CHAPTER 4

HIPPA LAKE STRATIGRAPHY[1]

Biologists have long been fascinated by the flora and fauna of islands. In Canada, the Queen Charlotte archipelago has been a site of special interest. Although recent studies have demonstrated that few vascular plant species are truly endemic (Pojar, 1980), curious biogeographic relationships still provide a research focus for botanists (e.g. Schuster and Schofield, 1982; Vitt and Schofield, 1976), entomologists (Kavanaugh, 1984), ichthyologists (Moodie and Reimchen, 1976), and especially palaeoecologists (Hann and Warner, 1987; Hebda and Mathewes, 1984; Warner, 1984; Warner and Chmielewski, 1987; Warner *et al.*, 1984).

The unique Queen Charlotte biota has been regarded as evidence for a glacial refugium. However, proof of a continuously ice–free refugium remains elusive. Radiocarbon chronologies can trace the advance of local Queen Charlotte ice after 27,500 yr B.P. (Warner *et al.*, 1984). The unusually early glacial retreat, which began prior to 16,000 yr B.P., in parts of eastern Graham Island, is also documented (Clague *et al.*, 1982; Mathewes *et al.*, 1985; Warner *et al.*, 1982). However, no terrestrial or freshwater record spans the interval of maximum glaciation to prove refugial status (Warner, 1984).

I have examined a fourth British Columbia site, situated on an island off the western coast of Graham Island, in the Queen Charlotte archipelago. This site, Hippa Lake, provides the longest complete late–glacial/Holocene lacustrine sequence as yet available for the archipelago. The record spans the interval 11,000 yr B.P. to the present. The lake's shallow basin, isolated setting and hyperoceanic climate represents a previously unstudied situation, contrasting with my earlier chironomid stratigraphic study sites in

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southwestern British Columbia.

Study area

The Queen Charlotte Islands are separated from other coastal islands nearer mainland British Columbia by Hecate Strait. Hecate Strait varies in width from *ca.* 50 to *ca.* 130 km along the length of the archipelago. Although fifty or more islands compose the Queen Charlotte archipelago (Fig. 4.1), Graham and Moresby Islands include most of the islands' mass. Many smaller islands lie scattered off the eastern shore of Moresby Island, but the western Queen Charlotte shoreline is abruptly defined by the Queen Charlotte Islands fault (Sutherland Brown, 1968).

Hippa Island (4.9 km^2) is one of the few small islands lying beyond Graham Island's western flank (Fig. 4.1). Lying 0.7 km offshore, climate at this study site is dominated by proximity to the Pacific Ocean. Weather stations at Langara Island and Cape St. James (Table 4.1), with similar settings to Hippa Island, suggest mean August temperatures averaging *ca.* 13.5° C near sea level. Corresponding January temperatures approach 3° C. Although the Langara and Cape St. James stations record *ca.* 1500 mm·yr^{-1} as rain, neither station is susceptible to the additional orographic precipitation that should be evident near Hippa Lake. For example, Tasu Sound receives 4173 mm·yr^{-1} as rain. However, sheltered from the direct Pacific influence, records at Tasu Sound reflect a more continental temperature regime. The temperature regime inferred for Hippa Lake is not unlike that for the Misty Lake area at present, but given the isolated setting of Hippa Lake, the possible importance of sea level fluctuations (Clague, 1981), and late–glacial outflow winds to Misty Lake's past climate, there is no assurance that this situation has existed throughout postglacial time.

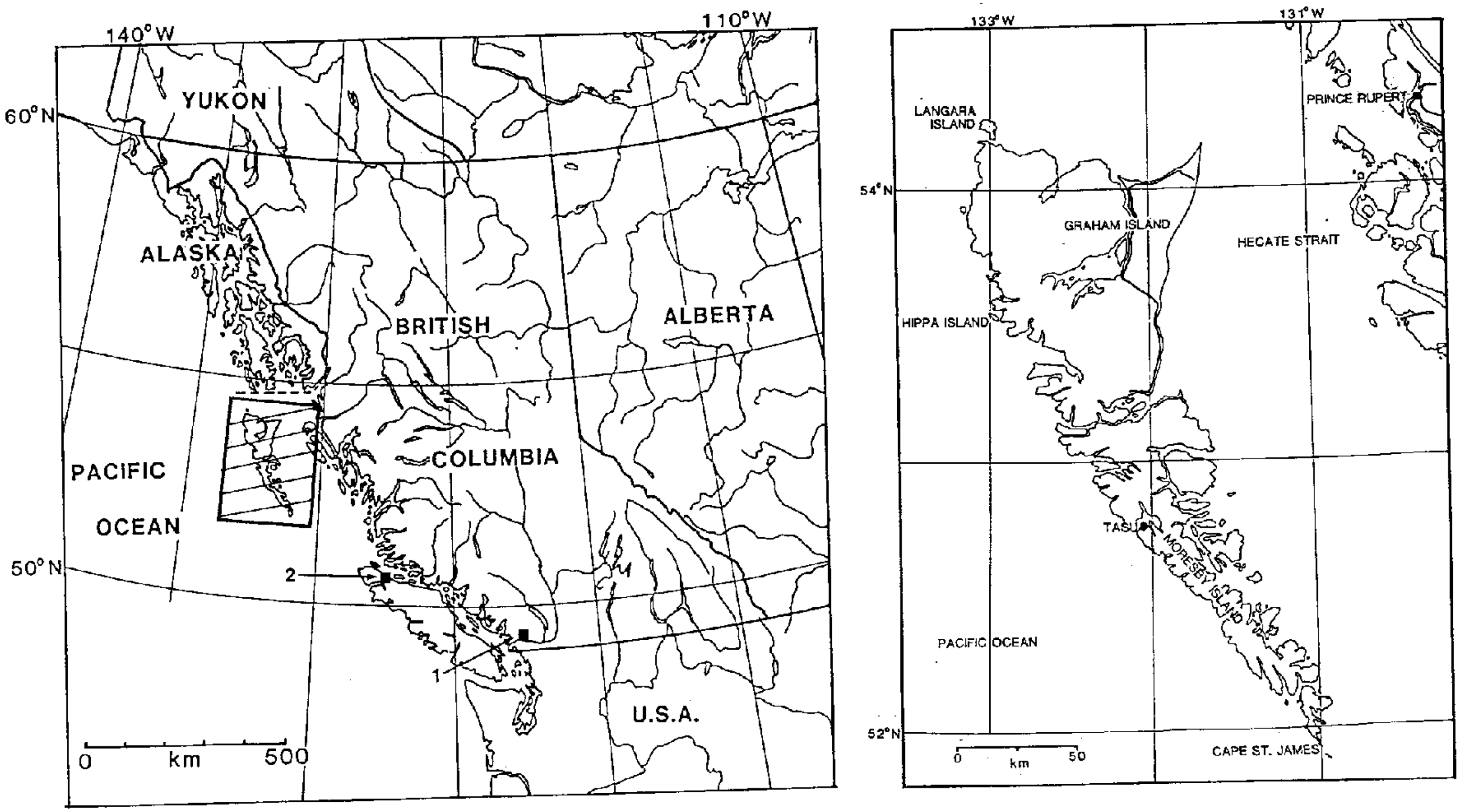

Figure 4.1 Location of Hippa Island, Queen Charlotte Islands, British Columbia, where Hippa Lake is located. (Arrows indicate location of earlier chironomid stratigraphic study sites – 1) Marion and Mike Lakes; 2) Misty Lake)

Table 4.1. Climatic summary (1951-1980) for Cape Saint James (51°56'N,131°01'W; 89 m elev.), Langara (54°15'N,133°03'W; 41 m), and Tasu Sound (52°46'N,132°03'W; 15 m elev.), western Queen Charlotte Islands, British Columbia.

	Cape St. James	Langara Island	Tasu Sound
Mean Daily Temperature (°C)			
Coldest Month (Jan)	3.9	2.3	2.8
Warmest Month (Aug)	13.8	13.2	14.6
Precipitation			
Rain (mm): Annual	1481.1	1658.1	4172.7
Wettest Month	197.5 (Oct)	193.2 (Nov)	596.1 (Oct)
Driest Month	58.4 (Jul)	80.1 (Jul)	123.9 (Jul)
Snow (cm): Annual	51.3	101.4	75.7
Frost-free Period (d)	265	242	217
Degree-days (°C·d)			
Above 0°C	3102.7	2767.8	3039.0
Above 5°C	1397.7	1180.3	1441.5

(Environment Canada, 1982)

Hippa Lake (53° 31.9'N, 132° 58.4'W), the only lake on Hippa Island, is small (3.2 ha) and shallow (1.1 m). Situated at an elevation of 230 m, no permanent inflowing streams are apparent although local relief extends to 450 m, defining a 0.4 km^2 catchment. The lake, and most of the island are underlain by Tertiary basalt and rhyolite of the Masset Formation (Sutherland Brown, 1968). Quartz diorite and diorite of Jurassic age are exposed on the island's eastern flank.

The island has been placed in the Coastal Cedars-Pine-Hemlock Biogeoclimatic Zone (Banner *et al.*, 1983) which includes low elevation forests of the western Queen Charlotte Islands slopes. Forest inventories (Prov. of B.C., 1967) indicate western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis* (Bong.) Carr.) , and yellow cedar (*Chamaecyparis nootkatensis*) to be prominent trees of Hippa Island forests. Lodgepole pine (*Pinus contorta* var. *contorta*) is also present, and mountain hemlock (*Tsuga mertensiana*) can be abundant in forests of adjacent Graham Island.

Methods

The methods employed for stratigraphic studies at Hippa Lake differ little from those employed at Marion Lake.

A sediment core 3.55-m-long was obtained from a *Nuphar lutea* (L.) Sibth. & Sm. bed in the centre of Hippa Lake in 1.1 m of water by R.W. Mathewes and B.G. Warner. The core was cut into 5 cm slices, which were individually sealed in plastic bags. Sediment subsamples (1.0 to 5.0 mL) were retained for chironomid analysis. Samples were examined at 40 cm intervals throughout most of the core. Closer sampling was used to characterize late-glacial changes.

Sediment was deflocculated in hot 6% KOH and sieved (.075 mm mesh). Coarse matter retained by the sieve was later sorted wet, at 50X in a Bogorov counting tray. Head capsules recovered from the sediments were mounted in Permount® on microscope slides and identified, with reference mostly to Hamilton (1965) and Wiederholm (1983). Stratigraphic results were plotted using the computer program MICHIGRANA developed by R. Futyma and C. Meachum.

Results

The Hippa Lake basal sediments (3.47 to 3.55 m) consist of grey, pebbly clay with very low loss on ignition (Fig. 4.2). Light-tan coloured gyttja characterizes the remaining late-glacial deposits, between 3.20 and 3.47 m. Subsequent Holocene sediments are a coarse brown detritus gyttja including a rather small organic fraction. The organic fraction constitutes 20 to 30% by weight of the dry sediment (Fig. 4.2).

Radiocarbon dates have been obtained throughout the Hippa Lake core, as summarized in Table 4.2. Basal organic-rich sediment (3.40 to 3.47 m) is dated at 11,100 yr B.P. The late-glacial/Holocene transition *ca.* 9780 yr B.P. occurs at 3.20 to 3.25 m. This implies very slow sedimentation during the late-glacial. Although subsequent Holocene sedimentation was more rapid, the implied rates may be unrealistically high for the 1.70 to 2.65 m interval. The two dates defining this interval, although separated by 0.90 m, indicate a deposition time of less than 300 years. This raises questions as to the two dates' validity. For this reason I will not present chironomid influx estimates.

A detailed palynological study of Hippa Lake's sediments has not yet been completed. R. Mathewes has provided a preliminary outline of major changes in pollen stratigraphy. The pollen of early mineral-rich sediments (>346 cm) suggests a sparse herbaceous-type vegetation, perhaps similar to tundra. Coincident with the shift to an

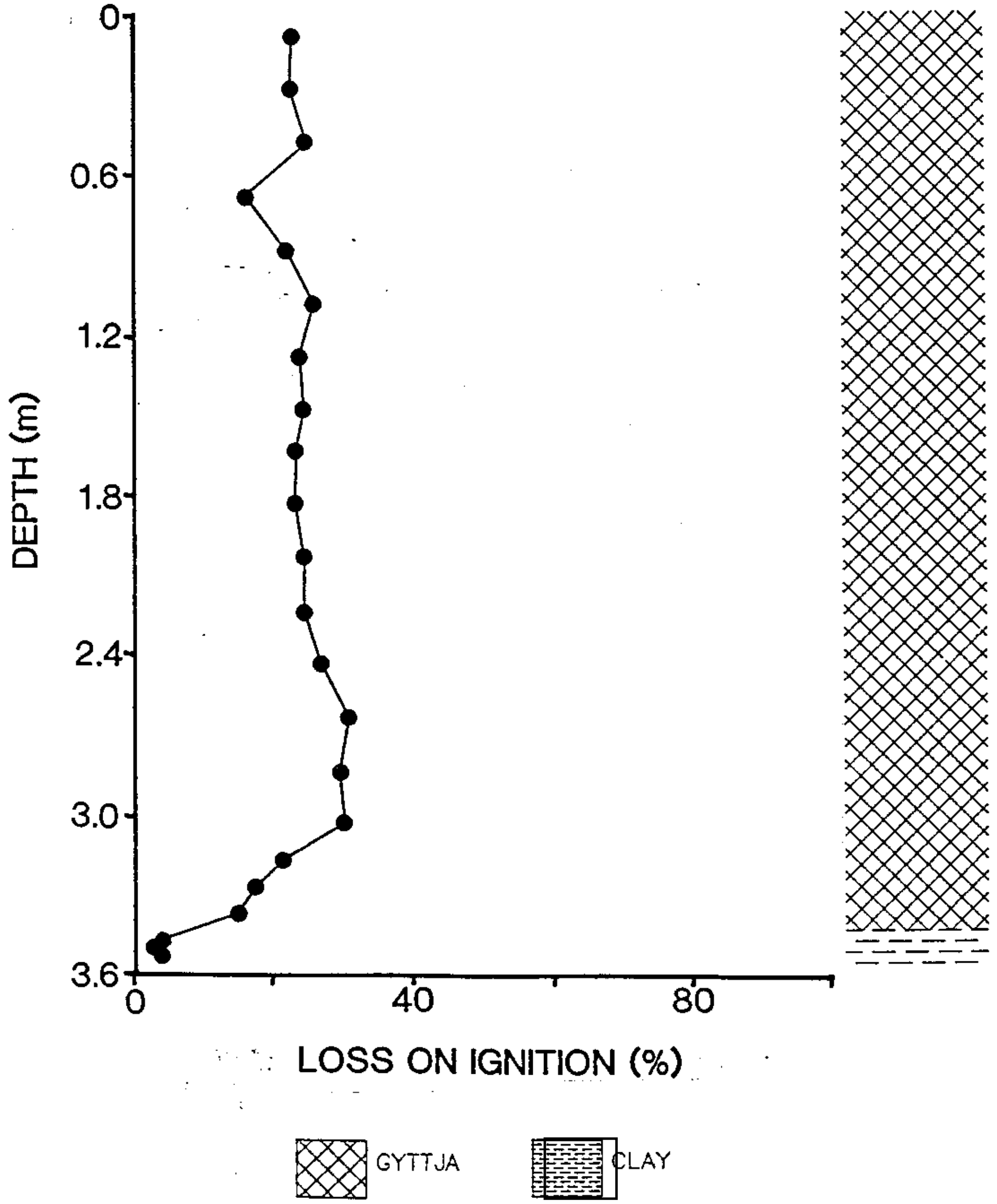

Figure 4.2 Sediment lithology and loss on ignition diagram for dry, postglacial sediments of Hippa Lake, Queen Charlotte Islands, B.C.

Table 4.2. Radiocarbon age for Hippa Lake sediments, Queen Charlotte Islands, British Columbia, Canada.

Sample Depth	Material Dated	Laboratory Reference No.	$\delta^{13}C$	Age (corrected)
80-85 cm	Sediment	BETA-16579	-25*	4860±140 yr B.P.
170-175	Sediment	BETA-16580	-25*	6760±130
260-265	Sediment	BETA-16581	-25*	7020±250
320-325	Sediment	GSC-3773	-25.7	9780±110
340-347	Sediment	GSC-3760	-24.2	11,100±220

*-assumed

organic-rich sediment, lodgepole pine pollen becomes very abundant. The decreased mineral-fraction probably reflects stabilization of adjacent slopes by vegetation.

As in southwestern British Columbia (e.g. Mathewes, 1973), lodgepole pine pollen predominates throughout the late-glacial organic-rich sediments. During the latter part of the late-glacial, spruce becomes abundant along with alder (*Alnus*) and ferns (Polypodiaceae).

The end of the late-glacial is marked by the arrival of western hemlock at 3.15 to 3.20 m. Spruce and western hemlock pollen, with some alder, dominated the subsequent early and mid-Holocene pollen rain. Cupressaceae pollen, presumably western red cedar, is also very common in more recent sediment (≤4000 yr B.P.).

This pollen record suggests a late-glacial/early Holocene warming trend, similar to that in southwestern British Columbia. However, there is little evidence of a warm, dry xerothermic interval. This feature may reflect the northern setting of the Queen Charlotte Islands, and the high precipitation along the archipelago's western margin. The pollen record at Hippa Lake is broadly similar to that described by Warner (1984) for the islands' eastern lowlands.

Chironomid stratigraphy

Very low chironomid numbers were recovered from the basal, mineral-rich sediments of Hippa Lake. Unfortunately, the samples retained for chironomid analysis were not sufficient to provide statistically meaningful results (Table 4.3). However, these results do indicate the very early arrival of *Corynocera* nr. *ambigua*, *Dicrotendipes*, *Heterotanytarsus* cf. *perennis* Sæther, *Heterotrissocladius*, *Microtendipes*, *Psectrocladius*, and *Tanytarsus* s.lat.

Table 4.3. Chironomid taxa recovered from the basal sediments (≥11,000 yr B.P.) of Hippa Lake, Queen Charlotte Islands, British Columbia, Canada. (Number of head capsules per sample).

Depth(cm)	347-349	351-353	Basal?
Corynocera nr. *ambigua* Zetterstedt	4		19
Dicrotendipes Kieffer	1		1
Heterotanytarsus cf. *perennis* Saether		0.5?	1
Heterotrissocladius Sparck	0.5	2.5	1.5
Microtendipes Kieffer	2		1
other* *Psectrocladius* Kieffer	0.5		0.5
Tanytarsus v.d.Wulp s.lat			1
Volume examined (mL)	5.0	5.0	5.0

*-"other *Psectrocladius*" includes all species of this genus, apart from subgenus *Monopsectrocladius* Laville.

Most of these early taxa belong to widely-distributed, eurythermic genera. However, three genera have restricted distributions in arctic-alpine environments (Danks, 1981). Although Moore (1978) records *Microtendipes*, at or just beyond tree-line in the Canadian arctic, it is not known elsewhere in North American arctic or alpine environments (Danks, 1981). *Dicrotendipes* also occurs at, or just beyond, tree-line (Moore, 1978). One species, *D. lobiger* (Kieffer), although rare, is recorded for Barrow, Alaska (Butler *et al.*, 1981). *Heterotanytarsus* Spärck has not been found in arctic habitats (Danks, 1981; Fitkau and Reiss, 1978; Sæther, 1975d). *Heterotanytarsus* seems to be most common in northern, oligotrophic waters (Sæther, 1975d). However, its known Nearctic distribution is limited to Marion Lake, B.C. (*H. perennis*), Ontario (*H. nudalis* Sæther), and New Brunswick (Sæther, 1975d; Walker *et al.*, 1985). Although a cooler climate than that of today possibly existed, late-glacial arctic conditions seem unlikely at Hippa Lake.

The lowermost organic-rich sample provided a tremendous concentration of head capsules, 690$\cdot$mL^{-1} (Fig. 4.3). This sample contained 13 taxa, but *Corynocera* nr. *ambigua* accounted for 72% of the total fauna. Other common taxa included *Dicrotendipes*, *Microtendipes*, *Procladius* Skuse, *Psectrocladius*, and *Tanytarsus* s.lat.

Subsequent late-glacial and Holocene deposits yield smaller concentrations, averaging 136 head capsules$\cdot$mL^{-1}. The initial faunal composition appears unstable (Fig. 4.4) with rapid changes in the abundance of several common taxa (e.g. *Corynocera* nr. *ambigua*, *Heterotrissocladius*, *Tanytarsus* s.lat.). Head capsules similar to *Corynocera oliveri* Lindeberg were also noted (see Appendix), but included with *Tanytarsus* s.lat. *C. oliveri* has been reported from Greenland sediments (Hofmann, 1983b), but not elsewhere in North America (Pinder and Reiss, 1983). The total number of Holocene taxa is low relative to other British Columbia sites. On average 11 to 12 taxa were recorded per sample at Hippa Lake, whereas 19 to 20 were typical for Mike Lake, near Vancouver.

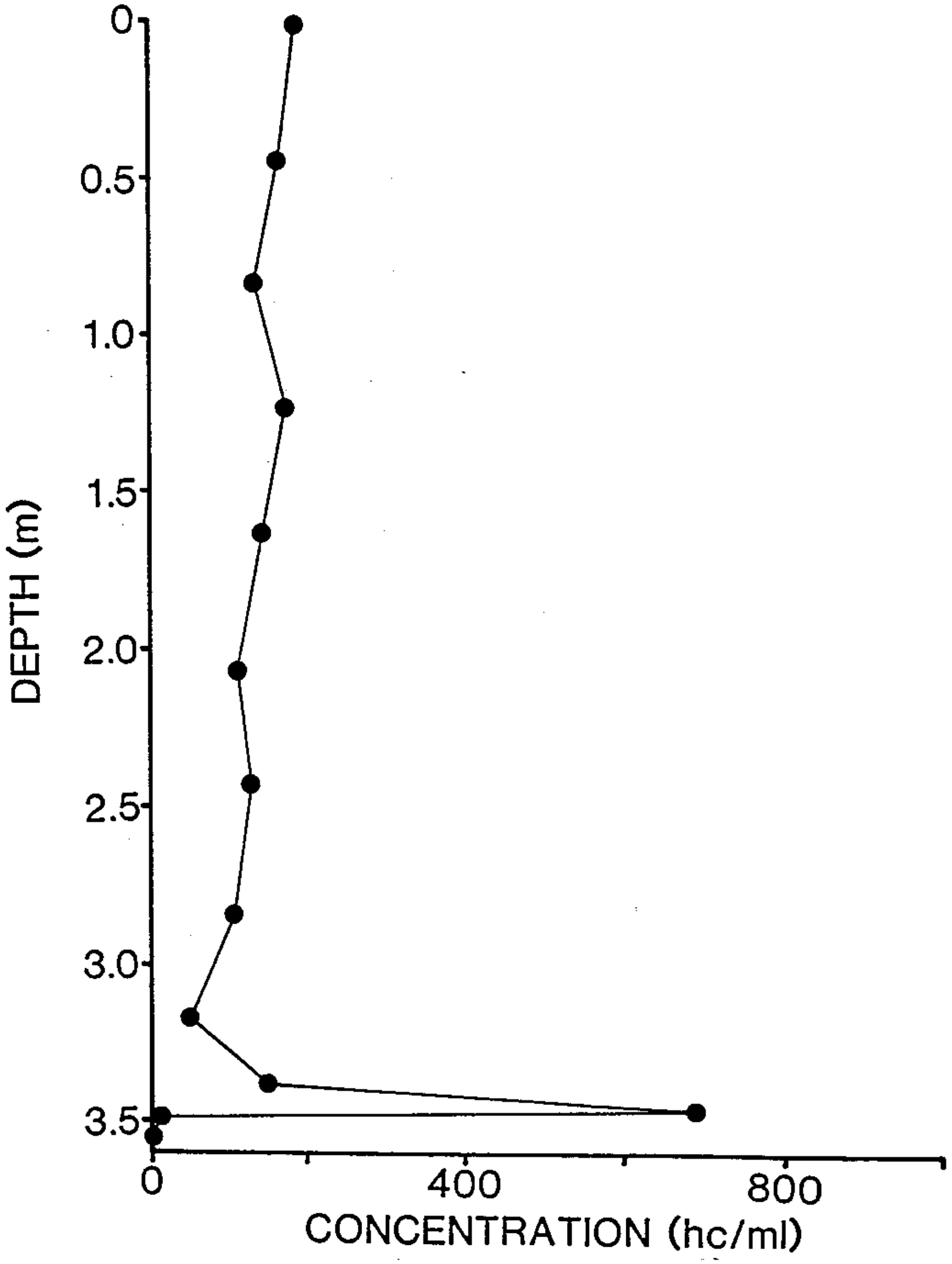

Figure 4.3 Chironomid head capsule concentrations in postglacial sediments of Hippa Lake, Queen Charlotte Islands, B.C.

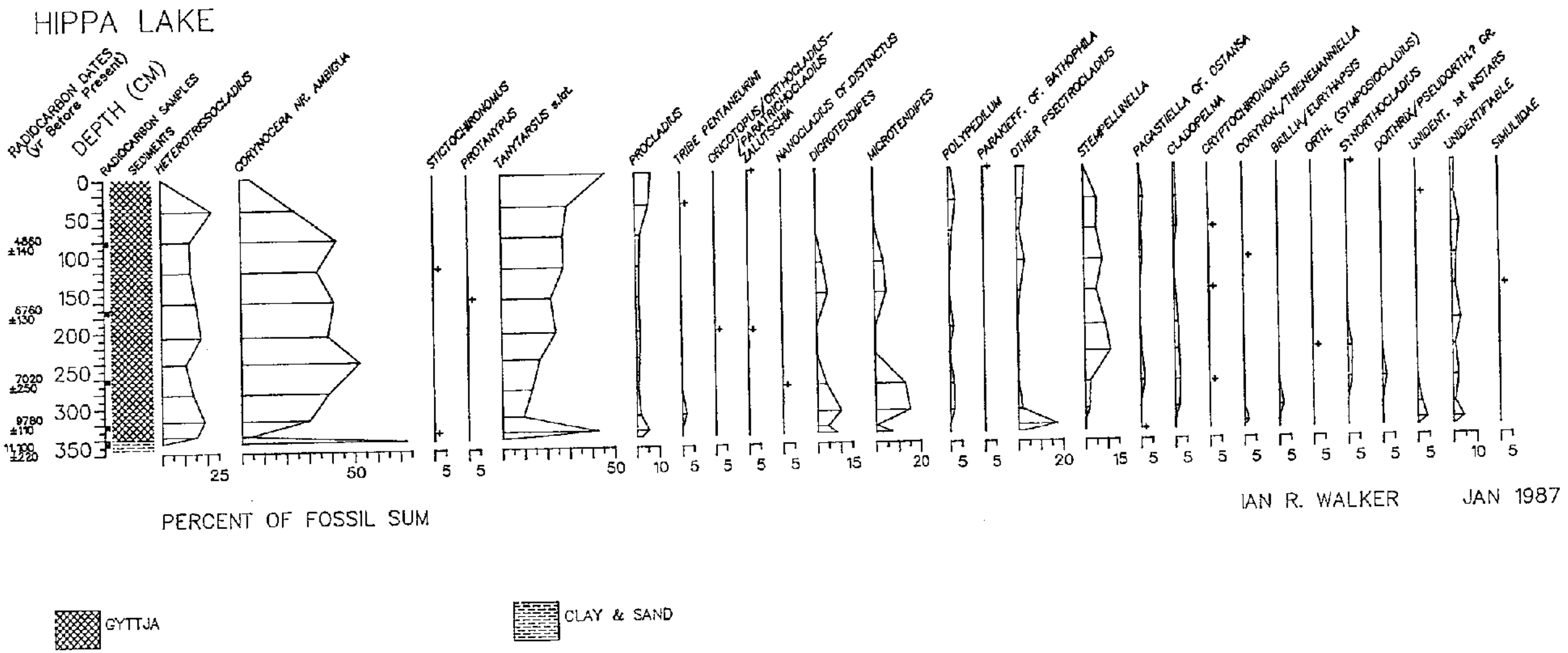

Figure 4.4 Percentage (of total number of chironomid head capsules at each sample level) diagram representing stratigraphy of Chironomidae at Hippa Lake, Queen Charlotte Islands. ("other *Psectrocladius*" refers to all species of the genus, apart from subgenus Monopsectrocladius; "+" indicates presence in small numbers).

The fauna of Hippa Lake has not changed markedly through postglacial time. However, the prevalence of ***Dicrotendipes***, ***Microtendipes***, and ***Psectrocladius*** in early sediments is striking. Also significant is the absence of a distinct late–glacial fauna. Of the postglacial chironomid taxa, only ***Heterotanytarsus*** has not been recorded north to tree–line. Most of the postglacial chironomid taxa have been reported from shallow low–elevation lakes or streams in the Vancouver area (Cranston, 1982a; Hamilton, 1965; Sæther, 1969, 1977; Walker and Mathewes, 1987a; this study–Chapter 5). To my knowledge only *Stictochironomus* has not been collected from such sites near Vancouver.

Heterotrissocladius remains occur throughout the Hippa Lake core. ***Protanypus*** and ***Stictochironomus*** are very rare, but both are recorded from mid–Holocene deposits.

Discussion

The results for Hippa Lake are not readily comparable to those of southwestern British Columbia. Hippa Lake has probably never exceeded 5.7 m depth and is exposed to the Pacific Ocean, and isolated from mainland glacial refugia. While nutrients supplied to my other British Columbia sites are likely to reflect weathering of local bedrock and surficial materials, Hippa Lake probably receives large nutrient inputs as marine aerosols (ie. "sea–spray").

Taxa considered typical of oligotrophic, cold–water environments (ie. ***Corynocera*** nr. ***ambigua***, ***Heterotrissocladius***) are evident throughout the core. ***Protanypus*** and ***Stictochironomus*** are rare, but also occur as mid–Holocene elements. This pattern suggests that the cooler, oceanic summer climate may provide refuge to these taxa. Another species frequently associated with these taxa, *Parakiefferiella* sp.A is absent.

Indeed, the Queen Charlotte Islands' climate allows many "high elevation plants" (e.g. mountain hemlock, yellow cedar) to occur near sea level. Calder and Taylor (1968: p. 87) remark that the ability of montane species "to become well established at low elevations is partly due to the uniform climate in the mountainous ranges at low and high altitudes." On the other hand, some southern low-elevation plants (e.g. Salal: *Gaultheria shallon* Pursh) benefit from the mild winters, and may occur abundantly on the islands, near the northern limits of their ranges. Many other taxa requiring warm, dry summers do not occur on the Queen Charlotte Islands (e.g. Douglas-fir: *Pseudotsuga menziesii*). A similar mix of northern and southern elements is evident along Newfoundland's coast, also a hyper-maritime environment (Damman, 1965).

However, cold-stenotherms could also cope if cold spring water feeds the lake. No inflowing streams are apparent, but water does percolate through surrounding talus seeps to the lake (R. Mathewes, pers. comm.). Also, the cold-stenothermous element at Hippa Lake may differ significantly in species composition from that apparent during the late-glacial of southwestern British Columbia. The late-glacial fauna of the deeper southern British Columbia sites is a profundal community, similar to that extant in deep, oligotrophic waters, like Parry Sound, Lake Huron. In Lake Huron, this deepwater fauna includes *Heterotrissocladius oliveri* Sæther (*H. subpilosus* group), *H. changi* Sæther (*H. marcidus* group), *Parakiefferiella* sp.A, *Protanypus ramosus* Sæther, and an unidentified *Stictochironomus* species, as well as several other taxa (Hare, 1976).

Since this "*Heterotrissocladius*" fauna is restricted to oligotrophic waters, its late-Pleistocene survival in small, southern British Columbia lakes reflects extremely low late-glacial productivity, probably limited by a cold climatic regime. During the late-glacial the southern British Columbia sites probably exceeded 10 m depth. However, data for Canadian Rocky Mountain national parks (D.B. Donald, pers. comm.), demonstrates that the fauna of shallow lakes (< *ca.* 5.0 m), often differs from that of deeper waters, even in glacial lakes where temperature, oxygen concentrations, and substrate are uniform, regardless of depth. Assuming a constant surface level, Hippa Lake would never have exceeded 5.7 m depth. Many shallow lakes, even in arctic climates, experience severe oxygen depletion beneath winter ice (Hobbie, 1973). Thus, a profundal community, similar to that at our southwestern British Columbia sites, cannot be expected.

On the basis of ecological information obtained elsewhere (Sæther, 1975b), the common *Heterotrissocladius* at Hippa Lake is probably *H. marcidus* or *H. latilaminus.* Both of these taxa occur in the shallow waters of Marion Lake today (Sæther, 1975b). I believe *H. oliveri* may have been the characteristic late–glacial species in southern British Columbia, and elsewhere in North America. Günther (1983) reports *H. subpilosus,* a very closely related species, from European late–glacial sediments. Donald's (pers. comm.) results indicate that *H. oliveri* may not occur in shallow waters, even in glacial lakes.

The isolated location of Hippa Island poses a biogeographic problem. As previously indicated, the fauna is less diverse than that of southern British Columbia sites. The number of chironomid species is known to decrease with increasing latitude. However, some virtually ubiquitous taxa (e.g. *Chironomus*) were not recorded at Hippa Lake. The ability of chironomids to cross Hecate Strait, or to survive in a Queen Charlotte Island refugium is an important consideration. The "instability" of the late–glacial fauna may reflect an extended colonization phase, resulting from Hippa Lake's isolated setting. As yet little knowledge exists as to what habitats, if any, were available in a Queen Charlotte refugium. Geologists have been willing to concede a few ice–free nunataks, or coastal headlands, but many doubt the existence of more extensive habitat (Banner *et al.*, 1983; Calder and Taylor, 1968; Sutherland Brown, 1968). Because most lakes have been formed through glacial scour, lakes are not common in unglaciated areas.

Although the Hippa Lake record is not comparable to my other British Columbia sites, it is strikingly similar to one reported in arctic Alaska. Livingstone *et al.* (1958) found *Corynocera* (as *Dryadotanytarsus*) and other Tanytarsini (as Calopsectrini) head capsules to be abundant in sediments of Eight Lake, in the Brooks Range. *Corynocera* occurred throughout the sediment column, and probably occurs there today. Extremely high chironomid head capsule concentrations were reported in the basal sediments, $8000 \cdot mL^{-1}$! This concentration stands as the world's record (Frey, 1964; Walker, 1987). Although it is tempting to attribute this high concentration to high early postglacial productivity, low sedimentation rates are possibly important.

Indications of climatic change are not readily apparent at Hippa Lake. Most of the taxa occur at arctic tree–line, and also at low elevations near Vancouver (Oliver *et al.*, 1978; Wiens *et al.*, 1975). Although late–glacial species diversity is low at Hippa Lake, this is also true throughout the Holocene sediments. Biogeographic isolation may have been more important than climate in regulating chironomid diversity at Hippa Lake. Although *Corynocera* seems to be most common in cold, oligotrophic lakes and ponds (Fjellberg, 1972; Pinder and Reiss, 1986), it does occur in temperate north German lakes. The larva and pupa of *C. ambigua* are supposed to be cold stenothermic, but eggs survive the temperate summer period (Berglund and Digerfeldt, 1970; Mothes, 1968). Emergence occurs in waters at *ca.* 8° C (Fjellberg, 1972).

Since cold–stenothermous chironomids tend to emerge during the spring – early summer thaw, when temperatures are still cool, larvae inhabiting littoral areas may be more susceptible than adults to the direct effects of temperature. Thus, it is intriguing that the littoral fauna of Hippa Lake does not suggest evidence of a climatic effect. Similarly, at Marion, Mike, and Misty Lakes in southwestern British Columbia, it is the profundal fauna, not the littoral fauna, that is most suggestive of climatic change. This leads to an ironic conclusion – that the littoral fauna of north temperate lakes, most exposed to climate, may be less responsive than the profundal fauna. Consequently, the effects of different north temperate climates upon chironomid communities may be mostly indirect.

The same situation is not apparent at tree-line. Although most Canadian chironomid genera occur north through temperate and boreal regions, many are not known from the Canadian arctic (Danks, 1981; Oliver and Roussel, 1983a). This pattern implies that littoral chironomids may be useful in distinguishing arctic palaeoclimates from warmer situations, but not so useful for describing recent Holocene changes, within the north temperate zone.

There is also little evidence to support a trophic interpretation of Hippa Lake's record. The initial high head capsule concentrations imply high productivity, as Livingstone *et al.* (1958) suggested. However, late-glacial organic sedimentation was very low. This low rate is also evident as very high pollen concentrations in the lowermost organic sediments (R. Mathewes, pers. comm.). Thus high chironomid concentrations are more likely a reflection of low sediment inputs, and perhaps some focusing of near-shore sediments and fossils to the main basin.

Palaeoecology and ecology of Corynocera

Remains similar to *Corynocera ambigua* are abundant at Hippa Lake. This taxon has always fascinated palaeoecologists. The larva was first described as ***Dryadotanytarsus edentulus*** Andersen, a subfossil in European late-glacial deposits. Deevey (1955b) found another subfossil species, *D. duffi* Deevey, in New Zealand sediments. Two years after the discovery of *Dryadotanytarsus* as an Alaskan subfossil (Livingstone *et al.*, 1958), *Dryadotanytarsus edentulus* was discovered emerging from a Finnish lake. Hirvenoja (1960, 1961) noted that adults had previously been described as *Corynocera ambigua* Zetterstedt (1838).

C. ambigua is extant in Ireland (Murray, 1983), Germany, Poland, the Soviet Union (both east and west of the Ural Mountains), Scandinavia (Fjellberg, 1972; Mothes, 1968; Fitkau and Reiss, 1978), and the Canadian low arctic and subarctic (Downes, 1962; Moore, 1978; Wiens *et al.*, 1975). Late-Quaternary records of *C. ambigua* group fossils also include Alaska, Scotland (Livingstone *et al.*, 1958), Switzerland (Hofmann, 1983b, 1985), and British Columbia. Fossils from the upper 20 cm of McDougal Lake (46° 3.2'N, 60° 25.8'W), Cape Breton Island, provide the only eastern North American record of the *C. ambigua* group (D.A. Livingstone *pers. comm.*). Tertiary fossils from Greenland, identified by W. Hofmann, record its more northerly presence, during a warmer time (O. Bennike, pers. comm.).

The early occurrence at Hippa Lake of *C.* nr. *ambigua* fossils is especially fascinating since the known adults of *Corynocera* species cannot fly (Fjellberg, 1972; Lindeberg, 1970). Instead, the brachypterous adults swarm by "whirling about on the surface of lakes" (Lindeberg, 1970). The early arrival of *Corynocera* at Hippa Lake attests either to its survival in a glacial refugium, an amazing ability to disperse with little apparent means, or the existence of a previously unknown species in the North American Cordillera, with well-developed wings.

The possible existence of a new species cannot be discounted. The British Columbia material differs from subfossils collected near Yellowknife, N.W.T. by having a darker, more variable mentum. A small, but distinct, apical projection is evident on the antennal pedestal in British Columbia collections, but not those from the Yellowknife area. Livingstone (1953) noted that the Alaskan subfossils are closer to *C. duffi* (Deevey) than *C. ambigua*. Downes (1962) claims the existence of an undescribed species in southern Alberta.

If *Corynocera* nr. *ambigua* is brachypterous, and is dispersed as readily as its early occurrence in Hippa Lake would suggest, it is difficult to imagine postglacial chironomid colonization as ever being significantly dispersal-limited. The dispersal abilities of *C. ambigua* are impressive. In Europe, it is among the first immigrants to lakes, following glacial retreat (Andersen, 1938; Berglund and Digerfeldt, 1970; Brodin, 1986; Hofmann, 1978, 1983a, b; Schakau and Frank, 1984). How it accomplishes this is not clear. It may "hitch" rides on waterfowl. Perhaps the species can be carried long distances by thermal convection and turbulent air masses. Active flight is not a prerequisite for aerial dispersal. Similar dispersal difficulties have not prevented the postglacial spread of trees across the same or similar barriers (Green, 1987). Records, albeit rare, even exist for fish and amphibians having fallen from the skies (Maguire, 1963). With regard to insects, Danks (1981: p. 369) notes "... many groups - including some that are wingless - although once believed to disperse little, in fact travel long distances in aerial plankton ...".

The unusual structure of the *C. ambigua* group's larval mentum suggests a unique feeding strategy. It has been suggested (Livingstone *et al.*, 1958) that larvae crush giant cells of characeous macroalgae, sucking out their contents. According to Fjellberg (1972), *C. ambigua* is often associated with Characeae. He notes that Characeae and *Corynocera* also occur together in several fossil localities (Andersen, 1943; Berglund and Digerfeldt, 1970; Deevey, 1955b). Late-glacial plant and animal fossils from Lobsigensee, Switzerland, also illustrate this relationship (Hofmann, 1983b, 1985; Tobolski, 1985). The one exception seems to be the Alaskan sequence. Livingstone *et al.* (1958) suggest that an obligate relationship does not exist.

A *Corynocera*-Characeae relationship could resolve *C.* nr. *ambigua*'s inconsistent fossil distribution in British Columbia. It occurs throughout the fossil record at Mike and Marion Lakes near Vancouver, and at Hippa Lake. In Marion Lake it is more abundant in late-Holocene sediments. In Misty Lake, northern Vancouver Island, it is restricted to late–glacial deposits.

To examine this hypothesis (an obligate dependence of *C.* nr. *ambigua* on Characeae) in greater detail, fossil Characeae and *Corynocera* distributions were compared. At present, such data are available in British Columbia for Marion, Misty, and Hippa Lakes (Fig. 4.5). A strong correlation is evident at Misty Lake. Also, at Hippa Lake, both *Corynocera* nr. *ambigua* and Characeae fossils are distributed throughout the core. However, despite the late Holocene abundance of *Corynocera* nr. *ambigua* at Marion Lake, only one Characeae oospore was found, at 260–270 cm (N. Wainman, pers. comm.). Unfortunately, taphonomic (decomposition, deposition, and preservation) processes clearly interfere with these results. Wainman (pers. comm.) reports *Nitella* Agardh oospores as abundant in Marion Lake surface samples, collected near a large spring. Since none of these were found at the core site, the oospores are not being evenly distributed throughout the lake. Thus, the test results are inconclusive. Characeae may or may not play an important role in regulating the occurrence and abundance of *Corynocera* nr. *ambigua*.

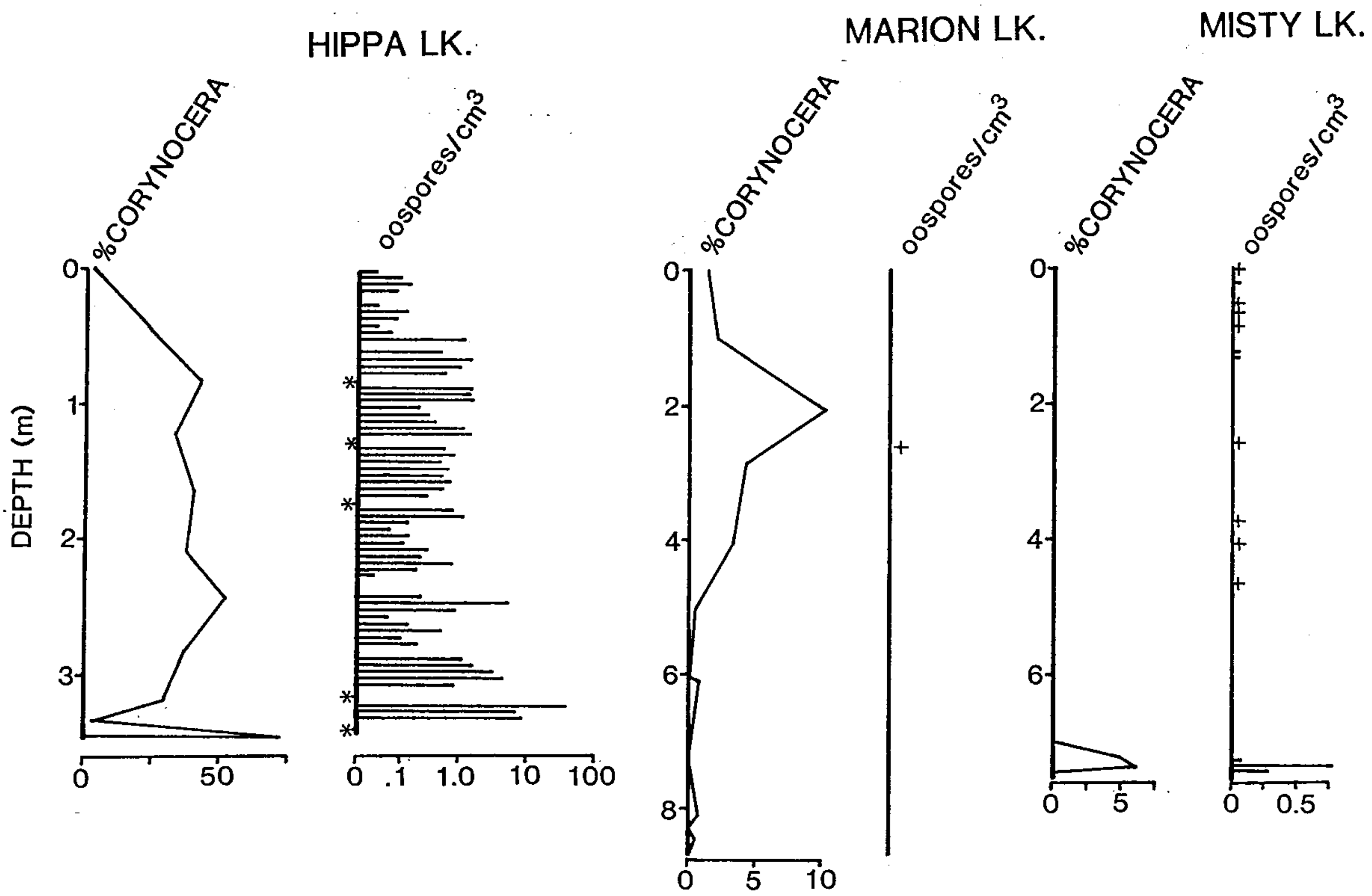

Figure 4.5 Comparison of fossil *Corynocera* nr. *ambigua* and Characeae oospore records for Marion, Misty, and Hippa Lakes, British Columbia. (*–indicate missing samples at Hippa Lake, mostly used for ^{14}C–dating; "+" indicates presence in small numbers; Note: log(x+1) scale used for Hippa Lake oospore record).