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Environmental Contaminants, Human Disturbance and Nesting of Double-crested Cormorants in Northwestern Washington

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Abstract.—Double-crested Cormorants (*Phalacrocorax auritus*) in extreme northwestern Washington produced few young (0.27/occupied nest) in 1984; the clutch size was generally small and eggs, if laid at all, were laid later than usual. Residues (geometric means, wet weight) of DDE (0.58 and 0.59 ppm) in eggs from Colville Island and Protection Island were lower than from other locations in the Pacific Northwest, while PCBs (2.19 and 1.37 ppm) were similar to those at most locations. Both contaminants in 1984 were below levels associated with reproductive problems. Eggs also contained concentrations of mercury (0.26 and 0.27 ppm) and selenium (0.31 and 0.28 ppm) below levels associated with reproductive problems. The distribution of nesting colonies in the study area changed dramatically since 1984. The cormorants were most likely responding to increased human disturbance in the San Juan Islands, coupled to additional protection and reduced human activity on Protection and Smith Islands. This presumably led to the abandonment of all nesting islands in the San Juans. The nesting population in the study area in 1988 (all on Protection and Smith Islands) was the highest recorded. *Received 13 June 1988, Accepted 15 March 1989.*

Key words.— Double-crested Cormorant, *Phalacrocorax auritus*, DDE, PCB, mercury, selenium, eggshell thinning, El Niño, productivity, clutch size, human disturbance.

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An estimated 34,300 pairs of seabirds nest along the Strait of Juan de Fuca and in nearby areas of extreme northwestern Washington (Fig. 1). Most nest on Protection Island and the San Juan Islands (Wahl *et al.* 1981). Seabirds in this area have received attention during the last decade because of concern about increased human activity and exposure to environmental pollutants in coastal zones. Double-crested Cormorants (*Phalacrocorax auritus*) began nesting on the inner coasts of southern British Columbia and northern Washington about 60 years ago (Drent and Guiguet 1961). About 3,300 Double-crested Cormorants usually breed at about 25 sites in more northern coastal marine areas of Washington (Speich and Wahl, in press).

Studies in Oregon from 1977 to 1980 produced background data. Eleven species of seabirds were studied along the Oregon coast in 1979 (Henny *et al.* 1982), and Double-crested Cormorants contained the second highest residues of polychlorinated biphenyls (PCBs) and the third highest residues of DDE. In addition, we collected and analyzed 19 Double-crested Cormorant eggs for organochlorine residues; one randomly selected egg was collected per clutch from the 19 active nests. Collection sites included: Klamath National Wildlife Refuge (NWR) (southcentral Oregon, 1977), Umatilla NWR (inland along the Columbia River, 1978-79), and Malheur NWR (eastern Oregon, 1980). The eggs were collected during other investigations, and the nests were not regularly revisited.

In 1984, we began more intensive studies of nesting Double-crested Cormorants at Protection Island, NWR in the Strait of Juan de Fuca; and at the San Juan Islands NWR (Williamson Rocks, Colville Island, and Bird Rocks) in Rosario Strait (Fig. 1). The study was designed to evaluate the effects on reproductive success of organochlorine, mercury, and selenium residues in eggs. Organochlorine residue data collected in 1977-80 provides comparative information. We also report counts of nesting pairs (occupied nests) in the northwestern Washington study area from the early 1970s through 1988.

METHODS AND ANALYTICAL PROCEDURES

During 1984, nesting at Protection Island was checked at about weekly intervals beginning in early April, while the San Juan Islands were visited at about 2-week intervals beginning in May. Smith Island was visited once in 1984 during July. During all other years, the San Juan Islands and Smith Island were visited once during late June or early July. Protection Island, on the other hand, was visited more frequently since 1985. Between 3 and 8 nest counts were

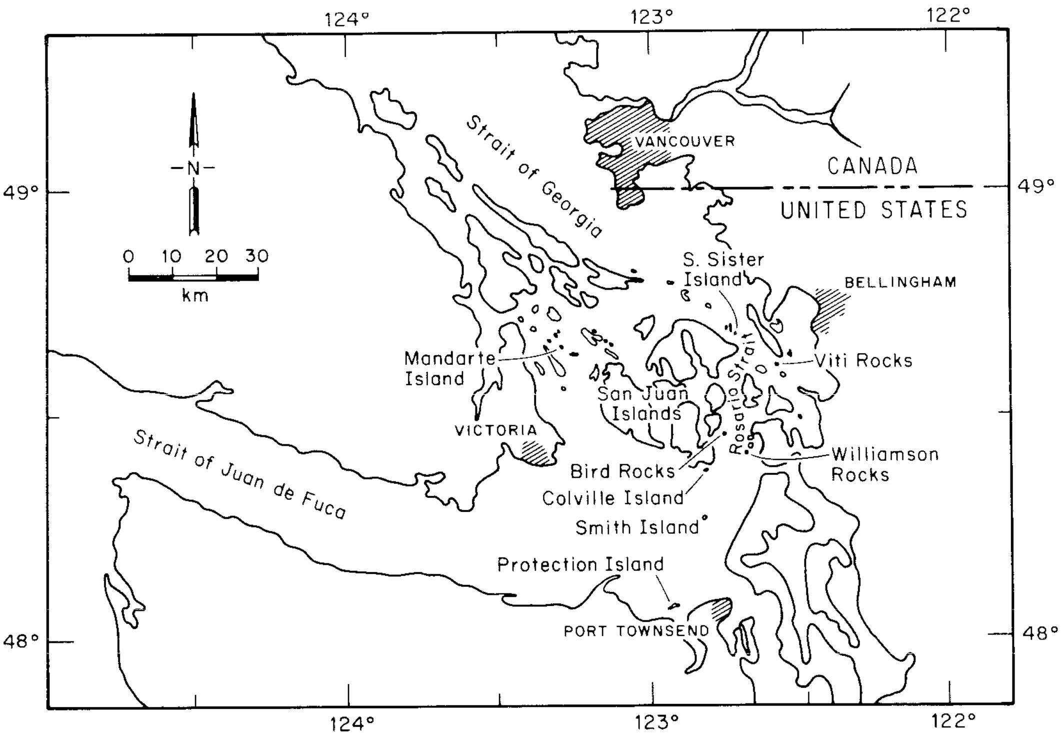

Figure 1. Map of Northwestern Washington showing the islands where Double-crested Cormorants nested.

conducted per breeding season on Protection Island, and sample nests were checked periodically for reproductive success. Nests in the San Juan Islands and on Smith Island were counted and inspected on foot, while nests on Protection Island were counted by circumnavigating the island by boat. In 1984, success of each nest was evaluated in relation to residues detected in the sample egg collected from that nest. Eleven eggs were collected on Protection Island and 36 on Colville Island.

Egg contents were placed in chemically-cleaned glass bottles and frozen. Analyses of samples for organochlorine pesticides, their metabolites, and PCBs were conducted at the Patuxent Wildlife Research Center (PWRC), Laurel, Maryland. Analytical methodology (Cromartie *et al.* 1975, Kaiser *et al.* 1980) was previously described for Double-crested Cormorant eggs from the Oregon Coast (Henny *et al.* 1982). The lower limit of residue quanitification was 0.1 ppm for pesticides and 0.5 ppm for PCBs. Residues in about 10% of the samples were confirmed with a gas chromatograph-mass spectrometer.

After eggs were homogenized, subsamples were taken for mercury and selenium anlysis at PWRC. Mercury samples were digested as described by Monk (1961) and analyzed on a Perkin Elmer 460 Atomic Absorption spectrometer (Hatch and Ott 1968). Selenium analyses were performed on nitric acid digests using a Perkin Elmer Zeeman 3030 graphite furnace atomic absorption spectrometer (Ohlendorf *et al.* 1986), with a lower limit of residue quantification of 0.05 ppm for both mercury and selenium. Livers and kidneys of three adult cormorants were analyzed for cadmium and a series of other heavy metals at the Environmental Trace Substances Research Center, Columbia, Missouri, by inductively coupled plasma (ICP Scan) emission spectroscopy using a Jarrell-Ash 1100 Mark III with a DEC 11/23+ computer, after perchloric/nitric acid digestion and presented on a wet weight basis.

The lower limit of quantification was halved for samples in which a contaminant was not detected in order to calculate geometric means. Contents of eggs were converted to approximate fresh wet weight using egg volume (Stickel *et al.* 1973); all residues in eggs were expressed on a fresh wet weight basis. Shell thickness (including membranes) was measured at three sites on the egg equator with a micrometer graduated in units of 0.01 mm; the average of the three measurements was used to represent the thickness of the shell. Egg volumes of sample eggs were determined by water displacement. Measurements of historic Double-crested Cormorant eggs were obtained from Henny *et al.* (1982). Concentrations of the contaminant residues were log-transformed for statistical comparisons and a 1-way analysis of variance (ANOVA) was used to compare residue means and eggshell thickness means among colonies.

RESULTS

Nesting chronology and clutch size, 1984

Double-crested Cormorants were first checked at Protection Island on 5 April 1984; nests were first observed on 26 May and nest building continued through late

July. An egg was collected from 11 of 19 nests on 3 July. Embryonic development in sample eggs (fresh to 3/4ths developed) indicated no strong synchrony in the 1984 nesting cycle. We estimated, based on embryo development of sample eggs collected, that clutches observed on 3 July were completed between 6 and 28 June (mean 17 June). An additional 5 nests were started after 3 July (total of 24 nests). On nearby Mandarte Island, British Columbia, Drent *et al.* (1964) reported egg laying by Double-crested Cormorants primarily in late April and May with some renesting in early August. The nest building at Protection Island was late compared to Mandarte Island, but the nesting activity was even more delayed at the other islands in 1984. At Bird and Williamson Rocks, nests were under construction in mid-May (Table 1), but eggs were not observed until 31 July or 1 August and then only at Williamson Rocks and Colville Island. At Williamson Rocks, three nests contained single eggs on 31 July. The reduced number of nests observed as the season progressed at Bird and Williamson Rocks probably resulted from cormorants taking nest material from abandoned nests and using it for their new nests (Lewis 1929). Birds at the large colony on Colville Island finally laid eggs in synchrony, based on embryonic development of sample eggs, between 23 and 27 July.

Height of nests at Bird Rocks increased as the season progressed (Fig. 2), but by 31 July the nests were abandoned. Only 12 Double-crested Cormorants were observed on the shoreline of the island, and none were associated with nests. On 31 July the mean height (± SD) of 24 nests on Bird Rocks was 49.9 ± 21.4 cm with a range of 8 to 92 cm. Recently discharged fireworks, including rockets, in the upper 20 cm of several nests indicated that nidification continued after early July. When Double-crested Cormorants use ground nests for several years in succession, new material is added each year and nests may develop into large heavy structures. The largest nests reported by Lewis (1929) were about 60 cm high, but the average height of old nests was about 43 cm. On Bird Rocks where no eggs were laid, maximum nest

Figure 2. Abandoned Double-crested Cormorant nests on Bird Rocks, 31 July 1984 (no eggs laid).

Table 1. Double-crested Cormorant nesting activity at San Juan Islands, NWR, Washington, 1984.

	Number Nests/Number adults[1]/Nests with eggs		
Date	Bird Rocks	Williamson Rocks	Colville Island
May 15	41/30/0[2]	25/NC/0[2]	NC
June 5	42/NC/0	26/NC/0	NC
June 18/21	36/37/0	27/36/0	230/186/0
July 10	28/NC/0	27/26/0	NC/NC/0
July 31/Aug. 1	NC/12/0[3]	24/NC/3[4]	229/NC/212[5]
September 12	NC/ 0/0	NC/ 8/0	66 young[6]

NC=No count.
[1]Adults counted at colony when we approached island.
[2]Nests under construction.
[3]Colony abandoned.
[4]Three nests contained a single egg each; most nests abandoned.
[5]An estimated 90 to 95% of nests contained eggs.
[6]We banded 31 young.

height was 92 cm—an apparent record for this species.

Clutches (mean ± SD) ranged from 3 to 5 eggs (3.55 ± 0.69) in 11 nests at Protection Island and from 2 to 5 eggs (2.86 ± 0.68) in 36 nests at Colville Island. The mean date for clutch completion was 17 June at Protection Island and 26 July at Colville Island. These findings compare with nearby Mandarte Island where 66 nests contained from 3 to 5 eggs (mean 4.14) (Drent *et al.* 1964).

Productivity and contaminants, 1984

No young were produced at either Bird (36 to 42 nests) or Williamson Rocks (27 nests), and only 3 eggs were found at the latter site on 1 August 1984. The nests on Colville Island were not followed individually, but only 66 young from 230 nests (0.29 young/occupied nest) were reared to two-thirds of adult size. Colville Island productivity was low when compared to 2.4 young/occupied nest on Mandarte Island in 1958 and 1959 (Drent *et al.* 1964). The 36 eggs taken from the 230 nests at Colville Island for residue analysis probably reduced production slightly. In 1984, the earliest nesting cormorants, those at Protection Island, had the largest clutch size and the highest production rate (18 young at 11 nests, 1.64 ± 0.81 young/occupied nest), but one egg was taken from each nest for residue analysis. Therefore, Double-crested Cormorants in the study area, except on Protection Island, experienced almost total reproductive failure in 1984.

DDE residues in eggs from Colville Island (0.58 ppm) and Protection Island (0.59 ppm) in 1984 were not significantly different and were the lowest reported in the Pacific Northwest since the late 1970's (Table 2). Ohlendorf *et al.* (1978) reported that 3 eggs from Mandarte Island in 1970 averaged about 4 ppm DDE (adjusted from lipid to wet weight). PCB residues in 1984 were similar to those at other locations in the Pacific Northwest in 1978-80, except for higher residues at Umatilla NWR on the Columbia River. PCB's in three eggs from Mandarte Island in 1970 averaged about 14 ppm. Dieldrin was not detected in eggs from coastal Washington, but ≤ 0.35 ppm was detected in 1 egg from the Oregon Coast, 2 eggs from Umatilla, NWR, 1 egg from Malheur NWR, and 2 eggs from Klamath NWR. Chlordane isomers (oxychlordane, *cis*-nonachlor, *trans*-nonachlor combined) were found in only 1 egg from Colville Island (0.13), 3 eggs from Umatilla NWR (≤ 1.09 ppm), 2 eggs from Klamath NWR (≤ 0.60 ppm), and 2 eggs from the Oregon Coast (≤ 0.25 ppm). The only other organochlorine de-

Table 2. DDE, PCBs, Mercury and Selenium concentrations (geometric means, ppm wet weight) in Double-crested Cormorant eggs from the Pacific Northwest.

Location	Years	N	DDE[1]	PCBs[2]	Mercury[3]	Selenium[4]
Colville Island	1984	36(12)[5]	0.58 A[6]	2.19 AB[6]	0.27 A[7]	0.31 A[7]
Protection Island NWR	1984	11	0.59 A	1.37 A	0.26 A	0.28 A
Oregon Coast[8]	1979	10	1.63 B	1.32 A	NA	NA
Malheur NWR	1980	6	2.01 B	1.27A	NA	NA
Klamath NWR	1977	5	3.58 BC	2.59 AB	NA	NA
Umatilla NWR	1978/79	8	5.59 C	6.76 B	NA	NA

Note: Moisture content of eggs at Colville and Protection Islands averaged 83.3% (range 80.8 to 84.5).
[1]DDE was detected (≥0.10 ppm) in all eggs; high values were Colville Island 3.2, Protection Island 1.7, Oregon Coast 5.2, Malheur NWR 3.5, Klamath NWR 7.3, and Umatilla NWR 11.
[2]PCBs were detected (≥0.50 ppm) in all eggs except 2 at Colville Island, 1 at Protection Island, 1 on Oregon Coast, 2 at Malheur NWR, and 1 at Klamath NWR. High values were Colville Island 25, Protection Island 12, Oregon Coast 10, Malheur NWR 7.2, Klamath NWR 10, and Umatilla NWR 16.
[3]Mercury was detected (≥0.05 ppm) in all eggs; high values were Colville Island 0.67, Protection Island 0.44. NA = not analysed.
[4]Selenium was detected (≥0.05 ppm) in all eggs; high values were Colville Island 0.41, Protection Island 0.47.
[5]N = 36 for organochlorines, 12 for mercury and selenium.
[6]Column means different from one another (Tukey's multiple comparison test method, $P<0.05$) do not share a common letter (ANOVA LgDDE $F = 23.6$, df = 5,70 $P<0.05$; LgPCB $F = 3.11$, df = 5,70 $P<0.05$).
[7]Column means different from one another (Students T-test, $P<0.05$) do not share a common letter (Lg Mercury $t = 0.59$, df = 21, $P>0.05$; Lg Selenium $t = 0.80$, df = 21, $P>0.05$).
[8]From Henny *et al.* (1982).

tected was 0.24 ppm toxaphene in 1 egg from Malheur NWR.

Pearce *et al.* (1979) reported that 10 ppm DDE (wet weight) was associated with 20% eggshell thinning in Double-crested Cormorants. The eggs we collected in 1984 and earlier from the Northwest included only one above 10 ppm DDE. The generally low DDE residues at the six colonies (Table 2) resulted in only one series of eggs (Umatilla 1978-79) with significant eggshell thinning compared to reference areas (Table 3), and they contained the highest DDE residues.

Mean mercury (0.26 and 0.27 ppm) concentrations in eggs from coastal Washington (Table 2) did not differ significantly ($P > 0.05$) between locations and were within the range (geometric means, 0.21 to 0.50) for Double-crested Cormorant eggs from eastern Canadian coastal waters between 1970 and 1976 (Pearce *et al.* 1979). Likewise, selenium concentrations in the cormorant eggs from coastal Washington (Table 2) did not differ significantly between locations ($P > 0.05$).

Three adult Double-crested Cormorants collected near Williamson Rocks on 31 July 1984, provide an additional measure of environmental contaminants since nests were abandoned and no eggs could be collected (Table 4). Each bird contained "normal" fat and had recently ingested fish. The stomach of the only male also contained four rocks that weighted 8.4g. Pooled stomach contents of the 3 comorants contained no detectable (<0.01 ppm) organochlorine residues. The testes of the male measured 31 x 13 mm, while one female had four orange-yellow follicles with diameters ranging from 10 to 20mm. The other female had four gray-yellow follicles with diameters ranging from 5 to 8mm.

Nesting population numbers and distribution

Double-crested Cormorant nests in the Washington study area increased from the early 1970's (Table 5), as reported in other studies of the widespread cormorant population increase in North America (Milton and Austin-Smith 1983, Ludwig 1984, Buckley and Buckley 1984, Vermeer and Rankin 1984, Price and Weseloh 1986). In addition to the general population increase over the last two decades, continued work in the study area after 1984 showed a complete redistribution of nesting effort. Nesting was discontinued on the San Juan Islands, and the Double-crested Cormorants apparently moved to Smith and Protection Islands. The reduced nesting success in 1984 seemed pivotal in the transition to Smith and Protection Islands. The total nesting population declined in 1985 and 1986, but then increased in 1987 and 1988 (Table 5).

DISCUSSION

Initially, we suspected pollutants caused the delay or absence of egg-laying as well as the low production at Colville Island in 1984. However, the Double-crested Cormorant population increases associated with a decrease in mean DDE levels in eggs from 9.6 to 4.8 ppm (wet weight) in Lake Ontario from 1971 to 1981 (Price and

Table 3. Eggshell thickness of Double-crested Cormorant eggs from the Pacific Northwest.

Location	Years	N	Shell Thickness(mm) mean ± SD		thinning[1]
Umatilla NWR, OR/WA	1978/79	8	0.385±0.041	A[2]	−10.9%
Colville Island, WA	1984	36	0.408±0.033	AB	−5.6%
Klamath NWR, OR	1977	5	0.413±0.033	AB	−4.4%
Oregon Coast	1979	10	0.432±0.045	AB	0.0%
No. Calif. to British Columbia	Pre-1947	51	0.432±0.038	AB	--
Malheur NWR, OR	1980	6	0.442±0.024	B	+2.3%
Protection Is. NWR, WA	1984	11	0.454±0.039	B	+5.1%

[1]Pre-1947 eggshell thickness from Henny *et al.* (1982).
[2]Means different from one another (Tukey's multiple comparison test, ($P<0.05$) do not share a common letter (ANOVA $F = 4.57$, $df = 6,120$ $P < 0.05$).

Table 4. Elements in livers or kidneys and organochlorines in breast muscle (ppm, wet weight) of three adult Double-crested Cormorants collected near Williamson Rocks, Washington, 31 July 1984.

Category	DCC-1	DCC-2	DCC-3
Age/Sex	Ad F	Ad M	Ad F
Whole Body (g)	2,577	2,850	2,550
Liver (g)	118	84	99
Residue concentrations			
Aluminum	0.6	<0.2	0.6
Cadmium	0.24 (0.88)[1]	0.49 (1.3)[1]	0.49 (1.0)[1]
Copper	3.6	4.8	5.2
Iron	180	309	242
Manganese	2.46	3.05	3.21
Zinc	21.4	20.8	27.1
Selenium	4.1	3.4	4.2
Mercury	12.0	6.4	5.7
Antimony	<0.05	<0.05	2.8
Arsenic	0.20	0.10	0.80
DDE	(0.14)[2]	(0.35)[2]	(0.17)[2]
PCBs	(0.49)[2]	(0.73)[2]	(0.55)[2]
% Lipid (breast muscle)	2.6	3.4	3.3
% Moisture (liver)	72.0	72.5	69.2
% Moisture (kidney)	75.8	76.9	75.4

Note: The following were not detected in the liver: beryllium (<0.007), cobalt (<0.07), chromium (<0.07), nickel (<0.08), thallium (<0.7).
[1]Cadmium in liver (kidney).
[2]DDE and PCBs (breast muscle).

Weseloh 1986), provided evidence that the low DDE residues we observed were not involved in the lowered reproductive success. Other organochlorine pesticides were detected infrequently and at low levels in Washington. DDE may have impacted production at some Umatilla NWR nests in 1978-79 when residues up to 11 ppm were recorded.

Bloom and Crecelius (1987) reported Puget Sound moderately impacted by anthropogenic silver, mercury, lead and copper. Our nesting colonies were immediately north of Puget Sound, but liver residues of selenium, mercury, cadmium, zinc, and copper (Table 3) were within the ranges reported for seabirds from Arctic and Antarctic waters (Norheim 1987). Although mercury sensitivity varies among species, geometric mean concentrations observed in eggs (0.27 and 0.26 ppm, wet weight) were below those associated with reproductive problems in field (Heinz *et al.* 1983) and laboratory studies (Heinz 1979). Concentrations of selenium (ppm, dry weight) in eggs of several freshwater

Table 5. Comparison of Double-crested Cormorant colony sites, 1970-1988.

Location	Number of occupied nests							
	1970-75	1978-79	1983	1984	1985	1986	1987	1988
San Juan Islands								
Bird Rocks	30[1]	95[1]	79	42	1	11	0	0
Williamson Rocks	0[1]	73[1]	46	27	18	16	0	0
Colville Island	0[1]	50[1]	247	230	110	0	0	0
Viti Rocks	29[1]	30[1]	0	23	0	0	0	0
South Sister Is.	2[1]	2[1]	0	0	0	0	0	0
Sub total	61	250	372	322	129	27	0	0
Smith Island	0	0	0	11	38	130	209	219
Protection Island	0	0	6	19	41	68	172	298
Grand Total	61	250	378	352	208	225	381	517

[1]Data from Vermeer and Rankin (1984).

and estuarine bird species ranged from 0.8 to 3.0 ppm (Eisler 1985). Selenium concentrations in Washington cormorant eggs (1.92 and 2.13, converted to ppm dry wt.) were in the middle of this range. Selenium in eggs > 10 ppm (dry weight) has been linked to reduced reproductive success (Ohlendorf *et al.* 1986).

Because the concentrations of DDE, PCBs, mercury, and selenium in eggs at Protection and Colville Islands were not significantly different and were below established critical levels, we conclude that these four contaminants were not implicated in the poor production at Colville Island in 1984. Based on studies of other species, it is doubtful that residue concentrations in the adult cormorants collected at Williamson Rocks were responsible for their failure to lay eggs, although mercury seemed elevated. This information led us to look for other possible causes of the nesting problems.

The cormorant population shifts from the San Juans to Protection and Smith Islands may be related to the changing levels of human disturbance. San Juan Island County is the fastest growing county in Washington. In 1970 the human population was 4,000; in 1988 it was 9,500, and has a projected estimate of 13,000 by the year 2,000 (Leming 1988). The population increase has brought a tremendous increase in recreational boating, fishing, and diving. In the county, 235 boats are owned per 1,000 people. On summer weekends the human population may be as high as 20,000 with many arriving by private boats.

In 1980 an explosive device was detonated on Bird Rocks during the cormorant nesting season (Weber *et al.* 1981). It destroyed 75 Double-crested Cormorant nests and killed at least 90 cormorants. During the same time, levels of human disturbance on Smith and Protection Islands were greatly reduced. Smith Island was a manned light station with a crew of four until 1976 when it was automated. Wildlife problems on Smith Island include domestic dog depredation of 10% (75 birds) of the Rhinoceros Auklet (*Cerorhinca monocerata*) nesting population in 1973 (Manuwal 1978). Protection Island became a National Wildlife Refuge with U. S. Fish and Wildlife Service presence on the island since 1985. In 1975-76 it was common to have more than 200 people on Protection Island on a summer weekend, but in the last 3 years it was rare to have more than 10. Some gull predation occurred at a few peripheral nests on Colville Island during our short visit when eggs were collected in 1984. Visitors to islands between our visits may have caused additional loss of eggs. Certainly the increased human population has impacted the cormorants usual habitat.

The reduced nesting success in the San Juan Islands in 1984, seemed to be the first step in the abandonment of those nesting islands. The Double-crested Cormorants nested successfully on Protection Island the last 3 years. Samples of 13, 28, and 25 nests yielded an average of 2.85 ± 1.34 young to near fledging/nest in 1986, 2.68 ± 1.02 in 1987, and 1.96 ± 1.34 in 1988. The pattern of leaving the nesting islands where the failure occurred in 1984, suggests that the redistribution was a response to changes in human activity patterns (reduced human activity on Protection Island and Smith Island and increased activity in the San Juan Islands) and leads us to conclude that human disturbance was the probable explanation for the redistribution of nesting activity during the last decade. Double-crested Cormorants are especially susceptible to human disturbance when nesting gulls are present. The long hiatus from the nest after being disturbed, facilitaties predation of their eggs and small young by gulls (Drent *et al.* 1964, Manuwal 1978).

Another possible disturbance was El Niño. An El Niño, or southern oscillation, is a periodic intrusion (about every 3-5 years) of anomalously warm water along the coast of Peru and Ecuador (Barber and Chavez 1983). During the last century, the warm waters of El Niños reached the Pacific Northwest Coast only in 1983, 1957-58, and perhaps in 1941 (Reed 1983). Schreiber and Schreiber (1984) stated that the 1982-83 El Niño caused small fish and squid to disappear; this caused the adult sea birds of Christmas Island to abandon the island and their nests. South of our study area along the Oregon and Washington Coast, the 1982-83 El Niño produced a higher than normal sea surface temperatures during the 1983 seabird breeding season. Concurrently, reproductive success was reduced in at least three species of marine birds, including Brandt's Cormorant (*P. penicillatus*) and the Pelagic Cormorant (*P. pelagicus*) (Hodder and Graybill 1985). Bayer (1986) likewise reported lowered breeding success of Pelagic Cormorants along the Oregon Coast in 1983 and 1984; he speculated that the effects of El Niño may extend beyond its initial year. Wilson observed 400 to 500 Double-crested Cormorant nests on the outer coast of Washington (Cape Flattery to Point Grenville) between 1979 and 1982, but the number declined to 174 in 1983 and to 7 in 1984, then increased again to 450 to 750 between 1985 and 1987, although some population shifts occurred. Cormorants commonly desert their nests during El Niño periods in the tropical Pacific (Cushing 1981) and nest abandonment was also widespread in Oregon during 1983 (Bayer 1986). However, negative impacts from El Niño seem doubtful in our study area in 1984, because (1) Rosario Strait has sheltered waters whose biological oceanography is considerably different from that of offshore waters (Wilson and Manuwal 1986), (2) nesting within the study area was not a complete failure (production was near-normal on Protection Island), and (3) the sites with poor production in 1984 were all later abandoned.

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