Biophysical Surveys of Aquatic Habitats in Gwaii Haanas 1993: Upper Victoria Lake, Lower Victoria Lake, Escarpment Lake and 14 Selected Streams

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2.2.3 ESCARPMENT LAKE

General description, morphometry and bathymetry

The lake, which is the third largest in Gwaii Haanas, is situated between Mike Inlet and Barry Inlets. It is characterized by eroded rock escarpments (post-tectonic plutons) that rise steeply from the lake shore several hundred meters in elevation (Figure 23). Narrow beaches of coarse white sands are prevalent on the north shoreline. The white sands, which are absent from the Victoria Lakes, probably result from differences in mineralogy of the plutonic rocks underlying these lakes. Escarpment Lake is situated on Pocket Inlet Batholith which contains the highest levels of quartz of any of the plutonic rocks (Sutherland Brown 1968). This will result in lighter coloured sands. General topography is shown in Figure 24. There are 22 inlet streams, many of which produce high (50 m) waterfalls, and occur only during periods of rainfall. The largest stream, which has multiple channels, drains the valley at the east end of the lake. There is a single narrow outflow stream that drops gradually (1:100) over a horizontal distance of 200 m before entering the ocean over a vertical rock escarpment.

General morphometric features of the lake are given in Table 11. The lake has a maximum length of 2.5 km and a surface area of 1227 ha, and occupies about 10% of the watershed area. Maximum depth (57 m) is adjacent to the large escarpment on the north side of the lake (see Figure 24). As lake elevation is 22 m, the lake bottom is some 30 m below sea level. There are no islands in the main lake basin but several small islets occur in the outlet bay.

Site localities for biophysical data collections are shown in Figure 25.

Figure 23 (opposite). Escarpment Lake. Upper left - major escarpments on north shore. Upper right - looking east down the lake. Lower left - sand beaches on northwest shore. Lower right - threespine stickleback captured in Fyke nets.

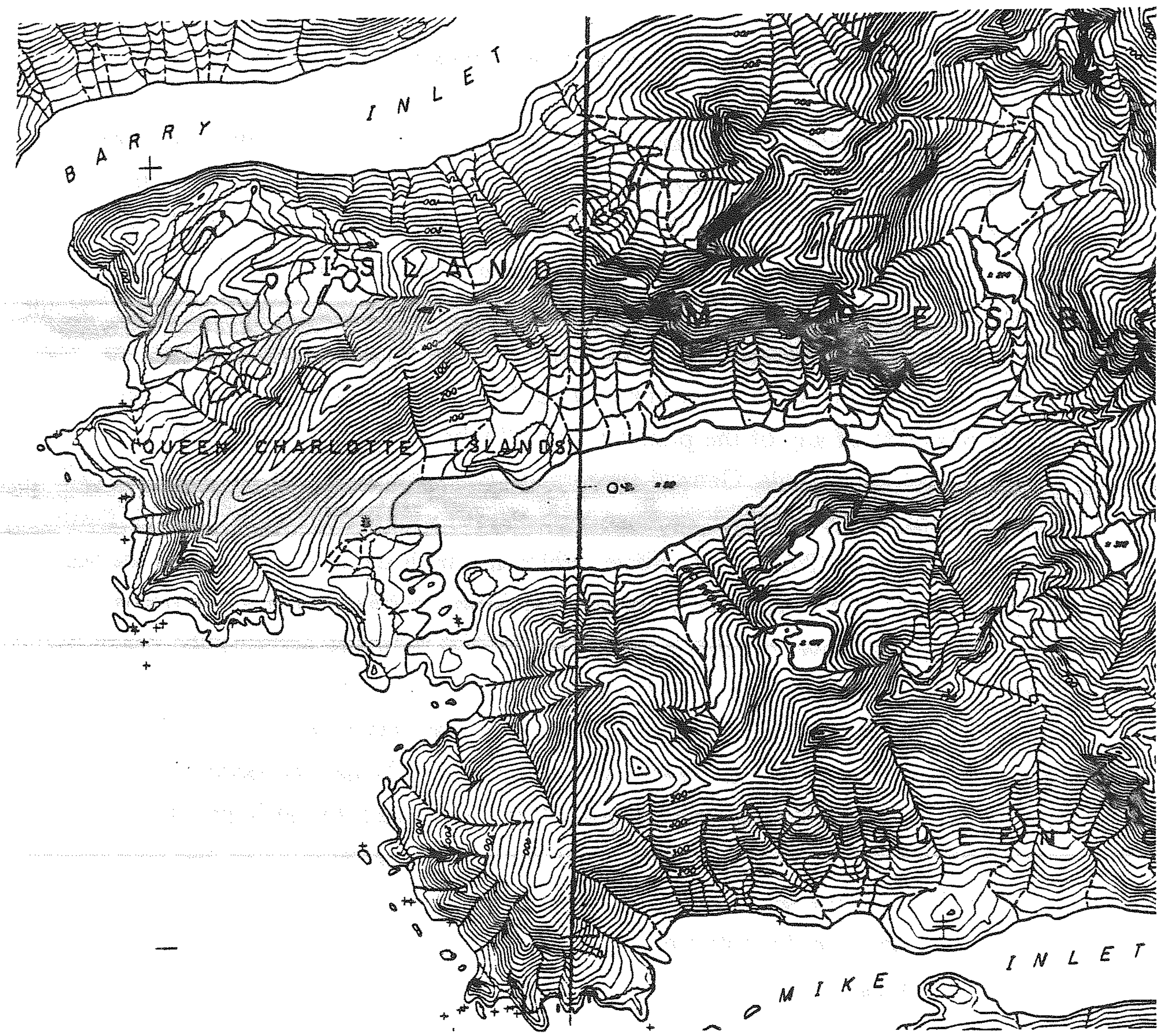

Figure 24. Topographic map of Escarpment Lake watershed. Scale: 1 cm = 300 m. Contours in 20 m intervals.

Table 11. Summary of morphometric parameters of Escarpment Lake.

Elevation	22 m
Watershed area	1227 ha
Lake area	113 ha
Volume	30,996,390 m^3
Maximum length	2459 m
Maximum width	636 m
Mean width	461 m
Maximum depth	57.3 m
Mean depth	27.4 m
Relative depth	4.77 %
Shoreline	6870 m
Shoreline development	1.8

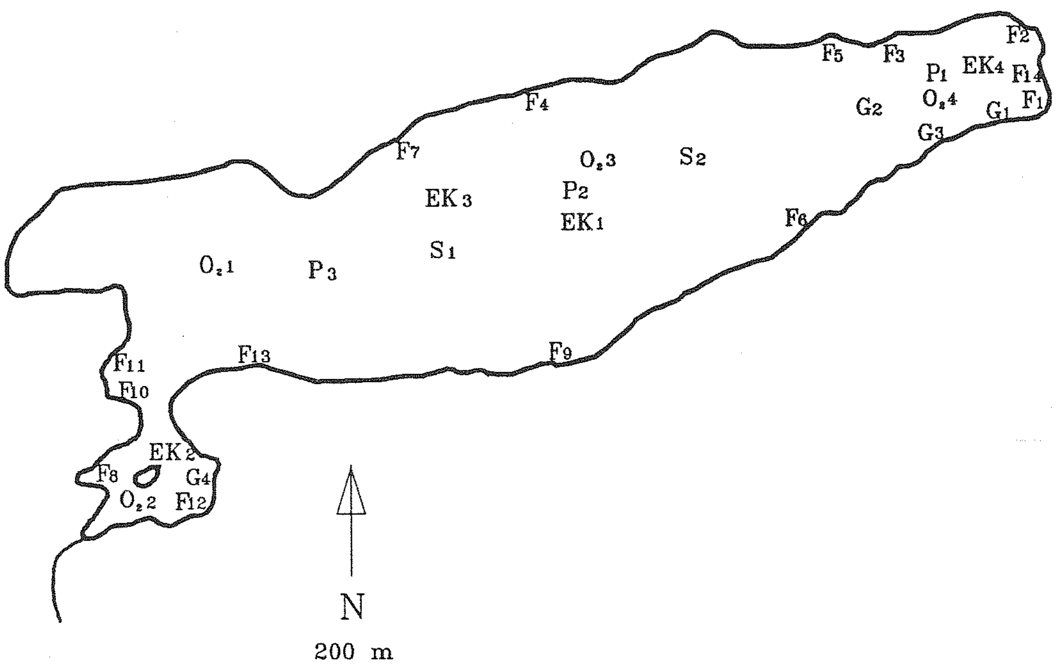

Figure 25. Site localities for biophysical data collections.

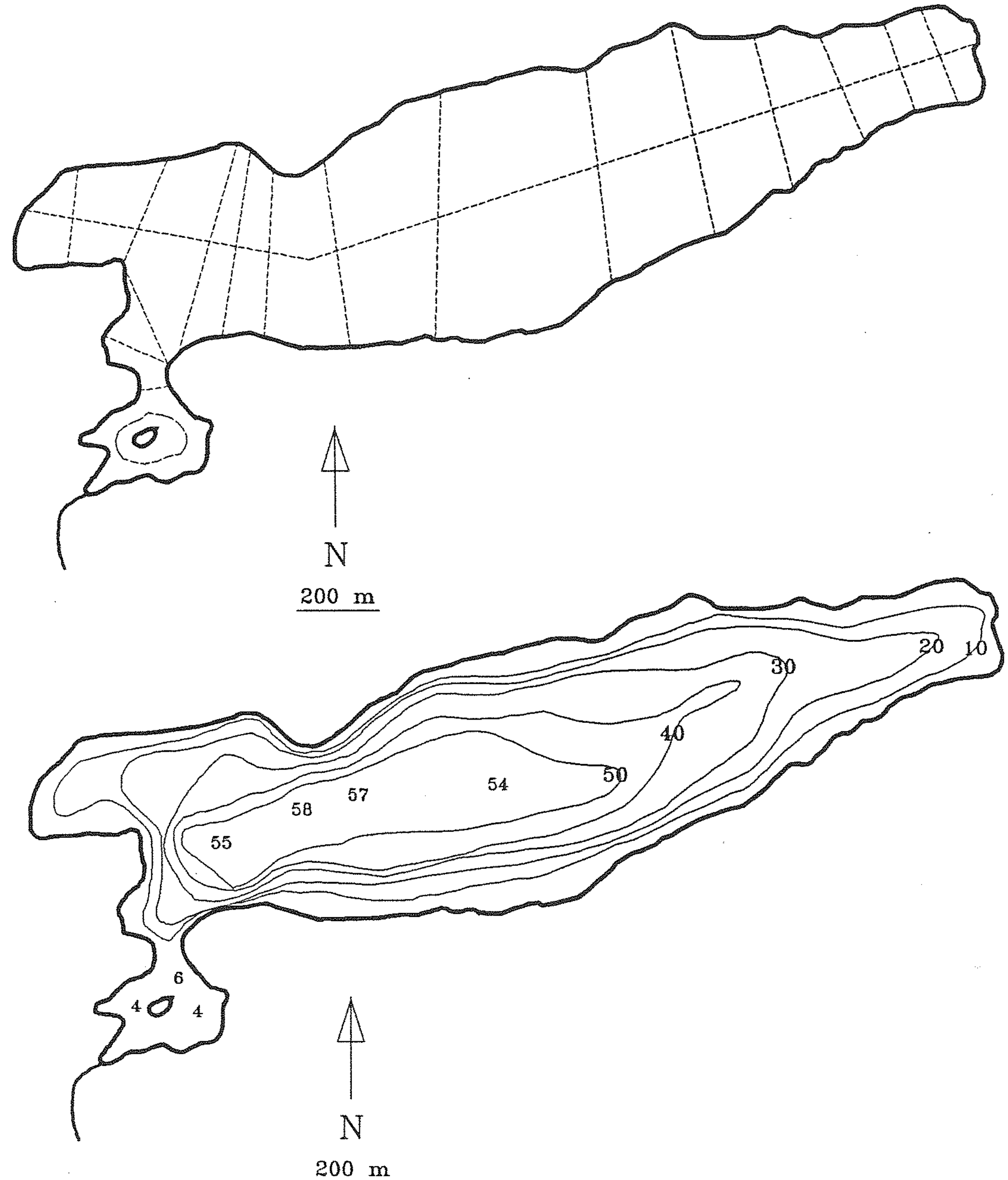

Figure 26. Bathymetry data for Escarpment Lake. Top - boat transect positions, Lower -depth contours (m) and maximum depth records for selected areas.

Bathymetry (Figure 26) demonstrates a steep gradient near shore followed by a relatively flat central bottom. Although the surface area is less than that of Lower Victoria, the depth and volume are greater. Hypsographic curve (Figure 27), as with the Victoria Lakes, shows that that about 25% of the lake surface is less than 10 m depth but this is largely from the presence of the shallow outlet bay rather than a wide littoral area in the main basin.

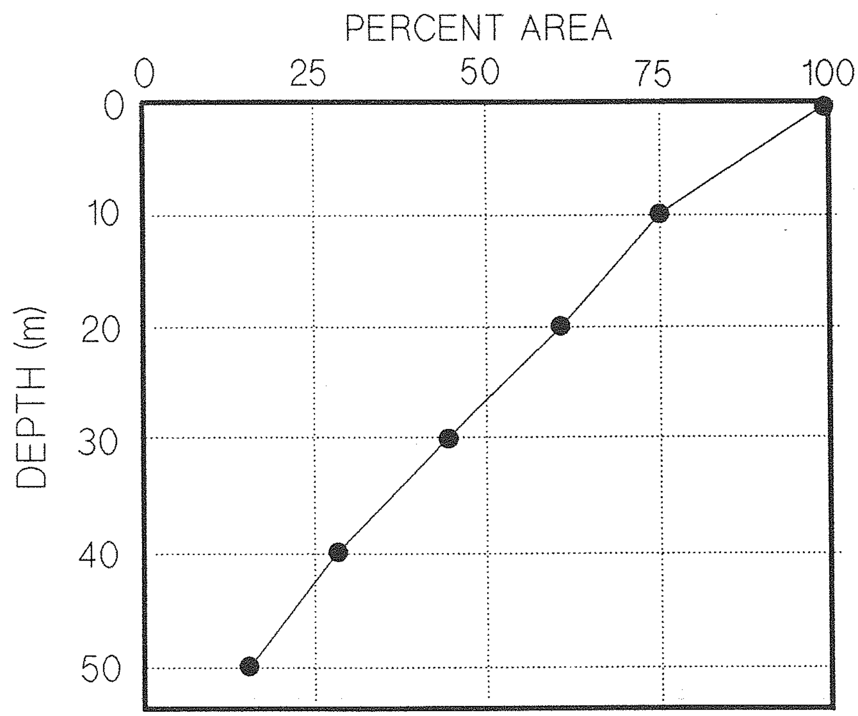

Figure 27. Hypsographic curve for Escarpment Lake.

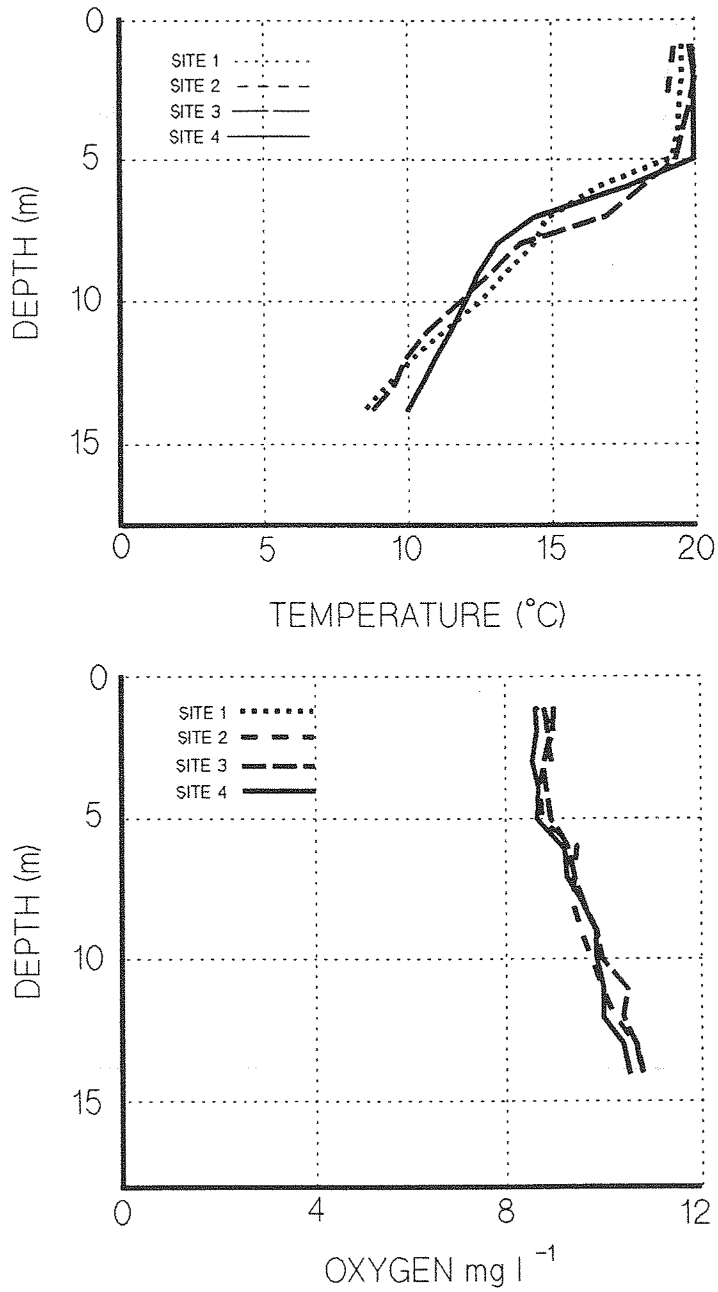

Figure 28. Temperature and oxygen profiles for Escarpment Lake.

Chemical and spectral analyses

Conductivity of the lake water was 35$_{\mu}$mhos cm^{-1} while pH was 6.3. Ekman dredge samples obtained from 40 m depth yielded a conductivity of 110$_{\mu}$mhos cm^{-1} and pH of 6.55. Chemical analyses (Table 12) indicates low levels for all elements other than sodium.

Maximum light penetration using a Secchi disk was 6.0 m at two sites while spectrophotometric analysis was 96.3% transmission at 400 nm (93.6% in 1986). This is the clearest lake surveyed.

Table 12. Water chemical analyses for Escarpment Lake. All results in ppm. Blank values (-) are below detectable limits.

P	S	Mg	As	Na	Al	Zn	Cu
0.035	0.643	0.598	0.022	5.113	0.220	0.020	0.018

Pb	Ti	Ni	K	Mn	Fe	Ca
0.009	-	-	0.834	0.002	-	1.098

Temperature and oxygen

Lake temperature was 20°C at the surface and 10°C at a depth of 15 m. At each of three open water sites, temperature profile (Figure 28) shows a sharp thermocline beginning at 5 m depth and extending to approximately 8m. Samples of bottom sediment obtained from several deep regions of the lake (33 m and 35 m) had a temperature of 11.5°C and 10.5°C, suggesting continuity from the bottom of the metalimnion (15 m) to the bottom of the lake. Temperatures in the shallow outlet bay (site 2) were not warmer but rather slightly cooler than surface temperatures elsewhere in the lake (19.3 vs 19.5°C)

Oxygen levels (Figure 28b) ranged from 8.8 mg l^{-1} to 10.8 mg l^{-1} or approximately 93-96% saturation. Levels were similar in the epilimnion but increased in the metalimnion. All of the bottom mud samples from the deep parts of the lake were anoxic even at the sediment/water interface.

Littoral substrate

The shoreline is generally narrow (<5 m) and has a highly variable substrate ranging from sands to bedrock (Figure 29, Table 13). The north shore of the lake (sectors 3 - 12) has coarse white sands composed. Occasional large (1 - 3 m) boulders, which have broken free from escarpments above the lake, occur on the sand beaches. Bedrock ledges in the littoral zone occur at the base of the rock escarpments on the north, southwest and southeast regions of the lake. The remaining shores are primarily large cobbles and boulders. Large submerged tree trunks occur in scattered localities on the south shore and extensively in the outlet bay. These result from land slides into the lake.

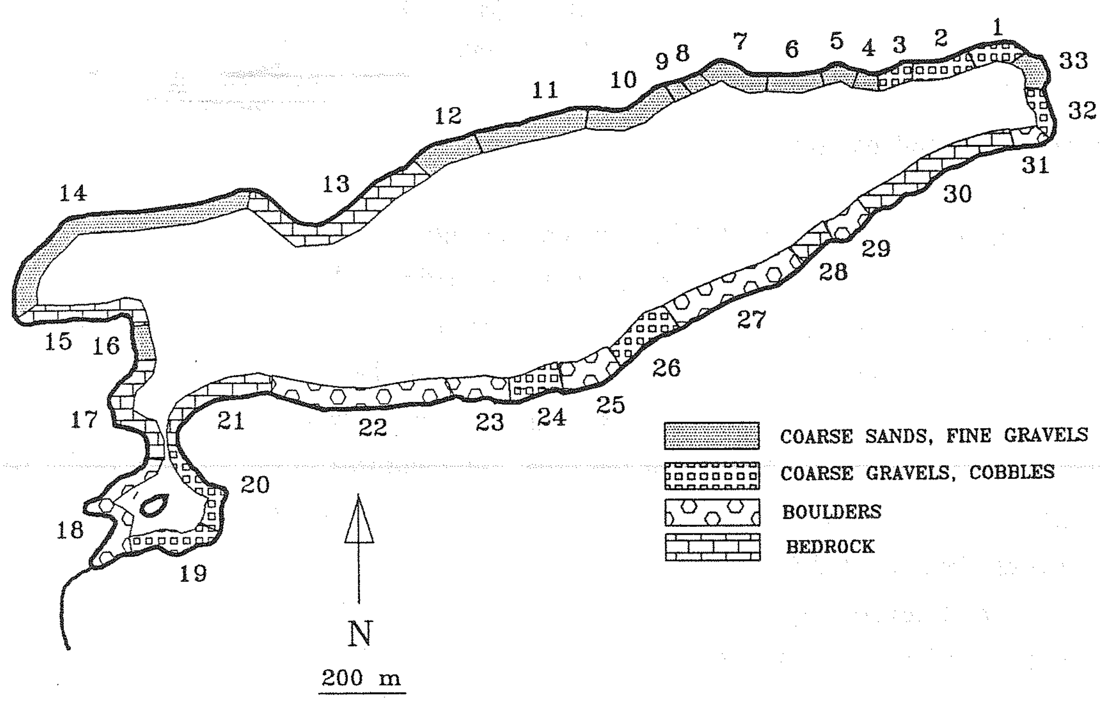

Figure 29. Dominant substrates in littoral zone for Escarpment Lake. Sectors show linear areas of similar substrate surveyed for macrophytes.

Vegetation

Aquatic

Escarpment Lake has low diversity and low abundance of aquatic vegetation (Table 13). There were only 4 species of vascular plants, 1 species of macroscopic algae and a sponge. A high number of sectors (16 of the 33 surveyed) had no vegetation. In half of these, there were vertical bedrock substrates which are unsuitable for aquatic plant colonization. Nine sites with gravel substrate also lacked all vegetation.

Isoetes echinospora was the only widely distributed species (present in 10 of the 33 sectors) in the littoral region and was abundant in several sites along the north shore of the lake. Substrates for Isoetes ranged from silt to coarse gravel, but the species was abundant only in silt and fine sand. A sponge was found in 7 sectors, but was abundant in patches only in a shallow protected bay in the southwest corner of the lake. This was the only sector with Utricularia intermedia and Sparganium hyperboreum. Ranunculus flammula was common in a single site on the south shore. Nuphar, the species normally found in bays of most lakes, was not observed in this survey and is either absent or rare in the lake.

Terrestrial

The north shoreline of the lake has large open areas of Sphagnum bog and exposed bedrock intermixed with sparse stands of sitka alder, yellow cedar and lodgepole pine. In the northwest corner of the lake (sector 14) and on the east side of the outlet bay, the dominant trees are sitka spruce, red cedar, western hemlock and sitka alder. There are stands of yellow cedar and lodgepole pine in the outlet bay and on cliffs (sectors 28 & 30). The northeast corner of the lake including the valley bottom and adjacent slopes is extensively forested with exceptional diversity in species and demographic structure. Sitka spruce, sitka alder and red alder are common on the shoreline, while red elderberry, grey berry, devil's club, salmon berry, red huckleberry and copperbush are abundant in riparian habitats by the inlet stream. Some of the sitka spruce on the slopes are large (2.9 m diameter breast height measured on 2 individuals). Occasional large boulders (3 m diameter) which have broken

Table 13. Dominant littoral substrates and macrophytes for Escarpment Lake. See Figure 29 for lake sectors. Values show percentage occurrence. Wood debris S - bark and twigs, L - large branches and trees. Macrophyte codes A - abundant, C - common, R - rare.

	LAKE SECTOR															
DEPTH SUBSTRATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<1m Gravel(<2mm)	20	20		80												
Gr(2-16mm)	10	10	20		80	90	90	90	90	90	90	80		60		90
Gr(16-64mm)	10	10	50													10
Gr(64-128mm)																
Gr(128-256mm)	30	30		20												
Gr(>256mm)	20	20	30		20	10	10	10	10	10	10	20	5		5	
Bedrock													95	40	95	
Wood debris																
>1m Gravel(<2mm)																
Gr(2-16mm)	10	90	20		20	90	90	90	90	90	90	80		60		
Gr(16-64mm)			50													80
Gr(64-128mm)																20
Gr(128-256mm)	50	10			80											
Gr(>256mm)	40		30			10	10	10	10	10	10	20	5		5	
Bedrock													95	40	95	
Wood debris																
Isoetes	A	R		A					A		C			C		
Sparganium																
Potamogeton																
Carex																
Juncus																
Eleocharis																
Nuphar																
Ranunculus																
Callitriche																
Lilaeopsis																
Utricularia																
Algae			C					C								R
Chara										C						
Liverwort																
Sponge											C					R

Table 13 cont.

LAKE SECTOR																
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
									10						20	90
		10	10						70						80	10
		90	90													
	20						90	10								
5	70			5	95	95	10	90	20	90	30	90	5	95		
95	10			95		5				10	70	10	95	5		
	L	L	L		L								L	L	L	
		95	95													
							95	90							20	90
							5								80	10
								10	80							
5	5			5	95	95			20	90	30	90	5	95		
95	95	5	5	95	5	5				10	70	10	95	5		
	L	L	L		L								L	L	L	
	C	C						R		R						
	R															
					C											
		C														
					C	C										
	A	R		R	R			R								

free of the rock escarpments have rolled and cleared trees from narrow strips. These areas have provided colonizing habitat for the diversity of shrubs. These episodic events such as clearance by boulders forms a spatially complex habitat.

Zooplankton

Zooplankton were very uncommon (Table 14) with an average density of 172 individuals per cubic meter (range 61 - 473). The greatest number were collected on the east end of the lake. Most (71%) were cladocerans while the remainder were calanoid and cyclopoid copepods. Total settled volume was 0.25 ml.

Table 14. Zooplankton counts for Escarpment Lake. See Figure 25 for site position in lake. Numbers include total counts for cladocerans and copepods.

SITE	TIME	DEPTH(m)	PLANKTON	NUMBER m^{-3}
P1	NOON	14.6	78	473
P1	MIDNIGHT	15.4	16	107
P2	NOON	34.7	24	61
P2	MIDNIGHT	30.5	37	107
P3	NOON	55.8	90	143
P3	MIDNIGHT	55.8	89	141
AVERAGE				**172**

Fish

Fourteen Fyke net samples yielded 67 Dolly Varden, 8 rainbow trout and 4,450 stickleback (Table 15). Gillnets had 33 Dolly Varden and 6 rainbow trout. The former were equally abundant in shoreline and open water gillnets (18 versus 15) while the latter were found only near shore (6 versus 0). Both species of salmonids appear to be solitary or in small schools since they occurred in low numbers in single Fyke or gillnets. Stickleback were observed in low numbers throughout littoral regions of the lake and also occurred in large schools (>1000 individuals) which consisted predominantly of gravid females (Figure 23). These schools were captured in three separate Fyke settings (F6, F9, F13) on the south shore of the lake. This probably is associated with greater cover by submerged logs relative to the north shore.

Dolly Varden from Fyke nets had a modal SL near 10 cm (range 6 - 23 cm, Figure 30) slightly less than those captured from gillnets (mean = 14.6 cm, range 10 - 24 cm). These fish showed a typical length-weight association (Figure 31). Rainbow trout from Fyke nets had a modal length of 18.5 cm (range 8 - 31 cm, Figure 32) which was smaller than those from gillnets (mean = 25.5 cm, range 21 - 29 cm). The weights of five trout were not sufficiently variable to establish a useful length-weight curve. Grouping of these fish with 6 individuals from Lower Victoria Lake provides a a representative curve (Figure 33). Modal length of stickleback was 70 mm (range 30 - 90).

All of the Dolly Varden collected in the Fyke nets (N = 67) were marked and released at the sites of capture. While there was up to 5 days for dispersal, no marked fish were recaptured. This excludes any meaningful calculation of population size. The relatively low numbers of Dolly Varden in both Fyke and gillnets in all parts of the lake suggest that density is low.

Sixteen rainbow trout were marked and released at the site of capture. Two were recaptured (gillnet) after 4 days at approximately 100 m from the release site. A gillnet, positioned on the south central shore, some 500 m from the release site in the east end of the lake, caught a single trout and this was a recapture. This demonstrates that numbers of trout are low and that dispersal is occurring. Using Schnabel's method gives a total estimate of 44 trout in the 500 m stretch. On the assumption that this abundance is representative of other littoral areas in the lake, total lake population

Table 15. Summarized data of fish collected in Fyke nets from Escarpment Lake. SITE - L(littoral), OWB(open water benthic), OWS(open water surface).

DATE	METHOD-SITE	DOLLY VARDEN	RAINBOW TROUT	STICKLE BACK
17/07/93	Fyke1 L	3	3	105
	Fyke2 L	3	3	30
	Fyke3 L	3	0	70
18/07/93	Fyke4 L	9	0	45
	Fyke5 L	1	2	15
	Fyke6 L	6	3	1500
19/07/93	Fyke7 L	6	0	500
	Fyke8 L	2	3	15
	Fyke9 L	6	1	1000
20/07/93	Fyke10 L	6	2	150
	Fyke11 L	3	1	70
21/07/93	Fyke12 L	11	0	120
	Fyke13 L	6	0	800
	Fyke14 L	2	0	30
18/07/93	GN1 L (4cm)	2	2	0
	GN2 OWB (1cm)	1	0	0
	GN1 L (5cm)	0	0	0
	GN3 L (5cm)	1	1	0
	GN1 L (11cm)	4	0	0
19/07/93	GN2 OWB (1cm)	9	0	0
	GN3 L (4cm)	0	0	0
	GN3 L (5cm)	1	1	0
20/07/93	GN3 L (4cm)	0	1	0
	GN1 L (5cm)	0	1	0
	GN2 OWS(1cm)	0	0	0
21/07/93	GN4 L (4cm)	5	0	0
	GN4 L (5cm)	5	0	0
	GN2 OWB (1cm)	5	0	0
	Totals	**100**	**24**	**4,450**

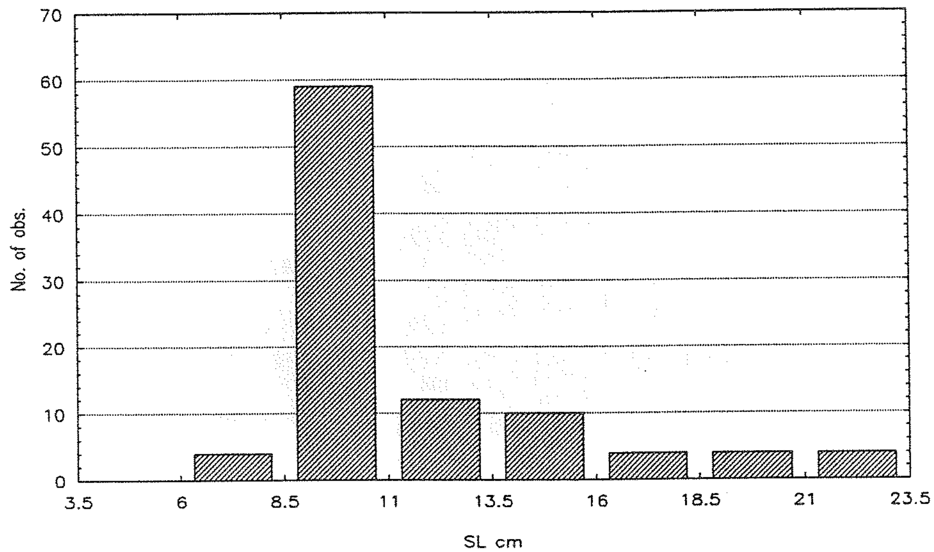

Figure 30. Frequency histogram of body length (SL) for Dolly Varden at Escarpment Lake.

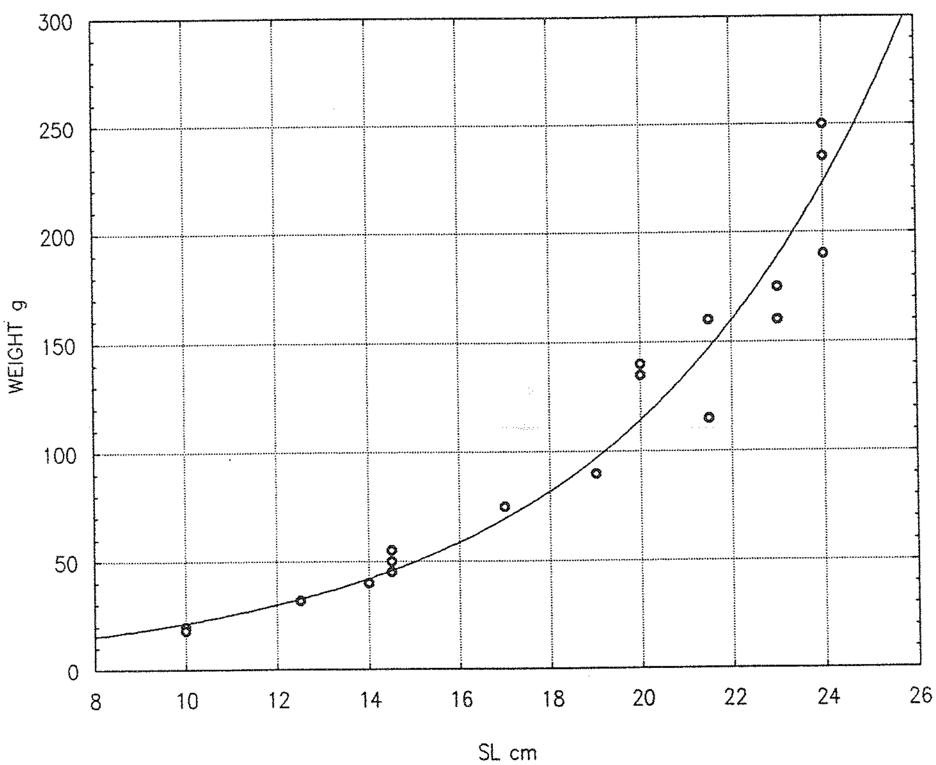

Figure 31. Length/weight relationship for Dolly Varden at Escarpment Lake. Exponential curve fitted to data points.

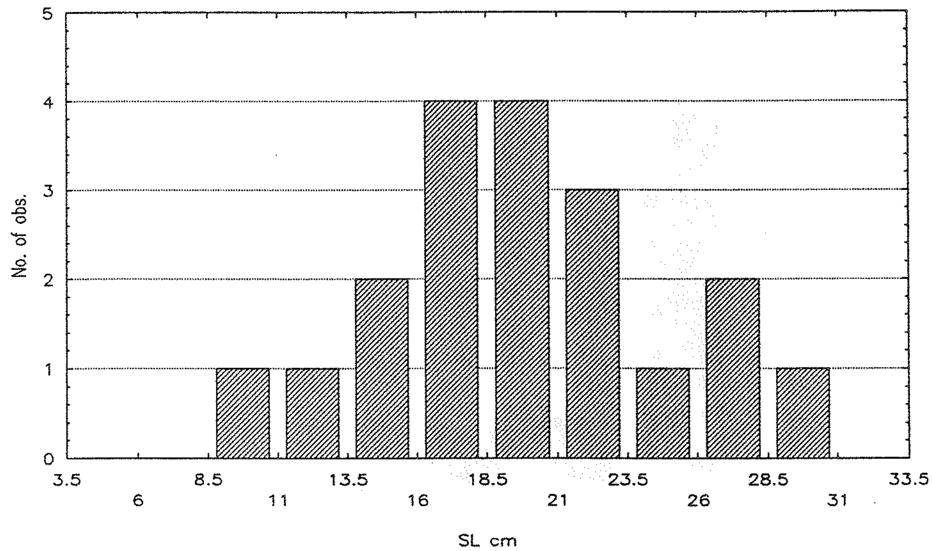

Figure 32. Frequency histogram of body length (SL) for rainbow trout at Escarpment Lake.

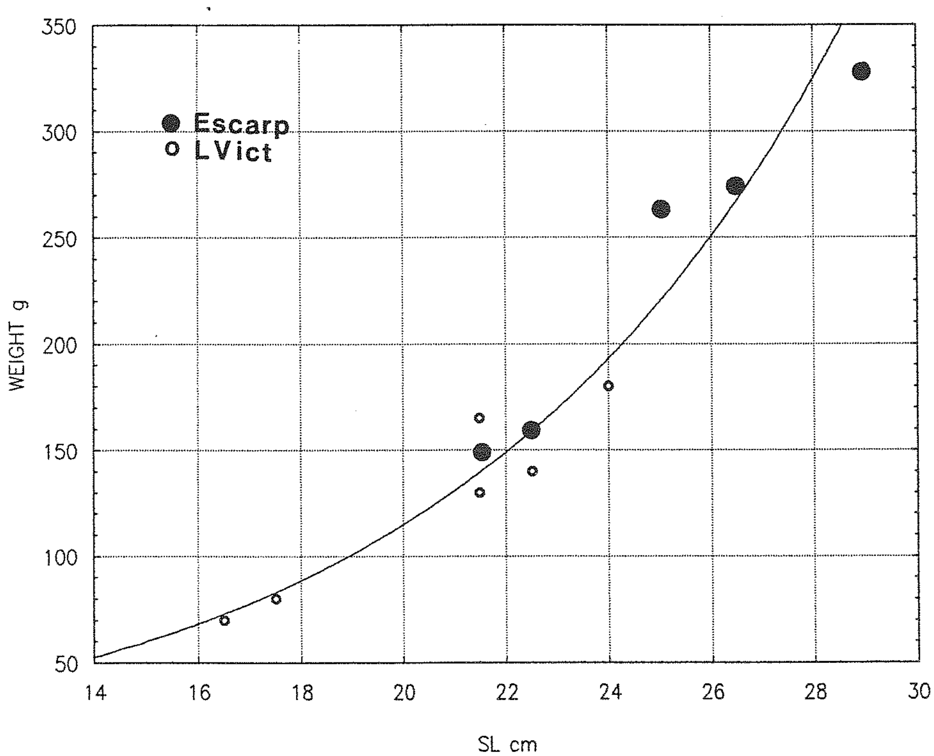

Figure 33. Length/weight relationship for rainbow trout at Escarpment and Lower Victoria Lakes. Exponential curve fitted to data points.

is estimated at 660 individuals. It is probable that this estimate is high because the southeast shore appears to be a more productive habitat than other littoral regions of the lake where there is little submerged debris for fish to shelter.

Stomach analyses of three rainbow trout stomachs showed Aeshna (Odonata) naiads (2 stomachs) and adult dipterans (1 stomach).

Amphibians, mammals and birds

No amphibians were observed in Escarpment drainage. Red squirrel occurred in forests at the east end of the lake. Deer were not observed but are presumed to be present. The abundance of conifer and shrub seedlings indicate that browsing pressure is limited.

Eleven bird species were observed on the surface and shoreline at Escarpment Lake during the survey:

Common Loon (1)
Mallard (1♀)
Barrow's Goldeneye (1 ♀, 1 juvenile)
Bald Eagle (2)
Marbled Murrelet (>200 calls/hour)
Common Raven (2)
Dipper (1)
Winter Wren (common)
Varied Thrush (common)
Western Flycatcher (common)
Crossbill (common)

There was a major dawn chorus of birds from the forests on the east end of the lake, the intensity of which was influenced by atmospheric conditions. On the morning of July 18, cloud cover descended to some 200 m above the lake surface and shrouded the steep forested slopes and rock escarpments bordering the lake. Beginning at 0515 h, Varied Thrush gave territorial calls and by 0530 h, continuous and uninterrupted calling pervaded the valley. At least 38 different individuals could be distinguished within a 2 minute interval. Marbled Murrelets were also abundant and highly vocal during this time. Within any 5 minute period, there were from 15 to 25 separate calls or detections. These included repeated calls from stationary birds on the surrounding slopes as well as birds in flight. Multiple simultaneous calls excluded any reliable estimate of detection rate over the dawn period. The continuity of high intensity calls over 90 minutes combined with actual counts during shorter time blocks would suggest total of at least 200 detections. While flight was occasionally close to the lake surface, most of the activity was in the mist and in the direction of the north, east and south slopes adjacent to the valley bottom. The upper slopes are a mosaic of exposed bedrock escarpments, moss and grass ledges. Below this are narrow fissures with scattered trees and at lower levels there are diverse stands of large trees with extensive epiphytic cover of mosses. Visibility was too limited to discern actual choice of habitats by the murrelets.

On the following morning during the same time period, the mist had lifted and the dawn vocal activity was greatly diminished. Varied Thrush calls, while still common, were down to 1 - 5 per minute while number of Marbled Murrelets calls were only 1 per 5 minute interval. This variability between two successive days at the same locality greatly limits the usefulness of dawn detection counts made during periods of clear atmospheric conditions.

Diurnal bird activity was extensive both in the canopy and the forest floor. Several large flocks of crossbills (>100 birds/flock) were active. The multiple canopy layers within the forest provided major habitat complexity.

The lake surface had limited bird activity. Two Common Loon occurred on the lake and foraged on threespine stickleback. A female Barrow's Goldeneye was seen in the outlet bay of the lake and on several occasions on the ocean adjacent to the mouth of the outlet stream. A young goldeneye, still covered in down, was present at the mouth of the stream and presumably floated downstream from the lake. Belted Kingfisher were also observed in the outlet bay of the lake foraging on stickleback which were abundant in the regions of submerged wood debris.

2.3 Discussion

Upper Victoria Lake, Lower Victoria Lake and Escarpment Lake, the largest lakes in Gwaii Haanas, are similar in many biophysical features including watershed area and lake volume. Each is characterized by steep rocky shorelines, high water clarity, a paucity of aquatic vegetation, low fish abundance and very limited use of the aquatic habitat by amphibians, mammals and birds.

The results confirm the observations made during earlier reconnaissance of the lakes (Reimchen 1992a). That is, Upper Victoria contained only Dolly Varden while Lower Victoria and Escarpment Lake had Dolly Varden, rainbow trout and threespine stickleback. Salmonids occurring in the Victoria Lakes are resident and are not maintained by movement of anadromous individuals from marine waters. The outflow channels have a steep gradient and the water falls on Lower Victoria Lake are unambiguously impassable for upstream movement of fish. It is not unexpected to find Dolly Varden in lakes above high gradient outflow streams as this species is common in headwater streams in numerous coastal watersheds. However, it is unusual that rainbow trout and threespine stickleback are present in lakes above impassable falls. It is possible these fish entered the lake during early postglacial periods when sea levels were higher than at present. Although the extent of rise is highly variable geographically (R Mathewes, D. Fedje - personal communication), the east side of the Queen Charlotte Islands had sea levels 15 m above current shorelines (Clague 1969). If the west side of Moresby Island had greater depression from increased ice cover, then a global rise in sea level would have produced more extensive inundation of west coast watesheds possibly reducing the size of the waterfalls to Lower Victoria Lake and allowing access to fish. Failure of trout and stickleback to colonize Upper Victoria Lake could extend from differences in elevation as Upper Victoria Lake is slightly higher (44 m) than Lower Victoria Lake (32 m).

There were no coho or sockeye salmon found in any of the lakes. For the Victoria Lakes, the lack of salmon is a consequence of the high gradient outlet streams to the ocean. However, the outlet from Escarpment Lake is comparatively low gradient and it remains plausible that anadromous salmonids are able to reach the lake and utilize the large low gradient stream flowing into the east end of the lake. If this is so, then the rainbow trout in Escarpment Lake might represent both resident and anadromous (steelhead) populations.

Intensive surveys of littoral areas around each of the lakes demonstrated that aquatic macrophytes and bottom fauna were rare. Part of this is because of the steep shoreline and unsuitable substrate including bedrock and boulders but also, it results from the general absence of bays protected from wind and waves that would allow a stable littoral substrate to develop. This is reflected in the low shoreline development indices for each of the lakes.

Zooplankton density was highest in Upper Victoria Lake (1778/m^3), intermediate in Lower Victoria Lake (425/m^3) and lowest in Escarpment Lake (172/m^3). Some of these differences are clearly associated with the fish populations. Dolly Varden was the only fish species in Upper Victoria Lake and was found primarily in benthic habitats. This species consumes macrobenthos in summer (Northcote and Clarotto 1975). Lower Victoria Lake and Escarpment Lake also have rainbow trout and threespine stickleback which forage on both zooplankton and macrobenthos (Nilsson and Northcote 1981, Wootton 1976).

During the surveys, extensive effort was directed at ascertaining fish abundance. Based both on total collecting effort and on mark release studies, it appeared that density of fish was very low. Total biomass of salmonids in each lake can be roughly estimated from the empirically derived population estimates and average weights. This yields total lake biomass (excluding threespine stickleback) of 242 kg, 293 kg and 184 kg for Upper Victoria Lake, Lower Victoria Lake and Escarpment Lake respectively or approximately 1.0 kg ha^{-1}, 1.8 kg ha^{-1} and 1.6 kg ha^{-1}. These values are at the lower range of estimates for northern temperate lakes of equivalent size (Ryder 1965). However, it is possible that the mark/release studies greatly underestimated salmonid abundance, perhaps due to insufficient dispersal of marked individuals into the population (leading to higher recapture rates and lower estimates).

It is unlikely that the different collecting techniques that were used (gillnet, Fyke net) would have overlooked any localized concentrations of fish in these lakes. Furthermore, if fish were common, piscivores such as river otter, Great Blue Heron (Ardea herodias), Common Merganser (Mergus merganser) and Hooded Merganser

(Lophodytes cucullatus) would have been expected. Each of these species are commonly found on Queen Charlotte Lakes during summer (Reimchen 1993). However, it is possible that fish are abundant but primarily benthic and outside of the foraging habitat of either wading or diving birds. This possibility can be partially tested by evaluation of gillnet capture rate reported for other British Columbia lakes. A positive correlation occurs between fish biomass and total dissolved solids (TDS) among lakes which yields the regression $y = 0.618x - 0.684$ where y is the weight of fish (kg) per gillnet (ca. 120 m^2) and x is total dissolved solids (ppm) (Northcote and Larkin 1956). In 100 lakes, the average weight was approximately 5 kg per gillnet (range 0 - 50). Conductivity of the Victoria and Escarpment lakes was 35 - 40 μmhos cm^{-1} which converts to a TDS value of approximately 25 ppm (from summation of individual weights). Substitution into the regression equation yields a predicted fish weight of 1.5 kg per gillnet set which is close to the lowest values observed in coastal lakes of British Columbia. Calculation of total gillnet effort for the three lakes (from Tables 5, 10, 15) yields actual values of 0.29 kg, 0.24 kg and 0.58 kg per equivalent net effort for Upper Victoria Lake, Lower Victoria Lake and Escarpment Lake respectively. Therefore, the estimated fish biomass of the three lakes is substantially lower than the expected values.

These remote mountain lakes are subject to some recreational fishing. While the extent has not been quantified, the total catch is probably low at this time due to remoteness and limited access. While this may contribute to the low fish abundance, it is unlikely to represent the primary cause.

Data on dissolved solids, when combined with mean lake depth, yields the morphoedaphic index (MEI). This index provides an independent measure of potential fish biomass in a lake (Ryder 1974). Calculation of MEI (TDS ÷ mean depth) for lakes in North America (areas 1 - 31820 ha) gives values ranging from 0.12 to 20.8 (Ryder 1965). Globally, MEI ranges from 0.03 to 300 000 and Ryder et al. (1974) conclude that maximum fish biomass occurs when MEI approaches 40 and declines with either higher or lower values. Using an average TDS value of 25 ppm for the three lakes surveyed, MEI would be 0.34, 0.42 and 0.28 for Upper Victoria Lake, Lower Victoria Lake and Escarpment Lake respectively, which are some of the lowest values recorded in small north temperate lakes. Because of the reasonable regression association between MEI and fish abundance across many lakes, fish biomass (kg/ha/yr) can be estimated as 0.966 * √MEI (Ryder et al. 1974). Calculation of these values for the three lakes in Gwaii Haanas yields values of 0.56 kg ha^{-1}, 0.63 kg ha^{-1} and 0.51 kg ha^{-1} for Upper Victoria Lake, Lower Victoria Lake and Escarpment Lake respectively. Total fish biomass for each lake is estimated at 134 kg, 105 kg and 58 kg respectively lower than the rough estimates derived from mark/release studies. These values based on MEI strongly suggest that the low abundance of salmonids observed during these lake surveys are the consequence of low primary productivity of the lakes. If the estimates are accurate, these lakes would be unable to sustain recreational fishing.

Concentrations of cations in waters allow additional insight into the biological potential of the lakes. Based on a global survey using many lakes, Rodhe (1949) derived a standard element concentrations (ppm) for lakes with different conductivities. Lakes overlying igneous rocks generally have low conductivity (<50μmhos cm^{-1} and correspondingly, low element concentrations and low biological production. For a conductivity of 40μmhos cm^{-1}, concentrations are 5.2 ppm for calcium, 1.45 ppm for sodium, 0.85 ppm for magnesium and 0.55 ppm for potassium. Actual values from the Victoria and Escarpment Lakes, which each overlie igneous rocks, averaged 1.09 ppm for calcium, 4.90 ppm for sodium, 0.56 ppm for magnesium and 0.80 ppm for potassium. In other words, calcium and to a lesser extent magnesium are well below predicted values, potassium is similar in abundance while sodium is in substantial excess. These low concentrations appear to persist over time as a water sample obtained from Escarpment Lake in August 1976 has similar conductivity and element concentrations to that from 1993 (Reimchen 1992a).

Among the major cations, increased calcium levels are correlated with both faunal and floral productivity (Macan 1961, Wetzel 1983). Calcium is essential for development of molluscan shell, arthropod exoskeleton and vertebrate bone and is required for many metabolic processes including membrane transport. The exceptionally low calcium levels in the Victoria and Escarpment lakes may be close minimal limits for biological processes. Recently, iron has also been implicated as a major limiting nutrient for primary producers (Kerr 1994); iron levels in the three lakes surveyed were below detectable limits. Presumed deficiency of phosphates and nitrates which characterizes natural waters overlying igneous rocks will further constrain productivity. Lack of access to the lake by coho and sockeye salmon exclude a potentially major source of nutrients that are derived from the decomposition of post-reproductive carcasses.

There are also aspects of morphometry of Victoria and Escarpment lakes that limit productivity, including a steep shore gradient and narrow littoral zones (see bathymetry maps and hypsographic curves, Figures 7, 8, 16, 17, 26, 27). This constrains growth of littoral macrophytes and associated bottom fauna. Low shoreline development indices (see Tables 1, 6, 11) also indicate a simple perimeter with few wave protected shorelines where littoral communities may thrive.

While calcium and other elements are less common than expected for the respective conductivities in the Victoria and Escarpment lakes, sodium levels are elevated and this may be primarily due to the geography and geology of the lake basins. High precipitation rates which characterizes Gwaii Haanas will result in elevated sodium levels as this is the dominant cation in rainfall near marine waters (Wetzel 1982). There is also direct incursion of salt spray onto the watershed when autumn wind storms blanket the archipelago. Sodium levels might also be accentuated by run-off over the igneous rocks as these are comparatively rich in sodium (Sutherland Brown 1968).

Surface use of the lakes by aquatic birds was very limited during the survey period. In summer, dystrophic (blackwater) lakes on the northeastern region of the Queen Charlotte Islands contain congregations of up to 90 Common Loon, 19 Red-throated Loon, 50-100 Canada Goose and 100 Mallards (Reimchen and Douglas 1980, 1984). None of the three lakes examined in the present survey contained any notable concentrations of these species (Common Loon - maximum 4, Red-throated Loon - maximum 2, Canada Goose - maximum 10, Mallard - maximum 2). This certainly reflects the low abundance of fish for the loons and lack of littoral plant and invertebrate production for ducks and geese. Lutea Lake, immediately to the east of Upper Victoria Lake, is a small, shallow lake which has high abundance of both fish and primary producers. Conductivity was 2200μmhos cm^{-1} which comprised high levels of calcium and all other elements (Reimchen 1992a). During a brief survey to this lake in September, some 40 birds were observed on the surface including mergansers, mallards and goldeneye. As well, two otter foraged in the lake. This also supports the interpretation that the low levels of use at the Victoria Lakes is not a geographical effect but rather a result of low primary production. It remains likely however that the Victoria and Escarpment lakes may used extensively as shelter during the autumn and winter ocean storms. Fifteen Red-throated loon were observed on the lake in August 1977 (Reimchen 1992a). As well, the high incidence of parasitic cestodes in Gasterosteus in both Lower Victoria Lake and Escarpment Lake indicates that diving birds must be prevalent at sometime during the year as these cestodes complete their life cycle in the intestine of avian piscivores (Reimchen 1992a).

Although use of the lake surface by birds was uncommon in each of the localities, Escarpment Lake had remarkably high use of the forests adjacent to the lake by Marbled Murrelets as well as numerous passerines. The general level of murrelet activity was comparable to those observed at the headwaters of the Coates River drainage on western Graham Island, which had the highest activities recorded in a broad geographical survey of 40 lakes on Haida Gwaii (Reimchen 1991a). Estimated dawn counts of 200 detection are greater than the maximum counts recorded by Rodway et al. (1991) on Graham Island (maximum per dawn = 160) and by Kuletz et al. (1994) in old growth habitats in Alaska (maximum per dawn = 71). Presumably there are particular characteristics of the Escarpment drainage that are ideal for murrelets. When other watersheds in Gwaii Haanas are surveyed, it will be possible to identify relative murrelet abundance in terrestrial habitats and possibly ascertain the critical features of the old growth forests that are preferred by murrelets. Mid-July surveys in 1990 of Marbled Murrelets off the west coast of Gwaii Haanas, detected only low numbers of birds (1.6 bird km^{-1}). At Mike Inlet, adjacent to Escarpment Lake, no birds were observed in 1 km stretch (Lawrence, unpublished). This suggests that murrelets are coming from greater distances to the Escarpment watershed.

Endemism occurs in a diversity of taxa in Gwaii Haanas including bryophytes, angiosperms and vertebrates. Threespine stickleback, which are found in about ⅓ of Haida Gwaii lakes, exhibits some of the greatest differentiation of all species (Reimchen et al. 1985). A genetic relic is found on the northeastern corner of Graham Island which may persisted in a glacial refugium throughout much of the Pleistocene (O'Reilly et al. 1993). Two of the three lakes surveyed in the current biophysical had stickleback. Those in Lower Victoria Lake contained a partially plated small-bodied form that was intermediate between the marine ancestor and the typical freshwater stickleback, suggesting post-glacial origin. Stickleback from Escarpment Lake were exceptionally large bodied, equivalent to the giant stickleback from several localities on Graham Island (Reimchen 1991b). The most distinctive feature of female stickleback in this population was the exceptionally great body depth on gravid individuals, comprising 35 - 40% of standard body length. Typical depths are 20 - 25% of body length (Reimchen et al. 1985). This could represent either a defensive adaptation against gape-limited piscivores such as diving birds or possibly a means of maximizing fecundity (Reimchen 1991b). DNA analyses are currently underway to ascertain the phylogenetic history of these populations. Other potential candidates for endemism are invertebrates. Unfortunately, the taxonomy of most of the aquatic invertebrates in western North America is largely unknown. The invertebrate collections from these three lakes have been sent to different taxonomic experts for analyses.

Haida legends suggest that the land surrounding Upper Victoria Lake was the home of the 'Fresh-Water-Haidas' sometime in the distant past (Dalzell 1973). There were no obvious artifacts evident during the present surveys and the data cannot comment directly on the veracity of these legends. Lake shoreline is broad enough to allow ease of movement around the lake or possibly as an interior corridor between different coastal habitats. Land surrounding the lake may also have provided shelter from oceanic storms and protection during conflicts with other coastal peoples. It is questionable whether the land around the lake could have provided sustenance for even a small number of people. The watershed has only sparse forest with small trees, there are very low densities of berry bushes and the lake has a paucity of aquatic plants and low abundance of fish.