WESTERN BIRDS

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SEABIRD ABUNDANCES OFF WASHINGTON, 1972–1998

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ABSTRACT: Twenty-seven years of observations revealed changes in seabird abundance associated with changes in oceanographic conditions and ocean productivity. The regime shift of 1976, El Niño of 1983–1984, and the prolonged decline in productivity of the 1990s were followed by great declines in several historically common species, particularly those foraging offshore: the Sooty Shearwater, a nonbreeding visitor from the southern hemisphere, and three alcids breeding regionally, the Common Murre, Cassin's Auklet, and Tufted Puffin. Species that increased included two offshore foragers associated with fishing vessels (Black-footed Albatross and Northern Fulmar), one inshore-foraging species that nests in southern California and Mexico (Brown Pelican), and an apparently adaptable alcid (Rhinoceros Auklet) that forages inshore and has increased all along the west coast of North America. The decrease of eight offshore species and two abundant widespread species coinciding with an increase in three fishing-vessel associates and two nearshore foragers imply a decline in oceanic productivity.

The distribution at sea of seabirds off western North America has been described primarily since the late 1960s. Most of our knowledge results from studies of the impacts of oil transportation and development (see Briggs et al. 1987, 1992), cruises on research vessels (e.g., Sanger 1972, Wahl et al. 1989, Morgan et al. 1991, Ainley et al. 1995b, Veit et al. 1997), and opportunistic observations from whale- or bird-watching trips (e.g., Ainley 1976).

Seabird distribution off Washington was described anecdotally by Jewett et al. (1953) and, after more systematic offshore vessel surveys, by Sanger (1965, 1970, 1972), Wahl (1975, 1984), Wahl and Heinemann (1979), Wahl et al. (1993), and, from aircraft surveys, by Briggs et al. (1992).

In late 1971 Wahl began systematic seabird censuses during one-day seabird-watching cruises from Grays Harbor on the southwest coast of Washington (Figure 1). These cruises sampled habitats from the shallow estuary channel entrance at Westport over the outer continental shelf out to the nearest deepwater indentation, Grays Canyon, about 50 km offshore. The study area is 40–90 km from the nearest seabird nesting colonies. It

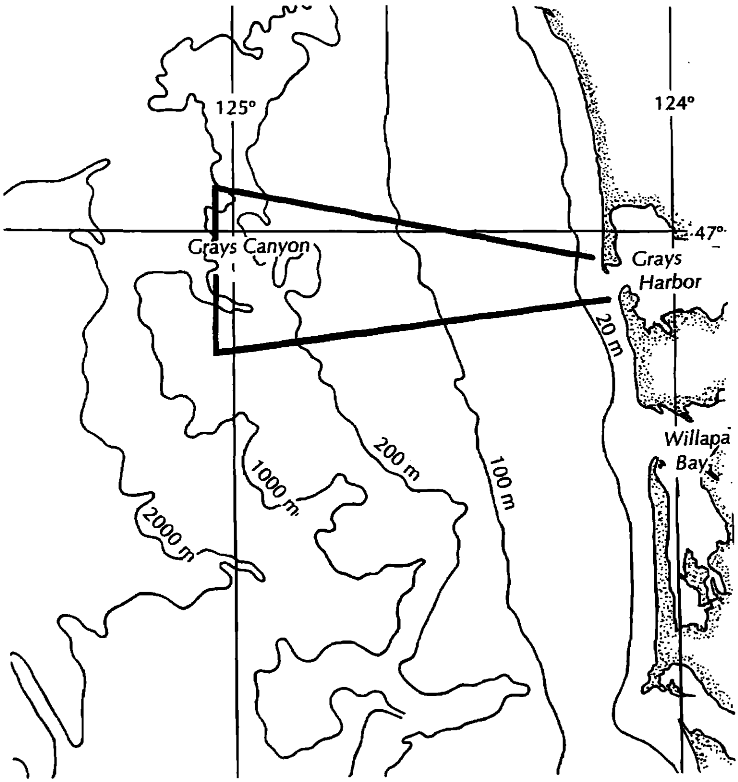


Figure 1. Study area off Grays Harbor, Washington.

includes nearshore waters, the gently sloping inner shelf, outer shelf area, and the periphery of the California Current offshore (Favorite et al. 1976). Sampling effort, mostly during the July–October southbound migration season, increased over time (Table 1).

We use data from 226 trips from 1972 through 1998 to show variation in numbers of birds observed and changes in abundance by species. We attempt to summarize those data with reference to several questions. What levels of year-to-year variability are apparent? Are long-term trends in abundances evident? Did variations in abundances of seabirds observed reflect local or widespread oceanographic events?

METHODS

Data Collection

Trips were made aboard chartered vessels 14–20 m long. The observer's eye level above the sea surface was about 3–4 m. We used a scheme of

Table 1 Census Effort off Grays Harbor, Washington, July–October

Year	Number of trips	Number of censuses	Distance covered (km)
1972	6	106	939
1973	5	78	616
1974	4	59	514
1975	5	84	765
1976	4	71	662
1977	7	137	1094
1978	6	119	882
1979	7	145	1071
1980	6	105	789
1981	4	68	505
1982	8	158	1138
1983	6	124	833
1984	10	208	1501
1985	9	170	1224
1986	7	142	989
1987	10	206	1363
1988	9	190	1224
1989	9	182	1129
1990	13	235	1516
1991	12	242	1564
1992	12	245	1597
1993	11	227	1491
1994	13	267	1760
1995	11	221	1496
1996	11	203	1389
1997	10	198	1361
1998	11	208	1456
Total	226	4398	30,736

periods of approximately 30 minutes during which two observers estimated numbers of all birds and other animals seen at all distances from both sides of the vessel. Time periods and transect lengths were controlled by depth contours. Grays Harbor channel was one census, and censuses from there were then stopped and started at depths of 20 m, 50 m, 100 m, 200 m, 1000 m, and 2000 m. Location, sea-surface temperature, sea and observation conditions were recorded for each period. In general, observation conditions were consistent because seasonal weather was comparable and the vessels' size restricted trips to relatively good weather and sea conditions (Beaufort sea state was 0–3 on 91% of censuses; swell height was <3 m on 95%). Vessels in the vicinity that were seen to be attracting birds were visited, and birds were chummed during stops at the most offshore location, at about 125° W longitude. Counts of birds at vessels and chum stops were separated from numbers recorded while our vessel was in motion (see Wahl and Heinemann 1979). Birds attracted to our vessel were counted when first observed but not (knowingly) thereafter. Corrections were not made for directions and speed of bird flight relative to our vessel (see Tasker et al. 1984, Spear et al. 1992, van Franeker 1994, Garthe and Hüppop 1999).

Observation efforts were consistent. All but 37 of the 226 trips had at least two primary observers, with Wahl, Tweit, D. R. Paulson, or B. LaBar present on 218 trips and at least two of them on most. The same vessel was used for 138 of 145 July–October trips from 1985 through 1998. We necessarily compromised between showing birds to birdwatchers who paid for vessel charters and rigid systematic censusing: we were compelled to look at and attempt to identify any animal encountered, regardless of distance.

Analysis

We used data for 24 "species" regularly found in the study area from July to October (Table 2): phalaropes, identified and unidentified as to species, were combined, as were the Western and Glaucous-winged gulls. Two- or three-month periods were used for seven species (Table 2) that were virtually

Table 2 Seasons (July–October) and Habitats of Seabirds off Washington

Species	Season[a]	Habitat[b]
Black-footed Albatross, *Phoebastria nigripes*[c]	Jul–Oct	O
Northern Fulmar, *Fulmarus glacialis*[c]	Jul–Oct	O
Pink-footed Shearwater, *Puffinus creatopus*[c]	Jul–Oct	O
Flesh-footed Shearwater, *P. carneipes*[c]	Jul–Oct	O
Buller's Shearwater, *P. bulleri*	Sep–Oct	O
Sooty Shearwater, *P. griseus*[c]	Jul–Oct	ON
Fork-tailed Storm-Petrel, *Oceanodroma furcata*	Jul–Sep	O
Brown Pelican, *Pelecanus occidentalis*	Jul–Oct	N
Phalaropes, *Phalaropus* spp.	Jul–Sep	ON
South Polar Skua, *Catharacta maccormicki*	Jul–Oct	O
Pomarine Jaeger, *Stercorarius pomarinus*	Jul–Oct	ON
Parasitic Jaeger, *S. parasiticus*	Jul–Oct	ON
Long-tailed Jaeger, *S. longicaudus*	Aug–Sep	O
Heermann's Gull, *Larus heermanni*	Jul–Oct	N
California Gull, *L. californicus*[c]	Jul–Oct	ON
Western/Glaucous-winged Gull, *L. occidentalis/glaucescens*[c]	Jul–Oct	ON
Black-legged Kittiwake, *Rissa tridactyla*	Jul–Oct	N
Sabine's Gull, *Xema sabini*	Aug–Oct	O
Arctic Tern, *Sterna paradisaea*	Aug–Sep	O
Common Murre, *Uria aalge*	Jul–Oct	ON
Marbled Murrelet, *Brachyramphus marmoratus*	Jul–Oct	N
Cassin's Auklet, *Ptychoramphus aleuticus*	Jul–Sep	O
Rhinoceros Auklet, *Cerorhinca monocerata*	Jul–Oct	ON
Tufted Puffin, *Fratercula cirrhata*	Jul–Oct	O

[a]If the season is other than July–October, 95–99% of birds occurred during the season given. Cassin's Auklets in October were assumed to be predominantly migrants and their numbers were not used in calculations.

[b]From July to October, >99% of birds classed as offshore (O) occurred at depths >20 m, except the Tufted Puffin at 92%. For species classed as nearshore (N), 97–99% occurred at depths <20 m.

[c]Species readily attracted to fishing vessels.

absent in other months. We identified each species' habitat as nearshore (at water depths <20 m), offshore (at depths >20 m), or both (Table 2).

We included data from counts at fishing vessels and chum stops. Our study area is within a region with consistent local fishing effort. We could not be certain whether vessels out of radar or visual range affected numbers of birds seen away from vessels, and there were obvious variations in the degree of attraction to a given vessel, possibly due to factors like numbers of vessels working locally or within a larger area, or how long a given vessel had been working. Our routine was consistent: we visited vessels attracting birds when possible, and we chummed birds at a similar location on each trip. Over the study there was no significant difference in vessels visited per kilometer.

Transect length was rounded to the nearest 0.5 km. "Abundance" (number of birds per kilometer) was calculated by dividing total numbers by total kilometers traveled within season and habitat. We used linear regression analysis to determine long-term trends and t tests to compare time periods.

We designated climatic periods or events on the basis of oceanographic descriptions (e.g., Ebbesmeyer et al. 1991, Springer 1998), upwelling indices (National Marine Fisheries Service), and periods positive or negative with respect to the Pacific Decadal Oscillation (PDO) (N. J. Mantua et al. unpubl. data). Ebbesmeyer et al. (1991) showed abrupt shifts in 40 multidisciplinary environmental variables in 1976. We used this "step" (or "regime shift") to assist in defining time periods. These periods are pre-step, 1972–76, post-step 1977–82; El Niño of 1982–83 (numbers of several abundant species indicate a delayed response to this event, and we use 1983–84 data to describe its effects), post-El Niño, 1985–89, and 1990–98, a warm period of generally low ocean productivity. The PDO has been positive since 1976 (Mantua et al. 1996). Of the minor Los Niños of 1973, 1976, and 1986, and Los Niños or noticeable food-web changes of 1978, 1989, and 1990 noted by Ainley et al. (1995a), we believe only the 1989–90 food-web change was noticeable in our data. Some anecdotal reports supplement discussions below.

RESULTS AND DISCUSSION

Two of the 24 species are postbreeding visitors from southern California and Mexico, eight breed in the Pacific Northwest, six are visitors from the southern hemisphere or the western central Pacific Ocean, and eight are Alaska–arctic breeders. Six of the Alaska–arctic breeders—phalaropes, jaegers, Sabine's Gull, and Arctic Tern—are migrants whose occurrence is quite variable. We believe that our sampling effort was likely inadequate to detect changes in populations of these species, which may migrate in "waves," complicating determination of annual variability. Especially during years of high abundance, variation was greater for these "migrants" than for other species.

Black-footed Albatross. Abundance increased significantly from 1972 to 1998 (Figure 2; Table 3). Albatrosses increased following the 1976 step and dramatically in the 1990s (Table 4). Large numbers of albatrosses and fulmars were often associated with fishing vessels.

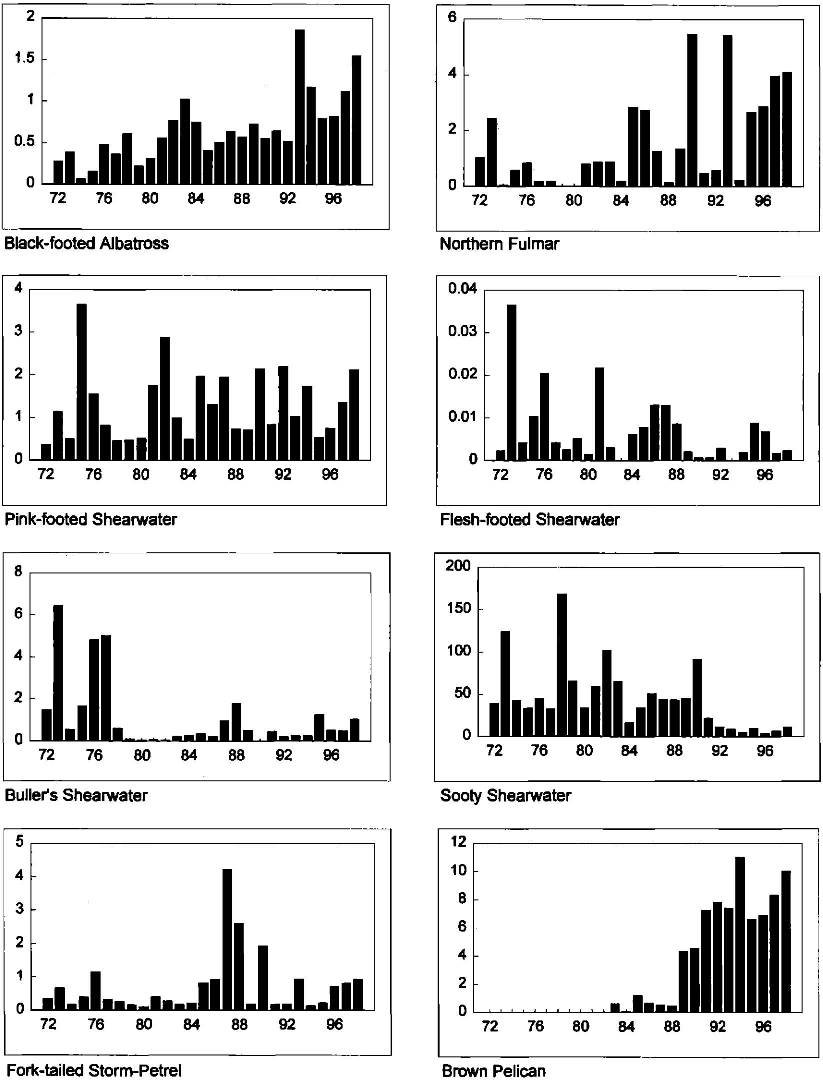
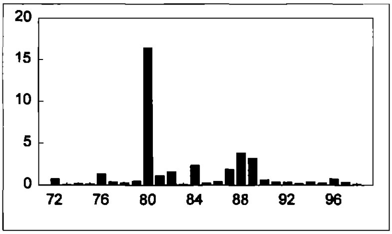


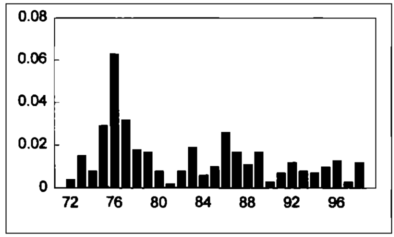
Figure 2. Number of birds per kilometer within habitat and season (see Table 2) by year.

Northern Fulmar. Though numbers of nonbreeding birds in the study area varied from year to year, they increased significantly over the entire study (Figure 2; Table 3) and in the 1990s (Table 4).

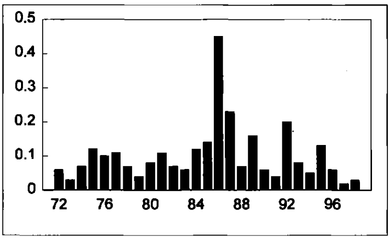
Pink-footed Shearwater. Abundance varied greatly by year (Figure 2), and no change was apparent. Though birds tended to concentrate at fishing



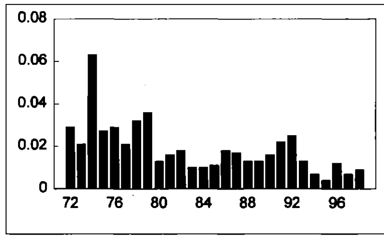
Phalaropes



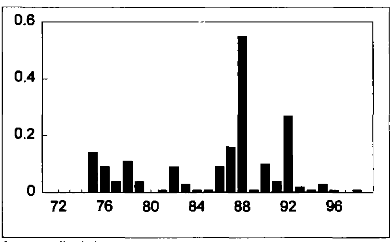
South Polar Skua



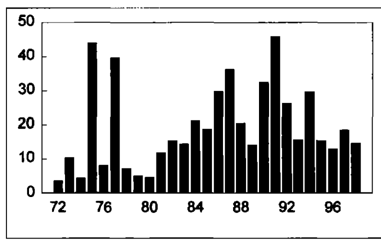
Pomarine Jaeger



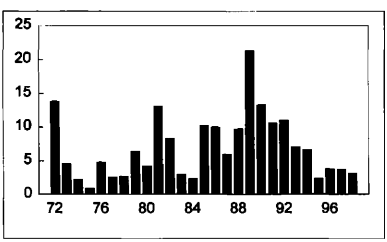
Parasitic Jaeger



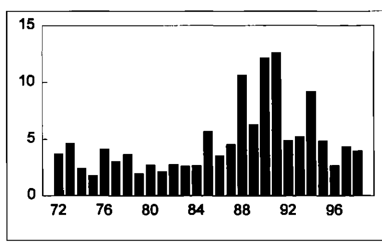
Long-tailed Jaeger



Heermann's Gull



California Gull

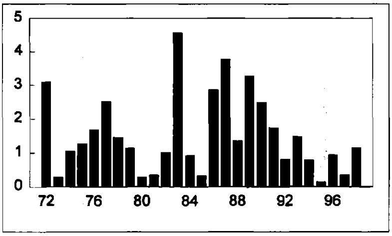


Western/Glaucous-winged gulls

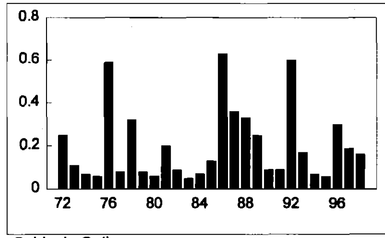
vessels, calculations using numbers of birds encountered away from vessels showed an increase in the 1990s ($P = 0.05$)

Flesh-footed Shearwater. Though this species was never common, numbers declined following the 1976 step change (Table 4). Ninety-six of 150 birds were noted at fishing vessels.

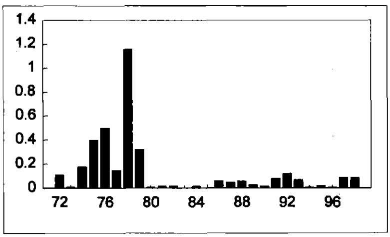
Buller's Shearwater. Numbers increased in the 1970s following near absence along the west coast of North America (see Jenkins 1974, Wahl



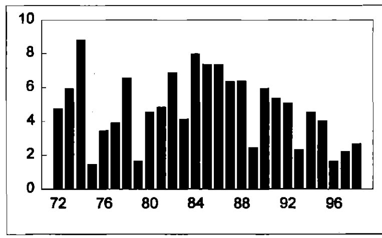
Black-legged Kittiwake



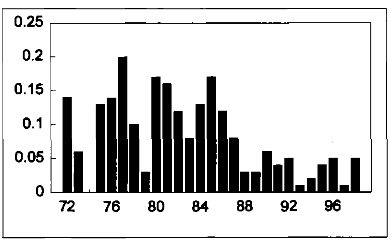
Sabine's Gull



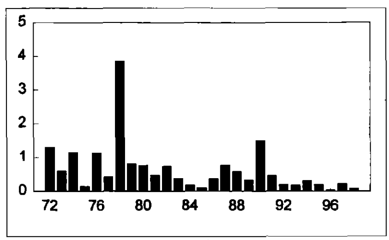
Arctic Tern



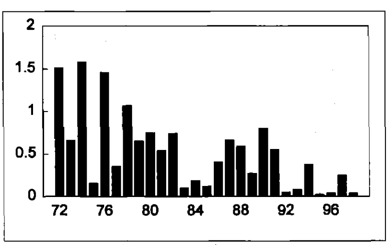
Common Murre



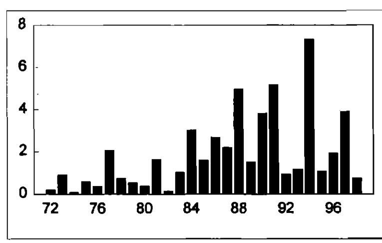
Marbled Murrelet



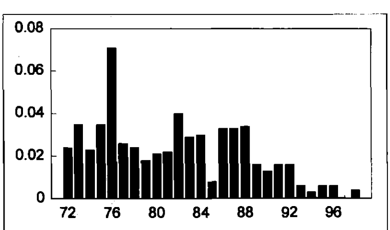
Cassin's Auklet - July-October



Cassin's Aulet - July-September



Rhinoceros Auklet



Tufted Puffin

Table 3 Results of Linear Regression Showing Changes in Abundance, 1972–1998

Species	Change	*P*
Black-footed Albatross	+	0.01
Northern Fulmar	+	0.01
Flesh-footed Shearwater	–	0.05
Buller's Shearwater	–	0.05
Sooty Shearwater	–	0.01
Brown Pelican	+	0.01
South Polar Skua	–	0.05
Parasitic Jaeger	–	0.01
Western/Glaucous-winged Gull	+	0.05
Arctic Tern	–	0.05
Marbled Murrelet	–	0.01
Cassin's Auklet (Jul–Sep)	–	0.01
Cassin's Auklet	–	0.05
Rhinoceros Auklet	+	0.01
Tufted Puffin	–	0.01

1985) but decreased after 1977 (Figure 2, Table 4), did not recover after that, and showed a long-term decrease (Table 3). This species does not forage at vessels (Wahl and Heinemann 1979), and its numbers appear to have been dependent on "natural" food sources.

Sooty Shearwater. The decline of this, the seasonally most abundant species along the west coast of North America, was obvious and drastic (Figure 2; see Veit et al. 1997). Numbers decreased over time (Table 3), more noticeably in the 1990s (Table 4). Though the Sooty Shearwater is attracted to fishing vessels, particularly shrimp trawlers, this attraction is less than for some other species (Wahl and Heinemann 1979). Very large proportions (1972–1998 average 67%) of all Sooty Shearwaters foraged in nearshore waters and the Grays Harbor channel. Though other species maintained their numbers or even increased in nearshore waters over time, Sooty Shearwater numbers decreased greatly there as they did in all habitats.

Fork-tailed Storm-Petrel. We did not see abundance changes over the long term.

Brown Pelican. Following years of near absence in Washington, nearshore-foraging pelicans reoccupied a historical nonbreeding range (Figure 2; see Jewett et al. 1953, Jacques et al. 1992), likely because of increasing reproductive success following an era of failure (Anderson and Anderson 1992). There was a significant long-term increase (Figure 2; Table 3). Highest abundances were in the 1990s (Figure 2; Table 4). In 1983 and the 1990s, periods of notably warm water, there was a noticeable increase in the proportion of juveniles (Wahl unpubl.). In the 1990s there was also an increase in sightings of pelicans offshore, with an occasional bird occurring to the outer limits of our surveys.

Phalaropes. Like other migrants, phalaropes varied greatly by year, and varied day to day by as much as an order of magnitude or more. Our

Table 4 Results of *t*-Test Comparisons of Seabird Numbers at Two Oceanographic Shifts

	1977–1998 vs. 1972–1998[a]		1990–1998 vs. 1972–1989	
Species	Change	*P*	Change	*P*
Black-footed Albatross	+	0.05	+	0.01
Northern Fulmar			+	0.01
Flesh-footed Shearwater	–	0.05		
Buller's Shearwater	–	0.01		
Sooty Shearwater			–	0.05
Brown Pelican			+	0.01
South Polar Skua			–	0.05
Parasitic Jaeger	–	0.01	–	0.05
Western/Glaucous-winged Gull			+	0.05
Common Murre (Sep–Oct)			–	0.05
Marbled Murrelet			–	0.01
Cassin's Auklet (Jul–Sep)	–	0.01	–	0.05
Rhinoceros Auklet	+	0.05	+	0.05
Tufted Puffin	–	0.05	–	0.01

[a]Comparison of post-step/PDO-positive period with pre-step/PDO-negative period.

sampling effort probably was inadequate to reveal significant changes over time. Red-necked Phalaropes (*Phalaropus lobatus*) migrate essentially over the continental shelf in the region (Wahl et al. 1989), but it is possible that Red Phalaropes (*P. fulicaria*) migrated farther offshore, west of the study area, in some years.

South Polar Skua. Abundance was highest from 1975 to 1977, after which a significant long-term decrease ensued (Table 3). In the 1990s decreases over previous periods were evident (Table 4).

Pomarine Jaeger, Though there were obvious peaks in occurrence (particularly in 1986; Figure 2), no trend was noticeable. The species migrates over the breadth of the subarctic North Pacific (Wahl et al. 1989), so changes in abundance may not be evident over the continental shelf. Jaegers are attracted to other birds at vessels and chum stops but were often noted migrating away from attractions. In peak years, migration in "waves" of up to 200 per day was noticeable.

Parasitic Jaeger. Migrating inshore more frequently than the other jaegers, the Parasitic appeared to decline (Table 3).

Long-tailed Jaeger. Like the Pomarine Jaeger, this species is a predominantly oceanic migrant, and changes in abundance may not be evident over the continental shelf. August–September occurrence was variable: large numbers were noted during particularly in 1988 and 1992 (Figure 2).

Heermann's Gull. Foraging almost strictly in nearshore waters and inside Grays Harbor, Heermann's Gulls appeared to increase over time (Figure 2), though this increase was not statistically significant. As with the Brown Pelican, in the warm-water periods of 1983 and the 1990s the proportion of juveniles increased noticeably (Wahl unpubl.).

California Gull. This species' population has increased greatly rangewide, by about 500% from the 1920s to 1980 (Conover 1983). The largest Washington colonies were established in the early 1970s (Conover et al. 1979). Perhaps not coincidentally, large numbers were attracted to industrial fishing fleets off Washington in the 1960s and 1970s (Wahl 1975). During the years of this study, no statistical trend is apparent. Though foreign fleets ceased operating off Washington in the late 1970s, Morgan et al. (1991) reported flocks of thousands of California Gulls at fleets off British Columbia just north of our study area during censuses starting in 1981. Abundances of California Gulls increased with distance from shore, where birds were associated with fishing vessels (see Wahl and Heinemann 1979).

Western/Glaucous-winged gulls. Because of extensive intergradation between the two resident breeding gulls (Hoffman et al. 1978, Bell 1996), their numbers were often lumped during surveys, and we combine them here. There was a significant increase from 1972 to 1998 (Table 3) and an increase in the 1990s over previous periods (Table 4).

Black-legged Kittiwake. Great variability in kittiwake numbers probably reflected changes in breeding status to the north of the study area (see Hatch et al. 1993). From July to October kittiwakes, largely nonbreeders, foraged almost exclusively in Grays Harbor or the outflow area and very seldom in their regular winter habitat offshore. There was no long-term trend in numbers spending the summer in the study area. Nonbreeding kittiwakes foraged in very large numbers at Grays Harbor in 1983 (Figure 2). Nesting productivity that year at the nearest colonies, in the Gulf of Alaska, was extremely low (Hatch et al. 1993).

Sabine's Gull. Apparently concentrating over the continental shelf when migrating off Washington (see Wahl et al. 1989), Sabine's Gull varied irregularly in abundance. Interestingly, because Sabine's Gulls are pursued by kleptoparasitic jaegers, 1986, 1988, and 1992 (Figure 2) were also peak years for the Pomarine or Long-tailed jaegers.

Arctic Tern. Arctic Terns declined (Figure 2; Table 3). They migrate ocean-wide (Wahl et al. 1989), and it is possible that some shifted to routes farther offshore following the step change and decline in ocean productivity in the mid-1970s.

Common Murre. Murre reproduction along the U.S. west coast declined starting in the early 1980s (e.g., Bayer 1986, Wilson 1991). Relatively few murres breed in Washington (Speich and Wahl 1989), and Wilson (1991) reported significantly depressed nesting success there in 1982 and 1983. Almost all murres in our study area July–October are from colonies south of Washington and move north for the winter. The major colonies in Oregon suffered low breeding success in the 1990s, especially in 1993 and 1996 (Lowe 1993, 1996), and in 1996 an Oregon survey of beached birds yielded the highest numbers of dead, emaciated murres of breeding age in 19 years (Lowe 1996). High rates of mortality and low productivity were also evident in 1997 (R. Lowe pers. comm.). Populations have also been stricken by oil spills (Speich and Thompson 1987, Ford et al. 1991, Divoky 1992) and in the 1990s by noticeably high gill-net mortality (Burger 1993, Kaiser 1993). Timing of movements probably depends on breeding success, which is dependent on ocean productivity. In 1984 our numbers were above average

(Figure 2). We believe numbers seen then and in the 1990s included large numbers of failed breeders (see Ainley et al. 1995b) and that our results understate the decline in overall numbers. The proportion of murres in nearshore waters (<20 m depth) increased over time ($P = 0.01$), from 40% in 1972–76 to 93% in the 1990s. Low sampling effort in nearshore murre habitat in 1978 complicates determination of abundance and may have resulted in our finding of nonsignificant long-term change.

Marbled Murrelet. As elsewhere, Marbled Murrelets declined significantly from 1972 to 1998 (Figure 2, Table 3; see Varoujean and Williams 1995) and in the 1990s compared to previous years (Table 4). This species' well-documented problems with loss of breeding habitat (Ralph et al. 1995), however, may obscure the effects of oceanographic events.

Cassin's Auklet. Numbers of Cassin's Auklets from July to October—some almost certainly migrants from large populations in British Columbia and Alaska—showed a decrease (Table 3). Numbers from July to September, presumably representing local breeders, decreased sharply following El Niño of 1982–1983 (Figure 2) and more generally over the entire study (Table 3). The species suffered not only low productivity at Oregon colonies (Lowe 1993) but also sizable mortality in an oil spill in 1988 and 1989 (Ford et al. 1991). Numbers from July to September 1977–1982 (Figure 2) decreased following the regime shift (Table 4).

Rhinoceros Auklet. Numbers increased significantly (Table 3) from 1972 to 1998, with highest values in the 1990s (Fig. 2). The increase reflects in part breeding success in the Protection Island colony on the Strait of Juan de Fuca (Speich and Wahl 1989), which fared better than the coastal colonies until the early 1990s (Wilson, in Smith et al. 1997), along with increased use of nearshore coastal waters ($P = 0.05$; from 82% 1972–76 to 98% in the 1990s).

Tufted Puffin. In correspondence with their poor nesting success (e.g., Lowe 1993), puffins decreased dramatically over time (Figure 2; Table 3), both following the step in 1976 and further in the 1990s (Table 4).

Other Species

We do not include analyses of data for two offshore species. Leach's Storm-Petrel (*Oceanodroma leucorhoa*) forages primarily west of our study area, and our sample size—just 31 records—for Xantus' Murrelet (*Synthliboramphus hypoleucus*) is inadequate. Our data are inadequate to address the status of nearshore foragers like cormorants (*Phalacrocorax* spp.), the Caspian Tern (*Sterna caspia*), and Pigeon Guillemot (*Cepphus columba*) or regular winter visitors and late migrants like the Short-tailed Shearwater (*P. tenuirostris*), Bonaparte's, Herring, Thayer's and Glaucous gulls (*L. philadelphia*, *argentatus*, *thayeri*, and *hyperboreus*, respectively), Ancient Murrelet (*Synthliboramphus antiquus*), and other alcids. It should be noted that the wintering status of the Northern Fulmar and Black-legged Kittiwake may differ considerably from these species' July–October status, which reflects the abundance and distribution of nonbreeders.

Changes in Abundances, 1972–1998

Of the five species that increased (Table 3), the Black-footed Albatross, Northern Fulmar, and Western/Glaucous-winged Gulls scavenge readily at fishing vessels, and the Brown Pelican and Rhinoceros Auklet forage primarily in nearshore waters. The latter were the only two species not foraging at fishing vessels that increased over time. The pelican's increase represents a population recovery and range reoccupation in the 1980s. The Rhinoceros Auklet may reflect a population and range expansion (Sowls et al. 1980), perhaps facilitated by the species' switching habitats and, along with pelicans, taking advantage of large anchovy (*Engraulis mordax*) schools inshore (pers. obs.).

Ten species (Table 3) decreased significantly. The decreases in three (and almost certainly four) breeding alcids and the huge decrease in the Sooty Shearwater (Figure 2; see Veit et al. 1997) appear to reflect a prolonged decline in ocean productivity.

Though large variations are apparent, nine species did not show statistically significant changes. Our data do not show changes in numbers of several Alaska–arctic migrants (phalaropes, at least two of the jaegers, and Sabine's Gull). The Black-legged Kittiwake's pattern presumably reflects variations in the distribution of nonbreeding birds. The Fork-tailed Storm-Petrel's variations may be due to localized feeding conditions and the distribution of nonbreeders and failed breeders.

Differences between Oceanographic Periods, "Regimes," or "Events"

In spite of obvious annual variations (Figure 2), comparisons by *t* test for each of the periods with those of the preceding period showed very few statistically significant changes. One "significance" of such comparisons may be in the difficulties in seeing changes over relatively short periods. Notations of periods of high and low numbers per kilometer nevertheless show overall differences between periods or events (Table 5).

Pre-regime shift/PDO-negative period: 1972–1976. There were high numbers of six offshore foragers (the three shearwaters, skua, Cassin's Auklet, and Tufted Puffin) and lowest numbers of three other species that later steadily increased over time. Though the sample size was relatively low (Table 1), additional data from a two-week research cruise off Grays Harbor in 1976 (Wahl unpubl.) gave a picture very similar to that gained from chartered vessels in that year.

Post-step/PDO-positive period: 1977–1982. Few species were at highest or lowest numbers, but changes were implicit in that numbers of many species declined obviously following the step. Sooty Shearwaters were at their greatest abundance.

El Niño 1983–1984. Ten species, seven of these offshore foragers, were at lowest numbers. High numbers of kittiwakes and murres probably reflected presence of nonbreeders and failed breeders, respectively. Additionally, along the coast Elegant Terns (*Sterna elegans*) (Hunn and Mattocks 1984) and offshore Wilson's Storm-Petrel (*Oceanites oceanicus*) (Harrington-Tweit and Mattocks 1984) were recorded for the first time in Washington.

1985–1989. Six species increased to highest levels following El Niño. These included the Long-tailed Jaeger and Sabine's Gull offshore, where peaks in numbers of Fork-tailed Storm-Petrels (Figure 2) were noteworthy. The effects of the 1988–1989 La Niña, which would presumably have been

Table 5 Periods of Highest (H) and Lowest (L) Numbers of Birds per Kilometer by Species

Species	1972–76 Pre-step	1977–82 Post-step	1983–84 El Niño	1985-89 post-El Niño	1990–98 1990s
Offshore					
Black-footed Albatross[a]	L				H
Northern Fulmar[a]		L			H
Pink-footed Shearwater[a]	H		L		
Flesh-footed Shearwater[a]	H				L
Buller's Shearwater	H		L		
Fork-tailed Storm-Petrel			L	H	
South Polar Skua	H				L
Long-tailed Jaeger			L	H	
Sabine's Gull			L	H	
Arctic Tern		H	L		
Cassin's Auklet	H		L		
Tufted Puffin	H				L
Offshore–nearshore					
Sooty Shearwater[a]		H			L
Phalaropes		H			L
Pomarine Jaeger				H	L
Parasitic Jaeger	H		L		
California Gull[a]			L	H	
Western/ Glaucous-winged Gull[a]		L		H	
Common Murre			H		L
Rhinoceros Auklet	L				H
Nearshore					
Brown Pelican	L				H
Heermann's Gull		L		H	
Black-legged Kittiwake			H		L
Marbled Murrelet		H			L

[a]Species readily attracted to fishing vessels.

reflected in increased ocean productivity in 1989, are not apparent in our findings.

The 1990s. Upwelling varied by region along the west coast of North America but was generally below long-term averages (National Marine Fisheries Service). Patterns of seabird abundance off Washington were in accord with this and a similar situation off California (Ainley et al. 1995b, Veit et al. 1997). Within the period strong El Niño conditions were noted in 1992–1993 and 1998. Overall, this period appeared to be the opposite of the pre-step period. The only offshore species found in high numbers were the fishing vessel-associates: albatrosses and fulmars. The offshore–nearshore foraging Western/Glaucous-winged gull and two nearshore foragers, the pelican and Rhinoceros Auklet, also reached highest numbers. Seven species were at lowest numbers of any of the five periods. The decline of the Sooty Shearwater was particularly evident. The average for 1990–

1998 was 75% lower than at the peak, 1977–1982. Similarly, numbers of four regional breeders, the Common Murre, Marbled Murrelet, Cassin's Auklet, and Tufted Puffin, were very low in the 1990s (Figure 2). Though numbers of other species apparently rebounded quickly following the 1983-1984 event, numbers of these remained low in the 1990s in spite of reported changes like La Niña events. Phalarope numbers were also conspicuously low. The duration of the shift in the 1990s appears particularly important.

Manx Shearwaters (*Puffinus puffinus*) (Tweit and Paulson 1994) and Elegant Terns (unrecorded since 1983; Tweit and Fix 1991) occurred several times. Laysan Albatrosses (*Phoebastria immutabilis*) increased dramatically in the mid-ocean northeast Pacific (K. Morgan pers. comm.) and along the west coast of North America (e.g., 30 off Washington in December 1995; Rogers 1996) and included Washington's first summer records. This species' increase was possibly in related in part to the expansion of its breeding range to islands off Mexico (Gallo-Reynoso and Figueroa-Carranza 1996).

Considerations and Questions

Changes in Habitats. Along with gulls, three historically abundant species forage widely over the continental shelf and can shift to available inshore prey when oceanic prey declines (see Burger 1993, Ainley et al. 1996). From 1972 to 1998 Common Murres and Rhinoceros Auklets increased near shore ($P = 0.01$ and $P = 0.05$, respectively), but Sooty Shearwaters declined there, as they did overall.

Near shore, Brown Pelicans reoccupied a historical nonbreeding range (Figure 2 and see Jewett et al. 1953). Rhinoceros Auklets increased, shifting to nearshore waters in the 1990s. Another nearshore forager, the Caspian Tern, expanded its breeding range into southwest Washington in 1957 (Penland 1982), and its colonies increased to thousands of breeding birds (see Bird 1994, Lowe 1996). As over much of North America, Double-crested Cormorants (*Phalacrocorax auritus*) increased over the period (e.g., Vermeer and Rankin 1984). These four species are primarily nearshore or estuarine foragers and may reflect associations with concentrations of anchovies. The situation may change in the future as sardines (*Sardinops sagax*) and anchovies alternate cyclically in abundance, and stocks of sardines along the northwest coast have been increasing greatly since 1983 (Bargmann 1997). Offshore, there were no replacements in seabird species or numbers.

Another switch is to inland marine waters of the Strait of Juan de Fuca and adjacent areas. Several offshore species occur sporadically in inland waters, and recent reports from this area suggest increased frequency and numbers of the Fork-tailed Storm-Petrel, jaegers, phalaropes, and Brown Pelicans (e.g., Tweit and Gilligan 1998).

Changes in migrations. Changes in abundance of the Red Phalarope, Pomarine and Long-tailed jaegers, and Arctic Tern over the continental shelf may not represent changes in populations but rather changes in foraging areas or migration paths in response to food availability. Summer-resident storm-petrels and phalaropes forage over oceanic waters farther offshore than the continental shelf and may shift foraging areas. Though this may also be the case for migrating phalaropes, the decline in the 1990s of one historically abundant planktivore, Cassin's Auklet (Figure 2; Speich and Wahl 1989), which forages primarily over the outer shelf and continental slope (see Briggs et al. 1992), was likely not due to a shift farther offshore than the study area. There was sizable mortality of beached birds in Oregon (see Lowe 1993) and large declines in breeding birds in huge colonies in British Columbia (Vermeer et al. 1997).

Effects on regional populations. Local productivity relates to prey species and regional breeding success (see Denman et al. 1989 and Thomson et al. 1989). For species covered by both our data and Ainley et al. (1994), our analyses agree with trends of species breeding in the northern California Current: declines in most species except for the Rhinoceros Auklet and large gulls. The increase in our Rhinoceros Auklet abundance follows the recent trend of populations along the west coast of North America described by Ainley et al. (1994).

Effects of conditions elsewhere. Veit et al. (1997) pointed out the importance of pre-migration feeding in the California Current to southbound Sooty Shearwaters. More recently, Spear and Ainley (1999) proposed that Sooty Shearwaters switched migration routes and foraging areas to the west and that the total population did not decrease when productivity off the west coast declined. Resolution of this question may be impossible without counts of the breeding population.

Effects of commercial fishing. Ainley et al. (1994) drew attention to the relationship of food availability with reproductive success and pointed out patterns off California similar to those seen in Peru, where intense fishing coinciding with climatic stress "wrecked" seabirds' main food supply. Ainley et al. (1994, 1996) also raised the subject of competition by human fishing with seabirds for prey species. We cannot address these issues here, but commercial fishing is a major, perhaps dominating, aspect of our study area's ecosystem.

Over the long term, three of seven species strongly attracted to vessels—albatrosses, fulmars, and Western/Glaucous-winged gulls—increased over time (Table 3), all with highest abundances in the 1990s. California Gulls probably increased. Of ship-following species only the Sooty Shearwater decreased.

We lack data on fishing effort, efficiency (catch), discards (bycatch), and regional distribution of vessels off British Columbia, Washington, and Oregon. Until 1976, for example, Russian fishing trawlers and processors regularly operated off Grays Harbor. Subsequent efforts by other foreign and domestic ventures have varied in effort and location. Though numbers of some birds may have been maintained by forage available at vessels, the effects of shifts in fishing effort on seabird distribution are unknown.

CONCLUSION

Additional years of sampling may show whether trends we have seen were part of a long-term shift (i.e., climate change) or were previously unquantified cyclical variations that will change over time. Many questions arise regarding shifts in migration routes, replacement of one species by another, the effects of and importance of type, effort, and changes in commercial fishing practices, and the effects of conditions off Washington on regional and southern hemisphere breeders. Additional studies of oceanography and prey species may shed light on annual variations not apparently related to large-scale events and on further questions implicit in our findings.

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