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RESPONSES OF THREE SEABIRD SPECIES TO EL NIÑO EVENTS AND OTHER WARM EPISODES ON THE WASHINGTON COAST, 1979–1990[1]

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Abstract. For 1979–1990, I compared satellite-based sea surface temperature anomaly data for Washington's outer coast with the annual number of nests of Double-crested Cormorants (*Phalacrocorax auritus*) and Brandt's Cormorants (*Phalacrocorax penicillatus*), and the number of Common Murres (*Uria aalge*). Sea surface temperatures were a minimum of 1°C above average for at least four consecutive months during three periods: January–April 1981, February–June 1983, and September 1987–February 1988. The first warm event was not associated with El Niño, while the second and third warm episodes were the results of a severe (1982–1983) and more moderate (1987) El Niño events. Numbers of the three seabird species were significantly negatively correlated with the intensity and occurrence of these warm events, although the effects of the 1981 event were not clear-cut. Cormorant nesting was depressed during El Niño and post-El Niño years. Differences in response of the two cormorant species may be related to differences in their breeding chronologies. In 1983, murres crashed to 13% of pre-1983 levels. With the exception of 1987, numbers remained at this level through 1990. The interpretation of ENSO effects on murres is complicated by several types of human disturbance.

Key words: Double-crested Cormorant; Brandt's Cormorant; Common Murre; sea surface temperature anomaly; El Niño Southern Oscillation; thermocline; Washington.

INTRODUCTION

The most spectacular instances of interannual variability in marine ecosystems are El Niño or ENSO (El Niño Southern Oscillation) events that occur at intervals of two to ten years (Cane 1983). Along the eastern Pacific rim these phenomena manifest themselves oceanographically in above normal sea surface temperatures (SST's), a depression of the thermocline, and a rise in sea level (Hamilton and Emery 1985, Norton et al. 1985). A more thorough description of the El Niño/ENSO phenomenon can be found in Cane (1983), Barber and Chavez (1983), Rasmussen and Wallace (1983), and Cane and Zebiak (1985). The 1982–1983 El Niño event was the strongest and best documented to date (Cane 1983). It resulted in a better understanding of ENSO effects on Pacific seabirds in South America (Hughes 1985, Duffy and Merlen 1986, Gibbs et al. 1987, Valle and Coulter 1987), the central Pacific (Schreiber and Schreiber 1984) and North America (Hodder and Graybill 1985, Bayer 1986, Hatch 1987, Takekawa et al. 1990). While most long-term ENSO studies of seabirds are from Peru (e.g., Duffy 1983, Schneider and Duffy 1988), studies from other areas in the Pacific are, except Hatch (1987), of relatively short duration without much quantitative climatological data. Several authors have recognized this problem and expressed the need for longer studies (Hodder and Graybill 1985, Gibbs et al. 1987). To provide a long term data set from an unstudied region in North America, I compared monthly sea surface temperature data with data on Double-crested Cormorants (*Phalacrocorax auritus*), Brandt's Cormorants (*Phalacrocorax penicillatus*), and Common Murres (*Uria aalge*) from the Washington outer coast from 1979–1990.

STUDY AREA AND METHODS

I calculated mean monthly sea surface temperature (SST) anomalies for Washington's offshore waters from monthly SST anomaly charts published in the National Oceanic and Atmospheric Administration's (NOAA) Oceanographic Monthly Summary. Within my area of analysis (45°N to 50°N and seaward to 130°W), these charts list 27 evenly spaced anomaly values for each month for the 1981–1990 period. Similar data, provided by NOAA Satellite Data Services Division, Washington, D.C. were the basis for the 1979 and 1980 anomaly estimates. The

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monthly anomaly is the difference between the monthly mean SST and the climatological monthly mean value. The monthly mean SST is derived from twice-weekly analyses using ship, buoy and satellite observations, while the climatological mean value is derived from a continually updated data base that extends back to 1965.

The seabird study area was the outer coast of Washington's Olympic Peninsula. Between Copalis Rock (47°09′N, 124°11′W) and Cape Flattery (48°23′N, 124°44′W), 28 major and hundreds of smaller rocks and islands are located within 3 km of shore. Most of the islands are typical sea stacks, but a few of them support vegetation dominated by salal (*Gaultheria shallon*) and salmonberry (*Rubus spectabilis*). Several also have small stands of Sitka spruce (*Picea sitchensis*). These islands are National Wildlife Refuges and support approximately 110,000 breeding pairs of seabirds.

From 1979–1990 I censused Double-crested Cormorants, Brandt's Cormorants, and Common Murres by annual aerial survey conducted between 10:00 and 14:00 hr during late June or early July. From 1979–1983 a small single engine aircraft (Cessna 172 or 182) was flown, and colonies were photographed from an altitude of 180–250 m with a motorized 35 mm camera equipped with 135 mm lens. I counted murres and occupied cormorant nests from slides taken during these flights. The use of a Hughes 500D helicopter since 1984 has allowed me to make direct counts. While hovering around the colonies, I counted murres and cormorant nests with a tally counter and binoculars. This was easily done since few murres were encountered since 1984. I also checked the major colonies several times each season, either from shore or from a small boat, to assure that birds attended the colonies thru the nesting season. Several of the very small colonies were excluded from this analysis because they could not be easily surveyed by fixed-wing aircraft. The colony sites sampled, however, make up over 90% of the three species counted during surveys of the outer coast of Washington.

Without question the helicopter method was the most accurate (5% error estimate), while the fixed-wing aircraft murre estimates were the least accurate (10% error estimate).

RESULTS

During this study, there were three major warm episodes during which mean monthly SST anomalies were a minimum of 1°C for at least four consecutive months (Table 1). The first warm event occurred from January–April of 1981. This episode lacked the characteristic depression of the thermocline of ENSO events, and was not associated with an El Niño episode (Cannon et al. 1985). The second warm event occurred during 1983, beginning in February and lasting through June (Table 1). This was the result of the 1982–1983 El Niño event which was the strongest of this century to date (Cane 1983). Another more moderate El Niño occurred during late 1987 (Kerr 1987), which produced anomalously warm water off Washington from September 1987 through February 1988. Because of the timing of this event it is unclear whether to call 1987 or 1988 an El Niño year. Since the warm period occurred after the 1987 Double-crested Cormorant and murre breeding seasons, I considered 1988 an ENSO year for these species. Because warm water reached Washington during the Brandt's Cormorant chick stage, I assumed 1987 was also an ENSO year for this species. In Washington, the three events were very similar in that they all reached SST peaks between 2.0 and 2.3°C above climatological mean and lasted between four and six months (Table 1). Beside these major events there were several periods when mean monthly SST anomalies exceeded 1°C for one or two months. These are likely the result of transient areas of warm surface water and were not considered to be major warm water events.

The lowest number of occupied Double-crested Cormorant nests occurred during and after the 1983 El Niño event (Fig. 1). During the 1983 breeding season only 216 nests were counted, less than half the number recorded during normal years. This decline continued through 1984 when only seven nests were located. Populations of Double-crested Cormorants appeared to recover from the severe 1982–1983 El Niño, as there was no significant difference in the number of nests observed before 1983, compared to those recorded since 1983 ($U = 16$, $P > 0.2$, Mann-Whitney U-test). In Washington, Double-crested Cormorant nesting was also poor in 1988 following the 1987–1988 El Niño. In contrast, there were more Double-crested Cormorant nests in 1981 than in 1979 and 1980 (Figure 1).

The number of Brandt's Cormorant nests also declined during the El Niño year of 1983 and no nests were found during 1984 (Fig. 1). Brandt's Cormorants apparently recovered from this se-

TABLE 1. Mean monthly sea surface temperature (SST) anomalies, Washington offshore waters 1979–1990. Anomalous values of +1°C and above are shown in bold print.

Month	Year											
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan.	−1.3	0.6	**1.2**	0.3	0.9	0.8	0.5	0.4	0.9	**1.5**	0.3	**1.4**
Feb.	−1.5	0.2	**2.1**	0.9	**1.8**	**1.4**	0.4	0.9	**1.3**	**1.2**	−0.5	0.7
Mar.	−0.3	0.1	**2.0**	0.7	**2.0**	**1.6**	0.5	**1.5**	**1.3**	0.2	−0.8	0.7
Apr.	0.2	0.3	**1.1**	0.1	**1.7**	0.9	0.4	0.9	0.9	0.1	0.6	0.8
May	0.5	0.1	0.9	0.1	**2.0**	0.6	0.4	0.6	0.7	−1.0	**1.7**	0.6
June	0.1	0.8	0.5	−0.3	**1.4**	0.1	0.6	0.9	−1.4	−1.0	0.4	0.3
July	0.6	0.5	−0.8	−0.6	0.8	−1.1	0.2	−0.5	−1.2	−1.5	0.2	0.2
Aug.	−0.2	0.7	−0.8	−0.5	0.1	−0.2	−0.6	−1.3	−0.6	−0.1	0.1	0.4
Sept.	0.3	−1.2	−0.1	0.0	−0.3	0.0	−1.0	−0.4	**1.0**	−0.1	−0.2	**1.0**
Oct.	0.8	−1.0	0.2	−0.1	0.4	−0.4	−0.5	0.0	**2.3**	**1.3**	0.5	0.0
Nov.	0.8	0.1	0.7	0.0	0.5	−0.3	−1.1	0.6	**2.2**	**1.3**	0.7	0.3
Dec.	0.5	0.3	0.5	0.5	0.4	−0.1	−0.9	0.6	**1.3**	0.9	0.8	−0.3

vere event since the numbers of nests prior to 1983 were not significantly different from those since 1983 ($U = 19$, $P > 0.2$, Mann-Whitney U-test). Nesting of Brandt's Cormorants was also depressed following the 1981 warm episode and during the 1987 and 1988 El Niño years (Fig. 1). The yearly numbers of Brandt's Cormorant nests were significantly negatively correlated with the number of warm months (minimum anomaly of +1°C) during the calendar year, the number of warm months during January–June, and the number of warm months during the breeding season, March–August (Table 2, comparisons 1–3).

The number of colony attending Common Murres varied between 18,355 and 31, 520 birds during 1979–1982 (Fig. 1). By 1980 a decline appeared underway and the lowest number of murres occurred during the 1981 breeding season which followed a period of anomalously warm water. The most drastic change occurred during the 1983 El Niño year when colony attendance dropped to 3,190 birds. As with cormorants, the lowest number of murres was observed during 1984. Unlike the two cormorants, murre numbers failed to recover from this event. The numbers of murres observed prior to 1983 were significantly different from those recorded since then ($U = 32$, $P < 0.005$, Mann-Whitney U-test). Following 1983 murre numbers were extremely low until 1987, when it appeared that a recovery was under way. During the latter part of this year however, the 1987–1988 El Niño event caused a warming of SSTs off Washington that persisted through February 1988. Following this event murre numbers again dropped to levels similar to those of the 1983–1986 period. Although Figure 1 may give the impression of a general murre decline, there was no evidence of such a trend (Spearman rank correlation, $r_s = -0.475$, $P > 0.05$). During years of low murre colony attendance, traditionally large colony sites were al-

TABLE 2. Spearman rank correlation analysis of sea surface temperature anomaly data vs. seabird data (yearly totals), Washington coast, 1979–1990.

SST anomaly variable	Species					
	Double-crested Cormorant		Brandt's Cormorant		Common Murre	
	r_s	P	r_s	P	r_s	P
1. No. warm months[1] during calendar year	0.032	>0.25	−0.603	<0.025	−0.319	>0.10
2. No. warm months[1] during Jan.–June	−0.173	>0.25	−0.644	<0.025	−0.520	<0.05
3. No. warm months[1] during Mar.–Aug.	−0.074	>0.25	−0.553	<0.05	−0.465	>0.05
4. Years ranked by warm event severity[2]	−0.538	<0.05	−0.836	<0.001	−0.522	<0.05
5. No. cold months[3] during calendar year	−0.317	>0.10	−0.190	>0.25	−0.097	>0.25
6. No. cold months[3] during Jan.–June	0.211	>0.25	0.102	>0.25	0.454	>0.05
7. No. cold months[3] during Mar.–Aug.	−0.011	>0.25	−0.526	<0.05	0.180	>0.25

[1] Minimum anomaly +1°C.
[2] See results.
[3] Negative anomaly.

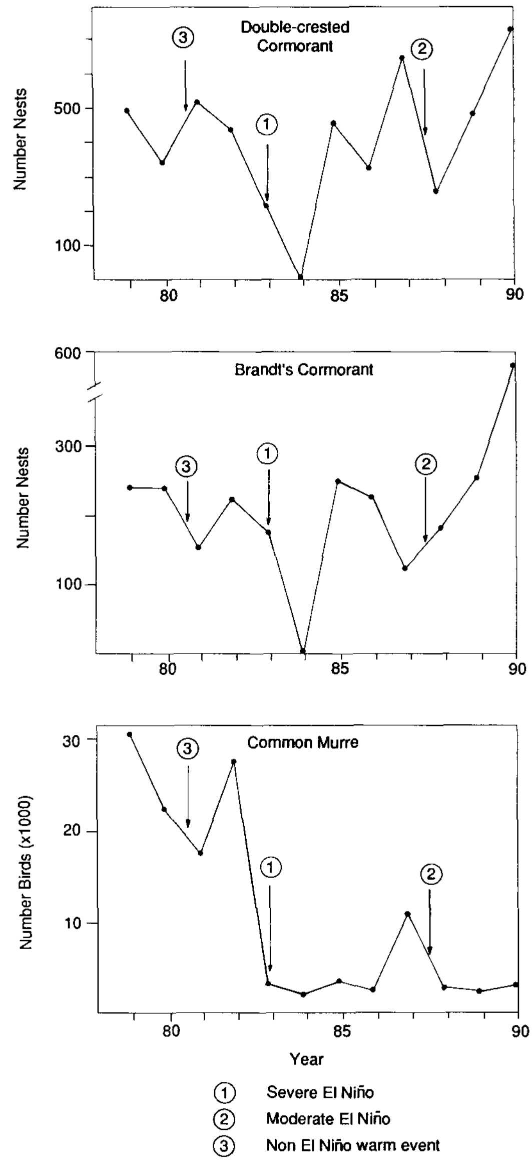

FIGURE 1. Seabird fluctuations and the occurrence of warm water events on the Washington outer coast, 1979–1990.

most totally deserted while some of the smaller colonies remained intact. During this study the yearly numbers of murres were significantly negatively correlated with the number of warm months during January–June (Table 2, comparison 2).

The lack of a significant correlation between Double-crested Cormorants and warm water is at least partially because post El Niño years, while having normal SST's, are biologically still under El Niño influence (Pearcy et al. 1985). To take this into account, I used information from Cannon et al. (1985), Quinn et al. (1987) and Table 1 to rank the years by the intensity of the influencing warm events. Thus, most severe were 1983 and 1984, moderately severe were 1988 and 1989 (but 1987 and 1988 for Brandt's Cormorants for reasons mentioned above), and least severe was 1981. I assumed that the remaining years were not influenced by the warm events. This analysis showed that all three species were significantly negatively correlated with the intensity and occurrence of the warm events identified earlier (Table 2, comparison 4).

While warm water is generally associated with negative effects on seabirds, cold water can have a positive effect on seabird breeding (Boersma 1978). I found no significant positive correlations between months with negative anomalies and the numbers of the three seabird species (Table 2, comparisons 5–7).

DISCUSSION

The lowest number of occupied nests of Double-crested and Brandt's cormorants occurred either during El Niño years or post-El Niño years. These observations are consistent with the findings of Bayer (1986) who determined that nesting success of Pelagic Cormorants (*Phalacrocorax pelagicus*) at Yaquina Head, Oregon, was poorer in 1984 than in 1983. During 1983 the density of zooplankton off Oregon was only 30% that of non-El Niño years (Miller et al. 1985), and off Washington the distributions and abundances of certain fishes and crabs were affected beyond the subsidence of the physical manifestations of the 1983 ENSO. Thus, a return to normal will likely work its way gradually up the food chain, with an inherent time lag for seabirds. This is presumably the reason why post-El Niño years were poor for seabirds.

The observed differences in response timing of the two cormorant species may be related to differences in their breeding chronologies. In Washington Brandt's Cormorants typically nest much later than Double-crested Cormorants (Jewett et al. 1953). These differences, and the results of Table 2 (comparisons 1–3), suggest that significant response variations can be expected even among closely related species. The finding, that the degree of response appears related to the degree of the warm event, has been observed by other workers (Anderson 1989, Duffy 1983), but never at higher latitudes.

While the drastic change in colony—attending Common Murres of 1983 is likely the result of that year's El Niño, their continued almost total absence from Washington is unclear. Evidently murres were absent from Washington during previous El Niños. During his early seabird surveys, conducted during 1905 and 1907, Dawson (1908) counted only 1,736 murres on the Washington coast. Interestingly, moderate El Niños occurred during both years of his study (Quinn et al. 1987). On the other hand, Manuwal and Campbell (1979) estimated the 1975 Washington outer coast murre population at 23,900 individuals. Since a moderate El Niño occurred in 1976 (Quinn et al. 1978, 1987), Washington murres must have recovered from this event as quickly as cormorants did during this study. While there are no documented cases of delayed seabird recovery from ENSO events for North America, they have been noted elsewhere (Hughes 1985, Tovar et al. 1987, Valle et al. 1987). During this study, Washington murres have also been adversely affected by oil spills (Wahl 1986, Speich and Thompson 1987, Rodway et al. 1989), gillnet mortality (Pat Gearin, pers. comm.) and U.S. Navy practice bombing (Speich et al. 1987). These disturbances complicate the interpretation of ENSO effects on murres and require further study.

That Brandt's Cormorants and murres were best correlated with the number of warm months during January–June (Table 2), may also be of significance. While this may partially be the result of the chronology of the warm water events themselves, it may also suggest that the early period before the breeding season is especially important to the birds.

Of the three warm episodes, the effects of the 1981 event were not clear-cut. Double-crested Cormorants increased during the event, and murres started to decline in the year prior to the event. Because this warm episode was not ENSO related, the observed patterns may be due to reduced biological effects on the birds.

Since, off Washington, SST's apparently give little information as to the severity and type of a given warm episode, marine ornithologists would be well advised to use SST data only as indicators to mark the onset of potentially unfavorable conditions for seabirds. The identification and rating of any given ENSO event is best left to atmospheric scientists.

Our present understanding of ENSO effects on seabirds is hindered by the variation exhibited by these warm events. Long-term monitoring studies, over 20 or 30 years, would undoubtedly provide additional insight. The relationships between seabirds and warm episodes may be so complex that, in order to understand them better, we need to accumulate the facts empirically. The future conservation of seabirds requires that we better comprehend and manage our own impacts on these species. This can only be accomplished with a prior knowledge of how environmental factors cause variation in seabird populations.

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