Changes in Waterfowl Abundance and Species Composition on Louisiana Coastal Wildlife Management Areas and Refuges 2004–2016

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Abstract: Aerial waterfowl surveys are conducted on major wintering areas to provide regional population indices and determine habitat use of non-breeding waterfowl. Coastal Louisiana supports more than one quarter of the continental dabbling duck population during winter. Thus, considerable effort is allocated to monitoring waterfowl abundance in coastal Louisiana with implications for future waterfowl habitat management in the region. We conducted monthly surveys on nine state-owned coastal wildlife management areas and refuges, November–January 2004–2016. Across all sites and survey years, the most commonly observed species were gadwall (*Mareca strepera*), green-winged teal (*Anas crecca*), and mallard (*Anas platyrhynchos*). Despite increases in continental breeding population indices to near record highs, their populations were stable region-wide in coastal Louisiana, with minor declines on some heavily-hunted and unmanaged areas. In contrast, northern pintail (*Anas acuta*) experienced a precipitous decline region-wide and on four of the nine major wintering areas surveyed. We hypothesize that this decline is related to changes in coastal and agricultural habitats. Diving duck populations tended to be increasing or stable: lesser scaup (*Aythya affinis*) increased on two areas, and ring-necked ducks (*Aythya collaris*) increased substantially on one area, perhaps because of increases in water depth from increased rainfall and changes in water management capacity on these areas. Our results demonstrate the utility of aerial surveys for monitoring waterfowl populations and documenting important trend data for commonly observed species. We also pose hypotheses about habitat change to help guide future analyses and coastal waterfowl management.

Key words: aerial survey, Chenier plain, deltaic plain, long-term dataset, population monitoring, wintering waterfowl

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The conservation of North American waterfowl (Anatidae; ducks, geese, and swans) is widely recognized as a premier example of a science-based wildlife management program (U.S. Department of Interior, North American Waterfowl Management Plan 2012). To set continentally sustainable harvest regulations and identify priority areas for conservation delivery, biologists routinely conduct aerial surveys to index waterfowl populations and habitats (Pearse et al. 2008). For example, the longest-running wildlife survey in North America is the waterfowl breeding population and habitat (BPOP) survey, which has been conducted annually since 1955 in conjunction with the U.S. Fish and Wildlife Service (USFWS), Canadian Wildlife Service, State Wildlife Management Agencies (SWMA), and others. The primary purpose is to provide information on spring breeding population size and trajectory for certain North American duck species (Smith 1995). These data are used extensively in the establishment of annual hunting regulations in the United States and Canada and to provide a robust time-series of data used to better understand bird-environment relationships that are critical to effective conservation planning (Smith 1995).

In addition to the BPOP survey, the USFWS in cooperation with many SWMA participates in conducting annual mid-winter waterfowl surveys. The mid-winter waterfowl survey is a landscape-level effort to survey waterfowl in areas of major concentration on their wintering grounds and provides information about distributions and habitat affiliations (Eggeman et al. 1989). This survey also serves as a primary source of data on population trends for some species (e.g., most geese; tribe Anserini) that breed in remote Arctic locations outside of the BPOP survey area (Sharp et al. 2002). Additionally, SWMA conduct other wintering waterfowl surveys to assess habitat conditions and waterfowl abundance on state-owned public areas. Management for wintering waterfowl is based on providing sufficient foraging habitat for target population sizes. Therefore, understanding the spatio-temporal distribution of ducks on the landscape is of paramount importance for targeting management actions (Esslinger and Wilson 2001). Wintering waterfowl abundance and distribution can be affected by numerous factors including food quantity and quality (Miller et al. 2009, Dalby et al. 2013), weather (Nichols et al. 1983, Hepp and Hines 1991, Schummer et al. 2010), ice cover (Ouellet et al. 2010), interspecific competition (DuBowy 1988), and hunting and other disturbances (St. James et al. 2013).

Louisiana's coastal wetlands comprise one of the most important waterfowl wintering areas in the United States (Michot 1996). One quarter of the North American dabbling duck population (Palmisano 1973) and two-thirds of the Mississippi Flyway waterfowl population historically wintered in coastal Louisiana (Bellrose 1990). Waterfowl species wintering in Louisiana commonly targeted by hunters or that are of conservation concern include green-winged teal (*Anas crecca*), gadwall (*Mareca strepera*), northern pintail (*Anas acuta*), and resident mottled duck (*Anas fulvigula*). These species rely on coastal wetlands that consist of diverse marsh types that differ in their functional roles for waterfowl (Chabreck 1989), including fresh, intermediate, brackish, and saline marsh. In general, dabbling ducks typically select shallow (<30 cm) fresh and intermediate marsh types whereas diving ducks (*Aythya* spp.) select deeper (>30 cm) brackish and saline marsh (White and James 1976), all of which occur across the diverse landscape of Louisiana coastal marsh.

From 2004–2016, coastal Louisiana experienced a wide array of natural and anthropogenic events (e.g., oil spills, hurricanes, tropical storms, oil/gas exploration), that forever altered the coastal Louisiana marsh ecosystems. Conservation planners and managers must understand how these natural and anthropogenic events have affected migrating and wintering waterfowl abundance and distribution in coastal Louisiana because millions of waterfowl rely on coastal marsh as wintering habitat. Further, understanding the current trajectories of these species may influence future management decisions. Our objective was to use data from aerial surveys to estimate abundances, species composition, and population trends of ducks using coastal Louisiana wildlife management areas (WMAs) and refuges during winter 2004–2016 by comparing annual spatio-temporal changes in waterfowl abundance and species composition.

Study Area

Aerial surveys were flown within coastal Louisiana from the southwestern Louisiana Chenier Plain region to the deltaic region at the mouth of the Mississippi river in southeast Louisiana. Aerial surveys were conducted on nine different sites encompassing approximately 225,000 ha. Our survey sites included Atchafalaya Delta WMA, Marsh Island Refuge, Pass-a-Loutre WMA, Pointe-Aux-Chenes WMA, Rockefeller Wildlife Refuge, Salvador WMA, State Wildlife Refuge, Wax Lake Delta, and White Lake Wetlands Conservation Area (Figure 1). These areas comprise state-owned

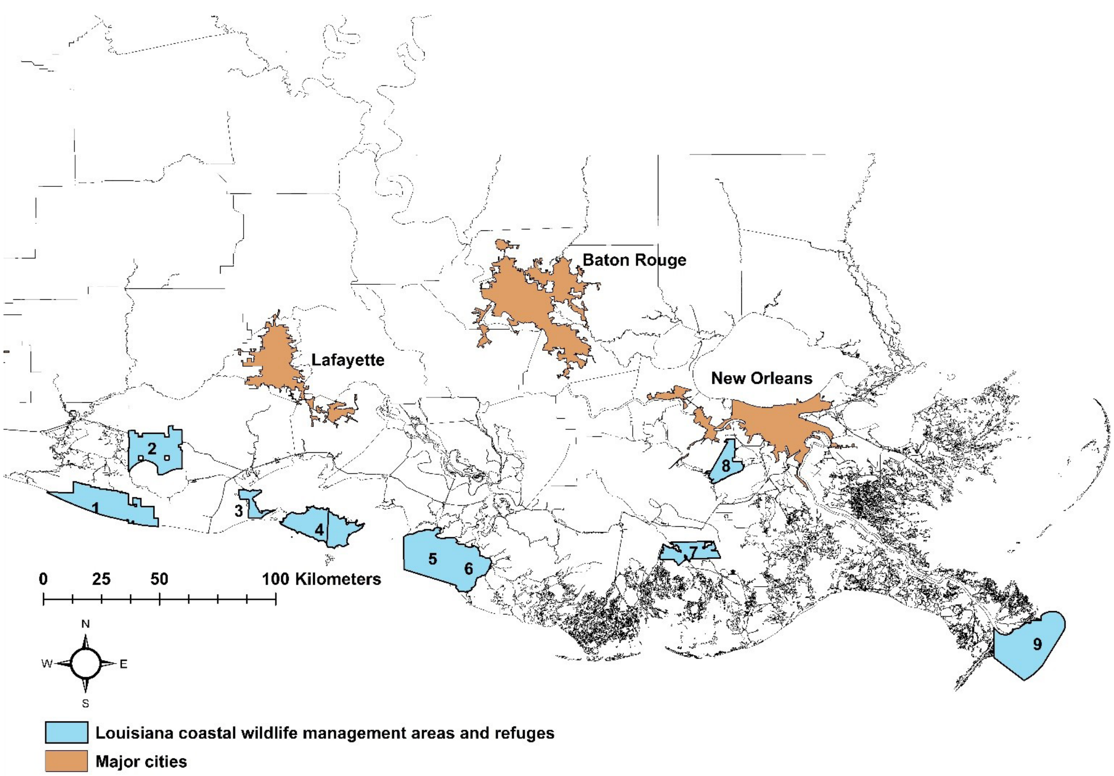

Figure 1. Louisiana state-owned wildlife management areas and refuges surveyed for waterfowl using fixed-winged aerial survey techniques from 2004–2016. 1) Rockefeller Wildlife Refuge; 2) White Lake Wetlands Conservation Area; 3) State Wildlife Refuge; 4) Marsh Island Wildlife Refuge; 5) Wax Lake Delta; 6) Atchafalaya Delta Wildlife Management Area; 7) Pointe-Aux-Chens Wildlife Management Area; 8) Salvador Wildlife Management Area; 9) Pass-A-Loutre Wildlife Management Area.

Table 1. Louisiana state-owned wildlife management areas (WMA) and refuges and associated habitat types.

Location	Area (ha)	Habitat type[a]
Atchafalaya Delta WMA	49,653	80% fresh 20% intermediate
Marsh Island Refuge	28,733	45% intermediate 45% brackish 10% saline
Pass-A-Loutre WMA	46,539	40% fresh 60% intermediate 10% brackish
Pointe-Aux-Chenes WMA	13,552	20% fresh 50% intermediate 30% brackish
Rockefeller Wildlife Refuge	28,733	30% fresh 40% intermediate 30% brackish
Salvador WMA	13,970	100% fresh
State Wildlife Refuge	5,261	45% intermediate 45% brackish 10% saline
Wax Lake Delta	6,070	80% fresh 20% intermediate
White Lake Wetlands Conservation Area	29,099	100% fresh

a. fresh = 0–2 ppt; intermediate = 2–5 ppt; brackish = 6–15 ppt; saline = 15+ ppt

wildlife property south of Interstate Hwy 10 in Louisiana, which is considered the coastal zone for purposes of Louisiana waterfowl hunting regulations. Three of these areas (Rockefeller Wildlife Refuge, State Wildlife Refuge, and Marsh Island Refuge) provide no hunting opportunities and serve solely as waterfowl sanctuaries for wintering and resident waterfowl. The remaining six areas (Atchafalaya Delta WMA, Pass-a-Loutre WMA, Pointe-Aux-Chenes WMA, Salvador WMA, Wax Lake Delta, and White Lake Wetlands Conservation Area) provide recreational waterfowl hunting. These nine areas support wetland habitats that range from entirely fresh water marshes (<0.5 parts per thousand salinity) to saline wetland habitat (>15 PPT) (Table 1).

Coastal Louisiana experiences relatively mild winters (November–January range: 4º–26º C) with variable precipitation (13–18 cm/month). The arrival of waterfowl to Louisiana can vary based upon the severity of winter weather in Louisiana and especially regions further north (Schummer et al. 2017). Obligate migrants rely primarily on changes in photoperiod and migrate in anticipation of changes in environmental conditions (Winkler 2005), whereas facultative migrants move based on current environmental conditions, (e.g., winter storms) and in many cases, only a portion of a population may move (Able 2004, Winkler 2005, Schummer et al. 2010). Blue-winged teal (*Spatula discors*) are considered obligate migrants and are the first of the migratory waterfowl species to arrive on Louisiana's coastal marsh, some as early as late August (Van Den Elsen 2016). Other species arrive later in Autumn as they are considered facultative migrants: northern pintail typically arrive after blue-winged teal, followed by other species that are more tolerant of cold, snow, and ice cover such as lesser scaup (*Aythya affinis*), green-winged teal, and mallard (*Anas platyrhynchos*) (Winkler 2005 & Schummer et al. 2010).

Methods

We conducted monthly aerial waterfowl surveys on coastal refuges and WMAs during the months of November, December, and January. This survey is flown in addition to an annual mid-winter aerial survey. We conducted November surveys one week prior to the opening weekend of waterfowl hunting season in Louisiana's coastal zone area. We conducted the December survey during the first week of the split (typically the first two weeks of December when there is no hunting), and the January survey was flown the last week of the hunting season. All surveys have been flown annually since 2004 during these same time periods, with minimal variation due to weather and airplane scheduling/availability/maintenance. Surveys were flown in a Louisiana Department of Wildlife and Fisheries department-owned-and-operated fixed-winged aircraft (Cessna 206 on floats or a Cessna 210 on wheels). Surveys were flown at an altitude of ~47 m and at a ground speed of ~90 knots (Bowman 2014). A navigator sat in the right-front seat and used a GPS-enabled laptop with ArcGIS 9.1 to guide the pilot along established survey routes. Waterfowl observers sat in the left-rear and right-rear seats and counted waterfowl observed at a distance of approximately 60 m away from the aircraft on their respective side. Surveys were not flown in adverse weather conditions (e.g., fog, heavy rain/thunderstorms, ice, or wind speed in excess of 25 knots). Correctly identifying species or counting birds in flocks during these low-level flights is extremely challenging and requires adequate training (Bowman 2014). Therefore, we typically employed the same observers and navigators to remain consistent throughout the survey.

Survey Design

Five of the nine areas were surveyed using aerial transect lines that were randomly selected to extend from coastal areas inland to encompass a gradient of salinities, marsh types, and waterfowl species (Bowman 2014): Rockefeller Wildlife Refuge, White Lake Wetlands Conservation Area, Marsh Island Refuge, Pointe-Aux-Chenes WMA, and Pass-A-Lourtre WMA. Observers counted waterfowl in a known area on either side of the aircraft (see above), and we used expansion factors based on the size of the impoundment/marsh to estimate the total abundance of waterfowl (Reinecke et al. 1992).

The remaining four areas (State Wildlife Refuge, Atchafalaya Delta WMA, Salvador WMA, and Wax Lake Delta) were surveyed using aerial cruise methods (Sharp et al. 2002). During a cruise survey, the aerial crew determines the best and most practical means to conduct a complete count of all waterfowl within a predefined unit area (Sharp et al. 2002). While they have been criticized for lack of sampling design and estimates variance (Eggeman and Johnson 1989, Reinecke et al. 1992), cruise survey methods are the primary survey style of many mid-winter surveys within the southern and mid-latitude states (Sharp et al. 2002) and the resulting population estimates have been shown to be similar to transect surveys (Ringelman et al. 2018). We did not shift between transect to cruise or vice versa at any site during our study.

Data Analysis

Some surveys began one afternoon and were completed the next morning, and so we summed the waterfowl counted on those two dates. We summed across survey units/transects within a site to get a total waterfowl count at each site for each month. Our objective was to compare annual spatio-temporal changes in waterfowl abundance and species composition. For each site, we averaged waterfowl counts across November, December, and January surveys to obtain a point estimate of species-specific abundance for each site-year (Ringelman et al. 2018). We did not calculate duck-use days on refuge areas because we lack even rough migration chronologies for sites in Louisiana (Ringelman et al. 2018). Several species of ducks were never abundant in surveys and were excluded from further analysis: bufflehead (*Bucephala albeola),* black-bellied whistling-duck (*Dendrocygna autumnalis*), blue-winged teal, redhead (*Aythya americana*), ruddy duck (*Oxyura jamaicensis*), and wood duck (*Aix sponsa*). To be included in the analyses presented here, a species must have been present at levels >10% relative abundance at a given site (in any year).

We used linear regression with a Gaussian error structure to evaluate temporal trends in duck abundance 2004–2016. Poisson or quasipoisson regression models often used for count data were inappropriate because they impose structure on the data that did not exist after consolidating survey data to point estimates as described above. As such, best-fit regression lines and confidence intervals often extended below zero across the observed span of years. Regression coefficient values can be difficult to interpret, so to underscore important changes in duck abundance, we also describe how (average) populations changed from the earliest three-year period in our sample (2004–2006) to the most recent three years (2014–2016). All analyses were run in Program R (R Core Team 2012). Duck species included in the analysis included green-winged teal, American wigeon (*Mareca americana*), canvasback (*Aythya valisineria*), gadwall, lesser scaup, mallard, mottled duck, northern pintail, northern shoveler (*Spatula clypeata*), and ring-necked duck (*Aythya collaris*). Geese were not included in the analysis due to relatively low abundance at many study sites.

Results

Across all sites and survey years, the most commonly observed species (mean annual abundance averaged across sites ± standard deviation) were dabbling ducks, especially in southwestern Louisiana: gadwall were most numerous (10,417 ± 4,392), followed by green-winged teal (5,569 ± 1,783), mallard (3,309 ± 1,258), northern pintail (3,104 ± 2,176), and northern shoveler (1,020 ± 438). American wigeon (217 ± 200) and resident mottled ducks (337 ± 184) were uncommon across all sites and years. Diving ducks were generally observed in lower numbers than dabblers and were more common at sites in southeastern Louisiana. Across the region, lesser scaup were the most numerous (1,417 ± 3,521), followed by ring-necked duck (983 ± 904), and canvasback (511 ± 364). Annual average species counts and relative abundance values can be found in Table 2.

Dabbling duck population trends

Between 2004–2016, gadwall populations were stable region-wide (Table 3), but experienced declines on Salvador WMA in southeastern Louisiana, as well as Atchafalaya Delta WMA and the adjoining Wax Lake Delta in southwestern Louisiana (Table 3, Figure 2). However, given their large regional distribution among wetlands, gadwall were never present in large numbers at those three sites: the most substantial decline was at Wax Lake Delta, where gadwall declined from an average of 4,282 ± 2,266 ducks in 2004–2006 to 1,299 ± 923 ducks in 2014–2016. Mallards were also stable region-wide (Table 3), and while they showed substantial declines (Table 3; Figure 3) at Atchafalaya Delta (2,101 ± 197 to 130 ± 84) and Wax Lake Delta (3,690 ± 1,535 to 1,034 ± 1,542), the major wintering area for Mallards in coastal Louisiana has always been and continues to be White Lake Wetlands Conservation Area (~23,000 mallards observed annually). Northern pintail on the other hand, declined precipitously region-wide and at nearly all sites (Table 3; Figure 4). Mean abundances 2004–2006 to 2014–2016 decreased at Pass-A-Loutre WMA (12,889 ± 5,534 to 932 ± 615), White Lake Wetlands Conservation Area (12,483 ± 10,614 to 1,914 ± 2,925), Wax Lake Delta (7,594 ± 3,220 to 199 ± 302) and the adjacent Atchafalaya Delta WMA (479 ± 179 to 18 ± 29). Rockefeller Wildlife Refuge is the only site surveyed that maintained a large, stable population of northern pintail (Table 3; Figure 4). Northern shoveler were relatively stable regionwide with the exception of Rockefeller Wildlife Refuge (decline from 6,681 ± 2,359 in 2004–2006 to 2,890 ± 1,642 in 2014–2016) (Table 3; Figure 5). Green-winged teal

Table 2. Average population counts and relative proportional abundance of ducks counted on Louisiana state-owned wildlife management areas and refuges, 2004–2016. AGWT (green-winged teal), AMWI (American wigeon), CANV (canvasback), GADW (gadwall), LESC (lesser scaup), MALL (mallard), MODU (mottled duck), NOPI (northern pintail), NSHO (northern shoveler), RNDU (ring-necked duck).

Year		AGWT	AMWI	CANV	GADW	LESC	MALL	MODU	NOPI	NSHO	RNDU
2004	Average	3,369	568	1,047	10,269	1,047	4,463	584	5,288	783	770
	Proportion	0.120	0.020	0.037	0.364	0.037	0.158	0.021	0.188	0.028	0.027
2005	Average	4012	79	555	5,645	345	4,767	163	4,355	1,554	1,779
	Proportion	0.173	0.003	0.024	0.243	0.015	0.205	0.007	0.187	0.067	0.077
2006	Average	7,053	148	291	8,030	57	2,241	331	2,342	1,475	660
	Proportion	0.312	0.007	0.013	0.355	0.003	0.099	0.015	0.104	0.065	0.029
2007	Average	8,510	360	1,136	14,631	35	4,341	373	7,902	1,140	1,795
	Proportion	0.212	0.009	0.028	0.364	0.001	0.108	0.009	0.196	0.028	0.045
2008	Average	6,727	330	919	12,165	346	1,598	426	2,655	1,412	1,454
	Proportion	0.240	0.012	0.033	0.434	0.012	0.057	0.015	0.095	0.050	0.052
2009	Average	3,880	267	21	8,200	234	3,164	574	4,520	1,562	11
	Proportion	0.173	0.012	0.001	0.366	0.010	0.141	0.026	0.201	0.070	0.000
2010	Average	7,781	492	619	17,113	281	5,548	605	4,852	711	132
	Proportion	0.204	0.013	0.016	0.449	0.007	0.145	0.016	0.127	0.019	0.003
2011	Average	5,385	429	156	7,594	262	3,356	441	1,468	708	48
	Proportion	0.271	0.022	0.008	0.383	0.013	0.169	0.022	0.074	0.036	0.002
2012	Average	5,973	59	157	6,770	724	2,230	289	1,697	672	671
	Proportion	0.310	0.003	0.008	0.352	0.038	0.116	0.015	0.088	0.035	0.035
2013	Average	5,334	49	711	7,803	286	3,485	217	914	840	406
	Proportion	0.266	0.002	0.035	0.389	0.014	0.174	0.011	0.046	0.042	0.020
2014	Average	6,547	26	554	19,274	999	3,935	230	1,211	1,441	603
	Proportion	0.188	0.001	0.016	0.554	0.029	0.113	0.007	0.035	0.041	0.017
2015	Average	2,455	4	191	5,673	13,083	2,077	95	181	176	1,240
	Proportion	0.098	0.000	0.008	0.225	0.520	0.083	0.004	0.007	0.007	0.049
2016	Average	5,366	12	288	12,255	720	1,809	50	2,969	781	3,210
	Proportion	0.195	0.000	0.010	0.446	0.026	0.066	0.002	0.108	0.028	0.117

Table 3. Beta coefficients (β) and *P*-values for regression analyses on average annual duck abundance on Louisiana state-owned wildlife management areas and refuges, 2004–2016[a,b]. AGWT (green-winged teal), AMWI (American wigeon), CANV (canvasback), GADW (gadwall), LESC (lesser scaup), MALL (mallard), MODU (mottled duck), NOPI (northern pintail), NSHO (northern shoveler), RNDU (ring-necked duck).

Site		AGWT	AMWI	CANV	GADW	LESC	MALL	MODU	NOPI	NSHO	RNDU
Atchafalaya Delta WMA	β	−9.06	–	−179.6	**−251.4**	–	**−180.80**	–	**−41.35**	–	9.4
	P	0.90	–	0.13	**0.04**	–	**< 0.01**	–	**< 0.01**	–	0.5
Marsh Island Refuge	β	395.2	–	–	368.7	–	–	–	–	–	–
	P	0.44	–	–	0.65	–	–	–	–	–	–
Pass-A-Loutre WMA	β	25.2	−86.03	−256.3	1103	267	–	–	**−1285.5**	–	–
	P	0.92	0.27	0.15	0.48	0.09	–	–	**0.04**	–	–
Pointe-Aux-Chenes WMA	β	0.62	–	–	170.4	**294.2**	–	−26.03	–	22.6	22.64
	P	0.98	–	–	0.22	**0.01**	–	0.07	–	0.2	0.6
Rockefeller Wildlife Refuge	β	−889.5	–	–	915.8	–	–	–	454.3	**−430.7**	–
	P	0.13	–	–	0.58	–	–	–	0.38	**0.01**	–
Salvador WMA	β	−8.6	–	−18.79	**−53.31**	**−11.15**	−0.61	–	–	–	**−30.35**
	P	0.34	–	0.17	**0.03**	**0.06**	0.33	–	–	–	**0.03**
State Wildlife Refuge	β	24.67	–	–	−110.9	–	−22.08	–	1.28	–	−14.16
	P	0.69	–	–	0.33	–	0.23	–	0.9	–	0.53
Wax Lake Delta	β	−99.84	**−141.81**	62.13	**−338.4**	15.8	**−252.40**	–	**−837.3**	−18.22	–
	P	0.62	**0.01**	0.70	**0.01**	0.62	**0.01**	–	**< 0.01**	0.38	–
White Lake Wetlands Conservation Area	β	197.4	–	–	−559.1	–	−557.80	–	**−1576.6**	–	390.5
	P	76.32	–	–	0.11	–	0.46	–	**0.04**	–	0.53
WMAs and Refuges Combined	β	−40.43	**−30.29**	−43.88	138.2	368.3	−130.30	**−26.5**	**−358.5**	−56.44	784.51
	P	0.77	**0.03**	0.11	0.69	0.17	0.17	**0.05**	**0.02**	0.08	0.64

a. Bold beta coefficients (β) and *P*-values indicate significant changes in annual abundance.

b. indicate that species represented <10% of total average annual duck abundance.

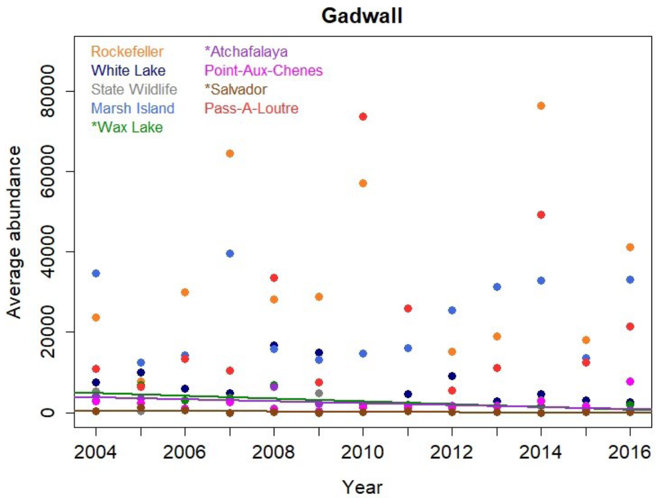

Figure 2. Average annual abundance of gadwall (*Mareca strepera*) on Louisiana state-owned wildlife management areas (WMAs) and refuges, 2004–2016. * Indicates significant change in average annual abundance.

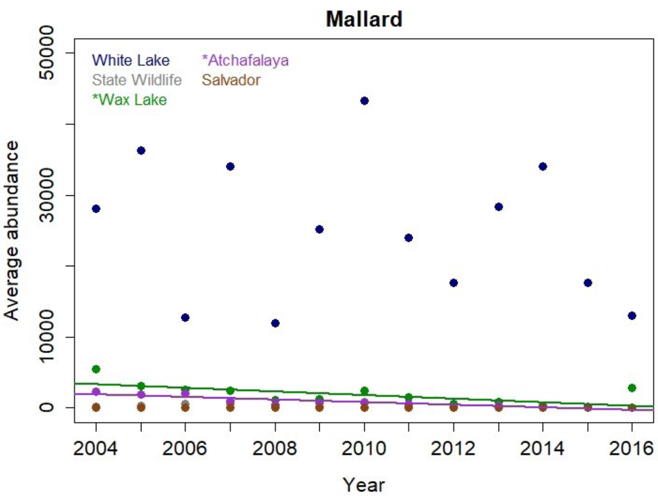

Figure 3. Average annual abundance of mallards (*Anas platyrhynchos*) on Louisiana state-owned wildlife management areas (WMAs) and refuges, 2004–2016. * Indicates significant change in average annual abundance.

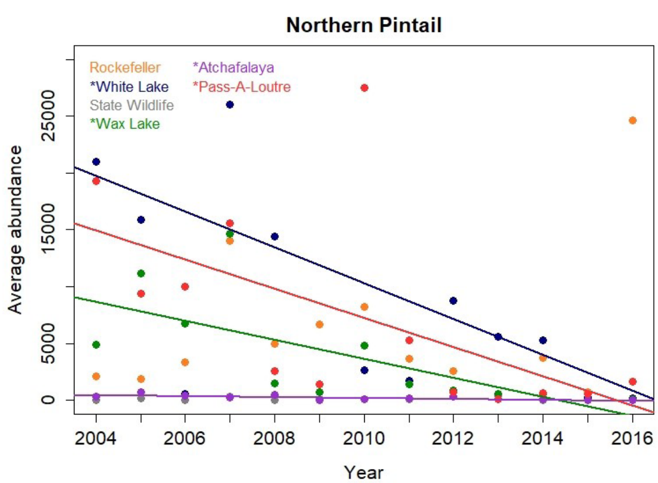

Figure 4. Average annual abundance of northern pintail (*Anas acuta*) on Louisiana state-owned wildlife management areas (WMAs) and refuges, 2004–2016. * Indicates significant change in average annual abundance.

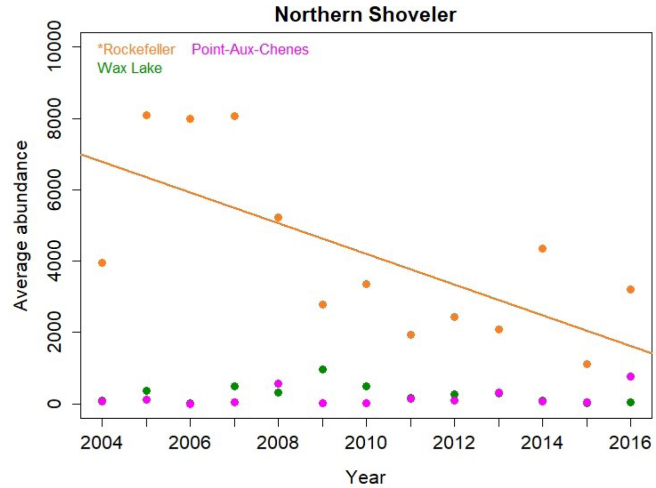

Figure 5. Average annual abundance of northern shoveler (*Spatula clypeata*) on Louisiana state-owned wildlife management areas (WMAs) and refuges, 2004–2016. * Indicates significant change in average annual abundance.

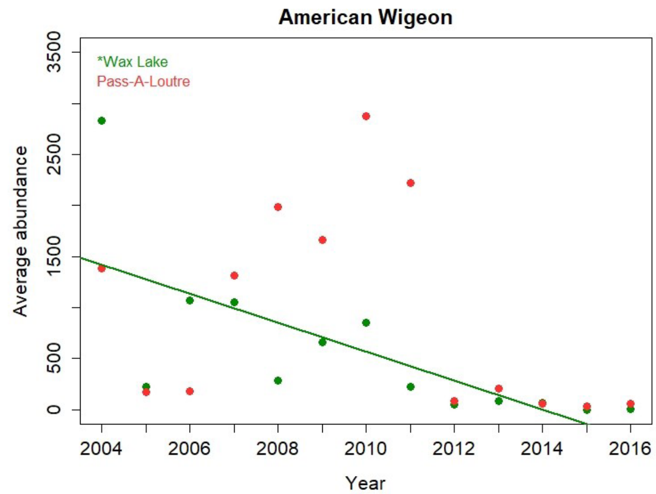

Figure 6. Average annual abundance of American wigeon (*Mareca americana*) on Louisiana state-owned wildlife management areas (WMAs) and refuges, 2004–2016. * Indicates significant change in average annual abundance.

were stable region-wide and at all individual sites (Table 3). American wigeon and mottled ducks were never common, individually never occurring at relative abundances >15% for any site-year in the aerial survey data, but declined at sites where they were present (Table 3; Figures 6).

Diving duck population trends

Lesser scaup were stable region-wide but showed substantial variability among sites. There was a decline at Salvador WMA (Table 3), but this was of little biological consequence (126 ± 136 ducks observed in 2004–2006, and no ducks observed 2014–2016). However, there were concurrent increases at Pointe-Aux-Chenes WMA (with an average increase from 192 ± 318 to 3,269 ± 2,549) and

Figure 7. Average annual abundance of lesser scaup (*Aythya affinis*) on Louisiana state-owned wildlife management areas (WMAs) and refuges, 2004–2016. * Indicates significant change in average annual abundance.

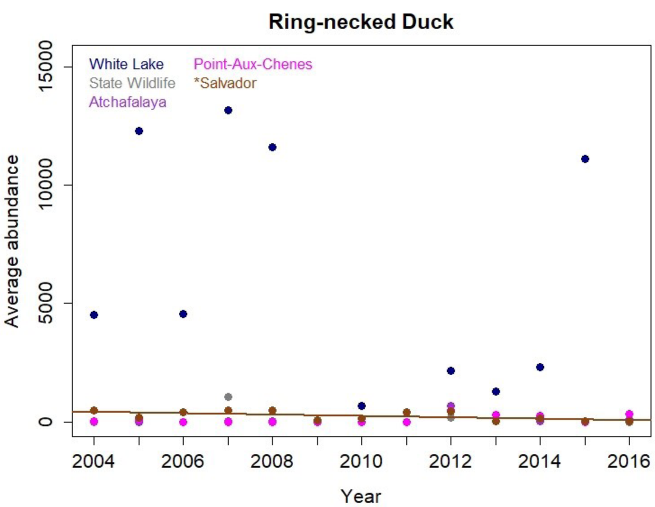

Figure 8. Average annual abundance of ring-necked ducks (*Aythya collaris*) on Louisiana state-owned wildlife management areas (WMAs) and refuges, 2004–2016. * Indicates significant change in average annual abundance.

Pass-A-Loutre WMA (with an average increase from 909 ± 1,059 to 4,484 ± 3,376; Table 3; Figure 7). Ring-necked ducks were relatively stable across our sample geography, but declined significantly on Salvador WMA (Table 3; Figure 8) where they were only present in low numbers (342 ± 156 ducks observed in 2004–2006 and 63 ± 75 observed 2014–2016). However, ring-necked duck abundance has recently increased on White Lake Wetlands Conservation Area (from 7,125 ± 4,482 in 2004–2006 to 13,791 ± 13,028 in 2014–2016), although this change was not significant (Table 3). Canvasbacks were stable region-wide and at every site (Table 3).

Discussion

Gadwall and green-winged teal were the most commonly observed species across survey years, and these results were similar to other waterfowl surveys that targeted broader coastal landscapes in Louisiana (Louisiana Department of Wildlife and Fisheries unpublished data). Coastal Louisiana is estimated to support ~66% of the wintering gadwall in the Mississippi flyway (Baldassarre 2014), and they strongly select intermediate marsh with >30% coverage of submerged aquatic vegetation (Paulus 1982, Bolduc 2002) which composes the majority of their diet during winter (White 1975, Leschack et al. 1997, Hartke et al. 2009). These are among the most common habitat types on coastal Louisiana refuges, with a relatively substantial abundance of gadwall typically being observed on coastal surveys. Additionally, ~20% of the continental population of green-winged teal overwinters in coastal Louisiana, although they tend to select for less saline portions of the coastal marsh than gadwall (Bolduc 2002). So while it is not surprising that gadwall and green-winged teal were among the most numerous ducks observed in our study, their population trends in Louisiana did not reflect the dramatic continental increase (>90%) above the long-term average and near record high numbers recorded by the BPOP (USFWS 2016). It is not clear where those fall-migrating birds are wintering, but our results indicate that wintering populations in coastal Louisiana have not seen the same proportional increases. Ongoing work to evaluate the carrying capacity of coastal wetlands along the Gulf Coast promises to further elucidate the relationship between waterfowl populations and their wintering foraging resources (DeMarco 2018).

Mallards are the most abundant of all duck species across North America with breeding estimates in 2016 of 11.8 ± 0.4 million which is 38% above the long-term average (USFWS 2016). In coastal Louisiana, mallard populations were stable region-wide, and most of the mallards in our survey were concentrated on White Lake Wetlands Conservation Area. This was unsurprising given that White Lake Wetlands Conservation Area is comprised of freshwater marsh, and that wintering mallards prefer this habitat (Chabreck et al. 1989, Link et al. 2011). Furthermore, mallards use both rice fields and coastal marsh to fulfill their energetic needs (Link et al. 2011), and White Lake provides ready access to both of these habitat types. Similar to green-winged teal, we did not observe commensurate increases in coastal mallard populations with a growing continental population. It seems likely that most individuals could be wintering in more northerly latitudes (Schummer et al. 2010, Notaro et al. 2016, Schummer et al. 2017).

Despite their abundance and region-wide stability, there was substantial site-specific variation in gadwall and mallard populations. For example, we observed significant declines in both gadwall and mallard populations at Atchafalaya Delta WMA and the adjacent Wax Lake Delta across our survey period. These areas have little active habitat management; most inter-annual variability and long-term change is driven by seasonal rainfall that drives flows of the Atchafalaya River and the accretion of sediment from Atchafalaya River and Wax Lake outlet in conjunction with extreme tidal fluctuations. We also noted declines in gadwall at Salvador WMA, which is in close proximity to New Orleans, Louisiana. We speculate that proximity to this human population center may contribute to hunting pressure, which could cause an overall decline in abundance of gadwall and other duck species on the area (Figure. 2; Table 3). In addition, Salvador also was affected by many wetland diversion projects adjacent to the property, particularly the Davis Pond Diversion. This diversion has been altered and manipulated prior and during the time period of this study which may have influenced wetland plant communities, salinity, and water levels and the waterfowl species that rely on them. However, from a broader perspective, it is important to note that Salvador WMA has never overwintered large numbers of ducks compared to other areas we surveyed.

Northern pintail have seen the most precipitous decline across survey years, which was relatively consistent among areas (Table 3; Figure 4). The most logical explanation for this decline is changes in the preferred wintering habitat of northern pintail. For example, the coastal wetlands of Louisiana are disappearing at an alarming rate: at least 75 km^2 annually (Couvillon et al. 2011). Moulten et al. (1997) reported that over 100,000 ha of coastal marsh habitat has been lost over the last 50 years. Moreover, the subsidence and sea-level rise that contribute to coastal land loss also affect marsh salinities and vegetative communities, resulting in a shift from the shallower fresher marshes preferred by northern pintail to deeper and more saline habitats. Additionally, rising costs have forced a reduction and consolidation of rice agriculture in coastal Louisiana (Baldwin et al. 2011). Concurrent with the decline of Louisiana rice, more northerly habitats in the Mississippi Alluvial Valley have seen an increased area in rice agriculture—especially the second ratoon rice crop that is important for wintering waterfowl (Petrie et al. 2014). These changes in agricultural practices have been driven by persistent increases in temperature in combination with the development of new cold-hardy rice varieties (Petrie et al. 2014). Given that coastal marsh and rice agriculture are estimated to account for 96% of the energetic needs of dabbling ducks wintering along the Gulf Coast (Petrie et al. 2014), it is perhaps surprising to not see similar declines in other species of dabbling ducks. We suggest that our survey results showing stable populations of most dabbling ducks but decreasing populations of pintail reflect the patterns in the continental BPOP of declining pintail and record numbers of other dabblers.

Diving duck trends

Overall diving duck abundance remained relatively stable across survey areas and years. However, diving ducks showed variability from year to year, and among sites within a single season, possibly attributed to fluctuations in water levels. Lesser scaup on Pointe-Aux-Chenes WMA and Pass-A-Loutre saw increases across survey years (Table 3; Figure 7). Pointe-Aux-Chenes diving duck numbers have increased due to increased water levels, driven in part by erosion of shallow wetland habitats. Moreover, wetland loss rates may have intensified due to tropical storms and hurricanes across the survey period (CPRA 2017). Additionally, these areas in southeast Louisiana have few impounded wetland units, so a lack of water control structures and levee systems make it difficult to control water levels and actively manage for desirable waterfowl species. Regardless, lesser scaup prefer this deeper water for foraging on mollusks (Christmas 1960, Harmon 1962, Rogers and Korschegen, 1966). The increases in scaup numbers on these two WMAs is consequential because the continental scaup population has declined markedly since 1978 (Afton and Anderson 2001), with the most recent breeding population estimate of 4.4 ± 0.2 million (USFWS 2016) 13% below the target management goals of 6.3 million set by NAWMP (USFWS and CWS 1986, USFWS and CWS 1996).

White Lake Wetlands Conservation Area saw a substantial increase in ring-necked ducks in recent years (Figure 8). This increase could be caused by increased water levels on the area due to breached levees systems and failed pumping systems during recent survey years. Additionally, the impoundments on the area are extremely large in size and water control structures may not be adequate for moving excess water off impoundments in a timely manner. This problem can become exacerbated during high water events from storms, creating large open water ponds which could be attractive to diving ducks such as the ring-necked duck.

Management Implications

We detected declines in the abundance of common dabbling ducks at several WMAs that are characterized by little active habitat management and potentially greater hunting pressure. Additionally, we believe hurricanes may have affected foraging habitat, ultimately influencing waterfowl abundance. We also noted that while species like gadwall, green-winged teal, and mallard are near all-time highs on the breeding grounds, we did not observe concomitant increases on coastal areas in Louisiana. It is not clear whether these coastal habitats are at carrying capacity (i.e., surplus waterfowl have to overwinter elsewhere), or whether other factors such as hunting, shifts in climate, or changing agricultural practices are driving distributions. The decline of the northern pintail across coastal Louisiana is cause for concern among waterfowl managers and biologists. The reasons for this decline are unclear, but merit further investigation: for example, are northern pintail shifting inland in Louisiana, northward to Arkansas, or west to Texas? It seems clear that aerial waterfowl surveys provide important trend data for waterfowl populations and should continue into the future. When paired with ground-based surveys, we enhance our understanding of changes in waterfowl migration chronologies. Additionally, we suggest that more intensive water level and vegetation monitoring be conducted on each area to compare wetland habitat conditions and long-term waterfowl trends. Finally, inter-regional coordination to survey spatio-temporal patterns of wintering waterfowl is sorely needed, and this will become increasingly important under scenarios of a changing climate and dynamic agricultural landscape.

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