Conservation Implications of the Large Colony of Double-crested Cormorants on East Sand Island, Columbia River Estuary, Oregon, U.S.A.

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Abstract.—The breeding colony of the Double-crested Cormorant (*Phalacrocorax auritus*) on East Sand Island in the Columbia River estuary has grown dramatically over the last 13 years, in contrast to declines at other colonies along the coast of the Pacific Northwest. Immigration from other colonies has occurred and the East Sand Island colony is now the largest for the species on the Pacific coast of North America. Despite substantial increases in the size of the East Sand Island colony, overall numbers of the West Coast subspecies (*P. a. albociliatus*) appear to be slowly increasing relative to the interior population (*P. a. auritus*). Based on the most recent regional population data available, a conservative estimate indicates that the colony on East Sand Island represents over 30% of *P. a. albociliatus* breeding adults. We advocate that the subspecies *P. a. albociliatus* be considered a distinct population segment and managed according to overall population size and trends for this subspecies. *Received 10 June 2003, accepted 14 November 2003.*

Key words.—Double-crested Cormorant, *Phalacrocorax auritus albociliatus*, colony size, population decline, Pacific coast.

Waterbirds 27(2): 155-160, 2004

The Double-crested Cormorant (*Phalacrocorax auritus*) has the most extensive range within North America of the six species of cormorants that breed on this continent (Hatch 1995). There are five subspecies of Double-crested Cormorants that are differentiated by size, crest characters, and regional distribution (Hatch 1995; Hatch and Weseloh 1999). The Double-crested Cormorants that nest along the Pacific coast of North America are recognized as two subspecies: the West Coast subspecies (*P. a. albociliatus*) and the Alaska subspecies (*P. a. cincinatus*). The West Coast subspecies breeds along the Pacific coast of North America from southern British Columbia, Canada to Sinaloa, Mexico (Carter *et al.* 1995; Cannings 1998). Members of the West Coast subspecies are distinguished from the Alaska subspecies by their smaller size and white crest plumage (Hatch 1995; Hatch and Weseloh 1999). To our knowledge, these population designations have not been supported by DNA studies and, thus, warrant further investigation.

The trend in colony size at the large nesting colony of Double-crested Cormorants on East Sand Island in the Columbia River estuary has been investigated for three reasons. First, the nesting season of these piscivorous waterbirds coincides with peak out-migration of juvenile salmonids (*Oncorhynchus* spp.) from the Columbia River basin (Fish Passage Center 2002). Cormorant predation in the estuary may be a considerable source of mortality for migrating smolts, many of which are listed as either threatened or endangered under the U.S. Endangered Species Act (ESA; National Marine Fisheries Service (NMFS) 2002). Second, the East Sand Island colony represents a substantial proportion of the West Coast population (Carter *et al.* 1995), which may be declining (Tyson *et al.*1999; Wires *et al.* 2001). Finally, a recent Draft Environmental Impact Statement proposed to manage and control numbers of the Double-crested Cormorant on both the breeding and wintering grounds throughout the contiguous U.S. (U.S. Fish and Wildlife Service (USFWS) 2001).

Numbers of the Double-crested Cormorant have increased dramatically across most of North America during the last 30 years (Hatch 1995; Sauer *et al.* 1997; Hatch and

Weseloh 1999). There is growing evidence that the overall rate of increase in some populations has declined over the past decade (Tyson *et al.* 1999), and in some regions, the Double-crested Cormorant may have actually declined in recent years (Carter *et al.* 1995; Wires *et al.* 2001).

There is evidence that the West Coast subspecies may be declining over much of its range. The Isla San Martín in Baja California, Mexico, was once considered the largest nesting colony of the Double-crested Cormorant on the west coast of North America (ca. 350,000 pairs, Wright 1913); however, this colony has declined dramatically and is currently estimated at ca. 600 pairs (Palacios and Mellink 2000). Formerly, large colonies in southern California have also declined. For example, over 5,000 pairs of the Double-crested Cormorant nested on Mullet Island in the Salton Sea National Wildlife Refuge (NWR) as recently as 1999 (D. Shuford, Point Reyes Bird Observatory, pers. comm.), yet the colony was abandoned in 2001 (K. Molina, National History Museum of Los Angeles County, pers. comm.).

Similar trends have been documented over much of British Columbia, Washington, and Oregon (hereon referred to as the "Pacific Northwest"). In British Columbia, the numbers of breeding Double-crested Cormorants have declined markedly and the species is currently designated as "threatened" on the provincial Red List (British Columbia Conservation Data Centre 2003). Colonies along the Washington coast have exhibited striking declines, with the total breeding numbers on the outer coast of Washington declining by 80% over the past decade (U. Wilson, USFWS, unpublished data). In Oregon, most of the documented inland colonies have declined or been abandoned (USFWS, unpublished data), possibly due to emigration to coastal colonies (Carter *et al.* 1995). Support for the hypothesis that breeding adults have emigrated from coastal British Columbia and Washington, and from the interior of Oregon comes from the colony on East Sand Island in the Columbia River estuary, which grew from less than 100 pairs in 1989 (R. Lowe, USFWS, pers. comm.) to over 2,000 breeding pairs in 1991 (Carter *et al.* 1995). Currently, East Sand Island supports the largest known Double-crested Cormorant colony on the Pacific coast of North America (Carter *et al.* 1995; Collis *et al.* 2002).

Several factors are blamed for recent declines in size and reproductive success of some colonies of the Double-crested Cormorant in the Pacific Northwest (e.g., Great Chain, Five Finger, and Mandarti Islands, British Columbia; Juan de Fuca Strait Islands, Washington; Sheepy Lake, Lower Klamath Lake NWR, Oregon). Possible factors causing the reduction in forage fish abundance are El Niño events (Wilson 1991) and ocean regime shifts (Emmett and Brodeur 2000). Additional factors may include habitat loss due to agricultural and water developments (Carter *et al.* 1995), and increases in disturbances at nesting colonies from the Bald Eagle (*Haliaeetus leucocephalus*) and humans (Verbeek 1982; Rodway 1991; Moul 1996; Moul 2000; Moul and Gebauer 2002). Here we present findings from our investigations of the recent trend in colony size at the largest colony of the Double-crested Cormorant on the Pacific coast of North America.

METHODS

Study Area

East Sand Island (46°15'45"N, 123°57'45"W) is a 21-ha, naturally formed island that lies 6-8 river km inland from the Pacific Ocean in the Columbia River estuary, Clatsop County, Oregon, U.S.A.

Colony Size Estimation

Numbers of Double-crested Cormorants on East Sand Island have been determined since 1991 by direct counts from aerial photographs taken during late incubation, when maximum colony attendance was assumed (Gaston and Smith 1984). Detailed methodology for aerial photography since 1997 is described in Collis *et al.* (2002). Briefly, individual adult cormorants located within delineated nesting areas on the photographs were enumerated using Zeiss PHOCUS software. A correction factor to convert number of individuals to number of breeding pairs was derived by determining in sample plots (from blinds near the colony) the fraction of the total number of adult cormorants in the colony that were incubating at the time the photographs were taken. The number of nesting pairs (colony size) was estimated by applying the correction factor to the direct count of adult cormorants at the colony. No measures of colony size were made in 1990, 1992, or 1994.

Data Analysis

We used a weighted linear regression model, where weights were $1/(SE)^2$ such that estimates with smaller standard errors received more weight (Ramsey and Schafer 1997), to investigate the trend in colony size estimates across years from 1989 to 2002 and tested the slope for significant difference from zero. We calculated annual growth rates (λ) between years as:

$$\lambda = N_t/N_{t-1}$$

using estimated number of nesting pairs from 1989 to 2002. When time between counts was 2 years, however, annual growth rates were calculated as:

$$\lambda = (N_t/N_{t-2})^{1/2}.$$

We simulated the fecundity necessary to achieve the observed growth rate for the period from 1991 to 2002 with a deterministic Leslie matrix model (S-PLUS 1999; Caswell 2001). Because there was strong evidence of a major immigration event between 1989 and 1991 (see Results), we assumed the colony was established with 2,026 breeding pairs in 1991 (Carter *et al.* 1995). We estimated the colony growth rate based on linear regression, using log-transformed estimates of number of nesting pairs. The Leslie matrix model was based on a pre-breeding census and three age classes with the following estimated annual survival rates: first-year survival (fledging to 1 year) of 0.48, second-year survival of 0.74, and subsequent annual survival of 0.85 (Van der Veen 1973). We assumed annual breeding probability to be 0%, 16.5%, and 78.8% for first, second, and older year classes, respectively, as reported by Van der Veen (1973). Clearly, these values do not represent firm, precise facts and they may not be completely applicable to a different colony in more recent years, however, they do represent the best estimates of annual survival and breeding probability currently available. Using these values, we simulated a range of average annual productivities (young fledged/nesting pair) necessary to achieve the estimated colony growth rate.

RESULTS

The nesting colony of Double-crested Cormorants on East Sand Island has increased nearly 100-fold since the colony was first recorded in 1989; in 2002 the colony consisted of an estimated 8,684 nesting pairs (Fig. 1). The colony has consistently shown positive annual growth increments (Table 1). Over the past 11 years (1991-2002), the average annual growth rate (λ) was 1.15 (linear regression model on log-transformed estimates: $F_{1,8} = 3062$, $r^2 = 0.997$, $P < 0.0001$).

Results from the Leslie matrix model indicated that the annual productivity of the colony would have needed to be 3.12 fledglings/nesting pair over the period 1991 to 2002 in order to yield the observed population growth rate, assuming no immigration.

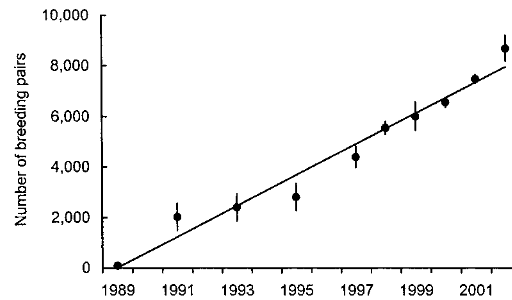

Figure 1. Estimated number of pairs (±SE) of Double-crested Cormorants nesting on East Sand Island, 1989-2002 (Linear regression: $F_{1,8} = 3062$, $r^2 = 0.997$, $P <$ 0.0001).

This estimated fledging rate exceeds the maximum estimates of productivity for both the East Sand Island colony (2.02 ± 0.10; Anderson 2002) and from published studies of other Double-crested Cormorant colonies (2.59 ± 1.27; McNeil and Léger 1987; Hatch and Weseloh 1999). Evidently, recruitment from other colonies, either within or outside of Oregon, continued to occur at the East Sand Island colony after 1991.

DISCUSSION

Food Availability

Immigration has evidently played a key role in the large increases in numbers of Double-crested Cormorants nesting at the

Table 1. Estimated annual growth rate (λ) of the nesting colony of Double-crested Cormorants on East Sand Island, 1989-2002.

Year	Annual population growth rate (λ)
1989[1]	
1991[2]	4.72
1993[3]	1.09
1995[3]	1.08
1997[4]	1.25
1998[4]	1.26
1999[4]	1.08
2000[4]	1.09
2001[4]	1.14
2002[4]	1.16

[1]R. Lowe, USFWS, pers. comm.
[2]Carter *et al.* 1995.
[3]A. Clark, USFWS, pers. comm.
[4]This study.

East Sand Island colony. The recruitment of breeding adults is likely to reflect emigration from colonies in interior Oregon during drought years (Carter *et al.* 1995), from coastal colonies in Washington, and perhaps from British Columbia (Wilson 1991). We speculate that food resources are more stable and predictable in the Columbia River estuary compared to coastal and interior nesting areas that are likely influenced to a greater extent by fluctuating oceanic and climatic conditions. Predictable food resources in the vicinity of East Sand Island are likely to make the island an appealing nesting area to prospecting Double-crested Cormorants. On East Sand Island, considerable space still remains for expansion of the present colony. We expect that the East Sand Island cormorant colony will continue to expand into available nesting habitat.

Management Implications

There is considerable overlap in the breeding and wintering areas of the West Coast subspecies of Double-crested Cormorants (Hatch and Weseloh 1999). Double-crested Cormorants banded as nestlings in British Columbia have been re-sighted in Oregon (Moul 1996) and adults tagged at East Sand Island have been re-sighted, both in the year they were tagged and in subsequent years, throughout Puget Sound, the Straits of Juan de Fuca, and into British Columbia (D. D. Roby, unpubl. data). These re-sightings suggest that the Double-crested Cormorant may not be highly philopatric and that young breeding birds may move to different colonies in the Pacific Northwest and, possibly, colonies further south in California and Baja California. The nesting colony of Double-crested Cormorants at East Sand Island represents a substantial proportion of the numbers of *P. a. albociliatus* breeding in the Pacific Northwest and throughout the west coast from British Columbia, Canada to Sinaloa, Mexico.

The number of Double-crested Cormorants on the Pacific coast of North America was recently estimated at 17,100 nesting pairs (Tyson *et al.* 1999). This estimate included both the West Coast subspecies (*albociliatus*) and the Alaskan subspecies (*cincinatus*; N = 2,935 nesting pairs). Based on the most recent regional population data available, we conservatively estimated that the Double-crested Cormorant colony on East Sand Island represented >30% of *P. a. albociliatus* breeding adults. To arrive at this estimate, we made the following adjustments to the most recent estimate of population size along the Pacific coast (Tyson *et al.* 1999). First, we excluded the Alaskan subspecies, which represented ca. 17% of the Pacific coast numbers at the time the survey was conducted (B. Blackwell, United States Department of Agriculture, pers. comm.). Second, we added 6,660 nesting pairs to the estimate of the total population size to account for the large increase in size of the East Sand Island colony since 1992, when the colony was counted for the Tyson *et al.* (1999) estimate. Finally, we assumed all other colonies have remained stable since the time of the most recent survey.

The East Sand Island colony may represent a greater proportion of the population of the West Coast subspecies for several reasons. First, colony sizes have not remained stable since 1992. Numerous west coast colonies have experienced declines (100s to 1,000s of nesting pairs) over the past decade since the surveys reported in Tyson *et al.* (1999) were conducted (e.g., Rice Island in the Columbia River estuary, Oregon; Mandarte Island and the Chain Islets in the Gulf Islands, British Columbia; South Farallon Island, California). Second, to our knowledge, very few west coast colonies have increased in size over the past decade. Exceptions include the East Sand Island colony and the Mullet Island colony in the Salton Sea, California. However, the Mullet Island colony was abandoned in 2001 (K. Molina, National History Museum of Los Angeles County, pers. comm.). Third, there have been few reports of new Double-crested Cormorant colonies along the west coast since Tyson *et al.* (1999). Six new Double-crested Cormorant nesting colonies have been discovered along the Oregon coast since 1992; however, it is likely that the new colonies were formed by cormorants emigrating from nearby nesting areas (R. Lowe, USFWS, pers. comm.).

There are few recent demographic data available for the West Coast subspecies of Double-crested Cormorant, especially from the Mexico portion of its breeding range. In many cases, surveys conducted over a decade ago (see Carter *et al.* 1995) represent the only demographic data available for *P. a. albociliatus.* More recent and range-wide data are necessary to understand the extent to which factors limiting colony size and reproductive success at the East Sand Island colony are also influencing population trends of the Double-crested Cormorant throughout the Pacific coast of North America. Despite dramatic increases in the size of the East Sand Island cormorant colony in the last 13 years, the available evidence indicates that the numbers of *P. a. albociliatus* are slowly decreasing relative to the interior population (*P. a. auritus*) (M. Naughton, pers comm.). In light of this uncertainty, recent proposals to manage and control breeding and wintering Double-crested Cormorants throughout the contiguous U.S. (USFWS 2001) should be reconsidered on a region-by-region basis. We advocate that the subspecies *P. a. albociliatus* be considered a distinct population segment (USFWS 1988) and managed according to overall population size and trends for this subspecies.

Acknowledgments

This research was funded by the Bonneville Power Administration (BPA) Contract 97BI33475. We thank Bergmann Photographic Services, Inc. (Portland, OR) for the aerial photographs of the East Sand Island cormorant colony and the Photogrammetry Department at BPA (Vancouver, WA) for the analysis of the photographs to estimate colony size; in particular, Ben Lakey, Ray Ronald, Kim Salarzon, and Eric Stone. Micheal Chutter, Alan Clark, Dave Craig, Gary Ivey, Roy Lowe, Don Lyons, Kathy Molina, Maura Naughton, Mark Rauzon, and Ulrich Wilson provided invaluable comments and unpublished data regarding current and/or historical Double-crested Cormorant nesting colonies along the Pacific coast. Nate Chelgren and Cliff Pereira provided statistical advice. Sue Haig and Rob Suryan provided helpful comments that improved earlier drafts of this manuscript.

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