# Fishes of the Coastal Marine, Riverine and Lacustrine Waters of the Queen Charlotte Islands



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## Abstract

Some 315 species of fish probably occur in coastal marine waters (up to 55 km offshore) of the Queen Charlotte Islands, but no clear evidence of geographic isolation or endemism has been found in this assemblage. Nevertheless coastal fishes occupy a wide range in habitats including open ocean bathypelagic (depths down to nearly 3,000 m), mesopelagic and epipelagic zones. Benthic fishes are richest in species, especially those of subtidal and continental shelf areas. Effects on distribution of oceanic, tidal and fjord– estuarine circulation as well as seasonal influences are described.

In contrast, only 14 species of freshwater fishes are found in 229 Queen Charlotte Islands streams, 8 of these being salmonids with anadromous forms. Only 3 stream species (1 lamprey, 2 cottids) are restricted to freshwater. Relatively high salinity surrounding the Queen Charlotte Islands and lack of introduction by man results in lower species diversity than on Vancouver Island. Distinctive distribution patterns between the 3 physiographic regions are evident for several species, most notably cutthroat trout—widespread in Lowlands but largely absent from Ranges. At least 12 marine species penetrate into streams, especially in Lowlands. Impacts of man on stream fishes seem most severe for salmon. Many runs have declined sharply or have stopped in an increasing number of streams.

A further reduction in diversity to 8 species is evident in 183 Queen Charlotte Islands lakes sampled, which is about 80% of all lakes probably containing fish but is only a fraction of the many small (<1 ha), fishless bog waterbodies mainly in Lowlands. Threespine stickleback, the most widespread lacustrine fish (86 lakes), show great morphological variation in size, plates and spines, often between closely situated allopatric populations or even within a system between parapatric populations. This is interpreted as a response to local and contemporary selective pressures rather than evidence for relic populations in refugia. Beaver introduction by man probably has had the most significant impact on lake habitats and fishes.

## Introduction

Over recent decades a long series of biogeographers and specialists interested in endemism, refugia and evolutionary processes have found rich material in the Queen Charlotte Islands. Accordingly we already have well documented treatises or other publications which deal at length with these problems in vascular plants, bryophytes, marine amphipods, birds and mammals to mention only some of the major floral and faunal groups so studied on this fascinating archipelago. But despite the fact that observations and collections of fish began

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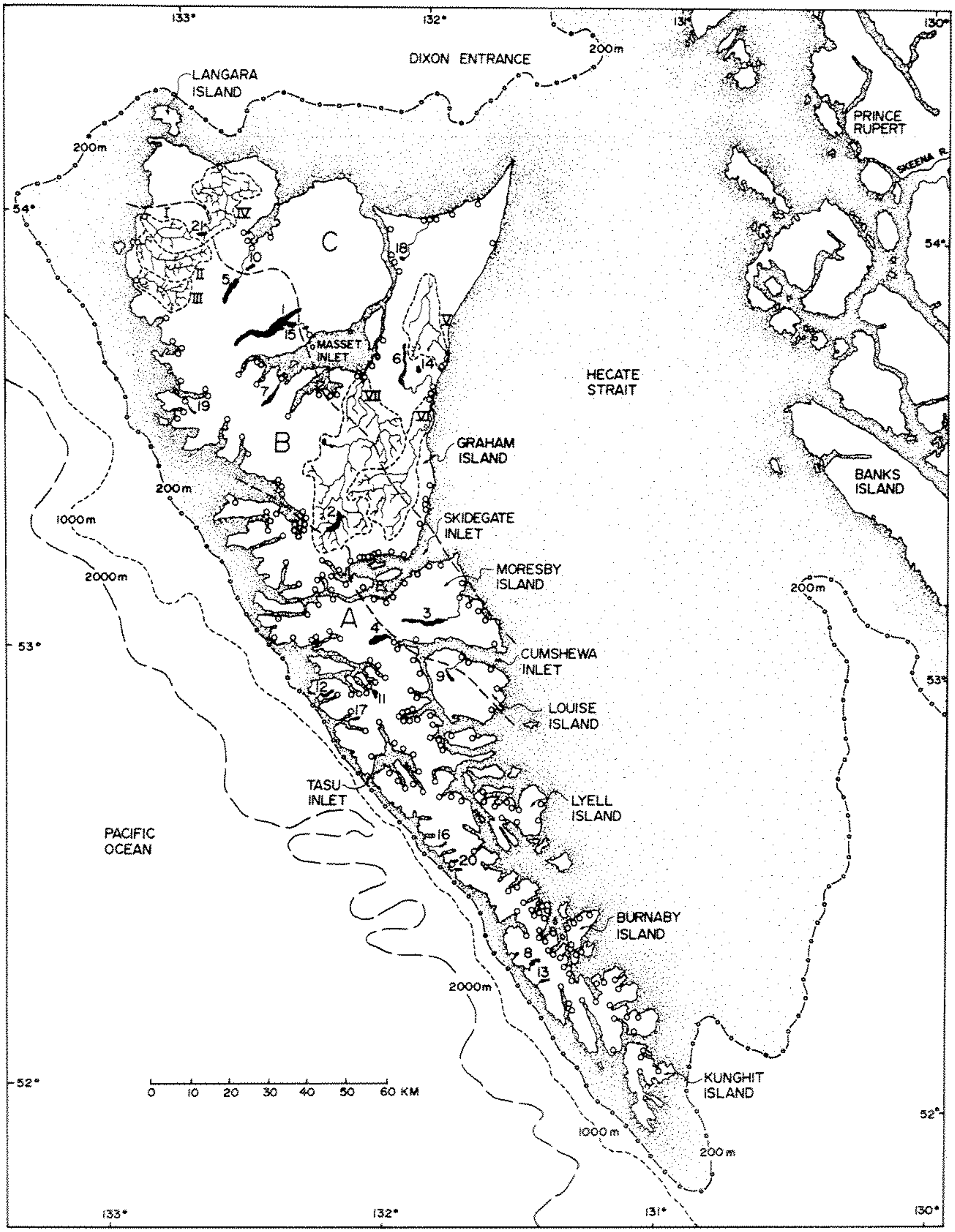


**Fig. 1.** Coastal marine waters (200, 1,000, 2,000 m depth contours), major physiographic regions, watersheds and lakes of the Queen Charlotte Islands. A) Queen Charlotte Ranges, B) Skidegate Plateau, C) Queen Charlotte Lowlands. Fourth order watersheds: I) Hana Koot, II) Haines, III) Cave, IV) Jalun, V) Cape Ball, VI) Tlell, VII) Yakoun. Lakes with surface area > 100 ha in descending size order: 1) Ian, 2) Yakoun, 3) Skidegate, 4) Mosquito, 5) Eden, 6) Mayer, 7) Awun, 8) Upper Victoria, 9) Mathers, 10) Marian, 11) Moresby, 12) Unnamed, 13) Lower Victoria, 14) Hickey, 15) Skundale, 16) Unnamed, 17) Unnamed, 18) Drizzle, 19) Mercer, 20) Unnamed, 21) Jalun. o = stream systems where salmon and/or other freshwater fish records are available.

in the latter half of the 19th century, about the same time as those for other groups, and that sporadic works have appeared on fishes of the region, it is only within the last 10 years or so that these important questions have been addressed in depth ichthyologically. Consequently for fishes the decision to hold an international symposium on the Queen Charlotte Islands was appropriate and timely.

In keeping with the overall objectives of the symposium, we were asked to provide an "up-to-date bench mark of the state of knowledge and of the interesting unanswered questions" on fishes of the region. We partitioned our efforts mainly into the three major aquatic habitats where each of us had focussed most of our attention (A.E. Peden, marine; T.G. Northcote, riverine; T.E. Reimchen, lacustrine) and which in many ways followed the development of ichthyological studies on the Islands—first coastal marine, then riverine and more recently lacustrine waters.

Within this tripartite format, we summarize relevant characteristics of these habitats before briefly reviewing the historical development of fish studies. Then we present the current information available on species distribution and note significant zoogeographical features. Where possible we also discuss ecological studies on the fishes as well as indicate the nature of man's impact on the stocks. Finally we suggest key problems and research possibilities for future fish studies in each of the habitats.

# Coastal Marine Waters

## General Characteristics

Because many studies relevant to marine fishes of the Queen Charlotte Islands also deal with other regions of the north Pacific Ocean, the following account must draw on inference from such work as well as on documented research specifically within the coastal waters. A 55 km zone around the Queen Charlotte Islands has been chosen as a convenient and appropriate area for defining "coastal" marine waters.

Within this zone, waters range from abyssal depths of nearly 3,000 m to shallow and rocky storm-tossed shores on the west coast, and include protected fjord habitats such as Skidegate, Cumshewa and Masset inlets, as well as shallow, sandy beaches on the northeast coast of Graham Island (Fig. 1). Accordingly, there exists within very short distances, fishes from a largely uninvestigated abyssal-benthic fauna, fishes inhabiting different strata of the continental slope, and fishes (some heavily exploited commercially) over the continental shelf. In addition there are also inshore fishes of the subtidal and intertidal zones and estuaries.

Recent summaries of marine life zones around the Queen Charlotte Islands (Anon., 1982) recognize: 1) a nearshore zone with sufficient light penetration to stimulate macrophyte production and where there is significant input of nutrients via run-off from adjacent land masses; 2) a continental shelf ecosystem in which the biota has direct contact with sun-lit waters through vertical migration or sedimentation of live and dead organisms from primary production above, and; 3) an offshore ecosystem that recycles carbon within the water column with very little energy derived from nearshore ecosystems.

Fishes may live in different habitats during various life stages (*e.g.* pelagic larvae vs. demersal adults) or may migrate temporarily into different zones. Furthermore, the definition of bottom-living vs. hovering just off the bottom is obscured in deep bottom trawls compared to direct visual observations possible for shallow-living species. Nevertheless it is obvious that the majority of marine fishes of the Queen Charlottes are those living near the bottom on the continental shelf, with large numbers of species also occurring in the subtidal region (Fig. 2, Tables 1-5). Pelagic-midwater species, even though inhabiting the largest volume of water, are fewer in number as are midwater forms living strictly inshore (Tables 3-5).

Midwater fishes associated with coastal influences over, and a short distance off, the continental shelf are frequently of economic importance (*e.g.* herring, hake), as are many of the transient oceanic species (*e.g.* tuna, salmon) that pass through the area by active migration or passive transport in oceanic currents. Relatively unstudied, and of less direct commercial value, are the mesopelagic and bathypelagic species west of the Queen Charlotte Islands, although these forms may enter the food web of salmonids as they undergo diel migration into surface waters. The depth range of 0-200 m has been ascribed to the epipelagic zone (Marshall, 1979) which coincidentally also provides the generally recognized inshore depth limit for the continental shelf. The mesopelagic or twilight zone is considered by Marshall to range from 200-1,000 m and is characterized by fishes which migrate vertically to plankton rich surface waters at night and retreat to the depths in daylight. In contrast to tropical areas, the northern latitudes of the Queen Charlotte Islands, with low incident light angles as well as high summer plankton production which further reduces light penetration, would seem to be characterized by a compression of these zones toward the sur-

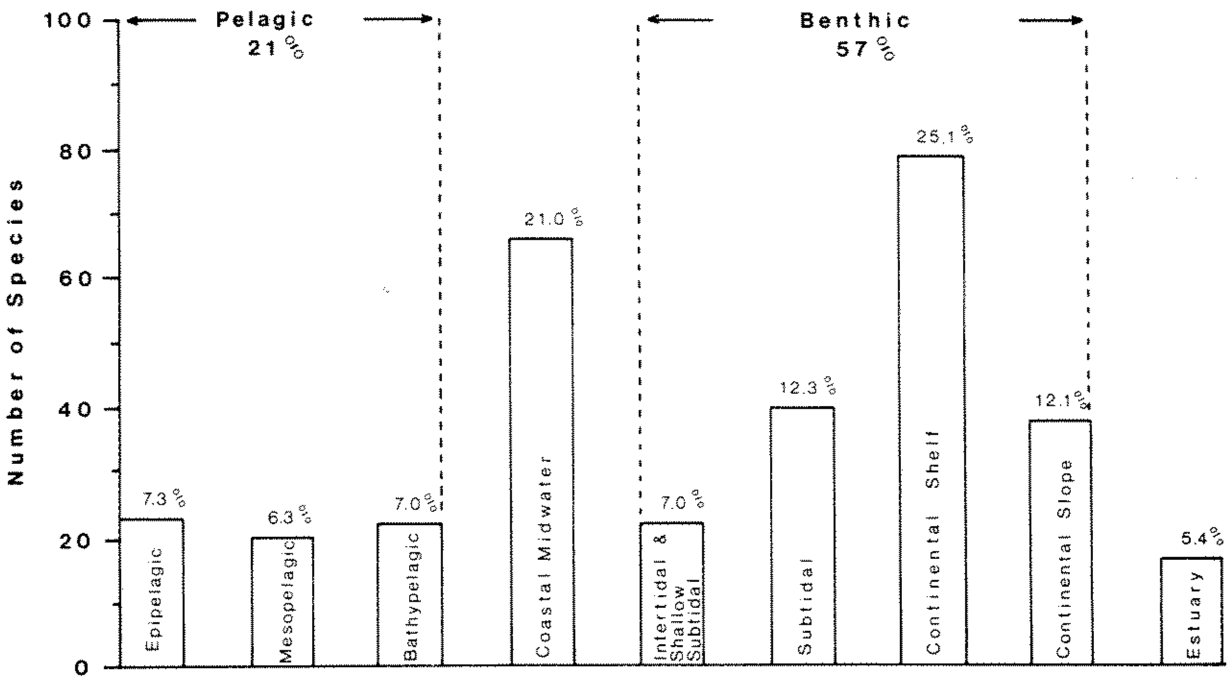


**Fig. 2.** Probable habitat distribution for 315 species of fishes expected to occur in coastal marine waters of the Queen Charlotte Islands. A few of the species shown occur in more than one habitat. Only juvenile and adult stages (not planktonic or postlarval stages) are represented. See text for further interpretative details (documented species list in prep. – A.E. Peden).

face. The epipelagic zone inhabited by fishes such as the salmonids or the saury is arbitrarily defined as being between 0-200 m. At these high latitudes, midwater trawl tows during daylight hours between 300-500 m catch many of the silvery myctophids known to undergo diel migration (*e.g. Stenobrachius leucopsarus, Diaphus theta, Protomyctophum thompsoni*; see Frost & McCrone, 1979; Peden *et al.*, 1985) and thus seem to indicate a recognizable mesopelagic zone. Catches at depths of 600 m or greater are dominated by fishes such as *Stenobrachius nannochir* which are jet black in colour and at least at Station Papa (50°N, 145°W) are not found abundantly in shallower water (Frost & McCrone, 1979). Depths greater than 600 m include black bathypelagic species, but several of them have been taken within a hundred meters of the surface at night (*e.g. Aristostomias scintillans, Bathophilus flemingi*) so they probably undergo diel migration into shallower waters. Midwaters below 1,000 meters are practically unexplored off the Queen Charlotte Islands. In this regard, it is important to note that an oxygen minimum layer of less than 1 ml/l occurs between 500 and 1,500 m in northeast Pacific waters (Favorite *et al.*, 1976), in contrast to the south Pacific and Atlantic oceans which have 3 to 5 ml/l at these depths (Sverdrup *et al.*, 1942). Fishes inhabiting this zone (*e.g. Cyclothone pacifica*) may have become adapted physiologically to low oxygen concentrations.

## Fish Collections and Studies

Records of marine fishes off the Queen Charlotte Islands were first brought to the attention of ichthyologists as early as the 1890s, especially after the collections of the U.S. research vessel *Albatross* (see Gilbert, 1895). However most systematic and distributional information has been derived from sporadic collecting of ichthyologists (Osgood, 1901) and the opportunistic discoveries resulting from economically and ecologically motivated investigations (Anon., 1982, 1983). Our data base for determining fish abundance and distribution is thus biased by the predominance of research relevant to commercial species and the associated choices of sampling gear. Because of the lack of comprehensive check lists that adequately document fishes for the area and the fact that many fishery field workers are untrained in identification of noneconomic species, accurate species records (quite apart from life history and ecological information) are incomplete for most marine fishes of the Queen Charlotte Islands.

Comprehensive summaries of literature relevant to coastal biological resources of the Queen Charlotte Islands have appeared recently (Anon., 1982, 1983). Of the numerous coastal and benthic fishes in the region (Anon., 1983) Pacific sand lance (*Ammodytes hexapterus*) is undoubtedly the most ubiquitous and ecologically important species with its larvae dominating the ichthyoplankton of northern Hecate Strait (Mason *et al.*, 1981a,b,c,d) and larger individuals being preyed upon by many fishes such as Pacific herring (*Clupea harengus*), Pacific salmon, Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), Pacific Ocean perch (*Sebastes alutus*), lingcod (*Ophiodon elongatus*), rock sole (*Lepidopsetta bilineata*) (Anon., 1983; Forrester, 1969; Jewitt, 1978; Claussen, 1981; Hart, 1949; Prakash, 1962) and by many coastal birds (Anon., 1983; Guiguet, 1972; Gabrielson & Lincoln, 1959; Ward, 1973; Sealy, 1975; Vermeer, 1979). Pacific herring have a similar dominance in the food of other commercial species but also direct economic value

**Table 1.** Number of fish species occupying benthic habitats as adults in coastal marine waters of the Queen Charlotte Islands (detailed documentation by species being prepared separately – A.E. Peden).

| | Habitat Categories | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | High Intertidal (exposed coast) | | Intertidal & Upper Subtidal (<10 m) | | Subtidal but enter Intertidal (esp. juveniles) | | Subtidal (0-30 m) | | Subtidal on Continental (C.) Shelf (0-200 m) | | Mostly Deeper on C. Shelf | | Lower C. Shelf & Upper C. Slope | | C. Slope & Deeper | | Total | |
| | D[a] | E[b] | D | E | D | E | D | E | D | E | D | E | D | E | D | E | D | E |
| Myxinidae | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 1 | 1 | 1 | 2 |
| Scyliorhinidae | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 1 |
| Rajidae | – | – | – | – | – | – | – | – | 2 | 2 | 2 | 3 | – | – | 2 | 2 | 6 | 7 |
| Chimaeridae | – | – | – | – | – | – | – | – | 1 | 1 | – | | – | – | – | – | 1 | 1 |
| Acipenseridae | – | – | – | – | – | – | – | – | – | – | – | 2 | – | – | – | – | – | 2 |
| Notacanthidae | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 1 |
| Moridae | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | 1 | 1 | 1 |
| Macrouridae | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 4 | 6 | 4 | 6 |
| Bythitidae | – | – | – | – | – | – | 1 | 1 | – | – | – | – | – | – | 1 | 1 | 2 | 2 |
| Oreosomatidae | – | – | – | – | – | – | – | – | – | – | – | – | 1 | 1 | – | – | 1 | 1 |
| Trichodontidae | – | – | – | – | – | – | 1 | 1 | – | – | – | – | – | – | – | – | 1 | 1 |
| Bathymasteridae | – | – | – | – | – | – | 1 | 1 | 1 | 1 | 1 | 1 | – | – | – | – | 3 | 3 |
| Stichaeidae | – | – | 4 | 4 | 1 | 1 | 4 | 4 | 1 | 1 | 2 | 4 | – | – | – | – | 12 | 14 |
| Pholididae | – | – | 2 | 2 | 1 | 1 | 1 | 1 | – | – | – | – | – | – | – | – | 4 | 4 |
| Anarhichadidae | – | – | – | – | – | – | – | – | 1 | 1 | – | – | – | – | – | – | 1 | 1 |
| Scytalinidae | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 1 | 1 |
| Ptilichthyidae[c] | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | 1 |
| Cryptacanthodidae | – | – | – | – | – | – | – | – | – | – | 1 | 2 | – | – | – | – | 1 | 2 |
| Ammodytidae[c] | – | – | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | 1 | 1 |
| Zoarcidae | – | – | – | – | – | – | – | – | – | – | 2 | 5 | – | 2 | 5 | 8 | 7 | 15 |
| Derepodichthyidae | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | 1 | 1 | 1 |
| Gobiedae | – | – | – | – | – | 1 | 1 | 1 | – | – | – | – | – | – | – | – | 1 | 2 |
| Scorpaenidae[d] | – | – | – | – | – | – | – | – | 5 | 5 | – | – | – | – | – | – | 5 | 5 |
| Hexagrammidae | – | – | – | – | – | – | 3 | 4 | 2 | 2 | – | – | – | – | – | – | 5 | 6 |
| Cottidae | 2 | 2 | 7 | 8 | 5 | 5 | 5 | 7 | 10 | 12 | 6 | 10 | – | – | 1 | 1 | 36 | 45 |
| Agonidae | – | – | 1 | 1 | – | – | 6 | 6 | 2 | 4 | 2 | 7 | – | – | – | – | 11 | 18 |
| Cyclopteridae | – | – | – | – | – | – | 1 | 1 | 1 | 1 | – | – | – | – | – | – | 2 | 2 |
| Liparididae | – | – | 4 | 4 | 1 | 1 | – | – | 2 | 4 | 2 | 2 | 1 | 1 | 3 | 6 | 13 | 18 |
| Bothidae | – | – | – | – | 1 | 1 | – | – | 1 | 1 | – | – | – | – | – | – | 2 | 2 |
| Pleuronectidae | – | – | – | – | – | – | – | – | 5 | 5 | 6 | 6 | 3 | 4 | 1 | 1 | 15 | 16 |
| Batrachoididae | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | 1 |
| Gobiesocidae | – | – | – | – | 2 | 2 | – | – | – | – | – | – | – | – | – | – | 2 | 2 |
| Total | 2 | 2 | 19 | 20 | 12 | 13 | 24 | 27 | 34 | 42 | 24 | 43 | 5 | 9 | 20 | 29 | 140 | 185 |
| % undocumented | 0 | | 5.0 | | 7.7 | | 11.1 | | 19.5 | | 44.2 | | 44.4 | | 31.0 | | 24.3 | |

a D = Documented species.
b E = Total expected species.
c Species reputed to bury in substrate and swim in midwater as adults.
d Some species may hover well off the bottom (see Table 2).

**Table 2.** Number (#) of fish species occupying non-benthic habitats in coastal marine waters of the Queen Charlotte Islands. (Fully documented list in preparation – A.E. Peden).

| Family | Mainly Summer Visitor | | Predominantly Oregonian[a] | | Predominantly Aleutian[b] | | Total | |
|---|---|---|---|---|---|---|---|---|
| | # of Sp. Documented | # of Sp. Expected | # of Sp. Documented | # of Sp. Expected | # of Sp. Documented | # of Sp. Expected | # of Sp. Documented | # of Sp. Expected |
| Petromyzontidae | – | – | 1 | 1 | – | 1 | 1 | 2 |
| Hexanchidae | – | – | – | 2 | – | – | – | 2 |
| Carcharhinidae | – | 1 | – | – | – | – | – | 1 |
| Squalidae | – | – | 1 | 1 | – | – | 1 | 1 |
| Cetorhinidae | – | – | – | 1 | – | – | – | 1 |
| Clupeidae | 1 | 1 | – | – | 1 | 1 | 2 | 2 |
| Engraulidae | – | – | 1 | 1 | – | – | 1 | 1 |
| Salmonidae | – | – | 2 | 2 | – | – | 2 | 2 |
| Osmeridae | – | – | 1 | 2 | 2 | 4 | 3 | 6 |
| Bathylagidae | – | – | – | – | 1 | 1 | 1 | 1 |
| Gadidae | – | – | – | – | 3 | 3 | 3 | 3 |
| Merluciidae | – | – | – | – | 1 | 1 | 1 | 1 |
| Gasterosteidae | – | – | – | – | 1 | 1 | 1 | 1 |
| Syngnathidae | – | – | 1 | 1 | – | – | 1 | 1 |
| Aulorhynchidae | – | – | 1 | 1 | – | – | 1 | 1 |
| Ptilichthyidae[c] | – | – | – | – | – | 1 | – | 1 |
| Zoarcidae | – | – | 1 | 1 | – | – | 1 | 1 |
| Zaproridae | – | – | – | – | 1 | 1 | 1 | 1 |
| Ammodytidae[c] | – | – | – | – | 1 | 1 | 1 | 1 |
| Sciaenidae | – | 1 | – | – | – | – | – | 1 |
| Scombridae | – | 1 | – | – | – | – | – | 1 |
| Embiotocidae | – | – | 3 | 4 | – | – | 3 | 4 |
| Sphyraenidae | – | 1 | – | – | – | – | – | 1 |
| Scorpaenidae[d] | – | – | 13 | 16 | 9 | 10 | 22 | 26 |
| Anoplopomatidae | – | – | – | – | 1 | 1 | 1 | 1 |
| Liparididae | – | – | 1 | 2 | – | – | 1 | 2 |
| Total | 1 | 5 | 26 | 35 | 21 | 26 | 48 | 66 |

a "Oregonian Province" species range extensively into California.
b "Aleutian Province" species range extensively into Aleutian Islands and Bering Sea.
c Adults may occur in midwater or bury in substrate.
d Some species may be closely tied to the bottom.

where they are harvested after their migration to spawning beds at Naden Harbour, Skidegate Inlet, Cumshewa and Selwyn Inlets, Darwin Sound and Skincuttle Inlet (Hourston & Haegele, 1980; Anon., 1983). Other important fishery areas include the shallow trawling grounds east of Graham and northern Morseby Islands where rock sole, English sole (*Parophrys vetulus*), and butter sole (*Isopsetta isolepis*) are caught (Ketchen, 1956; Forrester, 1969). In deeper shelf waters east of Moresby Island, Pacific cod are caught (Forrester, 1969). Commercially important rockfish, especially Pacific Ocean perch are found west of Dixon Entrance, the Queen Charlotte Islands, and in Queen Charlotte Sound near the deeper margins of the continental shelf (Smith, 1980, Nagtegaal *et al.*, 1980) although other important rockfishes of shallower depths (*e.g.* yellowtail rockfish, *Sebastes flavidus*) school inside Dixon Entrance and Hecate Strait (Taylor & Kieser, 1980; Barner *et al.*, 1980). Of all groundfish, halibut (*Hippoglossus stenolepis*) is commercially most valuable (Bell & St. Pierre, 1970) and extensive explorations by the International Pacific Halibut Commission have resulted in significant ichthyological collections around the Queen Charlotte Islands (Chapman, 1939, 1940) with noteworthy collections at the California Academy of Sciences and U.S. National Museum. Similarly, surveys of economicaly valuable rockfish and Pacific herring near the Queen Charlotte Islands by the Canadian Pacific Biological Station produced many important collections housed at the National Museum of Canada, the University of British Columbia and the British Columbia Provincial Museum (Peden, 1970, 1973; Taylor, 1967; Westerheim, 1968; Westerheim, *et al.*, 1967). Recent exploration and development of the sablefish (*Anoplopoma fimbria*) industry (Anon., 1983; Stockner, 1981) resulted in the capture of rare deep-sea fish west of the Queen Charlotte Islands (Peden & Ostermann, 1981; Peden, unpub.). Although food chains and community structure for coastal marine fish of the Queen Charlotte Islands are outlined (Anon., 1983; South Moresby Resource Planning Team, 1983) no detailed studies are available to link fish species with the many varied coastal marine habitats of the region.

In this section, emphasis is given to distributional barriers, endemism, and associated features which influence the distinct habitats and biota of the Queen Charlotte Islands. Most marine animals and plants have open dispersal routes from adjacent areas with even sedentary fauna usually possessing mobile larvae that readily can be transported into the region via oceanic currents. Therefore, any regional uniqueness in the coastal marine fishes probably involves racial clines and morphological variation due to selective influences of local conditions, and abilities of the animals to seek out special habitats. North-to-south, inshore (estuarine)-to-offshore (oceanic), and shallow-to-deepwater transitions of faunal assemblages and conspecific variation would seem to be the most relevant phenomena to explore, although localized geological features of the substrate also may modify distributional patterns.

## Ocean Circulation Effects on Fish Distribution

Oceanic waters off the Queen Charlotte Islands are part of the Subarctic Domain (Favorite *et al.*, 1976), but surface layers near the coast are diluted by terrestrial runoff and altered seasonally by precipitation, wind effects, and solar radiation. While across the north Pacific, pelagic organisms of the Subarctic Domain are subject to the meanderings of ocean currents, there is a general eastward flow of the Central Subarctic Domain at about 50°N latitude that branches off Vancouver Island, with its northern portion flowing past the Queen Charlotte Islands into the Gulf of Alaska. The dominant oceanic fishes off the Queen Charlotte Islands are typically distributed within this subarctic water mass (Tables 3-5). The subarctic current system north of this zone reputed-

**Table 3.** Epipelagic fish species expected to occupy coastal marine waters of the Queen Charlotte Islands. + = present, – = absent. (Detailed documentation being prepared separately – A.E. Peden).

| Species | Species Recorded Within 55 km of Shoreline | Family | Subarctic Domain | California Current |
|---|---|---|---|---|
| *Lamna ditropis* | + | Lamnidae | + | – |
| *Carcharodon carcharias* | + | Lamnidae | – | Summer only |
| *Prionace glauca* | + | Carcharhinidae | – | Summer only |
| *Oncorhynchus gorbuscha* | + | Salmonidae | + | + |
| *O. kisutch* | + | Salmonidae | + | + |
| *O. keta* | + | Salmonidae | + | + |
| *O. nerka* | + | Salmonidae | + | + |
| *O. tshawytscha* | + | Salmonidae | + | + |
| *Salmo gairdneri* | + | Salmonidae | + | + |
| *Anotopterus pharao* | + | Anotopteridae | + | + |
| *Cololabis saira* | + | Scomberesocidae | + | + |
| *Alepisaurus ferox* | + | Alepisauridae | + | + |
| *Allocyttus folletti* | – | Oreosomatidae | + | + |
| *A. folletti* (young) | – | Oreosomatidae | – | + |
| *Lampris regius* | – | Lampridae | – | Summer only |
| *Trachurus symmetricus* | + | Carangidae | – | Summer only |
| *Brama japonica* | – | Bramidae | – | Summer only |
| *Pentaceros richardsoni* | – | Pentacerotidae | + | + |
| *Scomber japonicus* | – | Scombridae | – | Summer only |
| *Thunnus alalunga* | – | Scombridae | – | Summer only |
| *T. thynnus* | – | Scombridae | – | Summer only |
| *Icichthys lockingtoni* | – | Centrolophidae | + | + |
| *Erilepis zonifer* (young) | + | Anoplopomatidae | + | + |
| *Mola mola* | – | Molidae | – | Summer only |

**Table 4.** Mesopelagic fish species expected to occupy coastal marine waters of the Queen Charlotte Islands. + = present, – = absent. (Detailed documentation being prepared separately – A.E. Peden).

| Species | Species Recorded Within 55 km of Shoreline | Family | Subarctic Domain | California Current |
|---|---|---|---|---|
| *Nemichthys scolopaceus* | – | Nemichthyidae | – | + |
| *Bathylagus ochotensis* | + | Bathylagidae | + | + |
| *Dolichopteryx* sp. | – | Opisthoproctidae | + | – |
| *Nansenia candida* | – | Argentinidae | – | + |
| *Cyclothone signata* | – | Gonostomatidae | – | + |
| *Chauliodus macouni* | + | Chauliodontidae | + | + |
| *Lestidium ringens* | + | Paralepidae | + | + |
| *Paralepis atlantica* | – | Paralepidae | + | + |
| *Notolepis rissoi* | – | Paralepidae | – | + |
| *Scopelosaurus harryi* | + | Scopelosauridae | + | + |
| *Diaphus theta* | + | Myctophidae | + | + |
| *Protomyctophum thompsoni* | + | Myctophidae | + | – |
| *Symbolophorus californiense* | – | Myctophidae | – | + |
| *Stenobrachius leucopsarus* | + | Myctophidae | + | + |
| *Tarletonbeania taylori* | + | Myctophidae | + | – |
| *Tarletonbeania crenularis* | – | Myctophidae | – | + |
| *Trachipterus altivelis* | – | Trachipteridae | – | + |
| *Taractes asper* | – | Bramidae | + | – |
| *Caristius macropus* | – | Caristiidae | + | + |
| *Icosteus aenigmaticus* | + | Icosteidae | + | + |

**Table 5.** Bathypelagic fish species expected to occupy coastal marine waters of the Queen Charlotte Islands. + = present, – = absent. (Detailed documentation being prepared separately – A.E. Peden).

| Species | Species Recorded Within 55 km of Shoreline | Family | Subarctic Domain | California Current |
|---|---|---|---|---|
| *Serrivomer jesperseni* | + | Serrivomeridae | – | + |
| *Avocettina infans* | – | Nemichthyidae | + | + |
| *Holtbyrnia macrops* | – | Searsidae | + | + |
| *Sagamichthys abei* | – | Searsidae | – | + |
| *Bathylagus milleri* | + | Bathylagidae | + | + |
| *B. pacificus* | + | Bathylagidae | + | + |
| *Macropinna microstoma* | – | Opisthoproctidae | + | + |
| *Cyclothone pacifica* | + | Gonostomatidae | + | + |
| *Aristostomias scintillans* | + | Malacosteidae | + | + |
| *Bathophilus flemingi* | – | Melanostomiatidae | – | + |
| *Tactostoma macropus* | + | Melanostomiatidae | + | + |
| *Benthalbella dentata* | + | Scopelarchidae | + | + |
| *Lampanyctus regalis* | – | Myctophidae | + | + |
| *L. ritteri* | + | Myctophidae | – | + |
| *Stenobrachius nannochir* | – | Myctophidae | + | + |
| *Oneirodes thompsoni* | – | Oneirodidae | + | + |
| *O. bulbosus* | – | Oneirodidae | + | + |
| *Chaenophryne* sp. | – | Oneirodidae | – | + |
| *Melamphaes lugubris* | – | Melamphaeidae | + | + |
| *Poromitra crassiceps* | – | Melamphaeidae | + | + |
| *Coryphaenoides acrolepis* | – | Macrouridae | + | + |
| *Tetragonurus cuvieri* | – | Tetragonuridae | + | + |

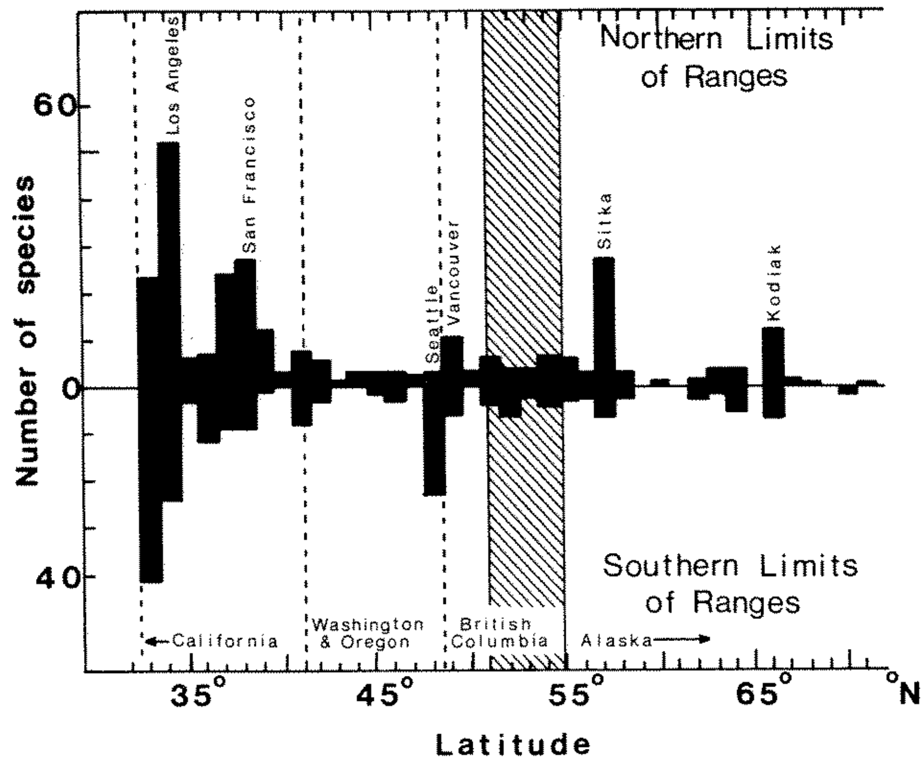


**Fig. 3.** Frequency of northern and southern limits of known geographic ranges of coastal and benthic fish species inhabiting continental shelf waters (<200 m deep) along the west coast of North America; Queen Charlotte Island waters indicated by cross-hatching. Data and methods from Peden and Wilson (1977), updated to include recent records and information. Latitude increments above 60°N distorted to accommodate E-W coastal orientation.

ly has transported western Pacific fishes such as *Ichthyococcus elongatus* as strays to the American coast and Queen Charlotte Islands (Mukhacheva, 1980). The southern portion of the Subarctic Domain flows southward and offshore toward California and then is incorportated into a northward flowing California current system along the coast. This current can have varying effects near the Queen Charlotte Islands and may disperse into this region fishes whose centers of abundance are farther south (Tables 2-5). The California current periodically can be warmed at the surface as happened in the recent year of El Niño (1983).

Seasonal changes occur at the surface by wind action. For example, summer northwesterlies may produce offshore flow and upwelling off Vancouver Island or Oregon to block the northward flow of the California surface current to British Columbia. Also winter southeasterlies may push diluted and relatively warm water northward against the coast. There have not been enough longterm studies on the many non-economic oceanic fishes to describe overall impacts of these seasonal effects on fish communities but during November 1983 the mesopelagic fishes, *Protomyctophum crockeri, Danaphos oculatus* and *Cyclothone signata,* were captured off Vancouver Island. As these species are common in the California current and rarely are reported off Canada, it would seem that during this time of El Niño such records could have extended into the Queen Charlotte region if appropriate sampling had been undertaken. Oceanic vagueries of current obviously would have similar effects on the dispersal of planktonic larvae of some benthic fishes that have very prolonged larval stages (*Hemilepidotus* sp., *Hexagrammo* ssp.) and are found as far offshore as Station Papa (50°N, 145°W – Peden *et al.*, 1985). Only recently have major studies been conducted on offshore larval distributions and dispersal in coastal British Columbia waters (Mason *et al.*, 1981a,b,c,d).

Large oceanic fishes that can migrate independently of current systems (*e.g.* pomfret, *Brama japonica*; albacore, *Thunnus alalunga*; and blue shark, *Prionace glauca*), are probably frequent summer offshore visitors to the Queen Charlotte region but they retreat southward with cooling winter temperatures (Neave & Hanavan, 1960). The northward movement of tunas and pomfrets in summer as offshore water temperatures rise above 10 to 12°C is complemented by a retreat of salmonids towards cooler waters near the Aleutian Islands and Bering Sea. Inshore however, tidal mixing and upwelling can produce cooler summer temperatures (*e.g.* at

Dixon Entrance – Dodimead, 1980) and probably restrict inshore occurrences of these summer visitors. In addition the summer migrations of salmonids through the area to southern spawning areas distort their trend to prefer waters north of the 10-12°C isotherm across the north Pacific.

## North-South Distribution

The diverging oceanic influence of the southern California current and northward flowing Alaskan current past the Queen Charlotte Islands provides a rationale for recognizing two distinct inshore faunal regions, especially since the planktonic fish larvae characteristic of most inshore fish species can be dispersed by these current systems. Within the Northern Boreal Fauna, which correlates broadly with the Subarctic Domain (Favorite *et al.*, 1976) from Point Conception in California to the Aleutian Islands, Briggs (1974) utilized invertebrate data (Valentine, 1966) to distinguish characteristic northern and southern faunal assemblages (Aleutian and Oregonian provinces, respectively). The sharpest transition between these assemblages occurred at Dixon Entrance. Although this suggests that the Queen Charlotte Islands would be in the northern limit of the Oregonian Province, Peden and Wilson (1977) showed that similar transitions for fishes were sharpest near the Strait of Juan de Fuca and Sitka, Alaska (Fig. 3). At the racial (subspecies) level, morphological clines may be pronounced in the Queen Charlotte Islands area as observed in rock sole (Wilimovsky *et al.*, 1967) suggesting sharp north to south habitat change near Dixon Entrance. Such transitions seem to be complicated by: 1) the mobility of adult fishes, especially midwater species; 2) the lack of comprehensive fish surveys along the entire coastline; and 3) the modifying effect of fjords which promote greater tidal mixing. Mixing modifies water temperatures and salinities and probably explains the tendency for southern species to be distributed farther northward on exposed outside waters than in diluted and glacial-fed fjords with their characteristic estuarine circulation (Peden, unpub.). In addition, analysis of geographic ranges such as that of Valentine's utilizes limits of known ranges, whereas many peripheral records in areas of transition may be based on expatriates or strays with little reproductive impact. Within this framework, Dixon Entrance appears to be significantly cooler than more southern areas because of the tidal mixing with Portland Inlet water which has significantly cooler deep bottom waters than other British Columbia inlets (Pickard, 1961). Many northern species such as *Nautichthys robustus*, *Chirolophis tarsodes*, *Myoxocephalus* sp. (Peden, 1970; Peden & Wilson, 1977) and *Stichaeus punctatus* reach their southern known limits near Dixon Entrance, whereas other southern forms such as *Coryphopterus nicholsi*, *Oxylebius pictus* and *Chitonotus pugetensis* are known to barely reach this far north.

## Fjord-Estuarine Circulation and Fish Distribution

Except for Masset Inlet, most other fjords of the Queen Charlotte Islands are small and more freely connected to oceanic water than are many major inlets along the coastal mainland of British Columbia. Coastal fishes, especially their pelagic larvae and midwater forms, have a more transitory existence in contrast to those permanently inhabiting inlets of the mainland coast (Peden, 1981). Similar interactions between inlet circulation and fish distribution may be expected in some river-fed inlets of the Queen Charlotte Islands.

Fjord environments and associated deep faunas are affected by the tidal mixing process, the amount of freshwater entering the inlet, and the depth of the sill. Accordingly, contrasting faunas should be encountered in deep-silled inlets such as Tasu which allow entrance of more oceanic water, compared to shallow-silled inlets such as Masset with extensive brackish habitat. Although collections from Queen Charlotte inlets are inadequate to test this possibility, some studies are suggestive of expected trends. Stockner and Levings (1982) report about 20 fish species from the Yakoun River estuary and adjacent Masset Inlet area. Although their fish sampling was ancillary to other objectives and not extensive enough to override the distortion of numbers in schooling species, it does point to the dominance of salmonids and the freshwater-tolerant *Leptocottus armatus*. Peden (unpub.) found a much richer fauna (38 species) at similar depths near the entrance of Tasu Inlet.

As for the possibility that distinct genetic stocks of marine fishes characterize different inlet systems of the Queen Charlottes, again too little information is available for the region. Studies of littoral fishes such as *Anoplarchus* (Yoshiyama & Sassaman, 1983; Sassaman & Yoshiyama, 1979; Sassaman *et al.*, 1983) suggest that changes of allele frequencies may depend on habitat exposure. Midwater inlet inhabitants appear to be less differentiated, especially those fishes studied by Peden (1981) (*Nectoliparis pelagicus*, *Lipariscus nanus*, *Lycodapus mandibularis*, *Lycodes diapterus*) which showed meristic differences between large isolated mainland inlets such as Georgia Strait and offshore waters. However, Queen Charlotte inlets are rarely deeper than 200 m so they may not accommodate such deep-dwelling inhabitants.

# Rivers and Streams

## General Characteristics

The Queen Charlotte Islands are divisible into three major physiographic regions (Ranges, Skidegate Plateau and Lowlands, Fig. 1) whose topographic, climatic and hydrographic differences must markedly affect stream ecosystem functioning and associated fish faunas. Over 60% of some 419 Queen Charlotte Islands rivers and streams drain the Ranges either to the open Pacific or to Hecate Strait (Table 6). Because of the steep, highly irregular topography and relatively long, convoluted shoreline of this physiographic region (Fig. 1), it is not surprising that two-thirds of its streams are of the first order (Strahler, 1957), draining small unbranched watersheds (Fig. 4). Indeed the Ranges contain only 5 small third order and no fourth order watersheds (Fig. 1). With such a high preponderance of first and second order watersheds, streams in the Ranges region must be largely dependant upon energy inputs from riparian vegetation (Cummins, 1974; Vannote *et al.*, 1980).

The Skidegate Plateau, although a little larger than the other two physiographic regions, drains less than a quarter of the Queen Charlotte Islands streams to the ocean (Table 6), in part a result of its relatively short coastline. Copper Creek, the largest watershed (165 km) almost entirely within the Plateau, also includes one of the largest lakes on the Islands, Skidegate. Thirteen third order and three fourth order watersheds (Hains, Cave, and Hana Koot, Fig. 1) are located in the Plateau region and in these systems autochthonous-based (within stream) primary production should contribute significantly to energy inputs.

**Table 6.** Physiographic regions[a] and rivers[b] of the Queen Charlotte Islands[c].

| Region | Area ($km^2$) | Coastline (km) | Rivers (number) | Rivers (%) |
|---|---|---|---|---|
| Q.C. Ranges | 3,017 | 1,760 | 252 | 60.2 |
| Skidegate Plateau | 3,654 | 633 | 99 | 23.6 |
| Q.C. Lowlands | 3,274 | 614 | 68 | 16.2 |
| Total | 9,945 | 3,007 | 419 | 100.0 |

a According to Sutherland Brown (1968).
b All river, stream and creek systems entering the coast.
c Based on 1:50,000 National Topographic System maps.

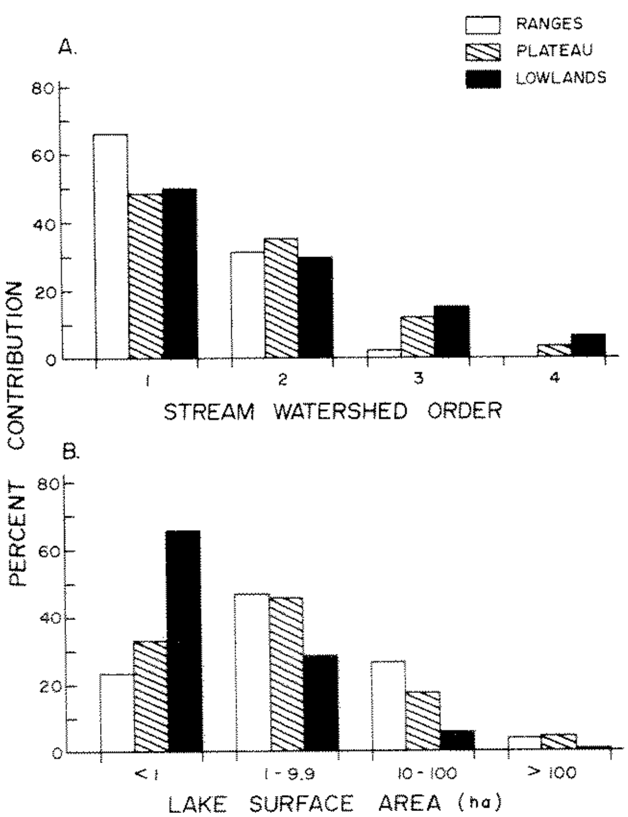


**Fig. 4.** Relative contribution of stream watershed orders (A) and lake surface areas (B) for the physiographic regions of the Queen Charlotte Islands. Based on 1:50,000 NTS maps.

Most of the larger streams and rivers draining through the Lowlands into Hecate Strait or Dixon Entrance arise in the Skidegate Plateau. For example the Yakoun River, the largest system on the Islands, flows through the Lowlands to enter Dixon Entrance via Masset Inlet (Fig. 1), but has about three-quarters of its 522 km watershed in the Skidegate Plateau. Compared to the Ranges and Plateau regions, the Lowlands has fewer rivers but relatively more larger ones (Table 6, Fig. 1), including four fourth order watersheds (Yakoun, Tlell, Cape Ball and Jalun). Bedrock joints and faults clearly control the rectangular or trellised drainage patterns in some areas such as the Jalun River and Beresford Creek headwaters (Alley & Thomson, 1978) whereas low relief areas such as the northeastern outwash plain have highly meandering channels. Although lower reaches of the larger Lowland streams (third and fourth order) might be expected to have considerable contributions of primary production from internal sources (periphyton and macrophytes), their highly brown-stained waters (Fig. 6) must severely limit these inputs.

Some morphometric features of 229 Queen Charlotte streams with recorded information on fish (over half of those in each physiographic region) are shown in Fig. 5. Not surprisingly most fish streams in the Ranges have small drainages, short mainstem lengths, and often waterfalls close to their mouths preventing upstream access to salmonids. Although not quantified, average gradients of Ranges fish streams would be greater than many Plateau and almost all Lowlands streams. Over 45% of Plateau fish streams also have small watersheds and short mainstem lengths, but there are many (more than 20%) with large watersheds and accessible lengths of 5 km or greater. The majority of Lowlands fish streams drain large watersheds and many have mainstem as well as accessible lengths exceeding 20 km.

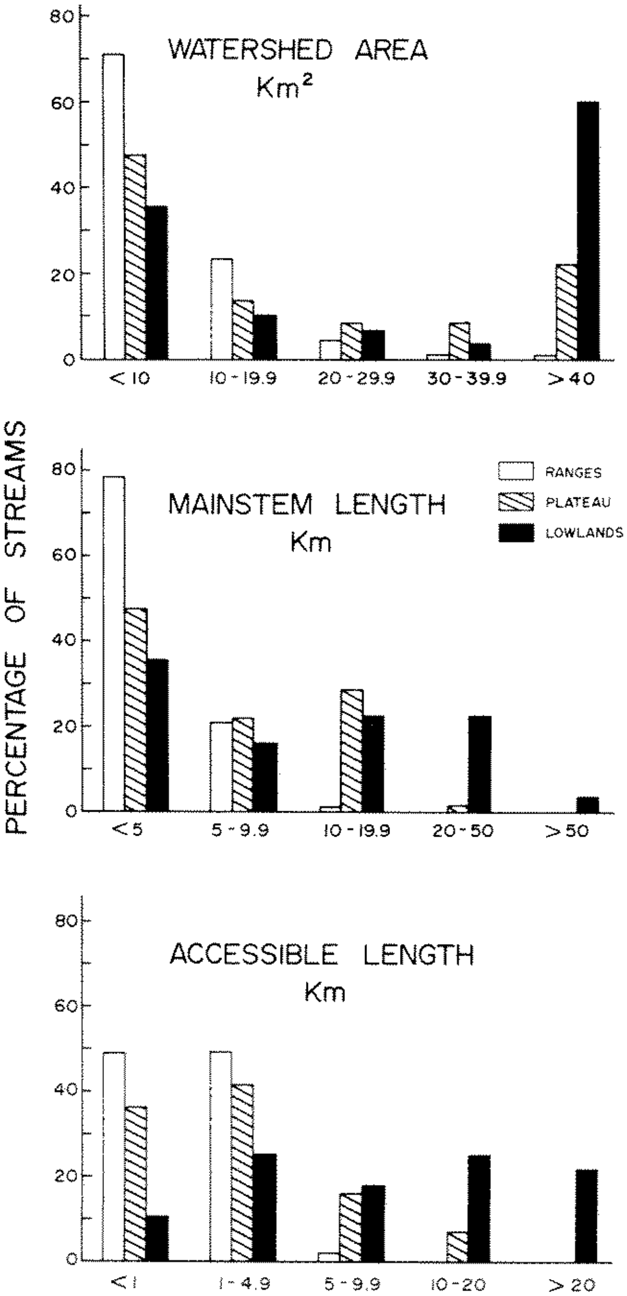


**Fig. 5.** Morphometric characteristics of fish streams in the physiographic regions of the Queen Charlotte Islands. Accessible length refers to upstream salmonid migrants.

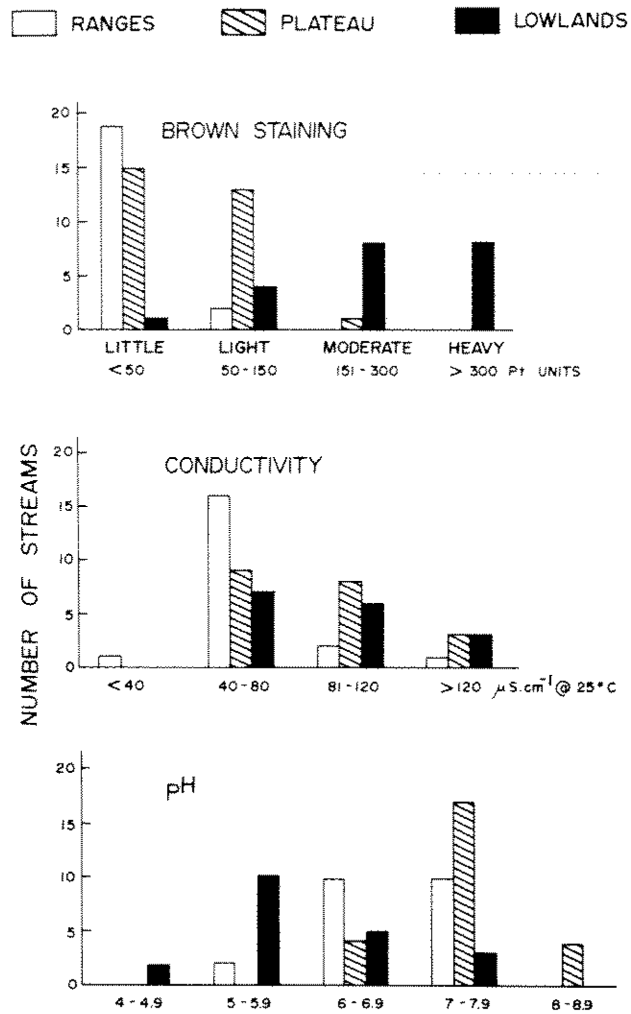


**Fig. 6.** Staining, conductivity and pH characteristics of fish streams in the physiographic regions of the Queen Charlotte Islands. Values for pH averaged where several available for a stream.

Seasonal hydrographs are available for one stream in each physiographic region (Fig. 7), but two of them (Pallant, and Yakoun) contain large lakes which would moderate flows. Monthly means for daily discharge clearly are highest for each of the streams in late autumn, decrease slightly during winter, and then decline gradually to midsummer lows. From September to at least April wide extremes may be expected especially in daily maximum discharge which may range from about 3 to more than 6 times the monthly average (Fig. 7). Streams without sizeable lakes in their watersheds, particularly those on the western side of the Ranges, no doubt would show even greater disparity between mean and maximum discharges. Only during late spring and summer is the extreme variability in discharge of Queen Charlotte streams dampened, and even then surprisingly high flows may occur during violent rainstorms, especially on the steep watersheds of the Ranges and Plateau regions.

Extensive series of water temperatures are available only for two streams (Fig. 7) and again each is influenced by a large low-lying mainstem lake (Mosquito Lake for Pallant Creek and Mathers Lake for Mathers Creek). Winter temperatures of these streams range from slightly below 1 to about 5°C, and summer temperatures from about 10 to as high as 22°C. Pallant Creek has a much higher summer temperature regime than is characteristic of most other Ranges streams which in midsummer fluctuate between about 8 and 15°C (Fig. 7).

Water quality characteristics (brown staining, conductivity and pH) are available for about 20 fish streams in each physiographic region of the Charlottes (Fig. 6). Streams in the Ranges and Plateau regions are relatively clear compared to most of those in the Lowlands which are moderately to heavily brown-stained, some

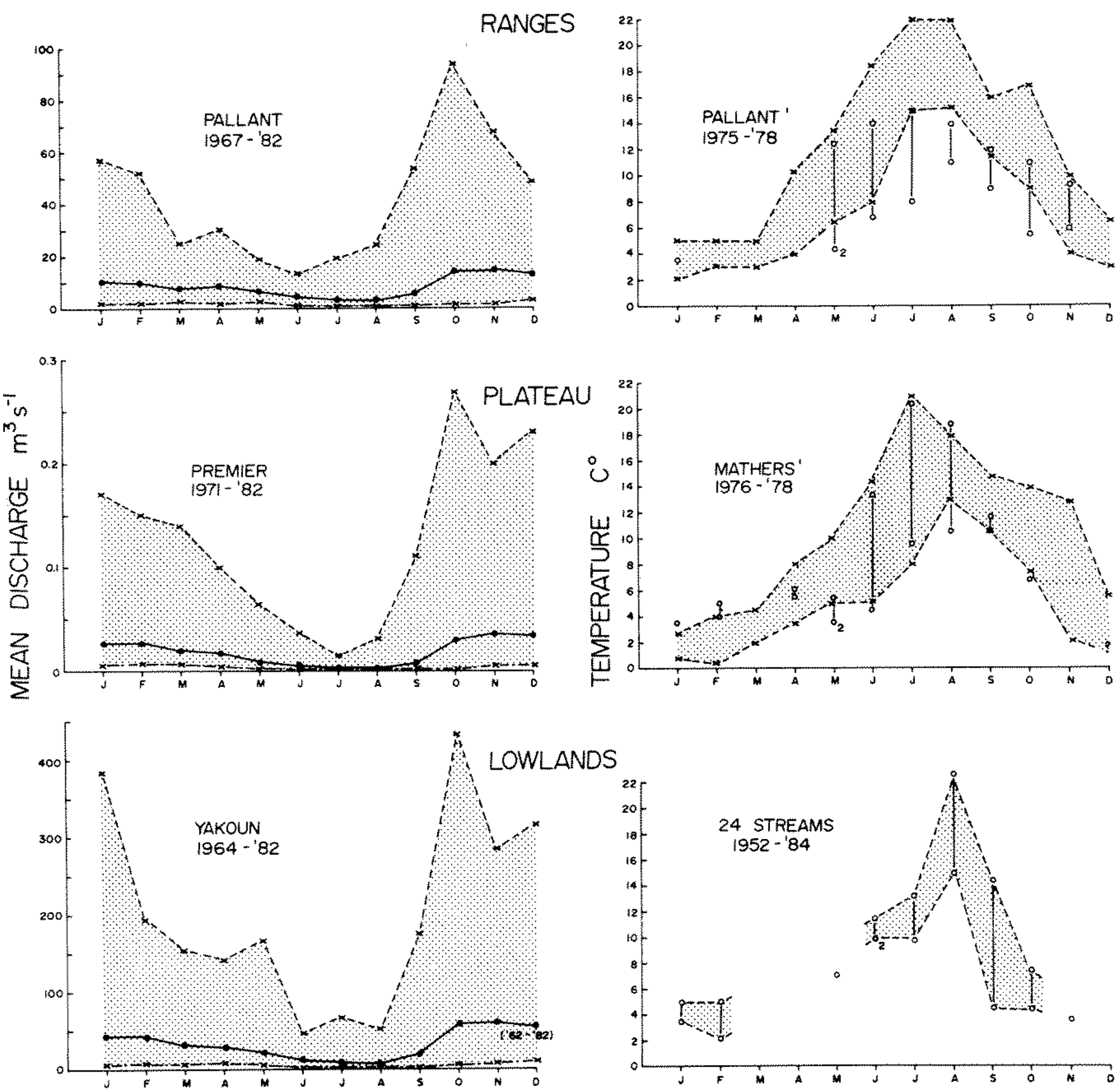


**Fig. 7.** Water discharge and temperature characteristics for streams in the physiographic regions of the Queen Charlotte Islands. Discharge: ● = monthly mean of the daily mean discharges, X = monthly extremes for the daily mean discharges (Water Survey of Canada records). Temperature: X = monthly extremes for daily maximum and minimum; data from Shepherd (1978, 1982); **o—o** gives minimum and maximum spot readings for several different streams within the region.

reaching Pt units of 400 or more (*e.g.* Kumdis and Hiellen). Most Ranges streams have relatively low conductivity (<80 μS • $cm^{-1}$) whereas many of those in the other two regions have values above 80 μS • $cm^{-1}$. Lowland streams are mostly acidic, some with pHs below 5. Those in the Ranges are mostly in the 6-7 range whereas those in the Plateau tend to be slightly higher with a few above pH 8 (Fig. 6).

## Fish Collections and Studies

Although Dawson (1880) suggests it is possible that the Spaniard de Fonte reached the Queen Charlotte Islands from Callao, Peru in 1640, perhaps entering Masset Inlet as well as examining one of its tributary rivers (Yakoun?) with large Indian boats, it was that Canadian geologist Dawson himself 238 years later (1878) who made the first well-documented observations on streams and freshwater fishes of these islands. He referred specifically to at least 14 streams and noted general features of many others along portions of the Queen Charlotte Islands coastline. He described the Tlell River water as being dark coffee or amber coloured and observed that a similar tint distinguished that of many other northern lowland streams. He noted the large autumn runs of salmon in the Hiellen, Yakoun and other Queen Charlotte Islands streams. In a few of the larger rivers he mentioned mid-July runs of a small red-fleshed salmon (probably sockeye, *Oncorhynchus nerka*) and in other streams starting about mid-August the sizable runs of larger species of salmon, in some lasting until January. With characteristic keen observation Dawson noted that the adult salmon ascended even very small streams when these were in flood with autumn rains. He recorded the Haida methods used to spear the salmon and trout in the river mouths or trap them farther upstream with split stick weirs. According to his appendix on Haida vocabulary there were 4 different types of salmon recognized in Skidegate dialect: "hook-bill" salmon (perhaps coho, *O. kisutch*), "small red" salmon (probably sockeye), "dog-tooth" salmon (probably chum, *O. keta*, and perhaps pink, *O. gorbuscha*) and "largest" salmon (probably chinook, *O. tshawytscha*, and perhaps coho). Trout were also recognized as well as eulachon, *Thaleichthys pacificus* (said by Dawson not to occur in Queen Charlotte Island streams) and sculpins.

Five years later (1883) Judge J.G. Swan, commissioned by the U.S. Smithsonian Institute, collected fishes along the Queen Charlotte coast, recorded runs of chum and coho salmon in Masset Inlet streams as well as runs of pink salmon in the Jalun River, noted the nets used by the Haidas to catch salmon and trout in rivers and their use of lampreys as a food fish (Swan, 1884). The following year N.H. Chittenden, exploring the Queen Charlotte Islands for the B.C. government, described spawning runs of chum salmon in the Zuboff River of Kano Inlet and noted a rock dam built across the creek at the head of Hutton Inlet by the Haidas to trap salmon (Dalzell, 1973). At the turn of the century W.H. Osgood made fish collections along the Queen Charlotte Island shores and recorded trout in some streams (Osgood, 1901).

The first scientific studies on riverine fishes of the Queen Charlotte Islands began in the autumn of 1928 with scientists from the Pacific Biological Station, Nanaimo, in particular A.L. Pritchard. An intensive investigation on the life history and production of pink salmon was centered at McClinton Creek, Masset Inlet and resulted in a series of publications mainly on this species over the next two decades (Pritchard, 1936a, 1937a, 1937b, 1937c, 1938a, 1938b, 1939, 1941, 1944,

**Table 7.** A list of riverine freshwater fishes recorded from the Queen Charlotte Islands, British Columbia.

| Family | Species | Common Name | General Distribution & Abundance |
|---|---|---|---|
| Petromyzonidae | *Entosphenus tridentatus* | Pacific lamprey | Widespread, common |
| Petromyzonidae | *Lampetra richardsoni* | Western brook lamprey | Widespread, common |
| Osmeridae | *Thaleichthys pacificus* | Eulachon | Yakoun River mouth, rare |
| Salmonidae | *Oncorhynchus gorbuscha* | Pink salmon | Widespread, abundant |
| Salmonidae | *O. keta* | Chum salmon | Widespread, abundant |
| Salmonidae | *O. kisutch* | Coho salmon | Widespread, abundant |
| Salmonidae | *O. nerka* | Sockeye salmon | Scattered, not abundant |
| Salmonidae | *O. tshawytscha* | Chinook salmon | Yakoun River, not abundant |
| Salmonidae | *Salmo gairdneri* | Rainbow trout, steelhead | Widespread, common |
| Salmonidae | *S. clarki* | Cutthroat trout | Mainly Plateau & Lowlands, common |
| Salmonidae | *Salvelinus malma* | Dolly Varden char | Widespread, common |
| Gasterosteidae | *Gasterosteus aculeatus* | Threespine stickleback | Scattered, common |
| Cottidae | *Cottus aleuticus* | Coastrange sculpin | Widespread in Ranges & Plateau, common |
| Cottidae | *C. asper* | Prickly sculpin | Scattered throughout, not common |

1948) but also on other riverine fishes (Pritchard, 1933, 1936b; Neave, 1955).

The next period of active work on Queen Charlotte streams seems to have started in the summer of 1960 when fishery biologists of the B.C. Fish and Wildlife Branch (J.C. Lyons, F.P. Maher, T.G. Northcote) made a series of collections and observations mainly on Lowlands streams. Also that summer, students associated with the Department of Zoology, University of British Columbia (A. Beadell, E.D. Lane) collected fishes from several other streams in the area. Walker (1970) reported on the 1965 migration of pink salmon fry in the Yakoun River.

In the summer of 1969 G.E. Moodie and T.E. Reimchen collected threespine stickleback (*Gasterosteus aculeatus*) from a few streams in addition to their lake sampling for this species. G.E. Moodie and A. Peden collected sculpins (*Cottus*) from the Hiellen River in 1972. With the onset of the Federal Fisheries Salmonid Enhancement Program (SEP), studies began in August 1977 on two Queen Charlotte chum spawning streams (Shepherd, 1978, 1982). In the spring of 1978 intensive sampling of 22 streams entering several Moresby Island inlets was undertaken by P.M. Mylechreest and T.G. Northcote to gather evidence for absence of cutthroat trout from the Ranges region. About the same time Federal fisheries biologists organized a set of extensive catalogues of Queen Charlotte salmon streams and spawning escapements (Marshall *et al.*, 1978a,b; Brown & Musgrave, 1979).

The first few years of the 1980s has witnessed a great increase in stream studies on the Queen Charlotte Islands. Part of this surge was stimulated by the SEP investigations and lake fertilization studies. For example the lower reaches and estuary of the Yakoun River were examined intensively in the spring and summer of 1980 (Stockner & Levings, 1982) to evaluate possibilities for artificial enrichment. But by far the greatest impetus to stream studies resulted from problems between forest harvesting and fisheries interests as well as those of recreationalists and environmentalists. Fisheries biologists with the Land Use Planning Advisory Team (LUPAT) of a major forestry company (MacMillan Bloedel Ltd.) had made surveys of several streams earlier (see for example Pollard, 1976; Bruce, 1978; Bruce & Pollard, 1978), and now intensified their work by starting stream enhancement projects (Lofthouse, 1980; Pollard, 1981; Lofthouse & Bruce, 1982). In 1981, through co-operative efforts of the B.C. ministries of Forestry and Environment along with the Federal Department of Fisheries and Oceans, a major program of research on fish and forestry interaction (FFIP) was launched to study problems of mass wasting affecting many Queen Charlotte watersheds (Poulin, 1983). By 1982 at least 43 watersheds (28 in the Ranges and 15 in the Skidegate Plateau) had been investigated and to date 10 working papers have been published (see esp. Bustard, 1983; Klassen, 1983; Carr, 1983) as well as a graduate thesis on salmonid stream improvement (Klassen, 1984).

The southern part of Moresby Island (including associated smaller islands), a region of some of the most outstanding natural features in the Charlottes, has been the focus of much concern by public, Native Indian, Provincial government and private industry bodies. This started in the 1960s and grew through the 1970s with the formation of the Islands Protection Society, the South Moresby Wilderness Proposal, and in 1979 the South Moresby Resource Planning Team with representatives from all above interest groups. Work for this team has identified over 100 fish streams in the area supporting stocks of salmonids, the majority with yearly runs of pink, chum and coho salmon (South Moresby Resource Planning Team, 1983).

**Table 8.** A summary of freshwater fish families and species recorded for the mainland and major islands of British Columbia.

| Family | Number Of Species: Mainland[a] | Vancouver Island | Q.C. Islands |
|---|---|---|---|
| Petromyzonidae (Lampreys) | 3 (p4)[b] | 4 | 2 (p3) |
| Acipenseridae (Sturgeons) | 2 | 1 | – |
| Clupeidae (Herrings) | 1 (i)[c] | 1 (i) | – |
| Osmeridae (Smelts) | 3 | – | 2 |
| Coregonidae (Whitefishes) | 3 | 1 (i) | – |
| Thymallidae (Grayling) | 1 | – | – |
| Salmonidae (Salmon, trout, char) | 13 (3i) | 11 (3i) | 8 |
| Catostomidae (Suckers) | 5 | – | – |
| Cyprinidae (Minnows) | 16 (3i) | 3 (1i) | – |
| Ictaluridae (Catfishes) | 2 (i) | 1 (i) | – |
| Esocidae (Pikes) | 1 | – | – |
| Gasterosteidae (Sticklebacks) | 1 | 1 | 1 |
| Gadidae (Codfishes) | 1 | – | – |
| Percidae (Perches) | 2 (1i) | – | – |
| Centrarchidae (Basses, sunfishes) | 4 (i) | 2 (i) | – |
| Cottidae (Sculpins) | 6 | 2 | 2 |
| Total families | 16 (3i) | 10 (4i) | 5 |
| Total species | 64 (14i) | 27 (9i) | 15 |

a In Carl *et al.*, 1959, McPhail & Lindsey, 1986; with minor modifications following more recent information; mainland refers to Pacific drainages only.
b p = possibly.
c i = introduced; some species listed as introduced may have made their way into B.C. from introductions outside the province.

**Table 9.** Occurrence and distribution of salmonids and freshwater sculpins in streams[a] of the Queen Charlotte Islands.

| | Physiographic Region | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ranges | | | Plateau | | | Lowlands | | | Total | |
| Species | Streams | Present | % Occur. | Streams | Present | % Occur. | Streams | Present | % Occur. | Streams | % Occur. |
| Pink | 137 | 98 | 71.5 | 57 | 30 | 52.6 | 30 | 14 | 46.7 | 224 | 63.6 |
| Chum | 137 | 128 | 93.4 | 57 | 37 | 64.9 | 30 | 8 | 26.7 | 224 | 77.3 |
| Coho | 137 | 120 | 87.6 | 57 | 53 | 93.0 | 30 | 29 | 96.7 | 224 | 90.2 |
| Sockeye | 137 | 2 | 1.4 | 57 | 4 | 7.0 | 30 | 5 | 16.7 | 224 | 4.9 |
| Chinook | 137 | 0 | 0.0 | 57 | 0 | 0.0 | 30 | 1 | 3.3 | 224 | 0.4 |
| Rainbow | 43 | 28 | 65.1 | 39 | 25 | 64.1 | 23 | 8 | 34.7 | 105 | 58.1 |
| Cutthroat | 43 | 1 | 2.3 | 39 | 12 | 30.8 | 23 | 17 | 73.9 | 105 | 28.6 |
| Dolly Varden | 43 | 34 | 79.1 | 39 | 32 | 82.1 | 23 | 19 | 82.6 | 105 | 81.0 |
| Coastrange Sculpin | 43 | 31 | 72.1 | 39 | 19 | 48.7 | 23 | 7 | 30.4 | 105 | 54.3 |
| Prickly Sculpin | 43 | 8 | 18.6 | 39 | 13 | 33.3 | 23 | 9 | 39.1 | 105 | 28.6 |

a Streams, here and elsewhere in this table refers to the number of streams that have been checked at appropriate times and with appropriate techniques to record the species in question; does not include sporadic occurrence of a very few individuals in longterm Federal Fisheries stream records; number of salmon streams larger than for other species because of inclusion of Federal Fisheries adult spawner escapement records.

## Fish Species and Distributions

### Species Diversity

A total of 14 species of freshwater fishes, representing 5 different families, have been recorded from riverine waters of the Queen Charlotte Islands (Table 7). Although caught in 4 out of 7 surface trawls at the mouth of the Yakoun River (Stockner & Levings, 1982), eulachon have not been recorded farther upstream and may not reproduce in that system. Clearly the restricted diversity of species is dominated by salmonids, all of them either entirely anadromous or known to have anadromous forms.

Compared to mainland British Columbia with at least 60 species representing 16 families (Table 8), the isolation from continental dispersion of species provided by the islands is obvious. Furthermore introductions by man also seem not to have occurred on the Queen Charlottes, whereas on Vancouver Island at least 9 of the 27 species have been introduced. Although more similar after discounting introductions, the freshwater fish faunas of Vancouver and Queen Charlotte Islands are not identical. For example, the cyprinid peamouth chub (*Mylocheilus caurinus*) has not been recorded on the latter nor has eulachon on the former.

Clark and McInerney (1974) provide good experimental evidence that peamouth chub, the only cyprinid occasionally taken in brackish water off the Fraser River mouth, probably has been able to reach Vancouver Island across the low salinity corridor provided during high freshet periods of the Fraser River. Using their temperature-salinity tolerance relationships for peamouth chub along with the most favourable environmental conditions prevailing in Hecate Strait during freshet conditions of the Skeena-Nass systems (Crean, 1967; Wickett & Ballantyne, 1978; Dodimead, 1980), one can estimate the median survival time for peamouth chub attempting such a crossing. Largely because of high minimal salinities in the Strait (*ca.* 28 ‰) survival time would be less than two hours, far too short to allow this species to swim from the coastal mainland.

### Species distribution

Two species of lamprey occur on the Queen Charlotte Islands—the Pacific lamprey (*Entosphenus tridentatus*) and the western brook lamprey (*Lampetra richardsoni*). The river lamprey (*L. ayresi*) has been reported in the Pallant system (Hart, 1973) but the specimens on which this is based (B.C. 60-203) are not *ayresi* and most probably *richardsoni* (R. Beamish, pers. comm.). Lamprey occur in 22 of 33 rivers sampled by R. Beamish, with both species present but not abundant in most rivers checked on Moresby and Graham Islands.

Salmonids and sculpins comprise the bulk of the riverine fish fauna of the Queen Charlottes (Table 9). Of these fishes, chum and coho salmon along with Dolly Varden char (*Salvelinus malma*) are by far the most commonly occurring species, followed by prickly sculpin (*C. asper*) and cutthroat trout (*S. clarki*). Sockeye salmon occur consistently only in 11 stream systems and chinook only in one, the Yakoun River.

Regionally, pink salmon are most common in Ranges streams, decreasing in Plateau streams and lowest in occurrence in the Lowlands (Table 9). Spawning runs of pink salmon typically occur on even-numbered years in the Queen Charlottes (57-67% of the streams regionally can be classified as "even-yeared"). Those with runs on both years often have smaller runs on the odd-numbered years but this is by no means invariable. "Both year" streams seem to be mainly located in the middle portion of the Ranges, lower portion of the Plateau and eastern portion of the Lowlands. No Queen Charlotte streams are recorded as having pink runs only on odd-numbered years. One Lowland river (Yakoun) is said to account for at least half the total pink production on the Queen Charlotte Islands and in 1984 an escapement of 1,086,000 was estimated in this river (M. Henderson, pers. comm.).

Chum salmon are clearly the most widely distributed stream fish in the Ranges (Fig. 8, Table 9); not recorded in only 9 of the 137 streams checked. Their occurrence drops off in the Plateau region and sharply in the Lowlands to far less than a third of that of the Ranges (27% compared to 93%). Unlike all other northern Queen Charlotte Islands streams, one creek (Stanley) in the Lowlands has a "summer" (August-September) run of chum salmon. Chum seem to be better able to utilize the short, steep drainages of the Ranges (note their

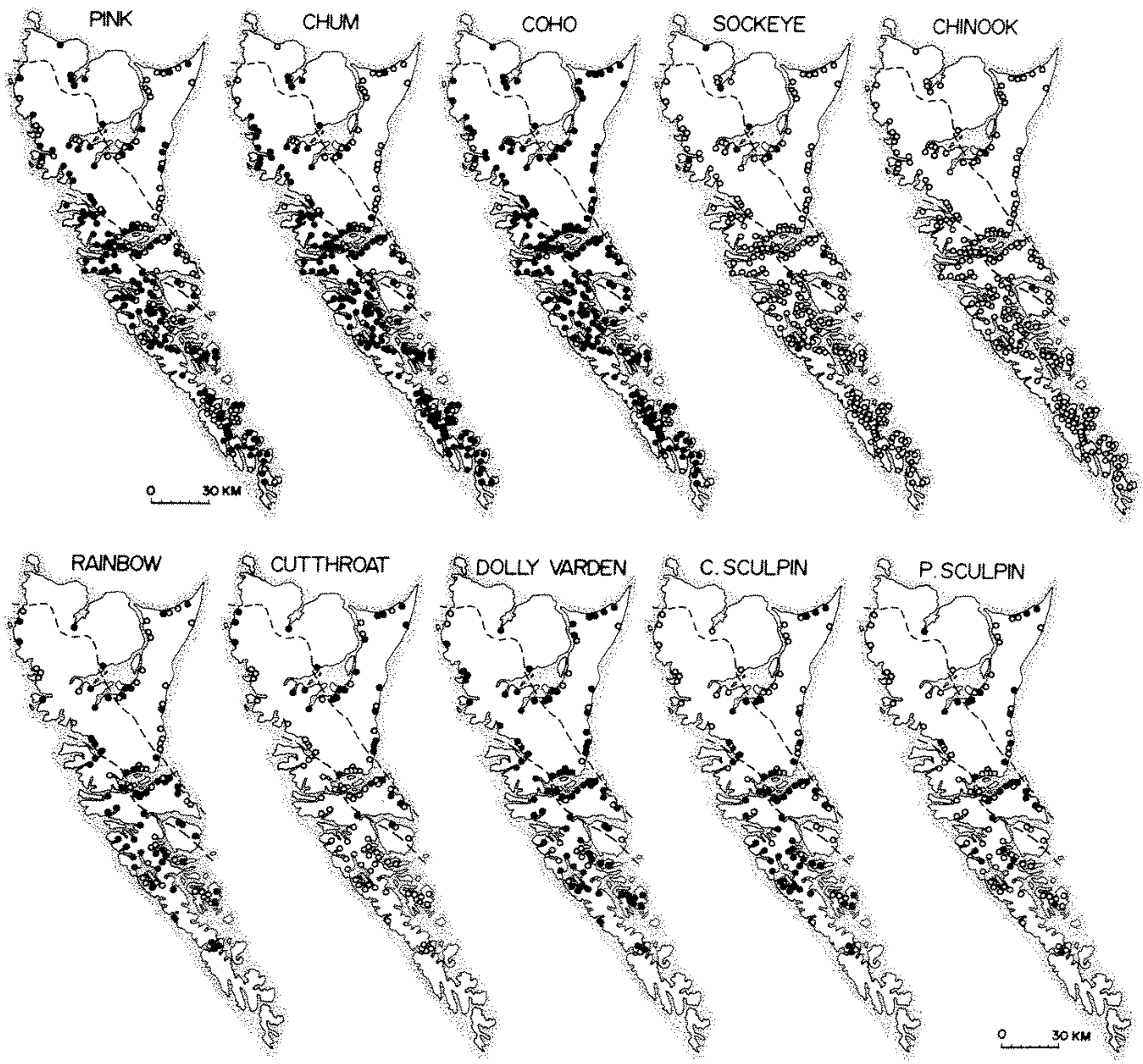


**Fig. 8.** Distribution records for salmonids and freshwater sculpins in stream systems in the physiographic regions of the Queen Charlotte Islands. ● = streams sampled where species present (see Table 9); O = streams sampled where species not recorded.

presence in every stream checked in the southern part of this region, Fig. 8) than the longer, highly branched and meandering drainages of the Lowlands.

In contrast, it is in the Plateau and especially the Lowlands where coho reach their highest percent occurrence, and are found in nearly all of the streams checked. Even in the Ranges coho still reach nearly 90% occurrence.

Sockeye salmon utilize only 2 stream systems in the Ranges, Fairfax Inlet Creek and Pallant Creek, the former with an accessible rearing lake. Most streams in the southern part of the Ranges are small and inaccessible to upstream migrants because of waterfalls (South Moresby Resource Planning Team, 1983). There are four sockeye streams in the Plataeu region, each with good rearing lakes, and all have supported annual spawning runs of several thousand fish. In Mathers Creek there is a spring run of mature adults which spawn between April and June, and in the Awun River maturing sockeye enter the system in May. Five Lowlands streams support sizeable sockeye runs, four of these with headwater rearing lakes (Ain, Eden, Jalun and Yakoun) whereas the Mamin has no rearing lake for juveniles although the adults are said to ascend the system for at least 8 km.

Chinook salmon runs up to several thousand fish have been recorded in the Yakoun River (Lowlands) until recently when numbers declined sharply.

Rainbow trout occur either as stream residents or as anadromous steelhead in about two-thirds of Ranges and Plateau streams. They seem to be represented in about a third of the Lowland streams mainly by the anadromous steelhead rather than by small resident forms. Cutthroat trout on the other hand have been recorded in only 1 of 43 streams examined in the Ranges, Pallant Creek on the border between the Ranges and Plateau regions (Fig. 8). Although apparently not widespread in the western Plateau (Fig. 8), cutthroat have been recorded in a third of the streams sampled in that region (Table 9). Cutthroat commonly occur as residents as well as anadromous forms in over 70% of the Lowland streams. Because many of these are large, highly branched systems, cutthroat are much more broadly distributed throughout the region than would be implied in Figure 8.

Dolly Varden char, like rainbow trout, are widely and about equally distributed in each of the physiographic regions (Fig. 8), occurring in over 80% of all streams checked (Table 9). Anadromous as well as stream resident forms are found in many of the systems.

**Table 10.** Relative abundance[a] of marine fishes in the lower reaches of 11 streams on the Queen Charlotte Islands.

| | Fish Species[b] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stream | *Col. sai.* | *Aul. fla.* | *Syg. gri.* | *Cli. acu.* | *Oli. mac.* | *Lep. arm.* | *Lip.* sp. | *Lum. sag.* | *Pho. lae.* | *Cit. sor.* | *Pla. ste.* | *Cit. sti.* | Collection |
| Ranges Region: | | | | | | | | | | | | | |
| Lagoon | – | – | – | – | – | +++ | – | – | – | – | – | – | UBC 60-428 Lane & Beadell |
| Plateau Region: | | | | | | | | | | | | | |
| McClinton | – | + | + | – | – | – | – | + | – | – | – | – | UBC 59-551 Pritchard |
| Unnamed #1[c] | – | – | – | – | – | + | – | – | – | – | – | – | UBC 60-439 Lane & Beadell |
| Slatechuck | – | – | – | +++ | ++ | +++ | + | – | + | – | – | – | UBC 60-534 Northcote *et al.* |
| Lowlands Region: | | | | | | | | | | | | | |
| Ain | + | – | – | – | – | – | – | – | – | – | – | – | Pritchard (1933) |
| Kumdis | – | – | – | – | – | ++ | – | – | – | – | – | – | Northcote & Klassen 1984 |
| Lawn | – | – | – | + | ++ | +++ | – | – | – | – | – | – | UBC 60-535Northcote *et al.*, Northcote & Klassen 1984 |
| Sangan | – | – | – | – | – | +++ | – | – | – | – | + | ++ | UBC 60-537 Northcote *et al.*, Northcote & Klassen 1984 |
| Tlell | – | – | – | – | – | +++ | – | – | – | + | +++ | – | UBC 60-541 Northcote *et al.* |
| Unnamed #2[c] | – | – | – | – | – | + | – | – | – | – | – | – | UBC 60-437 Lane & Beadell |
| Unnamed #3[c] | – | – | – | – | – | +++ | – | – | – | + | +++ | – | UBC 60-538 Northcote *et al.* |

a + = rare (< 5/collection); ++ = common (5-10/collection); +++ = abundant (> 10/collection); – = absent.

b From left to right: *Cololabis saira*, *Aulorhynchus flavidus*, *Sygnathus griseolineatus*, *Clinocottus acuticeps*, *Oligocottus maculosus*, *Leptocottus armatus*, *Liparis* sp., *Lumpenus sagitta*, *Pholis laeta*, *Citharichthys sordidus*, *Platichthys stellatus*, *Citharichthys stigmaeus*(?).

c #1 = 5 km W of Juskatla; #2 = 3 km W of Juskatla; #3 = McIntyre Bay, lot 838A.

Threespine stickleback have been recorded in about 10% of the streams checked in the Ranges and Plateau regions. They occur much more frequently in Lowland streams (39% of those sampled).

Coastrange sculpins have their most widespread distribution in streams of the Ranges, present in 31 of the 43 systems where sculpins were identified to species. Five other streams sampled in this region have sculpins but which species is not known. To the northeast, coastrange sculpins are less common, occurring in only about 30% of the streams sampled in the Lowlands (Fig. 8, Table 9). In direct contrast, prickly sculpins reach their highest percent occurrence in Lowland streams (39%) and their lowest (19%) in the Ranges.

## Stream Penetration by Marine Fishes

Although a few species of primarily marine fish are known to occur in the lower tidal reaches of large rivers along the North Pacific Coast such as the Fraser (Northcote *et al.*, 1978) and in the Yakoun River estuary (Stockner & Levings, 1982), in several Queen Charlotte rivers and streams marine species have been recorded in rapidly flowing, shallow portions above prevailing tidal influence. Such an occurrence is well illustrated by a collection made in mid-July 1960 from Slatechuck Creek (Table 10) where 5 species of marine fishes from 3 different families were taken between 46 and 230 m upstream from the stream mouth during low tide in a gravel reach with shallow depths (< 60 cm) and good flow (0.3-0.6 $m \cdot sec^{-1}$).

The staghorn sculpin (*Leptocottus armatus*) was the marine species most frequently noted in lower reaches of Queen Charlotte streams (9 out of 11 streams and abundant in 6, Table 10). It commonly enters lower portions of coastal Pacific streams (Hart, 1973). The starry flounder (*Platichthys stellatus*), a species known to be tolerant of low salinities (Hart, 1973), was taken from lower reaches of 3 streams. Penetration into freshwater seems to be a more common phenomenon in Lowland streams compared to those in the Ranges where such occurrence was recorded only once (Lagoon, Table 10) although the lowermost portions of at least 12 other streams in this region were intensively sampled. Perhaps the lower gradient of Lowland streams and large tidal fluctuation result in a long region of gradual salinity change, facilitating penetration by euryhaline marine species.

### Above Falls and Headwater Distribution

Low waterfalls on Pacific coastal streams often act as selective barriers to upstream movement of fish, preventing headwater access to most if not all non-salmonid fishes except perhaps lampreys, while permiting some but not necessarily all species of salmonids to move farther upstream into headwater reaches. In Queen Charlotte streams, especially in the Ranges and Plateau regions, pink and chum salmon frequently are confined to lower reaches by low waterfalls. Nevertheless the falls may be navigable at times, depending on discharge, by coho and sockeye salmon as well as by steelhead (rainbow) trout, which are more broadly distributed in middle if not upper reach tributaries. The streams at the head of Fairfax, Lagoon and Sewell inlets provide good examples of this form of species selectivity to upper reach access.

Other streams have waterfalls which now effectively prevent upstream passage of all fish. Presumably at one time in their recent geological history these falls either were not present or did not restrict movement of some species which now are found in headwater reaches above the falls. For example a drop of about 5 m high some 300 m up Lomgom Creek prevents farther upstream movement of pink, chum and coho salmon as well as coastrange sculpins yet resident rainbow trout and Dolly Varden char occur above the falls. The latter species is common in high gradient headwater sections of several Tasu inlet streams (*e.g.* above falls on Tasu Inlet Creek) as well as elsewhere in similar systems of the Ranges and Plateau regions as noted by Tripp and Poulin (1986a,b). Cutthroat trout also are found in high gradient headwater reaches of some Plateau streams (Phantom Creek, tributary to the Yakoun; Sachs and Mathers creeks) (Tripp & Poulin, 1986a,b).

## Ecological Studies

A long series of studies on riverine phases of pink salmon ecology were started in 1928 by A.L. Pritchard and others from the Pacific Biological Station working principally in McClinton Creek, Massett Inlet. Over two and a half decades or more, a large body of information was gathered on basic life history of the species, definitely establishing for the first time its fixed 2-year life cycle, its imprecise reproductive homing, its nocturnal juvenile downstream migratory behaviour, and its population production dynamics (Pritchard, 1936a, 1937a,b,c, 1944, 1948; Neave, 1955). In addition through transplantation experiments an attempt was made to establish pink spawning runs in the barren odd-numbered years at McClinton Creek (Pritchard, 1938a,b) and though unsuccessful, marked some of the earliest scientific work on factors controlling this still unresolved phenomenon (Barber, 1979). More recently, biologists from the Pacific Biological Station have been working on factors regulating survival and production of young salmon in estuarine waters of Masset Inlet (R.J. Le Brasseur, pers. comm.).

In the early 1960s J.R. Stein undertook an extensive survey of the freshwater algae in the Queen Charlotte Islands, which included examination of environmental conditions and algal flora of a few fish streams in each of the physiographic regions (Stein & Gerrath, 1969).

Although sporadic sampling of Queen Charlotte Islands streams and rivers has been made in more recent years, the only other general work on fish streams (apart from that associated with sport and commercial fisheries or environmental impact investigation) seems to have been the zoogeographic study (1978 and later) on rainbow and cutthroat trout distribution, stream conditions and aquatic invertebrates in the Ranges (Northcote & Mylechreest, unpub.). Cutthroat trout clearly have their centre of distribution in the Lowlands, but extend out into many Plateau systems (Fig. 8). Remarkably however, despite rather intensive sampling of some 43 streams, there is still only one definite record of a cutthroat system in the Ranges, that being Pallant Creek on the eastern margin of the region.

Causes for such a large and clear faunal gap are by no means obvious. On mainland British Columbia cutthroat trout typically inhabit headwater tributaries of lower Fraser Valley streams (Hartman & Gill, 1968) so the species would be expected to be able to colonize Ranges streams. As there are many anadromous cutthroat populations in the Lowlands, and as homing is never 100% effective, there must have been opportunity for the species to spread the relatively short distance involved between the Plateau and Ranges regions (Figs. 1,8). Interestingly, there does not seem to be any comparable pattern of distribution for rainbow and cutthroat trout in Vancouver Island streams. Both species occur in streams along the west coast of the island from its southern to northern end (Parkinson *et al.*, 1984; stream record files B.C. Fish and Wildlife Branch; J.D. McPhail, pers. comm.) although in several of those studied by Parkinson *et al.* (1984), rainbow rather than cutthroat trout were found in headwater reaches of the streams.

## Impacts of Man

### Declining Salmon Escapements

A sharp decline in total salmon ''escapement'' (number of adults which escape fishing and other mortality sources and return to spawn in the streams) has occurred on the Queen Charlotte Islands (Shirvell & Charbonneau, 1984). Total escapement for the 1948-52 period of well over 11 million adults has fallen to 3.4 million in the 1978-82 period. Pink and chum salmon have accounted for most of the decline in escapement for all areas, but there have been species differences in contribution to the decline between regions. Escapements of coho and sockeye salmon, not major commercial species in the Queen Charlotte Islands, have not changed appreciably over this three decade interval (Shirvell & Charbonneau, 1984). Chinook salmon escapements on the Yakoun River fluctuated between about 1,100 and 6,600 (5 year annual averages) up to 1968 and then declined sharply to averages between 750-940 fish (Brown & Musgrave, 1979; more recent records from S. Hahn).

Coupled with decline in escapements there has been the virtual extinction of some species in other Queen Charlotte streams (no recorded escapement or other evidence of the species for 10 consecutive years). Since 1947 at least 29 salmon stream populations have become ''extinct'' on the Queen Charlotte Islands: 13 for pink, 11 for coho, 4 for chum and 1 for sockeye. The rate of extinction has been increasing every year since 1958 (Shirvell & Charbonneau, 1984) so that by 1983 the average reached 4 populations per year! Indeed some streams like Douglas Inlet Creek (Ranges) which up to 1960 had annual escapements reaching 7,500 fish (mainly chum but some pink and coho) apparently now have become barren of all salmon.

The cause for decline and in some cases extinction is by no means clear but probably lies in a combination of sources that include severe habitat degradation and over-fishing. The multitude of small secluded streams, especially in the Ranges, with runs often of only a few hundred salmon would seem to be particularly vulnerable to stock decimation or extinction.

### Fish–Forestry Interaction

Largescale clearcut logging with associated cross-stream yarding and other practices destructive to salmonid spawning or rearing habitat no doubt have had serious negative effects on stocks in some areas. During the first and second world wars large blocks of spruce were logged for aircraft construction using techniques which gave little attention to fish habitat in streams. Queen Charlotte Islands streams generally were not used for log driving but at least one (Gate Creek) had a dam built across its mouth to facilitate log sluicing. Although later removed, this dam is said to have wiped out excellent salmon runs to the stream (Dalzell, 1973). Public concern over the effects of logging on salmonid stocks, clearly in decline, mounted in the late 1970s and culminated in a serious confrontation between fisheries and forestry agencies at Riley Creek on Rennell Sound. Court actions were brought against the B.C. Forestry Service, the Federal Fisheries Director and others by local native fishermen.

A five year program (FFIP) was initiated in 1981 to investigate problems associated with steep slope logging and stream fisheries management on the Queen Charlotte Islands. It has covered a broad front of research in forested and deforested watersheds within two main categories: 1) impact studies to document fish habitat damage and loss of forest productivity resulting from mass movement of soil; and 2) prescriptive studies to assess the suitability of alternative techniques for reducing slope instability caused by logging and for rehabilitating streams as well as forest sites damaged by debris torrents or landslides (Poulin, 1983). As noted previously a number of promising techniques have been developed and others are being tested which should help resolve in part the conflicts surrounding interactions between these two primary resources. Nevertheless because of the topography, bedrock and soil characteristics along with prevailing climatic conditions, there will no doubt continue to be local disasters—some natural and others man-induced. Possibly local fish stocks of the Queen Charlotte Islands streams have developed "resilience" to periodic and catostrophic reduction in numbers, as suggested many years ago by Pritchard (1948), but if the frequency and severity of such events is appreciably increased by various activities of man, those limits may well be exceeded, leading to stock decline or extinction.

### Road Construction

As elsewhere, Queen Charlotte Islands streams commonly have been used as convenient sources of gravel for construction or maintenance of public as well as private logging roads with damaging effects on salmonid habitat (K. Moore, pers. comm.). Furthermore, poorly designed or maintained road culverts have blocked salmonid movement and examples of these are still to be seen on main Queen Charlotte Islands highways. Road construction on steep slopes increases the chances of failure with consequent stream blockage or heavy inputs of sediment.

### Mining Impacts

Probably the largest and most recent long-term mining activity in the Queen Charlottes was that at Tasu Inlet (Ranges), mainly an open pit iron operation. Although some effects on the fish stream at the head of Fairfax Inlet were noted, these were minor and overall this mine, now closed, probably had little impact on stream salmonids other than to locally and temporarily increase sport fishing pressure.

Operation of a pilot plant for refining gold ore mined in the Yakoun River watershed has caused much local concern not only because of cyanide and other contaminates associated with the process but also because of high mercury levels in the ore body itself (M. Nicoll, pers. comm.).

Coal and oil exploration which started well before the turn of the century may have had temporary and local effects on stream habitat for fish. Sections of the Yakoun River were cleared of large organic debris to permit canoe freighting of supplies to coal survey parties in the early 1900s (Dalzell, 1973).

### Stream Fish Enhancement Projects

Although salmon egg collection facilities and small hatcheries had been operated by Federal Fisheries staff on several Queen Charlotte streams during the first half of this century, the Salmonid Enhancement Program (SEP) revitalized this type of work in the late 1970s with more modern techniques and approaches (Shepherd, 1978, 1982). A moderate sized federal salmon hatchery continues year-round operation at Pallant Creek, mainly for chum and some coho salmon. Juveniles of the latter species are released above natural obstructions in the creek to utilize upstream rearing potential although this may result in competitive interactions with resident salmonids. In addition, salmon incubation boxes are operated with SEP support or designs on a number of small streams by native Indian Bands, schools, forest companies, citizen groups and commercial fishermen.

Under the FFIP work several well designed and monitored projects have been carried out on streams subject to severe fish habitat destruction by debris torrents and avalanches. Large logs have been cabled into the bed of South Bay Dump Creek to provide stable rearing habitat for young coho (D. Tripp & V.A. Poulin, pers. comm.). Paired gabions have been placed in three experimental sites on nearby Sachs Creek to stabilize salmon spawning gravel (pink, chum, coho) and also form juvenile rearing areas (coho). These structures have survived several severe freshets and for the most part seem not only to be successful but also cost effective (Klassen, 1984). Urea fertilization of the Yakoun River estuary apparently did not enhance juvenile salmonid growth or survival in that system (Stockner & Levings, 1982).

## Research Problems and Needs

### Fish Distribution Studies

Although some stream systems have been subject to intensive fish survey work, in many areas little is known about the freshwater fish fauna especially for species other than salmon. Notable in this regard is the southern third of Moresby Island (western and eastern coastlines) and the northern coast of Graham Island (west of Masset) as well as the upper half of its western coast. In other areas only the lower reaches of streams have been adequately sampled so that unusual distribution patterns in headwater or above waterfall reaches (see Parkinson *et al.*, 1984, for Vancouver Island streams) may well have been missed.

### Microzoogeographical Patterns

Preliminary work on distribution of freshwater fishes in the Queen Charlotte Islands has revealed several intriguing patterns in microzoogeography which require rationalization. The most obvious of these is that shown by cutthroat trout, but clear regional differences in relative abundance of chum and coho salmon as well as coastrange and prickly sculpins also are evident. These need to be examined with experimental approaches.

### Local Stock Diversity

In part because of the large number of small, isolated stream systems (many with headwater or above waterfall fish populations) as well as the sharp regional differences in stream characteristics, it is not surprising to find evidence of marked local stock diversity in Queen Charlotte Islands stream fish populations. For example there are some sockeye stocks which spawn in spring and others which apparently rear in streams rather than lakes. Headwater populations may well have genetically distinct growth, maturity, fecundity and migratory characteristics (see Northcote, 1981). Although there may be compelling fisheries management reasons for introducing different species or stocks to better utilize headwater rearing areas in streams, this should be tempered with caution to preserve unique genetic traits that may have been selected in such headwater native fish populations.

**Freshwater Penetration By Marine Fishes**

The apparent high tolerance to low salinity evident in a number of marine fishes in the Queen Charlottes needs to be tested more rigorously, both by careful field studies and by controlled physiological studies in the laboratory. Furthermore the ecological significance of such penetration needs to be examined.

**Stream Enhancement Possibilities**

Although several well-tested methods for stream enhancement have been adapted successfully for use in Queen Charlotte streams, there should be more attempts to develop techniques especially tailored to the needs and peculiarities of local streams. Promising possibilities are being tested, in one case by creating small pond rearing habitats for juvenile coho in suitable stream reaches (V. Poulin, pers. comm.). Planned gravel releases by log jam removal perhaps could provide spawning substrate in gravel deprived reaches downstream or may improve access (Bustard, 1983). Furthermore if salmonid stocks are to be given adequate protection, let alone enhancement, we need to have much more precise information about their habitat needs and limiting factors in Queen Charlotte streams.

# Lakes

## General Characteristics

There are over 220 lakes on the Queen Charlotte Islands, most of them small, oligotrophic waterbodies. There are also thousands of shallow bog pools (<1 ha), principally in the Lowlands (Douglas & Reimchen 1988) (Fig.4). Most of the latter are temporary and dry up in summer or are shallow (<1 m) pools without surface inflow or outflow streams. Many lakes lack fish populations due to major falls on outflow streams or to their shallow or temporary nature. Winter temperatures are moderated by proximity to the ocean, yet small lakes (<200 ha) may have complete ice cover for several weeks each year.

Four of the five largest lakes on the Queen Charlotte Islands (Ian, 1,860 ha; Yakoun, 808 ha; Skidegate, 698 ha; Eden, 570 ha) occur on the Skidegate Plateau and represent nearly one third of the total lake surface area. Watersheds in this physiographic region are heavily forested; runoff is weakly stained and marginally acidic (pH 6-7). Littoral macrophytes are generally uncommon although Skidegate and Yakoun lakes, with stable substrates and broad littoral regions, have a macrophytic species diversity equivalent to that observed on mainland lakes (Calder & Taylor, 1968).

The Lowlands of northeast Graham Island are a mosaic of Sphagnum bogs, coniferous forest and numerous small lakes and ponds. Runoff is heavily stained and acidic (pH range 3.9-6.5); accordingly, littoral vegetation is sparse but includes locally abundant stands of *Nuphar luteum* and *Juncus oreganus*.

The montane lakes of the Ranges usually have clear water with pH close to neutrality (6.0-7.5). Aquatic vegetation such as *Potamogeton* and *Utricularia* is occasionally abundant in ponds and small lakes but rare in larger basins.

## Fish Collections and Studies

The endemism discovered in plants, birds and mammals (Foster, 1965; Calder & Taylor, 1968) suggested a possibility for divergence in fish populations in Queen Charlotte Islands lakes. In the mid-1960s, D.W. Hagen, then of the University of British Columbia, recognized a divergent form of threespine stickleback (*Gasterosteus aculeatus*) from collections made in 1929 at Mayer Lake on Graham Island. This initial observation led to a series of evolutionary studies on stickleback (Moodie, 1972a,b; Moodie & Reimchen, 1973, 1976a,b; Reimchen, 1980, 1983, 1988, 1989; Reimchen *et al.*, 1985; Reimchen & Nelson, 1987; Gach & Reimchen, 1989) which remain the principal biological research on lake fishes in the archipelago. As part of these ongoing studies, general baseline information has been acquired on habitat and distribution of other fish species.

Since 1977, a Federal-Provincial program (SEP) sponsored limnological surveys of several lakes with the goal of enhancing salmonid production, primarily sockeye (Stockner & Shortreed, 1978; Shortreed & Stockner, 1981; Costella, *et al.*, 1982, 1983a,b; Stephens & Stockner, 1983; Nidle *et al.*, 1984). Because stickleback as well as salmon can graze down enhanced zooplankton populations, these studies of necessity had to consider non-salmonids.

### Lacustrine Fish Species and Distribution

Collections in Queen Charlotte lakes have produced only 8 species of fish (4 families). This compares to 20 species (8 families) for Vancouver Island and 66 species (16 families) for mainland British Columbia (Carl *et al.*, 1959). All are anadromous or derived from anadromous populations. Obligate freshwater or introduced species have not been detected. Of 183 lakes sampled throughout the archipelago (Reimchen, unpub. data) representing approximately 80% of all potentially fish-inhabited lakes, the following species were found: threespine stickleback, 86 sites; Dolly Varden, 37 sites; coho salmon, 22 sites; cutthroat trout, 18 sites; prickly sculpin, 17 sites; rainbow trout, 13 sites; coastrange sculpin, 2 sites. The majority of ponds (<1 ha) in the Lowlands (not included in the previous total) lack fish as they are either temporary or do not have access streams.

Coho salmon juveniles (to 130 mm) are found in many low elevation lakes. Landlocked populations of kokanee occur in two lakes, Roy and Mosquito on the Plateau and Ranges respectively (K. Moore, pers. comm.; B.C. Fish and Wildlife Branch records). Sockeye salmon fry occur in most of the large lakes (9 sites; Marshall *et al.*, 1978a,b; Brown & Musgrave, 1979). Chum and pink salmon and brook lamprey may occur infrequently in some lakes. Chinook salmon may be present in Yakoun Lake.

Dolly Varden are widely distributed on the archipelago and are the only species found in higher elevation lakes (>200 m) or in lakes with high gradient outflow streams. It is unknown whether most of these populations are migratory or resident, but some certainly are not migratory.

Cutthroat trout occur in low elevation lakes from eastern and central regions of Graham and from north-eastern Moresby Islands. They would appear to be absent from lakes in west Graham and west and south-east Moresby Islands. Rainbow or subadult steelhead trout occur in lakes on western Graham and Moresby Islands. The species is sympatric with cutthroat trout in streams of this region (Ain, Yakoun, Mamin, Copper) yet they do not seem to co-exist within lakes.

Threespine stickleback are found in low elevation lakes on Graham, Moresby, Louise and Lyell islands. Sticklebacks are frequently the only species found in the small bog lakes. They are absent from Langara Island and from most lakes where steep gradients occur on outflow streams. Stickleback are the major prey item of cutthroat trout in some lakes (Moodie, 1972a; Reimchen, 1983) and also the major prey of avian piscivores such as loons (*Gavia*), grebes (*Podiceps*) and kingfisher (*Ceryle*) (Reimchen, 1980, 1988; Reimchen & Douglas, 1980, 1984a).

Prickly sculpin are common in Graham Island lakes but infrequent in those of Moresby Island. The coastrange sculpin has been found in only 2 lakes, both from south-east Moresby Island.

### Biological Research on Lake Fishes

Evolutionary studies on the threespine stickleback have provided a central theme for research on Queen Charlotte Islands lakes. Moodie (1972a,b) examined a "giant" form of black stickleback from Mayer Lake on eastern Graham Island. The fish are characterised by large body size (up to 116 mm), robust spines and extensive melanism. From both experimental and field data, Moodie was able to show that the black stickleback behaves as a distinct species to the typical form which inhabits adjacent streams, and that many of the divergent traits are adaptations to predators, principally cutthroat trout. While stickleback had been extensively collected and investigated in Europe (Wootton, 1976), this was one of the first studies to provide direct evidence for selection in a natural population of stickleback. Other giant black stickleback populations in the Lowlands have had an independent origin to that of the Mayer Lake form. One, occurring in the Sangan drainage and isolated from the Mayer Lake drainage, coexists in parapatry with a typical stream form and, as in Mayer Lake, the two forms act as separate species without any suggestion of hybridization (Stinson, 1983). Phenetic differentiation is as great between these overlapping populations as between geographically diverse allopatric populations in the region and as great as differences between marine and freshwater forms (Reimchen *et al.*, 1985).

Collections from other Queen Charlotte watersheds yielded additional distinct populations of stickleback, including those with loss of dorsal and pelvic spines and complete loss of lateral armour (Moodie & Reimchen, 1973; Reimchen, 1984; Reimchen *et al.*, 1985). These population differences, which occur over distances of a few kilometers, are exceptional in that they equal or exceed the variation found throughout the circumboreal distribution of the species. As with other archipelagos, this diversity provides a natural laboratory for examining function of morphological structures and evolutionary processes.

Samples obtained from throughout the Queen Charlotte Islands archipelago indicate that each case of extreme morphological divergence in stickleback occurs in the Lowlands of north-east Graham Island (Reimchen, 1984). These could reflect relic populations, since ice-free areas 16,000 yr B.P. have been detected on the eastern edge of the Lowlands (Warner *et al.*, 1982). Moodie and Reimchen (1976b) have discounted the direct relevance of refugia to endemism in these fish populations. Not only are divergent characters a response to local selective regimes, but more relevantly, comparable populations of stickleback are found in disjunct localities of post-Wisconsin origin on Vancouver Island, Alaska and the Outer Hebrides. Some of these conclusions may be incorrect since in recent analyses of stickleback mitochondrial DNA (Gach & Reimchen, 1989), allopatric freshwater populations from Graham Island were found to be more closely related to each other than they are to their assumed marine ancestor. Gach and Reimchen (1989) suggest the presence of periglacial freshwater habitats which would allow survival of a freshwater stickleback during the glacial advance. A more extensive DNA analysis of the Queen Charlotte stickleback populations is currently underway to test several of these hypotheses (O'Reilly & Reimchen, in prep.).

Preliminary examination of parasites from freshwater fishes on the Islands indicates differences from mainland British Columbia. An intestinal cestode, *Cyathocephalus truncatus*, has been detected in some 14 populations of stickleback with an infection rate reaching 60% in some populations (Reimchen, 1982). This pathogenic parasite normally has salmonids rather than stickleback as its definitive host and was previously thought to be rare in British Columbia. An unknown species of parasitic dinoflagellate has been found in a small bog pond on the north-eastern region of Graham Island, in which the autotrophic cyst, rather than the typical parasitic trophont, is the major infective stage found on the stickleback (Reimchen & Buckland-Nicks, in press). This provides further evidence for novel characteristics in the parasite fauna and emphasizes the need for further parasitological research in these insular lake habitats.

Current research at Drizzle Lake in north-east Graham Island has begun to examine prey consumption and foraging behaviour of piscivores in an effort to document all sources of mortality in resident fish populations. This 114 ha lake includes resident populations of stickleback, Dolly Varden, cutthroat trout and coho fry as well as a November immigration of anadromous Dolly Varden, cutthroat trout and coho salmon (Reimchen, unpub. data). Apart from the salmonids, 18 piscivorous species have been observed in the lake including 14 birds, 1 mammal, 2 odonates and 1 coleopteran. Estimates of total yearly consumption of fish by avian piscivores ranged from 0.26-0.51 $g \cdot m^{-2} \cdot yr^{-1}$ of which stickleback represented the major prey item and Common Loon (*Gavia immer*) and Red-necked Grebe (*Podiceps grisegena*) the major predators (Reimchen & Douglas, 1984a).

Yet the Red-throated Loon (*G. stellata*) which is the most common nesting piscivore on Queen Charlotte lakes, including Drizzle Lake (Reimchen & Douglas, 1980; Douglas & Reimchen, 1988), shows a very different pattern of fish predation. While there appears to be an abundance of small salmonids and stickleback in the nesting territory, greater than 99% of the prey brought to prefledged young by the adults are marine fish (Reimchen & Douglas, 1984b). The most common species brought to the lake following extended foraging flights were sea perch (*Cymatogaster aggregata*), Pacific sand lance (*Ammodytes hexapterus*), snake prickleback (*Lumpenus sagitta*) and "herring-type". Since loon chicks are fed throughout the 50 day prefledging period, some 1,000 fish are transported to the lake each successful breeding season. The evolutionary interpretation of this unusual foraging behaviour is obscure but may in part be related to avoidance of freshwater fish parasites which utilize birds as a final host or perhaps to increased nutrient value of marine fish.

## Impact of Man on Lake Fishes

Until recently, Queen Charlotte Island lakes have not incurred major alteration from industrial or recreational use. To the present, the lakes are free of exotic fish species, hydro-electric dams, and cultural eutrophication. While there has been extensive deforestation of watersheds, the impact on lakes is not known. There are no commercial lake fisheries and, until recently, only limited sport fishing. Native peoples utilized marine resources and would appear to have had little effect on fish stocks resident in freshwater.

A recent and possibly significant perturbation of lake habitats has occurred following the introduction of beaver (*Castor canadensis*) to the Queen Charlotte Islands. Beaver were initially released on eastern Graham Island in 1950 and have expanded their range to occupy many watersheds on Graham Island (Reimchen, unpub. data). Most Lowland lakes and ponds had stable littoral areas with substrates of sand and gravel. The majority of small lakes on Graham Island now have beaver dams and are surrounded by a wide fringe of submerged bog or dead trees extending up to 50 m back from historical shorelines. The result is a major accumulation of organics over the substrate, reduced light penetration from increased staining, and reduction of aquatic macrophytes. The cumulative effect of these changes on fish populations is unknown.

## Future Prospects

There are a number of biological problems on lakes and their fishes which merit investigation. Many lakes, which presently lack fish, and may have been continously free of fish in post-glacial periods, could yield unusual planktonic taxa or phenetic differentiation as observed in stickleback. As population pressures and development proceed, it seems unlikely that such lakes will remain free of fish introduction which could greatly alter a possibly indigenous invertebrate assemblage.

A recent interest in commercial stocks of salmon on the Queen Charlotte Islands has resulted in construction of hatcheries on both major and minor streams, stocking of lakes with hatchery reared fry, removal of natural barriers such as falls and enhancing primary productivity through aerial release of fertilizers. Each of these practices could lead to increased stocks of some species and reduction or loss of others as well as changes in interactions between species. They certainly increase the difficulty of interpreting behavioral, ecological and biochemical variability which exist in undisturbed populations of salmonids, information which may become more relevant as natural stocks are displaced with hatchery production. Efforts should be given to establishing the extent of phenotypic and genotypic differentiation within and between watersheds. Comparable studies with stickleback on the Queen Charlotte Islands archipelago have demonstrated that population differences are frequently the product of adaptation to selective pressures which went unrecognized until recently. It would seem prudent to identify whether existing variability in salmonids has a comparable interpretation.

## Concluding Comments

Despite the scattered and sporadic nature of studies over about a century on Queen Charlotte Islands fishes, a substantial body of work has been accomplished there, especially in recent years, and promising lines for further new research have been suggested. But clearly, there are warnings which should concern all of us. Strong indications of serious decline in Queen Charlotte Islands salmon stocks are appearing along with alarming evidence of their extinction in small streams. Several examples of unique fish stocks, especially in inland waters, have been documented. These need to be guarded and preserved as well as studied and perhaps, where appropriate, utilized. Enhancement programs for salmonids should take particular cognizance of such stocks. On the other hand, there are encouraging signs that with careful study and innovative approaches at least some negative effects of exploitation of fish and their varied habitats may be minimized in waters and watersheds of the Queen Charlotte Islands.

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