Pelagic Seabird Populations in Hecate Strait and Queen Charlotte Sound: Comparison with the West Coast of the Queen Charlotte Islands

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PELAGIC SEABIRD POPULATIONS IN HECATE STRAIT AND QUEEN CHARLOTTE SOUND: COMPARISON WITH THE WEST COAST OF THE QUEEN CHARLOTTE ISLANDS

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ABSTRACT

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Marine bird surveys were conducted from oceanographic vessels in Hecate Strait and Queen Charlotte Sound and off the west coast of the Queen Charlotte Islands during 7 months: May 1982; May, June, July and September 1983; and January and April 1984. Pelagic bird densities in the Strait and Sound ranged from 2 birds/km^2 in January, to 7 in April, 58 in May 1982, 170 in May 1983, 6 in June, 3 in July and 2 in September. Significant correlations between seabird density and waterdepth were found. The standing stock of pelagic birds in the Strait and Sound in May was estimated in the millions of birds, of which most were alcids and shearwaters. Recommendations are made to conduct systematic and random surveys simultaneously; to investigate the preferred feeding localities and diet of key bird species, and the life cycle of major prey species.

Key words: marine birds, Hecate Strait, Queen Charlotte Sound, west coast of the Queen Charlotte Islands.

RÉSUMÉ

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Des inventaires d'oiseaux de mer ont été effectués a partir de navires océanographiques dans les détroits d'Hécate et de Reine-Charlotte ainsi qu'au large de la côte ouest des îles Reine-Charlotte. Les inventaires ont été faits au cours des mois de mai 1982, de mai, juin, juillet et septembre 1983 et de janvier et avril 1984. Les densités d'oiseaux pélagiques dans les détroits, en nombre d'oiseaux par km^2, étaient de 2 en janvier, de 7 en avril, et de 58 en mai 1982, de 170 en mai 1983, de 6 en juin, de 3 en juillet et de 2 en septembre. On a noté des correlations significatives entre la densité des oiseaux de mer et la profondeur des eaux. La population totale d'oiseaux pélagiques des détroits en mai a été estimée a plusieurs millions d'individus, elle était surtout représentée par des alcidés et des puffins. On recommande d'effectuer simultanement des inventaires systématiques et aléatoires et d'étudier les lieux d'alimentation préférés et le régime alimentaire d'espèces d'oiseaux clés, de même que le cycle de vie des principales espèces prédatrices.

Mots-clés: oiseaux de mer, détroit d'Hécate, détroit de Reine-Charlotte, côte ouest des îles Reine-Charlotte.

INTRODUCTION

More than one million seabirds nest along the perimeters of Hecate Strait and Queen Charlotte Sound (hereinafter called Strait and Sound - Fig. 1) while tens of thousands of waterbirds annually visit its open shores, bays and inlets (Vermeer et al. 1983). Although there is some information on the population of seabird species nesting and feeding along the shoreline, little is known of the pelagic seabird populations of the region. Savard (1979) conducted a few surveys across Hecate Strait in winter; he observed gulls and scoters to be the most numerous species. Because of the scarcity of data, shipboard surveys of pelagic seabirds were carried out in the Strait and Sound in 1982, 1983 and 1984. For comparative purposes surveys were also conducted on the west coast of the Queen Charlotte Islands (hereafter called west coast - Fig. 1). A major incentive for conducting these post-1981 surveys is the possibility that drilling for offshore gas and oil may take place in these areas. Oil spillage poses a more serious threat to seabirds than to other marine organisms, and has already claimed hundreds of thousands of bird victims on the world's oceans (e.g. see Vermeer and Vermeer 1975).

The Strait and Sound form the largest semi-sheltered portion of the Continental Shelf on the British Columbia coast (Fig. 1). The region is well defined by a surrounding land mass, and its configuration facilitated in delineating its use by pelagic seabird populations. We have determined the densities and standing stock of seabirds in the Strait and Sound over the different seasons by applying the same methods that Sanger (1972) used to determine those parameters in the open subarctic Pacific region.

DESCRIPTION OF AREA

Aspects of the oceanography of the Strait and Sound have been described by various oceanographers (e.g. Barber and Tabata 1954, Barber 1957a, b, Barber 1958 a, b, Dodimead, 1980 and Thomson, 1980).

Bathymetry. Of the Strait and Sound area, the Strait is the shallowest and least exposed portion and has the most regular bathymetry (Fig. 1). The axis of the Strait is a narrow, 220 km long submarine valley that hugs the mainland coast, with depths ranging from about 150 fathoms in the south to about 25 fathoms in the north (Fig. 1). The Sound has a more complex bathymetry than the Strait and is marked by several broad troughs slicing inland across the Shelf (Fig. 1). Its eastern side is completely exposed to the Pacific Ocean (Fig. 1).

Salinity and temperature. The surface salinity of the Strait and Sound ranges from 28 to 32°/oo, with maximal values in winter and minimal values in summer (Thomson 1980). Average sea surface temperatures vary from 6°C in April to around 14°C in August. Solar heating of the region is modified by wind driven currents in summer and warm water in winter.

Wind and waves. Prevailing winds are from the northwest in summer and from the southeast in winter and are channeled by the mainland mountain range. Mean winds in the summer range from 5.5 m/s at the seaward approaches to 4 m/s near the mainland coast. In October winds strongly increase and throughout the winter wind speeds vary from 10 m/s at the western to about 7.5 m/s along the mainland side (Thomson 1980).

The Sound and the southern end of the Strait are especially vulnerable to deep-sea waves from the southwest. Wave conditions are most severe in autumn and winter, when wave heights in excess of 3.5m occur, and mildest in spring and summer.

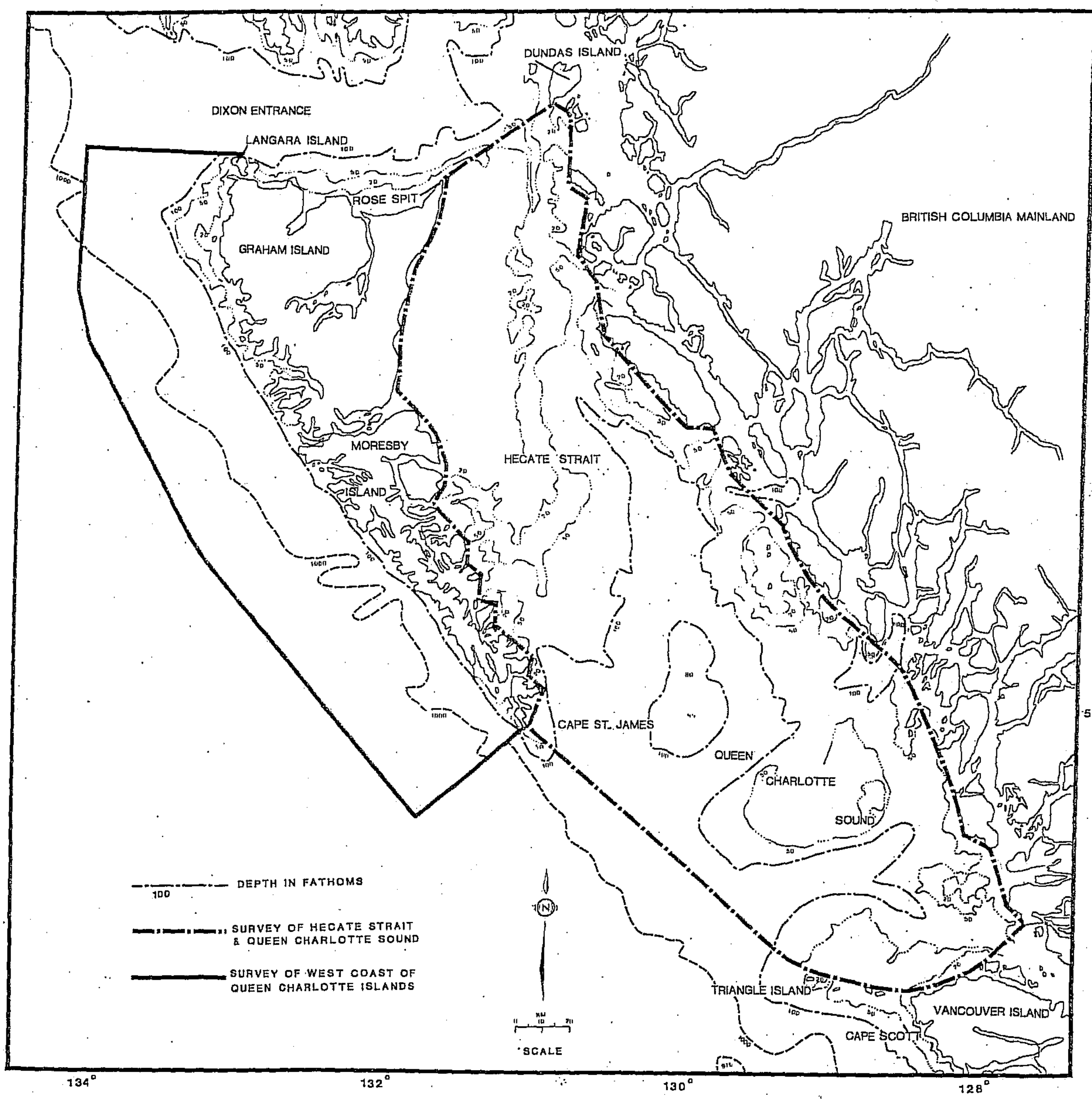

Figure 1. Survey regions of marine birds in Hecate Strait and Queen Charlotte Sound and on the west coast of the Queen Charlotte Islands.

METHODS

Area surveyed. The Strait and Sound region surveyed for pelagic seabirds encompasses 42,500 km^2. The northern boundary extended from Rose Spit to Dundas Island at a 50^o bearing. The southwestern limit is delineated by a line from Cape Scott at the north end of Vancouver Island to Cape St. James (Fig. 1). Coastal bays and fjords are excluded from the area as they are not generally frequented by pelagic seabirds. An area off the west coast of the Queen Charlotte Islands was also surveyed for comparative purposes, and ranged from Langara Island in the north to Cape St. James in the south. This latter area extends 65 km seaward from the coast and encompasses 22,050 km^2 (Fig. 1). A planimeter was used to calculate the areas of the two regions surveyed.

Transects at sea. Observational methods were essentially those used by Sanger (1972). Transects were carried out only when the ship was travelling forward during daylight. The bridge of the ship served as the point of observation. Generally, the sea was scanned with 7x35 binoculars in a 180^o "field" centered on the ship's bow and to the right and left. However, if the observer faced strong sunlight, a 180^o field was scanned with the sun at his or her back. Birds which approached and followed the ship, such as _Larus_ spp. and _Diomedea nigripes_, were counted only once and instantaneously, for each transect, except where three consecutive transects were surveyed, ship followers were counted once. Birds within 1 km of the mainland were not recorded. The species and number of all birds viewed during transects were recorded. Unidentified birds as well as birds only identified to genus were also noted. Estimations were made for numbers of birds in large flocks as they were difficult to count. No differentiations were made between flying and swimming birds. Tasker _et al_. (1984) suggest an instantaneous count of flying birds to remove bias in the overestimation of their relative abundance due to their movement. The location of the vessel at the beginning and at the end of each transect was recorded, as were distance travelled, direction of travel and the speed and direction of the wind.

Transects were generally conducted for half-hour periods, but this sometimes varied. The research vessels were involved with other oceanographic work, which created a series of random transects over which the observers had no control. Transects were carried out whenever ship movements and weather permitted.

Observations were carried out during May 1982, May, June, July and September 1983, and January and April 1984 along transects shown in the Appendix. Three research vessels, the CSS Parizeau, M.V. Pandora II, and G.B. Reed were involved, and each vessel carried one observer. Four different observers contributed to the surveys. The total linear distance covered during the survey transects was 4185 km.

Calculation of density and standing stock. Seabird density in the Strait and Sound was calculated with the aid of the formula:

$$D = N/2RL$$

where,

D = density of seabirds in the area

N = total number of birds observed along all transects

L = total length of all transects, ie. the total distance the ship travelled along all transects

R = effective visual range, the maximum estimated distance perpendicular to the path of ship travel that a species can be seen and identified; the factor 2 enters because birds are observed on both sides of the ship.

The standing stock of seabirds is defined as the total calculated population of an area during a particular survey period. The standing stock of seabirds in the Strait and Sound was calculated by multiplying seabird density (D) by the area of the region in km^2. Sanger (1972) accorded an R of 3.7 km for albatrosses because they are attracted to ships from relatively large distances. The size, visibility and flight behaviour of a species determined its visual range. The R's used during our surveys are shown for the different bird categories in Table 1. We reduced the R's for alcids, storm-petrels, and phalaropes from those given by Sanger (1972), as we found them to be appreciably smaller than those observed by Sanger. Dixon (1977), Wiens *et al*. (1978) and Briggs *et al*. (1981) also reported that inconspicuous and small species are not adequately counted at distances exceeding 100 to 180m from a ship.

Table 1. Effective visual range (R) used for calculating standing stock of seabirds in Hecate Strait and Queen Charlotte Sound (observation height 13.2m, Sanger 1972).

Bird categories	R (km)
Gaviidae	0.9
Diomedeidae	3.7
Procellariidae	0.9
Hydrobatidae	0.2
Phalacrocoracidae	0.9
Anseriformes	0.9
Scolopacidae	0.1
Laridae	
Large gulls	0.9
Small gulls	0.6
Alcidae	
Large alcids (*Uria* sp.)	0.6
Medium alcids (*Fratercula*, *Cerorhinca*, and *Cepphus* spp.)	0.4
Small alcids (*Synthliboramphus* and *Brachyramphus* spp.	0.2
Ptychoramphus aleuticus	0.1

Table 2. Number of marine birds observed along transects in Hecate Strait and Queen Charlotte Sound.

Bird categories	Jan. 12-14, 17-19,25, 1984	Apr.10-14 25, 1984	May 19-31, 1982	May 3,8-18 1983	June 8-21 1983	July 5-10, 14-16, 1983	Sept. 7-8, 18-28, 1983
Gaviidae (loons)	90	31	91	246	39	2	57
Diomedeidae (all Black-footed Albatross)	8	3	206	39	40	49	3
Procellariidae							
Shearwaters (mostly Sooty)	3	531	3,978	111,437	3,129	618	1,564
Northern Fulmar	2	0	228	38	10	41	58
Hydrobatidae							
Fork-tailed Storm-Petrel	0	32	560	253	245	244	45
Leach's Storm-Petrel	0	0	167	193	23	16	10
Phalacrocoracidae (cormorants)	41	112	34	26	6	0	35
Anseriformes (mostly White-winged Scoters)	89	1616	65	2,416	0	1	329
Scolopacidae (mostly phalaropes)	0	0	1,007	76	0	8	14
Laridae							
Glaucous-winged Gull	44	108	110	113	91	15	6
Herring and Thayer's Gull	94	400	72	486	433	29	877
Black-legged Kittiwake	0	1	30	196	4	0	216
Unid. large gulls	19	164	6	9	67	78	78
Misc. larids and stercorarids	8	0	9	7	8	1	6
Alcidae							
Common Murre	105	134	167	1,082	159	180	545
Thick-billed Murre	97	0	1	0	0	0	0
Rhinoceros Auklet	0	212	805	453	340	184	4
Ancient Murrelet	24	568	2,268	1,582	308	9	0
Cassin's Auklet	10	68	3,698	236	12	15	0
Unid. and misc. alcids	124	97	149	68	95	35	12
Unid. and misc. birds	0	6	0	0	53	5	3
Total number of birds	758	4,083	13,651	118,956	5,062	1,530	3,862
Total length of transects (km)	463.1	425.6	649.2	739.0	640.4	378.8	889.2
Average number of birds per km of transect	1.6	9.6	21.0	161.0	7.9	4.0	4.3

RESULTS AND DISCUSSION

1. Numbers of birds observed

Loons. Four species of loons, the Common Loon (Gavia immer), Arctic Loon (G. arctica), Yellow-billed Loon (G. adamsii), and Red-throated Loon (G. stellata), were observed. Loons were most numerous in the Strait and Sound in May (Table 2). Of 337 loons seen in May 1982 and 1983, 55% were Arctic, 37% Common, 4% Yellow-billed, 2% Red-throated and 2% unidentified loons (Table 3). The Arctic Loon, which was most numerous, migrates in spring by the tens of thousands along the west coast of Vancouver Island to its nesting grounds in Alaska and northern Canada (Vermeer and Vermeer 1975). Arctic Loons still made up 84% of the identified loons seen in June, probably reflecting the "tail" of the spring migration as none were observed in July. The Common Loon was the most numerous identified loon in September and January (Table 3). Only two Common Loons were seen in June, and none in July; perhaps most of them had by June departed for their nesting grounds in the interior of western Canada and Alaska. Fewer loons were seen off the west coast compared to the numbers observed in the Strait and Sound (Table 4).

Table 3. Number of loons observed in Hecate Strait and Queen Charlotte Sound.

Month Year	Common Loons	Arctic Loons	Red-throated Loons	Yellow-billed Loons	Unidentified loons
January 1984	24	0	4	0	62
April 1984	8	8	2	3	10
May 1982	43	36	8	0	4
May 1983	80	149	0	13	4
June 1983	2	27	0	3	7
July 1983	0	0	0	0	1
September 1983	28	0	0	1	0
Total	185	220	14	20	88

Black-footed Albatross. Most Black-footed Albatrosses (Diomedea nigripes) in the Strait and Sound were seen in May 1982, while few were encountered there in September 1983 or in January and April, 1984 (Table 2). However, the Black-footed Albatross was still numerous along the west coast in both July and September (Table 4). All albatrosses observed in the Strait and Sound were the Black-footed variety while a few Laysan Albatrosses (Diomedea immutabilis) were encountered off the west coast.

Table 4. Numbers of marine birds observed off the west coast of the Queen Charlotte Islands, May-September 1983 and April 1984.

Bird categories	April 18-20, 22-25	May 3-7	July 11-14	Sept. 8-15
Gaviidae (loons)	1	4	0	5
Diomedeidae (mostly Black-footed Albatross	103	23	376	656
Procellariidae				
Shearwaters (mostly Sooty)	6,063	41,711	41	348
Northern Fulmar	6	26	182	31
Hydrobatidae				
Fork-tailed Storm-Petrel	1	0	21	0
Phalacrocoracidae (cormorants)	69	11	0	8
Anseriformes	27	0	0	0
Scolopacidae (phalaropes)	0	0	37	4
Laridae				
Glaucous-winged Gull	66	63	3	1
Herring and Thayer's Gulls	312	147	18	757
Black-legged Kittiwake	1	18	0	479
Unid. large gulls	32	9	12	80
Misc. larids and stercorarids	0	3	4	23
Alcidae				
Common Murre	47	10	3	3
Rhinoceros Auklet	227	330	113	6
Ancient Murrelet	168	329	31	0
Cassin's Auklet	570	149	470	6
Unid. and misc. alcids	131	44	114	77
Unid. and misc. birds	1	0	38	0
Total number of birds	7,825	42,877	1,463	2,484
Total lengths of transects (km)	506.2	251.8	368.1	403.1
Average number of birds per km of transect	15.5	170.3	4.0	6.2

Procellarids. Sooty Shearwaters (Puffinus griseus) were the most numerous seabirds observed in the Strait and Sound in May, June, July and September but were almost non-existent in January (Table 2). One flock of 90,000 Sooty Shearwaters was seen in the Strait during May 1983. Sooty Shearwaters breed in the southern hemisphere and spend their non-breeding season in subarctic waters, where they become the most abundant pelagic seabirds during the northern summer (Murphy 1967, Sanger 1972). The scarcity of shearwaters in January can therefore be explained in that most of them had left for their nesting grounds in SE Australia, New Zealand, Tasmania, and the southern portion of South America. Pale-footed (P. carneipes), Pink-footed (P. creatopus) and Short-tailed Shearwaters (P. tenuirostris) were also occasionally observed. Short-tailed Shearwaters are probably more abundant than are the other species, as it is difficult to distinguish Short-tailed from Sooty shearwaters which they closely resemble. Sooties were also by far the most numerous seabirds seen on the west coast (Table 4). The average number of Sooty Shearwaters per linear km was less in the Strait and Sound (145.4 birds/km) than on the west coast (165.9 birds/km).

Northern Fulmars (Fulmarus glacialis) were most numerous in May in the Sound and Strait (Table 2), but on the west coast they were most numerous in July. The Northern Fulmar is a prolific breeder in Alaska (estimated population: two million, Sowls et al. 1978), but has not yet been reported to nest in British Columbia, although nesting is suspected on Triangle Island (Vermeer et al. 1976).

Storm-petrels. The Fork-tailed Storm-petrel (Oceanodroma furcata) and the Leach's Storm-petrel (O. leucorhoa) were observed in the Strait and Sound (Table 2). The Fork-tailed Storm-petrel was more frequently seen than the Leach's Storm-petrel. In January no storm-petrels were observed, while in April only Fork-tailed Storm-petrels were sighted. In May, June, July and September 1983, 69%, 91%, 94% and 82% of the storm-petrels counted, respectively, were Fork-tails. All others were Leach's Storm-petrels. No Leach's Storm-petrels were observed in the Strait and Sound on or over waters less than 50 fathoms deep. Leach's Storm-petrels in the Sound were observed an average distance of 49 km from shore. Martin and Myres (1969) also seldom observed Leach's Storm-petrel close to shore. On the west coast only 22 Fork-tailed Storm-petrels were sighted, all but one in July (Table 4). No Leach's Storm-petrels were seen on the west coast perhaps because relatively few transects were located offshore where those birds are usually observed. Both Leach's and Fork-tailed Storm-petrels nest in large numbers along the west coast (Campbell and Garrioch 1979, Vermeer et al. 1983).

Cormorants. Cormorants occurred in low numbers in the Strait and Sound as well as on the west coast (Tables 2, 4), which is not surprising as those birds prefer shoreline habitat (Vermeer et al. 1983). Of a total of 254 cormorants observed in the Strait and Sound, 63% were Pelagic (Phalacrocorax pelagicus), 15% Double-crested (P. auritus), 1% Brandt's (P. penicillatus) and 21% were unidentified cormorants. The Pelagic Cormorant is the most numerous nesting cormorant along the whole length of the British Columbia coast, while Double-crested Cormorants nest only in the Strait of Georgia (Vermeer et al. 1983). There are a few small nesting colonies of Brandt's Cormorants along the west coast of Vancouver Island (Vermeer et al. 1983), perhaps explaining the small number of that species observed. Most Brandt's Cormorants nest in California (Ainley and Lewis 1972, Sowls et al. 1980). On the west coast 87 of the 88 cormorants sighted were Pelagic Cormorants while the remaining individual was a Double-crested Cormorant.

White-winged Scoters. The White-winged Scoter (Melanitta fusca deglandi) made up more than half Anseriformes species observed in the Strait and Sound (Table 2). Almost all of the scoters were seen over shallow waters of the Strait. Although occurring in fair numbers in those waters, White-winged Scoters are more numerous directly along the shorelines, and are the most abundant seaducks occurring along the eastern shores of Graham Island and northeastern portion of Moresby Island in autumn (Vermeer et al. 1983). Only one White-winged Scoter was seen in the Strait in June and July (Table 2) reflecting the departure of the scoters to their interior nesting grounds (Vermeer 1969, Brown 1981). Other Anseriformes observed in the Strait were Brant (Branta bernicla), Canada Geese (B. canadensis), Surf Scoters (Melanitta perspicillata), Black Scoters (M. nigra), Oldsquaws (Clangula hyemalis), Harlequin Ducks (Histrionicus histrionicus), American Wigeon (Anas americana), Northern Pintails (A. acuta), Northern Shovelers (A. clypaeta) and Mallards (A. platyrhynchos).

Phalaropes and sandpipers. The vast majority of phalaropes in the Strait and Sound were observed in May, particularly in 1982 (Table 2). Most of the phalaropes seen were Red-necked Phalaropes (Phalaropus lobatus). Of a total of 1007 phalaropes observed there, 92% were Red-necked, 7% Red (P. fulicaria) and 1% were unidentified phalaropes. Of 41 phalaropes sighted on the west coast, 20 were identified as Red-necked and 3 as Red Phalaropes. Both Red-necked and Red Phalaropes breed in Arctic regions, and the large numbers seen in May are spring migrants. Dunlin (Caladris alpina), Black Turnstones (Arenaria melanocephala) and unidentified sandpipers were also observed.

Gulls. Glaucous-winged Gulls (Larus glaucescens) were numerous in May, but thereafter their numbers declined (Tables 2, 4). This decline is correlated with the gulls departure for their breeding colonies, where they remain until late August. After August they disperse again (Vermeer 1963). These are the only gulls which breed on islands in marine waters of British Columbia (Drent and Guiguet 1961, Vermeer et al. 1983). The Herring Gull (Larus argentatus) nests on lakes in the interior of western Canada and Alaska, while Thayer's Gull (Larus thayeri) nests in the western arctic portion of North America (Godfrey 1966). Herring and Thayer's gulls were more abundant than Glaucous-winged Gulls in pelagic waters of both the Strait and Sound (except May 1982) and the west coast. Perhaps Herring and Thayer's gulls migrate further offshore than Glaucous-winged Gulls in spring. The number of Herring and Thayer's gulls were unfortunately combined for the May-July period, but were recorded separately in September and January. Of the 877 Herring and Thayer's gulls observed in the Strait and Sound in September, 60% were Herring and 40% Thayer's gulls, and of the 94 gulls in January 71% were Herring and 29% Thayer's gulls. Herring and Thayer's gulls were most numerous in September while Glaucous-winged Gulls were then at their lowest numbers (Tables 2, 4). The post-breeding dispersal of the first two gull species is more offshore than that of the Glaucous-winged Gull which in autumn is mainly an inshore inhabitant (Butler et al. 1980, Vermeer 1983).

Black-legged Kittiwakes (Rissa tridactyla) were most abundant during September (Tables 2, 4). Kittiwakes breed in Alaska (Sowls et al. 1978) and their high numbers in September probably reflect post-breeding dispersal to southern areas. Their low numbers in June and July (Tables 2, 4) may reflect their departure for the nesting grounds. The miscellaneous larids include

Sabine's Gulls (Xema sabini) which migrate offshore along British Columbia to and from their nesting colonies in the Arctic (Guiguet (1974). Sabine's Gulls were seen in small numbers in May, June, July and September. Their closest sighting to land was 34km. Other larids seen were Bonaparte's Gulls (Larus philadelphia), Mew Gulls (L. canus), Glaucous Gulls (L. hyperboreus), California Gulls (L. californicus) and Arctic Terns (Sterna paradisaea).

Stercorarids. Four species of stercorarids, Long-tailed (Stercorarius longicaudus), Pomarine (S. pomarinus) and Parasitic (S. parasiticus) jaegers, and the Great Skua (Catharacta skua) were observed (Tables 2 and 4). Jaegers migrate to and from colonies in the Arctic tundra while skuas are non-breeding visitors to coastal waters (Godfrey 1966). Stercorarids were specifically seen in May, June, July and September, but 75% of the sightings occurred in the last month, which agrees with Guiguet's (1957) who reports that jaegers were most numerous in fall. Sixty-nine percent of the stercorarid sightings were on the west coast, while the remainder was seen in the Strait and Sound. Their average distance from land was 27km. Pomarine and parasitic jaegers were seen in equal numbers (9 each), while Long-tailed Jaegers were sighted twice.

Alcids. Common Murres (Uria aalge) were numerous in the Strait and Sound in all seasons (Table 2), while only small numbers were encountered on the west coast (Table 4), this may indicate a preference for the Shelf, rather than for the deeper waters on the west coast. Common Murres peaked in May 1983, probably reflecting spring migration to Alaska where they breed in the millions (Sowls et al. 1978). Only a few thousand pairs nest in British Columbia (Vermeer et al. 1983). Thick-billed Murre (Uria lomvia) numbers of any consequence were seen only in the Strait and Sound, in January. Since relatively few birds of this species breed on Triangle Island, northern Vancouver Island (Vallee and Cannings 1983), most Thick-billed Murres are thought to be visitors from Alaska where, like the Common Murres, they nest in the millions (Sowls et al. 1978).

Rhinoceros Auklets (Cerorhinca monocerata) were most abundant in May, and still occurred in fair numbers in June and July, but by September their numbers declined drastically (Tables 2, 4). Rhinoceros Auklets are numerous breeders in British Columbia and depart from their colonies in late August (Vermeer 1979) for more southern waters, which may explain their low numbers in September.

Ancient Murrelets (Synthliboramphus antiquus) and Cassin's Auklets (Ptychoramphus aleuticus) are the most numerous nesting seabirds in British Columbia (Vermeer et al. 1983). Ancient Murrelets were abundant in May, after which their numbers declined in both the Strait and Sound (Tables 2, 4). At the beginning of June murrelets start to disperse to offshore waters on the west coast (Vermeer et al. 1984), which may explain their less frequent sighting in summer. Cassin's Auklets in the Strait and Sound were also numerous in May (Table 2) after which their numbers declined similar to those of Ancient Murrelets. The largest colonies of Cassin's Auklets are found on the outer west coast of British Columbia (Vermeer et al. 1979), which may explain why auklets still were seen there in relatively large numbers in July (Table 4). Cassin's Auklets depart from their colonies about one month later than Ancient Murrelets. They forage mostly over seamounts and, like Ancient Murrelets, on the shelf break (Vermeer et al., in press).

The miscellaneous alcids included in Tables 2 and 4 were Tufted Puffins (*Fratercula cirrhata*), Marbled Murrelets (*Brachyramphus marmoratus*), Pigeon Guillemots (*Cepphus columba*) and a few Horned Puffins (*Fratercula corniculata*).

2. Bird occurrences and densities in relation to depth

Table 5 contrasts the occurrence of seabird species for waters less than and greater than 50 fathoms (90m) depth in the Strait and Sound. Loon, cormorant, White-winged Scoter and Common Murre occurrences were often significantly greater over waters shallower than 50 fathoms. This is not surprising since these birds, except Common Murres, are not considered to be truly pelagic inhabitants and are known to occur primarily in shallow inshore waters of British Columbia (Vermeer et al. 1983). The Common Murre is both an inshore and offshore forager in British Columbia (Vermeer 1983). It was surprising, however, that Sooty Shearwaters occurred mostly over waters less than 50 fathoms, although only once significantly so (June 1983), as that species is usually not seen near land. Sooty Shearwater numbers obtained on each transect were regressed on distance from shore, and on water depth. Only significant correlations between shearwater numbers and distance from land and water depth are shown in Table 6. Shearwaters significantly avoided deep water areas during spring and summer.

Black-footed Albatrosses, Leach's Storm-petrels, Ancient Murrelets and Cassin's Auklets often occurred significantly more over waters greater than 50 fathoms (Table 5). Black-footed Albatrosses and Leach's Storm-petrels are known to forage in deep and far offshore waters (eg. Kuroda 1960, Martin and Myres 1969, Sanger 1970, Vermeer et al. 1983), while large numbers of Ancient Murrelets and Cassin's Auklets have been seen foraging over the shelf break during the breeding season (Vermeer et al. in prep.). Tufted Puffins occurred at a significantly greater distance from land in the Strait and Sound (mean and 95% conf. int: 45.5±11.5km) than on the west coast (22.7±7.3 km), which perhaps relates to most puffin colonies being found on the west coast near greater water depths. There were no clearly consistent trends in bird occurrence in relation to water depth for the other species studied (Table 5). These species occurred in deep and shallow water at different times of year.

Loons, cormorants, White-winged Scoters and Common Murres generally had higher densities in waters less than 50 fathoms, while Black-footed Albatrosses, Leach's Storm-petrels, Ancient Murrelets and Cassin's Auklets were most numerous in waters over 50 fathoms (Table 7). Sooty Shearwater densities were generally greater in waters less than 50 fathoms. However, in May 1983, one flock of 90,000 birds was seen in waters of 80 fathoms, and produced a vastly higher density (8x) in waters over 50 fathoms (Table 7).

Table 5. Occurrence (%) of marine birds observed in relation to the 50 fathom (f.) contour in Hecate Strait and Queen Charlotte Sound, 1982-1984 (*significant $p<0.05$).

Bird categories	Jan. 1984 <50 f.	Jan. 1984 >50 f.	April 1984 <50 f.	April 1984 >50 f.	May 1982 <50 f.	May 1982 >50 f.	May 1983 <50 f.	May 1983 >50 f.	June 1983 <50 f.	June 1983 >50 f.	July 1983 <50 f.	July 1983 >50 f.	Sept. 1983 <50 f.	Sept. 1983 >50 f.
Gaviidae (loons)	75.0*	21.9	40.0	16.7	31.8	15.7	63.2	46.3	27.3	15.8	0	7.7	30.8*	9.5
Diomedeidae (all Black-footed Albatross)	0	15.6	0	11.1	13.6	62.7*	2.6	31.7*	4.5	28.9*	0	53.8*	0	7.1
Procellariidae														
Shearwaters (mostly Sooty)	8.3	6.3	70.0	38.9	95.5	84.3	92.1	90.2	79.5*	57.9	75.0	53.8	82.1	73.8
Northern Fulmar	0	6.3	0	0	45.4	39.2	7.9	39.0*	6.8	10.5	25.0	42.3	10.3	33.3*
Hydrobatidae														
Fork-tailed Storm-Petrel	0	0	20.0	33.3	95.5*	72.5	31.6	46.3	40.9*	10.5	25.0	76.9*	7.8	19.0*
Leach's Storm-Petrel	0	0	0	0	0	21.6*	0	17.1*	0	23.7*	0	23.1	0	9.5*
Phalacrocoracidae (cormorants)	58.3*	9.4	40.0*	5.6	18.2*	7.8	26.3*	2.4	4.5	5.3	0	0	12.8	7.1
Anseriformes (mostly White-winged Scoters)	25.0*	0	70.0*	16.7	4.5	11.8	52.6*	7.3	0	0	12.5	0	46.2*	11.9
Scolopacidae (mostly Phalaropes)	0	0	0	0	31.8	19.6	5.3	9.8	0	0	0	11.5	10.3	2.4
Laridae														
Glaucous-winged Gull	33.3	59.4	70.0	50.0	40.9	29.4	39.5	39.0	22.7	50.0*	12.5	26.9	0	9.5*
Herring and Thayer's Gulls	41.7	68.8	95.0*	55.6	31.8	37.3	89.5	95.1	61.4*	36.8	62.5	30.8	100*	88.1
Black-legged Kittiwake	0	0	0	5.6	18.2	13.7	55.3*	26.8	2.3	2.6	0	0	69.2*	40.5
Unid. large gulls	25	15.6	20.0	16.7	0	9.8	2.6	7.3	29.5	23.7	12.5	11.5	10.3*	0
Misc. larids and stercorarids	8.3	9.4	0	0	9.1	9.1	2.6	4.9	6.8	7.9	0	3.8	5.1	7.1
Alcidae														
Common Murre	83.3*	40.6	75.0*	22.2	63.6*	27.5	65.8*	24.4	54.5*	23.7	100.0*	34.6	56.4*	23.8
Thick-billed Murre	8.3	28.1	0	0	4.5	0	0	0	0	0	0	0	0	0
Rhinoceros Auklet	0	0	90.0	72.2	86.4	84.3	76.3	82.9	61.4	42.1	62.5	65.4	7.8	2.4
Ancient Murrelet	8.3	37.5	55.0	61.1	50	45.1	36.8	63.4*	13.6	23.7	0	11.5	0	0
Cassin's Auklet	0	12.5	15.0	66.6*	72.7	78.4	26.3	65.9*	13.6	10.5	12.5	30.8	0	0
Unid. and misc. alcids	41.7	34.4	60.0	33.3	18.2	37.3	28.9	29.2	45.4	42.1	87.5	50.0	12.8	9.5
Unid. and misc. birds	0	0	20.0	5.6%	0	0	0	0	18.2	15.8	37.5	0	0	0
Number of transects surveyed	12	32	20	18	22	51	38	41	44	38	8	26	39	42

Table 6. Regression equations for densities of Sooty Shearwaters in Hecate Strait and Queen Charlotte Sound and off the west coast of the Queen Charlotte Islands, where D=number of birds seen per transect, Dist=distance of transect centre from shore, and Depth=mean distance from water surface to seabottom.

Location	Observation period	p values	Regression equations	Coefficient of determination	Degrees of freedom (residual)
Strait, Sound	May 82	$p<0.005$	$D= 29{,}732(\text{Depth})^{-1.55}$	0.44, F=47.6	62
Strait, Sound	May 83	$p<0.05$	$D= 126.5\ (\text{Dist})^{1.08}\ (\text{Depth})^{-0.43}$	0.45, F= 3.6	73
Strait, Sound	June 83	$p<0.05$	$D= 8{,}778(\text{Depth})^{-1.63}$	0.46, F=47.2	55
Strait, Sound	July 83	$p<0.0005$	$D= 1{,}274(\text{Depth})^{-.099}$	0.57, F=23.4	18
West coast	May-Sept.83	$p<0.005$	$D= 83.9(\text{Dist})^{-0.84}$	0.18, F=16.4	76

Table 7. Observed bird density per 100km^2 in relation to the 50 fathom (f.) contour in Hecate Strait and Queen Charlotte Sound, 1982-1984.

Bird categories	Jan. 1984 <50f.	Jan. 1984 >50f.	April 1984 <50f.	April 1984 >50f.	May 1982 <50f.	May 1982 >50f.	May 1983 <50f.	May 1983 >50f.	June 1983 <50f.	June 1983 >50f.	July 1983 <50f.	July 1983 >50f.	Sept. 1983 <50f.	Sept. 1983 >50f.
Gaviidae (loons)	25.7	4.4	3.9	2.5	17.9	3.4	28.1	8.2	4.1	2.4	0	0.4	4.0	0.8
Diomedeidae (all Black-footed Albatross)	0	0.3	0	0.2	0.3	6.0	0.04	1.4	0.1	1.8	0	2.2	0	0.1
Procellariidae														
Shearwaters (mostly Sooty)	4.0	0.3	80.5	17.0	705.0	183.0	1,907.5	15,289.0	471.1	9.8	360.7	19.8	55.5	70.8
Northern Fulmar	0	0.3	0	0	7.4	2.5	0.8	5.1	0.5	1.4	1.4	7.2	0.7	6.9
Hydrobatidae														
Fork-tailed Storm-Petrel	0	0	9.1	27.8	216.0	215.5	60.9	111.9	60.6	141.7	34.9	194.1	2.5	20.9
Leach's Storm-Petrel	0	0	0	0	0	92.1	0	135.0	0	20.7	0	13.3	0	5.6
Phalacrocoracidae (cormorants)	13.3	1.4	18.4	0.9	7.1	1.1	2.3	1.6	0.5	0.6	0	0	3.6	0.6
Anseriformes (mostly White-winged Scoters)	35.8	0	204.6	125.3	7.1	4.9	349.9	1.9	0	0	0.7	0	21.6	5.1
Scolopacidae (mostly phalaropes)	0	0	0	0	1,855.0	309.8	9.2	96.6	0	0	0	13.3	13.8	1.1
Laridae														
Glaucous-winged Gull	6.4	4.8	14.2	7.4	8.5	9.8	7.3	9.8	7.0	9.0	0.7	2.6	0	0.8
Herring and Thayer's Gull	12.9	10.6	60.9	12.3	8.2	5.3	30.4	43.1	32.4	44.3	7.1	3.5	38.1	27.6
Black-legged Kittiwake	0	0	0	0.5	5.1	3.3	21.4	22.9	0.2	0.9	0	0	24.3	14.3
Unid. large gulls	4.8	1.2	27.2	0.9	0	0.7	0.4	0.9	6.6	4.8	52.9	0.6	9.8	0
Misc. larids and stercorarids	0.6	1.8	0	0	0.7	1.1	0.2	1.4	1.0	0.5	0	0.3	0.3	0.4
Alcidae														
Common Murre	20.5	18.2	30.4	6.5	50.2	9.0	222.7	14.5	32.1	5.7	165.2	6.7	46.4	5.4
Thick-billed Murre	6.0	22.3	0	0	0.4	0	0	0	0	0	0	0	0	0
Rhinoceros Auklet	0	0	81.9	35.4	127.1	167.0	57.3	97.3	56.1	79.8	182.7	28.7	0.9	0.3
Ancient Murrelet	7.2	15.4	264.0	306.9	232.5	1,149.9	252.8	836.8	53.0	208.3	0	7.5	0	0
Cassin's Auklet	0	20.0	12.2	166.7	1,160.0	3,576.6	40.6	286.8	11.0	7.2	12.7	21.7	0	0
Unid. and misc. alcids	34.4	80.8	50.2	19.4	24.9	43.3	14.0	14.3	37.5	25.7	34.9	11.3	3.1	2.0
Unid. and misc. birds	0	0	0.8	0.3	0	0	0	0	6.0	2.8	5.3	0	0	0.4
Total bird density	171.6	181.8	858.3	730.0	4,433.4	5,784.3	3,005.8	16,978.5	779.8	567.4	859.2	333.2	224.6	163.1

Table 8. Occurrence (%) of marine birds observed in Hecate Strait and Queen Charlotte Sound waters over 50 fathoms deep, and on the west coast of the Queen Charlotte Islands in May, July and September, 1983 and April 1984. Significantly different between Strait and Sound and west coast p<0.05.

Bird categories	Strait and Sound				West coast			
	April 10-14, 25	May 3, 8-18	July 5-10, 14-16	Sept. 7-8 18-28	April 18-20 22-25	May 3-7	July 11-14	Sept. 8-15
Gaviidae (loons)	16.7*	46.3*	7.7	9.5	2.0	7.4	0	5.1
Diomedeidae (all Black-footed Albatross)	11.1	31.7	53.8	7.1	52.0	51.9	55.9	82.1*
Procellariidae								
Shearwaters (mostly Sooty)	38.9	90.2	53.8	73.8	74.0	100	38.2	84.6
Northern Fulmar	0	39.0	42.3	33.3	6.0	51.9	88.2*	23.1
Hydrobatidae								
Fork-tailed Storm-Petrel	33.3*	46.3*	76.9*	19.0*	2.0	0	32.4	0
Leach's Storm-Petrel	0	17.1*	23.1*	9.5*	0	0	0	0
Phalacrocoracidae (cormorants)	5.6	2.4	0	7.1	4.0	7.4	0	5.1
Anseriformes	16.7	7.3	0	11.9*	6.0	0	0	0
Scolopacidae (phalaropes)	0	9.8	11.5	2.4	0	0	11.8	5.1
Laridae								
Glaucous-winged Gull	50.0	39.0	26.9	9.5	50.0	48.1	8.8	2.6
Herring and Thayer's Gulls	55.6	95.1	30.8	88.1	86.0	85.2	14.7	89.7
Black-legged Kittiwake	5.6	26.8	0	40.5	2.0	33.3	0	82.1*
Unid. large gulls	16.7	7.3	11.5	0	20.0	14.8	2.9	2.6
Misc. larids and stercorarids	0	4.9	3.8	7.1	0	7.4	11.8	30.8
Alcidae								
Common Murre	22.2	24.4	34.6*	23.8*	28.0	7.4	5.9	5.1
Rhinoceros Auklet	72.2	82.9*	65.4	2.4	72.0	55.6	67.6	7.7
Ancient Murrelet	61.1	63.4	11.5	0	42.0	74.1	26.5	0
Cassin's Auklet	66.6	65.9	30.8	0	68.0	48.1	55.9*	10.3*
Unid. and misc. alcids	33.3	29.2	50.0	9.5	66.0	40.7	61.8	56.4
Unid. and misc. birds	5.6	0	0	0	2.0	0	44.1	0
Number of transects	18	41	26	42	50	27	34	39

3. Comparisons with the west coast

The frequencies of sightings of birds over the Strait, Sound and off the west coast are compared for May, July and September 1983 and April 1984 in Table 8. The comparison for the Strait and Sound involves waters over 50 fathoms, in order to eliminate most birds showing a preference for shallow water foraging. Loons, Anseriformes, Common Murres and both species of storm-petrels were significantly more frequent in the Strait and Sound than on the west coast. This result was expected for the first three bird categories, since they frequently occur near land. Storm-petrels, however, are offshore foragers and it is interesting that they occurred more in the Strait and Sound than on the west coast. The Black-footed Albatross and Cassin's Auklet generally occurred more frequently on the west coast than in the Strait and Sound. Black-footed Albatross and Cassin's Auklet numbers found on each transect were regressed on distance from shore and water depth. Only significant correlations are shown in Table 9. Both species were significantly associated with deeper water.

Loons, Anseriformes, Common Murres and both species of storm-petrels were found in greater numbers in the Strait and Sound than on the west coast while the reverse was observed for Black-footed Albatrosses and Cassin's Auklets (Table 10). Densities of these birds therefore follow the same trend as their occurrences (cf. Tables 8 and 10). In addition, Ancient Murrelets were more numerous in the Strait and Sound, while Rhinoceros Auklets had higher densities on the west coast (Table 10).

Table 9. Regression equations for densities of Black-footed Albatrosses and Cassin's Auklets in Hecate Strait and Queen Charlotte Sound and off the west coast of the Queen Charlotte Islands, where D = number of birds seen per transect, and Depth = mean distance from water surface to seabottom.

Species, location	Observation period	p values	Regression equation	Coefficient of determination	Degrees of freedom (residual)
Black-footed Albatross					
West coast	May 1983	$p<0.005$	$D=0.74 + 0.001\ Depth$	0.53, F=13.3	12
Cassin's Auklet					
Strait, Sound	May 1983	$p<0.0005$	$D=0.94 + 0.35\ Depth$	0.29, F=15.6	38
West coast	July 1983	$p<0.005$	$D=0.018\ (Depth)^{0.82}$	0.42, F=12.3	17

Table 10. Observed bird density per 100 km^2 in Hecate Strait and Queen Charlotte Sound waters over 50 fathoms deep, and on the west coast of the Queen Charlotte Islands, May, July and September 1983 and April 1984.

	Strait and Sound				West Coast			
Bird categories	April 10-14,25	May 3, 8-18	July 5-10, 14-16	Sept. 7-8, 18-28	April 18-20 22-25	May 3-7	July 11-14	Sept. 8-15
Gaviidae (loons)	2.5	8.2	0.4	0.8	0.1	0.9	0	0.7
Diomedeidae (all Black-footed Albatross)	0.2	1.4	2.2	0.1	2.7	1.0	13.8	22.0
Procellariidae								
Shearwaters (mostly Sooty)	17.0	15,289.0	19.8	70.8	665.4	9,203.6	6.2	48.0
Northern Fulmar	0	5.1	7.2	6.9	0.7	6.0	27.5	4.3
Hydrobatidae								
Fork-tailed Storm-Petrel	27.8	111.9	194.1	20.9	0.5	0	14.3	0
Leach's Storm-Petrel	0	135.0	13.3	5.6		0	0	0
Phalacrocoracidae (cormorants)	0.9	1.6	0	0.6	7.6	2.4	0	1.1
Anseriformes	125.3	1.9	0	5.1	3.0	0	0	0
Scolopacidae (mostly phalaropes)	0	96.6	13.3	1.1	0	0	50.3	5.0
Laridae								
Glaucous-winged Gull	7.4	9.8	2.6	0.8	7.2	13.9	0.4	0.1
Herring and Thayer's Gul	12.3	43.1	3.5	27.6	34.2	32.4	2.7	104.3
Black-legged Kittiwake	0.5	22.9	0	14.3	0.2	5.9	0	99.0
Unid. large gulls	0.9	0.9	0.6	0	3.5	2.0	1.8	11.0
Misc. larids and stercorarids	0	1.4	0.3	0.4	0	0.7	0.5	3.4
Alcidae								
Common Murre	6.5	14.5	6.7	5.4	7.7	3.3	0.7	0.6
Rhinoceros Auklet	33.4	97.3	28.7	0.3	56.1	163.8	38.4	1.9
Ancient Murrelet	306.9	836.8	7.5	0	83.0	326.7	21.1	0
Cassin's Auklet	166.7	286.8	21.7	0	563.0	295.6	638.6	7.4
Unid. and misc. alcids	19.4	14.3	11.3	2.0	54.1	31.3	74.0	43.7
Unid. and misc. birds	0.3	0	0	0.4	0.1	0	5.7	0
Total bird density	728.0	16,880.3	333.2	163.2	1489.1	10,089.5	896.0	352.5

4. Standing stock

The overall standing stock of marine birds in the Strait and Sound increased from tens of thousands of birds in January to millions in May, and declined continuously thereafter to tens of thousands of birds again in September (Table 11). A similar trend for the standing stock of marine birds can be observed on the west coast (Table 12). Sooty Searwaters and alcids comprised most of the standing stock in the Strait and Sound, and on the west coast as well. The seasonal variation of the standing stock of the four major bird categories in the Strait and Sound and on the west coast is further shown in Fig. 2. Alcids made up most of the standing stock in May 1982, while Sooty Shearwaters did so in May 1983. This suggests major differences in standing-stock composition between years. Alternatively the timing of the spring migration of shearwaters may vary yearly which in turn could have resulted in observers "missing" most shearwaters in May 1982.

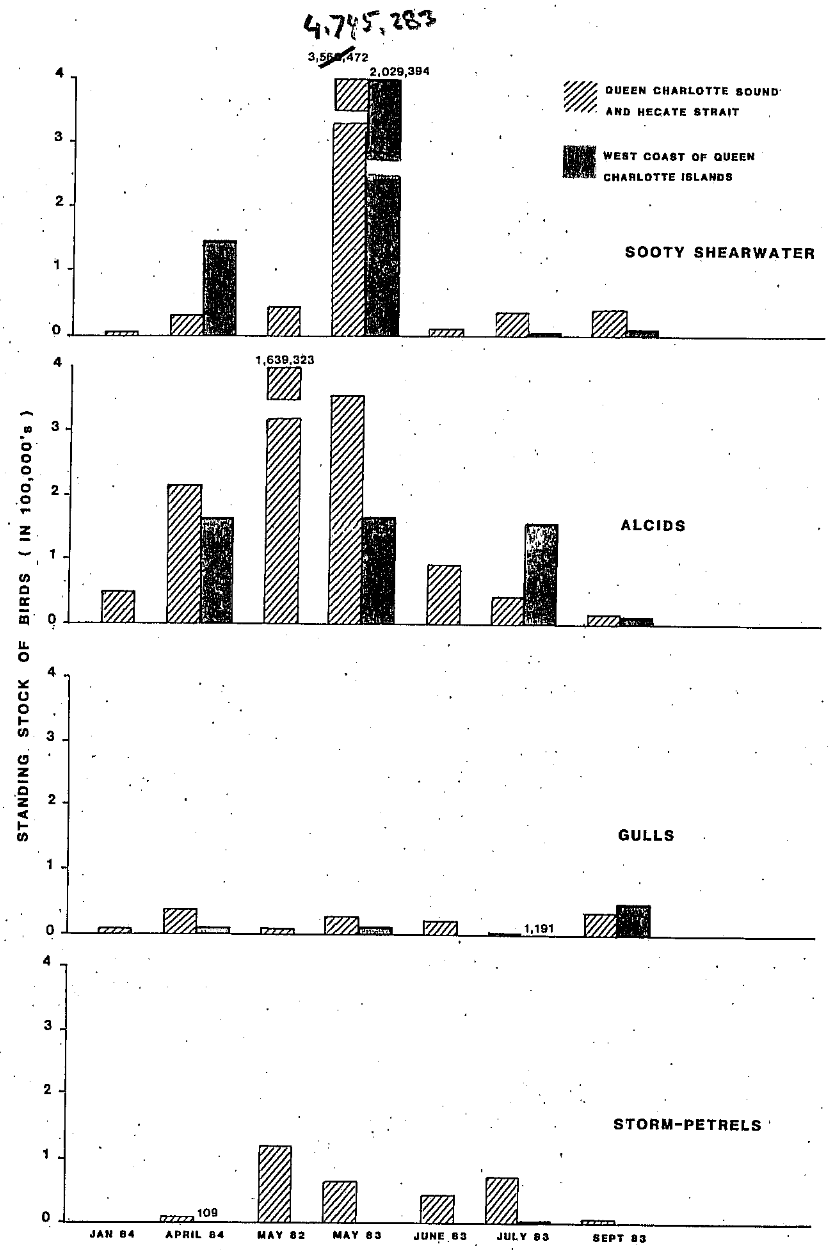

Figure 2. Seasonal variations in the standing stock of four major groups of birds in Hecate Strait and Queen Charlotte Sound and on the west coast of the Queen Charlotte Islands.

Table 11. Standing stock of marine birds in Hecate Strait and Queen Charlotte Sound.

Bird categories	Jan.12-14, 17-19, 25, 1984	April 10-14, 25, 1984	May 19-31, 1982	May 3, 8-18, 1983	June 8-21, 1983	July 5-10, 14-16, 1983	Sept.7-8, 18-28, 1983
Gaviidae (loons)	4,662	1,235	3,341	6,089	1,247	109	747
Diomedeidae (all Black-footed Albatross)	98	66	1,810	429	546	650	27
Procellariidae							
Shearwaters (mostly Sooty)	153	15,489	145,819	4,745,283	64,281	52,839	28,088
Northern Fulmar	101	0	8,255	1,607	473	2,312	2,121
Hydrobatidae							
Fork-tailed Storm-Petrel	0	9,376	91,652	40,929	49,621	61,755	6,472
Leach's Storm-Petrel	0	0	27,131	39,796	6,113	3,928	1,661
Phalacrocoracidae (cormorants)	2,132	2,674	1,250	761	237	0	657
Anseriformes (mostly White-winged Scoters)	4,662	63,585	2,369	46,142	0	92	4,330
Scolopacidae (phalaropes)	0	0	332,993	29,651	0	3,928	2,130
Laridae							
Glaucous-winged Gull	2,249	4,032	3,998	3,835	3,575	920	221
Herring and Thayer's Gull	4,800	11,569	2,625	16,657	17,278	1,957	13,081
Black-legged Kittiwake	0	136	1,641	9,524	296	0	7,369
Unid. large gulls	981	3,820	217	332	2,275	7,063	1,272
Misc. larids and stercorarids	608	0	418	409	278	82	165
Alcidae							
Common Murre	8,038	5,875	9,200	33,277	5,868	23,488	7,655
Thick-billed Murre	7,362	0	55	0	0	0	0
Rhinoceros Auklet	0	21,114	65,787	36,129	30,831	32,270	206
Ancient Murrelet	5,478	124,856	369,184	279,556	68,302	2,210	0
Cassin's Auklet	5,896	50,703	1,205,172	89,833	3,561	8,039	0
Unid. and misc. alcids	28,288	12,284	15,999	6,062	12,463	7,868	990
Unid. and misc. birds	0	201	0	0	1,604	690	111
Total standing stock	75,508	327,015	2,288,916	5,386,301	268,849	210,200	77,303

Table 12. Standing stock of marine birds off the west coast of the Queen Charlotte Islands, May-September 1983 and April 1984.

Bird categories	April 18-20, 22-25	May 3-7	July 11-14	Sept. 8-15
Gaviidae (loons)	24	198	0	152
Diomedeidae (mostly Black-footed Albatross)	606	221	3,043	4,849
Procellariidae				
Shearwaters (mostly Sooty)	146,724	2,029,394	1,367	10,575
Northern Fulmar	145	1,323	6,064	942
Hydrobatidae				
Fork-tailed Storm-Petrel	109	0	3,153	0
Phalacrocoracidae (cormorants)	1,670	529	0	243
Scolopacidae (phalaropes)	653	0	11,091	1,094
Laridae				
Glaucous-winged Gull	1,597	3,065	88	31
Herring and Thayer's Gull	7,550	7,144	595	23,005
Black-legged Kittiwake	36	1,301	0	21,834
Unid. large gulls	774	441	397	2,432
Misc. larids and stercorarids	0	154	110	745
Alcidae				
Common Murre	1,706	730	150	137
Rhinoceros Auklet	12,360	36,122	8,461	410
Ancient Murrelet	18,295	72,037	4,653	0
Cassin's Auklet	121,146	65,180	140,811	1,641
Unid. and misc. alcids	11,924	6,903	16,324	9,641
Unid. and misc. birds	24	0	1,257	0
Total standing stock	325,343	2,224,742	197,564	77,731

5. Comparison with pelagic bird distribution elsewhere in the North Pacific

Comparisons will be made for only some of the most important pelagic birds observed in this study. Since loons, cormorants and Anseriformes belong predominantly to the inshore fauna they will not be dealt with here.

Black-footed Albatross. The Black-footed Albatross was by far the most frequent albatross seen in British Columbia waters. It is also the dominant albatross off Washington, Oregon (Sanger 1972, T.R. Wahl pers. comm.), California (Miller 1940, Yocom 1947, McHugh 1955) and in the Gulf of Alaska (Kenyon 1950). The Laysan Albatross, which was occasionally seen in this study, has its main pelagic distribution in the northwestern Pacific (Robbins and Rice 1974). Ocean Station "P", (50°N, 145°W) is located about 1450km off the British Columbia coast. It was occupied by a Canadian weathership for many years. There the Black-footed Albatross was found to outnumber the Laysan Albatross, except in winter (Vermeer et al. 1983). The Laysan Albatross, however, is more frequently seen at Ocean Station "P", than along the British Columbia coast, suggesting a more offshore distribution for that species in the northeastern Pacific. Kuroda's (1960) observations also suggest a more offshore distribution of the Laysan than the Black-footed Albatross in the northwestern Pacific.

Kuroda (1960) and Sanger (1970) suggested that the Laysan Albatross forages in colder waters than the Black-footed Albatross and avoids areas of low salinity (Sanger 1970). British Columbia shelf surface waters are colder and less saline than those further offshore, because of extensive freshwater run-off from the mainland, particularly in spring (Thomson 1980). Our observations therefore indicate that the Black-footed Albatross commonly feeds over the colder and less saline Shelf while the Laysan Albatross does not.

Sooty Shearwater. The Strait and Sound and the relatively shallow Shelf waters (50-100 fathoms) on the west coast of the Queen Charlotte Islands appear to be important foraging areas for thousands of Sooty Shearwaters during spring and summer. P.W. Martin (in Guzman and Myres 1983) estimated about half a million Sooty Shearwaters to be present along the east coast of Moresby Island on May 22, 1977. Guzman and Myres (1983) observed tens of thousands of Sooty Shearwaters (on one occasion a flock of 100,000 birds) visiting the Shelf waters (50-100 fathoms) off the west coast of Vancouver Island in May 1977 and 1978. Harrison (1982) reported large flocks of Sooty and Short-tailed Shearwaters in the relatively shallow Shelf waters of the Gulf of Alaska in May 1977 and stated that the shearwaters clearly preferred the Continental Shelf. Harrison found that shearwater densities in the Gulf of Alaska declined drastically from May to June, a result similar to that found in the present study. T.R. Wahl (pers. comm.), who has conducted extensive bird surveys over the Shelf waters off Washington, found that Sooty Shearwaters were most numerous. He observed two peaks of shearwater densities, one occurring in May and the other from late August until the beginning of October. The latter peak represents the fall migration of shearwaters, which either was missed in the present study, or is less pronounced off northern British Columbia than off Washington. All the above observations indicate that Sooty Shearwaters are among the most abundant seabirds visiting the Shelf waters from Washington to southern Alaska. In the northwestern Gulf of Alaska and the eastern Bering Sea, Short-tailed Shearwaters far outnumber Sooty Shearwaters and are the most common birds visiting the Shelf from June to September (Hunt et al. 1981, Harrison 1982).

Flocks of 100,000 birds are not uncommon and occasionally over 1,000,000 have been recorded in the Bering Sea (Hunt et al. 1981). Hence there appears to be a geographical "replacement" of visiting shearwater species from mostly Sooties on the British Columbia Shelf to chiefly Short-taileds on the western Gulf of Alaska and the eastern Bering Sea Shelf.

Northern Fulmar. Guiguet (1971) and Sanger (1970) observed that fulmars are common in winter and spring and rare or uncommon in summer off the British Columbia coast. Our observations indicate that fulmars are common in summer as well as in spring and autumn, suggesting that fulmar numbers off British Columbia vary from year to year. Wahl (pers. comm.) found that fulmars off Washington are common in summer, but were most abundant in October and November. Hunt et al. (1981) observed that most fulmars occurred over the shelf break in the eastern Bering Sea and suggest that the birds may have been attracted there by the availability of fish offal. Forsell and Gould (1981) observed that fulmars in Alaska preferred the shelfbreak in winter. Harrison (1982) found that fulmar numbers stayed relatively constant over the Shelf and shelfbreak but did not observe fulmars in waters less than 25 fathoms. This agrees with our findings. On the west coast no fulmars were seen over waters shallower than 25 fathoms, and in the Strait and Sound only 9% of the fulmars occurred there.

Storm-petrels. Martin and Myres (1969) reported that the Fork-tailed Storm-petrel chiefly inhabits the colder waters off British Columbia and is rarely seen far offshore in warm water, while the Leach's Storm-petrel appears to be associated with warmer waters farther offshore. Kuroda (1960) for the western North Pacific and Gould (1983) for the North Pacific, concluded that Fork-tailed Storm-petrels inhabit colder waters than Leach's Storm-petrels. The Leach's Storm-petrel, however, tolerates a greater range of water temperature. The first author conducted a marine bird survey from the British Columbia coast to Ocean Station "P" in August 1981. Storm-petrel densities observed during that survey were regressed on distance from land, water depth and surface water temperature (Table 13). A significant and positive correlation was found between Leach's Storm-petrel densities and surface water temperatures, which were lower on the Shelf than in offshore waters, supporting Martin and Myres' hypothesis that the pelagic distribution of the Leach's Storm-petrel is related to higher surface-water temperatures. Although the correlation was significant, the coefficient of determination was weak, indicating that more data are needed to determine which factors govern the Leach's Storm-petrel distribution. A positive correlation was observed between Fork-tailed Storm-petrel densities and distance from land, indicating that those storm-petrels forage far from shore.

Phalaropes. Most phalaropes were seen in May in this study (Table 2), a time coinciding with their spring migration. Vermeer and Vermeer (1975) reported tens of thousands of Red-necked Phalaropes migrating northward along the west coast of Vancouver Island in May, 1973. Wahl (pers. comm.) observed hundreds of Red-necked Phalaropes and a smaller number of Red Phalaropes off Washington. Most of these Red-necked Phalaropes were seen in May and early September, and probably reflect spring and fall migration respectively.

Larids. Glaucous-winged, Herring and Thayer's gulls were common close to, as well as far from, shore, but the latter two species were seen more frequently offshore than was the Glaucous-winged Gull (Tables 2 and 4). Sanger (1973) and Harrington (1975) also observed both Glaucous-winged and Herring gulls to be common offshore in California, but Herring Gulls were most abundant 80 to 240 km from the coast. In the Atlantic, however, Herring Gulls occur more inshore than in the Pacific (W.H. Drury in Harrington 1975).

Black-legged Kittiwakes appear to be more pelagic in their distribution than either the Glaucous-winged or Herring gull (e.g. Harrington 1975, Forsell and Gould 1981, Vermeer et al. 1983, Vermeer 1983). In this study, the greatest numbers occurred on the west coast in September (Table 4). At Ocean Station "P", highest numbers of Black-legged Kittiwakes were also recorded in autumn (Vermeer et al. 1983). High numbers on the west coast and at Station "P" in autumn most likely reflect post-breeding dispersal to wintering areas south of Alaska.

Alcids. Alcids were the second most abundant family observed, the procellarids being the first (Tables 2, 4, 11 and 12). Of the alcids, Common Murres appeared to show the greatest preference for inshore Shelf waters. In Alaska, Common Murres also occur mostly over the Shelf (Swartz 1967, Shuntov 1972, Bartonek and Gibson 1972, Hunt et al. 1981). In summer, Common Murres forage close to their colonies, more so than do the Thick-billed Murres (Swartz 1967). In the autumn, Common Murres scatter over the Shelf, (Hunt et al. 1981). In this study, Rhinoceros Auklets were mostly seen over the Shelf, Ancient Murrelets over the Shelf and shelfbreak and Cassin's Auklets over the shelfbreak. Of all nesting seabirds in British Columbia, fish-eating Rhinoceros Auklets and plankton-feeding Ancient Murrelets and Cassin's Auklets are most numerous (Vermeer et al., 1983). On the Continental Shelf of Alaska these species are numerically replaced by fish-eating Tufted Puffins and the planktivorous Least, Crested and Parakeet auklets. Therefore no comparisons can be made for the same species between Alaska and British Columbia, except for Common Murres.

The most numerous alcids seen over the Washington Shelf were Common Murres, with Cassin's and Rhinoceros auklets placing a distant second (Wahl, pers. comm.). Both Cassin's and Rhinoceros auklets peaked sharply in Washington in summer, this may indicate the presence of breeders. A second, but small peak observed by Wahl in October and November, may have represented fall migrants. Wahl observed few Ancient Murrelets on the Washington Shelf which is not surprising, since no colonies are known to exist south of central British Columbia.

Table 13. Linear regression equations for storm-petrel densities along the Victoria to Station "P" route. D = number of birds/km/hr, DIS = distance from shore, DEPTH = distance from water surface to sea bottom, and TEMP = mean surface water temperature. Observation Period: August 18 to 27, 1981.

Species	p value	Regression equation	Coefficient of determination	Degrees of freedom (residual)
Leach's Storm-Petrel	$p < 0.05$	D = -0.98 + 0.007 TEMP	0.16, F =5.7	30
Fork-tailed Storm-petrel	$p < 0.05$	D = 0.72 - 0.302 DEPTH + 0.001 DIS (F = 26.0) (F = 8.1)	0.51, F=15.2 (F = 15.2)	29

CONCLUSION AND RECOMMENDATIONS

The overall densities of birds per month in Strait and Sound waters over 50 fathoms ranged from approximately 2 birds/km^2 in January, to 7 in April, 58 in May 1982, 170 in May 1983, 6 in June, 3 in July and 2 in September (Table 7). A similar trend of bird densities was observed in waters less than 50 fathoms (Table 7). By far the greatest pelagic bird densities in the Strait and Sound occurred in May and were chiefly made up of alcids which breed in the region (May 1982), and of visiting Sooty Shearwaters (May 1983) from the southern hemisphere. Their standing stocks accounted for several millions of birds (Table 11). In the spring, the Strait and Sound appear to be a particularly important foraging area for these two bird families, as well as others. Care should be taken during offshore drilling operations at all times in the Strait and Sound, but particularly in May, to prevent damage to this large bird resource.

The present study could not include a systematic survey of marine birds in the Strait and Sound, as the observers involved had no control over the ship's course. The result was a somewhat spotty coverage of some areas in the region involved, with however the added advantage that the surveys were random from the observers' viewpoint. We recommend that at least one systematic and one random survey by ship should be simultaneously conducted in the Strait and Sound to compare survey results between the two methods. Since highest bird densities were observed in May, this could be the best month for such a comparison. In addition some replicate systematic counts should be conducted also, for comparative purposes, simultaneously by airplane and by boat. Briggs et al. (in press) observed that under ideal conditions aerial surveys yield higher bird densities than do ship surveys, but that under actual field observations a variety of factors underestimated bird density from both platforms by a similar amount. We also support a standardized survey approach for counting birds in future, as suggested by Tasker et al. (1984).

It is unknown why millions of birds concentrate in the Strait and Sound in May, but the presence of food is the most likely explanation. At present there is no information on the diet of adult seabirds in the region. The birds' diet, preferred feeding localities, as well as the life cycle of major prey species should be investigated. If prey is adversely affected by offshore drilling activities, alcids and shearwaters may be forced to forage elsewhere where food conditions are less than optimal for their survival.

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APPENDIX

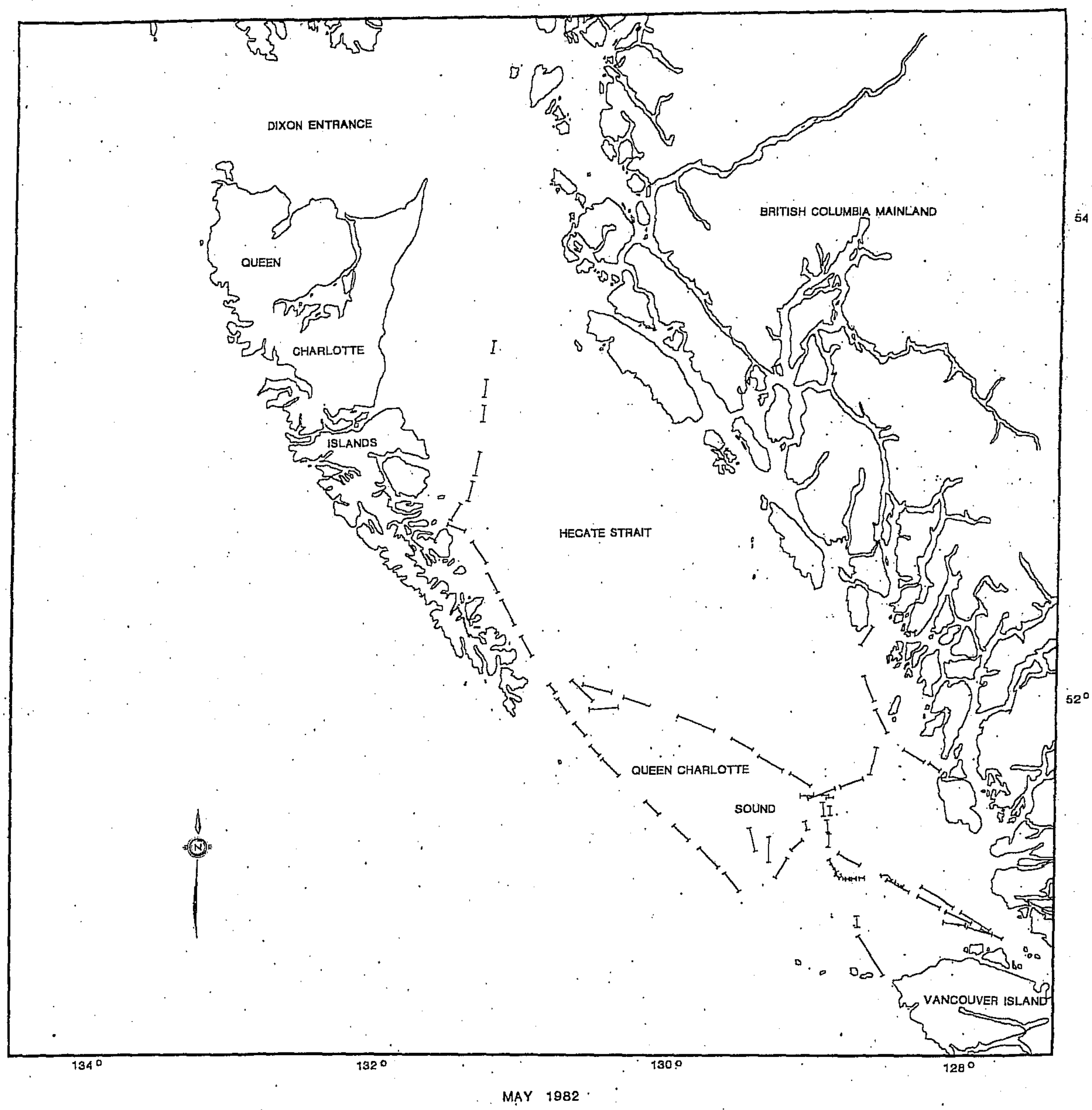

Figure 1. Location of survey transects during observations of marine birds in Hecate Strait and Queen Charlotte Sound, May 1982.

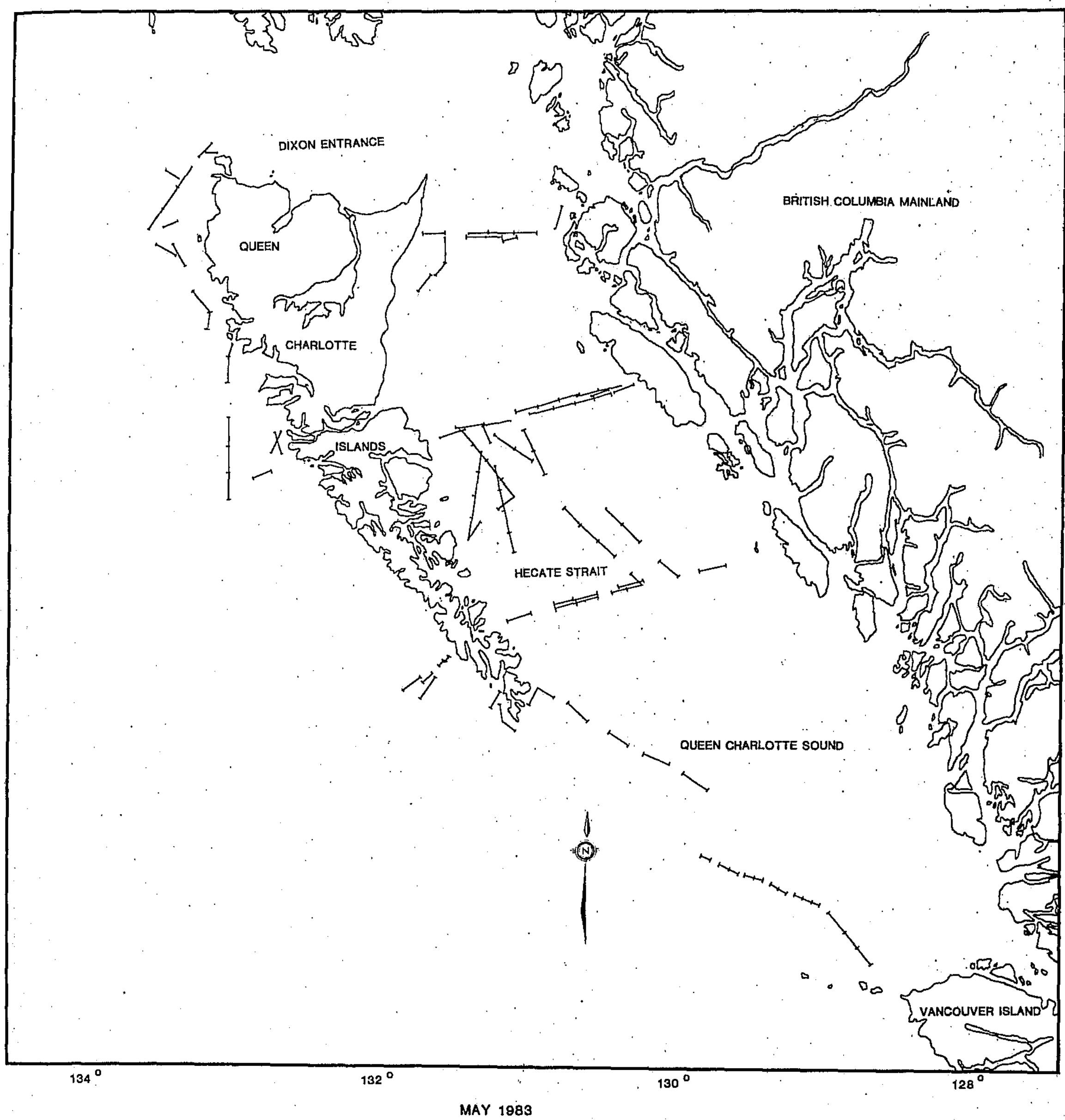

Figure 2. Location of survey transects during observations of marine birds in Hecate Strait and Queen Charlotte Sound and on the west coast of the Queen Charlotte Islands, May 1983.

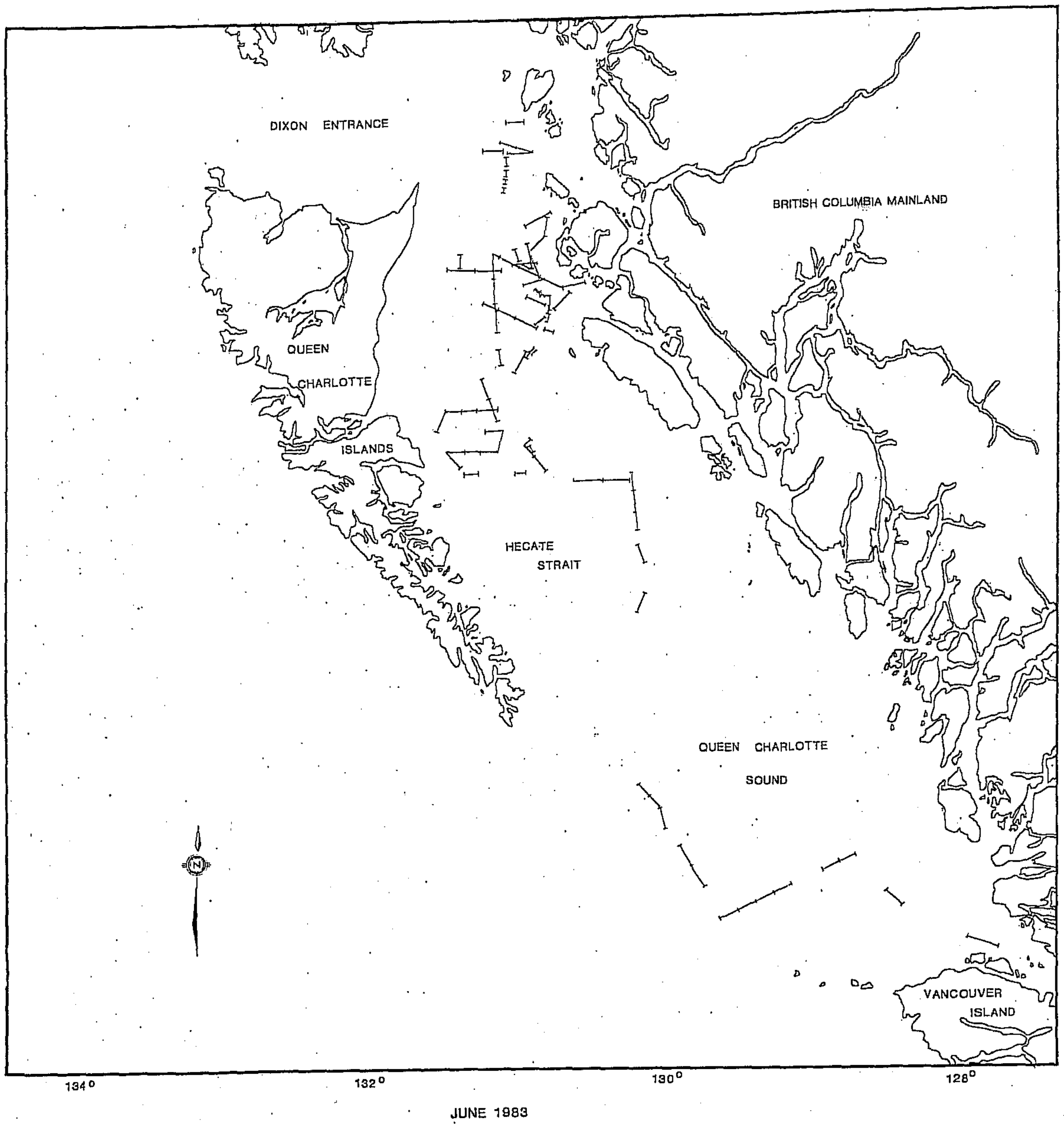

Figure 3. Location of survey transects during observations of marine birds in Hecate Strait and Queen Charlotte Sound, June 1983.

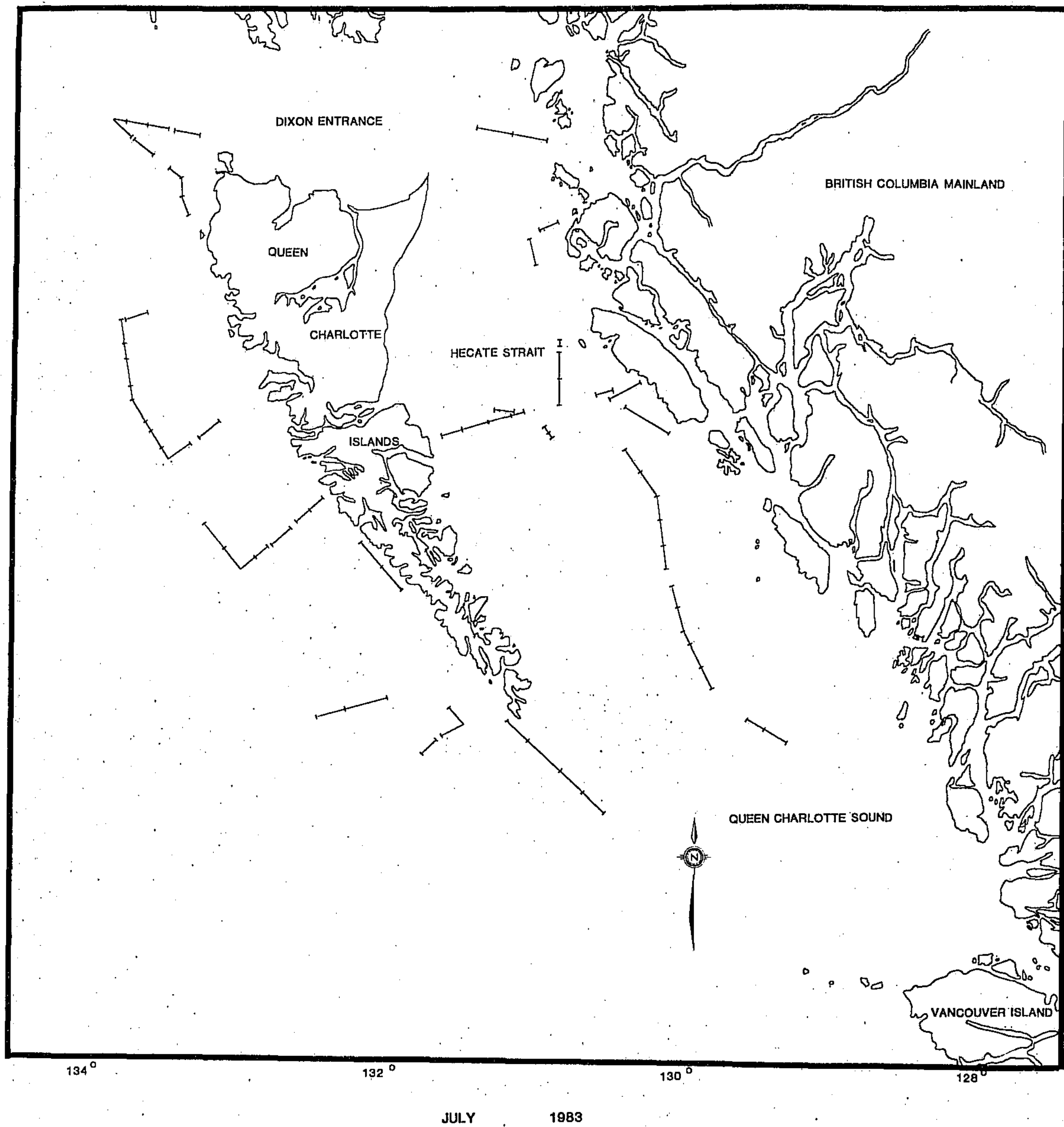

Figure 4. Location of survey transects during observations of marine birds in Hecate Strait and Queen Charlotte Sound and on the west coast of Queen Charlotte Islands, July 1983.

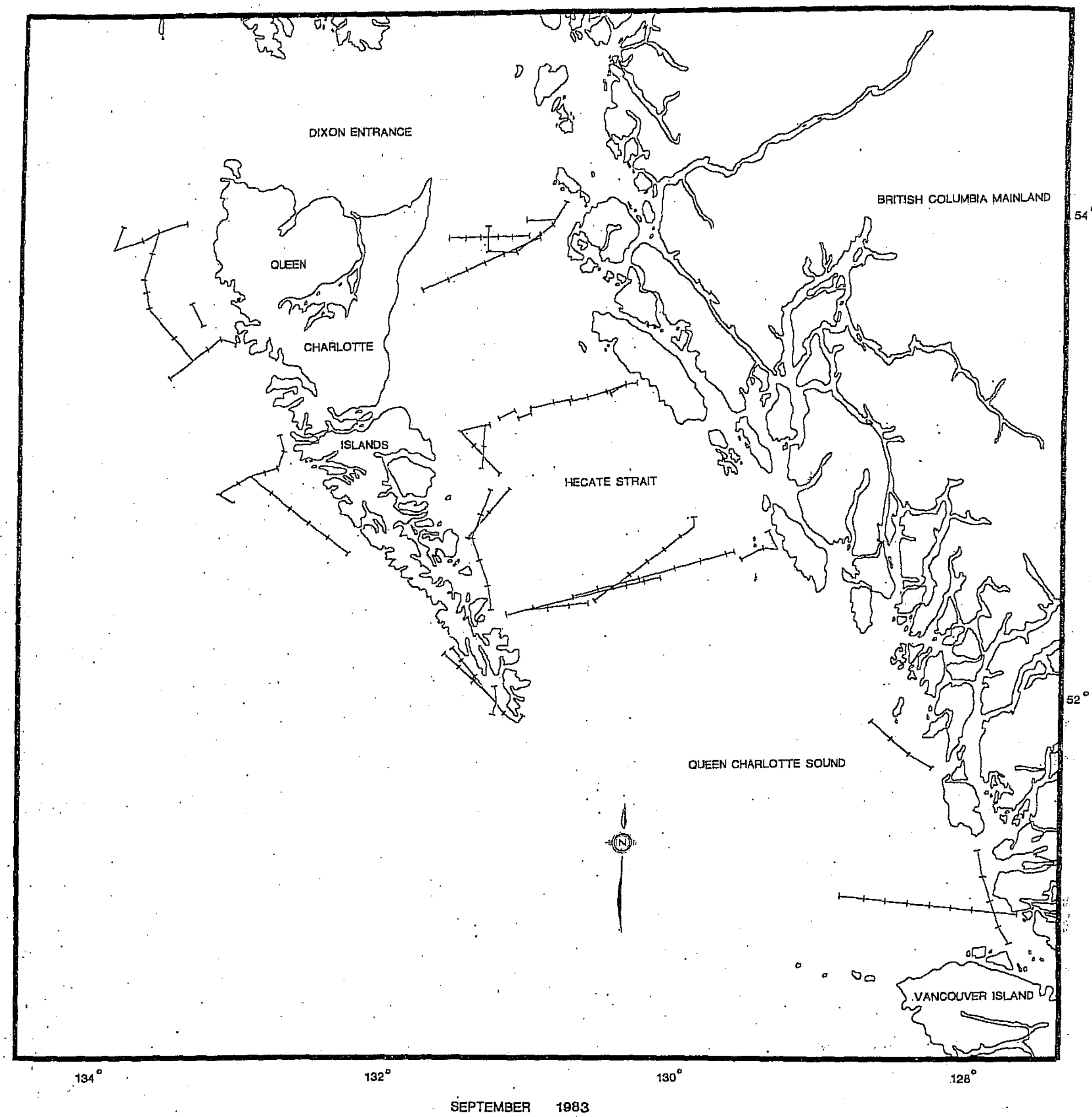

Figure 5. Location of survey transects during observations of marine birds in Hecate Strait and Queen Charlotte Sound and on the west coast of the Queen Charlotte Islands, September 1983.

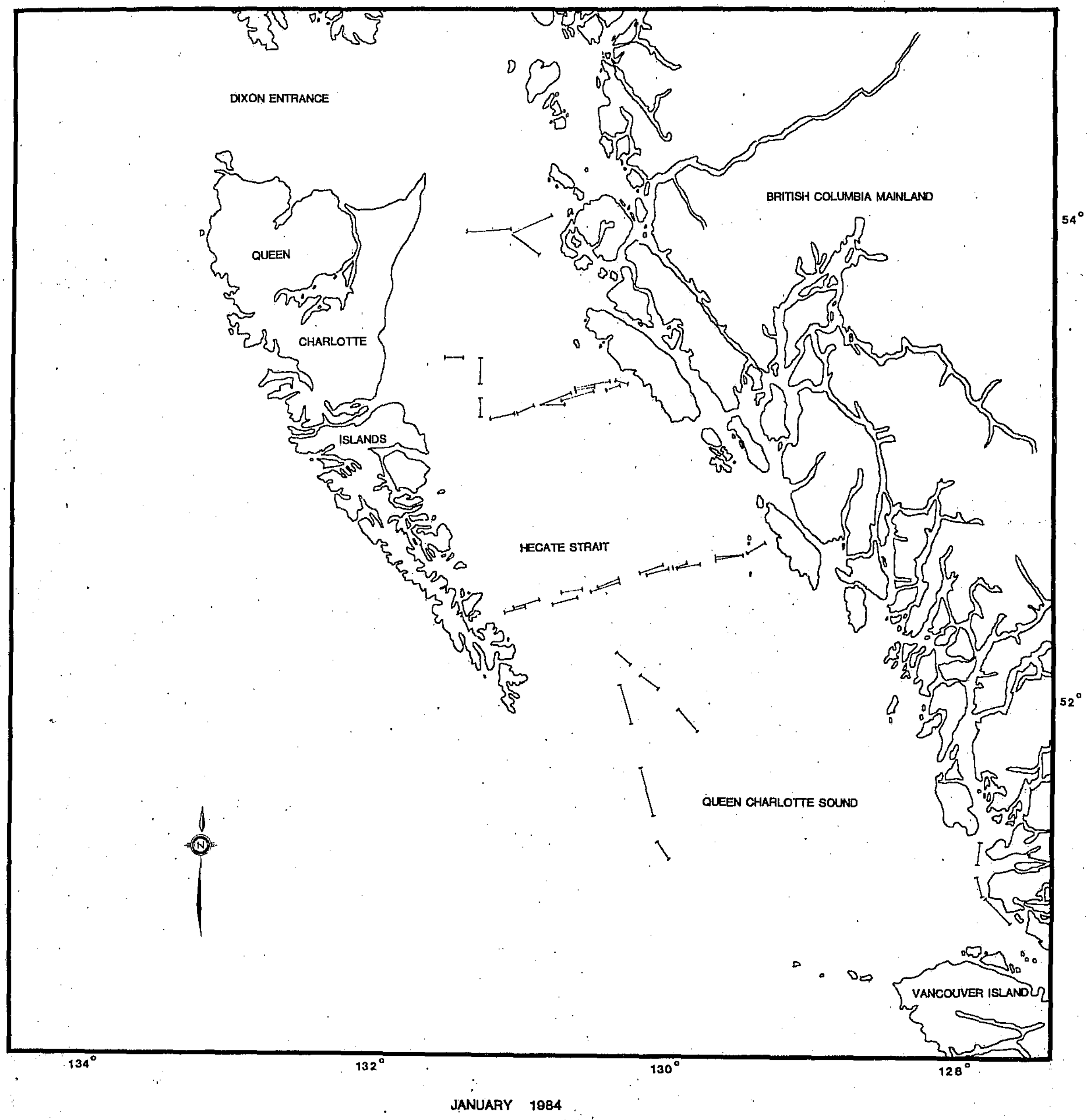

Figure 6. Location of survey transects during observations of marine birds in Hecate Strait and Queen Charlotte Sound, January 1984.

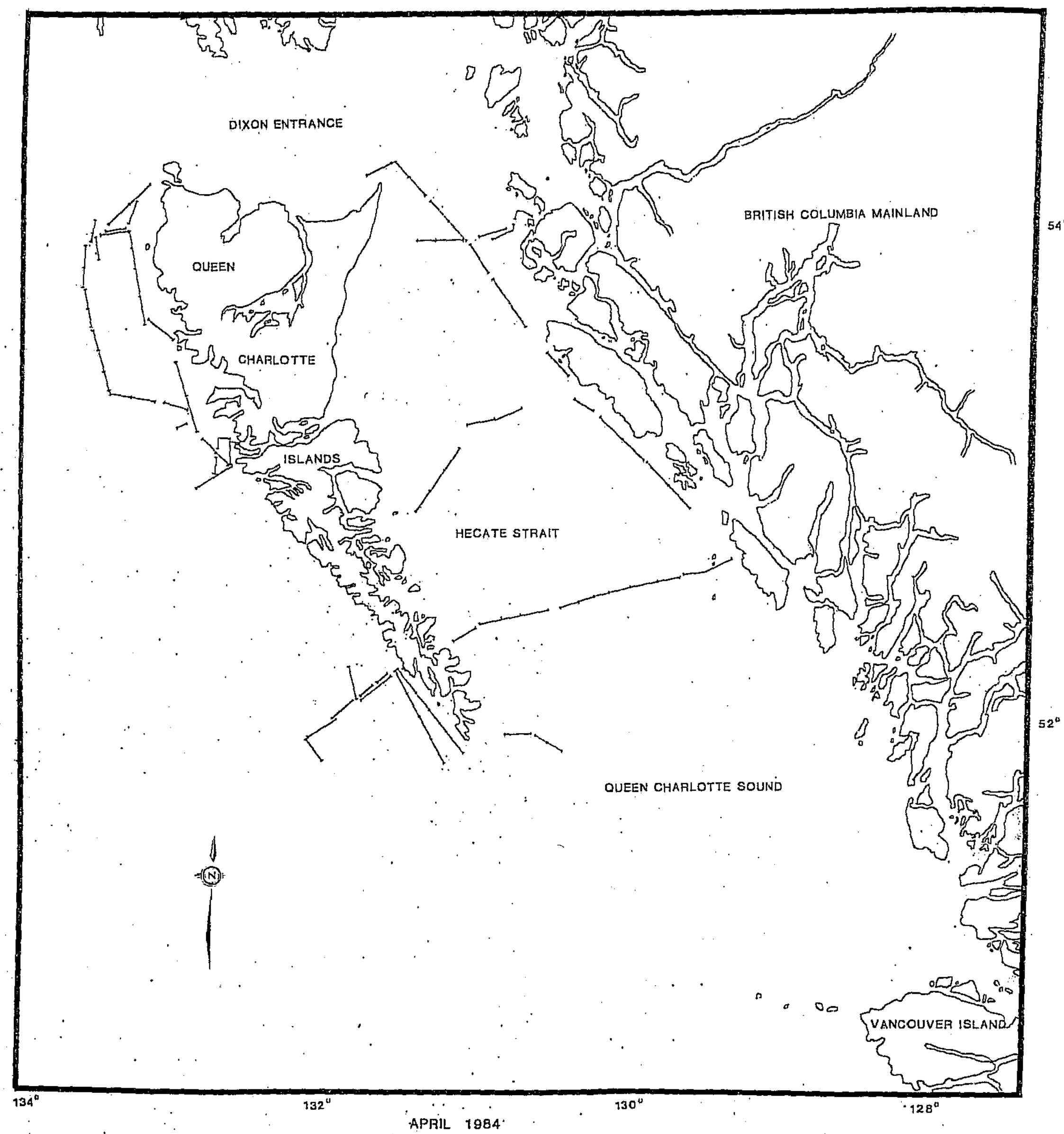

Figure 7. Location of survey transects during observations of marine birds in Hecate Strait and Queen Charlotte Sound and on the west coast of the Queen Charlotte Islands, April 1984.