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Winter Waterfowl Relative Abundance Trends in New England's Largest Estuary

Clara Cooper-Mullin¹, Peter W.C. Paton¹, Jennifer Kilburn², and Scott R. McWilliams^{1,*}

Abstract - In the North Atlantic, bays and estuaries provide important habitat for wintering waterfowl, although this key waterfowl habitat often occurs in some of the most densely human-populated areas in North America. We used 3 different long-term surveys, the National Audubon Christmas Bird Count (CBC), the Rhode Island Department of Environmental Management Division of Fish and Wildlife aerial survey, and the Narragansett Bay Winter Waterfowl Survey (NBWWS), to examine the relative abundance and population trends for 19 species of waterfowl in Narragansett Bay, the largest bay and estuary in New England. The most abundant species based on NBWWS surveys were diving ducks that are dependent on shellfish (*Aythya* spp. [scaup], *Somateria mollissima* [Common Eider], *Bucephala albeola* [Bufflehead], and *Bucephala clangula* [Common Goldeneye]) and geese that graze on submergent vegetation (*Branta bernicla* [Brant]) or lawns adjacent to the bay (*Branta canadensis* [Canada Goose]). Overall, waterfowl relative abundance remained constant over the 17 years (2004–2020) for all 3 survey types. However, for the NBWWS and CBC surveys, we detected significant declines in the relative abundance of *Anas rubripes* (American Black Duck), *Histrionicus histrionicus* (Harlequin Duck), Common Goldeneye, and *Mergus serrator* (Red-breasted Merganser). We also detected population declines in *Mareca strepera* (Gadwall), *Mareca americana* (American Wigeon), and scaup spp. based on NBWWS surveys and a recent decline in Canada Goose based on CBC estimates. These declines were presumably driven by changing environmental and foraging conditions within this urban estuary and across their entire range. Protection and restoration of Narragansett Bay's shallow-water habitats and minimizing shoreline development are 2 key conservation strategies needed to maintain waterfowl populations in the region.

Introduction

Waterfowl are ecologically and economically important birds that are useful bioindicators for wetland health at local and regional spatial scales (Amat and Green 2010, Fox et al. 2025). Given this importance, biologists in North America have monitored waterfowl populations on their breeding grounds since 1955 with the Waterfowl Breeding Population and Habitat Survey (WBPHS; Cowardin and Blohm 1992, Kumar and Rice 2021, USFWS 2023), and at wintering areas since 1935 with the Midwinter Waterfowl Survey (Moore et al. 2023). In addition, long-term avian survey data are available from community-based monitoring programs such as the National Audubon's Christmas Bird Count (CBC) since 1901 (Butcher et al. 1990). Surveys during the non-breeding season can provide estimates of

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flyway- and continent-scale wintering populations of waterfowl across North America (Meehan et al. 2021), although understanding factors influencing these broad geographic trends can be meaningfully informed by more narrowly focused regional studies (Eggeman and Johnson 2006, Rahbek 2005).

North Atlantic estuaries and coastal areas support large numbers of swans, geese, sea ducks, dabbling ducks, and diving ducks in the winter (Kreakie et al. 2015, McKinney 2005, McKinney et al. 2015). These coastal habitats are also where waterfowl are most likely to interact with humans, as these bays and estuaries are some of the most densely populated areas in North America. Human–waterfowl interactions can be direct, such as hunting or aquaculture development, or indirect through anthropogenic influences from human encroachment and degradation of coastal habitats (Madsen 1995). Further, obtaining adequate food and cover during the winter months is crucial for the survival of waterfowl and may impact their ability to successfully breed (Sedinger and Alisauskas 2014). Therefore, understanding how waterfowl abundance is changing within important wintering areas can help to inform waterfowl biologists and managers on the causes and consequences of long-term changes in abundance and distribution at local and regional scales.

Narragansett Bay is the largest bay and estuary in New England and is a particularly important area for wintering waterfowl in eastern North America (McKinney 2005, McKinney et al. 2015). Three different long-term surveys were conducted to monitor wintering waterfowl in Narragansett Bay: the CBC, Rhode Island Department of Environmental Management Division of Fish and Wildlife’s aerial survey (hereafter DFW aerial survey), and the Narragansett Bay Winter Waterfowl Survey (NBWWS). Here, our 2 objectives were to use these long-term surveys to examine the (1) relative abundance and (2) population trends of waterfowl in Narragansett Bay from 2004 to 2020. Given that much is known about the history and ecology of Narragansett Bay, it affords a good opportunity to investigate factors affecting the trends in the relative abundance of waterfowl in southern New England.

Materials and Methods

Study area

We examined waterfowl use of Narragansett Bay (hereafter, “the Bay”), which is a 368-km² estuary that receives discharge from a 4660-km² watershed encompassing much of Rhode Island and southeastern Massachusetts. The Bay has a narrow salinity gradient (29–32 ppt) that is classified as partially stratified to well mixed (Kremer and Nixon 1978, Ross and Randhir 2022). The Bay’s 3 primary rivers, the Taunton, the Blackstone, and the Pawtuxet, drain 75% of the watershed. The watershed is highly urbanized, particularly in the northern portion, and as such, the Bay has a history of being heavily loaded with sewage-effluent nutrients since the late 1800s (Oviatt et al. 2017). By 2012, nitrogen inputs were reduced by over 50% (Oviatt et al. 2017) with the advent of waste-water treatment facilities (NEBP 2017). Rainfall has averaged about 10.2 cm per month, with slightly greater levels of precipitation in the late fall and early winter (Ries 1990). The lowest monthly temperatures have occurred in January (Providence = -2.1 °C; Ries 1990). The Bay

provides nurseries and habitat for more than 60 species of fish and shellfish (Oviatt et al. 2003, Tiner et al. 2004), over 200 bird species (McKinney et al. 2015), and 16 species of marine mammals (Raposa 2009).

Survey methods

We used 3 systematic bird surveys to examine long-term trends in the relative abundance of waterfowl wintering in the Bay from 2004 to 2020. During the CBC, which is a community-based volunteer survey that occurs across the US and Canada, birders survey specific areas within a designated 24-km diameter circle on 1 day in December or early January, counting each bird they detect (Butcher et al. 1990). The coastal segments on CBC circles in Rhode Island are highly coveted and generally conducted by the same observers for decades; thus we assumed that survey effort was relatively consistent among years. We restricted our analyses to the 5 count circles in Rhode Island that were consistently monitored since 1975 (Fig. 1a).

The DFW aerial survey has been conducted by Rhode Island Department of Environmental Management (RIDEM) biologists since 1950 and originally intended to estimate waterfowl relative abundance to provide data to set harvest regulations in the Atlantic Flyway. This transect survey is typically conducted annually in early January by helicopter with a pilot and 1–2 observers. The specific transect route, flight altitude and speed, and duration of the survey has varied annually. During aerial surveys, *Bucephala clangula* (L.) (Common Goldeneye) and *Bucephala islandica* (J.F. Gmelin) (Barrow's Goldeneye) were pooled as “goldeneye” due to similarities in identification. The goal of DFW aerial surveys has been to estimate relative abundance in 3 major zones across the state of Rhode Island, including the Bay (Fig. 1b; J. Kilburn, unpubl. data). We included data from 1982 to 2020 from the DFW aerial survey in our analysis.

The NBWWS was implemented in 2004 by a group of biologists from local, state, and federal wildlife and environmental agencies and academic institutions (Kreakie et al. 2015, McKinney 2005, McKinney et al. 2015). The NBWWS was designed as a ground-based survey conducted by teams of experienced ornithologists that covered as much of the Bay as possible during daylight hours within 1 day. These land-based point-count stations were conducted at public access points located throughout the Bay (Fig. 1c). NBWWS survey participants were given a route of land-based point-count stations within the Bay to survey, usually during first week of January, so that all survey points were visited within a 24-hour period (see McKinney et al. 2015 for full survey details). In brief, each survey was conducted from the same fixed locations on the shoreline, and observers recorded all waterfowl present at a site and used as much time as needed to identify all birds; therefore, we assumed perfect detection and that survey effort was relatively consistent among years. The sites along the 6 survey routes were chosen to represent all available habitat types along each route while being far enough apart to avoid double-counting and so each survey route could be completed by an observer within a single day (McKinney et al. 2015).

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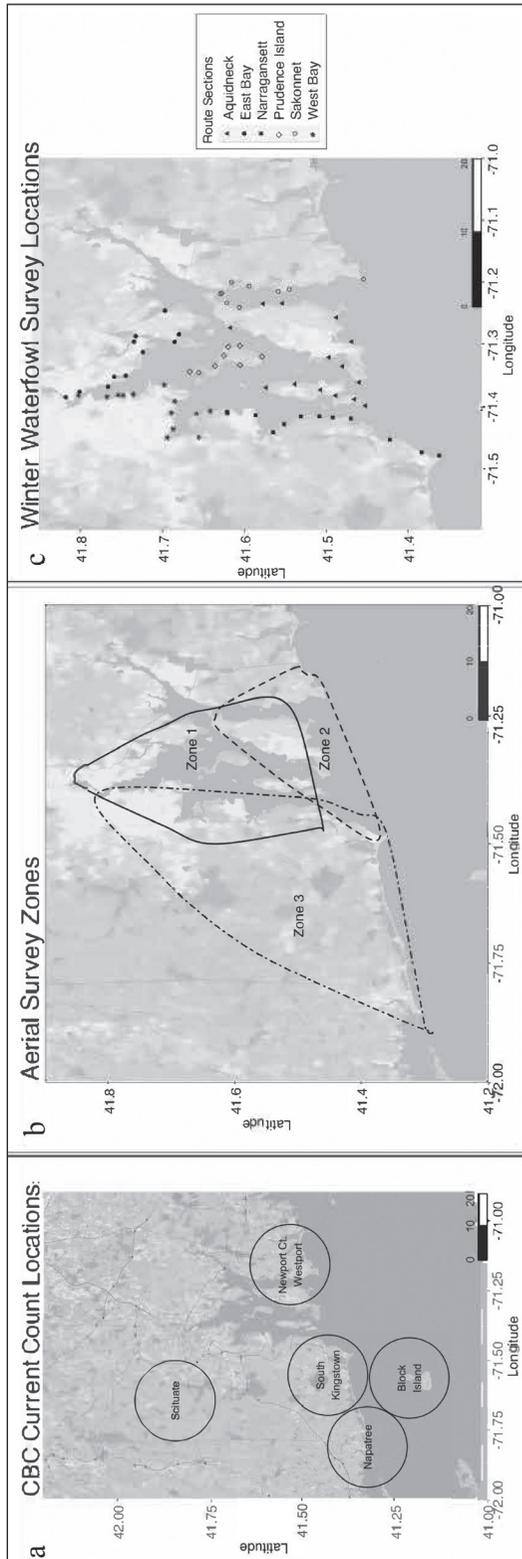


Figure 1. Locations of land-based stations in Narragansett Bay, RI, surveyed from 2004 to 2020. (a) Designated 24-km-diameter circles for 5 Christmas Bird Counts: Block Island, Newport and Westport, Napatree, Scituate, and South Kingstown. (b) Three major zones of Narragansett Bay designated for the Rhode Island Department of Environmental Management, Division of Fish and Wildlife’s aerial survey. (c) Six survey routes for the Narragansett Bay Winter Waterfowl Survey including Aquidneck Island (filled triangles), East Bay (filled circles), North and South Narragansett (filled rectangles), Prudence Island (open diamonds), Sakonnet (open circles), and West Bay (stars).

The NBWWS has consistently monitored 19 waterfowl species, so we restricted our analysis for the CBC and DFW aerial surveys to those same species for uniformity (Table 1). We aggregated species that were challenging to identify to the species level during surveys for analysis. Specifically, we pooled *Aythya marila* (L.) (Greater Scaup) and *Aythya affinis* (Eyton) (Lesser Scaup) into “scaup”; all species of swans into “swans” (although over 99% were *Cygnus olor* (J.F. Gmelin) [Mute Swan]); and *Melanitta perspicillata* (L.) (Surf Scoter), *M. deglandi* (Bonaparte) (White-winged Scoter), *M. americana* (Swainson) (Black Scoter) into “scoters” (Table 1).

Population trends

To quantify annual trends in wintering-bird relative abundance for each species, we used generalized additive mixed models to determine non-linear population trends separately for each of the 3 survey types. We only calculated trend analyses for species that accounted for more than 1% of the overall relative abundance of waterfowl in the Bay. We included the number of birds as a dependent factor and year as an independent factor. To control for variation within each survey type, we included count circle ($n = 5$; Fig. 1a) as a random factor for models of CBC data, zone ($n = 3$; Fig. 1b) as a random factor for models of DFW aerial survey data, and survey segment ($n = 6$; Fig. 1c) as a random factor for models of NBWWS data. For the DFW aerial surveys and the CBC, we quantified trends within the same time frame as the NBWWS was conducted (2004–2020) for comparison. Since the NBWWS is the most comprehensive spatially explicit standardized survey of the Bay, we used the NBWWS to validate the other surveys, which had potential drawbacks of citizen science surveys (CBC) or detection issues from non-standardized aerial surveys. If the population trends for a given species were similar in direction (i.e., negative, positive, stable) between the NBWWS and the DFW aerial survey or the CBC, we then examined trends for that species over the entire period each survey was conducted (i.e., from 1975 for CBC, from 1982 for DFW aerial surveys) to understand how trends may have changed over the longer time period. We used the package ‘poptrend’ v. 0.2.0 in software R v. 4.4.2 to fit a log-linear model with quasipoisson or negative binomial distribution using restricted maximum likelihood (Knape 2016, R Core Team 2022). We chose the data distribution for each species and survey type based on examination of model residuals and explained deviance (Bell et al. 2020, Knape 2016). Positive values indicated increasing trends across years, and negative values indicated decreasing trends across years. We used a 95% confidence interval to assess significance. We report the trends as the average percent annual change and confidence intervals computed using 2.5% and 97.5% quantiles of the bootstrapped trends (Knape 2016).

Results

On average, the CBC detected the largest total numbers of waterfowl throughout Narragansett Bay ($28,671 \pm 7358$), followed by the DFW aerial survey ($25,038 \pm$

Table 1. Average (\pm SD) relative abundance and annual trends, 2004–2020, for waterfowl in Narragansett Bay. The 3 survey types include the land-based Narragansett Bay Winter Waterbird Survey (NBWWS), Christmas Bird Count (CBC) and Rhode Island Department of Environmental Management (DEM) Division of Fish and Wildlife (DFW) aerial survey. Relative abundance is shown as the mean number of individuals detected annually throughout the study area. Estimated percentage of population changes (trend) for each year from 2004 to 2020 were calculated using generalized additive mixed models. * indicates significant. No trend analyses were conducted on rare species that accounted for less than 1% of the waterfowl. [Table continued on following page.]

Species	Scientific name	NBWWS		CBC		RI DEM DFW aerial survey	
		Mean \pm SD	Trend (95% CI)	Mean \pm SD	Trend (95% CI)	Mean \pm SD	Trend (95% CI)
All Waterfowl		19,210 \pm 4823	-23% (-63%, 58%)	28,671 \pm 7358	-32% (-60%, 24%)	25,038 \pm 14,137	73% (-9.1%, 213%)
Brant	<i>Branta bernicla</i>	2587 \pm 851	108% (-18%, 481%)	183 \pm 165	NA	1667 \pm 1468	763% (209%, 2116%)
Canada Goose	<i>Branta canadensis</i>	3022 \pm 1113	100% (-7.7%, 366%)	9437 \pm 648	-99%* (-100%, -75%)	7512 \pm 5619	214% (5.2%, 884%)
Swans	<i>Cygnus</i> spp.	498 \pm 291	-75% (-95%, 21%)	351 \pm 217	50% (-24%, 215%)	826 \pm 415	70% (-29%, 307%)
Gadwall	<i>Mareca strepera</i>	125 \pm 88	-88%* (-96%, -63%)	140 \pm 107	56% (-32%, 255%)	153 \pm 165	-31% (-85%, 167%)
American Wigeon	<i>Mareca americana</i>	330 \pm 282	-88%* (-97%, -50%)	139 \pm 153	539% (196%, 1188%)	212 \pm 188	-33% (-90%, 334%)
Mallard	<i>Anas platyrhynchos</i>	966 \pm 449	-55% (-88%, 56%)	1748 \pm 784	-39% (-80%, 73%)	1206 \pm 990	776% (45%, 8844%)
American Black Duck	<i>Anas rubripes</i>	956 \pm 384	-68%* (-79%, -52%)	2518 \pm 1055	-50%* (-72%, -10%)	2466 \pm 1412	105% (-58%, 982%)
Scaups	<i>Aythya</i> spp.	5152 \pm 714	-63%* (-95%, -25%)	1826 \pm 1459	197% (-13%, 939%)	1943 \pm 2659	35% (-50%, 226%)
King Eider	<i>Somateria spectabilis</i>	0.05	NA	3 \pm 5	NA	NA	NA
Common Eider	<i>Somateria mollissima</i>	1435 \pm 1278	-77% (-97%, 65%)	2694 \pm 2504	-80% (-97%, 61%)	2847 \pm 4258	18392% (-69%, 1.6e+07%)

Table 1, continued.

Species	Scientific name	NBWWS		CBC		RI DEM DFW aerial survey	
		Mean \pm SD	Trend (95% CI)	Mean \pm SD	Trend (95% CI)	Mean \pm SD	Trend (95% CI)
Harlequin Duck	<i>Histrionicus histrionicus</i>	71 \pm 20	-54%* (-74%, -23%)	53 \pm 41	-82%* (-94%, -45%)	26 \pm 30	-64% (-97%, 685%)
Scoters	<i>Melanitta spp.</i>	936 \pm 1499	21% (-91%, 1973%)	1741 \pm 1837	-61% (-96%, 302%)	568 \pm 953	1472% (-91%, 333580%)
Long-tailed Duck	<i>Clangula hyemalis</i>	3 \pm 9	NA	31 \pm 47	NA	18 \pm 10	NA
Bufflehead	<i>Bucephala albeola</i>	1218 \pm 401	39% (-34%, 189%)	511 \pm 477	5% (-40%, 79%)	1294 \pm 1312	567% (-54%, 8856%)
Common Goldeneye	<i>Bucephala clangula</i>	1235 \pm 466	-69%* (-85%, -31%)	846 \pm 628	-59%* (-77%, -28%)	759 \pm 824	-20% (-86%, 375%)
Barrow's Goldeneye	<i>Bucephala islandica</i>	0.2 \pm 0.9	NA	0.5 \pm 0	NA	NA	NA
Hooded Merganser	<i>Lophodytes cucullatus</i>	188 \pm 123	NA	189 \pm 291	NA	29 \pm 16	NA
Common Merganser	<i>Mergus merganser</i>	27 \pm 24	NA	211 \pm 176	NA	30 \pm 22	NA
Red-breasted Merganser	<i>Mergus serrator</i>	680 \pm 253	-58%* (-82%, -17%)	2969 \pm 648	-51%* (-75%, -2%)	769 \pm 455	-31% (-80%, 139%)

14,137) and the NBWWS ($19,210 \pm 4823$). The most abundant species (i.e., counts varied from ~1200 to ~7500 individuals per species on average each year) included Canada Goose, scaup, Common Eider, *Anas platyrhynchos* L. (Mallard), and *Anas rubripes* Brewster (American Black Duck) for all 3 surveys (Table 1). In addition, *Branta bernicla* (L.) (Brant), scoters, *Bucephala albeola* (L.) (Bufflehead), Common Goldeneye, and *Mergus serrator* L. (Red-breasted Merganser) were among the most abundant species in 1 or 2 of the 3 surveys (Table 1).

Annual trends

The total number of waterfowl counted annually did not significantly change over the 17-year (2004–2020) survey period for the NBWWS, CBC, or DFW aerial survey (Table 1). However, we detected significant declines in American Black Duck, Common Goldeneye, *Histrionicus histrionicus* (L.) (Harlequin Duck), and Red-breasted Merganser for the NBWWS counts from 2004 to 2020. The CBC showed similar population declines for these species over this 17-year time span (Table 1). For example, the relative abundance of American Black Duck decreased 68% during NBWWS and 50% during CBC counts between 2004 and 2020 (Table 1, Fig. 2a). Across all years of the CBC that we assessed (1975 to 2020), the relative abundance of American Black Duck decreased 59% (CI: -73% to -38%; Fig. 2a). Numbers of Common Goldeneye decreased 69% (CI: -85% to -31%) and 59% (CI: -77% to -28%) between 2004 and 2020 for the NBWWS and CBC, respectively (Fig. 2b). Further, although Common Goldeneye counted by the CBC increased 34% between 1975 and 1986, this species decreased 61% from 1986 to 2020 (Fig. 2b). Numbers of Red-breasted Mergansers also decreased since 2004 for the CBC and NBWWS (Table 1). However, when all years of the CBC were considered, Red-breasted Merganser numbers remained stable since 1975 (trend: -4.1%, CI: -74% to 233%; Fig. 2c). Numbers of Harlequin Duck decreased by 54% (CI: -74% to -23%) and 82% (CI: -94% to -45%) between 2004 and 2020 for the NBWWS and CBC, respectively (Fig. 2d). However, Harlequin Duck counts from the CBC steadily increased from 1975 to 2000 before declining over the last 15 years (Fig. 2d). In sum, we detected no significant trends in relative abundance of waterfowl species or groups with the DFW aerial survey counts. In contrast, we detected significant declines in relative abundance from 2004 to 2020 for 7 and 5 species of waterfowl based on the NBWWS and CBC counts, respectively, and these declines in relative abundance were consistent across these 2 survey types for 4 species (i.e., American Black Duck, Common Goldeneye, Harlequin Duck, and Red-breasted Merganser).

Relative-abundance trends for other waterfowl species or groups were less consistent across the 3 survey types. For example, numbers of *Mareca americana* (J.F. Gmelin) (American Wigeon), *Mareca strepera* (L.) (Gadwall), and scaup (Fig. 3a, b, c) decreased from 2004 to 2020 according to the NBWWS counts, but these trends were not apparent for CBC counts or the DFW aerial survey (Table 1). Additionally, Canada Goose counted by the CBC increased from 1975 to 2008 and then subsequently decreased by 83% from 2004 to 2020, which was due in large part to declines in 2019 and 2020 (CI: -96% to -26%; Fig. 3d), but this latter declining trend was not apparent for the NBWWS counts or the DFW aerial survey (Table 1).

Discussion

We documented that the overwintering waterfowl community in Narragansett Bay was dominated by Canada Goose, scaup, Common Eider, Mallard, and American Black Duck for all 3 surveys, and in addition Brant, scoters, Bufflehead, Common Goldeneye, and Red-breasted Merganser were among the most abundant species according to 1 or 2 of the 3 survey types. Across all surveys conducted in and around the Bay, we detected declines in relative abundance for 8 species from 2004 to 2020: Canada Goose, Gadwall, American Wigeon, American Black Duck, scaup, Common Goldeneye, Harlequin Duck, and Red-breasted Merganser. Based on the CBC counts for American Black Duck and Common Goldeneye, these

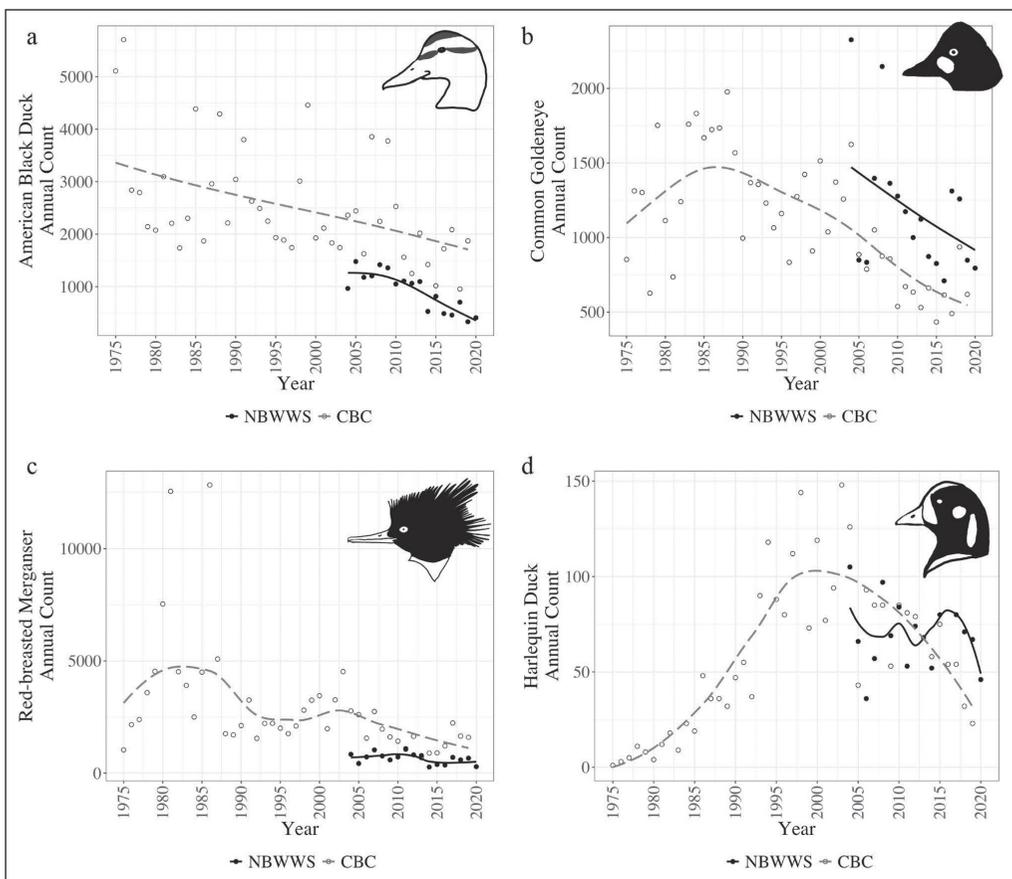


Figure 2. Consistent relative abundance trends from 2 land-based surveys for 4 species of waterfowl in Narragansett Bay, RI: (a) American Black Duck, (b) Common Goldeneye, (c) Red-breasted Merganser, and (d) Harlequin Duck. All species were significantly declining from 2004 to 2020, and the general additive mixed models identified time periods with significantly different positive and negative slopes for 2 species (see text for details). Surveys include the Narragansett Bay Winter Waterfowl Survey (NBWWS) annual counts (filled circles and solid lines) conducted since 2004 and the Christmas Bird Count (CBC) (open circles and dotted lines) conducted since 1975 (see methods for rationale for using counts from this time period).

declines were apparent since at least 1975 (Fig. 2), whereas the declining trend for Canada Goose and Harlequin Duck only occurred more recently (Figs. 2, 3). A previous analysis of NBWWS data from 2005 to 2014 detected this declining trend in relative abundance of American Black Duck (McKinney et al. 2015), but an additional 5 years of data collection was required to fully illuminate relative abundance declines in the other 7 species (Figs. 2, 3). In fact, Gadwall were thought to be increasing in the Bay between 2005 and 2014 (McKinney et al. 2015), yet our updated analysis demonstrated declining numbers over the longer time period (Fig. 3b). We detected no significant increases in relative abundance for any of the other 11 waterfowl species over this same time period (Table 1).

Several possible explanations exist for the apparent inconsistencies in trends among the different surveys. First, NBWWS was designed to estimate waterfowl

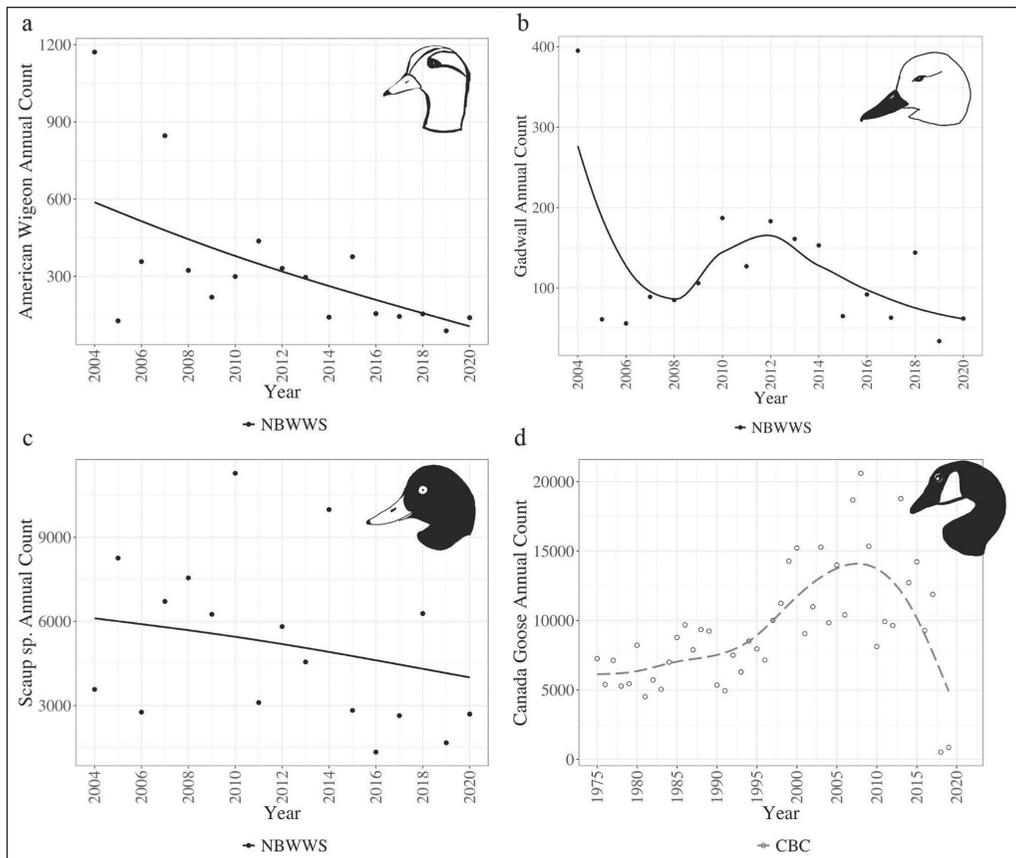


Figure 3. Relative abundance trends for 4 species of waterfowl in Narragansett Bay, RI: (a) American Wigeon, (b) Gadwall, (c) scaup species, and (d) Canada Goose. Three of these species were significantly declining according to the Narragansett Bay winter waterfowl survey data (filled circles, solid lines), but not according to the Christmas Bird Count or aerial survey data (see Table 1). (d) According to the Christmas Bird Count data (open circles, dotted line), Canada Geese were increasing prior to 2000 and then declined significantly between 2004 and 2020 as identified by the general additive mixed model analyses (see text for details).

relative abundance over as much of the Bay as possible during 1 survey from dawn to dusk, whereas the CBC was designed to estimate relative abundance of a broader suite of bird species, and the count circles in Rhode Island that had our focal waterfowl species tended to be closer to the southern coast of Rhode Island. Therefore, it is more likely that the CBC tracked the relative abundance for species that prefer coastal areas, whereas the NBWWS better represents the numbers and distribution of species that occur throughout the Bay. Although the DFW aerial survey was also designed to assess waterfowl species numbers across the state, the variation in route effort, altitude of the plane, and the target species for the survey each year (e.g., Brant in some years, Canada Goose in others) led to higher annual variation in spatial coverage and waterfowl counts (J. Kilburn, unpubl. data), likely obscuring any long-term trends in the data. Developing and incorporating a more standardized survey method (Gilbert et al. 2021, Masto et al. 2020) as well as expanding the DFW aerial survey or NBWWS to more consistently cover coastal salt ponds and other inland water bodies that are often used by wintering waterfowl would likely help to obtain data more suited to long-term analysis of waterfowl relative abundance trends in Rhode Island.

Biologists that have analyzed waterfowl population trends at larger spatial scales (e.g., continental or flyway-wide trends and/or bird conservation regions) have documented similar long-term trends in relative abundance compared to the more local-scale NBWWS and Rhode Island CBC surveys. Furthermore, 2 of the 8 species that had significantly negative relative abundance trends in the Bay (Canada Goose and American Black Duck) are listed as highest priority species within the New England/Mid-Atlantic Coast Bird Conservation Region (BCR 30); scaup are high priority, and the remaining 5 species are listed as moderate priority (Steinkamp 2005). Declining numbers of Canada Goose and American Black Duck in the Bay since 2004 are consistent with declining trends (1998–2018) observed in the eastern survey area of the Waterfowl Breeding Population and Habitat Survey (USFWS 2019). However, a declining trend in Mallard relative abundance in the eastern survey area (USFWS 2019) was not observed in the Bay. In contrast, analyses of CBC data at the continental scale or in the New England/Mid-Atlantic Bird Conservation Region showed an increasing Mallard trend between 1970 and 2019 (Meehan et al. 2020). Therefore, the spatial scale of a given survey as well as the time of year a survey was conducted (e.g., breeding season versus winter) may lead to different insights into the population status of a given species.

Although our study suggests that the relative abundances of American Wigeon and Red-breasted Merganser were declining in the Bay, analyses of these species at larger spatial scales found no evidence of changes in relative abundance (Meehan et al. 2020, 2021; Soykan et al. 2016; USFWS 2023), indicating that these species may be affected locally by changes in available wintering habitat or food resources in the Bay that are not reflected in the remainder of their ranges. Gadwall and Harlequin Duck numbers are declining in the Bay, yet available evidence suggests that the relative abundance trends for these species were increasing at larger spatial scales including the New England/Mid-Atlantic Bird Conservation Region and at the

continental scale (Canadian Wildlife Service Waterfowl Committee 2015, Meehan et al. 2020, 2021; Soykan et al. 2016; USFWS 2023). However, given the relatively small size of the Bay compared to the entire wintering range of these species, it is possible that a shift in prey availability (Caron and Paton 2007) prompted these ducks to move outside of the study area, including into the coastal salt ponds of Rhode Island, which to date are not surveyed or included in the NBWWS and CBC analyses. Relative abundance of Common Goldeneyes declined in the Bay, yet a previous analysis of continental trends in CBC data showed no changes in the relative abundance of that species (Meehan et al. 2021). However, relative abundance trends of Common Goldeneye were negatively associated with average winter temperature, and its relative abundance is projected to decrease across the Mid-Atlantic states with an increase in global annual temperature (Meehan et al. 2021).

We detected declining trends in relative abundance for 4 species of dabbling ducks and 4 species of diving ducks in the Bay that are all likely affected by changing environmental and foraging conditions within the Bay as well as across their entire range. Much of the Bay is surrounded by high-density urban and suburban residential areas (Oviatt et al. 2017), which over the years has reduced available habitat for waterfowl. Between 1950 and 1999, the Bay lost 222 ha of intertidal habitat, estuarine marshes, and intertidal non-vegetated wetlands (Tiner et al. 2004). Since these habitats are important for most waterfowl species, loss of this key habitat could have led to the declining numbers of American Black Duck and Common Goldeneye prior to 2000. Notably, American Black Duck populations across the Atlantic flyway have been in decline since the 1950s (Longcore et al. 2020, USFWS 2019). An analysis of CBC data from 1966 to 2003 across North America indicated that American Black Duck numbers were declining more precipitously in the south and central portions of its range compared to the Northeast (Link et al. 2006), yet the trend was not significant at a continental-scale (Meehan et al. 2021). Our analysis of CBC and NBWWS surveys to assess trends in American Black Duck numbers suggests that the declining trend in this region has continued just as for the southern and central populations. Since this species has traditionally been harvested by hunters in North America, a variety of monitoring and management activities have been implemented to better conserve the species (Conroy et al. 2002), yet loss of important wintering habitat in the Bay to development may be hindering conservation efforts for this local population. For Rhode Island to meet the 80% population goal for American Black Duck outlined in the North American Waterfowl Management Plan (NAWMP), the state would need to protect 1517 ha and restore 891 ha of wintering waterfowl habitat (Hartley and Weldon 2020). This claim is largely driven by the idea that food availability during the non-breeding period influences survival and productivity (Hartley and Weldon 2020, Williams et al. 2014).

Climate change is also likely a driving force for some of the trends of declining relative abundance of waterfowl in the Bay (Kollars et al. 2017, Schummer et al. 2010). Declining scaup numbers in the Bay are indicative of population trends in the traditional survey area of the Waterfowl Breeding Population and Habitat Survey (USFWS 2023) and are supported by harvest-regime changes to reduce harvest rate

and increase survival. However, efforts to reduce harvest rate have not resulted in a rebounding population, likely because declines are linked to other changing environmental conditions on both the wintering and breeding grounds (Ross and Randhir 2022). Breeding estimates of Common Goldeneye have varied from 1.00 million in the early 2000s to a low of 0.52 million in 2013 (USFWS 2022). Declining trends observed in the Bay are consistent with declines observed across the Atlantic Coast, and while available nesting habitat is thought to be the most important factor, Common Goldeneye are also sensitive to climate change and pollution (Eadie et al. 2020). Protecting Narragansett Bay's remaining shallow-water habitats, restoring important salt marsh habitats, managing for resilience, and reducing disturbance and shoreline development in key regions of the Bay should be conservation priorities for waterfowl and the many other wetland-dependent species (McKinney et al. 2015).

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