

**SEASONAL AND SPATIAL VARIATIONS IN DENSITIES AND COMPOSITION
OF SEABIRD COMMUNITIES OFF SOUTHWEST VANCOUVER ISLAND,
1993-1995.**

ALAN E. BURGER

Department of Biology, University of Victoria, Victoria, British Columbia, V8W 3N5,
Canada;

ANDREA D. LAWRENCE

5012 Old West Saanich Road, Victoria, British Columbia, V9E 2B2, Canada;

E. ANNE STEWART

Bamfield Marine Station, Bamfield, British Columbia, V0R 1B0, Canada;

Cite this report as:

Burger, A. E., A. D. Lawrence, and E. A. Stewart. 2002. Seasonal and spatial variations in densities and composition of seabird communities off southwest Vancouver Island, 1993-1995. In: Burger, A. E. (editor). 2002. Distribution and abundance of seabirds off southwest Vancouver Island: a year-round study in relation to the risks of oil spills. Report to Nestucca Trust Fund and BC Ministry of Water, Land, and Air Protection, Victoria, BC.

ABSTRACT

The ocean off southwest Vancouver Island is a productive area supporting a diverse avifauna of seabirds and waterfowl. We document species-composition, density and distribution of birds in three marine zones between May 1993 and December 1995. Ours is the first study in this area to use year-round, repeated transect surveys covering a wide range of habitats. The area has a high risk of a major oil spill, and there are additional risks to birds from chronic oiling and fisheries by-catch. We counted birds from vessels along fixed transect routes within the Nearshore zone (sheltered inland waters within 1-2 km of shore; 43 km transect; 56 surveys), the Inshore zone (exposed waters <50 m deep and within 6 km of shore; 19 km transect; 39 surveys), and the Offshore zone (shelf and canyon waters >50 m deep and >6 km from shore; average 93 km transect; 29 surveys). Our study included the tail-end of the 1992-1993 El Niño event. We found few significant inter-annual variations in bird densities, but the power of the tests was low. There were, however, strong seasonal trends in each zone, and marked differences in the species composition, foraging niches and densities among the zones. Year-round densities averaged 23.4 ± 10.9 , 40.0 ± 21.6 , and 54.6 ± 59.2 birds km^{-2} in Nearshore, Inshore and Offshore zones, respectively. Seasonal changes in density increased from Nearshore through Offshore zones (co-efficient of variation was 46%, 54% and 108%, respectively). Densities were high from spring through autumn. The Nearshore community was dominated by migrant waterfowl in winter and Marbled Murrelets (*Brachyramphus marmoratus*) in spring through summer, the Inshore community by Common Murres (*Uria aalge*) year-round and California Gulls (*Larus californicus*) and Sooty Shearwaters (*Puffinus griseus*) in summer and autumn, and the Offshore community by murres, California Gulls, shearwaters and some pelagic species. Seasonal and spatial variations in density in each zone are documented for 41 regularly occurring species. Our data show the cosmopolitan nature of the avifauna and the global importance of the area as a foraging ground, migratory passageway and wintering ground. Birds which breed in or near the study area made up only 37%, 21% and 14% of the year-round counts in Nearshore, Inshore and Offshore zones. The bulk of the birds were non-breeding visitors, whose breeding grounds include the coast of B.C., Washington and

Alaska, the Arctic, inland temperate areas in continental North America, the southern hemisphere (shearwaters), Hawaii, and Mexico. This widespread breeding distribution makes it virtually impossible to track population impacts of oil spills or other catastrophes off Vancouver Island. To compensate for this, we suggest continuous monitoring of chronic oiling, fisheries by-catch and other human impacts, and accurate assessments of the on-site impacts of catastrophic oil spills.

INTRODUCTION

Year-round censuses of mid- to high-latitude seabirds at sea are rare (e.g. Briggs et al. 1987). This is largely due to the limitations and expense of vessel or aircraft time, and inclement winter weather. Such censuses, however, are essential for assessing the roles of seabirds in marine ecosystems, the factors affecting or limiting local populations, and the risks of oil spills, fishing and other human activities. Lack of information on the distribution and densities of seabirds in winter, when oil spills are most likely, severely limits impact assessments. Off the southwest coast of Vancouver Island, British Columbia, the paucity of information on wintering seabirds hindered the impact assessment of the December 1988 *Nestucca* oil spill, which killed an estimated 56,000 seabirds off Washington and southwest Vancouver Island (Rodway et al. 1989, Ford et al. 1991, Burger 1993a). High volumes of shipping, including over 300 laden oil tankers and over 100,000 other vessels per year, traverse the continental shelf waters off southwest Vancouver Island (Shaffer et al. 1990), and the risks of further oil spills and other chemical contamination in this region are high (Vermeer and Vermeer 1975, Cohen and Aylesworth 1990, Burger 1992).

The continental shelf and coastal ecosystems off Vancouver Island are highly productive, supporting important fisheries and large populations of resident and migratory seabirds. The oceanography is complex, but many important ocean processes have been identified (Thomson 1981, Thomson et al. 1989, Freeland 1992). Winter conditions have received little attention (Thomas and Emery 1986). There have been several previous studies of

seabirds over the shelf and coastal waters of southwest Vancouver Island (e.g. Martin and Myres 1969, Vermeer et al. 1983, 1987, 1989, Hay 1992, Logerwell and Hargreaves 1996, Parrish et al. 1998, Wahl et al. 1989), but information from winter and early spring is sparse (Ford et al. 1991, Morgan et al. 1991, Wahl et al. 1993). Most studies focused on summer and early fall within a single year. Our study is the first to undertake year-round censuses along fixed transect routes covering a wide range of ocean types off the British Columbia coast.

This study was initiated in response to gaps in data which became obvious during the assessment of the *Nestucca* oil spill. The goals of this paper are: a) to provide year-round information on the distributions, densities and species composition of seabirds off southwest Vancouver Island; and b) to compare these seabird parameters at coarse spatial scales (10-100 km range) in this region. The paper describes the species and avian communities likely to be affected by oil spills in three oceanic zones off southwest Vancouver Island at any time of year. Other products from this research will investigate physical and biological oceanic factors affecting the seabirds at coarse and fine-scaled (0.1-1.0 km) spatial and temporal patterns (papers in this compendium). The database from the study is also available for mapping and GIS analysis.

STUDY AREA, HABITAT DEFINITIONS AND SEASONS

Surveys covered three marine habitats, defined as follows (modified from Kessel 1979):

- a) **Nearshore waters** - protected coastal waters, including bays and inlets, which are generally shallow (usually <20 m deep), within 1-2 km of shore, and have little heavy wave action;
- b) **Inshore waters** - exposed coastal waters less than 50 m deep, within 6 km of shore, and within or around the inner oceanic front, but which experience wave action from the open ocean;
- c) **Offshore waters** - exposed open seas over the continental shelf, generally >6 km from shore with depths >50 m (these waters constitute the mid- and outer-continental shelf as defined by Kessel 1979). We use the term Offshore for consistency with our other terms,

but others have used the term to denote oceanic waters beyond the continental shelf break (e.g., Logerwell and Hargreaves 1996), which were not sampled in our study.

Based on the marine ecosystem classification for British Columbia (Zacharias et al. 1998), the Nearshore waters were classified as either HCLLH (H: high wave exposure with fetch >500 km and ocean swells; C: shallow [20-200 m]; L: low sea floor relief; L: low currents [maximum <3 knots]; and H: hard substrate) or HCHLH (as above except for high [H] sea floor relief around islands). Inshore waters were all HCLLH (as above). Offshore waters were a mix of HCLLH (as above), HCLLM (similar to HCLLH except for muddy and sandy mud [M] substrates), and HCHLH (as above; with high [H] sea floor relief around ocean canyons).

The three marine zones were sampled as follows:

- a) Nearshore waters were sampled along a 43 km transect within Trevor Channel, Barkley Sound, which ran parallel to the shore at 200 and 600 m offshore for most of the route (Figure 1A);
- b) Inshore waters were sampled along an L-shaped transect averaging 19.4 km which ran down the middle of Trevor Channel across the inner front near Cape Beale onto the shelf, and then parallel to the shore to end at Seabird Rocks (transect legs *Trevor* and *Beale* in Figure 1B);
- c) Offshore waters were sampled along a 117 km transect line, following a rough rectangle in a clockwise direction (Figure 1B). Water depths were 50-60 m deep in the *Pachena* and *Inshelf* legs and the shoreward half of *Crossshelf* leg, 60-220 m in the *Canyon* leg which covered the shelf edge and part of the Juan de Fuca Canyon, and 80-120 m in the *Offshelf* leg and the outer half of *Crossshelf*. Between November and mid-March, when daylight was limiting, the transect ran diagonally across the shelf from the outer end of the *Canyon* leg to the junction of the *Trevor* and *Beale* legs. The average distance covered year-round was 93 km per survey.

Following Morgan et al. (1991) we defined the seasons as: winter (16 December – 15 March); spring (16 March – 15 June); summer (16 June – 15 September); autumn (16

September – 15 December). Data were usually plotted as monthly means to show the seasonal trends, but for statistical analyses data were usually pooled by season to increase sample sizes.

METHODS

In all three sample sets, birds were counted from a vessel moving at a relatively constant speed averaging 8 knots (14.8 km h^{-1}), and usually within a range of 7-10 knots ($13.0\text{-}18.5 \text{ km h}^{-1}$). The vessel was occasionally slowed to permit counting and identification of birds in dense flocks. Observations were made by two observers on either side of the vessel, each scanning 90° horizontally ahead and to one side. All birds within 150 m on either side of the vessel were included in the 300 m wide strip transect. Tests in these waters suggested that few birds were missed within 150 m, but wider strips underestimated densities (A.E.B. unpubl. data). Birds within the transect strip were recorded in 1-min intervals. During this time a vessel travelling at 8 knots moves 250 m. Birds flying more than 250 m ahead of the vessel, following the vessel, or crossing behind the vessel were not counted. Flying birds and those on the water were recorded separately, but in this coarse-scale analysis these data were pooled, to simplify comparisons and to ensure that species which spend most of their time on the wing were included. This is likely to produce an overestimate of the densities of flying birds (Tasker et al. 1984, Van Franeker 1994), but this error should be consistent within species and species-groups. Fine-scaled analyses reported elsewhere focused on birds on the water (see other papers in this compendium.).

Data were recorded on a tape recorder (Nearshore surveys), or on paper by a third person (Inshore and Offshore). Surveys were usually restricted to periods when wind and seas were at Beaufort sea state 3 or less (winds $<5.5 \text{ m s}^{-1}$ and white-caps from breaking wavelets rare), although data were collected during some Offshore transects during brief periods of stronger winds to maintain continuity.

Nearshore surveys in Trevor Channel were made from open motorboats (eye level 1.5-2.0 m above sea level). In most cases the driver was one of the two observers. Navigation was with reference to a chart and conspicuous landmarks. Inshore and Offshore surveys used the 11 m research vessel M.V. *Alta* (eye-level 2.0-2.5 m above the sea), and occasionally other similar vessels, and used LORAN and Global Positioning System (GPS) for navigation. During Offshore transects, several observers took turns on duty to avoid fatigue.

Counts of waterfowl in the Nearshore zone (Anatidae), apart from Harlequin Ducks, were inconsistent in 1993 (flying birds were not always included by all observers), therefore this group was excluded from interannual analyses, except where noted. Seasonal patterns in waterfowl distribution in this zone could still be calculated from the complete counts. Analysis focused on loons, cormorants, grebes, procellariids, jaegers, phalaropes, gulls, and alcids. Scientific names and breeding locations of all species recorded are given in Table 1.

Nearshore surveys were made twice a month through the year, except when rough seas precluded surveys in some winter months (Table 2). Inshore and Offshore surveys were scheduled as monthly events, but some were missed due to bad weather in winter, and in some summer months there were 2-4 additional Inshore surveys (Table 2). Data from field data sheets were transcribed to spreadsheets for analysis and archiving. Statistical analysis used SPSS 10.0. Throughout, data were first collated into monthly means to adjust for unequal sampling among months.

RESULTS AND DISCUSSION

Inter-annual variations and effects of sea temperature

Sea surface temperatures measured during the Inshore and Offshore surveys showed significant seasonal trends, as expected, but also some variations among years, with spring and summer temperatures higher in 1993 than in other years (Figure 2). A two-

way ANOVA, using temperature data grouped into four seasons, showed significant effects of both year and season in both Inshore (Year: $F_{2,35} = 6.96$, $P = 0.004$; Season: $F_{3,35} = 14.282$, $P < 0.001$) and Offshore (Year: $F_{2,27} = 6.65$, $P = 0.008$; Season: $F_{3,27} = 7.71$, $P = 0.002$) samples, but the interaction of year x season was not significant in either case ($P > 0.05$). There were insufficient Nearshore temperature data from our surveys for analysis.

Nearshore ocean temperatures measured at Amphitrite Point, at the northwest end of Barkley Sound, during the 1990s were generally higher than the long-term averages (Institute of Ocean Sciences, Sidney, B.C. <http://www.ios.bc.ca/ios/osap/data/>). Temperatures were particularly high from late spring through early fall (May through October) in 1992 and 1993, when this region experienced El-Niño like conditions (Burger 2000, H. Freeland, pers. comm.). During this time Barkley Sound experienced an influx of chub mackerel (*Scomber japonicus*), typical of warm water, which appeared to cause a reduction in densities of small schooling fish (notably salmon smolts and juvenile herring, D.E. Hay, pers. comm.). The warm water, reduced dissolved nitrates, lower phytoplankton densities, and presence of mackerel was also linked to unusually low densities of euphausiids within Barkley Sound. Densities and recruitment of *Thysanoessa spinifera* were sensitive to temperature, and declined significantly in and near Barkley Sound during the 1992 El Niño event (Tanasichuk 1998a,b).

We tested possible effects of the higher 1993 temperatures, but found no significant difference in bird densities among years (two-way ANOVA, using season and year as fixed factors, on species with sufficient data, or groups of species including loons, grebes, cormorants, procellariiforms, alcids, surface-feeding birds, diving birds, and all birds combined; $P > 0.05$ for all tests,). The only exception was that Pigeon Guillemot densities in the Nearshore surveys were significantly higher in 1995 than in 1993 and 1994 (Year effect: $F_{2,56} = 4.11$, $P = 0.023$), which did not appear to be an El Niño effect. The power of these tests, however, was limited by the small sample sizes (range of power values, Nearshore data: 0.05-0.264, Inshore: 0.06-0.32, Offshore: 0.05-0.28). Consequently, we

disregarded the effects of year on seabird densities and focused on seasonal and spatial distributions.

The effect of the 1992-1993 El Niño was evidently waning when we began sampling in May 1993. By the July 1993 sea temperatures in our study area were close to the long-term average. Given this declining effect, and the high variance in counts of most species, it was not possible to determine obvious effects of the El Niño on these avian communities. In temperate oceans, the effects of El Niño are more likely to be apparent in breeding parameters measured at colonies, which tend to have less variability *within* seasons, than in densities and distributions at sea, which are more variable *within* and *among* seasons (Ainley and Boekelheide 1990).

Species composition and mean densities of seabirds

The overall species richness in Nearshore, Inshore and Offshore surveys was remarkably similar (37, 39 and 41 species, respectively), but the species composition and numerical dominance of species and families differed (Tables 3-5, Figure 3). The five most common species within each zone made up 61%, 71% and 80% of the bird densities in Nearshore, Inshore and Offshore surveys, respectively. The year-round mean densities were lowest in Nearshore surveys, intermediate in Inshore and highest in Offshore surveys (23.4 ± 10.9 , 40.0 ± 21.6 , and 54.6 ± 59.2 birds km^{-2} , respectively), but the variation in densities through the year followed the reverse order (Coefficient of Variation was 46%, 54% and 108%, respectively).

Nearshore surveys were dominated by grebes (primarily Western Grebe), cormorants (Pelagic Cormorant), anatids (Surf Scoter), gulls (California and Glaucous-winged Gulls) and alcids (Common Murre and Marbled Murrelet) (Table 3, Figure 3). The seasonal trend was driven largely by the influx of wintering grebes and waterfowl from October through April, breeding Marbled Murrelets in summer (May through July) and post-breeding Common Murres and California Gulls in late summer and early fall (July through September).

Inshore surveys were dominated by procellariiforms (primarily migrant Sooty Shearwater in May through September), gulls (primarily post-breeding California Gulls in July through October, and to a lesser extent locally breeding Glaucous-winged Gulls year-round), and alcids (predominantly Common Murres, especially from May through January, and locally breeding Rhinoceros Auklets from March through September) (Table 4, Figure 3).

Offshore surveys, showed the strongest seasonal variations and were dominated by late summer and fall migrants (Table 5, Figure 3). Dominant birds were procellariiforms (particularly Sooty Shearwater and Northern Fulmar and to a lesser extent Fork-tailed Storm-petrel), gulls (particularly California Gull and to a lesser extent Glaucous-winged Gull), and alcids (particularly Common Murre, and to a lesser extent Cassin's Auklet and Rhinoceros Auklet).

Variations within taxonomic groups

Comparisons within families (or orders where noted) and species follows. Monthly means (all years pooled) were plotted for seasonal comparisons.

Loons (Gaviidae) - Three species of loon were found in each zone (Tables 3-5, Figure 4). Pacific Loons were most widespread and abundant, particularly in the Inshore zone. Common Loons were regular only in the Nearshore zone. Red-throated Loons were sparse in all zones. Highest numbers of loons were recorded during their spring migration in April and May, and fall migration in October and November, with smaller overwintering populations of all three species, and a few Common Loons present in summer (Figure 4).

Grebes (Podicipedidae) - Three species were recorded, concentrated in the Nearshore zone with negligible densities further offshore (Tables 3-5, Figure 5). Western Grebes were most common and widespread, and their numbers fluctuated less than those of most other water birds. A flock of 80-130 Western Grebes could reliably be found every winter

in sheltered water south of Helby Island in Trevor Channel. These birds appeared to disperse to feed at dusk in other parts of Trevor Channel.

Procellariiforms (Order Procellariiformes) - Eight species were recorded in the Inshore (mostly Sooty Shearwaters) and Offshore (all species) zones (Tables 3-5, Figure 6). Black-footed Albatrosses were uncommon, usually found associated with hake trawlers on the shelf in late summer. Laysan Albatrosses, rare visitors to our area (Morgan et al. 1991) were not recorded in our surveys. Northern Fulmars were common from late summer through fall, with low densities through the winter in the Offshore. They too, were often associated with hake trawlers. Sooty Shearwaters were the most common procellariid in the area, with large flocks in both the Inshore and Offshore zones through the summer and fall. Short-tailed Shearwaters are difficult to separate from Sooty Shearwaters in the field, and a few were undoubtedly included in the Sooty counts. Short-tailed Shearwaters were recorded in the Offshore zone in all seasons, most commonly in November, and were the only positively identified shearwaters in winter. Sightings of Buller's and Pink-footed Shearwaters were sporadic and usually associated with trawlers, or surface swarms of euphausiids. Fork-tailed Storm-petrels and Leach's Storm-petrels breed on Seabird Rocks (190 and 430 pairs respectively, Rodway 1991), and in similar numbers at colonies near Cape Flattery, Washington near the survey area (Speich and Wahl 1989). Leach's Storm-petrels forage further offshore, at and beyond the continental shelf break (Morgan et al. 1991), and were very rare in our Offshore surveys (Table 5). Fork-tailed Storm Petrels were common in summer (May through August) and often associated with hake trawlers.

Cormorants (Phalacrocoracidae) - Three species were found year-round, but in varying densities (Tables 3-5, Figure 7). Double-crested Cormorants were most common in sheltered Nearshore water and never Offshore. Brandt's Cormorants were the most widespread species, usually foraged in the Nearshore or Inshore zones but were occasionally found >10 km from land over the shelf. Pelagic Cormorants, despite their name, were largely restricted to Nearshore waters, but were occasionally found further from land. Pelagic Cormorants (<200 pairs in total) nest in scattered, small colonies of

Barkley Sound and nearby exposed shores of Vancouver Island (Rodway 1991, Vermeer et al. 1992). Small numbers (maximum 150 pairs) of Brandt's Cormorants nested near Barkley Sound in the 1970s, but there appear to be no active colonies now (Rodway 1991, AEB, personal observations). About 75 pairs of Double-crested Cormorants, 5 pairs of Brandt's Cormorants and 450 pairs of Pelagic Cormorants breed around Cape Flattery near the survey area (Speich and Wahl 1989).

Anatids (Anatidae) - Ducks and geese were common only in Nearshore waters, with the exception of scoters which were also commonly found in Inshore waters and occasionally Offshore (Tables 3-5, Figure 8). High-flying flocks of migratory Brant, Canada Geese and Greater White-fronted Geese, seen in spring and fall were excluded from these counts, but Brant were occasionally reported on Inshore waters. Harlequin Ducks were underestimated in our Nearshore surveys, since the survey area included little of their favoured foraging areas of exposed subtidal rocks. Scoters, predominantly Surf Scoters, were the most widespread and common sea ducks. Most were found in winter, but small numbers of non-breeders remained in summer. Scoters were sometimes found in the Offshore zone, usually flying but occasionally on the water.

Phalaropes (Scolopacidae) - Red and Red-necked Phalaropes were regularly recorded, usually in exposed Inshore or Offshore waters (Tables 3-5, Figure 9). Separation of these two species was sometimes difficult from a moving vessel, but Red-necked was the species most commonly identified, except in May. Red Phalaropes were recorded in both spring (May) and late summer/ fall (July through September) migrations, with occasional sightings in late fall and winter. In the winter of 1995-1996 small numbers of Red Phalaropes were recorded in Christmas Bird Counts in southern B.C. and the Olympic Peninsula and several dead birds were recovered on beach surveys bordering our survey area, but this winter occurrence is highly unusual. Red-necked Phalaropes did not occur in high densities during the spring migration, but were common in the post-breeding migration (July through September).

Jaegers and skua (Laridae) – Migrant Parasitic and Pomarine Jaegers were uncommon, occurring in summer through fall, mostly Offshore (Table 3-5, Figure 10). Jaegers were usually associated with the small gulls they kleptoparasitized (California and Sabine's Gulls, and Black-legged Kittiwake). No Long-tailed Jaegers were seen. South Polar Skua has been recorded in the survey area (AEB, unpublished data) but was not seen on our surveys.

Gulls (Laridae) - Gulls were the most diverse group in the study area, dominated by tens of thousands of California Gulls in late summer through fall, and smaller numbers of resident Glaucous-winged Gulls (Tables 3-5, Figure 11). The Glaucous-winged Gull is the only locally-breeding larid. About 700 pairs breed on Seabird Rocks and in Barkley Sound (Vermeer et al. 1992), and about 2,200 (including some Western Gulls) around Cape Flattery (Speich and Wahl 1989). The increase in density of Glaucous-winged Gulls in fall and winter (Figure 11) suggests that additional birds migrate into this area to winter. Although California and Glaucous-winged gulls are most often seen resting on the shore, they appeared to use the Offshore more than the Nearshore or Inshore for foraging. Most of the Offshore foraging flocks were associated with trawlers, but many were also found with surface swarms of euphausiids over the shelf and Juan de Fuca Canyon.

Other species of gulls pass through as migrants, remaining for variable lengths of time. Among the larger gulls, Western, Thayer's and Herring Gulls were found in all three zones (Tables 3-5, Figure 12). Western Gulls were generally rare. Migrants from the Arctic and sub-Arctic, Thayer's Gulls were common in winter and early spring, while Herring Gulls were found from late summer through spring and were quite common Offshore in late fall.

Mew Gulls were regular wintering visitors, foraging in all three zones; Heermann's Gulls occurred regularly in summer in low densities in Nearshore waters; and Bonaparte's and Ring-billed Gulls were uncommon and recorded sporadically in all three zones (Tables 3-5, Figure 13). The two pelagic species, Sabine's Gull and Black-legged Kittiwake were

regularly found only in Offshore waters (Tables 3-5). Sabine's Gull was common only during its post-breeding migration (August and September), but kittiwakes were recorded in both spring and fall migrations (Figure 14).

Alcids (Alcidae) – Alcids formed a significant part of the avian population in all three marine zones. Common Murres were common in all three zones through most of the year, and Marbled Murrelets were the most abundant seabird in Nearshore waters during the spring and summer. Other alcid species were less common.

Our study area was an important foraging ground for Common Murres, even though there were no breeding colonies within the area sampled. Birds from the nearby Tatoosh Island colony (2000+ pairs, J. Parrish data) off the tip of the Olympic Peninsula in Washington were commonly seen flying north-west along the Vancouver Island coast, sometimes carrying fish for nestlings. Adults accompanied by newly fledged chicks from this colony were also a common feature on the waters in all three habitats in late summer. Migrants from colonies elsewhere in Washington, Oregon and from Triangle Island, British Columbia were likely also present during the fall and winter. Murres showed some seasonal movements among the three marine zones (Figure 15). Highest densities in fall and winter were in both Inshore and Offshore zones (see also Ford et al. 1991), whereas in late spring and summer most murres were in the Inshore zone. The Nearshore waters in Barkley Sound were used by small numbers of murres through the year, with an increase in late summer, which included parents accompanied by partly-grown chicks. Common Murres were the species most often killed by past oil spills in the north Pacific (Burger and Fry 1993). They were the most numerous of the birds killed by the *Nestucca* oil spill in the winter of 1988-1989 (Rodway et al. 1989), and high densities of murres over the shelf at this time of year were also confirmed by Ford et al. (1991).

Rhinoceros Auklets used all three zones, with seasonal movements among them (Tables 3-5, Figure 15). This species overwinters south of British Columbia, with high winter densities in California (Briggs et al. 1987). In our area, pre-breeding aggregations in late winter and early spring were in the Offshore and Inshore zones, but during breeding the

birds tended to remain in Inshore zone, close to the colony on Seabird Rocks (130-170 pairs; Davoren 1997). Breeding Rhinoceros Auklets are usually found within a few km of their colonies (Parrish et al. 1998, Davoren 1997, 2000). Small numbers of Rhinoceros Auklets, including some newly fledged juveniles, ventured into the Nearshore waters of Barkley Sound in September and October (Figure 15).

Cassin's Auklets tend to forage on aggregations of zooplankton at or near the continental shelf edge off Vancouver Island (Morgan et al. 1991). They were common in our Offshore transects in August through November, and occasionally in Inshore waters (Tables 3-5, Figure 15). The concentrations seen in late summer and fall must have included migrants from elsewhere, because only small numbers breed in or near our area (Seabird Rocks: ca. 160 pairs, Cleland Island: 800 pairs; Rodway 1991). Cassin's Auklets were the second most numerous of birds killed by the *Nestucca* spill (Rodway et al. 1989). The aerial surveys made by Ford et al. (1991) indicated that the greatest aggregations in the winter were over the shelf south of the Juan de Fuca canyon, outside our study area.

Tufted Puffins were rare, found only in spring and summer in Inshore and Offshore waters (Tables 3-5, Figure 16). Fewer than five pairs breed on Seabird Rocks in our area (AEB, unpublished data), with similar small numbers on Cleland Island off Tofino, outside our area (Rodway 1991), but about 4,000 pairs around Cape Flattery to the south of our study area (Speich and Wahl 1989). Ancient Murrelets occurred sporadically in moderate densities in all three zones, primarily in fall and winter (Tables 3-5, Figure 16). High densities were recorded during a winter survey in December in the Inshore area off the West Coast Trail (see Paper 5 in this compendium). This species does not breed in or near our study area. Pigeon Guillemots remain year-round in these waters, foraging primarily in Nearshore waters, and from March through October, in the more shallow Inshore waters (Tables 3-5, Figure 16). About 1,500 pairs of guillemots breed in Barkley Sound, on Seabird Rocks and along the shores of the West Coast Trail (Rodway 1991, AEB and AS personal observations).

Marbled Murrelets are a threatened species in Canada, and have been the focus of considerable research. Southwest Vancouver Island is home to a substantial portion of the British Columbia breeding population (Burger 1995, see also paper 5 in this compendium). Several studies covered the marine distribution and densities of murrelets in this area, but nearly all were restricted to the summer breeding season (Carter 1984, Sealy and Carter 1984, Carter and Sealy 1990, Kelson et al. 1995, Burger 1995, 1997, 2000). Our data are the first to show year-round densities in a range of marine habitats. Our study did not include deep fjords, inland waters far from the outer coast, or coastal lakes (e.g., Nitinat lake), in which Marbled Murrelets are known to overwinter in small, scattered groups (AS and AEB, unpublished data).

As expected, Marbled Murrelets were found predominantly in the Nearshore waters, and Inshore waters closest to the shore (Tables 3-5, Figure 17). This is consistent with other studies which showed that most murrelets off Vancouver Island were found within 500 m of shore (Carter 1984, Burger 1995, 1997). Our data indicate the extent of migration in the local population. Murrelets left the area immediately after the end of breeding (July and August), and densities during the fall were extremely low. Some appeared to return to the area in winter (December-March), but the bulk of the local population returned at the onset of the breeding season in late April and May. Our data confirm that Marbled Murrelets do not overwinter in Offshore waters over the continental shelf (Morgan et al. 1991), but appear to migrate to more sheltered waters in Georgia Strait and Puget Sound (Burger 1995).

Our data explain the low mortality of Marbled Murrelet in the winter *Nestucca* oil spill (12 carcasses were found on Vancouver Island and 143 were estimated killed in these waters; Rodway et al. 1989, Burger 1993a). A summer spill affecting Nearshore waters off Vancouver Island, however, would likely have a devastating impact on this threatened species.

Breeding origins of the species recorded off southwest Vancouver Island

Birds recorded in our surveys were classified by their breeding origins. Local breeders were considered to be species breeding within our study area or within commuting distance when nesting (e.g. 10-50 km). These species included Pelagic Cormorant, Fork-tailed and Leach's Storm-petrels, Glaucous-winged Gull, Pigeon Guillemot, Marbled Murrelet, Rhinoceros Auklet, and Tufted Puffin (Table 1). Cassin's Auklet was not included here, because the bulk of the records were in winter and the large numbers counted on some transects, relative to the small local colonies, suggested that most were not local breeders. Other categories covered species which breed in the following areas: coast of B.C. or Washington (e.g., Brandt's Cormorants, Common Murres, Ancient Murrelets); Alaska coast (e.g., Northern Fulmar); Arctic (e.g., Thayer's Gull, Red-necked Phalarope); interior of B.C. and other temperate interior areas on the North American continent (e.g., Harlequin Duck, California Gull); and the southern hemisphere (e.g., Sooty and Short-tailed Shearwaters). A few less common species which breed in diverse places such as Mexico (Heermann's Gull) and Hawaii (Black-footed Albatross) were pooled as Elsewhere. The complete list is in Table 1.

Most of the birds recorded in all three zones did not breed in or near the study area. Throughout the year, local breeders comprised 37%, 21% and 14% of the Nearshore, Inshore and Offshore birds, respectively (Table 6). The proportion was lower in the fall, winter and early spring (Figure 18). Collectively, the at-sea avifauna consisted of a diverse assemblage of species from many parts of the Pacific and continental North America. Two major implications of this diversity of breeding origin are discussed below.

Implications of the cosmopolitan marine avifauna

Our data indicate the cosmopolitan nature of the avifauna and the global importance of the area as a foraging ground, migratory passageway and wintering ground. Canada and B.C. clearly have global responsibilities for protecting the diverse marine avifauna, but protection of the marine habitat and food resources of seabirds has seldom been a priority for either level of government. We recognise several ways in which such protection can

be instated. Reduction of the risks from oil spills, fisheries by-catch, and over-fishing of prey stocks are three obvious and essential precautions.

The highly publicised impacts of the *Nestucca*, *Exxon Valdez* and other major oil spills over the past 15 years has raised awareness of the threats of such spills, and improved some regulations affecting shipping in the northeast Pacific. Chronic oiling from small, often unreported spills continually kills seabirds off B.C., but based on densities of oiled carcasses in beached surveys, this mortality is much lower than in many other parts of the world (Burger 1993b). Until recently, there was no ongoing monitoring to assess whether this situation was changing, which was a concern with the levels of shipping involved, and possible lifting of the moratorium on offshore oil-exploration off B.C. In 2002 Bird Studies Canada and the Canadian Wildlife Service resumed the volunteer beached bird survey program which will provide some monitoring of oiling rates.

By-catch mortality of seabirds in the gill-net, seining and long-line fisheries has, until recently, been largely ignored off B.C. The pioneering study by Carter and Sealy (1984) in Barkley Sound demonstrated the potentially serious impact of gill-nets on Marbled Murrelets, although changes to timing and size of this fishery appear to have reduced the risks in that area. Recent work in Washington has shown that significant numbers of Common Murres, and occasionally other species such as Marbled Murrelets, Rhinoceros Auklets and Western Grebes, are killed by gill-nets (Pierce et al. 1994, Melvin et al. 1999). These studies also investigated ways of reducing this by-catch. The Canadian Wildlife Service and federal Department of Fisheries and Oceans have launched a multi-year study to investigate the impacts and possible mitigation of fisheries by-catch in B.C. waters (K. Morgan and J. Smith, personal communication).

Competition with commercial fisheries, and over-fishing have had negative impacts on seabird populations in many parts of the world (Montevecchi 1993). At present there are no obvious reductions of the prey stocks eaten by birds which are directly caused by fishing in B.C., although fishing probably affects the availability of juvenile herring and salmonids commonly eaten by birds. Direct competition with fisheries might occur if

euphausiids or sand lance (*Ammodytes hexapterus*) were commercially fished, as they are in other parts of the world. Seabirds benefit from discarded waste and losses of dead fish from nets in the demersal hake fishery off southwest Vancouver Island, and thousands of gulls, shearwaters, fulmars and storm-petrels can sometimes be seen behind these vessels (Vermeer et al. 1989, this study).

Current discussions aimed at establishing marine protected areas in B.C. should consider the year-round use by seabirds, although the flexible and highly mobile foraging behaviour of seabirds makes protection of important foraging grounds a formidable objective. In our study area, narrow strips of the Nearshore and Inshore waters fall within the Pacific Rim National Park Reserve, and basic inventories of birds and other organisms are underway in these and adjacent areas. Areas which routinely support high densities of seabirds and other marine organisms, such as the Swiftsure Bank, might be candidates for protected areas, but more research is needed to determine whether this is necessary or beneficial.

Problems in monitoring the effects of oiling and by-catch on seabird populations

A further implication of the widespread breeding distribution of the birds using the waters off Vancouver Island is the problem of monitoring and detecting the impacts of major oil spills, low-volume chronic oiling, and fisheries by-catch. The immediate impact of these events is usually measured by counting carcasses on beaches or at sea. The longer-term impacts on populations, however, can be done only at breeding sites, which are usually colonies. Detecting and interpreting changes caused by spills is often a contentious and difficult task, even when the spill happens close to the breeding colonies, as was the case with the *Exxon Valdez* spill (Piatt et al. 1990, Parrish and Boersma 1995, Piatt 1996, Wiens 1996). When birds are killed thousands of km from their breeding sites, or if the breeding sites of birds are not known, it becomes extremely difficult to assess the long-term population impacts of an oil spill or other catastrophe.

The extent of this problem off southwest Vancouver Island is obvious when considering the wide geographic range from which birds originate (Table 6, Figure 18). Monitoring

population changes in locally-breeding birds will provide only a partial view of the likely impacts of either catastrophic or chronic mortality. This applies to events that happen in any season. Even monitoring local breeders is difficult, because the most common breeder is the Marbled Murrelet. Estimating and monitoring breeding populations of murrelets is notoriously difficult, because they are not colonial, but nest secretively and dispersed in forest canopies within 30-50 km of the shore. At-sea boat surveys (Becker et al. 1997) and radar counts of murrelets entering watersheds (Burger 2001) could provide indications of population change, although neither method identifies breeders and non-breeders, and neither provides the same precision as repeated counts at colonies.

Measuring and monitoring the impacts of an oil spill off Vancouver Island on populations of local breeders and migrants seems extremely difficult. This makes it imperative that the immediate impacts of such events (i.e., dead or injured birds) be accurately measured and reported.

CONCLUSIONS

Our study is the first to provide year-round counts of seabirds along consistent transect routes off Vancouver Island, in an area with a large, diverse and globally significant avifauna. We covered a wide range of habitats within three major marine zones frequently used by birds. Some habitats were not included, for logistical and financial reasons. These include the more sheltered Nearshore waters of the denser island groups and deep fjords, in which large populations of waterfowl, loons and grebes overwinter, and which might be important for Marbled Murrelets in winter. These Nearshore areas have, however been well sampled at several locations on the B.C. coast (e.g., Vermeer and Butler 1989, Vermeer et al. 1992).

Our funding and small vessel precluded sampling the oceanic environment at the outer shelf break and beyond the continental shelf. Consequently, we did not adequately sample the habitats used by shelf-edge specialists such as Cassin's Auklets and Leach's Storm-petrels, nor those of the more oceanic species, such as albatrosses. Although these areas have been reasonably well studied in summer, the distribution and densities of birds

in winter and early spring is not well known (Morgan et al. 1991). The lack of knowledge of the offshore fauna in winter was highlighted by the unexpected discovery in January 1989 of at least 15 Parakeet Auklets (*Cyclorhynchus psittacula*) among the victims of the *Nestucca* spill washed ashore on Vancouver Island (Rodway et al. 1989). This species has been reliably sighted off BC only two or three times (Campbell et al. 1990, K. Morgan, personal communication).

This paper focused on the seasonal variations and broad-scale distribution of seabirds off southwest Vancouver Island. Additional analyses of these data to elucidate fine-scale distribution patterns (1-10 km range), and the underlying causes of this distribution, have also been done (other papers in this compendium).

ACKNOWLEDGEMENTS

The study was funded by the Nestucca Trust Fund, with additional support from grants to AEB from NSERC Canada, the Endangered Species Recovery Fund (World Wildlife Fund Canada and Canadian Wildlife Service), Habitat Conservation Trust Fund, Forest Renewal B.C., and Heritage Canada (Pacific Rim National Park). Bamfield Marine Station provided vessels, accommodation and other logistic support. We particularly thank the many volunteers and assistants, especially those who made repeated offshore cruises, including Suzanne Beauchesne, Mike Bentley, Christian Engelstoft, Cecily Grant, Kevin Little, Nigel Mathews, Kelly Nordin, Dawn Renfrew, Clive Strauss, and Alex Welcel. For their important contributions we thank: skippers Rick Garcia, Stan Logan, Mitch McPhee, James Nookemus, and the late Tim Wenstob; wardens of Pacific Rim National Park; and, the students and staff from Bamfield Marine Station.

LITERATURE CITED

Ainley, D. G., and R. J. Boekelheide, editors. 1990. Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling-system community. Stanford University Press, Stanford, CA.

- Becker, B. H., S. R. Beissinger, and H. R. Carter. 1997. At-sea density monitoring of Marbled Murrelets in central California: methodological considerations. *Condor* 99:743-755.
- Briggs, K. T., W. B. Tyler, D. B. Lewis and D. R. Carlson. 1987. Bird communities at sea off California: 1975 to 1983. *Studies in Avian Biology* 11:1-74.
- Burger, A. E. 1992. The effects of oil pollution on seabirds off the west coast of Vancouver Island. Pp. 120-128 In, *The ecology, status and conservation of marine and shoreline birds of the west coast of Vancouver Island* (K. Vermeer, R.W. Butler and K.H. Morgan, eds.). Occasional Paper No. 75, Canadian Wildlife Service, Ottawa.
- Burger, A. E. 1993a. Effects of the '*Nestucca*' oil spill on seabirds along the coast of Vancouver Island in 1989. Canadian Wildlife Service Technical Report Series No. 179. Pacific and Yukon Region, British Columbia.
- Burger, A. E. 1993b. Mortality of seabirds assessed from beached bird surveys in British Columbia. *Canadian Field-Naturalist* 107:164-176.
- Burger, A. E. 1995. Marine distribution, abundance, and habitats of Marbled Murrelets in British Columbia. Pages 295-312 in C. J. Ralph, G. L. Hunt Jr., M. G. Raphael, and J. F. Piatt, eds. *Ecology and conservation of the Marbled Murrelet*. USDA Forest Service General Technical Report PSW-GTR-152.
- Burger, A. E. 1997. Distribution and abundance of Marbled Murrelets and other seabirds off the West Coast Trail, Pacific Rim National Park in 1996. Report to Heritage Canada, Pacific Rim National Park, Ucluelet.
- Burger, A. E. 2000. Bird in hot water: responses by Marbled Murrelets to variable ocean temperatures off southwest Vancouver Island. Pp. 723-732 in, *Proceedings of a Conference on the Biology and Management of Species and Habitats At Risk*, Kamloops, B.C., 15-19 February 1999. Volume 2. (L. M. Darling, ed.). B.C. Ministry of Environment, Lands and Parks, Victoria, B.C., and University College of the Cariboo, Kamloops, B.C.
- Burger, A. E. 2001. Using radar to estimate populations and assess habitat associations of Marbled Murrelets. *Journal of Wildlife Management* 65:696-715

- Burger, A. E. and D. M. Fry. 1993. Effects of oil pollution on seabirds in the northeast Pacific. Pp. 254-263 in, The status, ecology, and conservation of marine birds of the North Pacific (K. Vermeer, K.T. Briggs, K.H. Morgan and D. Siegel-Causey, eds.). Canadian Wildlife Service Special Publication, Ottawa.
- Campbell, R. W., N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, and M. C. E. McNall. 1990. The birds of British Columbia. Volume 2. Royal British Columbia Museum and Canadian Wildlife Service, Victoria, BC.
- Carter, H. R. 1984. At-sea biology of the Marbled Murrelet (*Brachyramphus marmoratus*) in Barkley Sound, British Columbia. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.
- Carter, H. R. and S.G. Sealy. 1984. Marbled Murrelet (*Brachyramphus marmoratus*) mortality due to gill-net fishing in Barkley Sound, British Columbia. Pp. 212-220 in Marine birds: their feeding ecology and commercial fisheries relationships (D. N. Nettleship, G. A. Sanger, and P. F. Springer, eds.). Canadian Wildlife Service Special Publication. Minister of Supply and Services, Ottawa.
- Carter, H. R., and S. G. Sealy. 1990. Daily foraging behavior of Marbled Murrelets. *Studies in Avian Biology* 14: 93-102.
- Cohen, P. and R. Aylesworth. 1990. Oil spill risk for southern B.C./northern Washington coast marine area. Final report of the States/British Columbia oil spill task force, Appendix VII. Publication of the Province of British Columbia and the States of Washington, Oregon, Alaska and California. 105 p.
- Davoren, G. K. 1997. Parental investment in the Rhinoceros Auklet (*Cerorhinca monocerata*) at the colony and at sea off southwest Vancouver Island. MSc thesis, University of Victoria, Victoria, BC.
- Davoren, G. K. 2000. Variability in foraging in response to changing prey distributions in rhinoceros auklets. *Marine Ecology Progress Series* 198: 283-291.
- Ford, R.G. , J.L. Casey, C. H. Hewitt, D. B. Lewis, D. H. Varoujean, D. R. Warrick and W. A. Williams. 1991. Seabird mortality resulting from the *Nestucca* oil spill incident, winter 1988-89. Report for Washington Dept. Wildlife. Ecological Consulting Inc., Portland, Oregon.

- Freeland, H. J. 1992. The physical oceanography of the west coast of Vancouver Island. Pages 10-14 in K. Vermeer, R. W. Butler and K. H. Morgan, editors. The ecology, status and conservation of marine and shoreline birds of the west coast of Vancouver Island. Occasional Paper No. 75, Canadian Wildlife Service, Ottawa.
- Hay, R. B. 1992. The oceanic habitats of seabirds: their zonal distribution off Vancouver Island, British Columbia, Canada. *Journal of Biogeography* 19:67-85.
- Kelson, J. D., I. A. Manley, and H. R. Carter. 1995. Decline of the Marbled Murrelet in Clayoquot Sound, British Columbia: 1982-1993. *Northwestern Naturalist* 76:90-98.
- Kessel, B. 1979. Avian habitat classification for Alaska. *Murrelet* 60:86-94.
- Logerwell, E. A. and N. B. Hargreaves. 1996. The distribution of sea birds relative to their fish prey off Vancouver Island: opposing results at large and small spatial scales. *Fisheries Oceanography* 5:163-175.
- Martin, P. W. and M. T. Myres. 1969. Observations on the distribution and migration of some seabirds off the outer coasts of British Columbia and Washington State, 1946-1949. *Syesis* 2:241-256.
- Melvin, E. F., J. K. Parrish, and L. L. Conquest. 1999. Novel tools to reduce seabird bycatch in coastal gillnet fisheries. *Conservation Biology* 13:1386-1397.
- Montevecchi, W. A. 1993. Birds as indicators of change in marine prey stocks. Pp. 217-266 in *Birds as monitors of environmental change* (R.W. Furness and J.J.D. Greenwood, eds.). Chapman and Hall, New York.
- Morgan, K. H., K. Vermeer and R.W. McKelvey. 1991. Atlas of pelagic birds of Western Canada. Occasional Paper No. 72, Canadian Wildlife Service, Ottawa.
- Parrish, J.K. and P.D. Boersma. 1995. Muddy waters. *American Scientist* 83:112-115.
- Parrish, J. K., N. Lemberg, and L. South-Oryshchyn. 1998. Effects of colony location and nekton abundance on the at-sea distribution of four seabird species. *Fisheries Oceanography* 7:126-135.
- Piatt, J.F. 1996. Water over the bridge. *American Scientist* 83:396-398.
- Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek, and D. R. Nysewander. 1990. Immediate impact of the *Exxon Valdez* oil spill on marine birds. *Auk* 107(2): 387-397.

- Pierce, D., W. Ritchie, R. Kruezigar. 1994. Preliminary findings of seabird interactions with non-treaty salmon gillnet fishery: Puget Sound and Hood Canal, Washington. Washington Department of Fish and Wildlife.
- Rodway, M.S. 1991. Status and conservation of breeding seabirds in British Columbia. Pp. 43-102 *in* Status and Conservation of the world's seabirds (J.P. Croxall, ed.). International Council for Bird Preservation, Technical Publication No. 11, Cambridge, U.K.
- Rodway, M. S., J. F. Lemon, J.-P. Savard and R. McKelvey. 1989. Nestucca oil spill: impact assessment on avian populations and habitat. Technical Report Series No. 68. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.
- Sealy, S. G. and H. R. Carter. 1984. At-sea distribution and nesting habitat of the Marbled Murrelet in British Columbia: problems in the conservation of a solitary nesting seabird. Pp. 737-756 *In* Status and conservation of the world's seabirds (J. P. Croxall, P. G. H. Evans, and R. W. Schreiber, eds.) Technical Publication No. 2. International Council for Bird Preservation. Norwich, UK: Page Bros.
- Shaffer, M. and Associates Ltd. 1990. Crude oil and petroleum product traffic in British Columbia and Puget Sound. Final Report of the States/British Columbia oil spill task force, Appendix IV. Publ. Province of British Columbia and the States of Washington, Oregon, Alaska and California. 51 pp.
- Speich, S. M., and T. R. Wahl. 1989. Catalog of Washington seabird colonies. Biological Report 88(6). Washington, DC: U.S. Fish and Wildlife Service; 510 p.
- Tanasichuk, R. W. 1998a. Interannual variations in the population biology and productivity of *Euphausia pacifica* in Barkley Sound, Canada, with special reference to the 1992 and 1993 warm ocean years. Marine Ecology Progress Series 173:163-180.
- Tanasichuk, R. W. 1998b. Interannual variations in the population biology and productivity of *Thysanoessa spinifera* in Barkley Sound, Canada, with special reference to the 1992 and 1993 warm ocean years. Marine Ecology Progress Series 173:181-195.

- Tasker, M. L., P Hope Jones, T. Dixon, and B. F. Blake. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *Auk* 101:567-577.
- Thomas, A. C. and W.J. Emery. 1986. Winter hydrography and plankton distribution on the southern British Columbia continental shelf. *Canadian Journal of Fisheries and Aquatic Science* 43:1249-1258.
- Thomson, R. E. 1981. Oceanography of the British Columbia coast Canadian Special Publication Fisheries and Aquatic Science 56, 291 p.
- Thomson, R. E., B. M. Hickey and P. H. LeBlond. 1989. The Vancouver Island coastal current: fisheries barrier and conduit. Pp. 265-296. In R. J. Beamish and G.A. McFarlane (eds.) Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Canadian Special Publication Fisheries and Aquatic Science 108.
- Van Franeker, J. A. 1994. A comparison of methods for counting seabirds at sea in the Southern Ocean. *Journal of Field Ornithology*. 65:96-108.
- Vermeer, K., and R. W. Butler, eds. 1989. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia. Special Publication, Canadian Wildlife Service, Ottawa.
- Vermeer, K., R. W. Butler, and K. H. Morgan. eds. 1992. The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island. Occasional Paper No. 75. Canadian Wildlife Service, Ottawa.
- Vermeer, K., R. Hay and L. Rankin. 1987. Pelagic seabird populations off southwest Vancouver Island. Canadian Technical Report on Hydrographic Ocean Science. No. 87:iii + 26 p.
- Vermeer, K., K. H. Morgan and P.J. Ewins. 1992. Population trends of Pelagic Cormorants and Glaucous-winged Gulls nesting on the west coast of Vancouver Island. Pp. 60-64 in The ecology, status and conservation of marine and shoreline birds on the west coast of Vancouver Island (K. Vermeer, R.W. Butler and K.H. Morgan, eds.). Canadian Wildlife Service Occasional Paper No. 75, Ottawa.
- Vermeer, K., K. H. Morgan, G. E. J. Smith and R. Hay. 1989. Fall distribution of pelagic birds over the shelf off SW Vancouver Island. *Colonial Waterbirds* 12:207-214.

- Vermeer, K., I. Robertson, R. W. Campbell, R. W. Kaiser and M. Lemon. 1983.
Distribution and densities of marine birds on the Canadian west coast. Canadian Wildlife Service Report, Vancouver, B. C.
- Vermeer, K. and R. Vermeer. 1975. Oil threat to birds on the Canadian West Coast. Canadian Field-Naturalist 89:278-298.
- Wahl, T. R., D. G. Ainley, A. H. Benedict and A. R. DeGange. 1989. Associations between seabirds and water-masses in the northern Pacific Ocean in summer. Marine Biology 103:1-11.
- Wahl, T.R., K.H. Morgan and K. Vermeer. 1993. Seabird distribution off British Columbia and Washington. Pp. 39-47 in The status, ecology and conservation of marine birds of the North Pacific (K. Vermeer, K.T. Briggs, K. Morgan and D. Siegel-Causey, eds.). Canadian Wildlife Service Special Publ., Ottawa.
- Wiens, J. 1996. Oil, seabirds and science: the effects of the *Exxon Valdez* oil spill. Bioscience 46:587-597.
- Zacharias, M. A., D. E. Howes, J. H. Harper, and P. Wainwright. 1998. The British Columbia marine ecosystem classification: rationale, development, and verification. Coastal Management 26:105-124.

Table 1. Species of birds reported on surveys off southwest Vancouver Island in 1993-1995, and the geographic location in which they regularly breed.

Family	English name	Species	Code for breeding origin*
Loons (Gaviidae)			
	Red-throated Loon	<i>Gavia stellata</i>	Inland
	Pacific Loon	<i>Gavia pacifica</i>	Arctic
	Common Loon	<i>Gavia immer</i>	Inland
Grebes (Podicipedidae)			
	Horned Grebe	<i>Podiceps auritus</i>	Inland
	Red-necked Grebe	<i>Podiceps grisegena</i>	Inland
	Western Grebe	<i>Aechmophorus occidentalis</i>	Inland
Procellariids (Order Procellariiformes)			
	Black-footed Albatross	<i>Phoebastria nigripes</i>	Hawaii
	Northern Fulmar	<i>Fulmarus glacialis</i>	Alaska
	Pink-footed Shearwater	<i>Puffinus creatopus</i>	S. Hemisphere
	Buller's Shearwater	<i>Puffinus bulleri</i>	S. Hemisphere
	Sooty Shearwater	<i>Puffinus griseus</i>	S. Hemisphere
	Short-tailed Shearwater	<i>Puffinus tenuirostris</i>	S. Hemisphere
	Fork-tailed Storm-petrel	<i>Oceanodroma furcata</i>	Local
	Leach's Storm-petrel	<i>Oceanodroma leucorhoa</i>	Local
Cormorants (Phalacrocoracidae)			
	Double-crested Cormorant	<i>Phalacrocorax auritus</i>	BC & WA
	Brant's Cormorant	<i>Phalacrocorax penicillatus</i>	BC & WA
	Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	Local
Waterfowl (Anatidae)			
	Brant	<i>Branta bernicla</i>	
	Green-winged Teal	<i>Anas crecca</i>	Inland
	Gadwall	<i>Anas strepera</i>	Inland
	American Widgeon	<i>Anas americana</i>	Inland
	Greater Scaup	<i>Aythya marila</i>	Inland
	Harlequin Duck	<i>Histrionicus histrionicus</i>	Inland
	Long-tailed Duck	<i>Clangula hyemalis</i>	Inland
	Black Scoter	<i>Melanitta nigra</i>	Inland
	Surf Scoter	<i>Melanitta perspicillata</i>	Inland
	White-winged Scoter	<i>Melanitta fusca</i>	Inland
	Common Goldeneye	<i>Bucephala clangula</i>	Inland
	Bufflehead	<i>Bucephala albeola</i>	Inland
	Hooded Merganser	<i>Lophodytes cucullatus</i>	Inland
	Common Merganser	<i>Mergus merganser</i>	Local

Red-breasted Merganser	<i>Mergus serrator</i>	Inland
Phalaropes (Scolopacidae)		
Red-necked Phalarope	<i>Phalaropus lobatus</i>	Arctic
Red Phalarope	<i>Phalaropus fulicaria</i>	Arctic
Jaegers and Gulls (Laridae)		
Pomarine Jaeger	<i>Stercorarius pomarinus</i>	Arctic
Parasitic Jaeger	<i>Stercorarius parasiticus</i>	Arctic
Bonaparte's Gull	<i>Larus philadelphia</i>	Inland
Heermann's Gull	<i>Larus heermanni</i>	Mexico
Mew Gull	<i>Larus canus</i>	Inland
Ring-billed Gull	<i>Larus delawarensis</i>	Inland
California Gull	<i>Larus californicus</i>	Inland
Herring Gull	<i>Larus argentatus</i>	Inland
Thayer's Gull	<i>Larus thayeri</i>	Arctic
Western Gull	<i>Larus occidentalis</i>	BC & WA
Glaucous-winged Gull	<i>Larus glaucescens</i>	Local
Black-legged Kittiwake	<i>Rissa tridactyla</i>	Alaska
Sabine's Gull	<i>Xema sabini</i>	Arctic
Alcids (Alcidae)		
Common Murre	<i>Uria aalge</i>	BC & WA
Pigeon Guillemot	<i>Cephus columba</i>	Local
Marbled Murrelet	<i>Brachyramphus marmoratus</i>	Local
Ancient Murrelet	<i>Synthliboramphus antiquus</i>	BC & WA
Cassin's Auklet	<i>Ptychoramphus aleuticus</i>	BC & WA
Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	Local
Tufted Puffin	<i>Fratercula cirrhata</i>	Local

*Codes for breeding locations:

Local	Within 50 km of the study area
BC & WA	Coast of BC and/or Washington
Alaska	Coast and islands of Alaska
Arctic	Arctic tundra or islands
Inland	Inland in temperate continental North America
S. Hemisphere	Southern hemisphere
Elsewhere	Mexico, Hawaii

Table 2. Number of surveys made in each marine zone off southwest Vancouver Island in each month.

Month	Nearshore surveys				Inshore surveys				Offshore surveys			
	1993	1994	1995	Total	1993	1994	1995	Total	1993	1994	1995	Total
Jan	-	1	3	4	-	1	1	2	-	1	0	1
Feb	-	0	2	2	-	0	1	1	-	0	1	1
Mar	-	2	3	5	-	2	0	2	-	2	0	2
Apr	-	2	1	3	-	1	2	3	-	1	1	2
May	2	3	2	7	1	1	2	4	1	1	1	3
Jun	2	3	1	6	1	2	1	4	1	1	1	3
Jul	2	2	2	6	2	1	2	5	1	1	1	3
Aug	2	3	2	7	4	1	5	10	2	1	3	6
Sep	2	2	2	6	1	1	0	2	1	1	0	2
Oct	2	1	-	3	1	1	0	2	1	1	0	2
Nov	2	1	-	3	1	0	1	2	1	0	1	2
Dec	2	2	-	4	0	0	1	1	0	0	1	1

Table 3. Summary of densities and percentage occurrence per species in 56 **Nearshore** surveys made in 28 months between May 1993 and December 1995.

	Density (birds per sq. km)				Percentage occurrence in surveys	Maximum count
	Mean	SD	CV	% of total		
Red-throated Loon	0.00	0.01	529	0.0	2	1
Pacific Loon	0.19	0.32	166	0.8	41	25
Common Loon	0.22	0.20	91	0.9	66	9
Loon sp.	0.02	0.05	217	0.1	16	3
Horned Grebe	0.23	0.41	175	1.0	32	23
Red-necked Grebe	0.31	0.39	126	1.3	50	26
Western Grebe	2.61	4.34	166	11.2	41	284
Grebe sp.	0.01	0.02	245	0.0	9	2
Fork-tailed Storm-petrel	0.00	0.01	529	0.0	2	1
Double-crested Cormorant	0.24	0.46	190	1.0	54	30
Brandt's Cormorant	0.63	0.84	133	2.7	63	56
Pelagic Cormorant	1.49	1.14	77	6.4	95	66
Cormorant sp.	0.08	0.29	358	0.3	18	31
Harlequin Duck	0.34	0.44	130	1.4	59	22
Long-tailed Duck	0.00	0.01	529	0.0	2	1
Black Scoter	0.02	0.06	367	0.1	4	6
Surf Scoter	2.60	3.76	145	11.1	54	239
White-winged Scoter	0.35	0.39	113	1.5	46	29
Scoter sp.	0.10	0.28	285	0.4	11	32
Common Goldeneye	0.03	0.08	265	0.1	11	9
Goldeneye sp.	0.01	0.04	328	0.0	5	6
Bufflehead	0.48	1.01	211	2.1	32	125
Hooded Merganser	0.01	0.04	529	0.0	2	6
Common Merganser	0.16	0.41	251	0.7	23	48
Red-breasted Merganser	0.12	0.23	199	0.5	21	13
Merganser sp	0.00	0.01	529	0.0	2	2
Gadwall	0.00	0.01	529	0.0	2	2
Duck sp	0.03	0.07	240	0.1	14	5
Scaup sp	0.01	0.04	457	0.0	4	3
Red-necked Phalarope	0.28	1.18	419	1.2	9	160
Bonaparte's Gull	0.01	0.03	529	0.0	2	4
Heermann's Gull	0.01	0.07	529	0.1	2	10
Mew Gull	0.32	0.74	229	1.4	32	51
Ring-billed Gull	0.01	0.03	421	0.0	4	5
California Gull	0.74	1.67	225	3.2	25	77
Herring Gull	0.12	0.34	275	0.5	13	23
Thayer's Gull	0.13	0.46	368	0.5	11	60
Western Gull	0.22	1.14	519	0.9	5	78
Glaucous-winged Gull	1.30	1.59	122	5.6	68	119
Gull sp.	0.78	2.25	287	3.4	23	390
Common Murre	2.48	3.55	143	10.6	91	365
Pigeon Guillemot	0.50	0.29	59	2.1	93	25
Marbled Murrelet	5.70	8.38	147	24.4	86	642
Ancient Murrelet	0.02	0.05	278	0.1	7	5
Cassin's Auklet	0.01	0.03	433	0.0	5	3
Rhinoceros Auklet	0.43	0.80	185	1.8	52	46
Alcid sp.	0.01	0.02	252	0.0	7	2
Total of all birds	23.36	10.85	46	100.0	100	947

Table 4. Summary of densities and percentage occurrence per species in 38 **Inshore** surveys made in 27 months between May 1993 and December 1995.

	Density (birds per sq. km)				Percentage occurrence in surveys	Maximum count
	Mean	SD	CV	% of total		
Red-throated Loon	0.03	0.09	264	0.1	15	3
Pacific Loon	1.41	3.10	219	3.5	63	88
Common Loon	0.12	0.21	171	0.3	37	5
Loon sp.	0.40	0.89	226	1.0	44	21
Red-necked Grebe	0.08	0.22	258	0.2	15	5
Western Grebe	0.39	0.74	192	1.0	37	15
Grebe sp.	0.03	0.13	529	0.1	4	4
Sooty Shearwater	5.57	11.33	203	13.9	52	247
Buller's Shearwater	0.00	0.01	529	0.0	4	1
Shearwater spp.	0.01	0.03	529	0.0	4	1
Northern Fulmar	0.03	0.13	433	0.1	7	16
Fork-tailed Storm-petrel	0.15	0.67	454	0.4	11	41
Double-crested Cormorant	0.08	0.23	301	0.2	22	7
Brant's Cormorant	1.40	1.80	128	3.5	93	65
Pelagic Cormorant	0.31	0.42	133	0.8	56	14
Cormorant spp.	0.17	0.53	311	0.4	33	16
Brant	0.13	0.56	430	0.3	11	18
Harlequin Duck	0.01	0.05	302	0.0	11	2
Surf Scoter	0.64	1.07	167	1.6	59	21
White-winged Scoter	0.30	0.75	249	0.8	41	19
Scoter spp.	0.43	1.18	272	1.1	26	26
Other waterfowl*	0.25	0.78	315	0.6	22	22
Red-necked Phalarope	0.36	0.80	222	0.9	26	29
Red Phalarope	0.02	0.13	529	0.1	4	8
Phalarope spp.	0.57	2.15	378	1.4	30	64
Pomarine Jaeger	0.00	0.01	529	0.0	4	1
Jaeger sp.	0.01	0.03	529	0.0	4	1
Heermann's Gull	0.02	0.05	307	0.0	11	1
Mew Gull	0.47	1.99	424	1.2	37	63
Ring-billed Gull	0.03	0.15	529	0.1	4	9
California Gull	3.45	5.56	161	8.6	63	243
Herring Gull	0.02	0.05	294	0.0	11	1
Thayer's Gull	0.21	0.48	223	0.5	22	11
Western Gull	0.02	0.08	314	0.1	7	2
Glaucous-winged Gull	3.11	1.86	60	7.8	100	43
Black-legged Kittiwake	0.01	0.04	367	0.0	7	1
Gull spp.	0.54	0.96	178	1.3	48	19
Common Murre	13.52	11.85	88	33.8	100	269
Pigeon Guillemot	0.27	0.49	179	0.7	52	20
Marbled Murrelet	1.50	1.91	127	3.7	89	57
Ancient Murrelet	0.07	0.18	263	0.2	19	4
Cassin's Auklet	0.50	1.84	367	1.2	37	58
Rhinoceros Auklet	2.67	3.13	117	6.7	89	67
Tufted Puffin	0.02	0.05	230	0.1	19	1
Alcid spp.	0.08	0.25	315	0.2	19	7
Total birds	40.02	21.57	54	99	100	649

*Single sightings of small migrating flocks of Green-winged Teal, American Wigeon, Scaup sp., and Merganser sp.

Table 5. Summary of densities and percentage occurrence per species in 29 **Offshore** surveys made in 27 months between May 1993 and December 1995.

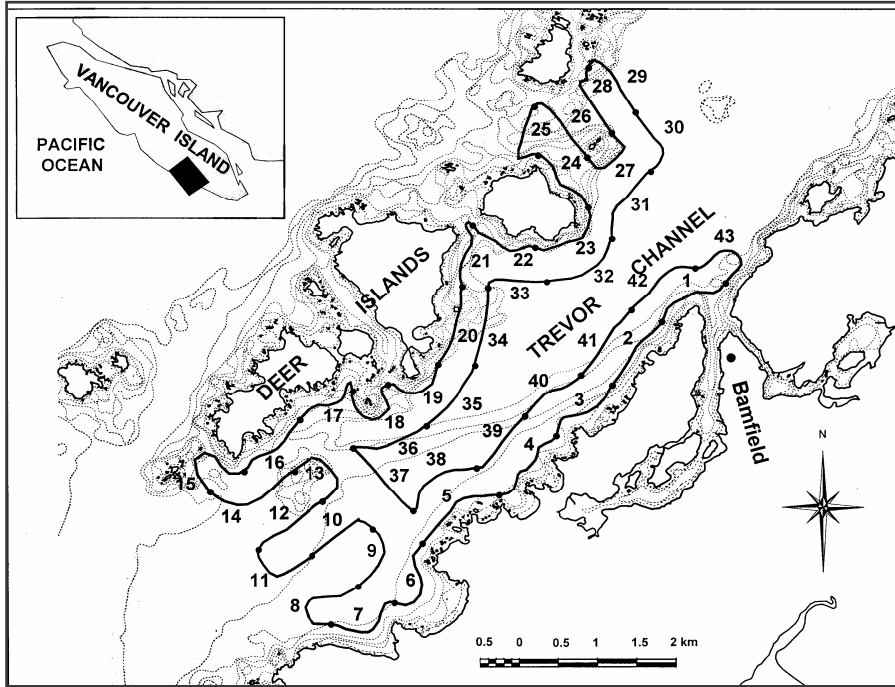
	Density (birds per sq. km)				Percentage occurrence in surveys	Maximum count
	Mean	SD	CV	% of total		
Red-throated Loon	0.01	0.05	487	0.0	7	2
Pacific Loon	0.27	0.35	127	0.5	69	39
Common Loon	0.01	0.04	313	0.0	14	1
Loon spp.	0.09	0.27	286	0.2	31	35
Western Grebe	0.01	0.04	290	0.0	14	5
Black-footed Albatross	0.03	0.07	282	0.0	21	7
Northern Fulmar	3.84	7.08	184	7.0	76	999
Pink-footed Shearwater	0.05	0.13	264	0.1	34	22
Buller's Shearwater	0.01	0.04	289	0.0	17	5
Sooty Shearwater	10.85	12.70	117	19.9	83	1690
Short-tailed Shearwater	0.16	0.41	248	0.3	62	58
Fork-tailed Storm-petrel	1.35	3.09	229	2.5	59	489
Leach's Storm-petrel	0.00	0.02	539	0.0	3	4
Brant's Cormorant	0.34	0.92	268	0.6	72	160
Pelagic Cormorant	0.07	0.12	175	0.1	52	7
Cormorant spp.	0.01	0.02	239	0.0	17	3
Surf Scoter	0.30	0.90	305	0.5	34	172
White-winged Scoter	0.07	0.17	256	0.1	31	25
Black Scoter	0.05	0.21	384	0.1	7	35
Scoter sp.	0.14	0.33	238	0.3	34	41
Other waterfowl*	0.34	1.01	299	0.6	31	173
Red-necked Phalarope	1.19	4.79	402	2.2	48	902
Red Phalarope	0.05	0.20	414	0.1	10	39
Phalarope spp.	0.29	0.62	211	0.5	45	76
Pomarine Jaeger	0.03	0.07	230	0.1	21	9
Parasitic Jaeger	0.00	0.01	300	0.0	10	1
Jaeger sp.	0.00	0.01	381	0.0	7	1
Bonaparte's Gull	0.01	0.04	358	0.0	10	7
Mew Gull	0.14	0.48	339	0.3	21	86
Ring-billed Gull	0.01	0.02	397	0.0	7	4
California Gull	16.70	39.45	236	30.6	79	6975
Herring Gull	0.29	1.00	347	0.5	52	184
Thayer's Gull	0.15	0.36	236	0.3	28	57
Western Gull	0.04	0.05	111	0.1	59	5
Glaucous-winged Gull	4.44	4.45	100	8.1	100	708
Black-legged Kittiwake	0.51	1.42	281	0.9	31	220
Sabine's Gull	1.31	3.55	270	2.4	31	539
Gull sp.	0.59	1.34	229	1.1	69	171
Common Murre	7.77	7.78	100	14.2	100	904
Pigeon Guillemot	0.03	0.07	231	0.1	28	10
Marbled Murrelet	0.13	0.24	182	0.2	52	19
Ancient Murrelet	0.06	0.18	285	0.1	17	26
Cassin's Auklet	1.94	3.97	205	3.5	79	686
Rhinoceros Auklet	0.85	1.00	117	1.6	93	106
Tufted Puffin	0.04	0.13	346	0.1	24	5
Alcid sp.	0.04	0.09	244	0.1	24	11
Total birds	54.63	59.16	108	100.0	100	10396

*Single sightings of lone Harlequin Duck and Red-brested Merganser, and a flock of 31 Brant.

Table 6. Percentage breakdown of the breeding locations of the birds reported in the surveys in the Nearshore, Inshore and Offshore waters off southwestern Vancouver Island. Species were placed in the geographic category from which most of the birds seen in the study area were likely to have originated (see Table 1 for each species' breeding origin).

Breeding location	Nearshore	Inshore	Offshore
Within 50 km of the study area	36.9	21.2	14.0
Coast of BC and/or Washington	15.5	41.4	20.3
Coast and islands of Alaska	0.0	0.1	8.6
Arctic tundra or islands	2.5	6.7	5.8
Inland in temperate continental North America	45.1	17.9	32.1
Southern hemisphere	0.0	12.2	19.2
Elsewhere (Mexico, Hawaii etc.)	0.0	0.4	0.1

Map A



Map B

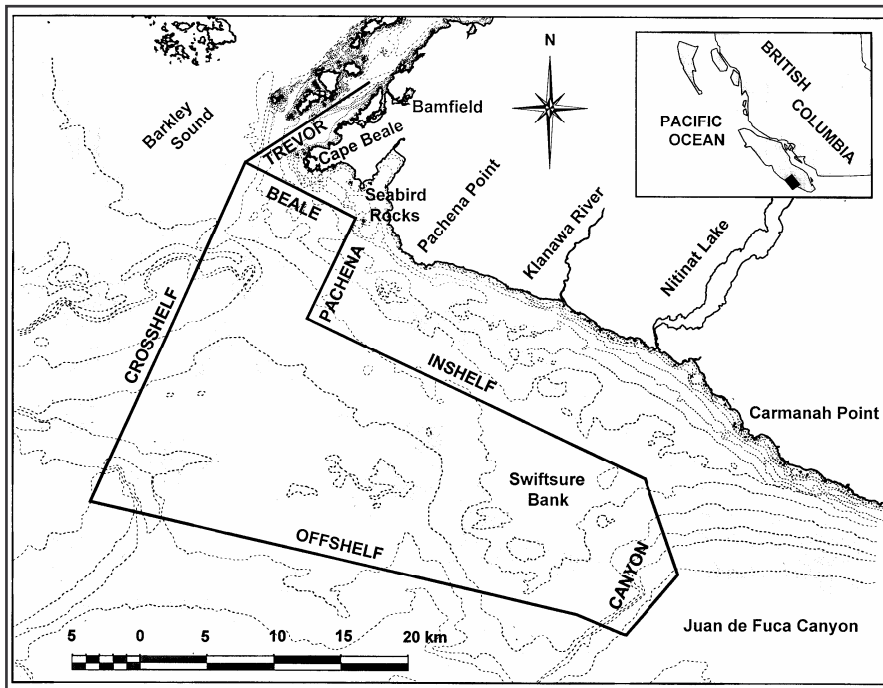


Figure 1. Transect routes used for seabird counts off southwest Vancouver Island. Map A: **Nearshore** surveys were made along a 43 km route in Trevor Channel. Numbers along the route indicate the km. Depth contours are shown at intervals of 2, 5, 10, 20, 30, 40 and 50 m. Map B: **Inshore** surveys were made along legs *Trevor* and *Beale* averaging 19 km, while **Offshore** surveys covered the remaining legs over the shelf, averaging 120 km. Depth contours at 2, 5, 10, 20, 30, 50, 70, 100, 130, 150, 200 and 300 m.

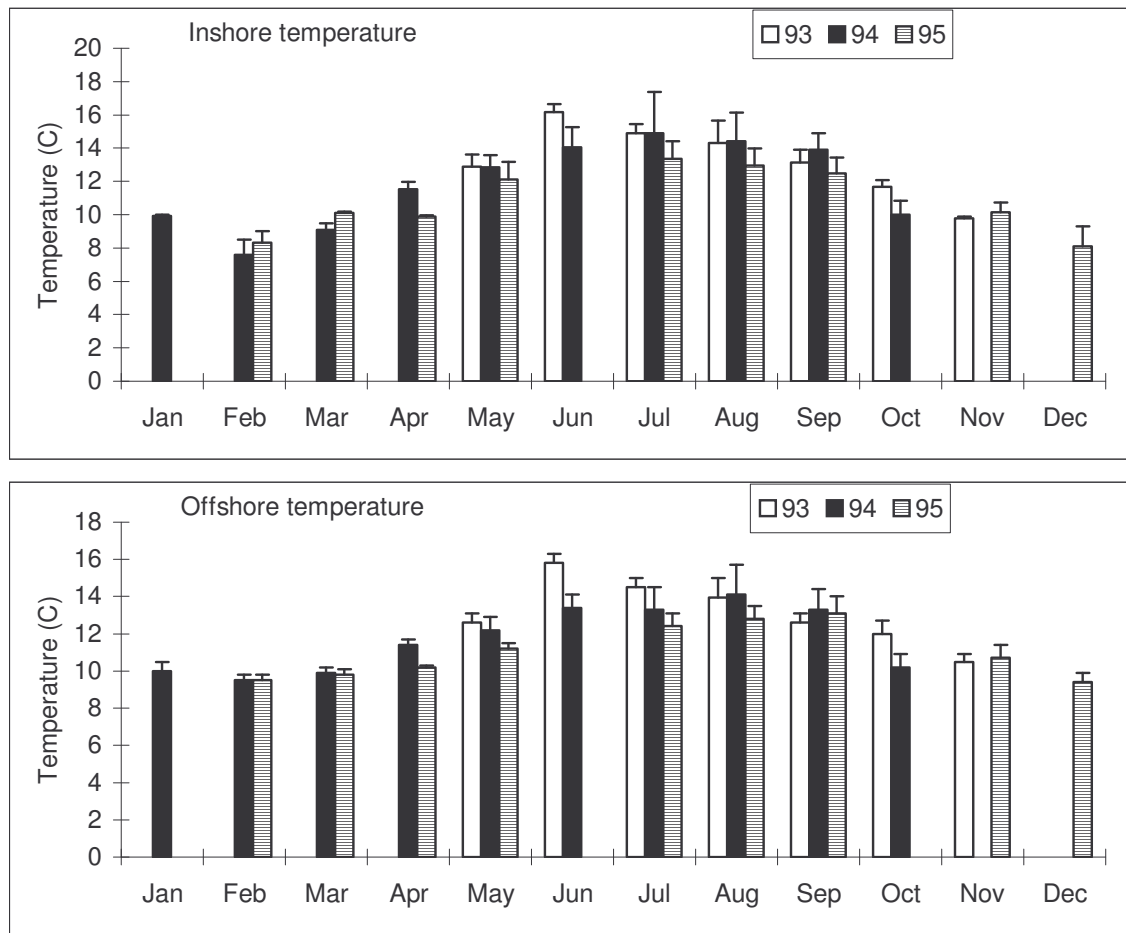


Figure 2. Sea surface temperatures measured during Inshore (upper graph) and Offshore (lower) surveys off southwest Vancouver Island between May 1993 and December 1995. Temperatures were measured at 1 min intervals throughout surveys. Error bars show standard deviations. Temperature data from Nearshore surveys were insufficient for analysis.

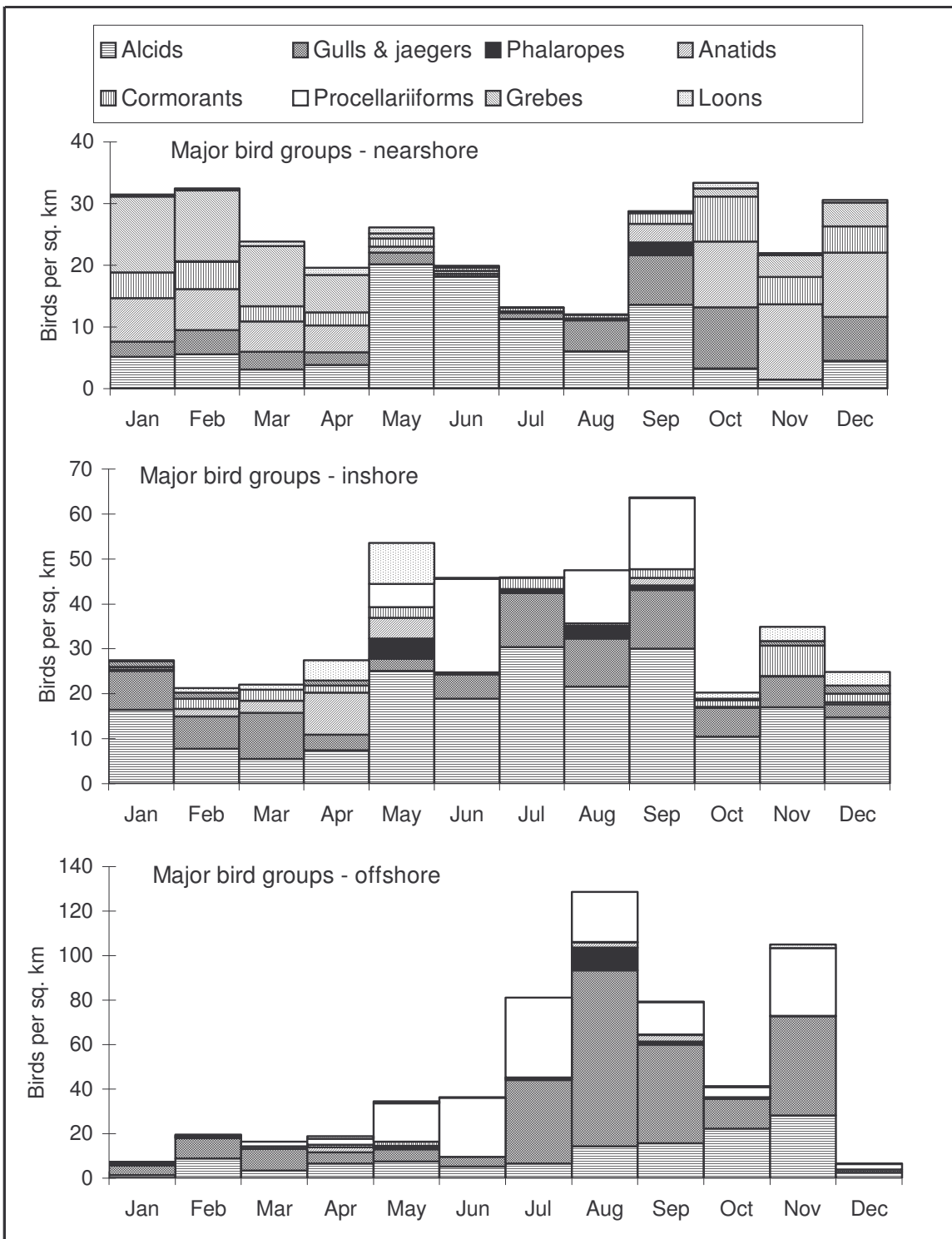


Figure 3. Monthly variations in the composition and density of major groups of seabirds off southwest Vancouver Island, in Nearshore, Inshore and Offshore zones in 1993-1995. Note that the y-axis scale varies among the graphs.

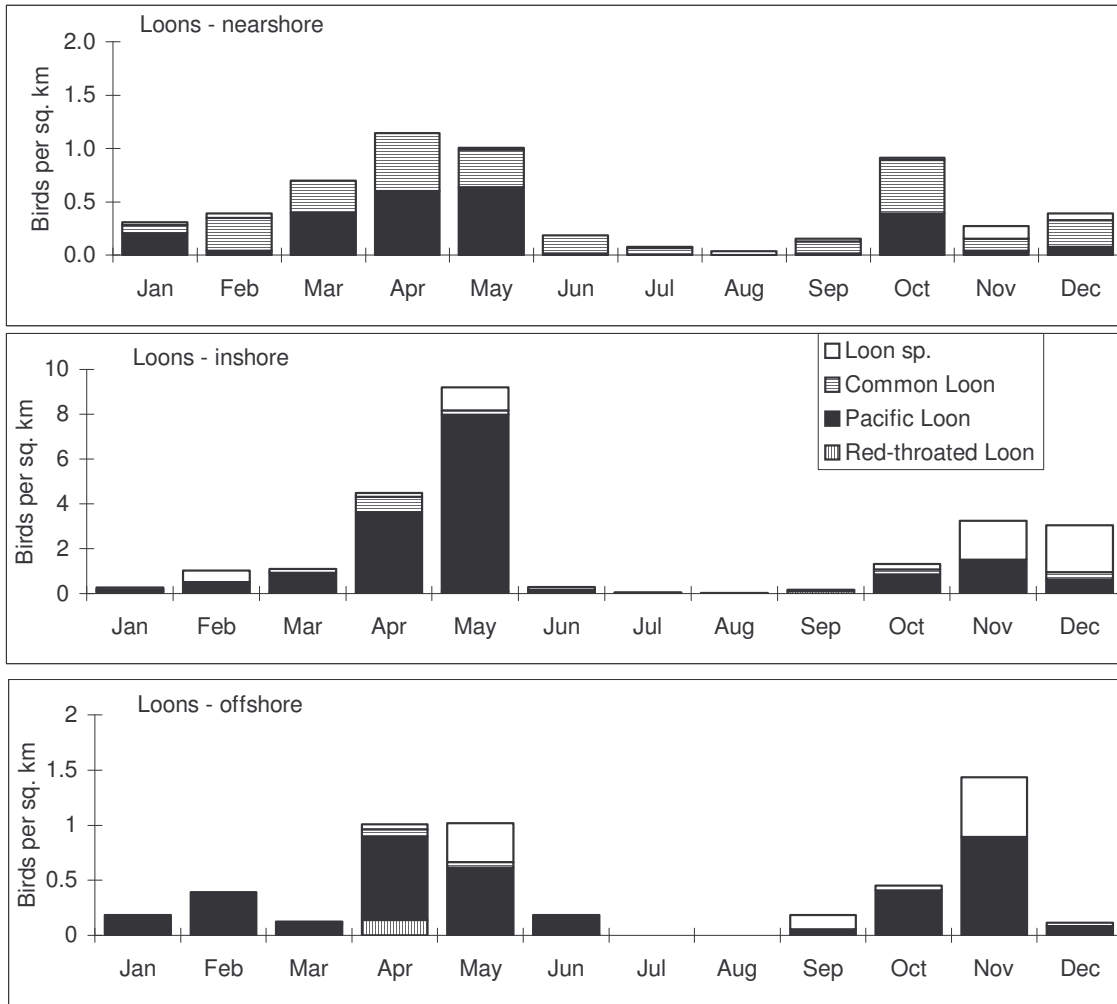


Figure 4. Mean monthly densities of loons in Nearshore, Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995. Note that the y-axis scale (density) varies among graphs.

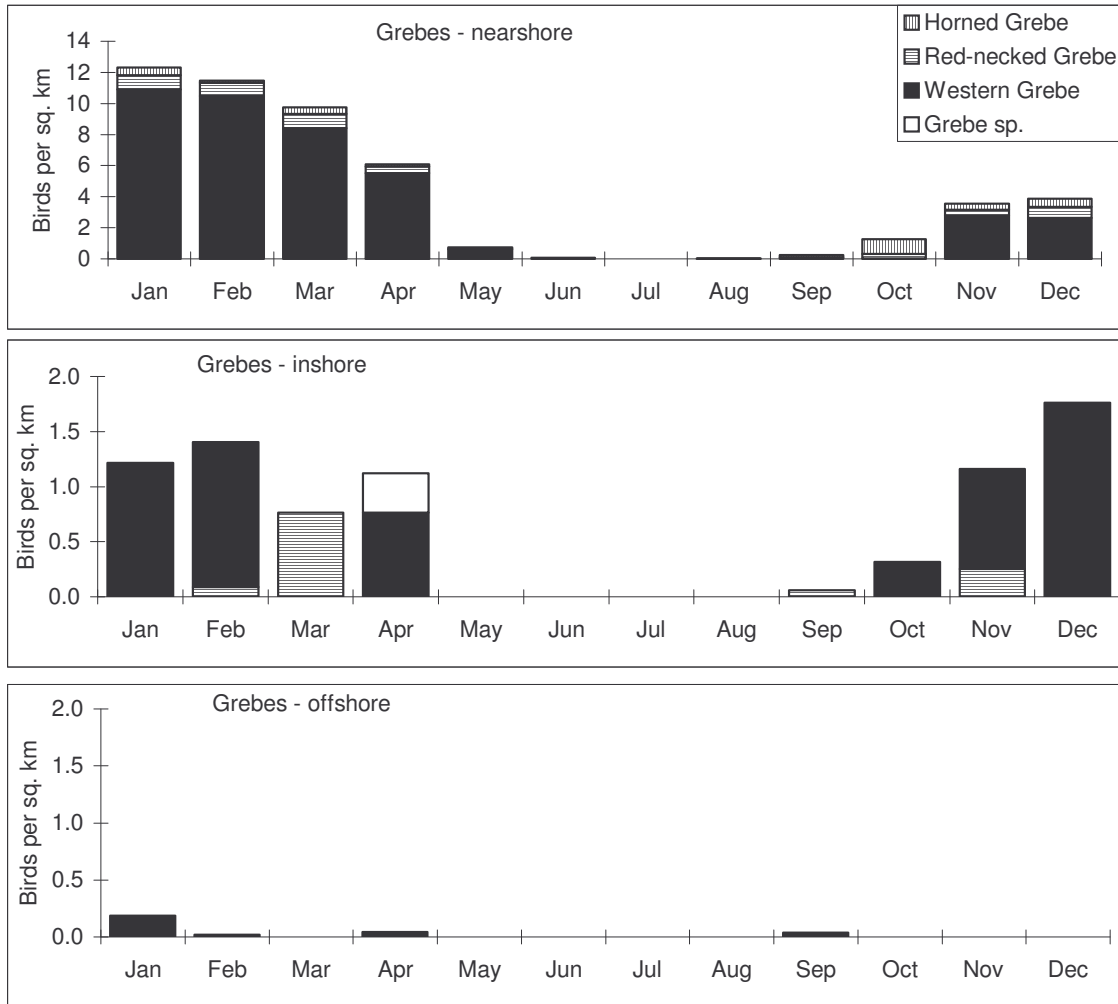


Figure 5. Mean monthly densities of grebes in Nearshore, Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995. Note that the y-axis scale (density) varies among graphs.

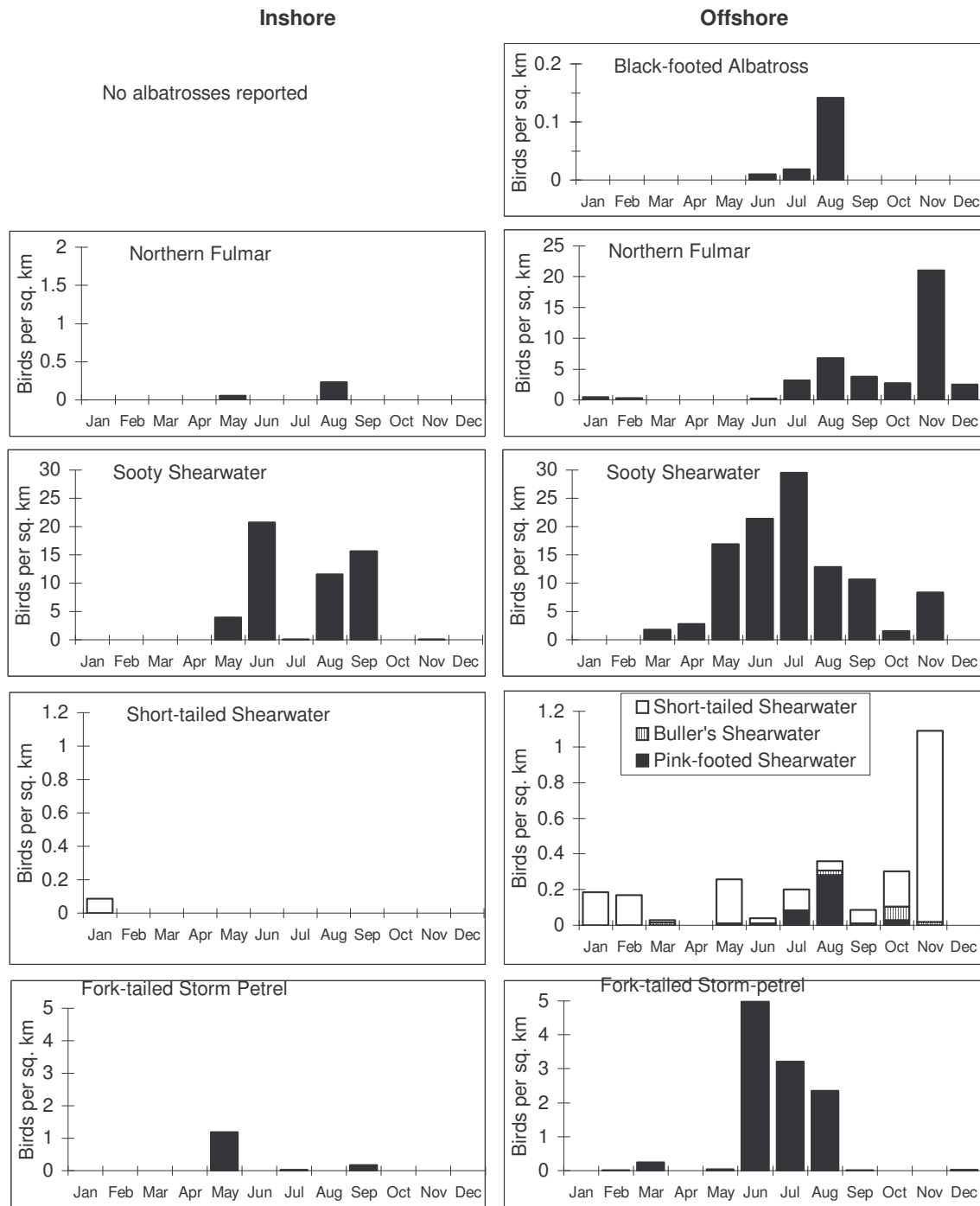


Figure 6. Mean monthly densities of procellariids (albatross, petrels, storm-petrels) on Inshore (left graphs) and Offshore surveys (right graphs) off southwest Vancouver Island in 1993-1995. No procellariids were encountered in Nearshore waters. Note that the y-axis scale (density) varies for the Northern Fulmar's graphs.

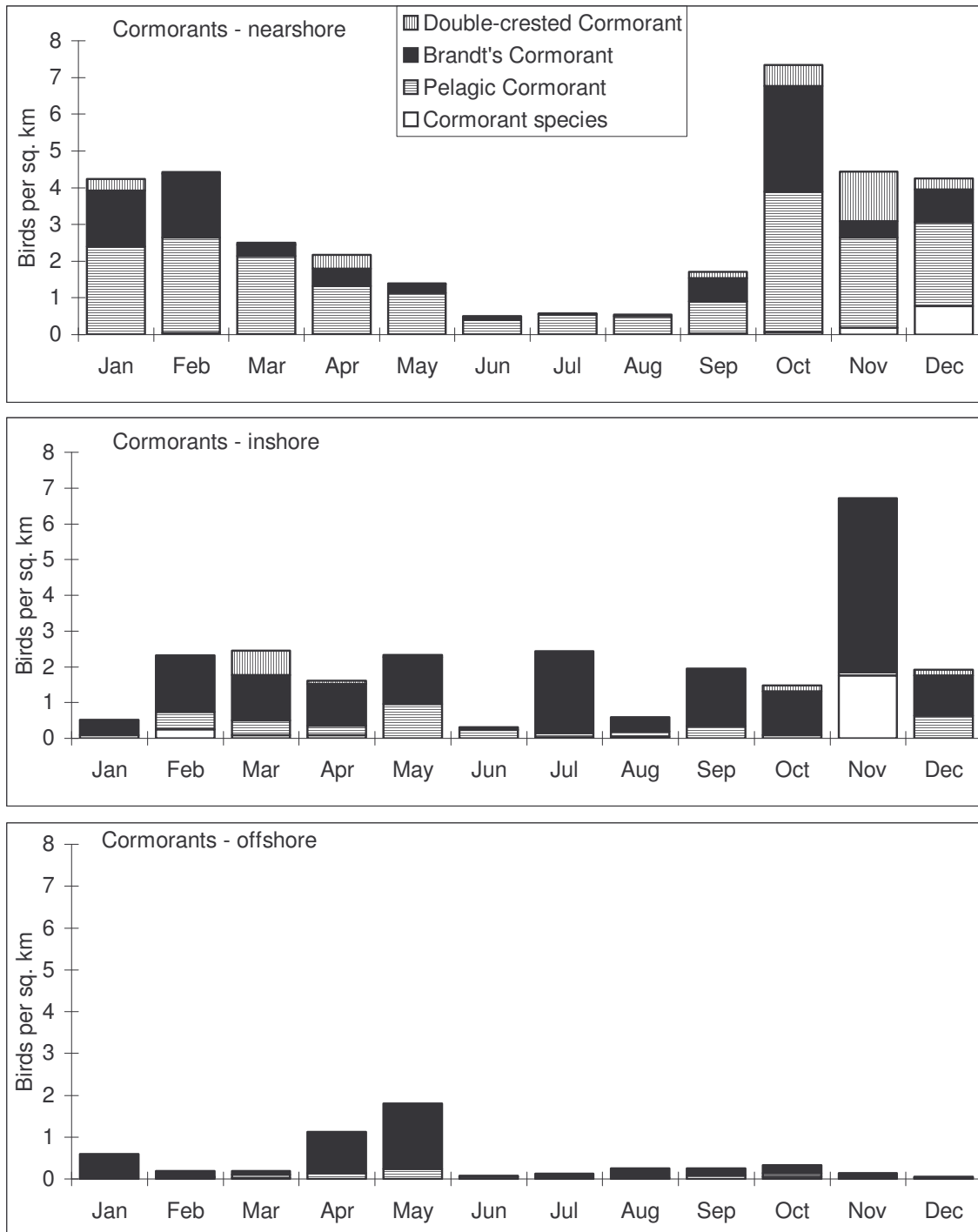


Figure 7. Mean monthly densities of cormorants in Nearshore, Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995.

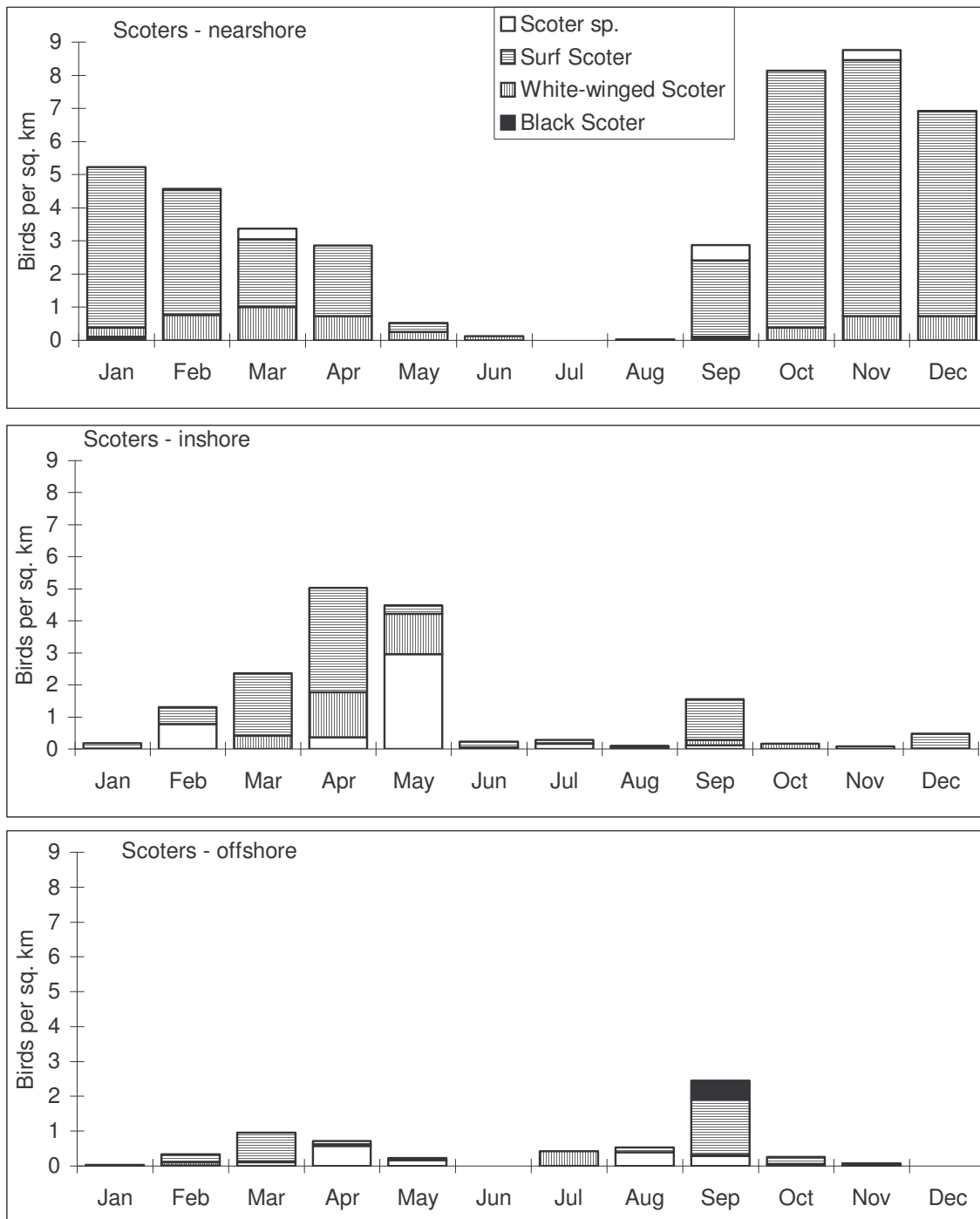


Figure 8. Mean monthly densities of scoters in Nearshore, Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995.

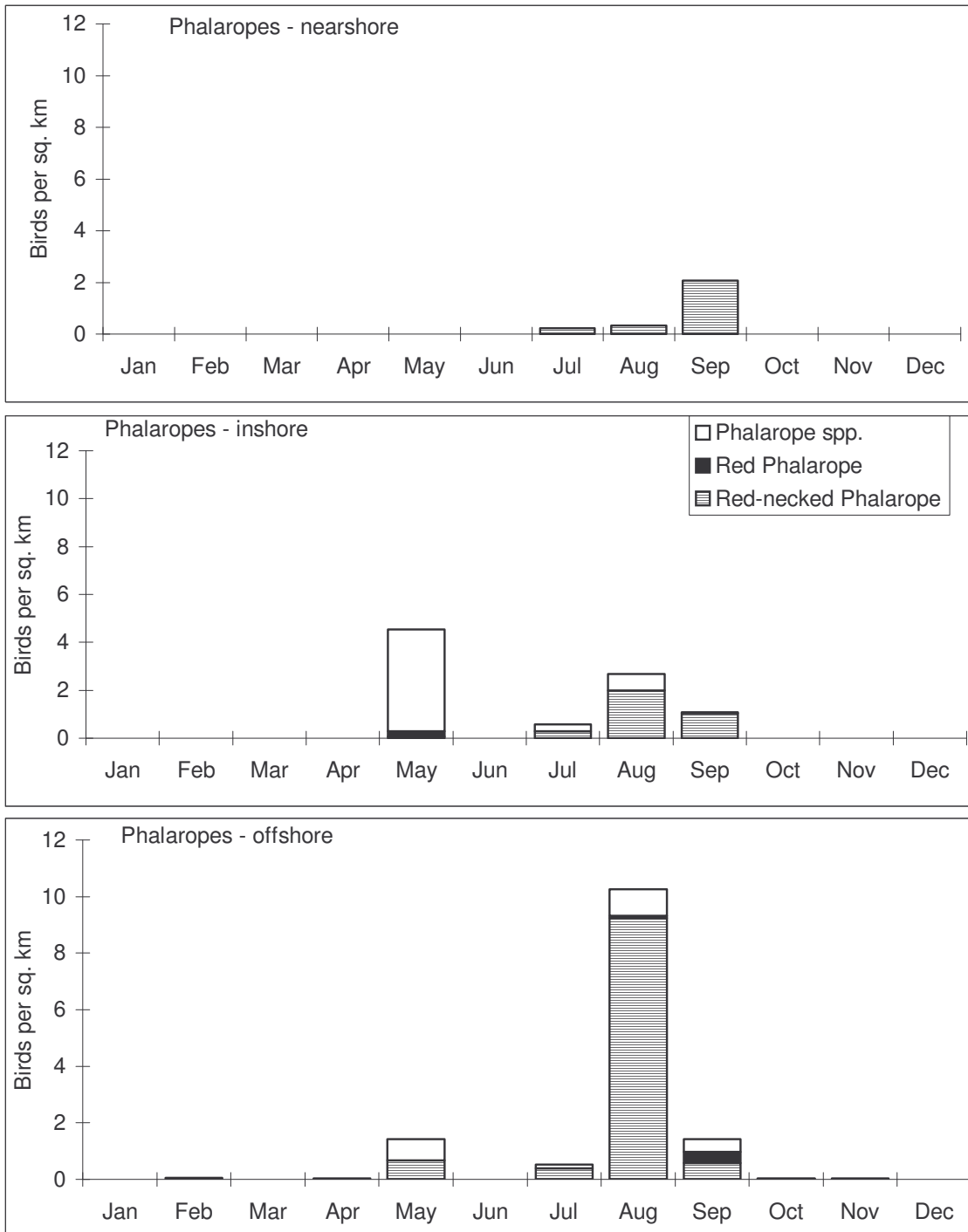


Figure 9. Mean monthly densities of phalaropes in Nearshore, Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995.

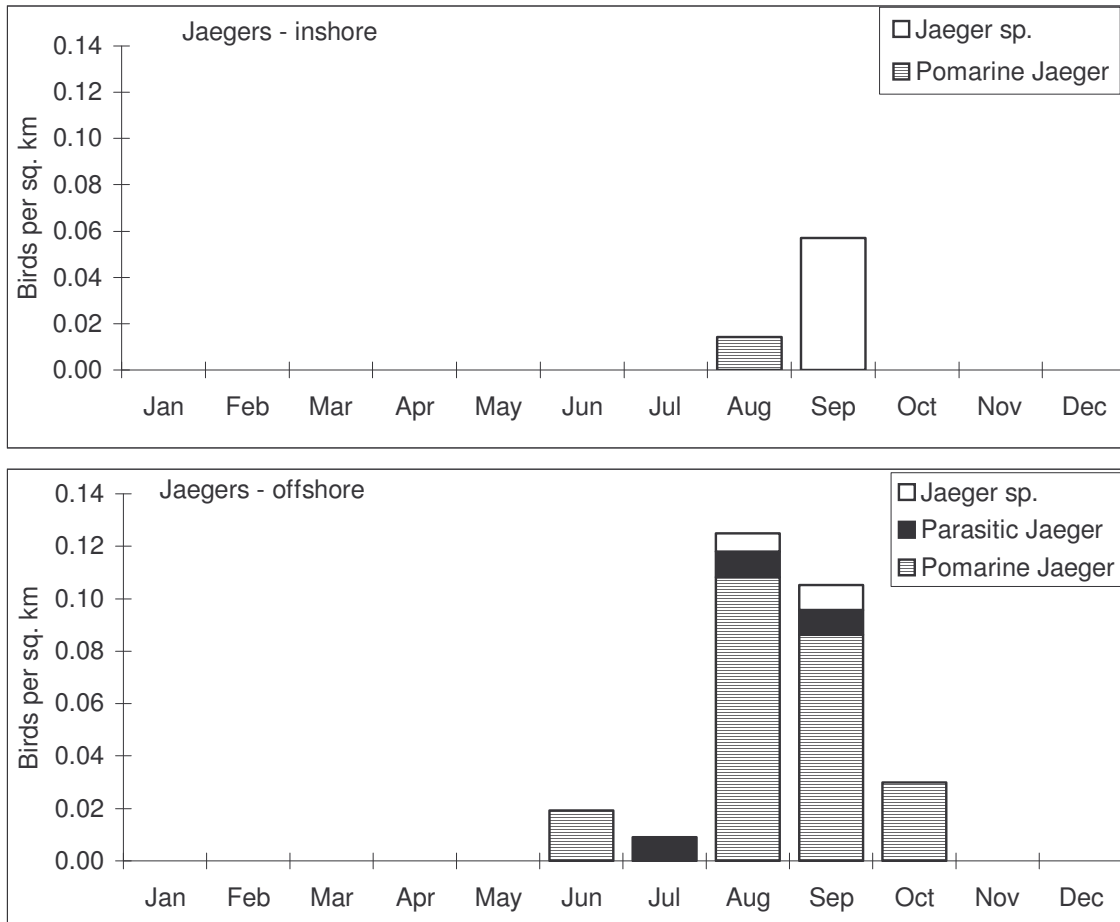


Figure 10. Mean monthly densities of jaegers in Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995. Jaegers were not seen in Nearshore waters. Note the very low densities compared to most other seabirds.

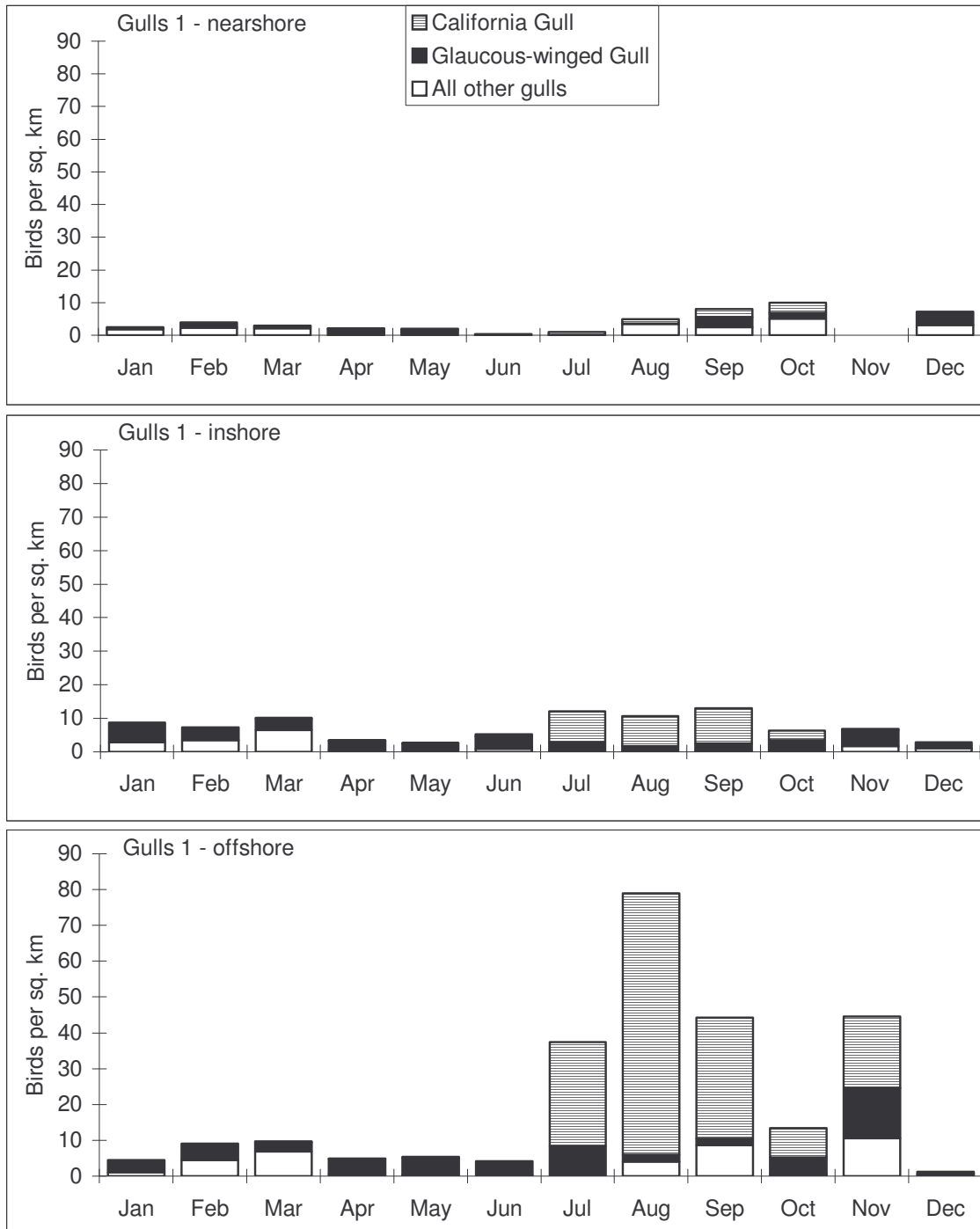


Figure 11. Mean monthly densities of California and Glaucous-winged Gulls, compared to densities of all other species combined off southwest Vancouver Island in 1993-1995.

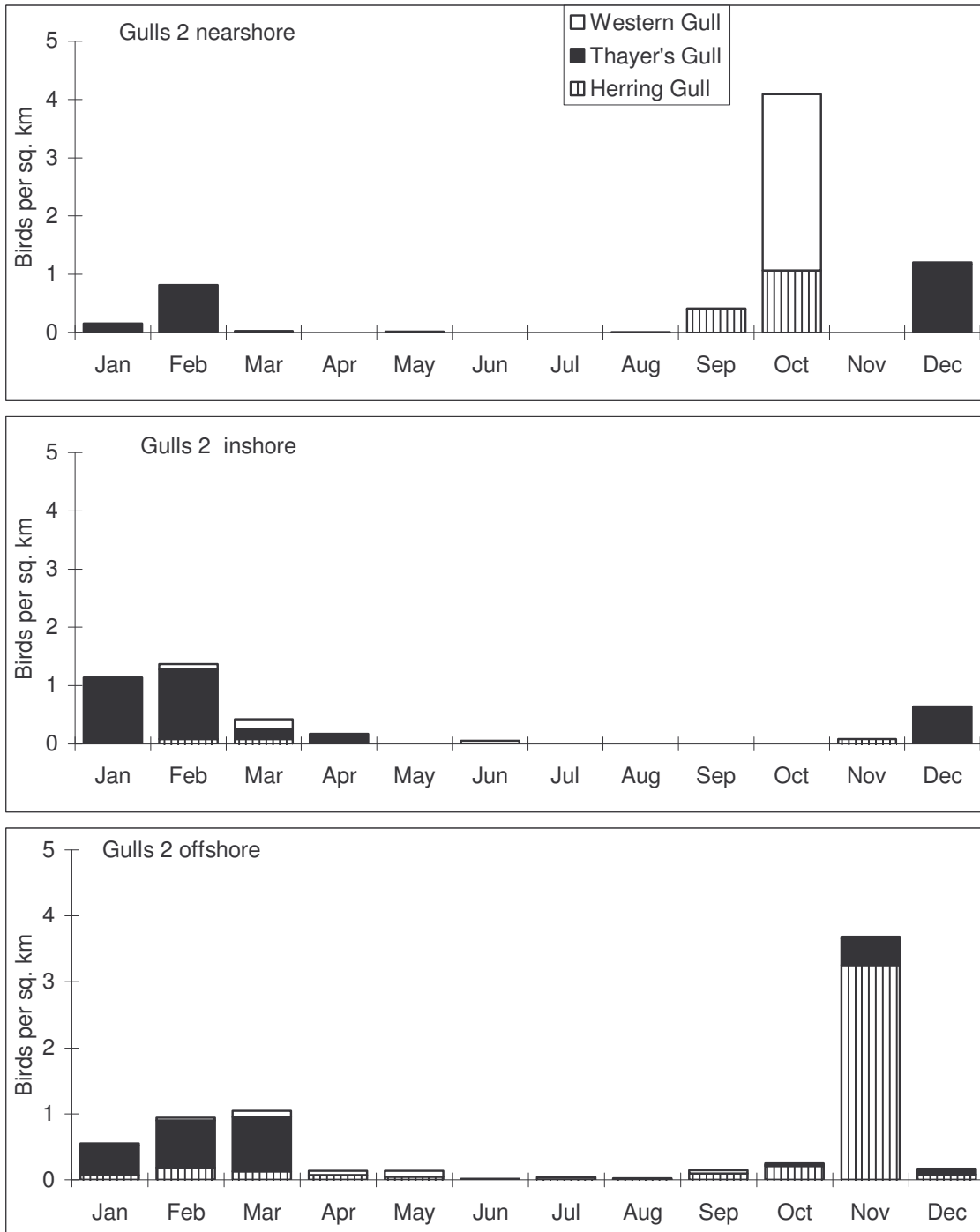


Figure 12. Mean monthly densities of Western, Thayer's and Herring Gulls off southwest Vancouver Island in 1993-1995.

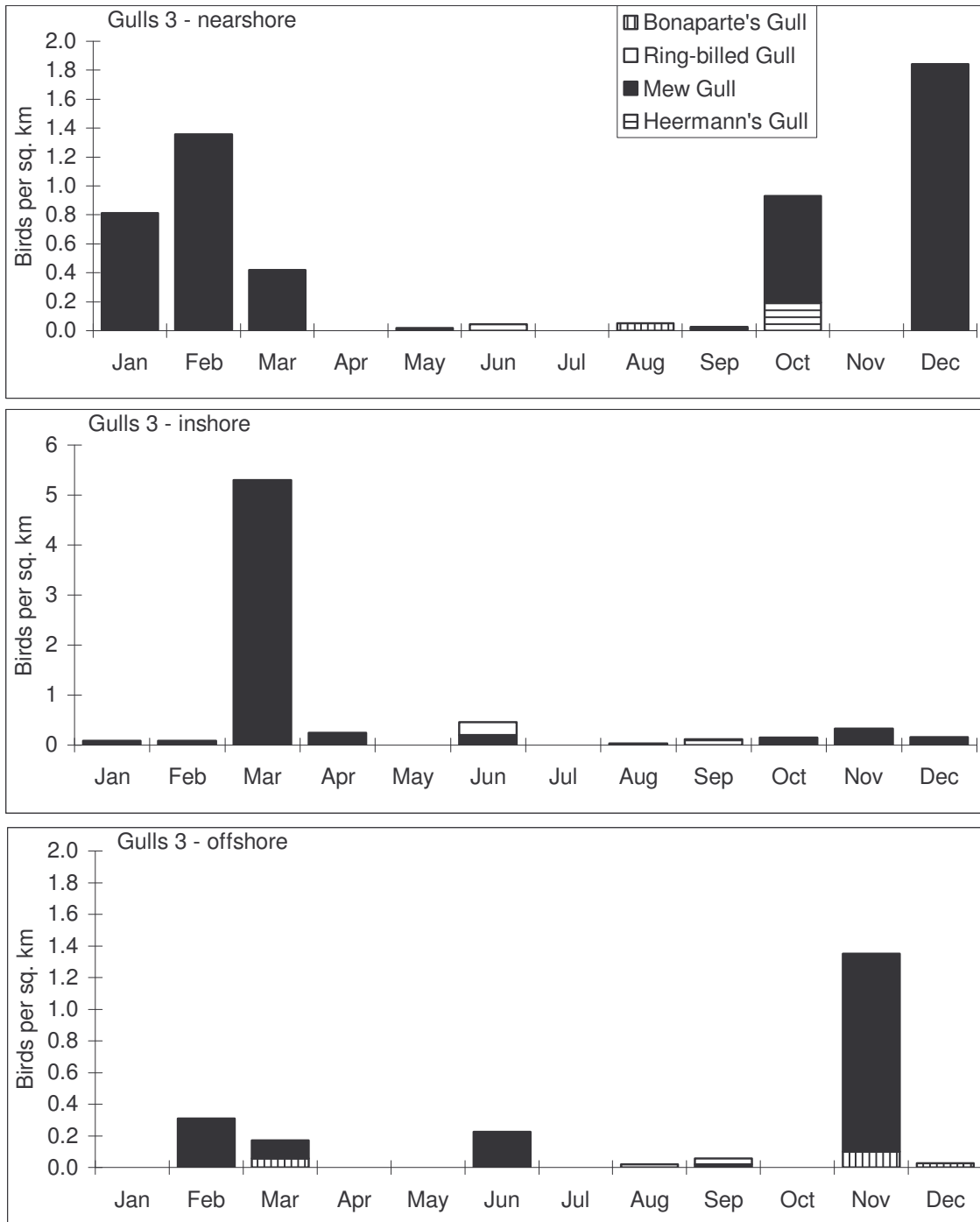


Figure 13. Mean monthly densities of Bonaparte's, Ring-billed, Mew, and Heermann's Gulls off southwest Vancouver Island in 1993-1995. Note that the y-axis scale varies.

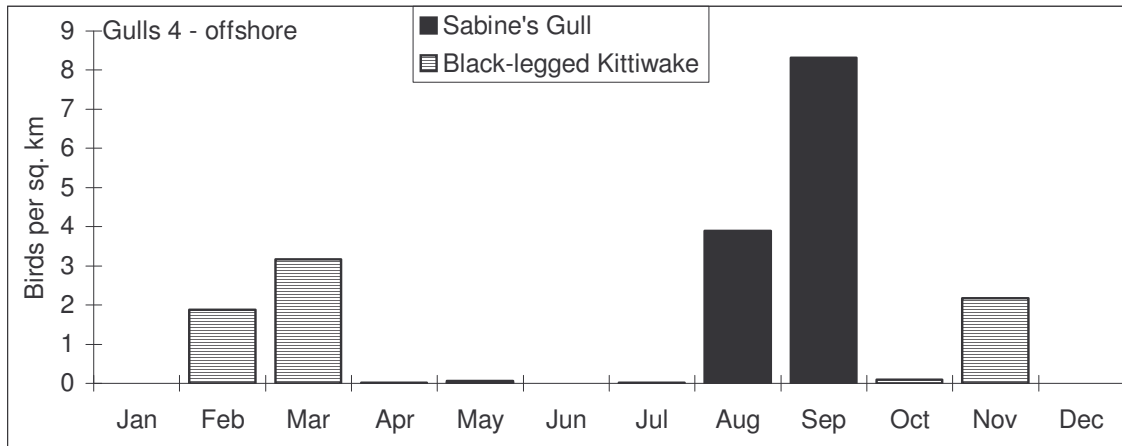


Figure 14. Mean monthly densities of Sabine's Gulls and Black-legged Kittiwakes in Offshore surveys off southwest Vancouver Island in 1993-1995. These species were absent or extremely rare in Nearshore or Inshore waters (not plotted).

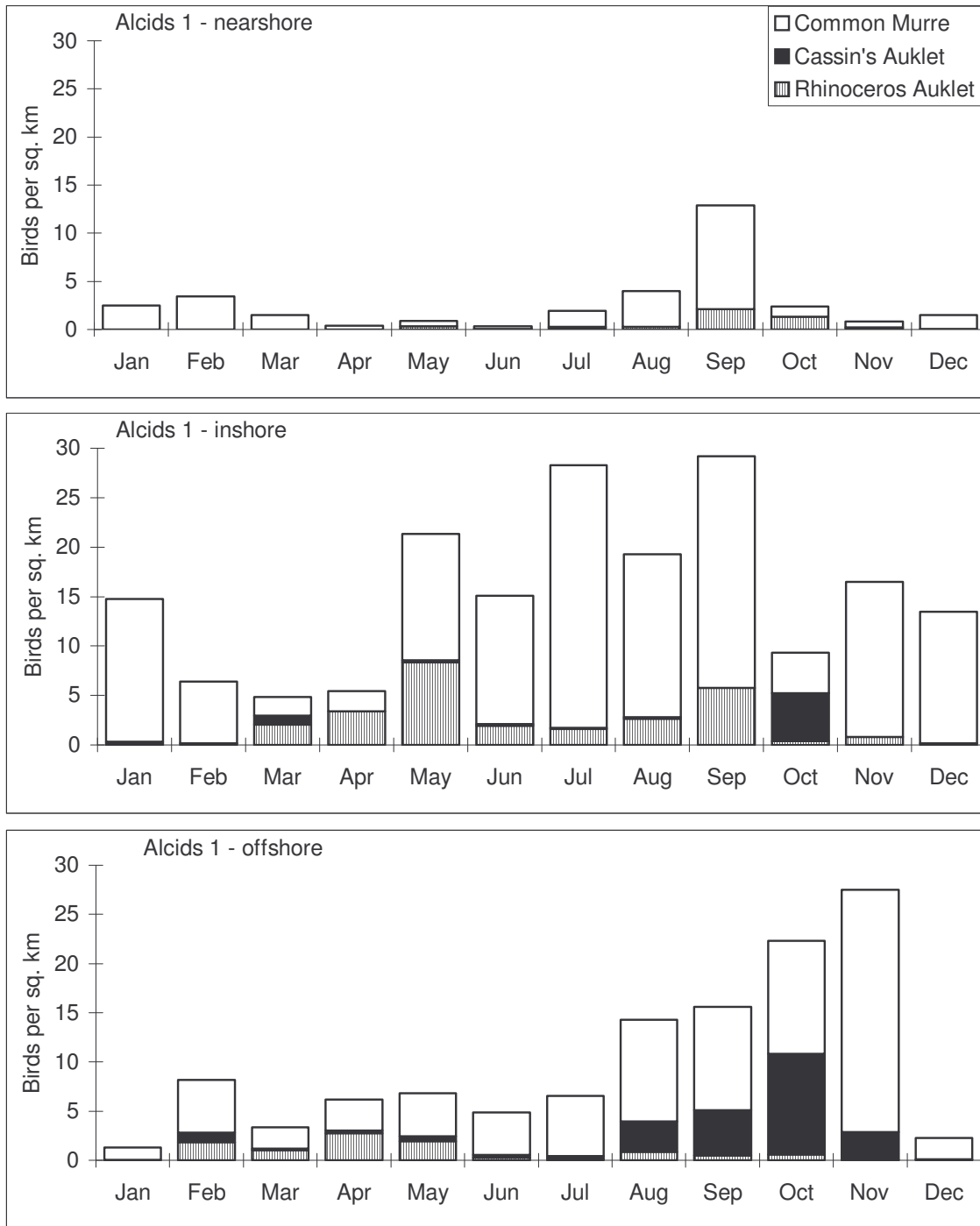


Figure 15. Mean monthly densities of Common Murres, Cassin's Auklets, and Rhinoceros Auklets in Nearshore, Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995.

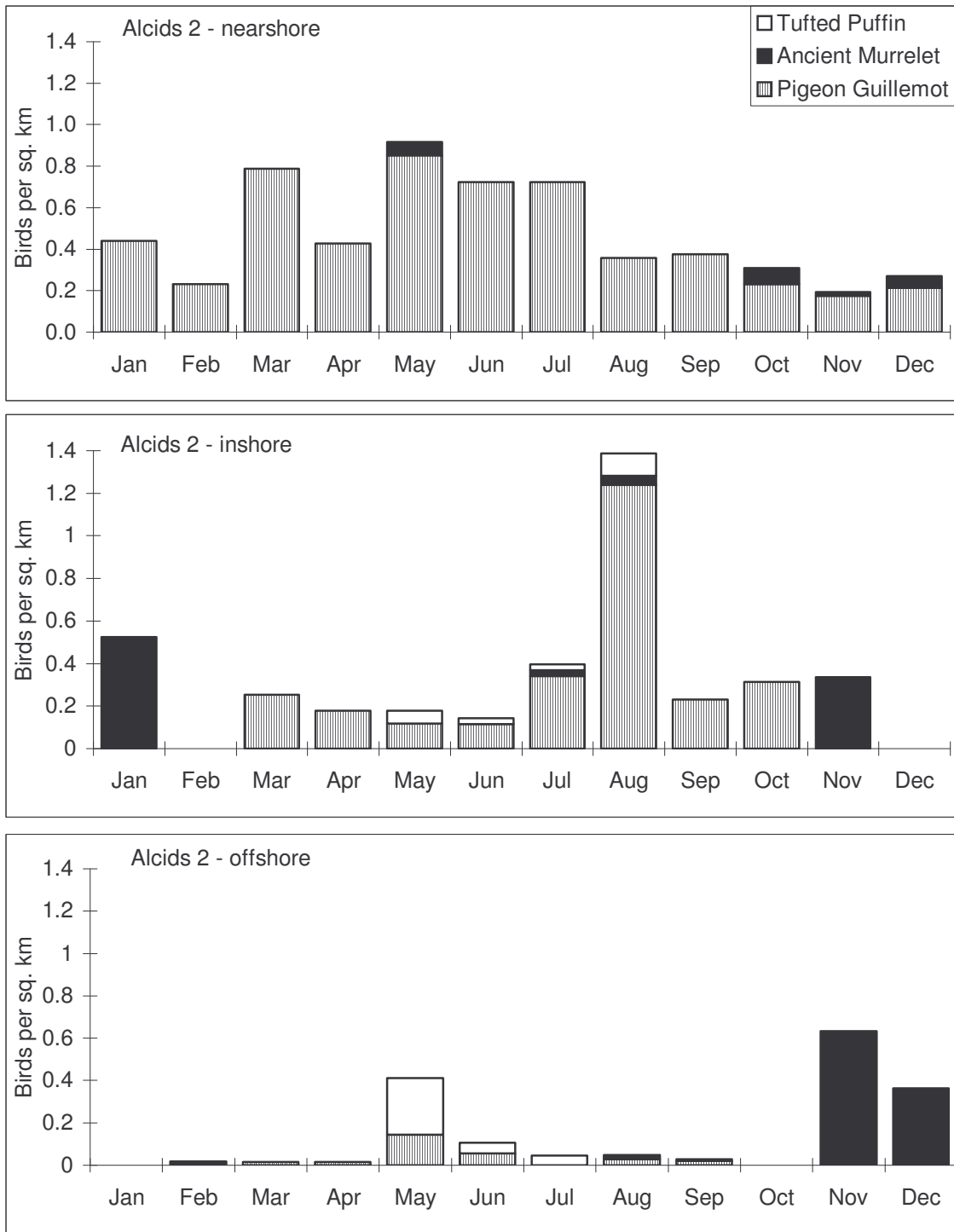


Figure 16. Mean monthly densities of Tufted Puffins, Ancient Murrelets, and Pigeon Guillemots in Nearshore, Inshore and Offshore surveys off southwestern Vancouver Island in 1993-1995.

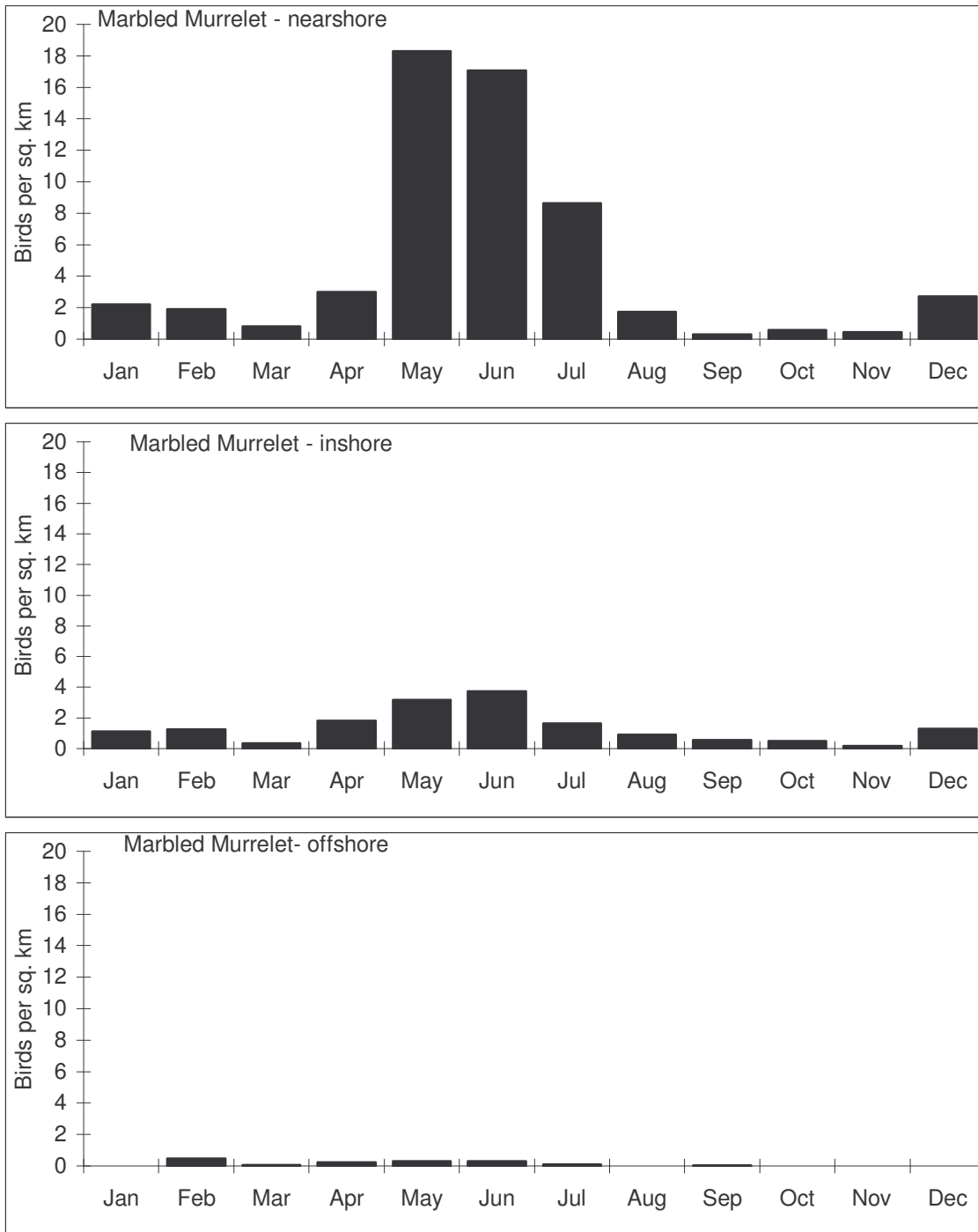


Figure 17. Mean monthly densities of Marbled Murrelets in Nearshore, Inshore and Offshore surveys off southwest Vancouver Island in 1993-1995.

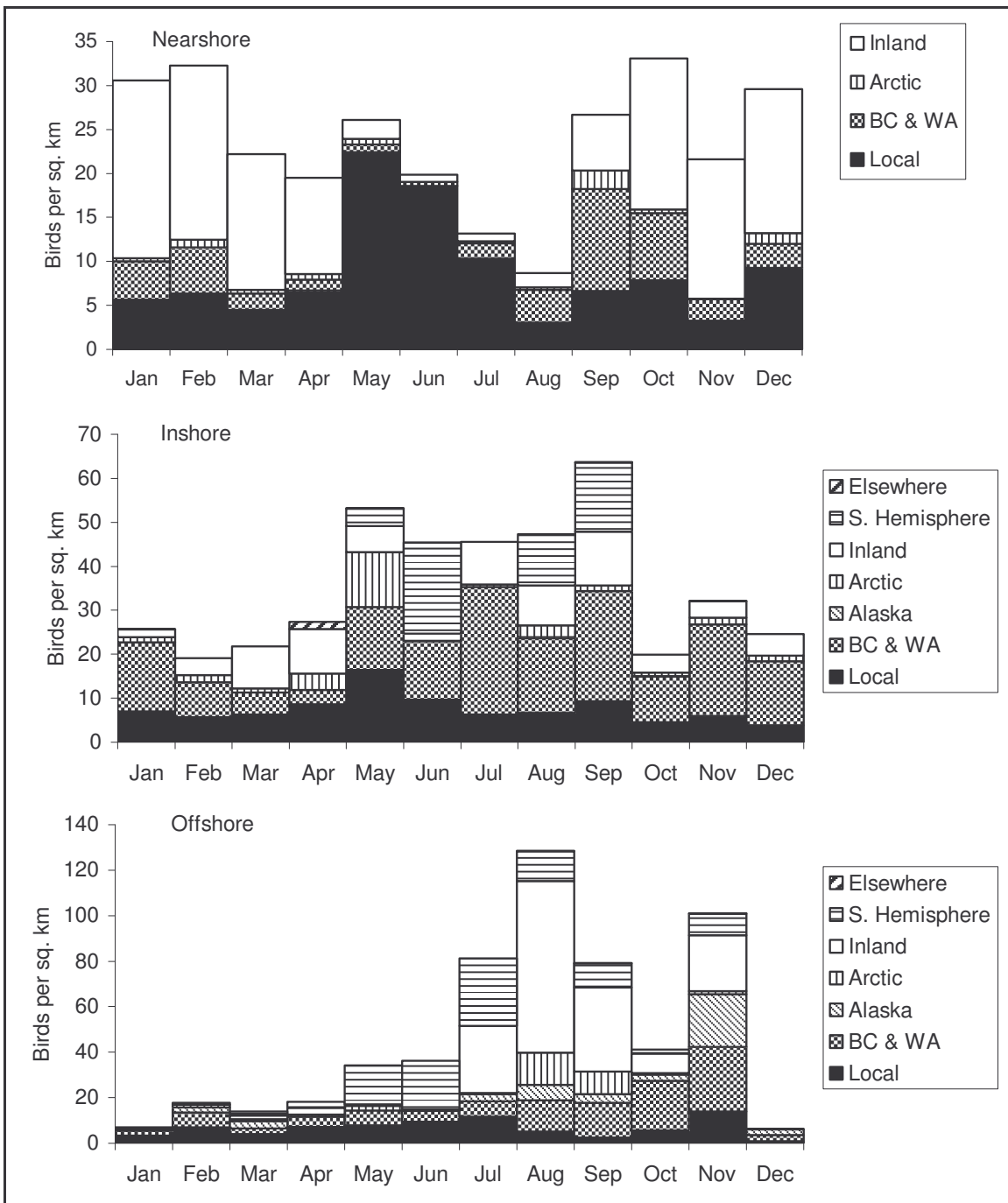


Figure 18. Breeding origins of the birds recorded in Nearshore, Inshore and Offshore surveys off southwestern Vancouver Island. Categories were species breeding: within the study area (Local); on the coast of BC and/or Washington (BC & WA); coast of Alaska (Alaska); the Arctic; inland temperate continental North America (Inland); southern hemisphere (S. Hemisphere); or less common species breeding in Hawaii or Mexico (Elsewhere). See Appendix 1 for full listing of species in each category. Note differences in the y-axis scale among the graphs.