CHAPTER 3

MIKE AND MISTY LAKE STRATIGRAPHY[1]

Although the chironomid stratigraphic results obtained from Marion Lake, discussed in the preceding chapter, and those of several earlier investigations (Andersen, 1938; Günther, 1983; Hofmann, 1983a, b, 1985) suggest a climatic control upon chironomid faunas, a more rigorous test of this hypothesis is desirable. Without the ability to experimentally manipulate climate, it is necessary to examine other fossil evidence from critical periods of rapid climatic change. This process Deevey (1969) dubbed "Coaxing history to conduct experiments."

It would be expected, if climate is directly or indirectly responsible for the late-Pleistocene faunal changes at Marion Lake, that similar changes should be evident, synchronously, at other lakes within the same region. Thus two lakes, Mike Lake and Misty Lake in southwestern British Columbia were selected for study. These are small, low-elevation lakes of comparable depth to Marion Lake.

Study sites

Mike lake (225 m elev.; 49° 16.5'N, 122° 32.3'W) is located 3 km south of Marion Lake, in Golden Ears Provincial Park. Because it lies farther from the mountains and at lower elevation (Fig. 3.1), the climate at Mike Lake is probably slightly warmer and drier. Forests surrounding the lake are placed within the drier subzone of the Coastal Western Hemlock zone (Klinka, 1976). These distances, elevation differences, and expected climatic discrepancies are slight however. Although two University of British Columbia Research Forest weather stations in the area near Marion and Mike Lakes

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[1] A manuscript adapted from this chapter has been submitted to Journal of Paleolimnology.

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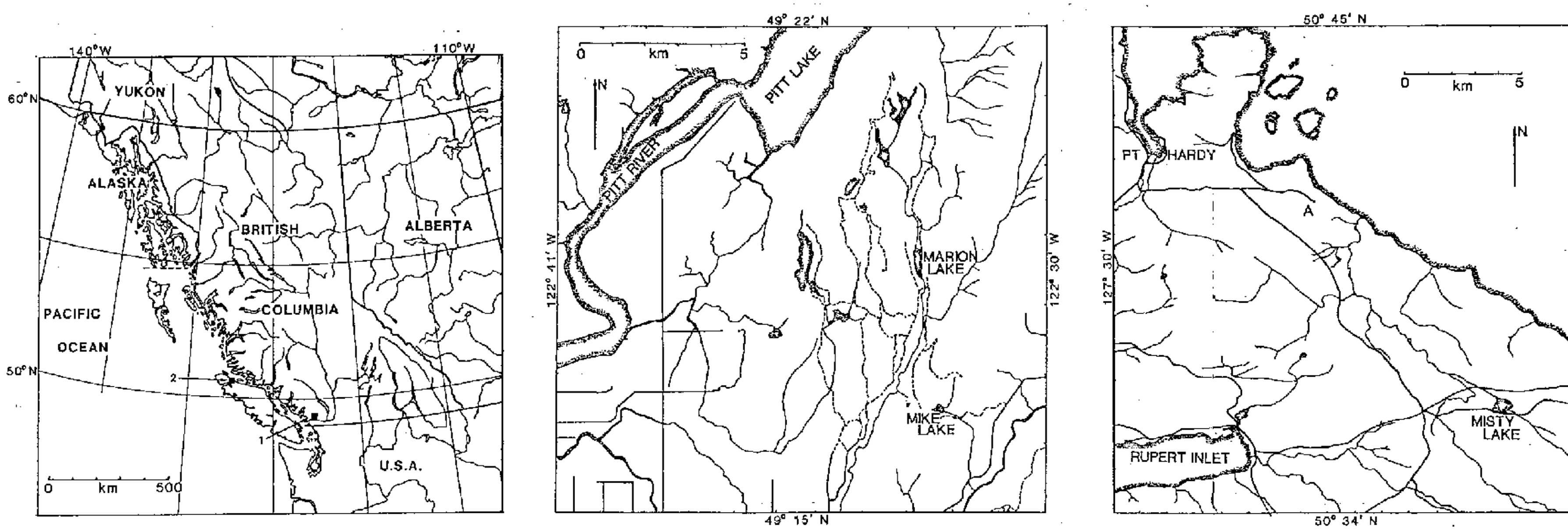

Figure 3.1 Locations of Mike and Misty Lakes in southwestern British Columbia, Canada. (1–indicates Mike Lake study area; 2–indicates Misty Lake study area)

(Table 3.1) are separated by 211 m elevation, mean temperatures differ by less than 1°C. Annual precipitation is about 16% less at the lower site. Consequently, a very similar climatic regime must also exist for Marion and Mike Lakes, now and in the past. This, it was expected, would be reflected in the chironomid record.

With a surface area of 4.5 ha and maximum depth of 6.5 m, Mike Lake's catchment extends to at least 200 m above lake level. Owing to the limited, 1.7 km^2 catchment, inflowing streams are small. During summer a distinct thermal stratification is apparent. On August 22, 1987, the upper 3.0 m of water ranged from 19 to 21.5°C, but waters below 5.0 m varied from 12.5 to 10°C. The lake is surrounded, and presumably underlain by a thick morainal blanket (Klinka, 1976). Bedrock beneath the lake and catchment consists of base-poor crystalline plutonic rocks, diorite, of the coast mountain complex (Roddick, 1965). The surrounding forests are similar to those at Marion Lake.

Misty Lake (70 m elev.; 50° 36.3' N, 127° 15.7' W) is situated 360 km northwest of Marion and Mike Lakes, near Port Hardy on northern Vancouver Island (Fig 3.1). Despite the great distance separating this site from Marion and Mike Lakes, the similar vegetation and climate also place this site (Farley, 1979) within the Coastal Western Hemlock biogeoclimatic unit (wetter subzone). Port Hardy (Table 3.2) is drier than the southern stations, receiving 1700 $mm \cdot yr^{-1}$ as rain. Although Port Hardy is warmer in winter, its summers are cooler. Differences in the forest cover are evident. Although western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) dominate at mesic sites, the low relief and cool summer climate have allowed extensive paludification (Hebda, 1983). Thus bog forest complexes are prominent throughout the area. According to Hebda (1983) Douglas-fir (*Pseudotsuga meneziesii*) is uncommon, restricted to xeric sites, and trees typical of higher elevations near Vancouver (e.g. *Chamaecyparis nootkatensis* (D.Don) Spach) are more widespread.

Table 3.1. Climatic summary (1951-1980) for Loon Lake (49°18'N, 122°35'W; 354 m elev.), and Administration (49°16'N, 122°34'W; 143 m elev.), University of British Columbia Research Forest, Haney, British Columbia.

	Loon Lk	Administration
Mean Daily Temperature (°C)		
Coldest Month (Jan)	0.5	1.4
Warmest Month (Jul)	16.3	16.8
Precipitation		
Rain (mm): Annual	2459.1	2059.3
Wettest Month (Dec)	343.3	306.3
Driest Month (Jul)	86.7	65.5
Snow (cm): Annual	195.2	81.6
Frost-free Period (d)	199	198
Degree-days (°C·d)		
Above 0°C	3092.7	3445.7
Above 5°C	1633.7	1882.1

(Environment Canada, 1982)

Table 3.2. Climatic summary (1951-1980) for Port Hardy Airport (50°41',127°22'W; 22 m elev.), northern Vancouver Island, British Columbia.

Mean Daily Temperature	
Coldest Month (Jan)	2.4°C
Warmest Month (Aug)	13.8
Precipitation	
Rain: Annual	1705.8 mm
Wettest Month (Dec)	260.3
Driest Month (Jul)	52.0
Snow: Annual	72.1 cm
Frost-free Period	177 d
Degree-days	
Above 0°C	2931.2°C·d
Above 5°C	1350.0

(Environment Canada, 1982)

With a surface area of 36 ha and maximum depth of 5.2 m, Misty Lake's catchment extends to approximately 100 m above lake level, encompassing 10 km^2. Although an extensive stream system enters the lake, the core was taken near the maximum depth, distant from the inflow. The lake and catchment are underlain by Mesozoic rocks. To the northeast side are Cretaceous sedimentary rocks consisting largely of shales, sandstones, siltstones, and conglomerates, with some coal. Southwestward, Triassic rocks, including both sedimentary (limestone and dolomite) and volcanic units (andesite, basalt, and rhyolite), are exposed (Prov. of B.C., undated).

Methods

The methods used in the stratigraphic study of Mike and Misty Lakes differ little from those described for Marion Lake in the preceding chapter. A 5–cm–diameter sediment core, 6.43 m long, was obtained from the centre of Mike Lake, Golden Ears Provincial Park, at a water depth of 6.47 m. At Misty Lake, 7.53 m of sediment were removed near the lake centre, in 5.2 m of water. For Mike Lake, the 1.0–m–long piston core segments were stored intact, but Misty Lake sediments were bagged as smaller units. For Misty Lake, the upper 7.00 m of sediment were cut into 0.10 m sections, which were individually sealed in plastic bags. To allow closer sampling of the late–glacial deposit, sediment below 7.00 m was packaged as 0.05 m slices. During analysis sediment subsamples of 1.0 to 2.0 mL were examined at 0.80 m intervals throughout most of both cores. Closer sampling was necessary to characterize changes within the late–glacial sediments and, for Mike Lake, near the Mazama volcanic ash.

The sediment subsamples were deflocculated in warm 6% KOH and then sieved (.075 mm mesh). The coarse matter retained was later manually sorted, at 50X magnification in Bogorov counting trays. Fossil chironomids were mounted in Permount®

and identified, principally with reference to Hamilton (1965) and Wiederholm (1983). Diagnostic features used for identification of specific taxa are reported in the Appendix. Percentage diagrams were plotted using the computer program MICHIGRANA developed by R. Futyma and C. Meachum.

Results: Mike Lake

The basal sediments (6.40 – 6.43 m) of Mike Lake are inorganic (Fig. 3.2), composed mostly of grey clay with little, if any, sand or coarser matter. A mottled grey-brown clay-gyttja was subsequently deposited (6.32 – 6.40 m), grading into organic gyttja above (6.275 – 6.32 m). This progression to more organic-rich sediments is interrupted by a thin compact clay layer between 6.26 and 6.275 m. Subsequent sediments, above 6.26 m, consist of a rather uniform-looking organic dy or gyttja, except for the Mazama ash at 4.25 to 4.28 m. Although organic matter and water compose much of the sediment bulk, mineral matter constitutes, by weight, approximately 70 to 80% of the dry residue from 6.1 to 3.0 m. Above 3.0 m, sediments are only slightly less inorganic (*ca.* 60%).

Radiocarbon dates have been obtained on sediments from the lower half of the Mike Lake core, as summarized in Table 3.3. Basal organic-rich sediment at 640 cm dates to 12,910 yr B.P. Thus the timing of deglaciation at Mike Lake is very similar to that at Marion Lake. Dates of 10,350 and 10,360 yr B.P., on sediments near 5.9 m, approximately define the Pleistocene/Holocene boundary.

Although a detailed palynological investigation of Mike Lake's sediments is not yet complete, preliminary data, provided by R. Mathewes, suggest a vegetation history similar to that evident at Marion Lake. As at Marion Lake, the basal sediments (>6.40 m; >12,000 yr B.P.) are a clay in which two shrubs, willow (*Salix*) and soapberry

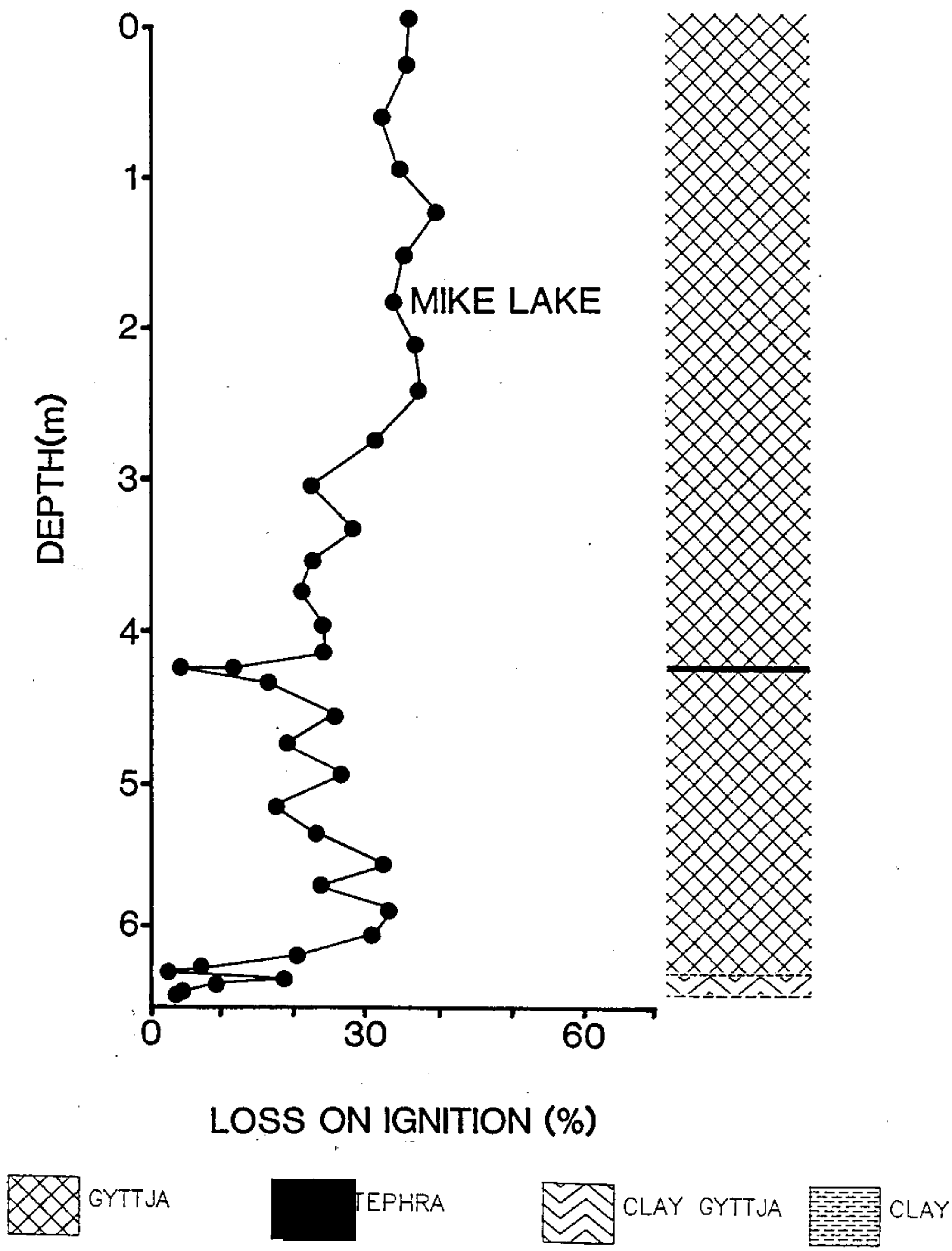

Figure 3.2 Sediment lithology and loss on ignition diagram for dry sediments of Mike Lake, B.C.

Table 3.3. Radiocarbon age for Mike and Misty Lake sediments, British Columbia, Canada.

Sample Depth	Material Dated	Laboratory Reference No.	$\delta^{13}C$*	Age (corrected)
Mike Lake**				
425 cm	Sediment	RIDDL-647	-25	7040±110 yr B.P.
425-428	Mazama Ash	(Bacon, 1983)		6845±50
428	Sediment	RIDDL-648	-25	7500±110
589	Sediment	RIDDL-649	-25	10,350±100
598	Sediment	RIDDL-650	-25	10,360±110
628	Sediment	RIDDL-651	-25	11,850±170
640	Sediment	RIDDL-653	-25	12,910±160
Misty Lake				
90-100	Sediment	BETA-16582	-25	1760±80
290-300	Sediment	BETA-16583	-25	2860±80
490-500	Sediment	BETA-16584	-25	5720±90
590-600	Sediment	BETA-16585	-25	6960±110
705-710	Sediment	BETA-16586	-25	10,180±130
735-740	Sediment	GSC-4029	-25	12,100±130

*-assumed

**-Mike Lake dates are Accelerator Mass Spectroscopy dates, on sediment following KOH, HCl, and HF treatment

(*Shepherdia canadensis*) are prominent, as well as pine (*Pinus* L.). Subsequent forest establishment is marked by the sharp increase in sediment organic content and a preponderance of lodgepole pine (*Pinus contorta*) pollen. Pollen evidence also suggests the presence of balsam fir (*Abies*), spruce (*Picea*), and poplar or cottonwood (*Populus* L.). The thin clay band between 6.26 and 6.275 m (Fig. 3.2) is apparently not distinguished by a distinctive fossil spectrum. Lodgepole pine pollen continues to dominate the sediments through late–glacial time (6.40 to *ca.* 5.90 m; *ca.* 12,000 to 10,000 yr B.P.) with the proportion of balsam, spruce, and alder (*Alnus* Hill) being greater above the clay band.

Western hemlock and mountain hemlock (*Tsuga mertensiana*) are relatively abundant near the Pleistocene/Holocene boundary (*ca.* 5.90 m; 10,000 yr B.P.). Early Holocene sediments (above 5.85 m) include a high proportion of Douglas–fir suggesting a xerothermic interval. However, the renewed abundance of western hemlock pollen (above *ca.* 5.2 m), arrival of western red cedar at *ca.* 3.5 m, and corresponding decline in Douglas–fir indicate, thereafter, a gradual Holocene shift towards the moist climate presently extant in the lower Fraser Valley.

The chironomid record at Mike Lake is in many respects comparable to that at Marion Lake. The results have been portrayed both as percentage data (Fig. 3.3) and total influx (Fig. 3.4). Since the chironomid records do appear similar, the Mike Lake profile will also be discussed in terms of 3 zones. As at Marion Lake, the lowermost zone (6.43 to 5.90 m) encompasses late–glacial sediments deposited prior to 10,000 yr B.P. The second, pre–Mazama zone (5.90 to 4.28 m) was deposited between *ca.* 10,000 yr B.P. and 6800 yr B.P. The third zone, comprising sediments above the Mazama ash (4.25 to 0.0 m), spans the period from 6800 yr B.P. to the present.

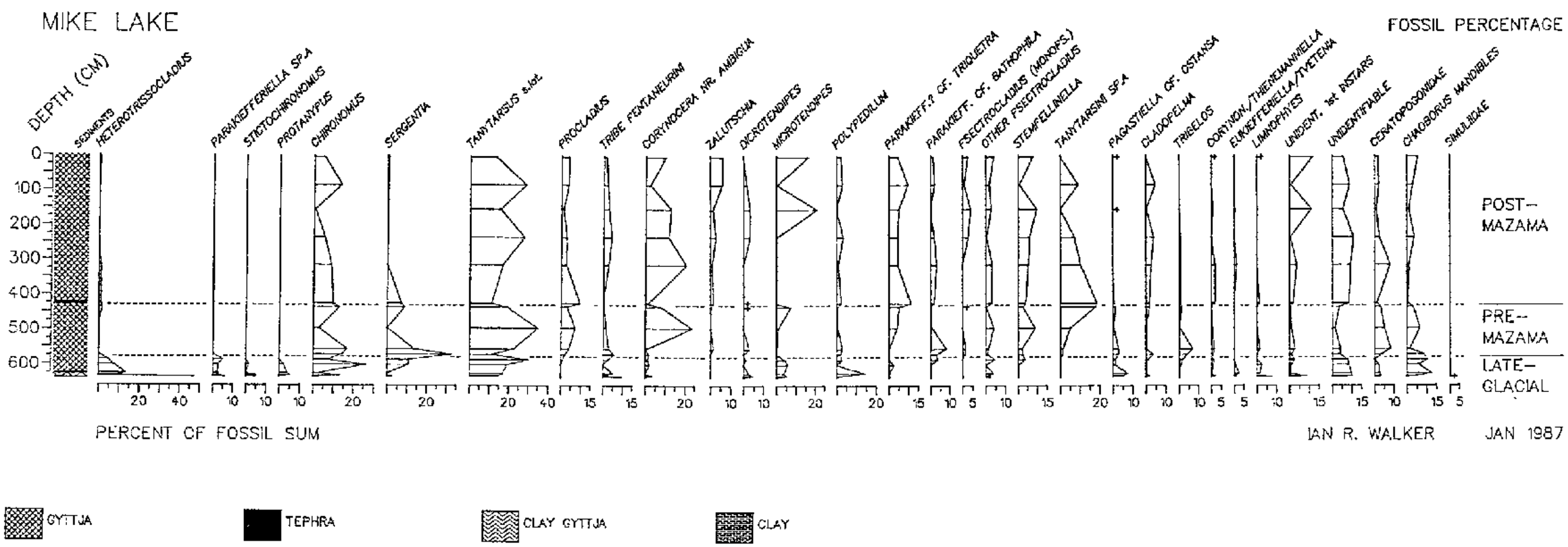

Figure 3.3 Percentage (of total number of chironomid head capsules at each sample level) diagram representing stratigraphy of common Chironomidae at Mike Lake, B.C. (Several rare taxa have been excluded; "+" indicates presence in small numbers).

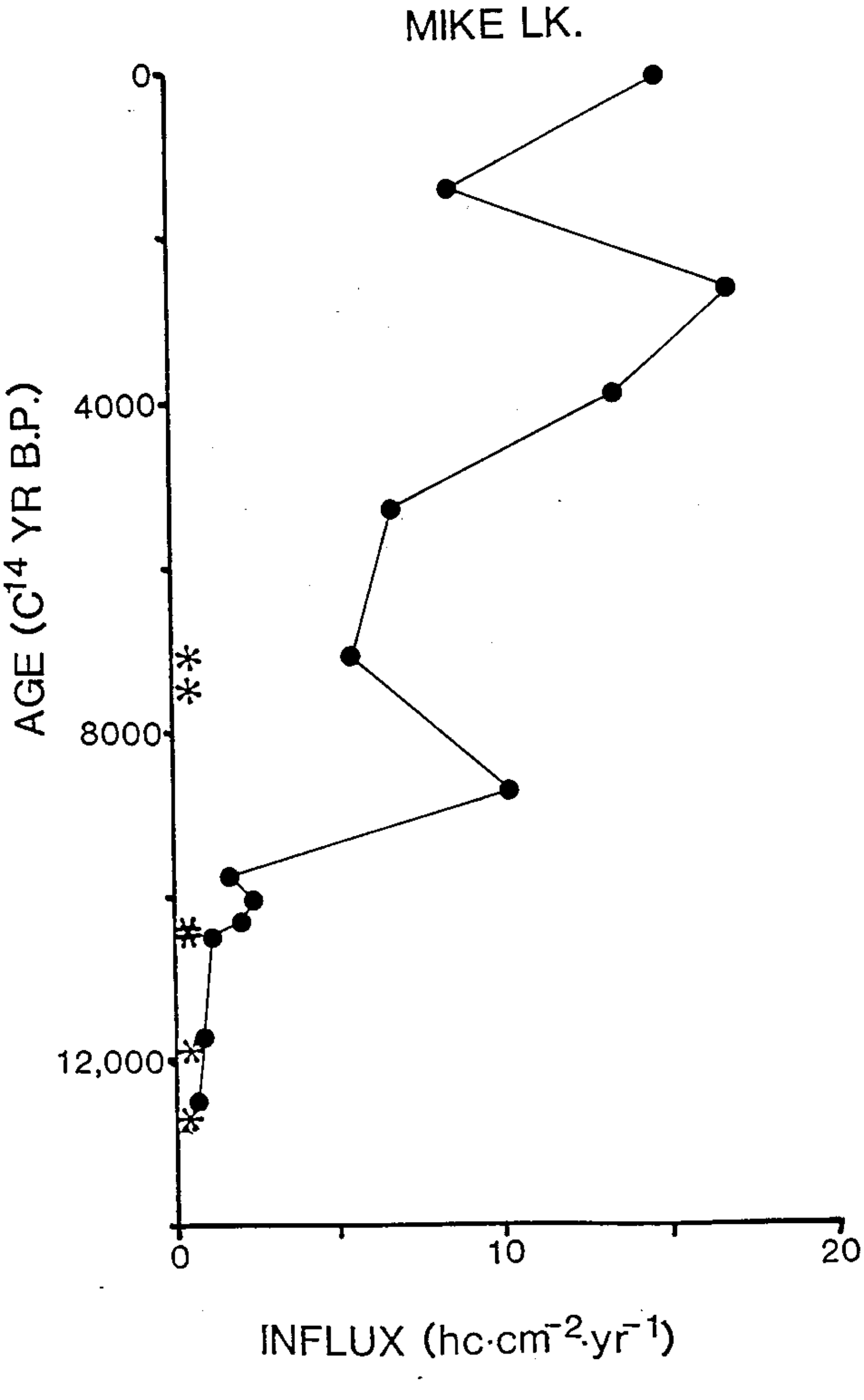

Figure 3.4 Total chironomid influx at Mike Lake, B.C. (*–indicate ^{14}C-dated levels).

Late-glacial assemblages

Late–glacial head capsule influx was low, *ca.* 1.0 $hc \cdot cm^{-2} \cdot yr^{-1}$ (Fig. 3.4). Prominent late–glacial taxa at Mike Lake included each of the oligotrophic, cold–stenothermous elements recorded at Marion Lake, apart from *Pseudodiamesa*[2] (ie. *Heterotrissocladius, Parakiefferiella* sp.A, *Protanypus,* and *Stictochironomus*). Many other taxa (e.g. *Chironomus, Corynocera* nr. *ambigua, Microtendipes* Kieffer, *Pagastiella* cf. *ostansa, Psectrocladius, Sergentia, Tanytarsus* s.lat.) are also represented. Although, as compared to Marion Lake, the cold–stenothermous taxa at Mike Lake constitute a smaller proportion of the total fauna, the late–glacial trend is distinctly similar. This cold element persists throughout the late–glacial to essentially disappear at 5.7 to 5.85 m, near the Pleistocene/Holocene boundary. *Heterotrissocladius* is the only genus of this group represented in later sediments.

Holocene assemblages

The Holocene is characterized by gradually increasing chironomid influx, rising from near 1.0 $hc \cdot cm^{-2} \cdot yr^{-1}$ during the earliest Holocene to 17.0 $hc \cdot cm^{-2} \cdot yr^{-1}$ for modern sediments (Fig. 3.4). A marked separation between early and late Holocene faunas is not evident.

Apart from a single record of *Heterotrissocladius* just below the Mazama ash, the late–glacial cold–stenotherms are absent from pre–Mazama Holocene sediments. *Corynocera* nr. *ambigua* occurs abundantly. Although *C. ambigua* is often regarded as a cold–stenotherm, it is recorded as a littoral resident, occurring throughout Scandinavia, and in the temperate lowlands of north Germany (Fitkau and Reiss, 1978; Mothes, 1968). Its northern limit is in the low arctic (Danks, 1981).

[2] *Pseudodiamesa* has been found in the late–glacial sediments of Marion Lake since Walker and Mathewes' (1987a) account.

At Mike Lake, *Sergentia* is very abundant in the earliest Holocene sediments, rapidly declining in later deposits. As a common profundal inhabitant of northern oligo-mesotrophic waters (Brundin, 1958; Sæther, 1979), *Sergentia* is probably intolerant of warm water (Pinder and Reiss, 1986), but has survived elsewhere in low-elevation profundal environments of the Pacific Northwest (Wiederholm, 1976: as *Phaenopsectra coracina* (Zetterstedt)). However, the increasing productivity, and reduction in hypolimnetic volume, as Mike Lake shallowed, would have adversely affected this relatively O_2-sensitive taxon. In mid-to late Holocene deposits *Sergentia* disappears from the fauna.

In contrast to Marion Lake, *Heterotrissocladius* is rare in post-Mazama deposits of Mike Lake. The presence of cold lake-bottom springs is likely responsible for the greater abundance of cold-stenotherms at Marion Lake. *Corynocera* nr. *ambigua* is no more abundant during the late-Holocene than during the early Holocene. Thus, no evidence suggestive of cooler or more oligotrophic late Holocene conditions is noted. Although some littoral taxa (e.g. *Dicrotendipes* Kieffer, *Microtendipes*, *Zalutschia* Lipina) appear more abundantly in post-Mazama sediments, the palaeoecological significance of such minor changes remains obscure. Gradual shallowing of the lake and expansion of littoral habitats are likely to be important influences.

A conspicuous difference between the Mike and Marion Lake profiles is the rarity of rheophiles ("stream-loving" taxa) at Mike Lake. With a much smaller stream input (catchment area of 1.7 km^2, vs 15 km^2 for Marion Lake), this feature was not unexpected.

Results: Misty Lake

Inorganic sediments were also encountered at the base of the Misty Lake core on northern Vancouver Island. This clay deposit, extending from 7.53 to 7.40 m includes sand and pebbles as minor constituents. Thereafter, throughout the remaining late–glacial and Holocene deposits, the sediment is a uniform dark brown dy or gyttja, averaging *ca.* 55% mineral matter on a dry weight basis (Fig. 3.5).

Radiocarbon dates have been obtained throughout the core, as summarized in Table 3.3. Basal, organic–rich sediments (7.35 to 7.40 m) date to 12,100 yr B.P. A date of 10,180 yr B.P. at 7.05 – 7.10 m approximately defines the Pleistocene/Holocene boundary. This indicates a rather thin, 0.45 m late–glacial deposit. Slow sedimentation continued through the early Holocene, but increased towards the present day.

A detailed palynological record is, not yet, available for Misty Lake. R. Mathewes has provided preliminary data on major changes. Lodgepole pine pollen dominates throughout the late–glacial sediments. Balsam, spruce, and mountain hemlock also occur. Western hemlock is first evident at 7.20 – 7.25 m (*ca.* 11,000 yr B.P.). The beginning of the Holocene is marked by the first occurrence of Douglas–fir pollen (6.90 – 7.00 m).

In contrast to Marion and Mike Lakes, Douglas–fir pollen is not abundant during the early Holocene. Instead, western hemlock and spruce prevail from 7.0 to *ca.* 4.0 m (*ca.* 10,000 to *ca.* 4000 yr B.P.). This suggests a wetter and perhaps cooler early Holocene climate than existed at the two southerly sites. The gradual Holocene climatic deterioration and paludification of adjacent forests is marked by the prevalence of skunk cabbage (*Lysichiton americanum* Hultén & St.John) pollen above 6.0 m, and later occurrence of burnet (*Sanguisorba* L.) and Douglas' Gentian (*Gentiana douglasiana* Bong.). Above 4.0 m, western hemlock and Cupressaceae (probably western red cedar) dominate,

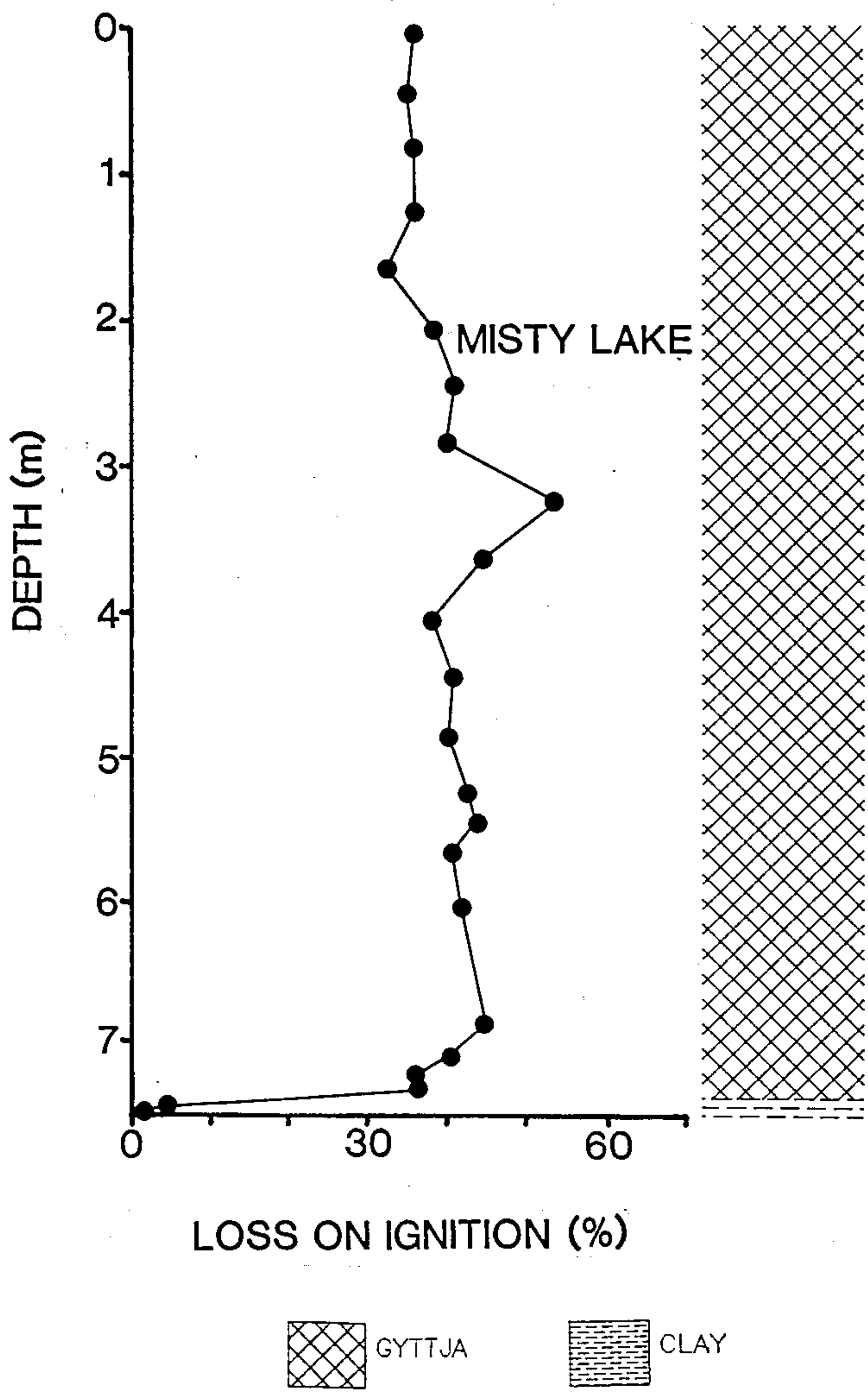

Figure 3.5 Sediment lithology and loss on ignition diagram for dry sediments of Misty Lake, B.C.

as they do today.

Correlation of the late–glacial/early Holocene pollen record with Hebda's (1983) Bear Cove Bog profile, 18 km northwest of Misty Lake, has proven difficult. The dates on Bear Cove Bog imply the arrival of Douglas–fir and decline in mountain hemlock around 8000, and not 10,000 yr B.P. In this report, I assume the Misty Lake dates to be correct. Roots penetrating deeper peat from above could have contaminated Bear Cove radiocarbon samples, making them too young.

The major chironomid changes at Misty Lake are also best described in terms of 3 zones, the late–glacial, early Holocene, and late Holocene (Fig. 3.6). The late–glacial (≥7.00 m) is represented by the lowermost 0.45 m. A division between early and late Holocene deposits is possible at a marked decline in *Sergentia* abundance, *ca.* 4.40 m (about 5500 yr B.P.).

Late– glacial assemblages

At Misty Lake, the influx of chironomid head capsules was initially low, about 1.0 $hc \cdot cm^{-2} \cdot yr^{-1}$ (Fig. 3.7). The cold–stenothermous element is represented by *Heterotrissocladius*, *Protanypus*, and *Stictochironomus* (Fig. 3.6). The two latter taxa are present in very small numbers, and only in the two lowermost samples. As at Mike Lake, the cold–stenothermous elements have essentially disappeared by 10,000 yr B.P.

Several other taxa also occur in the late–Pleistocene sediments. Particularly intriguing is the presence of *Corynocera* nr. *ambigua* in the late–glacial, but not in subsequent Holocene sediments. As expressed earlier, *C. ambigua* has occasionally been regarded as a cold–stenotherm. It is frequently recorded in European late–glacial deposits (e.g. Andersen, 1938; Fjellberg, 1972), but its littoral habitat and geographical distribution also suggest its occurrence in warm waters.

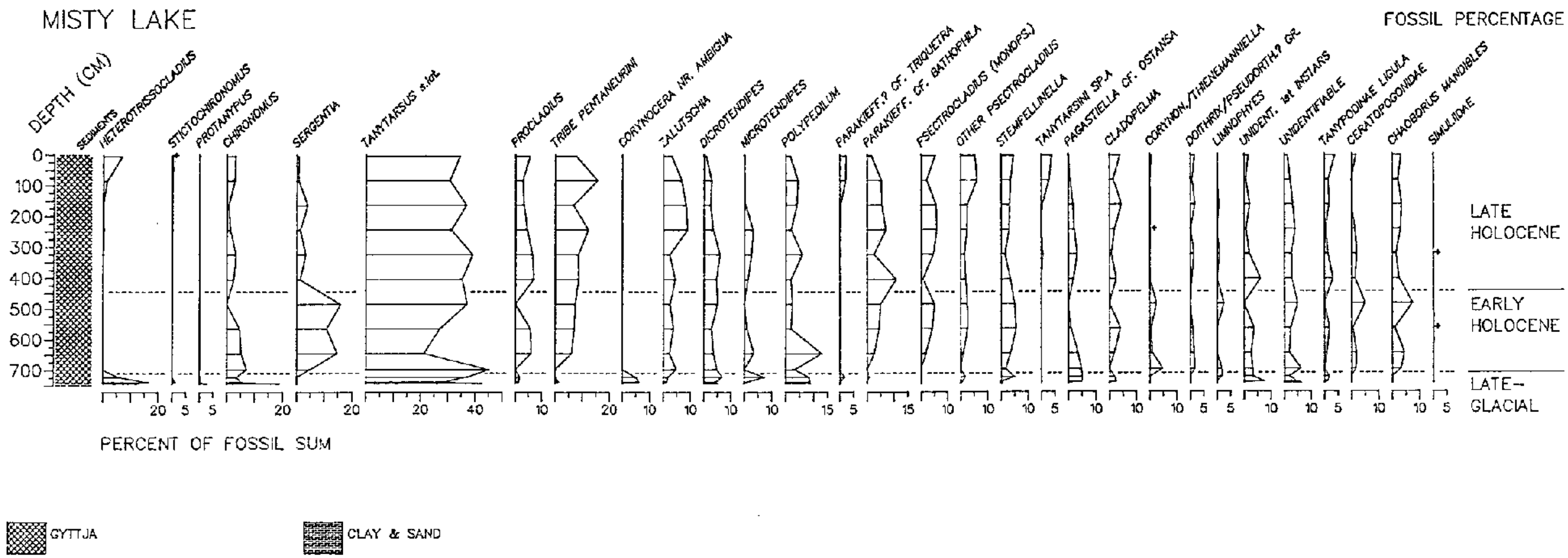

Figure 3.6 Percentage (of total number of chironomid head capsules at each sample level) diagram representing stratigraphy of common Chironomidae at Misty Lake, B.C. (Several rare taxa have been excluded; "+" indicates presence in small numbers).

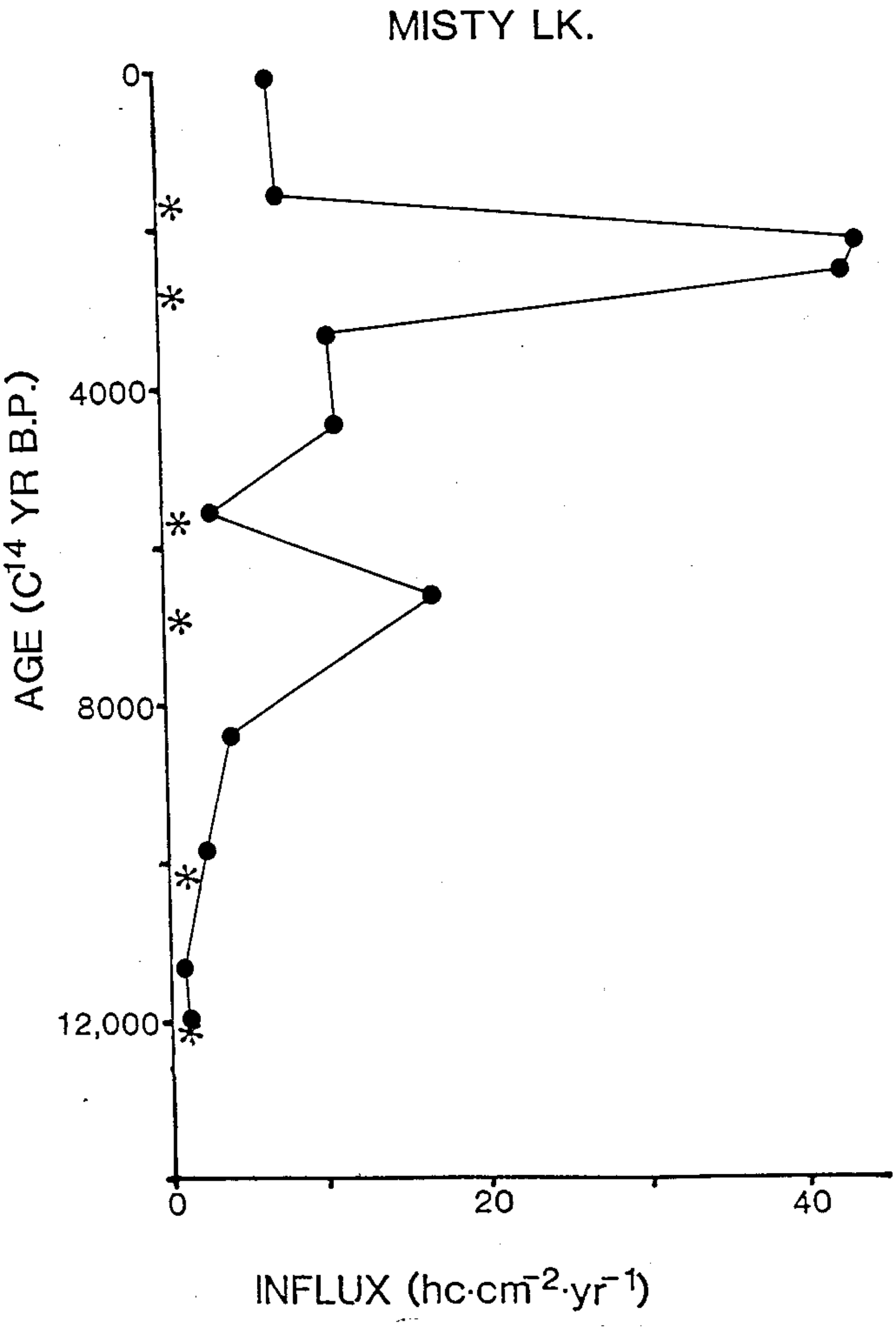

Figure 3.7 Total chironomid influx at Misty Lake, B.C. (*–indicate ^{14}C–dated levels).

Apart from the lowermost sample, the late–glacial faunal diversity is close to that in Holocene deposits. However, this may not be unusual, even for a subarctic lake. Most Canadian chironomid genera occur north to tree–line (Oliver *et al.*, 1978; Oliver and Roussel, 1983a; Wiens *et al.*, 1975), although many are not known from the arctic (Danks, 1981).

Holocene assemblages

Chironomid influx at Misty Lake gradually increases throughout much of the Holocene. Peak influx may exceed 40 $hc \cdot cm^{-2} \cdot yr^{-1}$ at about 2500 yr B.P. (*ca.* 2.0–m–depth) (Fig. 3.7). Interpretation of influx profiles is complex, owing in part to the possible concentration of head capsules in sublittoral environments.

The Holocene faunal changes at Misty Lake illustrate few trends. Most striking is the early Holocene prominence of *Sergentia*, which abruptly declines in abundance *ca.* 5000 yr B.P. An explanation for this distinct shift is not readily apparent. However, the gradual infilling of Misty Lake would have slowly reduced the available cool, relatively well–oxygenated profundal habitat.

In the uppermost sediments, three taxa which had been present during the late–glacial again appear, *Heterotrissocladius*, *Parakiefferiella*? cf. *triquetra*, and *Stictochironomus*. Since two of these taxa, *Heterotrissocladius* and *Stictochironomus* seem to be associated with cool, oligotrophic environments in British Columbia, their presence could indicate a recent trend to cooler or more oligotrophic conditions. The mid to late–Holocene deterioration of Pacific Northwest climate (neoglaciation) has been well documented through other evidence (Clague, 1981; Mathewes, 1985).

As at Mike Lake, few rheophiles were identified from the core. Although Misty Lake receives significant stream input, the coring site was distant from this supply.

Discussion

The above results are largely in accord with the hypothesis that climatic changes were responsible for the late-glacial faunal changes. In Marion, Mike and Misty Lakes, a pronounced oligotrophic, cold-stenothermous element is evident through the late-glacial, but is much less common in subsequent Holocene sediments. Thus, global climatic change may have had an important bearing upon chironomid succession.

This pattern is similar to that in New Brunswick (Walker and Paterson, 1983) and Germany (Hofmann, 1971a, 1983a) where late-glacial chironomid faunal changes appear to occur with similar timing among lakes. This implies that the lakes and their faunas are not reacting independently. A regional influence, like climate, appears to be directing late-glacial change.

Local watershed characteristics would seem to be less important. There is no change in sediment composition evident in the British Columbia lakes at the Pleistocene/Holocene boundary. Chironomids do not appear to be responsive to the late-glacial/early Holocene pH and alkalinity variations noted elsewhere (Walker and Paterson, unpublished data).

There is a possibility that terrestrial vegetation could influence chironomid faunal composition, perhaps through the detritus food chain, or through biogeochemical pathways within the watershed. The problem of distinguishing vegetation's possible role is not trivial in British Columbia. Since full-glacial and late-glacial refugia for common trees probably existed within a few hundred kilometres of southern British Columbia (Barnosky, 1984; Heusser, 1972; Tsukada, 1982), I have assumed that late-glacial vegetation was in equilibrium or near equilibrium with climate. Migration lags for major tree species, apparently a major influence on early postglacial vegetation in eastern North America (Davis, 1984), were probably of short duration in southern British Columbia. Thus, floristic changes should provide reliable evidence for climatic change.

Linkages between the terrestrial and aquatic environments should not be ignored. However, any demonstration that the late–glacial faunal changes in British Columbia were independent of terrestrial vegetation changes, and were instead climatically dependent requires that climate change with little indication of a vegetation response. At each British Columbia site, the decline in pine pollen, and arrival of Douglas–fir, *ca.* 10,000 yr B.P., indicates a shift in forest composition. This forest change occurs over the same time interval throughout southwestern British Columbia, and thus is probably climatically induced. Forest vegetation can influence lake and stream biogeochemistry, including both nutrient and allochthonous organic inputs (Likens and Bormann, 1974). However, the earlier shift from a non–forested to a forested environment should have had more dramatic consequences for lake biota than a shift in coniferous forest composition.

Despite these concerns there is little evidence that many chironomid distributions are influenced significantly by terrestrial vegetation. It is pertinent that despite a continuously changing forest composition at Portey Pond, in New Brunswick, the chironomid fauna has changed little in 9000 yr (Walker and Paterson, 1983). In Portey and Wood's Ponds, the major late–glacial chironomid faunal change is not accompanied by a marked change in either terrestrial vegetation or sediment type.

A pronounced late–glacial climatic warming could have had both direct and indirect effects upon chironomids. Lethal warmth would have eliminated cold–stenotherms from littoral habitats. However, summer stratification is evident at Mike Lake today. Thus, a cool hypolimnetic region must also have existed in the deeper late–glacial/early Holocene basin. Survival of cold–stenotherms should have been possible in the profundal zone. Consequently, increased Holocene productivity, and the resultant hypolimnetic O_2–deficit must have contributed to the faunal change. The summer O_2 profile of Mike Lake (Fig.

3.8) illustrates the hypolimnetic O_2 demand. This profile is typical for mesotrophic lakes (Wetzel, 1975).

A similar explanation could account for early faunal changes at Elk Lake, Minnesota (Stark, 1976). Despite being isolated from the direct influence of climate by 30 m of water, the Elk Lake chironomid faunal changes parallel palynological evidence for climatic amelioration (Walker and Mathewes, 1987b).

It is significant that in Marion, Mike, and Misty Lakes the faunal changes are gradual. The abundance of cold-stenothermous oligotrophic taxa gradually decreases through the entire late-glacial interval. This differs from the temperature record provided by Mathewes and Heusser (1981). They indicate a rapid warming between 11,000 and 10,000 yr B.P. However, the pollen record on which it is based (Mathewes, 1973) indicates a more gradual floristic shift. Similar gradual patterns are suggested at Saanich Inlet, Squeah Lake, and Surprise Lake (Heusser, 1983; Mathewes, 1973; Mathewes and Rouse, 1975). Thus the late-glacial amelioration may have been less abrupt than the pollen/climate transfer functions indicate. The retreat of Cordilleran ice is evidence that a full-glacial climate no longer existed. However, cold, catabatic winds from persistent interior British Columbia ice, directed eastward by valleys and a major continental anticyclone (Broccoli and Manabe, 1987), could have maintained cooler conditions locally.

Subsequent Holocene changes cannot be correlated among lakes. The similarities of successional pattern are more subtle and time-transgressive. Consequently, it is difficult, or perhaps impossible, to justify a climatic cause.

Sergentia is common in the early Holocene sediments of Mike and Misty Lakes, but much less common through the late Holocene. Many littoral taxa are abundant in recent sediments. As suggested earlier, these changes may relate to the gradual shallowing of the lakes. The similarity of successional pattern among the lakes may correspond to

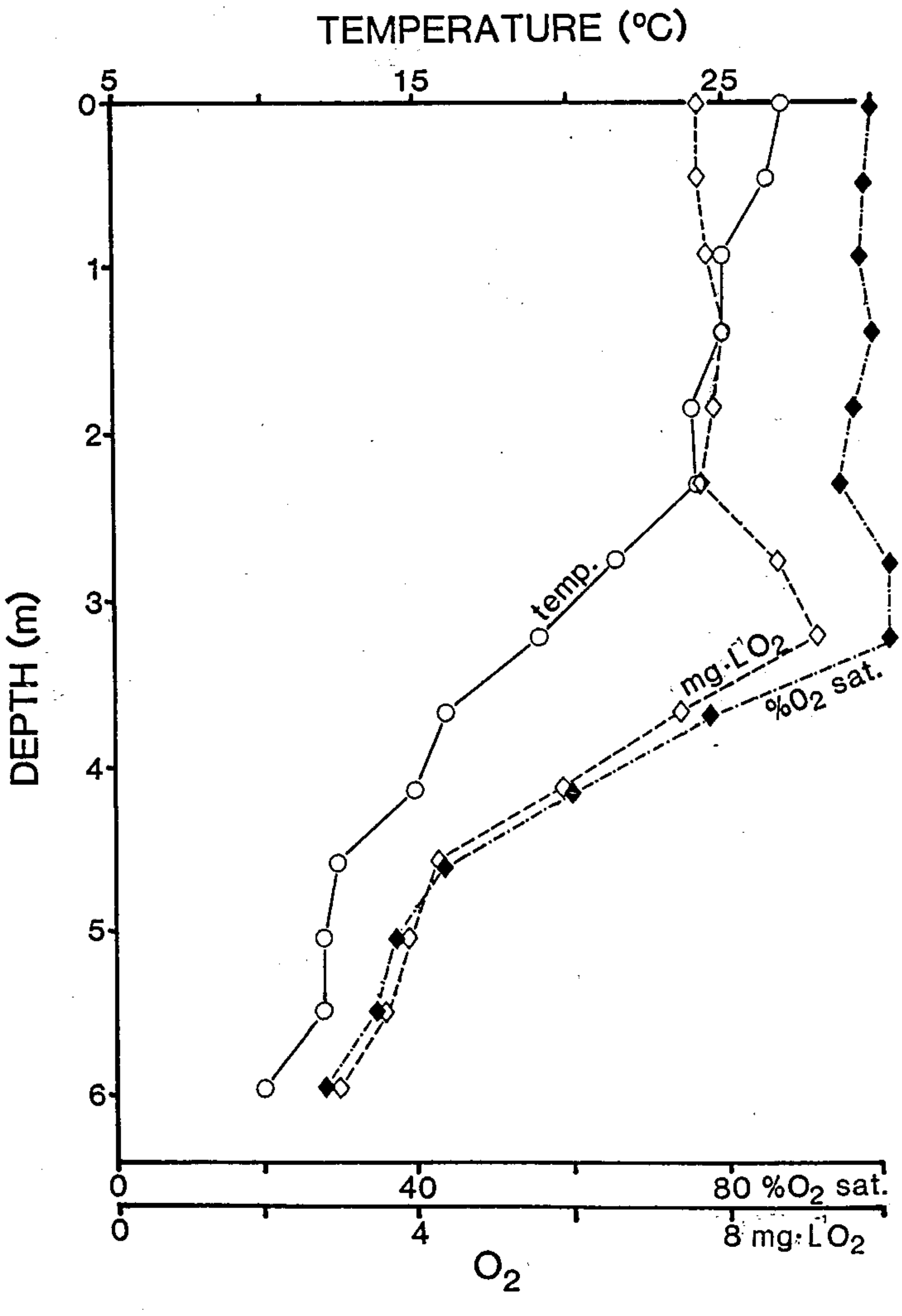

Figure 3.8 Late summer oxygen and temperature profile of Mike Lake, B.C. (late afternoon September 7, 1987).

the similarity of the lakes' depths throughout postglacial time. If constant surface levels are assumed, the initial depths of Marion, Mike and Misty Lakes were, repectively, 15.0, 12.9, and 12.7 m. Their present depths vary from 6.5 to 5.2 m. As Mike and Misty Lakes shallowed the smaller hypolimnetic volume was expressed partly as decreased O_2 concentrations. Deevey (1955a) and Sæther (1980a) have, respectively, noted the importance of hypolimnetic volume to lake trophic state and benthic fauna.

The late Holocene increase of *Corynocera* nr. *ambigua*, and *Heterotrissocladius* at Marion Lake, and recent reappearance of *Heterotrissocladius* and *Stictochironomus* at Misty Lake, could relate to the cooler or more oligotrophic late Holocene conditions. However, no similar trend is evident at Mike Lake. The trends are too inconsistent among lakes, and through time to define a clear pattern.

It is interesting to compare the rates of chironomid head capsule deposition among Marion, Mike and Misty Lakes (Fig. 3.9). In each case a late–glacial influx of *ca.* 1.0 to 2.0 $hc \cdot cm^{-2} \cdot yr^{-1}$ is evident. After 10,000 yr B.P. a trend to greatly increased chironomid influx exists. Peak influx values range from 17 to 43 $hc \cdot cm^{-2} \cdot yr^{-1}$. Recently, at Mike and Marion Lakes, influx declined.

The influx records probably reflect complex changes within the lakes. Late–glacial chironomid populations may have been low, owing to deep water and low productivity. However, late–glacial transport of littoral head capsules to the core sites may have been limited by the less turbulent waters of the deepwater environment. Within a lake, chironomid production is typically greater in the shallower waters (Brinkhurst, 1974). Thus, the Holocene trend to greater influx may relate to higher productivity (partly a function of climate, and lake depth), decreasing depth, and the influence of "head–capsule focusing". Separation of these effects is not yet possible. Influx profiles from lakes of greater and lesser depths could prove interesting. For example, the influence of water

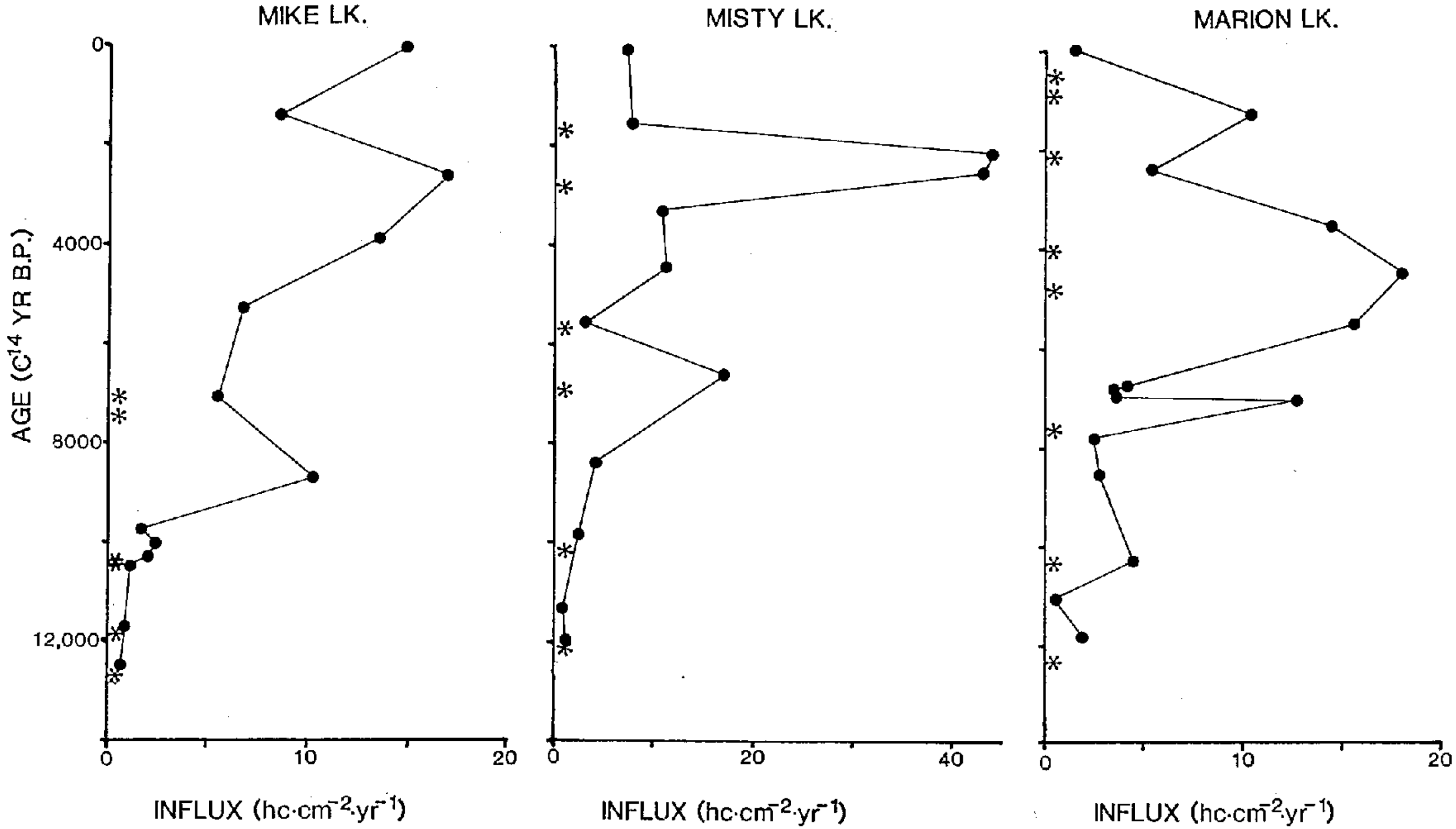

Figure 3.9 Comparison of total chironomid influx among Mike, Misty, and Marion Lakes, southwestern British Columbia. (*–indicate ^{14}C–dated levels).

depth and focusing should be minimal in a deep lake which, morphometrically, has not changed greatly through postglacial time.

Although postglacial succession has not been examined in any of the deep lakes of British Columbia, late-glacial/early Holocene faunal changes would probably parallel those of the shallow lakes presently studied. The influence of a great hypolimnetic volume would likely be evident, however, with the faunal changes being much less dramatic in the deeper lakes. Such an investigation would be a valuable extension to the present research.