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Demographics of Piscivorous Colonial Waterbirds and Management Implications for ESA-listed Salmonids on the Columbia Plateau

Abstract

We investigated colony size, productivity, and limiting factors for five piscivorous waterbird species nesting at 18 locations on the Columbia Plateau (Washington) during 2004–2010 with emphasis on species with a history of salmonid (*Oncorhynchus* spp.) depredation. Numbers of nesting Caspian terns (*Hydroprogne caspia*) and double-crested cormorants (*Phalacrocorax auritus*) were stable at about 700–1,000 breeding pairs at five colonies and about 1,200–1,500 breeding pairs at four colonies, respectively. Numbers of American white pelicans (*Pelecanus erythrorhynchos*) increased at Badger Island, the sole breeding colony for the species on the Columbia Plateau, from about 900 individuals in 2007 to over 2,000 individuals in 2010. Overall numbers of breeding California gulls (*Larus californicus*) and ring-billed gulls (*L. delawarensis*) declined during the study, mostly because of the abandonment of a large colony in the mid-Columbia River. Three gull colonies below the confluence of the Snake and Columbia rivers increased substantially, however. Factors that may limit colony size and productivity for piscivorous waterbirds nesting on the Columbia Plateau included availability of suitable nesting habitat, interspecific competition for nest sites, predation, gull kleptoparasitism, food availability, and human disturbance. Based on observed population trends alone, there is little reason to project increased impacts to juvenile salmonid survival from tern and cormorant populations. Additional monitoring and evaluation may be warranted to assess future impacts of the growing Badger Island American white pelican colony and those gull colonies located near mainstem dams or associated with Caspian tern colonies where kleptoparasitism is common.

Keywords: piscivorous waterbirds, Columbia Plateau, colony size, productivity, limiting factors

Introduction

Piscivorous colonial waterbirds, specifically Caspian terns (*Hydroprogne caspia*), double-crested cormorants (*Phalacrocorax auritus*), American white pelicans (*Pelecanus erythrorhynchos*), California gulls (*Larus californicus*), and ring-billed gulls (*L. delawarensis*), have a well documented history of nesting in the Columbia Plateau region of eastern Washington State (Brown 1926, Kitchin 1930, Decker and Bowles 1932, Hanson 1968, Conover et al. 1979, Thompson and Tabor 1981, Speich and Wahl 1989). Human manipulation of

water conditions and nesting habitat have influenced the distribution and size of breeding colonies for these species in the region (Johnsgard 1956, Hanson 1963, Ackerman 1994), as well as their impacts on fish species of conservation concern (e.g., anadromous salmonids [*Oncorhynchus* spp.]; Ruggerone 1986, Schaeffer 1991, Jones et al. 1996, Collis et al. 2002, Roby et al. 2003, Antolos et al. 2005, Wiese et al. 2008).

Kitchin (1930) noted the first breeding record for Caspian terns in Washington State at Moses Lake in 1929; however, Gill and Mewaldt (1983) suggested that Caspian terns were established as a breeding species in inland Washington prior to 1929. The location of Caspian tern breeding colonies in the Columbia Plateau region shifted from Moses Lake and along the mid-Columbia River near Pasco, Washington, to Potholes Reservoir after

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its formation by the construction of the O'Sullivan Dam in the 1950s (Johnsgard 1956, Penland 1982) and to Crescent Island on the mid-Columbia River (near Pasco, Washington) after its creation from disposal of dredged materials in 1985 (Ackerman 1994). California and ring-billed gulls followed a similar pattern, shifting from breeding colonies at Moses Lake to Potholes Reservoir after its formation (Johnsgard 1956, Conover et al. 1979) and colonizing Crescent Island soon after the initial colonization by Caspian terns (Ackerman 1994). Both species of gull nested on other islands in the mid-Columbia River and a dramatic increase in their numbers was associated with expanding agricultural development and new islands created by dam impoundments (Broadbooks 1961, Hanson 1963, Conover et al. 1979, Thompson and Tabor 1981, Collis et al. 2002).

Double-crested cormorants were thought to breed in the Columbia Plateau region prior to 1932 and were common in the region up to 1953; however, island nesting habitat was lost and numbers of nesting birds declined as a result of impoundment of the Columbia River behind McNary Dam beginning in 1954 (Hanson 1968). Double-crested cormorants were also known to nest on the Snake River upstream of Clarkston, Washington prior to dam impoundments (Weber and Larrison 1977, Smith et al. 1997). During this time period, range-wide declines in double-crested cormorant numbers were attributed in part to widespread use of DDT (Wires and Cuthbert 2006).

The first documented breeding record for American white pelicans in the Columbia Plateau region was at Moses Lake in 1926 (Brown 1926). While white pelicans were observed in the region in the interim, their breeding status was unclear until 1994, when they were recorded nesting on Crescent Island (Ackerman 1994). In 1997, the location of the breeding colony shifted from Crescent Island to Badger Island, about 1 km up-river.

Populations of anadromous salmonids in the Columbia River basin are the subjects of intense conservation activity following decades of decline (NRC 1996, Lichatowich 1999). In recent years, avian predation across the basin has been consid-

ered a factor limiting recovery of these imperiled fish populations (NOAA 2008), resulting in the management of a large waterbird colony in the Columbia River estuary to reduce its impact (Roby et al. 2002; USFWS 2005, 2006) and consideration of additional avian predation management initiatives in the Columbia River estuary and on the Columbia Plateau.

The overall goal of this study was to evaluate the breeding status and population trends of piscivorous colonial waterbirds across the Columbia Plateau region to inform regional resource managers assessing the current (2004–2010) and potential future impacts of these avian predators on fish of conservation concern. Specific objectives were three-fold: (1) estimate colony size for all known breeding colonies of Caspian terns, double-crested cormorants, American white pelicans, ring-billed gulls, and California gulls in the region; (2) assess productivity at these colonies, when feasible; and (3) identify potential factors that may be limiting the size and productivity of breeding colonies of these species in the region. These data will likely be important in the development of an avian predation management plan to reduce the impacts to juvenile salmonids by piscivorous waterbirds that nest in the Columbia Plateau region (NOAA 2008).

Study Area

This study was conducted at Caspian tern, double-crested cormorant, American white pelican, California gull, and ring-billed gull breeding colonies in the Columbia Plateau region of Washington State (hereafter, "Columbia Plateau") during 2004–2010 (Table 1, Figure 1).

Data from the Caspian tern and double-crested cormorant colonies at East Sand Island, Oregon were included for comparison purposes. East Sand Island in the Columbia River estuary is home to the largest Caspian tern colony in the world (Suryan et al. 2004), which is currently being managed to reduce the size of the colony and its impact on survival of juvenile salmonids from throughout the Columbia Basin (USFWS 2005, 2006). The double-crested cormorant colony at East Sand Island is also the largest in North

TABLE 1. Characteristics of piscivorous waterbird colonies on the Columbia Plateau, with East Sand Island included for comparison. Species abbreviations are as follows: AWPE = American white pelican, BCNH = black-crowned night-heron (*Nycticorax nycticorax*), BRAC = Brandt's cormorant (*P. penicillatus*), CATE = Caspian tern, CAGU = California gull, DCCO = double-crested cormorant, FOTE = Forster's tern, GBHE = great blue heron, GREG = great egret (*A. alba*), GWGU/WEGU = glaucous-winged/Western gull (*L. glaucescens/L. occidentalis*), and RBGU = ring-billed gull. "Primary Nesting Species" are species that nest at the location in relatively large numbers and/or in most years of the study and "Secondary Nesting Species" are species that nest at the location in relatively small numbers and/or in few years of the study.

General Area Colony	Latitude	Longitude	Primary Nesting Species	Primary Nesting Type	Secondary Nesting Species	Secondary Nesting Type
Columbia River Estuary						
East Sand Is.	46.262	-123.975	CATE, DCCO	Ground	GWGU/WEGU, RBGU, BRAC	Ground
Mid-Columbia River						
Miller Rocks	45.657	-120.872	CAGU, RBGU	Ground	DCCO	Ground
Three Mile Canyon Is.	45.817	-119.963	CAGU, RBGU	Ground	GBHE, BCNH	Tree
Rock Is. (Blalocks)	45.910	-119.629	CATE, RBGU	Ground	FOTE	Ground
Anvil Is. (Blalocks)	45.914	-119.619	RBGU	Ground	CATE	Ground
Crescent Is.	46.094	-118.938	CATE, CAGU	Ground	RBGU, GBHE BCNH, GREG	Ground/Tree
Badger Is.	46.110	-118.938	AWPE	Ground		
Foundation Is.	46.159	-118.991	DCCO	Tree	GBHE, BCNH	Tree
Island 18	46.361	-119.263	RBGU, CAGU	Ground	GREG, GBHE	Tree
Island 20	46.313	-119.254	RBGU, CAGU	Ground		
Hanford Reach	46.655	-119.417	GBHE, GREG	Tree	DCCO	Tree
Mouth of Okanogan River	48.093	-119.710	DCCO	Tree	GBHE	Tree
Lower Snake River						
Lyons Ferry (RR Trestle)	46.589	-118.224	GBHE	Artificial Structure	DCCO	Artificial Structure
Potholes Reservoir						
Goose Is.	46.985	-119.310	CATE, RBGU, CAGU	Ground	FOTE	Ground
Solstice Is.	47.023	-119.353	CATE, RBGU, CAGU	Ground		
North Potholes Reserve	47.062	-119.419	DCCO	Tree	GREG, GBHE, BCNH	Tree
Banks Lake						
Twining Is.	47.624	-119.304	CATE, RBGU, CAGU	Ground		
Goose Is.	47.647	-119.291	RBGU, CAGU	Ground	CATE	Ground
Sprague Lake						
Harper Is.	47.241	-118.084	DCCO, RBGU, CAGU	Ground	CATE	Ground

America (Francine Cuthbert, University of Minnesota personal communication) and is under consideration for management due to its impacts on smolt survival (USACE 2012).

Methods

Colony Size and Productivity

Aerial, boat, and road surveys were completed to identify active breeding colonies of focal waterbird species on the Columbia Plateau. Estimates of

colony size for colonial waterbirds were obtained late in incubation, when the greatest numbers of adults are aggregated at nesting colonies (Bullock and Gomersal 1981, Gaston and Smith 1984). Although it is possible that small colonies (i.e., < 10 breeding pairs) may have been missed during these surveys, we are confident that all colonies of consequence were identified within the study area due to the coverage extent of aerial surveys and communication with other researchers and agencies familiar with waterbird nesting in the region.

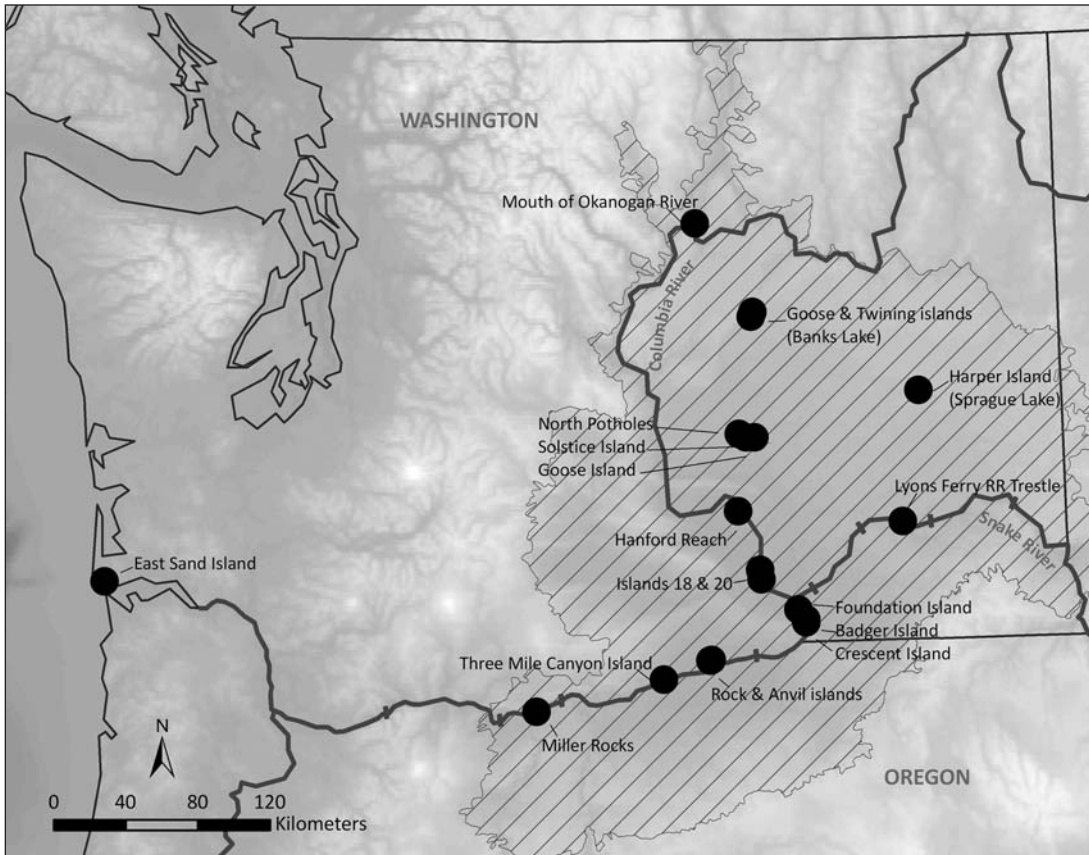


Figure 1. Map of the study area including the piscivorous waterbird colonies on the Columbia Plateau and in the Columbia River estuary that are mentioned in the text. Eight Federal Columbia River Power System dams are represented by hatch marks along the Columbia and Snake rivers for reference. Hatched area delineates the boundary of the Columbia Plateau.

Productivity (number of young raised to fledging age per breeding pair) was estimated for Caspian terns nesting at Crescent Island (2004–2010) and Goose Island in Potholes Reservoir (2010) and for double-crested cormorants nesting at Foundation Island (2005–2010) using ground counts of chicks just prior to the fledging period.

Caspian Terns—Numbers of breeding pairs of Caspian terns at colonies on the Columbia Plateau were estimated from either counts of nesting birds in digital aerial photographs or ground counts of attended nests late in incubation. Colony size estimates from digital photos were either direct counts of all incubating birds or direct counts of all adults on-colony corrected using simultaneous ground counts of incubating and non-incubating

birds in seven 5 m x 5 m plots. All ground counts were made from an observation blind or boat situated near the edge of the colony. Colony size estimates for Goose Island in Potholes Reservoir in 2005 were from Maranto et al. (2010) from daily ground counts of the number of adults observed on and around the breeding colony. When reported, productivity at Caspian tern colonies was estimated by dividing a count of all juveniles present on-colony just prior to fledging by the number of breeding pairs. See Antolos et al. (2004) for further details on the methods used to estimate colony size and productivity at Caspian tern colonies.

Double-Crested Cormorants—The number of breeding pairs of double-crested cormorants at

Foundation Island was estimated using the peak count of attended nests based on weekly counts of the colony from late March through July. Counts were conducted from an observation blind located in the water, approximately 25 m off the eastern shore of the island. Estimates of colony size should be considered minimums, however, as vegetation partially obscured some nests over the course of the breeding season. At other cormorant colonies, colony size estimates were determined from either direct counts of attended nests in digital aerial photographs or direct ground counts of attended nests (i.e., from an observation blind or a boat) around the peak of incubation. Productivity at the Foundation Island cormorant colony was estimated from the number of chicks in monitored nests (range of 50–73) at 28 days post-hatching; after 28 days chicks frequently left their nests, making it difficult or impossible to obtain per-nest productivity.

American White Pelicans—To estimate colony size at the Badger Island pelican colony, aerial photographs were taken of the colony during the late incubation period. Most, but probably not all, pelicans present on the island were visible in the aerial photographs (a few were potentially obscured by overhanging trees or shrubs). We could not correct counts from aerial photographs to estimate the number of breeding pairs because we were unable to obtain representative counts of incubating and non-incubating pelicans. Counts of adult pelicans from aerial photographs are, therefore, an index to the number of breeding pairs utilizing Badger Island. Productivity was not quantified, but was confirmed by observing the presence of juveniles during boat-based surveys near the end of the breeding season.

California and Ring-Billed Gulls—For those years in which we estimated colony size, aerial photographs were taken of the colony during late incubation. Most, but probably not all, gulls present on a given colony were visible in the aerial photographs as some nesting birds were likely obscured by vegetation. As with pelicans, we could not correct counts from aerial photographs to estimate the number of breeding pairs because representative counts of incubating and

non-incubating gulls from the ground were not available. Therefore counts of adult gulls from aerial photographs serve as an index to the number of breeding pairs utilizing the colony. In 2009, all gull colonies were photographed in order to estimate the total number of gulls nesting on the Columbia Plateau during that year. To investigate population trends, the count of gulls nesting at colonies on the mid-Columbia River from The Dalles Dam to Rock Island Dam were then compared to the last comprehensive survey of nesting gulls conducted in this same reach in 1997–1998 (Collis et al. 2002). Productivity was not estimated, but was confirmed by observing the presence of fledglings during ground and boat-based surveys.

Results

During 2004–2010 there were 18 different nesting locations utilized by piscivorous waterbirds on the Columbia Plateau. Most (67%) nesting locations were on the mainstem Columbia ($n = 11$) and Snake ($n = 1$) rivers, with the remainder ($n = 6$) located on three nearby lakes or reservoirs (Tables 1 and 2). In total, there were 12 gull colonies (most comprised of both California and ring-billed gulls), 8 Caspian tern colonies, 7 double-crested cormorant colonies, and 2 American white pelican colonies located on the Columbia Plateau during 2004–2010 (Tables 1 and 2). Terns and gulls nested exclusively on the ground on islands, in close association with one another. Cormorants nested in trees ($n = 4$), on the ground on islands ($n = 2$), and on a man-made structure (railroad trestle; $n = 1$). In the latter two cases, nesting cormorants were associated with nesting herons and/or egrets (Table 1). Pelicans nested on the ground, primarily on one island (Badger Island) in the mid-Columbia River; nesting occurred on both Badger and Crescent islands in 2010, but all nesting attempts at Crescent Island failed (Tables 1 and 2).

Caspian Terns

The total number of Caspian terns nesting on the Columbia Plateau ranged from approximately 710 (in 2007) to 980 (in 2009) breeding pairs, with no overall population trend evident during 2005–2010 (comparable estimates were not available from all colonies in 2004; Figure 2). The average number

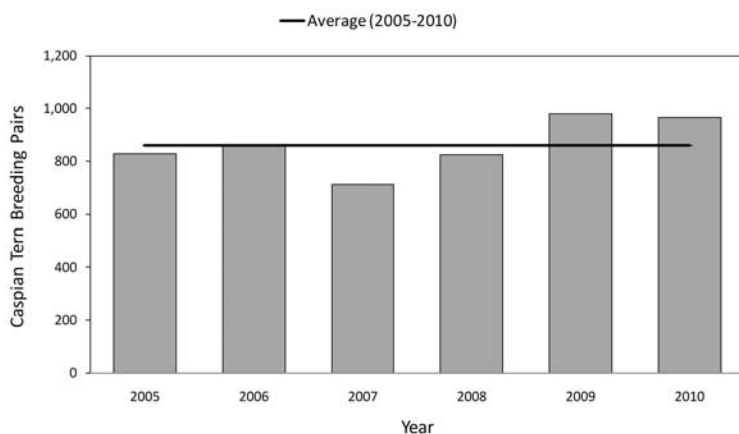


Figure 2. Total number of Caspian tern breeding pairs nesting at all colonies on the Columbia Plateau, 2005–2010.

of Caspian terns that bred on the Columbia Plateau (ca. 860 breeding pairs) was more than an order of magnitude less than the average number of terns that bred at East Sand Island in the Columbia River estuary (ca. 9,400 breeding pairs; Collis et al. 2005, 2006, 2007, 2009; Roby et al. 2008, 2010, 2011) during the study period.

The higher number of Caspian terns breeding on the Columbia Plateau during 2009 was primarily due to the growth of the Goose Island colony in Potholes Reservoir, which increased by nearly five-fold since 2004 (Table 2). In 2004, approximately 40 Caspian terns attempted to nest at Solstice Island in the upper portion of Potholes Reservoir; however, the colony failed due to flooding and Caspian terns have not nested at Solstice Island since 2004 (Table 2). Precise productivity estimates for Caspian terns nesting at Potholes Reservoir are not available for most years, but observations indicated that terns successfully fledged young in every year during the study period. In 2010, however, the colony nearly failed when only three terns fledged (0.01 young per breeding pair).

During 2004–2010, the size of the Caspian tern colony on Crescent Island exhibited a downward trend (Table 2), and ranged from a high of 530 breeding pairs in 2004 to a low of 349 breeding pairs in 2009. During this time period, productivity averaged 0.50 fledglings/breeding pair (range = 0.28–0.68).

Caspian tern nesting was first detected at the Blalock Islands in the mid-Columbia River in 2005 (Table 2), when about six pairs of terns attempted to nest on Rock Island amidst a colony of ring-billed gulls and Forster's terns (*Sterna forsteri*). The Rock Island colony peaked at 110 breeding pairs in 2006 and declined to 79 breeding pairs in 2009 before terns abandoned nesting at the site and were observed nesting at Anvil Island (another island in the Blalock Island group) in 2010 (Table 2). In 2010, the

Caspian tern nesting colony on Anvil Island consisted of 136 breeding pairs, the largest Caspian tern colony ever recorded in the Blalock Islands (Table 2). The Anvil Island colony completely failed in 2010, however, possibly due to flooding. This was the fifth consecutive year that Caspian terns nesting in the Blalock Islands failed or nearly failed to produce fledglings.

During the study period, we identified three additional Caspian tern colonies on the Columbia Plateau. All were small colonies amidst much larger gull colonies located approximately 45–70 km and 67–132 km away from the Columbia and Snake rivers, respectively. Two colonies were on Banks Lake at Twining Island and Goose Island and the other was on Harper Island in Sprague Lake (Figure 1). During 2004–2005, Caspian terns nested on Goose Island in Banks Lake and abandoned the colony site thereafter (Table 2). In 2005, Caspian terns also nested on Twining Island in Banks Lake, where the colony size has ranged between 13 and 61 breeding pairs during the study period (Table 2). Caspian terns at these colonies were successful in fledging at least some young in all years of this study. Productivity estimates for this colony, however, are only available for 2008 and 2009, when an average of 0.33 fledglings/breeding pair were raised in both years. Colony size at Harper Island in Sprague Lake was estimated during 2005–2010 and ranged from a low of zero breeding pairs in 2007 to a high of 11 breeding

TABLE 2. Estimates of numbers of Caspian terns (CATE), double-crested cormorants (DCCO), American white pelicans (AWPE), California gulls (CAGU), and ring-billed gulls (RBGU) at breeding colonies on the Columbia Plateau and at East Sand Island, Oregon, during 2004–2010. Estimates of terns and cormorants are number of breeding pairs and estimates of pelicans and gulls are number of adults on-colony. “B” denotes that birds were breeding at the colony but the colony size was not determined. Dash (“–”) indicates that the colony was not censused to determine breeding status.

General Area		2004	2005	2006	2007	2008	2009	2010
Colony	Species							
Columbia River Estuary								
East Sand Is.	CATE	9,502	8,882	8,929	9,623	10,668	9,854	8,283
	DCCO	12,480	12,287	13,738	13,771	10,950	12,087	13,596
Mid-Columbia River								
Miller Rocks	DCCO	–	–	5	0	0	0	0
	CAGU, RBGU	B	B	B	3,509	4,443	6,016	5,532
Three Mile Canyon Is.	CAGU, RBGU	B	B	B	B	B	6,161	B
Rock Is. (Blalocks)	CATE	0	6	110	43	104	79	0
	RBGU	–	B	B	B	B	940	0
Anvil Is. (Blalocks)	CATE	–	–	–	–	–	0	136
	RBGU	–	–	–	–	–	691	B
Crescent Is.	CATE	530	476	448	355	388	349	375
	CAGU, RBGU	B	B	B	5,601	8,567	8,575	B
	AWPE	0	0	0	0	0	0	50 ^a
Badger Is.	AWPE	B	1,057	1,310	913	1,349	1,754	2,048
Foundation Is.	DCCO	300	315	359	334	357	309	308
Island 18	CAGU, RBGU	B	B	B	B	0	0	0
Island 20	CAGU, RBGU	B	B	B	B	20,999	19,341	B
Hanford Reach	DCCO	–	–	–	8	0	0	0
Mouth of Okanogan River	DCCO	25	38	32	10	33	36	26
Lower Snake River								
Lyons Ferry (RR Trestle)	DCCO	–	–	2	0	0	0	0
Potholes Reservoir								
Goose Is.	CATE	87	325 ^b	273	282	293	487	416
	CAGU, RBGU	B	B	B	B	B	13,022	B
Solstice Is.	CATE	42	0	0	0	0	0	0
	CAGU, RBGU	B	B	B	0	0	0	0
North Potholes	DCCO	B	865	1,156	1,015	1,000 ^a	809	827
Banks Lake								
Twining Is.	CATE	0	13	23	31	27	61	34
	CAGU, RBGU	B	B	B	B	B	3,271	B
Goose Is.	CATE	B	7	0	0	0	0	0
	CAGU, RBGU	B	B	B	B	B	3,331	B
Sprague Lake								
	CATE	B	7	7	0	11	4	4
	DCCO	–	0	0	0	38	42	86
	CAGU, RBGU	B	B	B	B	B	6,302	B

^a Approximate estimate

^b Maranto et al. (2010)

pairs in 2008 (Table 2). We were unable to confirm nesting success at Harper Island in 2009; however, this colony failed to fledge any young in all other years of this study.

Double-Crested Cormorants

The total number of double-crested cormorants nesting throughout the Columbia Plateau ranged from approximately 1,200 (in 2009) to 1,550

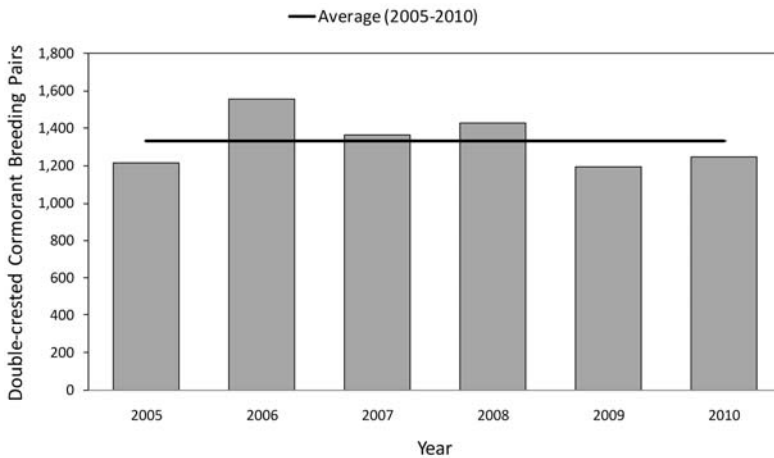


Figure 3. Total number of double-crested cormorant breeding pairs nesting at all colonies on the Columbia Plateau, 2005–2010.

breeding pairs (in 2006) during the study period (Figure 3). During 2005–2010, the overall population trend was stable (comparable estimates were not available from all colonies in 2004; Figure 3). The average number of double-crested cormorants that bred on the Columbia Plateau (ca. 1,340 breeding pairs) was an order of magnitude less than the average number of cormorants that bred on East Sand Island in the Columbia River estuary (ca. 12,700 breeding pairs; Collis et al. 2005, 2006, 2007, 2009; Roby et al. 2008, 2010, 2011) during the study period.

The largest double-crested cormorant colony on the Columbia Plateau during 2004–2010 was in the North Potholes Reserve at Potholes Reservoir, although numbers varied considerably. Colony size peaked in 2006, when approximately 1,160 breeding pairs nested at the North Potholes colony, and then declined to about 810 breeding pairs by 2009, however, there was no clear trend in colony size during the 2005–2010 period (Table 2). Precise productivity estimates are not available for the North Potholes cormorant colony; however, this colony was successful in fledging young in all years of the study.

During 2004–2006 the Foundation Island cormorant colony on the mid-Columbia River gradually grew from approximately 300 breeding pairs to approximately 360 breeding pairs, before

leveling off and then declining to about 310 breeding pairs in 2010 (Table 2). The average productivity at the Foundation Island colony during 2005–2010 (no productivity estimate is available for 2004) was 2.12 fledglings/breeding pair (range = 1.37–2.72).

Double-crested cormorants nested at a small colony in trees near the mouth of the Okanogan River on the mid-Columbia River during 2004–2010. The colony ranged in size from a low of 10 breeding pairs in 2007

to a high of 38 breeding pairs in 2005 (Table 2). Precise productivity estimates are not available for this site, but observations indicate that this colony fledged young in most years.

A double-crested cormorant colony first formed on Harper Island in Sprague Lake in 2008, when approximately 38 breeding pairs nested on the island. The colony grew in each of the following two years, with 86 breeding pairs counted at the site in 2010. Productivity at this colony is unknown.

Three ephemeral double-crested cormorant colonies were identified on the Columbia Plateau during the study period (Table 2). In 2006, five breeding pairs nested on rocks at Miller Rocks, an island group on the Columbia River just upstream from the confluence of the Deschutes and Columbia rivers, and two breeding pairs nested on a railroad trestle bridge amidst nesting great blue herons (*Ardea herodias*) on the lower Snake River near Lyons Ferry Hatchery (Table 2, Figure 1). In 2007, eight breeding pairs nested in trees on the east bank of the Columbia River in the Wahluke Unit of Hanford Reach National Monument (Table 2, Figure 1). Productivity at all three of these colonies is unknown. Unconfirmed nesting activity has also been reported at a small tree-nesting colony on the Yakima River near Selah, Washington (Mike Livingston, Washington Department of Fish and Wildlife, personal communication).

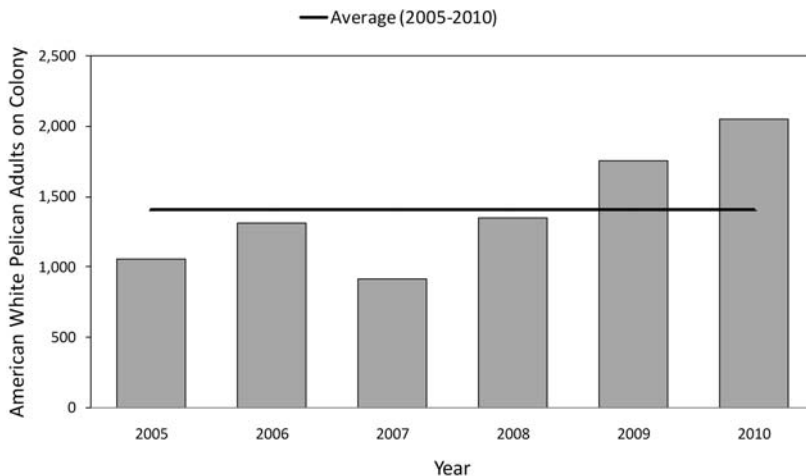


Figure 4. Total number of adult American white pelicans counted on the Badger Island colony, 2005–2009. With the exception of a failed nesting attempt in 2010 at Crescent Island, Badger Island is the only nesting colony for the species on the Columbia Plateau. Counts of the number of adult pelicans on-colony are an index to the number of breeding pairs rather than a count of nesting pairs.

American White Pelicans

Badger Island was the only known successful breeding colony of American white pelicans on the Columbia Plateau during 2004–2010. The only other known location where American white pelicans attempted to nest and subsequently failed was at Crescent Island in 2010 (Table 2). The count of approximately 2,050 adult American white pelicans on Badger Island recorded in 2010 was the highest total observed during the study period (Table 2). Annual counts of adults on-colony have increased in all years since 2005 (a comparable colony size estimate is not available for 2004), with the exception of 2007 (Figure 4). Precise productivity estimates are not available for the Badger Island colony; however, observations indicate that pelicans at this site were successful in fledging young in all years of the study.

California and Ring-Billed Gulls

Nesting gulls (California and ring-billed gulls) were confirmed on 12 islands on the Columbia Plateau during 2004–2010: Miller Rocks, Three Mile Canyon Island, Anvil and Rock islands in the Blalock Islands, Crescent Island, Island 18, Island 20, Goose and Solstice Islands on Potholes

Reservoir, Twining and Goose Islands on Banks Lake, and Harper Island on Sprague Lake (Table 2, Figure 1). Most (67%) of these gull colonies were active in each year during 2005–2010 (five colonies were not censused in 2004). While breeding was documented at these colonies in most years of the study, precise colony size estimates are only available for 2009 (Table 2).

The total number of gulls nesting on the Columbia Plateau in 2009 was approximately 67,650 adults, with the

largest colonies on Island 20 on the mid-Columbia River (ca. 19,340 adults) and on Goose Island in Potholes Reservoir (ca. 13,020 adults; Table 2). The total number of gulls nesting on the Columbia Plateau in 2009 was divided between California gulls (ca. 37,680 adults) and ring-billed gulls (ca. 29,970 adults; Figure 5). Roughly 62% of the nesting gulls were at colonies on the mid-Columbia River, with the remainder at four colonies on three nearby lakes or reservoirs (Table 2).

Precise productivity estimates are not available for these gull colonies; however, observations indicate that gulls nesting at colonies on the Columbia Plateau were typically successful in fledging young during the study period.

Discussion

Caspian Terns

During the most recent population census (1997–2000), nearly three-quarters of the Pacific Coast population of Caspian terns nested in the Columbia River basin, of which an estimated 1,060 pairs (11%) nested at five colonies on the Columbia Plateau (Suryan et al. 2004). Although more recent census data are not available for the entire

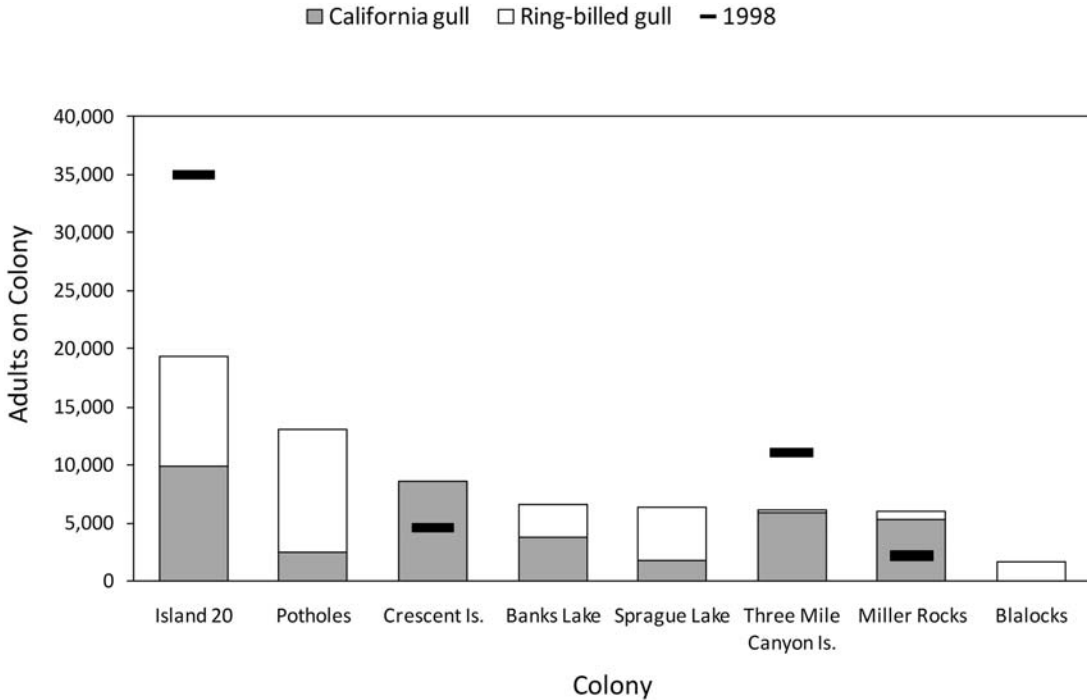


Figure 5. Total number of adult California and ring-billed gulls counted at all colonies on the Columbia Plateau in 2009. Total combined number of adult California and ring-billed gulls counted at all colonies on the Columbia River in 1998 (from Collis et al. 2002). Counts of the number of adult gulls on-colony are an index to the number of breeding pairs rather than a count of nesting pairs.

Pacific Coast Caspian tern population, this study indicates that an estimated 965 pairs of terns nested at five colonies on the Columbia Plateau in 2010, suggesting that the regional population has been relatively stable over the past decade. Despite this, there have been notable changes in the size of some Caspian tern breeding colonies on the Columbia Plateau during this study. The Crescent Island tern colony experienced a 29% decline in the number of breeding pairs from 2004–2010, partially due to decreased recruitment of breeders to the colony and increased emigration to other colonies (Suzuki 2012). Numbers of Caspian terns nesting at colonies in the Blalock Islands and Potholes Reservoir increased during the same time period, with the latter showing a three-fold increase. Although movements of terns among Columbia Plateau colonies has been well documented (Suzuki 2012), it does not appear that the colony growth observed at these colonies can be explained entirely by these movements, sug-

gesting that some portion of this increase might be attributed to either intrinsic growth or immigration of terns from other colonies located outside the Columbia Plateau (e.g., East Sand Island). Suzuki (2012) indicated a high degree of connectivity between the Caspian tern colony at East Sand Island in the Columbia River estuary and tern colonies on the Columbia Plateau, especially for terns banded as chicks on East Sand Island that were later observed and confirmed breeding at Plateau colonies (Suzuki 2012).

Although Columbia Plateau-wide productivity estimates are not available for Caspian terns, at Crescent Island, one of the larger colonies in the region, nesting success was slightly lower (0.5 fledglings/breeding pair) than at other well-studied Caspian tern colonies in North America (0.6–1.6 fledglings/breeding pair; Cuthbert and Wires 1999), and was less than the productivity measured at this colony in 2000 and 2001 (0.62 and 1.00 fledglings/breeding pair, respectively;

Antolos et al. 2004). The reasons for the apparent decline in tern productivity at Crescent Island over the past decade may be due in part to the increase in the number of gulls nesting on Crescent Island over the same time period (see below) and the associated impacts of gulls on tern nesting success (i.e., kleptoparasitism, nest predation, and interspecific competition for nest sites; Cuthbert and Wires 1999, Antolos 2003).

The most common factors that likely limited colony size at tern colonies on the Columbia Plateau include availability of suitable nesting substrate (i.e., bare sand or dirt), nest site encroachment by nesting gulls, and avian and mammalian predation. Nesting gulls surround and outnumber the Caspian tern colonies at Goose Island in Potholes Reservoir and at Crescent Island, competing for nest sites with terns. Predation and disturbance by American mink (*Neovison vison*) and great horned owls (*Bubo virginianus*) caused the near failure of the Goose Island tern colony in Potholes Reservoir in 2010. Mink predation and unidentified avian predation (possibly great horned owl or peregrine falcon [*Falco peregrines*]) were observed to limit the colony size and productivity of Caspian terns nesting in the Blalock Islands in 2006 and 2007, respectively.

Additional limiting factors were likely influential at some of the tern colonies. Local food availability was apparently a limiting factor for the tern colonies at Goose Island in Potholes Reservoir, Banks Lake, and Sprague Lake. Caspian terns from these colonies commute over 100 km round trip to feed on juvenile salmonids from the Columbia River (Goose Island, Banks Lake, and Sprague Lake colonies) or Snake River (Banks Lake and Sprague Lake colonies; Antolos et al. 2004, Evans et al. 2012, authors' unpublished data). Gull kleptoparasitism (i.e., stealing) is a potentially important limiting factor at Crescent Island. Gulls that nest at the periphery of Caspian tern colonies in the Columbia Basin may have a negative effect on the productivity of Caspian terns as well as the survival of juvenile salmonids; some individuals kleptoparasitize juvenile salmonids, as well as other prey taxa, from terns as they return to the colony with fish in their bills to feed to mates and young. California gulls at Crescent Island are

likely having a significant impact on the foraging efficiency and energetic demands of Caspian terns nesting at this site. If the fish that a tern delivers to the colony is stolen, that individual (or its mate) must compensate by spending more time and energy foraging. Flooding was observed to limit Caspian terns nesting in the Blalock Islands in 2008 and 2010. Although the U.S. Army Corps of Engineers, the agency responsible for dam operations in the Columbia and lower Snake rivers, regulates water flow, fluctuations in elevation occur (USACE 2014). As a result, some of the low-lying islands (e.g. Rock and Anvil islands in the Blalock Islands) are subject to flooding during storm events, spring run-off, and fluctuations in spill level and volume. Thus, fluctuations in the water table, although minor compared to those of a free-flowing river, do occur and the magnitude and influence of these functions vary by year, reservoir, and island.

Double-Crested Cormorants

The most recent population census of double-crested cormorants in western North America (ca. 2009) estimated the entire western population to be approximately 31,200 breeding pairs (Adkins et al. 2014), of which roughly 44% and 4% nested in the Columbia River estuary and on the Columbia Plateau in 2010, respectively. As with Caspian terns, most nesting cormorants in the Columbia River Basin were located at East Sand Island in the Columbia River estuary in 2010, with four smaller colonies located on the Columbia Plateau. There was no trend observed in the total number of double-crested cormorants nesting on the Columbia Plateau during the study period. The Harper Island cormorant colony appeared to be the only colony that increased during the study period; all other colonies showed no trend in number of nesting pairs. There was substantial inter-annual variation in colony size at the North Potholes colony, the largest cormorant colony on the Columbia Plateau, comprising approximately 75% of breeding cormorants in the region.

Results from this study on the size and distribution of double-crested cormorant colonies on the Columbia Plateau, combined with results from leg band recovery and satellite-tracking

studies of cormorants marked in the Columbia River estuary (Clark et al. 2006 and Courtot et al. 2012, respectively), suggest that there is limited demographic connectivity between cormorant colonies on the Columbia Plateau and those along the coast. Based on these data it is likely that the demographics of the Columbia Plateau sub-population of double-crested cormorants are less influenced by coastal sub-populations compared to Caspian terns.

Productivity at the Foundation Island cormorant colony was generally at the upper range of productivity estimates reported for double-crested cormorants nesting throughout North America (1.2–2.4 fledglings/breeding pair; Hatch and Weseloh 1999). Despite this, the colony did not grow in size during the study period suggesting that this colony may be experiencing high sub-adult and/or adult mortality rates or that young produced at Foundation Island may be recruiting into the breeding population at other colony locations.

While nesting habitat on the Columbia Plateau appears to be limited for Caspian terns, this is not the case for double-crested cormorants. Like terns, cormorants select nest sites that are safe from mammalian predators and near preferred foraging grounds. Unlike terns on the Columbia Plateau, which nest exclusively on islands with unvegetated substrate, cormorants nest in a variety of habitats including in trees, on islands with rocky or sandy substrate, on emergent vegetation in marshes, and on artificial structures such as bridges, navigational markers, and transmission towers (Hatch and Weseloh 1999). Suitable nesting habitat for double-crested cormorants is readily available throughout the Columbia Plateau; during the study period, tree nesting was most common (four colonies), followed by ground nesting (two colonies) and nesting on man-made structures (one colony). Factors limiting colony size and productivity at double-crested cormorant colonies on the Columbia Plateau are largely unknown; however, windstorms have been known to destroy nests at the Foundation Island colony and the Hanford Reach colony was abandoned in 2008 due to a wild fire that destroyed trees used for nesting.

American White Pelicans

American white pelicans are listed as endangered by the State of Washington (WDFW 2011). Of all the piscivorous waterbirds investigated as part of this study, American white pelicans were the only species whose numbers increased, nearly doubling during the study period. It is unknown whether this increase was due to intrinsic growth, because productivity data for the Badger Island colony is unavailable, or recruitment of breeding birds to Badger Island from other colonies in western North America. Nesting habitat for pelicans on Badger Island does not appear to be a limiting factor; hence continued growth of this colony is likely possible.

Factors observed or suspected to limit colony size or productivity of American white pelicans on the Columbia Plateau include mammalian nest predators at Badger Island and human disturbance at Crescent Island. In 2010, raccoon (*Procyon lotor*) tracks were observed on the Badger Island pelican colony before and after the breeding season suggesting that predation may have limited productivity at that colony in that year. That same year, pelicans were discovered to be nesting at Crescent Island when researchers accessed an observation blind used to observe the Caspian tern colony and inadvertently flushed pelicans off nests. Research activity at Crescent Island was subsequently suspended to avoid further human disturbance and allow pelicans an opportunity to nest. While pelicans were observed in the nesting area in the days following the initial disturbance, the site was abandoned within a few weeks despite the continued suspension of research activity. American white pelicans are highly susceptible to disturbance at the breeding colony, especially during the early stages of the nesting season, and human disturbance has been determined to be one of the most significant limiting factors for American white pelicans throughout North America (Evans and Knopf 1993). American white pelicans are also highly susceptible to disease, namely avian botulism and West Nile virus, which have caused large die-offs of pelicans throughout North America (Roche et al. 2005). While West Nile virus was diagnosed in an American white

pelican at the North Potholes Reserve in the fall of 2010 (WDH 2010), no infectious diseases have been reported in pelicans nesting on Badger Island.

California and Ring-Billed Gulls

To our knowledge, this study is the first published comprehensive assessment of the number of California and ring-billed gulls nesting throughout the Columbia Plateau. Collis et al. (2002) estimated approximately 53,250 gulls nesting at colonies located on the mid-Columbia River in 1998 compared to 41,720 nesting gulls estimated in 2009; this represents a 22% decline in the number of gulls counted at colonies on the mid-Columbia River during this time period. This decline was largely driven by the reduction in the number of gulls nesting on islands in the Tri-Cities area (Islands 18, 19, and 20 on the mid-Columbia River); about 35,020 gulls and about 19,360 gulls were counted at colonies on these islands in 1998 and 2009, respectively (Figure 5). Also, the gull colony at Three Mile Canyon Island declined from approximately 11,100 gulls in 1998 to approximately 6,160 gulls in 2009. Despite the overall decline in the number of gulls nesting at colonies on the mid-Columbia River from 1998 to 2009, three gull colonies increased in size during this time period. The number of gulls counted at the Miller Rocks colony increased from approximately 2,180 gulls in 1998 to approximately 6,020 gulls in 2009; the number of gulls counted at colonies in the Blalock Islands (Rock and Anvil islands) increased from zero gulls in 1998 to about 1,630 gulls in 2009; and the number of gulls counted at Crescent Island increased from about 4,600 gulls in 1998 to about 8,580 gulls in 2009. Overall, the breeding populations of ring-billed gulls and California gulls on the Columbia Plateau appear to have declined in the last decade, even though most colonies apparently successfully fledged young in each year during the study period.

Disturbance and predation appear to be the primary limiting factors for gulls nesting on the Columbia Plateau. Island 18 was not re-colonized following colony abandonment likely due to coyote and human disturbance in 2008 (Heidi Newsome, U.S. Fish and Wildlife Service, personal commu-

nication). The large Three Mile Canyon Island gull colony has declined over the last decade, coinciding with the failure of the Caspian tern colony on the island due to predation and disturbance by mink in the early 2000s (Antolos et al. 2004). Encroaching vegetation at the Three Mile Canyon Island, Solstice Island, and perhaps other colonies may also be an important factor that has limited colony size for gulls on the Columbia Plateau. Since gulls are plastic in their diets (Collis et al. 2002), they are less likely to be limited by food availability as compared to the other species that are strictly piscivorous. The available evidence suggests that the decline in numbers of breeding gulls on the Columbia Plateau is due to apparent declines in suitable colony sites free of disturbance and predator activity.

Management Implications

Of the piscivorous waterbird species included in this study that nest in the Columbia River basin, Caspian terns and double-crested cormorants have the greatest impact on the survival of juvenile salmonids, some of which are listed under the United States Endangered Species Act (Ryan et al. 2001, Antolos et al. 2005, Maranto et al. 2010, Evans et al. 2012). Caspian terns appear to be significantly constrained by nesting habitat availability, whereas factors limiting cormorant populations are less clear. The Columbia Plateau populations of both species were stable during 2004–2010, suggesting potential future impacts to juvenile salmonid survival are unlikely to rapidly increase due to changes in tern or cormorant population levels. American white pelicans have had lower per capita impacts on juvenile salmonids than other piscivorous waterbirds (Evans et al. 2012); however, if the size of the Badger Island colony continues to increase the cumulative impact of this colony may warrant further investigation. Impacts of California and ring-billed gulls on juvenile salmonid survival have been variable and are colony and foraging site-dependent (Collis et al. 2002, Evans et al. 2012). Gull colonies that increased in size during our study, particularly those near mainstem dams where salmonids may be particularly vulnerable (e.g., Miller Rocks,

Blalock Islands) or associated with Caspian tern colonies where kleptoparasitism is common (e.g., Crescent Island), may have greater potential to impact juvenile salmonid survival in the future. Additional monitoring and evaluation of the impacts of these colonies may be warranted.

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