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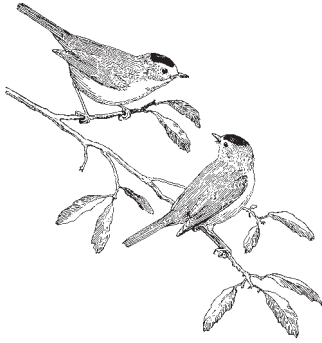
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The regional, national, and international importance of Louisiana's coastal avifauna

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ABSTRACT—Coastal Louisiana—and its Mississippi River Delta, in particular—provides large and diverse habitats for many types of birds in North America and beyond. The Mississippi River and its distributaries have shaped Louisiana's unique coast, which includes extensive marsh and marsh islands, sandy barrier headlands and sandy islands, and isolated patches of maritime forest on natural levees, cheniers, and canal spoil banks. Louisiana thus supports large populations of many obligate marsh bird species as well as marine bird species that require islands for breeding sites. Here, we have collated available data and attempt to estimate the breeding population sizes of 17 bird species in coastal Louisiana. We then summarize the importance of the Louisiana coast for these bird species in the contexts of regional, national, and global bird populations. These preliminary estimates indicate that Louisiana's coast supports a high percentage of regional, national, and, in some cases, global populations of several coastal bird species. For example, we estimate that 73% of the United States population of Sandwich Tern (*Thalasseus sandvicensis*) breeds in Louisiana, and comparable estimates range from 24 to 55% for Mottled Duck (*Anas fulvigula*), Clapper Rail (*Rallus crepitans*), Tricolored Heron (*Egretta tricolor*), Wilson's Plover (*Charadrius wilsonia*), Royal Tern (*Thalasseus maximus*), Black Skimmer (*Rynchops niger*), and Seaside Sparrow (*Ammodramus maritimus*). Because most of these other bird species are distributed across state, regional, and national jurisdictions, management of birds and bird habitats in Louisiana has wide-reaching implications for the conservation of these shared natural resources. In this light, this paper is intended to be a resource for managers of avian resources in North America and beyond. Received 21 May 2018. Accepted 6 November 2018.

Key words: barrier islands, coastal bird conservation, Louisiana coastal birds, Mississippi River delta, population estimates

La importancia regional, nacional e internacional de la avifauna costera de Louisiana

RESUMEN (Spanish)—La costa de Louisiana —y en particular el delta del río Mississippi— provee grandes y diversos hábitats para muchos diferentes tipos de aves en Norteamérica y más allá. El río Mississippi y sus distributarios han formado una costa única, que incluye extensas ciénagas, islas en ciénagas, barras arenosas de tierra firme, islas arenosas, parches aislados de bosques marítimos en diques naturales, dunas ondulantes y bancos de material de dragado de canales. Con ello, Louisiana alberga grandes poblaciones de muchas especies obligadas de humedales, así como especies de aves marinas que requieren islas como sitios de reproducción. Aquí recopilamos los datos disponibles e intentamos estimar el tamaño de las poblaciones reproductivas de 17 especies de aves de la costa de Louisiana. A continuación, sintetizamos la importancia de la costa de Louisiana para estas especies de aves en el contexto de sus

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poblaciones regional, nacional y global. Estas estimaciones poblacionales indican que la costa de Louisiana alberga un alto porcentaje de las poblaciones regionales, nacionales, y en algunos casos, globales de varias especies de aves costeras. Por ejemplo, estimamos que el 73% de la población de los Estados Unidos del charrán *Thalasseus sandvicensis* se reproduce en Louisiana, y estimaciones comparables varían de 24 a 55% del pato *Anas fulvigula*, el rascón *Rallus crepitans*, la garza *Egretta tricolor*, el chorlo *Charadrius wilsonia*, el charrán *Thalasseus maximus*, el rayador *Rynchops niger* y el gorrión *Ammodramus maritimus*. Debido a que la mayoría de estas especies están distribuidas a lo largo de jurisdicciones estatales, regionales y nacionales, su manejo y el de sus hábitats tiene implicaciones de gran alcance para la conservación de estos recursos naturales compartidos. A la luz de esta información, este artículo tiene la intención de ser un recurso para quienes manejan aves en Norteamérica y más allá.

Palabras clave: aves costeras de Louisiana, conservación de aves costeras, estimación de poblaciones, delta del río Mississippi, islas de barrera

The Mississippi River, the largest river in North America and one of the largest in the world, makes a dramatic imprint on the coastline of the United States. The unique outline of Louisiana's coast (Fig. 1) is created by the protrusion of the Holocene Mississippi River Delta (MRD) into the northern Gulf of Mexico (hereafter nGOM). The MRD, all of which lies within the boundaries of the state of Louisiana, is the fifth-largest delta system on the planet and the largest in the Western Hemisphere (Coleman and Huh 2004). It is flanked to the west by the Chenier Plain, a Holocene formation built from MRD sediments carried by longshore drift combined with sedimentary inputs from smaller coastal plain rivers. Because of its sheer size, as well as the heterogeneity of its coastal habitats, the MRD likely supports the continent's largest populations of the flora and fauna that depend on deltaic habitats, such as coastal marshes and nearshore islands. However, we are unaware of comprehensive analyses that document the comparative importance of coastal Louisiana to other regions in terms of magnitude of biodiversity.

Current population estimates are the cornerstone of any conservation strategy (Soulé 1986); not only do they allow assessment of trends through time, but they also permit evaluation of the consequences of major mortality events. Population estimates at multiple spatial scales (e.g., local, regional, global) are required for evaluating the importance of any region within a species' distribution to the overall population. For North American birds, population estimates of endangered species are routine components of any recovery plan, as they also are for management of game species and certain other species of conservation concern. For the rest of North America's birds, estimates are typically few, coarse, or outdated.

To address this fundamental need, we provide here preliminary population estimates for coastal breeding bird species in the state of Louisiana relative to regional, national, and international estimates for those species. Our primary objectives were (1) to assess Louisiana's relative importance to the conservation of those species on regional to global scales, and (2) to provide baseline data for evaluation of future trends and for assessments of impacts, such as potentially catastrophic events (e.g., oil spills, hurricanes).

We focus on coastal breeding bird species because they are especially susceptible to negative anthropogenic effects, such as coastal land loss, sea level rise, and oil spills (Votier et al. 2005, Erwin et al. 2006a, Bergeron Burns et al. 2012). Nowhere in the United States are these threats more evident than in Louisiana (CPRA 2012). For example, Louisiana's coastline is among the most vulnerable to sea level rise in the nGOM (Pendleton et al. 2010): between 1932 and 2010, 4,877 km² of land eroded or subsided (Couvillion et al. 2017). Without an aggressive program of restoration and riverine reintroduction, Louisiana is now projected to lose as much as 10,400 km² (nearly two-thirds of remaining coastal wetlands, including freshwater forested wetlands) over the next 50 yr. Even with current proposed restoration projects in place, nearly half of coastal wetlands could be lost in as little as 50 yr under the highest climate change scenario modelled (CPRA 2012). Furthermore, nearly half of the nGOM shoreline affected by the 2010 *Deepwater Horizon* (DWH) oil spill was marsh habitat, and approximately 95% of that oiled marsh was in Louisiana (Michel et al. 2013). Louisiana's coastal and offshore zones host infrastructure that supplies 90% of the U.S. outer continental shelf oil and gas resources (CPRA 2012), serving as a reminder of the potential threat of future spills. Natural threats such as hurricanes can also affect coastal nesting

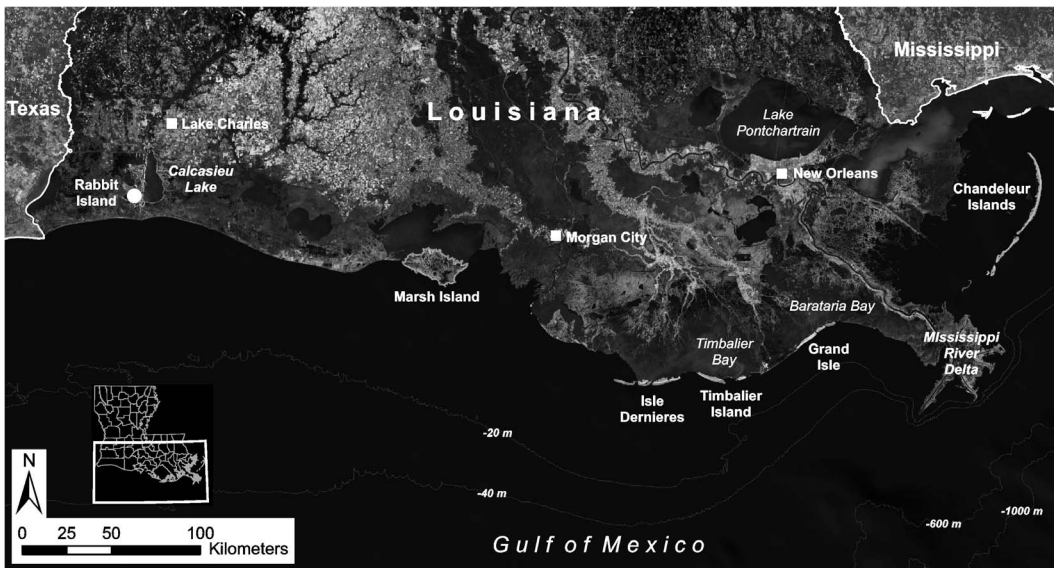


Figure 1. Louisiana coast region, with major localities mentioned in text.

bird populations (Leberg et al. 2007); such tropical storms have been shown to impact success of coastal restoration activities in providing habitat for nesting waterbird populations (Raynor et al. 2013, Walter et al. 2013).

Another reason that we focus on species completely or primarily restricted to coastal areas is that their nearly linear ranges naturally limit their population sizes; this makes estimation of population abundances more feasible relative to species with extensive inland distributions that are not subject to the same threats. Although our primary focus is breeding birds, we also briefly summarize information on nonbreeding birds of coastal Louisiana.

We acknowledge significant challenges inherent in synthesizing data from multiple sources, and we describe below our approaches for dealing with these transparently and reasonably. In this vein, we hope that this paper represents a step toward more robust, comprehensive population estimates, and that the results will catalyze more thorough, rigorous survey data and analyses in Louisiana and elsewhere to improve these estimates.

Methods

To provide preliminary population estimates from Louisiana and to compare these to data from

other regions, we compiled existing published and unpublished data, and for some species, generated new population estimates using other techniques (see Supplement). We acknowledge that our estimates and the degree of uncertainty associated with them vary widely among species. We describe our approach below, with greater methodological detail in the Supplement.

Selection of species

We restrict our estimates to those species or subspecies that breed in Louisiana exclusively or primarily on the coastline, offshore islands, or in salt or brackish to intermediate marshes. Thus, many coastal breeders that also regularly occur farther inland (i.e., away from tidal influence) are not included. For example, species (e.g., herons) that also nest in floodplain bottomland forest regions are not included despite their abundance in coastal areas (Michot et al. 2003, Green et al. 2006). To define the list of focal species, we first compiled a list of all species that breed along the coast of Louisiana, from offshore islands to as far inland as the influence of saltwater extends (i.e., intermediate marsh); we hereafter refer to this area as the “coastal zone.” Next, we selected a subset of those species with breeding ranges restricted to the Louisiana coastal zone, using Wiedenfeld and Swan (2000) and our decades of collective

personal field experience in Louisiana. From that list of coastal zone breeders, we then excluded the following 5 species because their breeding populations in Louisiana are clearly only a tiny fraction of their North American or global populations: the Snowy Plover (*Charadrius nivosus*), the American Oystercatcher (*Haematopus palliatus*), the Sooty Tern (*Onychoprion fuscatus*), the Gull-billed Tern (*Gelochelidon nilotica*), and the Caspian Tern (*Hydroprogne caspia*).

We made the following additions to our list of focal species. We also searched for subspecies restricted to the coastal zone even if most of the species' population breeds elsewhere. This procedure identified one subspecies of a widespread species that is endemic to the coastal marshes of the nGOM: the subspecies *marianae* of the Marsh Wren (*Cistothorus palustris*; Kroodsma and Verner 2014). We also included 3 additional species for which most of Louisiana's breeding population is in the coastal zone, but which also have relatively smaller breeding populations in freshwater habitats farther inland: the Mottled Duck (*Anas fulvigula*), the Tricolored Heron (*Egretta tricolor*), and the Boat-tailed Grackle (*Quiscalus major*). Finally, we included a population of gulls that has formed on the Chandeleur Islands as a result of hybridization between Herring Gull (*Larus argentatus*) and Kelp Gull (*L. dominicanus*) (Dittmann and Cardiff 2005) that is of general biological interest because it represents a potential case of "hybrid speciation." Our final list of bird species and subspecies included 17 coastal zone breeders (Table 1).

Species names follow the American Ornithological Society (<http://checklist.aou.org/>), and subspecies names follow Dickinson and Remsen (2013) and Dickinson and Christidis (2014). Designations for Species of Greatest Conservation Need in Louisiana are included (Table 1). Scientific names and detailed methods used to generate population estimates for each species are described in the Supplement.

Data sources

For each focal species or subspecies (Table 1; see Supplement for scientific names), we searched published literature on population estimates from any portion of their ranges, using several online databases (e.g., SORA [Searchable Ornithological Research Archive: <https://sora.unm.edu/>], Birds of

North America [<http://bna.birds.cornell.edu/bna/>]), and online search engines (e.g., Web of Science, Google Scholar). We also incorporated unpublished survey data for some species from the Louisiana Department of Wildlife and Fisheries Natural Heritage and Waterfowl programs, the Texas Colonial Waterbird Society database, and the Florida Shorebird Database (Florida Fish and Wildlife Conservation Commission 2016), from other state natural resource agency databases, and in some cases data from eBird (<http://ebird.org/content/ebird>). We also contacted colleagues in other organizations to obtain additional unpublished survey data for some species (see Acknowledgments). Because all bird populations are subject to external drivers—some recognized and others unknown—population trends can fluctuate annually, be stable, or demonstrate unidirectional change over time depending on the population and drivers. To reflect this variation, each population estimate is annotated with survey year(s). These datasets and survey inventories are in many cases the same as those in the Birds of North America species accounts, regional (Portnoy 1977, 1978; Keller et al. 1984, Spendelow and Patton 1988, Martin and Lester 1990, Visser and Peterson 1994, Michot et al. 2003, Fontenot et al. 2012) and national waterbird and shorebird conservation plans (Brown et al. 2001, Hunter et al. 2006), and even international conservation plans (Wetlands International 2012). Our assessment of these datasets and survey initiatives goes beyond those plans to include the most recent population estimates available, and also puts them in context of state, regional, national, and international relevance. Each of these scales has distinct and important regulatory and conservation planning implications. By combining these multiple data sources, and as long as a 40 yr timespan of estimates in most species treated here, we evaluate broad population changes and shifts, even if at a coarse and qualitative level.

Special cases

For 4 saltmarsh species lacking population census data (i.e., Willet [*Tringa semipalmata*], Clapper Rail [*Rallus crepitans*], *marianae* Marsh Wren, and Seaside Sparrow [*Ammodramus maritimus*]), we estimated populations for each Gulf and Atlantic U.S. state using the following 3

Table 1. Conservation status of bird species whose breeding areas in Louisiana are restricted to the Coastal Zone.

Species	Louisiana Wildlife Action Plan (Holcomb et al. 2015) ^a	Southeastern U.S. Waterbird Conservation Plan (Humer et al. 2006)	Birds of Conservation Concern (USFWS 2008)	Audubon WatchList (Butcher et al. 2007) ^b	Shorebird Conservation Plan (Brown et al. 2001)	North American Waterfowl Conservation Plan (NAWMCP Committee 2004)	Partners in Flight – North American Landbird Plan (Rich et al. 2004)
Mottled Duck	S4	N/A	N/A	Red	N/A	Moderate Concern	N/A
Clapper Rail	S5	Planning and Responsibility	U.S.	Yellow	N/A	N/A	N/A
Wilson's Plover	S2B, S1N	N/A	U.S.	Yellow	High Concern	N/A	N/A
Willet (subspecies <i>sempalmatta</i>)		N/A	N/A	N/A	Moderate Concern	N/A	N/A
Laughing Gull	S5	Population Control	N/A	N/A	N/A	N/A	N/A
“Chandeleur Gull”	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Least Tern (subspecies <i>antillarum</i>)	S4B	Management Attention	U.S.	Red	N/A	N/A	N/A
Forster's Tern	S5	Planning and Responsibility	N/A	N/A	N/A	N/A	N/A
Royal Tern	S5	Planning and Responsibility	N/A	N/A	N/A	N/A	N/A
Sandwich Tern	S4	Management Attention	BCR 27, 37	N/A	N/A	N/A	N/A
Black Skimmer	S3	Management Attention	U.S.	Yellow	N/A	N/A	N/A
Brown Pelican (subspecies <i>carolinensis</i>) ^a	S3	Planning and Responsibility	N/A	N/A	N/A	N/A	N/A
Reddish Egret	S1	Immediate Management	U.S.	Red	N/A	N/A	N/A
Tricolored Heron	S5B	Planning and Responsibility	N/A	N/A	N/A	N/A	N/A
Marsh Wren (subspecies <i>marrianae</i>)	S4	N/A	N/A	N/A	N/A	N/A	N/A
Seaside Sparrow	S4	N/A	U.S.	Red	N/A	N/A	Planning and Responsibility
Boat-tailed Grackle	S5	N/A	N/A	N/A	N/A	N/A	Responsibility

^a Rank explanations: S1 = critically imperiled; S2 = imperiled; S3 = rare and/or local; S4 = apparently secure; S5 = demonstrably secure. Additional state rank ranks were obtained from NatureServe (2015).

^b Rank explanations: Red = globally threatened; Yellow = declining or rare

approaches, which we summarize here (see species accounts in Supplement for additional details). First, for *marianae* Marsh Wren, we extrapolated population size from published estimates of home range size to the extent of suitable habitat. Second, for Clapper Rail and Seaside Sparrow, we extrapolated population size from breeding density estimates to the extent of suitable habitat. Habitat quality—which affects home range size and bird density—is not equivalent across the range, and plant assemblages in tidal marshes may vary greatly across the region (Hester et al. 2005), thereby potentially affecting home range size and bird density. As such, we considered the variation of published density estimates for Clapper Rail and Seaside Sparrow by conducting a *t*-test to determine whether nGOM estimates differed from Atlantic Coast estimates. Based on this test, we either pooled density estimates across the 2 regions (in Clapper Rail) or treated them separately (in Seaside Sparrow) to estimate population size based on the potential area of suitable habitat ($\pm 95\%$ CI). Third, for Willet, we used the relative availability of suitable habitat across states for comparison and estimated state-by-state population size from 2 data sources: (1) a global population estimate (Andres et al. 2012), and (2) density estimates generated from point counts in the northern Atlantic states (Wiest et al. 2016).

To estimate the potential area of suitable habitat for these 4 marsh species, we followed a 2-step process. First, we calculated the area of predicted distribution from the U.S. Geological Survey (USGS) Gap Analysis Program (GAP) for each Gulf and Atlantic state in the species' range (USGS 2013). The GAP model did not consider salinity as a limiting parameter and thus overestimates the distribution of the 3 primarily salt-marsh-dwelling species (Willet, Clapper Rail, Seaside Sparrow) by including them in freshwater and saltwater marshes. Second, therefore, we removed freshwater marsh areas from these distributions as defined by the National Wetlands Inventory database (USFWS 2016) as “freshwater emergent wetland,” “freshwater forested/shrub wetland,” “freshwater pond,” “lake,” or “riverine.” We then used the remaining saltwater distribution and, based on the literature review of published estimates described above, we extrapolated the population size ($\pm 95\%$ CI) in each state from Texas to Maine. Marsh Wren extends into

coastal freshwater wetlands, so we retained these habitat categories in estimating the potential suitable habitat area.

Uncertainty and caveats

It is important to recognize that our estimates are preliminary in most cases, because estimating absolute sizes of populations of breeding birds, even when some data are available, is very difficult. Although attempts at regional counts extend back into the 1970s (Portnoy 1977, 1978), methodologies across states, time, and species have not been standardized. Coastal habitats, and the birds that depend on them, are also naturally dynamic systems, with erosion and storms constantly reshaping the landscape. Human modification of these habitats, both in positive and negative ways, also contributes to local and regional shifts in coastal bird populations (Frederick and Ogden 1997). Our compilation should be considered as approximations subject to major modification with additional data; every estimate has these implicit caveats. Nevertheless, we regard these as reasonable estimates given the data available, but cautionary wording is appropriate for figures cited in the report and the Supplement, where the details are given for each estimate of breeding populations.

Results

General results

Breeding population estimates for Louisiana (presented as the number of breeding individuals—males and females—unless otherwise noted) for the target species ranged from 130 (Reddish Egret) to 3.57 million (Seaside Sparrow). The contributions of Louisiana's populations to those across the nGOM are estimated to represent from as low as 5% (Reddish Egret) to as high as 83% (Sandwich Tern) and 100% (“Chandeleur Gull”). At the scale of the eastern United States as a whole, Louisiana estimates range from 4% (Reddish Egret) to 73% (Sandwich Tern) and 77% (*marianae* Marsh Wren) of total abundance. Percent representations of global populations were more often incalculable because estimates were less readily available at that scale. However, one example—the Seaside Sparrow—showed that Louisiana accounts for about 55% of the species'

global abundance. In other cases, population estimates of hemispheric-scale subspecies were possible—for example, Louisiana supports 26% of the New World Royal Tern (*Thalasseus m. maxima*) and 70% of the New World Sandwich Tern (“Cabot’s Tern,” *T. s. acufavidus*) populations. The derivations of these estimates are described below.

Colonial-nesting waterbirds of coastal islands

Species in this category are those that breed in colonies on islands along the coast. Coastal Louisiana has a unique system of islands that supports some of the largest colonies of waterbirds in the United States. From large barrier islands, such as those in the Isles Dernieres (Raccoon Island, ~60 ha) and the Chandeleurs (collectively more than 400 ha), to small coastal marsh islands and shell keys such as Queen Bess in Barataria Bay (~8 ha), the Louisiana coast provides a large number and diversity of islands (Visser and Peterson 1994, Visser et al. 2005, Walter et al. 2013, Curtiss and Pierce 2016, Selman et al. 2016). Many species of coastal waterbirds require isolated islands for nest sites for protection from predators, particularly mammals, and many waterbird species are wholly dependent on such islands for successful reproduction (e.g., Visser et al. 2005, Raynor et al. 2012b). In particular, Louisiana’s barrier and coastal islands are the only suitable nesting habitat for several species, many of which are Species of Greatest Conservation Need in Louisiana (Holcomb et al. 2015), a fact that cannot be overemphasized. Because these coastal islands are limited in size and host significant concentrations of species and individuals in small areas, the colonies are especially vulnerable to human disturbance, oil spills, relative sea level rise, land loss, and tropical cyclones.

Population estimates of colonial nesters are generally more accurate than those of any other coastal waterbirds because their breeding populations congregate at relatively few nesting areas, thus facilitating surveys. However, as we point out below, colony estimates typically include only nesting individuals and not nonbreeders. Also, surveys of colonies are often conducted from aircraft; this technique, particularly with rotary-wing aircraft, is most effective for surveying species that are visually conspicuous (i.e., those

with high contrast between plumage aspects and nesting substrates) and least effective at detecting species that are rare, small, or low contrast (Rodgers et al. 2005, Green et al. 2008). Details for each species follow.

Brown Pelican—We estimate that Louisiana’s breeding population of 35,000 Brown Pelicans accounts for approximately 33% of the breeding population of the eastern United States and 47% of the population of the nGOM (Table 2). Louisiana has considerably more breeding birds than any other state, with roughly 14,000 more individuals than Texas, the state with the second-largest breeding population. Brown Pelican populations are generally rebounding from lows (and the cessation of breeding) recorded in the 1960s during the height of impacts of the DDT era (Williams and Martin 1968, King et al. 1977, USFWS 2009, Shields 2014). After the banning of DDT in 1972 and diligent reintroduction and conservation efforts, we estimate the total global population to be 418,000, slightly higher than other recent estimates (e.g., Wetlands International 2012, Shields 2014). Nonetheless, this species remains highly susceptible to mortality due to pesticides, oiling, and natural and anthropogenic disturbances of nesting colonies. For example, the DWH Trustees estimated a loss of ~12,000–27,000 Brown Pelicans caused by the DWH spill (DWH NRDA Trustees 2016). The Brown Pelican is also the official “state bird” of Louisiana and thus has special cultural and management significance.

Royal Tern—We estimate that Louisiana’s breeding population of 50,000 Royal Terns represents ~51% of the breeding population of the nGOM, 30% of the breeding population of the eastern United States, and 26% of the global population of *T. m. maxima*. Louisiana has more breeding birds than any other state (by 15,000 birds) and is clearly the most important place worldwide for breeding populations of this species, which are concentrated in the southeastern United States. Thus, Louisiana’s population is critical to this species as a whole. Although the Royal Tern is not a species of global conservation concern, its total population is rather small (~191,350; Supplement). From 2,900 to 5,000 Royal Terns were killed by the DWH oil spill (DWH NRDA Trustees 2016).

Sandwich Tern—Along with the Royal Tern, with which it breeds sympatrically, nesting

Table 2. Breeding population abundance (number of breeding individuals, males and females) for selected bird species of the Louisiana coast and the proportion this represents of total population abundance at the scales of the nGOM, the eastern United States, and globally for each species. Species are listed in order of national importance of the Louisiana coastal zone breeding population (% eastern U.S. population in Louisiana). For species for which estimates are given as ranges, the midpoint is used here. For species in which the estimates are restricted to a single subspecies, the subspecies are listed next to the species name. See Supplement for all calculations.

Species	Estimated Louisiana population	Louisiana rank (vs. other nGOM states)	Louisiana's estimated contribution (%) to species' population abundance at each scale		
			nGOM	Eastern United States	Global
“Chandeleur Gull”	<50?	1	100%	100%	100%
Marsh Wren (subspecies <i>marianae</i>)	93,350	1	77%	77%	77%
Sandwich Tern (subspecies <i>acufavidus</i>)	75,000	1	83%	73%	70%
Seaside Sparrow	3,569,000	1	69%	55%	~55%
Mottled Duck	77,500	1	48%	40%	Unknown
Clapper Rail	884,000	1	67%	38%	Unknown
Willet (subspecies <i>semipalmatus</i>)	17,000	1	54%	35%	20%
Brown Pelican (subspecies <i>carolinensis</i>)	35,000	1	47%	33%	23%
Forster's Tern	7,500	1	71%	33%	15%
Wilson's Plover	2,550	1 ^a	43%	31%	9%
Royal Tern (subspecies <i>maxima</i>)	50,000	1	51%	30%	26%
Black Skimmer (subspecies <i>niger</i>)	10,000	1	44%	26%	10%
Tricolored Heron (subspecies <i>ruficollis</i>)	15,000	1	48%	24%	17%
Laughing Gull	100,000	2	33%	21%	12%
Boat-tailed Grackle	400,000	1	51%	20%	20%
Least Tern (subspecies <i>antillarum</i>)	6,000	2	28%	11%	Unknown
Reddish Egret	130	3	5%	4%	2%

^a Louisiana and Texas both have the highest abundance.

Sandwich Terns require sandy islands free of mammalian predators (Raynor et al. 2012b, Owen and Pierce 2014). We estimate that Louisiana's breeding population of more than 75,000 Sandwich Terns represents 73% of the breeding population of the United States and 83% of the nGOM population. Louisiana has by far the largest population of Sandwich Terns in any state, with about 6 times the population of Texas, the state with the second-highest population. Louisiana's population experiences dramatic fluctuations, making it difficult to determine long-term trends, which contributes substantially to great uncertainty in regional and global population estimates. The Chandeleur Islands supported the largest breeding colonies in the world during the 1980s and 1990s (Spendelov and Patton 1988, USFWS 2013), at least prior to recent hurricane damage to the islands (e.g., Katrina in 2005). As many as 46,613 nests were counted on a single island in the Chandeleurs (Stake Island; Purrington 1988) and over 90,000 nests in 1994 at Breton National Wildlife Refuge (NWR) before these islands were devastated by hurricanes. A nest count in 2011

detected over 70,000 Sandwich Tern nests at Breton NWR, about 5 times as many as any other count between 2005 and 2012 (USFWS 2013). Although the Sandwich Tern is not a species of global conservation concern, its total population is relatively small for a seabird. Up to 1,000 Sandwich Terns were killed by the DWH spill (DWH NRDA Trustees 2016), and Louisiana populations are likely critical to the population as a whole. Three subspecies exist: one in Europe, one in the southern Caribbean, and one that breeds in Mexico, Greater Antilles, and the United States, including in Louisiana, *T. s. acufavidus*; this subspecies is treated as a separate species (“Cabot's Tern”) by some (Sangster et al. 2011). Estimates of the population sizes of *eurygnatha* in the south Caribbean and South America are smaller than those for *acufavidus*, with 53,400–58,400 individuals, whereas Old World *sandvicensis* has 171,000–307,000 (Wetlands International 2012).

Black Skimmer—We estimate that Louisiana's breeding population of about 10,000 Black Skimmers represents about 26% of the breeding

population of the United States and 44% of that of the nGOM. Although not as high a percentage as the previous 3 species, at one time the largest single colony known was on East Timbalier Island (Clapp et al. 1983). Louisiana's population is higher than that of any other state. Like the previous 3 species, Black Skimmer is a Species of Greatest Conservation Need in Louisiana, and it is on the endangered or threatened lists of several other states. The species showed worrisome population declines in the United States through the 1970s but may have stabilized (Gochfeld and Burger 1994). Regional concerns continue following several years of low productivity on the central Texas coast (D. Newstead, pers. comm.) and elsewhere because of human disturbance and overwash events during tropical cyclones and other weather systems during the breeding season. Louisiana colonies are also prone to failure from overwash events (Owen and Pierce 2013). In addition, 1,500–2,700 Black Skimmers were killed by the DWH spill (DWH NRDA Trustees 2016). Therefore, the Black Skimmer was chosen as a focal species for the Gulf Coast Vulnerability Assessment, which focused largely on the effects of sea level rise and climate change (Watson et al. 2015). With a total population estimate of only ~39,000 birds in the United States, the population is small, which imparts an additional level of vulnerability. Unlike most other seabirds that rely on islands for nesting, the Black Skimmer may occasionally use urban rooftops and mainland beaches, although productivity may be reduced in such situations (Furfey 2014). Furthermore, small islands created from dredge material can rival large barrier island systems in meeting breeding habitat requirements for nest success (Mallach and Leberg 1999, Owen and Pierce 2013).

Laughing Gull—We estimate Louisiana's breeding population of Laughing Gulls to be ~100,000; this total is lower than that in Texas but higher than that in Florida (the other 2 main breeding concentrations in the nGOM). This represents about 33% of the Gulf and 21% of the eastern U.S. population (see Supplement). The Laughing Gull is not generally a species of conservation concern, and, in some circumstances, particularly where populations are increased by human influences, it may be advisable to reduce populations because the species is a nest predator of birds of conservation concern (Hunter et al. 2006). It

typically thrives in coastal areas with high human populations, where it takes advantage of anthropogenic sources of food such as refuse dumps, fisheries bycatch, and fish-cleaning operations. The Laughing Gull may be especially prone to oiling; it was the most frequently collected species during the DWH oil spill of 2010; 23,000–37,000 Laughing Gulls were killed by direct oiling or eliminated by reduced productivity through 2011 (DWH NRDA Trustees 2016).

“Chandeleur Gull”—The “Chandeleur Gull” is a hybrid swarm between Herring and Kelp gulls that has been present for ~20 yr on the Chandeleurs (Dittmann and Cardiff 2005). It is the only such swarm in the world (although a few breeding attempts have been noted in coastal Alabama; McConnell 2010) and potentially represents an important biological event, namely speciation through hybridization (Ottenburghs et al. 2016). Louisiana's population of “Chandeleur Gull” represents 100% of the world's known breeding population. Adults attending juveniles and active nests were observed by MAS, DAO, and JVR in the Chandeleurs in 2015.

Additional species—Louisiana islands also support breeding colonies of the Gull-billed Tern (*Gelochelidon nilotica*; ~800 individuals) and the Caspian Tern (*Hydroprogne caspia*; ~850 individuals), as well as some of the only breeding Common Terns (*Sterna hirundo*) in the nGOM (66 birds in 2015; Louisiana Natural Heritage Program [LNHP] data). Curlew Island in the Chandeleurs formerly supported (e.g., Purrington 1970) the only breeding population of Sooty Terns (*Onychoprion fuscatus*) in the United States other than those on the Dry Tortugas off Florida and locally the Texas coast. However, the Louisiana population effectively disappeared after Hurricane Georges ravaged Curlew Island in 1998; they have not recolonized, although one individual was observed at a nest scrape there in 2015 (MAS). Also, 3 nesting pairs were recently discovered in the Isles Dernieres in Terrebonne Parish (Raynor et al. 2012a).

Birds of coastal marshes

Here we define “coastal marsh” as the emergent wetland adjacent to the coastline. The marsh itself may be any of 4 categories (saline, brackish, intermediate, fresh) depending on its proximity to

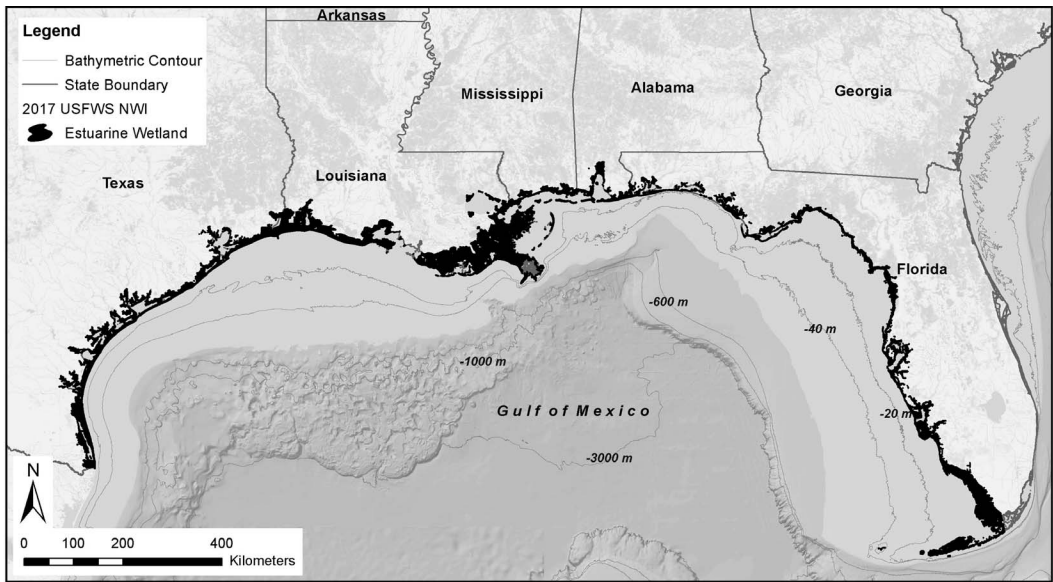


Figure 2. Extent of coastal marsh (black) in northern Gulf of Mexico.

freshwater outflow, especially the Mississippi and Atchafalaya rivers (Chabreck 1972, Sasser et al. 2013). Louisiana has one of the largest expanses of saline, brackish, and intermediate marshes of anywhere in the world, and the largest by far of any state in the eastern United States (Fig. 2), representing 46% of 2.3×10^6 ha of what we reference as “saltmarsh” in the conterminous United States (Stedman and Dahl 2008). Calculations of the acreage in Louisiana (from Sasser et al. 2013) are as follows: saline (~295,000 ha), brackish marsh (~404,000 ha), intermediate marsh (~380,000 ha), and fresh marsh (~387,000 ha). In this paper, we focus primarily on estuarine saltmarsh (saline, brackish, and intermediate marsh) because it supports 3 Species of Greatest Conservation Need in Louisiana that are saltmarsh specialists, although we did include coastal freshwater habitats used by Mottled Duck, *marianae* Marsh Wren, and Boat-tailed Grackle in total population estimates. Based on the National Wetlands Inventory (USFWS 2016) estimate of the area of estuarine saltmarsh habitat, Louisiana has 26% more saltmarsh than any other state (Florida is second) and 27% of the total saltmarsh area in the eastern United States.

Clapper Rail—Louisiana supports globally important populations of the Clapper Rail, a

species restricted to salt and brackish marshes. It is also a game bird in Louisiana, and so has direct economic importance in terms of hunter-generated revenue (Eddleman et al. 1988). Because this habitat is restricted to a narrow and patchily distributed linear strip along the coast, the total population of this habitat specialist is small. Based on extrapolations of published density estimates to extent of suitable habitat, we estimate that the Louisiana population of Clapper Rails is ~884,000 individuals (Supplement). Louisiana supports ~38% of all Clapper Rails in the eastern United States and 70% more individuals of this species than does any other state (Florida is second) because of the relatively large and continuous area of suitable habitat. Although our analysis focuses only on the eastern United States and nGOM population, the species as a whole breeds from Massachusetts to Mexico and the West Indies. The subspecies that breeds in Louisiana, *R. c. saturatus*, is found only in the nGOM, from Alabama to northeastern Mexico. Therefore, Louisiana has a very high percentage, probably at least 50%, of the global population of this subspecies.

Seaside Sparrow—This is one of only a few bird species that is nearly endemic to the United States. Because this species is almost identical in habitat requirements and range to the Clapper Rail,

the main difference in the calculations is in their relatively higher density. About 56% of the U.S. population occurs in Louisiana, with ~3.57 million birds (Supplement). Louisiana has about 4 times as many individuals as any other state (Texas is second) because of the large and continuous area of suitable habitat. Our calculations exclude *A. m. sennetti*, a rare and poorly known subspecies from south Texas and northeast Mexico; although this inflates Louisiana's importance, it does so only slightly, because the population of *A. m. sennetti* may number only in the tens of thousands. The subspecies that breeds in Louisiana, *A. m. fisheri*, is restricted to the north-central GOM, from Alabama to central Texas. Therefore, Louisiana has roughly 75% of the global population of this subspecies.

Mottled Duck—This species is largely restricted to coastal areas of the nGOM and the southern Atlantic Coast. As such, it has one of the smallest breeding ranges of any North American waterfowl species. In Louisiana, ~70% of the estimated population of Louisiana's 77,500 birds breed in coastal marshes, where found in marshes of all salinities (Supplement). We estimate that populations in coastal Louisiana marshes represent roughly 28% of the population in the United States and about 48% of the United States population of the western subspecies *A. f. maculosa*, which recent data suggest may be a separate species from the Florida population, *A. f. fulvigula* (McCracken et al. 2001).

Marsh Wren (subspecies *marianae*)—Although the Marsh Wren is widespread in North America, some of its subspecies have narrow, linear distributions along coastlines. One of those is *C. p. marianae*, found only on the coastline of the nGOM, from eastern Texas to central Florida, with the highest densities perhaps found in fresh to brackish marshes, where it occupies *Phragmites* and other tall, emergent vegetation (Kroodsma and Verner 2014). Because of its linear distribution, the total global population of this subspecies must be relatively small. Furthermore, in our experience, densities of *C. p. marianae* are much lower than those of subspecies of inland freshwater marshes away from the nGOM. Unfortunately, our estimates of total population size for this subspecies are very crude, relying on only a few available estimates of bird density and territory size in conjunction with the USGS Gap Analysis (USGS

2013) distribution model for this species, and balanced against PIFSC (2013) estimates. Nevertheless, we estimate that Louisiana has roughly 93,350 individuals, which represents ~77% of the world population of this subspecies.

Boat-tailed Grackle—Like the Seaside Sparrow, the Boat-tailed Grackle is one of only a few bird species that is endemic to the United States, where it breeds from Connecticut (Mantlik et al. 1998) to eastern Texas. Although common within most of its range, often thriving in areas affected by humans, its total world population is relatively small because of its linear, coastal distribution. Population estimates are difficult because the species is colonial or semi-colonial and are only available through the PIFSC (2013) database, which estimates 400,000 individuals in Louisiana, about 22% of the world population. Louisiana's population is second only to Florida, which is likely the core of the species' distribution, with 66% of the world population. Thus, other states contribute relatively little to the world population. The subspecies that breeds in Louisiana, *Quiscalus major major*, is found only in Louisiana and eastern Texas. We estimate that Louisiana supports 82% of this subspecies' population.

Additional species—Non-focal species that are not coastal marsh specialists but that have substantial breeding populations in that habitat are the Pied-billed Grebe (*Podilymbus podiceps*), the Common Gallinule (*Gallinula galeata*), the Least Bittern (*Ixobrychus exilis*), the Common Yellowthroat (*Geothlypis trichas*), the Red-winged Blackbird (*Agelaius phoeniceus*; mostly in *Phragmites*), and the Orchard Oriole (*Icterus spurius*; primarily in *Phragmites*). Also, the Green Heron (*Butorides virescens*) nests in coastal marshes, sometimes in high densities, and uses this habitat extensively for foraging during the breeding season (Folkerts 2015).

Birds of other nearshore habitats

Here we define "nearshore habitat" as the area extending from the outer edge of the marsh to the seaward edge of the continental shelf waters. Therefore, it includes mudflats at the marsh's edge, pools and channels within the marsh, beaches, estuaries, and Gulf waters from the beach line to the continental shelf. Note that most of the species in the "Colonial-nesting waterbirds of coastal

islands” section above feed in these habitats. Therefore, this section concentrates on the species that do not require islands for nesting.

All bird species that nest in the island colonies (see “Colonial-nesting waterbirds of coastal islands” section above) feed in Louisiana’s near-shore waters and are prominent members of the shoreline ecosystem. The islands would be useless for breeding unless embedded in a matrix of healthy and productive nearshore habitat to support the energetic demands associated with successful nesting (Liechty et al. 2016). The productivity of this nearshore habitat is also important to colonial island-nesters for post-breeding habitat for molting and pre-migratory fattening for migratory species (e.g., Sandwich Tern) and for year-round nonbreeding habitat for the permanent residents.

In addition to the colonial nesters on islands, Louisiana’s nearshore habitats support nationally important populations of the following species, almost all of which also breed to some extent on islands.

Reddish Egret—Because of the linear nature of this species’ habitat and the constant loss or disturbance of such habitat throughout its range, the Reddish Egret is the rarest heron species in the United States; the Reddish Egret Working Group believes that the world population consists of only 5,000–7,000 individuals (Wilson et al. 2014). It is the only heron in the Western Hemisphere restricted to the immediate coast and is a critically imperiled resident of the narrow strip of coastal habitat in Louisiana. This egret nests within colonies of other species of herons, usually on islands, and feeds primarily in clear shallow waters with hard bottoms adjacent to coastal marsh. We estimate that Louisiana has ~130 breeding birds (~4% of the U.S. breeding population of 3,000 birds). As many as 40 Reddish Egrets were killed by the DWH oil spill (DWH NRDA Trustees 2016), which would represent about 28% of the Louisiana and Alabama population combined (see Supplement).

Wilson’s Plover—The Wilson’s Plover breeds in a narrow linear zone of habitat along the coast where beaches meet areas with some vegetation cover; this habitat has undergone dramatic losses over the last several decades because of beach development and increased human use of beaches for recreation (Zdravkovic 2013). Louisiana’s

estimated 2,550 breeding birds represents ~31% of the U.S. breeding population and 43% of the nGOM population. No other state except perhaps Texas has more breeding Wilson’s Plovers, and Louisiana has 2 of the 4 sites ranked as Globally Important by Zdravkovic (2013). The U.S. Shorebird Conservation Plan lists this as a Species of High Concern, and it appears to be experiencing a population decline in the United States (Andres et al. 2012). Because of the linear nature of this species’ habitat, the total world population is undoubtedly very small despite the large geographic range. Zdravkovic (2013) suggested a global population of only ~29,000 birds, which would mean that Louisiana’s population represents 9% of the global population.

Forster’s Tern—Virtually all of Louisiana’s population of the Forster’s Tern breeds in the coastal zone, and a substantial but unknown percentage of that population forages in nearshore waters and nests in places such as spoil banks adjacent to the coast. Wrack lines within marsh islands are clearly favored based on LNHP aerial surveys (MAS). The Louisiana population represents about 17% of the national population and 71% of the nGOM population; thus, Louisiana is certainly one of the most important states for this species.

Willet—The coastal subspecies (*Tringa s. semipalmata*) of the Willet is narrowly distributed along the Gulf and Atlantic coasts and may be a separate species from the more widespread interior form (*T. s. inornata*) (see Oswald et al. 2016). It requires a mix of salt or brackish marsh and vegetated beach for nest sites and mudflat and beach for feeding. The percentage of the world population that breeds in Louisiana is unknown, but is likely substantial because so much of the Louisiana coast is suitable breeding habitat (in contrast to the scarcity of marsh on the coastlines of so many other states). Andres et al. (2012) suggested a global (U.S. and Canada) population of ~90,000 birds for *T. s. semipalmata*. Morrison et al. (2001) suggested that 10% of the North American Willet population is in Canada (which likely includes *T. s. inornata*), but Erskine’s (1992) census data of coastal *T. s. semipalmata* suggests that the proportion of this subspecies’ population in Canada is closer to 2%. An unknown portion of the population also breeds in the Bahamas and Greater Antilles, but we assume that it is about

40% based on crude comparisons of extent of coastlines. Thus, the same crude assumptions suggest roughly 55% of the population is in the United States. Although population densities are not readily available, we calculated a suitable habitat area of 2.6×10^6 ha from Maine to Texas, suggesting an average of 0.19 birds/ha across the range if using the Andres et al. (2012) population estimate. This would translate to about 17,000 birds in Louisiana. Wiest et al. (2016) estimated 117,000 Willets (95% CI = 88,000–146,000) from Delaware Bay to northern Maine based on long-term point-count data, about 15 times higher for the region than expected based on Andres et al.'s (2012) population estimate. Considering this discrepancy, it is possible that by extrapolating estimates reported by Wiest et al. (2016), Louisiana may support as many as 256,000 Willets, over an order of magnitude higher than the estimate based on Andres et al.'s (2012) global population estimate; this discrepancy requires further research. To be conservative, we used Andres et al.'s (2012) estimate.

Least Tern—Louisiana's Least Tern populations consist of a coastal breeding population (*S. a. antillarum*) and a much smaller interior population (*S. a. athalassos*) that is federally endangered and breeds on river islands along the Mississippi, Red, Missouri, and other rivers. The former nests in colonies primarily on the mainland coast in areas with extensive sandy beaches and overwash fans, making it a classic early successional species that relies mainly on recent disturbance rather than isolation to reduce predation pressure on nesting success. Thus, in many ways, its nesting habitat is more limited (and much more vulnerable to human disturbance) than that of species restricted to islands. We estimate that Louisiana has roughly 6,000 breeding birds (~11% of the Atlantic/nGOM breeding population).

Tricolored Heron—Although the Tricolored Heron breeds to varying degrees inland, the center of abundance is in coastal areas. We estimate that Louisiana has 15,000 breeding birds, which represents roughly 24% of the U.S. breeding population and 48% of the nGOM population. Tangentially, this adds validity to the original English name for this species, Louisiana Heron, which was in universal use until 1982. This species appears to have experienced a substantial decline in Louisiana since the 1970s, when

Louisiana's coastal marshes contributed to about 72% of the United States population (Portnoy 1977, Frederick 2013). Although modest population increases since the 1970s have occurred along the Atlantic, this has not offset substantial declines in the nGOM (Supplement).

Additional species—Other species of herons, ibises, and waterbirds commonly nest in colonies along the coast, often in wooded nearshore islands (thus some populations could be included in "Colonial-nesting waterbirds of coastal islands" section above), but they also have substantial inland breeding populations (Michot et al. 2003).

Importance of coastal Louisiana for nonbreeding birds

Although this paper focuses only on the bird species more or less restricted to Louisiana's coast, it is obvious to any naturalist who has visited Louisiana that, during migration and winter, coastal habitats also support exceptionally high numbers of shorebirds, waterfowl, and other waterbirds that depend on this ecosystem. Therefore, in this section, we discuss the importance of coastal Louisiana to wintering and migratory bird species.

Wintering birds—Population estimates for the most common wintering waterfowl in the Southeast Zone of Louisiana only (based on the 3 most-recent years of Louisiana Department of Wildlife and Fisheries [LDWF] surveys) are as follows: Gadwall (*Anas strepera*; 506,000), Ring-necked Duck (*Aythya collaris*; 241,000), Green-winged Teal (*Anas crecca*; 206,000), Lesser Scaup (*Aythya affinis*; 162,000), Canvasback (*Aythya valisineria*; 84,000), Northern Pintail (*Anas acuta*; 69,000), Blue-winged Teal (*Anas discolor*; 30,000), American Wigeon (*Anas penelope*; 19,000), Northern Shoveler (*Anas clypeata*; 14,000), and Mallard (*Anas platyrhynchos*; 14,000).

In addition to wintering waterfowl, coastal Louisiana provides habitat for several species of migratory and wintering shorebirds. More than 10,000 ha of (nonbreeding) Critical Habitat has been designated in Louisiana for the federally Threatened and Endangered Piping Plover (*Charadrius melodus*). The average annual count of nonbreeding Piping Plovers in Louisiana is ~250 individuals (LNHP, unpublished data from 1991 to 2014; 11 survey years; high count of 750 in 1991).

Because the geographic extent of surveys varied greatly year to year, typically at the expense of the Chandeleur Islands, actual populations are likely much higher than the averages given. For example, in 1991, almost half of the 750 birds were detected in the Chandeleurs (LNHP, unpublished data). Population estimates are not yet available for other shorebirds (Charadrii), but are likely in the 10,000–100,000 range for the Dunlin (*Calidris alpina*), the Sanderling (*C. alba*), the Western Sandpiper (*C. mauri*), and the Short-billed Dowitcher (*Limnodromus griseus*); and in the 1,000–10,000 range for the Semipalmated Plover (*Charadrius semipalmatus*), the Black-bellied Plover (*Pluvialis squatarola*), the American Avocet (*Recurvirostra americana*), the Least Sandpiper (*Calidris minutilla*), the Red Knot (*C. canutus rufa*; federal status = Threatened; Endangered status under evaluation), and the Marbled Godwit (*Limosa fedoa*).

Other bird species also rely on coastal Louisiana for wintering habitat. A substantial proportion of the U.S. population of the American White Pelican (*Pelecanus erythrorhynchos*) may winter in near-shore habitat in Louisiana, and the Louisiana coast also may harbor important wintering populations of the Common Loon (*Gavia immer*). A high proportion of the U.S. population of the formerly Endangered Peregrine Falcon (*Falco peregrinus*) almost certainly passes through the Louisiana coast during migration, and perhaps hundreds overwinter there. Our preliminary calculations of wintering populations of the Nelson's Sparrow (*Ammodramus nelsoni*) indicate that a substantial percentage of the world's population winters in Louisiana coastal marshes. In winter and spring, the offshore waters support a fairly large population of the Northern Gannets (*Morus bassanus*) from eastern Canadian breeding grounds (Montevocchi et al. 2012).

Migratory birds—Louisiana's Gulf Coast is legendary for its abundance and diversity of migratory birds (Lowery 1974). For bird species migrating to and from their tropical wintering grounds, the Louisiana coastline provides critical stopover habitat (Gauthreaux 1992, Moore et al. 1993, Dobbs et al. 2009). Aquatic habitats along the coast support large numbers of migratory sandpipers, plovers, waterfowl, terns and gulls, and herons (e.g., Withers 2002, Curtis and Pierce 2016); although census data are not available,

these transient populations likely number in the hundreds of thousands to, in some cases, millions of individuals. A substantial percentage of North America's migratory Peregrine Falcons and Merlins also feed on these migratory waterbirds as they make their way to and from wintering grounds along the coast.

The first wooded habitats inland from the immediate coast in the nGOM may be the most important stopover habitat in the world for migratory landbirds (Mehlman et al. 2005, Cohen et al. 2017). The abundance and richness of migrant landbird species that rely on these rare and imperiled coastal woodlands (i.e., cheniers and maritime forest) and coastal shrub–scrub are well known. Each day during spring, one million or more individual birds of up to ~100 species use this habitat for refueling and resting during migration (Gauthreaux 1971). The maritime forests provide critical refueling habitat for migrating landbirds (e.g., Moore et al. 2005). The persistence of these vital habitats depends on the adjacent coastal marsh and beach for buffering them from salt spray, storm surge, saltwater intrusion, and erosion; these habitats also depend upon adoption of sustainable use, particularly by those who graze livestock.

Discussion

The MRD, which is entirely contained within Louisiana's borders, supports the largest area of coastal marsh in North America and one of the largest in the world (Coleman and Huh 2004, Couvillion et al. 2017). Consequently, the richness and abundance of birds that inhabit coastal marsh is matched nowhere in the United States. This paper represents the first attempt to compile available data on a wide range of birds that breed in coastal Louisiana and to put those comprehensive population estimates in regional, national, and global contexts. Our results demonstrate that Louisiana's contribution to these species is significant: the state hosts up to two-thirds of the regional and global abundance of some species. We also outline the importance of the Louisiana coast to a broader range of nonbreeding birds as well.

Our estimates document the exceptional value of Louisiana's coastal zone to the overall abun-

dance of several bird species across taxonomic groups. This is especially important because the Louisiana coast, particularly the deltaic portion, is subject to major natural and anthropogenic threats. Land loss due to subsidence, sea level rise, and erosion, coupled with the significant reduction of natural sediment deposition from the channelization and flood control and navigation projects of the Mississippi River, has dramatically decreased the areal extent of habitats (CPRA 2012). The development of roads, canals, and other infrastructure has further accelerated land loss and saltwater intrusion by altering the coastal hydrology and patterns of sediment deposition (Boesch et al. 1994). In addition to the catastrophic consequences of major oil and chemical spills, such as the DWH oil spill, the omnipresent potential for pollution and contamination of the coast because of the proliferation of industrial activities make the entire ecosystem vulnerable to chronic low-level perturbation (CPRA 2012, DWH NRDA Trustees 2016). Formation of hypoxic zones off the coast due to allochthonous inputs of nutrients and chemicals from the Mississippi River further endangers the integrity of the coastal ecosystems (Rabalais et al. 2001, 2002). The major international shipping traffic to and from the ports of New Orleans, Baton Rouge, and elsewhere through the Mississippi River represents an additional array of chronic anthropogenic disturbances with direct and indirect negative consequences for Louisiana's coastal ecosystems. Therefore, the geographic overlap of these human activities with the presence of some of the most important bird populations in the United States creates a volatile situation that requires long-term monitoring and dynamic management. In addition, already high rates of both natural and anthropogenic subsidence, coupled with chronic sediment starvation, make coastal Louisiana especially vulnerable to sea level rise driven by climate change. For these reasons, management actions in Louisiana should be designed to safeguard or restore bird habitats, which, as shown herein, will have significant implications for the rest of the nGOM and beyond.

Several logical "next steps" emerge clearly from our examination of coastal bird populations in the MRD. Most obviously, refined population estimates and improved survey techniques are badly needed. Use of improved and standardized monitoring protocols is needed among states to

identify broad-scale shifts in populations to facilitate conservation planning and prioritization processes. Development of processes to quantify threat levels at the most crucial nesting sites would also benefit conservation planning and aid in the interpretation of population changes.

Although the accuracy of our estimates requires further refining, we predict that the general finding concerning the pivotal position of Louisiana for the population health of coastal bird species will remain robust. Therefore, Louisiana and federal agencies managing birds, habitats, and ecosystem health must recognize their tremendous responsibility for managing these species to sustain regional and global populations. The threats to these species are many, especially habitat loss because of coastal erosion and rising sea levels; these are exacerbated by other anthropogenic effects such as oil spills (e.g., DWH oil spill; DWH NRDA Trustees 2016). Louisiana's 50-year, \$50 billion Coastal Master Plan (CPRA 2012) offers a comprehensive approach to restore Louisiana's coastline for protecting human communities and providing wildlife and fisheries habitat. Although the conservation and restoration activities outlined therein for barrier islands, coastal shorelines, and coastal marshes are paramount, to maximize benefits to bird populations, additional strategies should be included that seek to reduce human disturbance, to decrease exposure and vulnerability to oil spills and pollution, and to control populations of predators and invasive species. Furthermore, restoration and creation of small, isolated, predator-free bay islands, not included in the plan because of their high cost for small land areas, are especially important for many colonial waterbird and seabird species (e.g., Wine Island, Terrebonne Parish; Raynor et al. 2012b, Curtiss and Pierce 2016). Beneficial use of dredged material could opportunistically create these habitats to minimize the costly need to stabilize or rebuild existing islands (Leberg et al. 1995). The DWH NRDA Trustees (2016) Programmatic Damage Assessment and Restoration Plan indicated that over \$400 million are allocated to fund these restoration approaches designed to restore the loss of avian species across the nGOM. These and other funding mechanisms (e.g., RESTORE Act, Gulf Environmental Benefit Fund administered by National Fish and Wildlife Foundation) represent important opportunities to

ensure healthy bird habitats in Louisiana and the rest of the nGOM.

Ultimately, a suite of conservation strategies, coupled with monitoring and adaptive management of the most critical or sensitive sites, are crucial to sustain these regionally and globally important nesting populations. The estimates that we provide should be a useful resource to managers and decision-makers in the near- and long-term future.

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