}Cs present in the sediments. The absence of cesium in the sediments is confirmation that little or no recent sediments have accumulated in the lakes.

C. Diatoms

1. Current Community

The periphyton and plankton samples revealed that a tychoplanktonic assemblage exists. Tychoplankton is the community resulting from the periphyton being entrained into the plankton. There is sufficient mixing within each lake that the communities usually associated with periphytic habitats (e.g., *Cymbella* spp., *Cocconeis* spp., *Epithemia* spp., *Eunotia* spp., *Fragilaria construens* etc) are mixed with the communities usually restricted to planktonic habitats (e.g., centrics such as *Cyclostephanos dubia*, *Cyclotella* spp., *Stephanodiscus* spp.).

Similar periphytic communities were observed in both lakes. The most common diatom in the periphyton of these lakes was *Epithemia sorex*. Other common diatoms observed in these samples included mostly periphytic diatoms although some centrics were also observed (e.g., *Aulacoseira* spp., *Eunotia eruca, Fragilaria construens* and *F. construens* var *venter*, *Gomphonema* spp., *Gyrosigma* spp., *Navicula* spp., *Nitzschia* spp., *Rhopalodia* spp., *Synedra* spp., *Stephanodiscus hantzschia, Cyclostephanos dubia*).

Phytoplanktonic communities were also similar in the lakes. Both communities contained planktonic centrics such as *Cyclostephanos dubia, Stephanodiscus hantzschia,* and *Cyclotella* spp., as well as the entrained periphytic diatoms such as *Achnanthes*, *Cocconeis* spp., *Cymbella* spp., *Synedra* spp., *Fragilaria vaucheriae*, *Fragilaria construens*, *Gyrosigma* spp and *Nitzschia* spp. A common genus, *Aulacoseira* spp. is often common to both the plankton as well as the periphyton, depending upon seasonal variations in the mixing regimes of a system.

2. Sediment Cores

General observation from the scans of the initial sediment samples collected in January 1994 showed that diatoms are numerous throughout the cores. The main difference or trend observed is that there is a noticeable lack of centrics in the bottom two samples (Table 4).

Table 4. General description of diatom taxa present a various depths in the sediments of Smith Lake. Core collected January 1994.

0-1 cm	5-6 cm
Aulacoseira *Cocconeis* spp. *Cyclotella* spp. *Cymbella* spp. *Epithemia* spp. *Fragilaria* spp. *Gomphonema* spp. *Gyrosigma* spp. *Navicula cuspidata* *Navicula* spp. *Nitzschia* spp. *Pinnularia* spp. *Rhoicosphenia* spp. *Rhopalodia* spp. *Synedra* spp. *Stephanodiscus* spp. Other siliceous microfossils: sponge	Similar to the above 16-18 cm Similar species assemblage to above but included *Fragilaria construens* and *Diploneis ovalis* Noticeably, there was a lack of *Cyclotella* and other centrics in general. 34-36 cm Similar to above with addition of *Amphora*, *Surirella*; no centrics (*Cyclostephanos* etc).

The relative abundance of diatoms was determined for the surface sediments (0-1 cm) from the Smith Lake core collected in July 1994 (Table 5). Scans of the remainder of the depths (e.g., 4, 9, 10, 12, 14, 16, 18 and 23 cm in particular) showed that most of the diatoms are consistently present throughout the entire core. However, at a general level, *Aulacoseira* spp. are more abundant at the top of the core. Different centrics dominate throughout the core with *Cyclostephanos dubia* being more abundant at the top and declining towards the bottom. *Stephanodiscus hantzschia* shows an increase in abundance with depth.

Table 5. Relative abundance of diatom remains in surface sediments of Smith Lake.

Taxa	Relative Abundance (%) (n=320)
Achnanthes minutissima	1.3
Achnanthes spp.	0.3
Asterionella formosa	0.6
Aulacoseira spp.	28.4
Cyclostephanos dubia	16.9
Cyclotella meneghiniana	1.0
Cyclotella pseudostelligera	1.9
Cyclotella stelligera	0.6
Navicula halophila	0.3
Cymbella minuta	0.6
Cymbella spp.	1.0
Cocconeis placentula var *lineata*	1.3
Diatoma sp.	0.3
Epithemia sorex	2.6
Fragilaria brevistriata	1.3
Fragilaria construens	3.8
Fragilaria construens var *venter*	1.0
Fragilaria pinnata	12.2
Fragilaria spp.	4.1
Hantzschia sp.	1.0
Navicula gottlandica	0.3
Navicula radiosa	0.6
Nitzschia spp.	11.9
Rhopalodia spp.	1.0
Stephanodiscus hantzschia	2.8
Stephanodiscus spp.	0.6
Others (obscured valves, rare forms)*	2.9

* Fragments of *Campylodiscus, Fragilaria binodis, Navicula bacillum, Gyrosigma* sp.
Scales of *Mallomonas crassisquama*
Sponge spicules, protozoan plates from *Trinema*

A similar diatom assemblage was observed in Bybee Lake (1, 10, 23 cm depths in particular). Similar trends with respect to depth were also observed, with fewer centrics being observed with increasing depth.

V. DISCUSSION

The results of analyses of sediment cores collected from Smith and Bybee Lakes show that a major portion of the sediments in both lakes are not recent (i.e., this century). There are two aspects of this finding that require explanation. First, no sediments from the first half of the century were found in the lakes. This is particularly perplexing in view of the floods that have been documented during this period. Second, no sediments from post-1982 were found. These questions are explored in detail below. Whereas most lakes are efficient collectors of sediment, Smith and Bybee Lakes historically were subject to considerable hydrologic forces associated with seasonal flooding of the Columbia River and daily erosion associated with tidal fluctuations.

Smith and Bybee Lakes historically were inundated during major spring floods. The last major flood occurred in 1948 and was referred to as the Vanport flood for the town that was destroyed. The flood waters carried fine clay particles which were deposited in the lakes as the flood receded. We believe that fine clays constitute the majority of the sediments currently in the lakes and explain the low water and organic content in the cores. Such massive floods have been effectively eliminated with the completion of the numerous hydroelectric generating dams on the Columbia River (1938-1968) and the flood control reservoirs in the Willamette Basin (1942-1968). Although the spring floods along the Columbia River provided a source of additional sediment to the lakes, we believe most of these deposits were effectively removed by tidal action. The rivers in Portland and vicinity are influenced by tidal fluctuations from the Columbia Estuary. The magnitude of daily tidal amplitude on the Columbia River at Portland is typically about 0.6 m (Columbia River Pilots, pers. comm.), with a maximum annual fluctuation of about 3 m. Photographs of Smith and Bybee Lakes reveal the considerable change in stage and exposed sediments in earlier years (photographs on file at Metro). The erosive force associated with the tides could have stripped the lakes of all unconsolidated sediments.

Several major hydrologic modifications have been made directly to Smith and Bybee Lakes beginning principally after 1940. Around 1940, tidegates and weirs also were installed at the outlets of both lakes. In 1956, additional earthen dikes were added to restrict outflow. The earthen dike for Smith Lake was removed in 1967, and in 1968 a new dike was placed about 75 m upstream in the North Slough. In 1973, the North Slough dike was breached with a 1.2 m wide ditch connecting a swale on the north side with Bybee Lake. In 1982, a control structure was placed on the Columbia Slough effectively eliminating connection with the slough and stabilizing lake levels at a high permanent stage. The stated purpose of this action was to reduce the likelihood of outbreaks of avian botulism (U.S. Army Corps of Engineers 1982, Johnson et al. 1985). As a consequence, the lake does not receive the high degree of hydrologic exchange that it did in the pre-1940 period. But if the restriction of tidal fluctuation since 1982 eliminated effective flushing of the lakes, why didn't we observe post-1982 sediment? This probably was a function of the very low sedimentation rate that now exists in the lakes and because of wind disturbance of the sediments. Whereas, floods occasionally deposited sediments in the lake, the current watershed is restricted to a small contributing area in the immediate vicinity of the lakes. Annual sedimentation rates in such lakes can be expected to be < 1 mm/yr. Another contributing factor is that the deeper areas of the lakes which were cored are subject to considerable wind turbulence. These openings in the macrophyte beds are subject to greater turbulence than the areas of the lakes with dense macrophytes and what little sediment had accumulated probably was moved elsewhere.

In effect, Smith and Bybee Lakes have been transformed from highly dynamic depositional/erosional environments to stable (hydrologically) depositional environments having much lower rates of sediment accumulation than was the case historically. The depths of both lakes can be expected to slowly decrease as organic matter accumulates over the largely inorganic sediments. The rate of sediment accumulation will be low because future sediments will be generated from autochthonous (within-lake) sources. In addition, the nutrient cycling regime will change from a system in which nutrients are exported from the lakes to one in which nutrients will accumulate. The shallow depth of the lakes will insure high availability of nutrients for macrophytes and phytoplankton.

VI. SUMMARY AND CONCLUSIONS

Sediment cores were collected from Smith and Bybee Lakes. The radioactive dating with ^{210}Pb and ^{137}Cs isotopes showed that relatively little sediment from the 20th century has accumulated in the lakes. The lakes historically were strongly influenced by tidal fluctuations and periodically by floods from the Columbia and Willamette Rivers. The floods have been controlled by dams and the tidal fluctuations have been eliminated by a control structure on the remaining connection with the Columbia Slough. The lakes historically were depositional/erosional systems receiving seasonal inputs of sediment and exporting sediment and nutrients with the outgoing tides. They have been transformed into depositional environments which effectively retain sediment and nutrients. The long-term consequences of maintaining the current management regime will be to increase the productivity of Smith and Bybee Lakes. Emergent macrophytes can be expected to become more widespread leading to a reduction in open water. The open areas of the lake are already dominated by submerged macrophytes (*P. crispus*) which can be expected to further proliferate.

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