



RESEARCH ARTICLE

REVISED Developing a wintering waterfowl community baseline for environmental monitoring of Narragansett Bay, Rhode Island [version 2; referees: 3 approved with reservations]

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Abstract

In 2004, the Atlantic Ecology Division of the US Environmental Protection Agency’s Office of Research and Development began an annual winter waterfowl survey of Rhode Island’s Narragansett Bay. Herein, we explore the survey data gathered from 2004 to 2011 in order to establish a benchmark understanding of our waterfowl communities and to establish a statistical framework for future environmental monitoring. The abundance and diversity of wintering waterfowl were relatively stable during the initial years of this survey, except in 2010 when there was a large spike in abundance and a reciprocal fall in diversity. There was no significant change in ranked abundance of most waterfowl species, with only Bufflehead (*Bucephala albeola*) and Hooded Merganser (*Lophodytes cucullatus*) showing a slight yet significant upward trend during the course of our survey period. Nonmetric multidimensional scaling (NMDS) was used to examine the community structure of wintering waterfowl. The results of the NMDS indicate that there is a spatial structure to the waterfowl communities of Narragansett Bay and this structure has remained relatively stable since the survey began. Our NMDS analysis helps to solidify what is known anecdotally about the bay’s waterfowl ecology, and provides a formalized benchmark for long-term monitoring of Narragansett Bay’s waterfowl communities. Birds, including waterfowl, are preferred bioindicators and we propose using our multivariate approach to monitor the future health of the bay. While this research focuses on a specific area of New England, these methods can be easily applied to novel areas of concern and provide a straightforward nonparametric approach to community-level monitoring. The methods provide a statistic test to examine potential drivers of community turnover and well-suited visualization tools.

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REVISED Amendments from Version 1

This version of the manuscript corrected small typos and added several stylistic changes. These corrections did not change any substantive meaning to the text; they simply increased the readability. In Table 2, we converted the population proportions to percentages. Again the actual results were not altered, this was done to aid with interpretation. Editorially, we did add text to the Abstract and Introduction to explain how these methods could be applied more widely. Instead of this be strictly a study about Narragansett Bay, we wanted to highlight how these methods can be used elsewhere for monitoring. Additionally, we have moved text from the Results to the Discussion and expanding upon our interpretation of these specific results. This material was in reference to Section 2 of our study area and we added material about how this might change given increases in ice coverage.

See referee reports

Introduction

As modern environmental pressures continue to adversely impact natural habitats, global waterfowl populations are declining at accelerated rates. According to the Millennium Ecosystem Assessment, approximately 12% of all bird species are presently threatened with extinction, and 41% of all waterfowl populations are declining in abundance (Assessment, 2003; Assessment, 2005). Narragansett Bay's waterfowl communities are not immune to the global drivers of waterfowl population decline and modifications of waterfowl communities; Narragansett Bay is exposed to habitat conversion, shoreline hardening, increased sedimentation and pollution, and increased threats from climate change (Nixon & Fulweiler, 2012). Even though we know that these changing conditions are having a global impact on waterfowl populations, we are uncertain about the specific ramifications on Narragansett Bay's wintering waterfowl communities. Twenty-three North American waterfowl species have been observed wintering in Narragansett Bay, including 11 of the 15 known species of sea ducks, a guild of waterfowl that breed in boreal Canada and winter as far south as Chesapeake Bay (McKinney, 2004). Understanding or predicting deviations from normal is not possible without baseline monitoring data on waterfowl communities (Temple & Wiens, 1989).

In 2004, the Atlantic Ecology Division (AED) of the US Environmental Protection Agency's (EPA's) Office of Research and Development, in collaboration with state wildlife agencies and local environmental groups, began an annual winter waterfowl survey of Rhode Island's Narragansett Bay (hence forth referred to as the Bay). Every year in January, local wildlife biologists and environmental scientists conduct a comprehensive survey of the Bay's waterfowl. The waterfowl survey was implemented in an attempt to fill critical gaps in our ecological knowledge about the Bay's waterfowl communities. While there have been numerous waterfowl studies conducted in this area (Caron & Paton, 2007; Loring *et al.*, 2013; McKinney & McWilliams, 2005), we are unaware of

any long-term multispecies studies. Consequently, we are still relatively ill-informed about long-term trends of the Bay's waterfowl populations and communities. The survey data can also provide us a means to monitor the Bay's overall environmental health by using waterfowl as a bioindicator. Due to waterfowl's comparatively high trophic status, waterfowl communities provide insight about local food webs' relative health and stability.

To determine the underlying waterfowl community structure, we used a multivariate ordination technique, Nonmetric multidimensional scaling (NMDS) (Austin, 1976; Clarke, 1993). Additionally, we propose employing the NMDS as a statistical framework for environmental monitoring of the Bay (Gabrey & Afton, 2004; Urban, 2006). Like other ordination methods, the NMDS approach reduces data complexity, which is critical when analyzing data that are complex and highly variable. Yet unlike other ordination methods, NMDS requires few, if any, a priori assumptions about the distribution of the data. This multivariate approach allows us to detect any relative shifts in community composition between sites and years, and also to explore relationships with potential environmental drivers of change (Clarke & Ainsworth, 1993; Karydis, 1992).

Birds, especially waterfowl, are often the logical candidates for monitoring environmental health (Amat & Green, 2010; Kushlan, 1993). Since waterfowl are high trophic level foragers, the environmental stressors of all lower trophic levels accumulate in waterfowl (Matsinos & Wolff, 2003; O'Connell *et al.*, 2000). Waterfowl have, therefore, been used successfully to monitor a wide array of environmental stressors. For example, these species have been used to monitor a range of heavy metals, including cadmium, mercury, and lead (Di Giulio & Scanlon, 1984; Mochizuki *et al.*, 2002; Monteiro & Furness, 1995; Ribeiro *et al.*, 2005), and the impacts of habitat conversion, e.g., forested land to agriculture or road (Austin, 1976; Koper & Schmiegelow, 2006; Maisonneuve *et al.*, 2006). Birds respond to habitat conversion at multiple temporal and spatial scales (DeLuca *et al.*, 2004). Waterfowl respond to these stressors at the local up to the regional scale and their responses can be apparent nearly immediately and continue after substantial time lags (Findlay & Bourdages, 2000). These species have a high detection probability and are easy to identify by even novice birders (Pagano & Arnold, 2009), which further strengthen the argument of using waterfowl as bioindicators of environmental health.

It is nearly impossible to overstate the economic and environmental significance of Narragansett Bay to New England. Narragansett Bay contributes meaningfully to the economy through recreation, tourism, fishing, and shipping (Pastore, 2011; Tyrrell *et al.*, 1994). Its economic contributions are equally matched by its environmental contributions. The Bay serves as critical habitat to numerous species and provides innumerable ecosystem services. This study analyzes the first eight years of our survey data in order to develop a baseline understanding of waterfowl community spatial and temporal structure in the Bay, which can be used to track future changes in the overall health of the Bay.

Methods

Study site

Narragansett Bay is a well-mixed embayment containing a complex of estuaries (Figure 1). The Bay is 234 km² in area and has a mean depth of 8.7m (Calabretta & Oviatt, 2008; Nixon *et al.*, 2009). In the northern portion of the Bay, the Seekonk and Providence Rivers are the main freshwater sources. This area is also more urban, and exposed to periodic hypoxia, especially in the summer months (Codiga *et al.*, 2009). The southern portion of the Bay is deeper and has more intense oceanic influences. Additionally, the land surrounding the southern portion tends to be less densely developed and populated.

Survey method

Initiated in 2004, the NBWWS is completed annually by eight teams composed of 2–4 observers who survey waterfowl at 67 site locations throughout Narragansett Bay (McKinney, 2004). Survey locations were determined by dividing the bay first into sections, and then further into sites within the sections (Figure 1). The number of sites in each section ranged from eight sites in sections 4 and 5 to

15 sites in section 6. The division of sections and sites was based on the geography of the Bay; this layout ensures that all areas of the Bay will be visible from the survey locations (Figure 1).

Coordinated sampling occurs at all sites during a single day in early to mid-January, beginning at approximately 0730 in the morning and ending by 1645 in the afternoon. This is a shore-based survey and observers use direct counts to record all waterfowl present at a location at the time of the observation. We define waterfowl species as ducks, geese, swans, and grebes. All birds were identified to the species level, except Lesser and Greater Scaups, that were simple categorized into a single Scaup (*Aythya* spp.) taxonomic group due to the difficulty of distinguishing them.

Counting is completed from a stationary point from which the entire area (i.e., cove or embayment) is scanned with binoculars or a spotting scope. Every bird seen on the water surface or on the adjoining shoreline up to 50 m from the water is counted; when possible sex and age were also noted. Large flocks of greater than 100 birds are estimated by counting in groups of ten or one hundred. Observers

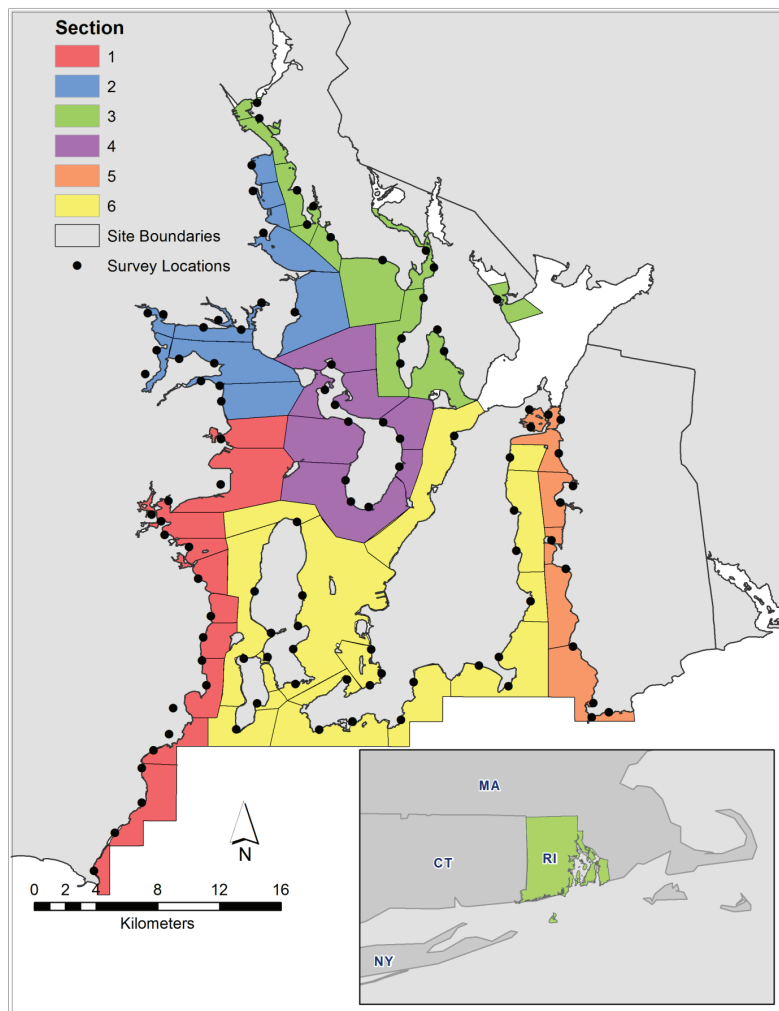


Figure 1. Map of Narragansett Bay, Rhode Island. Inset of Rhode Island (USA). Sections are color-coded and site boundaries delineated. The points represent the approximate observation locations for the surveys.

take as much time as necessary to accurately count and record all waterfowl observed. Most locations require between 10–20 minutes to survey.

Data analysis

We initially explored basic population trends for each waterfowl species. This included average abundance and standard deviations between years. We calculated ranked abundance for non-rare species and fitted regression trends and tested significance for each species. Ranked abundance allowed us to examine the relative dominance or rarity of a species given the current community. Furthermore, we assessed total waterfowl abundance and Shannon diversity index by year.

We used nonmetric multidimensional scaling to identify the community level structure of wintering waterfowl in Narragansett Bay (Austin *et al.*, 2001; Clarke & Ainsworth, 1993; Kruskal, 1964). Nonmetric multidimensional scaling is a nonparametric ordination technique used to reduce the dimensionality of a complex data set while maintaining the relative relationship between species composition of sites (Dixon, 2009). This specific ordination method does not require a prior constraining of axes or assumptions of normality. NMDS fits all ordination axes simultaneously not by sequentially finding orthogonal linear axes. Therefore, calculating

variance explained by axis or linear goodness of fit measures are not applicable to this specific ordination method.

Nonmetric multidimensional scaling was conducted using survey data collected from 2004 to 2011. A Wisconsin double transform, standardized by species percent abundance and by maximum for each species, was conducted on the species data, and Bray-Curtis distance was used to calculate community distance (for in-depth discussion of methods see Faith *et al.*, 1987; Minchin, 1987). We iteratively fit NMDS solutions of increasing dimensionality to determine the solution with adequate levels of decreased stress. Stress is a measure of goodness of fit; it is a measure of the agreement between the distance in ordination space and observed waterfowl community distance (Kruskal, 1964). Our goal was to minimize stress while avoiding superfluous ordination axes. To find the global stress minimization of an NMDS, random configurations of start locations were interjected into the fitting algorithm (Kruskal & Wish, 1978). All analyses were conducted in R version 2.13.1 (R Development Core Team, 2013) and NMDS was conducted with the Vegan package (Oksanen *et al.*, 2007).

To explore relationships between environmental conditions and the waterfowl community structure, we tested for correlations between the NMDS axes and ancillary variables (Table 1). Ancillary variable

Table 1. Ancillary variables.

Abbreviation	Description
Latitude	Latitude of site centroid
Longitude	Longitude of site centroid
mean_bath	Average bathymetry of site
Depth	Deepest point in the site
low_bath	Shallowest point in the site
std_bath	Standard deviation of bathymetry in the site
Area	Total area of the site
Perimeter	Total length of the site perimeter
degr_wet_area	Total area of wetlands classified as degraded within the site
Wetland	Total wetland area within the site
NAO.1	North Atlantic Oscillation Index for January of survey year
NAO.12	North Atlantic Oscillation Index for December prior to survey
NAO.11	North Atlantic Oscillation Index for November prior to survey
NAO.win	Average North Atlantic Oscillation Index for January, December, and November prior to survey
NAO.10	North Atlantic Oscillation Index for October prior to survey
NAO.9	North Atlantic Oscillation Index for September prior to survey
NAO.8	North Atlantic Oscillation Index for August prior to survey
NAO.fall	Average North Atlantic Oscillation Index for October, September, and August prior to survey
WS_day	Wind speed the day of survey
WS_day_b4	Wind speed the day before survey
WS_3day	Average wind speed for the three days prior to survey
WS_7day	Average wind speed for the seven days prior to survey
WS_30day	Average wind speed for the thirty days prior to survey
WD_day	Wind direction the day of survey
WD_day_b4	Wind direction the day before survey
WD_3day	Average wind direction for the three days prior to survey
WD_7day	Average wind direction for the seven days prior to survey

selection was hypothesis driven. Initially, we examined the area effect and spatial structure of the waterfowl community composition. Also, we explored the impacts of near shore habitat conversion. Furthermore, we hypothesized that winter intensity and extreme wind events might be driving inter-annual variation. All ancillary variables (Table 1) were initially tested for significance to the final four-dimensional NMDS structure and then cross correlation between variables. Among highly correlated variables, only the most significant variables to the NMDS structure were included in the final analysis.

Location was measured as the latitude and longitude of each site's centroid. Delineated site boundaries were used to calculate area and site perimeter length (Figure 1). Degraded wetland area was calculated using RI Department of Environmental Management (RI DEM) Statewide Planning Program's impacted wetland digital vector data, which were downloaded from the RI Geographic Information System (RIGIS) (<http://www.edc.uri.edu/rigis>). Total wetland area was calculated from the US Fish and Wildlife Service (US FWS) National Wetland Inventory (<http://www.fws.gov/wetlands>). National Oceanic and Atmospheric Administration's (NOAA) bathymetry data were also downloaded from RIGIS.

The North Atlantic Oscillation (NAO) is a large-scale climate index that measures the atmospheric pressure at sea level between the Icelandic low and Azores high, which captures information about the relative intensity of the winter (Hurrell, 1995). A strongly positive NAO index is related to above normal temperatures in the study region, whereas a negative NAO index is associated with colder, more severe winters (Visbeck *et al.*, 2001). The NAO index data were obtained from the National Center for Atmospheric Research (NCAR) (climatedataguide.ucar.edu). We used the NAO index to investigate whether winter waterfowl habitat selection was impacted by the relative severity of the winter weather. Wind speed variables were calculated from data downloaded from the NOAA National Climatic Data Center (<http://www.ncdc.noaa.gov>).

Results

Dataset 1. Environmental data

10.5256/f1000research.6080.d42953

Ancillary variables: The abbreviation definitions can be found in Table 1.

Dataset 2. Winter waterfowl survey

10.5256/f1000research.6080.d42954

Species data: The abbreviation definitions can be found in Table 2.

A total of 23 waterfowl taxa were recorded and included in the analysis presented within this study (Table 2). The total waterfowl population for the Bay averaged approximately 20,000 individuals annually. Total count was lowest in 2006 (15,090 individuals) and highest in 2010 (26,503 individuals) (Figure 2). The 2010 peak in abundance was due to a spike in the number of Scaup spp. present

Table 2. Species summary of the Narragansett Bay Winter Waterfowl Survey for 2004–2011. Mean is the average abundance for each species throughout the entire study area. Percent represents the fraction that each species contributes to the total for duration of the study. *Species making up less than 1% of the community, and considered rare. Trend analysis (Figure 3) were not conducted on these rare species.

Species	Species Code	Mean (+/-) SD	Percent
American Black Duck <i>Anas rubripes</i>	ABDU	1205 ± 176	5.95
American Wigeon <i>Anas americana</i>	AMWI	456 ± 334	2.25
Barrow's Goldeneye* <i>Bucephala islandica</i>	BAGO	0.3 ± 0.7	~0
Black Scoter <i>Melanitta americana</i>	BLSC	316 ± 355	1.56
Brant <i>Branta bernicla</i>	BRAN	2525 ± 881	12.5
Bufflehead <i>Bucephala albeola</i>	BUFF	1052 ± 431	5.19
Canada Goose <i>Branta canadensis</i>	CAGO	2713 ± 1249	13.4
Common Eider <i>Somateria mollissima</i>	COEI	1302 ± 579	6.43
Common Goldeneye <i>Bucephala clangula</i>	COGO	1374 ± 532	6.78
Common Loon* <i>Gavia immer</i>	COLO	67 ± 41	0.332
Common Merganser* <i>Mergus merganser</i>	COME	26 ± 23	0.128
Gadwall* <i>Anas strepera</i>	GADW	144 ± 105	0.712
Harlequin Duck* <i>Histrionicus histrionicus</i>	HADU	71 ± 22	0.351
Hooded Merganser* <i>Lophodytes cucullatus</i>	HOME	171 ± 110	0.842
Horned Grebe* <i>Podiceps auritus</i>	HOGR	138 ± 185	0.682
King Eider* <i>Somateria spectabilis</i>	KIEI	0.1 ± 0.3	~0
Long-tailed Duck* <i>Clangula hyemalis</i>	LTDU	1 ± 2	~0
Mallard <i>Anas platyrhynchos</i>	MALL	1002 ± 410	4.94
Red-breasted Merganser <i>Mergus serrator</i>	RBME	771 ± 205	3.8
Scaup spp. <i>Aythya spp.</i>	SCAUP	6146 ± 2750	30.3
Surf Scoter* <i>Melanitta perspicillata</i>	SUSC	81 ± 66	0.401
Swan <i>Cygnus spp.</i>	SWAN	618 ± 267	3.05
White-winged Scoter* <i>Melanitta fusca</i>	WWSC	78 ± 130	0.386

in the Bay. This jump in Scaup spp. abundance corresponded to a reciprocal dip in the 2010 Shannon diversity index (Figure 2). Ranked abundances of individual species showed no significant trends of increase or decrease over the course of this study, except for slight increases in Bufflehead (*Bucephala albeola*) and Hooded Merganser (*Lophodytes cucullatus*) (Figure 3).

Our final NMDS fit had four dimensions and a stress value of 0.1449 (Figure 4A), and is well within the acceptable stress limits of NMDS (Clarke, 1993; Kruskal & Wish, 1978). Sites in the NMDS plot that are closer in ordination space are more similar in species composition. As the distance between points increases, the species composition becomes more dissimilar. Our final presentation of the NMDS rotated the data so that greatest distance between site scores are plotted on NMDS axis 1. There is some spatial clustering of survey sections across the first two NMDS axes. Sections 1 and 6 are concentrated on the left side of the NMDS axis 1, while

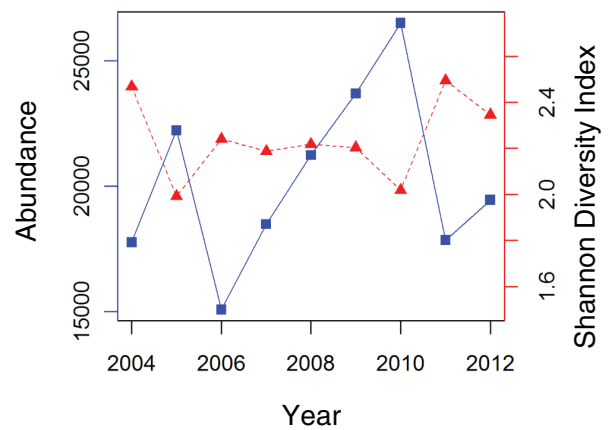


Figure 2. Waterfowl abundance and Shannon diversity index.

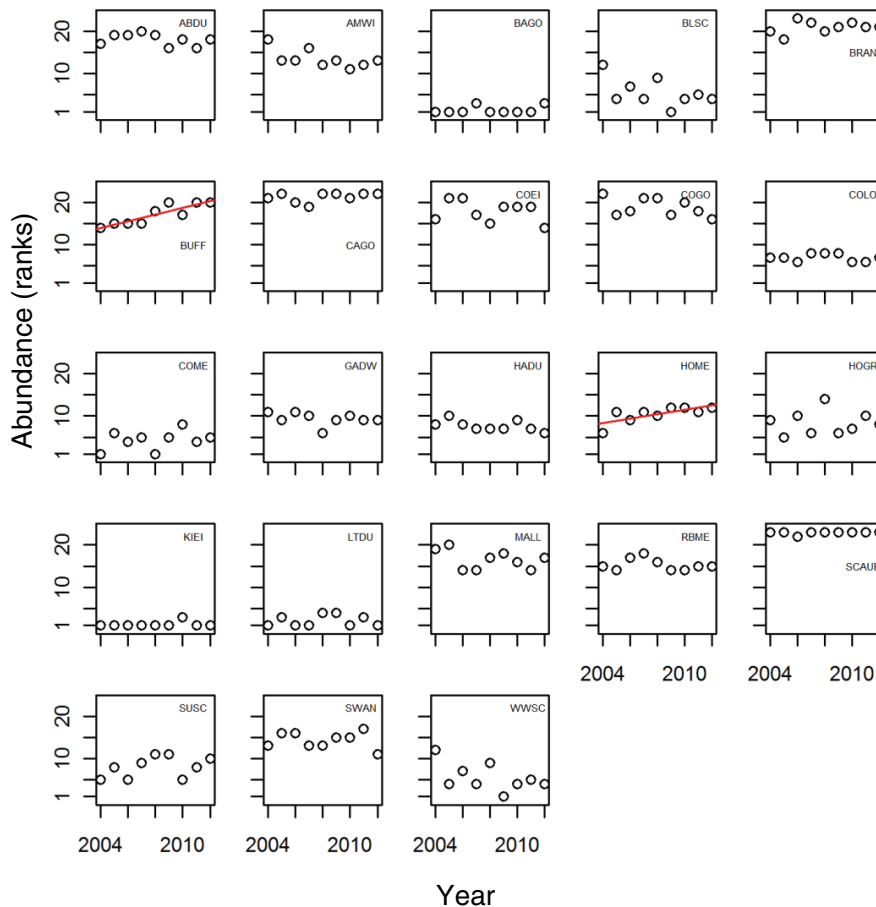


Figure 3. Non-rare species ranked abundances.

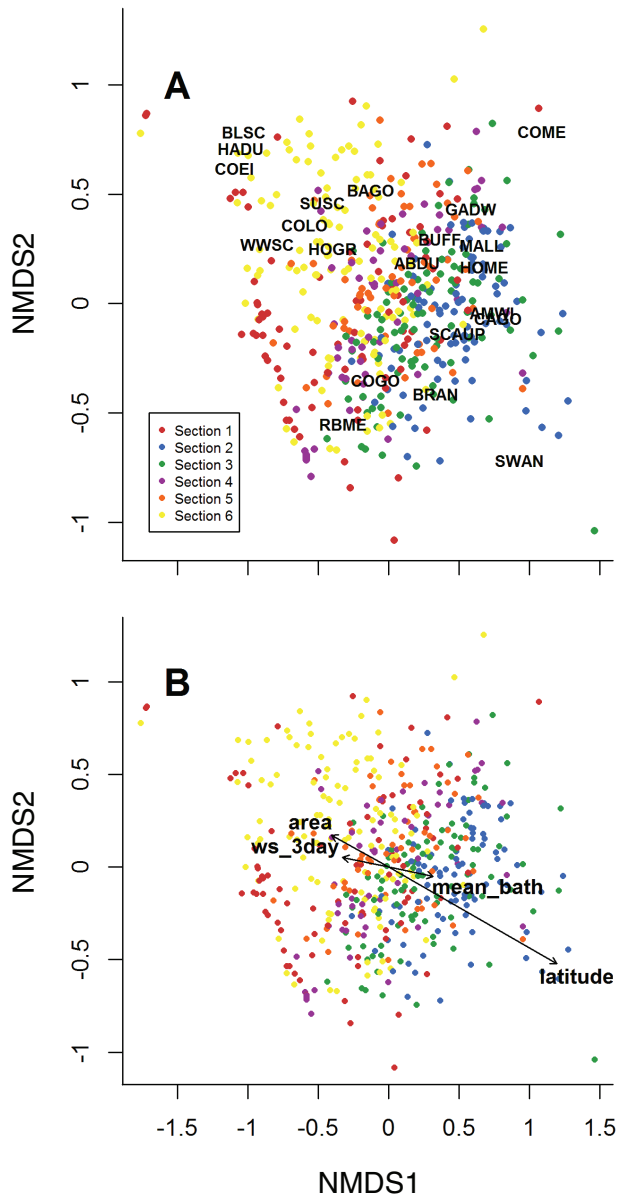


Figure 4. Final NMDS results. The circles illustrate the location of a single site for each surveyed year. The sites are color-coded by section. **Figure 4A:** Species locations are illustrated with four-letter abbreviation. **Figure 4B:** Bi-plot of NMDS axis one and two with vectors of significant environmental variables overlaid. The arrow's direction illustrates the environmental gradient and the length is proportional to the correlation strength between the variable and the NMDS (See Table 3).

sections 2 and 3 are predominantly on the right side. Sections 4 and 5 are located approximately in the middle, as they are in actual Bay position.

Species location in the ordination space can approximate how species sort into habitat types along the spatial gradient in the Bay (Figure 4a). The upper left of the ordination space reflects

Table 3. Results of final NMDS.

Variable	NMDS 1	NMDS 2
Latitude***	0.916	-0.401
mean_bath**	0.987	-0.160
Area***	-0.920	0.392
NAO.12	0.247	-0.969
NAO.11	-0.0618	0.998
NAO.win	0.145	-0.989
WS_3day**	-0.988	0.157
WS_30day	0.600	0.799
WD_day**	0.563	-0.826
WD_day_b4*	-0.335	0.942

Significance codes: "****" < 0.001, "***" < 0.01, "**" < 0.05

predominantly open ocean, deep-water sites (sections 1 and 6). In line with the habitat location in ordination space, indicator species of deeper water oceanic habitat (e.g. Harlequin Duck (*Histrionicus histrionicus*) and Common Eider (*Somateria mollissima*)) are also positioned in the upper left hand corner of the ordination. Northern sites in the Bay are more shallow and marsh-like (sections 2 and 3), with species indicative of this habitat type (e.g. Atlantic Brant (*Branta bernicla*) and Canada Goose (*Branta canadensis*)).

After the removal of correlated variables, ten ancillary variables were fit to the NMDS results (Table 3). Only latitude, mean bathymetry, area, and the average wind speed three days prior to the survey were significantly correlated to the NMDS (Figure 4B). Wind speed the day of the survey and day before were slightly less significant. Although not significant, the NAO index for November, December, and winter average showed strong relationships with NMDS axis 2.

Most sections' locations in the ordination space did not change drastically between years; they remained in the same relative location of the ordination (Figure 5). The relative stability of sections in ordination space among years indicates that communities had consistent species composition between years. Section 2 shifted the most among years, especially between 2008 and 2009 (Figure 5). Additionally, when compared to the other sections, section 2 had the greatest between group average distances through the duration of this study.

Discussion

Our community level analysis allowed us to establish the expected spatial and temporal structure of the Bay's winter waterfowl communities which can be used to monitor future environmental changes. Spatially, the NMDS analysis formalized several aspects of the Bay's waterfowl community that were previously understood only anecdotally, and provided a clear depiction of the community spatial structure across the Bay. NMDS as a monitoring tool in conjunction with the baseline conditions identified in this study could be particularly useful in identifying any future changes in waterfowl community structure in this region and change in the Bay's overall health.

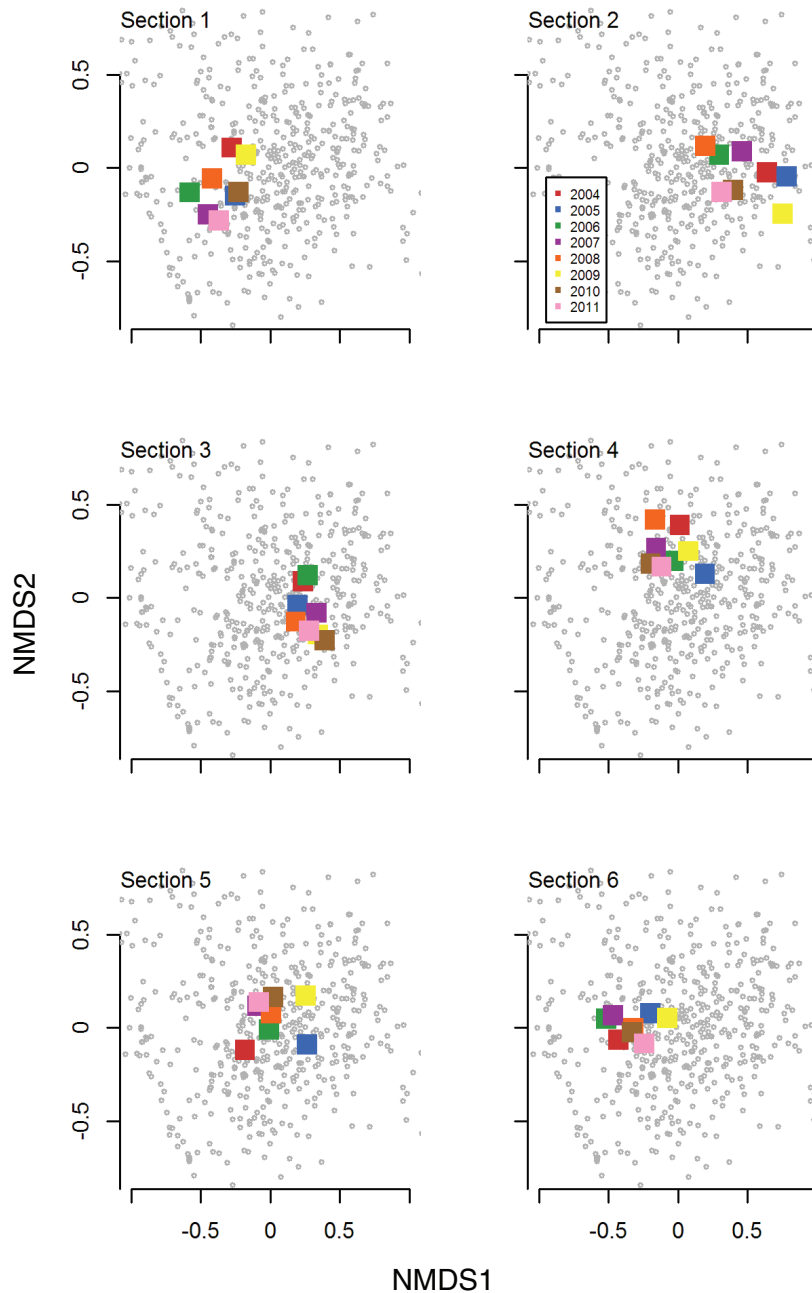


Figure 5. Final NMDS illustrating average community ordination location of section by year. Illustrates where the section exists in the overall ordination space and how that position changes through the study period.

In the upper portions of the Bay (sections 2 and 3), waterfowl habitat is characterized by shallow, salt-marsh dominated coves and sheltered coves and shorelines with ample freshwater inputs. These sites mapped predominantly on the right-side of the NMDS (Figure 4). Dabbling duck species such as Mallard (*Anas platyrhynchos*) and American Black Duck (*Anas rubripes*) use salt-marsh sites at high tide for cover, protection from predators, and as sites for

roosting at low tide (Bellrose, 1980). Several smaller diving ducks, including benthic-feeding Bufflehead and piscivorous Hooded Merganser use sheltered coves and shorelines for feeding during the day (McKinney, 2004). Canada Goose and Mute Swan (*Cygnus olor*) also utilize these sites as they presumably provide ready access to submerged aquatic vegetation on which these species feed (Mowbray *et al.*, 2002). An urban center (city of Providence)

and several expansive suburban cities are located in close proximity to the upper Bay sites, and it is in this region of the Bay where urban development would be expected to most influence waterfowl distribution.

The middle portion of the Bay is characterized by an increase in deeper, open water habitats, which continue towards the Bay mouth where they are supplemented by rocky shoreline habitats. These sites concentrated on the left-side of the NMDS (Figure 4, color-coded red and yellow). Open-water species such as Red-breasted Merganser (*Mergus serrator*), Common Goldeneye (*Bucephala clangula*), Scoter species (*Melanitta* spp.), and Common Eider use this region of the Bay. These species have larger body sizes that enable them to dive in deeper water to take advantage of prey not found in shallow water areas (e.g., Blue Mussel, *Mytilus edulis*), and of benthic prey such as crabs that migrate to deeper water during winter (Ehrlich *et al.*, 1988). Harlequin Duck uses rocky shoreline habitats found near the mouth of the Bay that reflect their northern rocky stream breeding sites and where they can feed on benthic invertebrates such as amphipods (Robertson & Ian Goudie, 1999). The lower Bay sites are currently less impacted by adjacent urbanization effects as shorelines tend to be more sparsely populated. However, knowledge of baseline conditions could lend insight into interpreting data from future monitoring and aid in identifying any impacts of increased urbanization, or changes in waterfowl community structure resulting from displacement of upper Bay species.

In addition to species' life history strategies, climatic factors can potentially influence waterfowl distribution in estuaries. In our study, wind speed, averaged over the three day period before sampling, was the only significant dynamic variable included in the final NMDS. This too reinforces what was communicated anecdotally about the movement of waterfowl through the Bay. Large groups of birds will shift their location in the Bay during prolonged high wind events, such as nor'easters. Typically before and during large storms, birds will relocate to the leeward side of islands or into wind protected coves. Due to global climate change, nor'easter frequency and intensity have increased on a global scale (Yohe & Hope, 2013). It is assumed that Narragansett Bay will be impacted by this increase in predicted probability of severe winter events. Our study suggests waterfowl respond to short-term changes in wind speed, and it will be of interest to monitor how waterfowl respond to any increase in both intensity and frequency of extreme wind events.

We observed a small, yet significant, increase in the ranked abundance of Hooded Merganser, and an even more apparent upward trend of the Bufflehead population. The Bufflehead trend may be the effect of increased level of protection for this species. In the early 20th century, Bufflehead populations were in decline due to over harvest and in response received increased protection through such means as reduced bag limits (Gauthier, 1993). In addition, Bufflehead nesting boxes were installed to compensate for loss of breeding habitat (Erskine, 1960; Owen & Black, 1990). Population numbers have been growing steadily since, and perhaps this rebound could explain the increasing trend we saw in Narragansett Bay. Since we used ranked abundance, we hypothesize that the elevated conservation status of Bufflehead and subsequent population

growth is providing the Bufflehead a competitive advantage in the Bay. However, more research is needed to fully understand the dynamics and drivers of the changes in Bufflehead populations in the Bay.

As we move forward with our monitoring, the NMDS approach can provide a useful means to compare future survey data with baseline conditions established during the first ten years of the survey. The NMDS provides a statistical framework to analyze monitoring data at the site and section level, but in context of the entire Bay (Faith *et al.*, 1987). Due to random noise, we expect the position of the site or the average position of the section (as in Figure 5) to undergo relatively small changes in ordination space from year to year. In contrast, locations that jump from one year to the next, or that display a trajectory through NMDS space through time may indicate environmental forcing that is more than random.

For example, the relatively large shifts of section 2 between years may be a characteristic of this particular section; it is thought that waterfowl communities in this part of the Bay vary greatly according to the intensity of winter and amount of ice. However, large shifts among years or over the course of several years may be an indicator of environmental change. Additionally, if we see more variability in the amount of ice in this section, it may be more difficult to define a collective waterfowl community for this section. The turnover between years might simply overwhelm any potential community signal. To highlight the effectiveness of the method for monitoring, we already know from this baseline analysis that section 2 is an area that requires special consideration in the future.

Although the NMDS shows promise as an effective statistical framework, there are obvious limitations to our approach. First and foremost, annual surveys provide discrete snapshots of the Bay's waterfowl community through time. We survey one day a year, and only in the winter when these species are present. We do not have a quantitative estimate of the amount of variability data arising from either short-term (i.e., daily) or longer-term (weekly or monthly) movements of individuals among sites, or into and out of our study area. Because of this, our ability to detect change in community composition may require data collection over an extended time period. Yet despite these shortcomings, the ease of data collection and robustness of the NMDS method make it a viable long-term monitoring option.

In this study we proposed an approach to analyzing long-term waterfowl monitoring data in order to establish baseline conditions against which future trends in community composition and habitat utilization can be compared. This approach provides a quantitative yet visual means to represent baseline community structure and observed patterns of waterfowl distribution, and provides an easily interpreted series of templates against which future observations or patterns of change can be evaluated. Our approach was developed for waterfowl Narragansett Bay, but can be applied to other estuaries and potentially other species, although environmental factors in the model may need to be modified to reflect those relevant to the species investigated. Overall, our approach will help facilitate the use of waterfowl populations, as well as other relevant species, to monitor the environmental health of a large bay.

Data availability

F1000Research: Dataset 1. Environmental data, [10.5256/f1000research.6080.d42953](#) (Kreakie *et al.*, 2014a).

F1000Research: Dataset 2. Winter waterfowl survey, [10.5256/f1000research.6080.d42954](#) (Kreakie *et al.*, 2014b).

Author contributions

RM designed, implemented, and supervised all waterfowl surveys. Additionally, RM curates all survey data. BK conducted coding and analysis, and prepared the manuscript for publication. KW has participated in waterfowl surveys. All authors were involved in developing conclusions and revising the manuscript. All authors agree to the final content.

Competing interests

No competing interests were disclosed.

Grant information

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José Manuel Arcos

SEO/BirdLife, Barcelona, Spain

This is an interesting paper describing a waterfowl winter community and its evolution through time. Authors use non-metric dimensional scaling to assess changes in community structure, taking into account environmental features (habitat, climatic, meteorological). The work seems adequately conducted and is based on a sound dataset that extends along 8 years. I find therefore the work worthy to be indexed. However, I have some concerns about how the work is presented. Overall, it has a too local focus and should be put in a wider context, with clear aims. I hope the following comments, by sections, will help authors to improve the current version.

Abstract

This section is particularly too local it should give a wider view of the work and its potential contribution beyond the study area. The authors propose a methodological approach that could be extended to other areas, to solve similar questions (i.e. how to assess changes in wintering waterfowl communities over time, in a scenario of climate change and increasing coastal development). The last paragraph of the discussion is written under this philosophy, and part of it could be used here. Of course it's also important to depict the results, but they need to be better contextualized.

Another issue to address is the excess of repetitions (the same problem is applicable to other sections of the manuscript). For instance, Narragansett Bay is quoted eight times in the abstract alone, and the analytical tool "nonmetric multidimensional scaling" is written in full three times (worth introducing here the acronym NMDS).

Introduction

Again I find the text too local. Only the first two sentences of paragraph 1, plus paragraph 4 attempt to put the study in a wider context. I suggest to join (and slightly extend) these wider issues at the beginning, as well as introduce afterwards the proposed methodological approach, and leave the local considerations for the end of the introduction (except for a final paragraph stating the aims of the paper, trying again to give a wider view and to describe clear objectives). The text in the current last paragraph related to the economic and environmental significance of Narragansett Bay could be better suited (and slightly extended) in the discussion. On the other hand, some of the detailed information of the Bay could be moved to the Methods (study site/study method).

As a last minor comment, it'd be appropriate to provide a reference for the statement that *Waterfowl*

respond to these stressors at the local up to the regional scale and their responses can be apparent nearly immediately and continue after substantial time lags (4th paragraph).

Methods

Study site

Remove the first sentence from this section (it describes the waterfowl survey, not the study site). Also consider, if necessary, to move some of the information provided in the introduction here, avoiding repetitions.

Survey method

Overall, try to be consistent with the verb forms. Most of this section is written in present tense, but some sentences use the past simple tense.

In the 2nd paragraph of this section, quote grebes along with ducks, geese and swans (Horned Grebe is also considered). Also in this paragraph, I suggest rewriting the last sentence, to start saying that in most cases birds were identified to species level. For instance: "All birds were identified to the species level, except Lesser and Greater Scaups, that were simple categorized into a single Scaup (*Aythya* spp.) taxonomic group due to the difficulty of distinguishing them."

Data analysis

Just as a comment, I find that there are too many pre-selected ancillary variables, particularly NAO-related variables. I understand that this has a minor effect, however, as most of them were removed from the final model. On this regard, it'd be worth explaining why a threshold of $r = 0.8$ was adopted.

In the third paragraph of this section, I'd suggest to change "for in-depth discussion of methods see (Faith et al., 1987; Minchin, 1987)" to "(for in-depth discussion of methods see Faith et al., 1987; Minchin, 1987)". Also change "All analysis was conducted in R" to "All analyses were conducted in R"

Results

Table 2. Check wording. For instance, at the end of the table caption, change "were not be conducted" to "were not conducted". I'd suggest changing the last column of the table to %, as this would be more visual for the reader.

The last two sentences of the results' section seem more appropriate for the discussion. This issue, on the other hand (stability of most sections/changes in section 2 over time) deserve some further attention in the discussion.

Discussion

Again I'd slightly change the structure, and try to avoid excessive description. I'd condensate the description of the waterfowl community site by site, trying to avoid references to conservation issues (e.g. implications of highly urbanized areas) here (see below).

I feel a bit uneasy with the sentence "In addition to species' life history strategies, environmental factors can potentially influence waterfowl distribution in estuaries". I understand that some environmental factors

(such as habitat features) are closely related to life history. So maybe change “environmental” to “climatic”/“meteorological”?

I'd add a paragraph regarding conservation-related issues, including coastal-development issues (i.e. the higher pressure in the inner Bay), as well as other relevant local considerations, plus references to climate change.

Regarding the increase of Hooded Merganser and Bufflehead, why only the latter is discussed? I miss an explanation for the increase of Hooded Merganser too. On the other hand, I miss some more precision regarding the dates of eventsw regarding Bufflehead (e.g. when –roughly- protection measures started to be in place?). And last regarding this issue, I don't understand why increased protection to buffleheads provides them a competitive advantage in the Bay. They increase in relative numbers, and therefore their rank position changes, but is this an actual advantage in the wintering area?

I appreciate the considerations on the limitations of the study, as described in the penultimate paragraph.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Competing Interests: No competing interests were disclosed.

Author Response 10 Sep 2015

Betty Kreakie, US EPA ORD, USA

Thank you so much for taking the time to give us such a thoughtful review. It is clear that your recommendations have greatly improved the text. Below we can included point-by-point responses to your review and have posted a new version based on your comments to F1000Research. Hopefully, this version of the manuscript will be met with your approval. Please let us know if you have any additional concerns or questions.

1. This section is particularly too local it should give a wider view of the work and its potential contribution beyond the study area. The authors propose a methodological approach that could be extended to other areas, to solve similar questions (i.e. how to assess changes in wintering waterfowl communities over time, in a scenario of climate change and increasing coastal development). The last paragraph of the discussion is written under this philosophy, and part of it could be used here. Of course it's also important to depict the results, but they need to be better contextualized.

Response: We completely agree with this statement. n fact, early drafts of the manuscript were more focused on developing this method for wide use in environmental monitoring. However, previous reviewers and co-authors felt that we were overreaching and felt it was more interesting to just focus on this particular study area. To compromise, we have added back some text about the broad application of this method.

2. Another issue to address is the excess of repetitions (the same problem is applicable to other sections of the manuscript). For instance, Narragansett Bay is quoted eight times in the abstract alone, and the analytical tool "nonmetric multidimensional scaling" is written in full three times (worth introducing here the acronym NMDS).

Response: Thank you for pointing this out. We have rework the abstract (and the remaining text) to remove several of the redundancies and introduced the NMDS acronym to the abstract.

3. Again I find the text too local. Only the first two sentences of paragraph 1, plus paragraph 4 attempt to put the study in a wider context. I suggest to join (and slightly extend) these wider issues at the beginning, as well as introduce afterwards the proposed methodological approach, and leave the local considerations for the end of the introduction (except for a final paragraph stating the aims of the paper, trying again to give a wider view and to describe clear objectives). The text in the current last paragraph related to the economic and environmental significance of Narragansett Bay could be better suited (and slightly extended) in the discussion. On the other hand, some of the detailed information of the Bay could be moved to the Methods (study site/study method).

Response: We agree that the previous version of manuscript appears to be very local. As noted in the responses to comment #1, we have added and edited to manuscript to broaden the scope and present the application of the methods. Hopefully the reviewer will feel that we accomplished the goal of broaden the manuscripts scope. Yet coauthors and previous reviewer still feel that this research is in essence simple an analysis of bird communities in Narragansett Bay. We feel that their concern of overreaching is valid. Hopefully with these edits, we have found a balance.

4. As a last minor comment, it'd be appropriate to provide a reference for the statement that *Waterfowl respond to these stressors at the local up to the regional scale and their responses can be apparent nearly immediately and continue after substantial time lags* (4th paragraph).

Response: This error has been corrected.

5. Remove the first sentence from this section (it describes the waterfowl survey, not the study site). Also consider, if necessary, to move some of the information provided in the introduction here, avoiding repetitions.

Response: This edited has been included into the recent version. Due to convention, we have decided to leave some of material about the study area in this section.

6. Overall, try to be consistent with the verb forms. Most of this section is written in present tense, but some sentences use the past simple tense.

Response: We have reread this section and made edits as needed. However, this section does require the both the past and present tense. Since this survey is ongoing and yet the survey design was completed at the beginning of the study, we used verb tense to indicate which decision were made historically and which still are being used.

7. In the 2nd paragraph of this section, quote grebes along with ducks, geese and swans (Horned Grebe is also considered). Also in this paragraph, I suggest rewriting the last sentence, to start saying that in most cases birds were identified to species level. For instance: "All birds were identified to the species level, except Lesser and Greater Scaups,

that were simple categorized into a single Scaup (*Aythya* spp.) taxonomic group due to the difficulty of distinguishing them.”

Response: Both of these suggestions have been incorporated.

8. Just as a comment, I find that there are too many pre-selected ancillary variables, particularly NAO-related variables. I understand that this has a minor effect, however, as most of them were removed from the final model. On this regard, it'd be worth explaining why a threshold of $r = 0.8$ was adopted.

Response: We agree that there were a lot of pre-selected ancillary variables. We knew that we wanted examine the correlations between climatic and other variables and our NMDS structure, but there was not enough literature on the subject to reduce those variables *a priori*. Since these variables were computational easy to derived, we decided to error on the side of caution. We also change the wording to thresholding to reflect more accurately how we selected variables.

9. In the third paragraph of this section, I'd suggest to change “for in-depth discussion of methods see (Faith et al., 1987; Minchin, 1987)” to “(for in-depth discussion of methods see Faith et al., 1987; Minchin, 1987)”. Also change “All analysis was conducted in R” to “All analyses were conducted in R”

Response: We have corrected both of these errors.

10. Table 2. Check wording. For instance, at the end of the table caption, change “were not be conducted” to “were not conducted”. I'd suggest changing the last column of the table to %, as this would be more visual for the reader.

Response: This error has been corrected and proportions have been converted to percentages.

11. The last two sentences of the results' section seem more appropriate for the discussion. This issue, on the other hand (stability of most sections/changes in section 2 over time) deserve some further attention in the discussion.

Response: This comment had been completely incorporated into the text. We have deleted the last two sentences from results. This text has been added the discussion along with additional explanation.

12. Again I'd slightly change the structure, and try to avoid excessive description. I'd condensate the description of the waterfowl community site by site, trying to avoid references to conservation issues (e.g. implications of highly urbanized areas) here (see below).

Response: This concern has been addressed through the edits to other comments.

13. I feel a bit uneasy with the sentence “In addition to species' life history strategies, environmental factors can potentially influence waterfowl distribution in estuaries”. I understand that some environmental factors (such as habitat features) are closely related to

life history. So maybe change “environmental” to “climatic”/“meteorological”?

Response: We have incorporated this suggestion into the text.

14. I'd add a paragraph regarding conservation-related issues, including coastal-development issues (i.e. the higher pressure in the inner Bay), as well as other relevant local considerations, plus references to climate change.

Response: This concern has been addressed through the additional paragraph in the discussion.

15. Regarding the increase of Hooded Merganser and Bufflehead, why only the latter is discussed? I miss an explanation for the increase of Hooded Merganser too. On the other hand, I miss some more precision regarding the dates of events regarding Bufflehead (e.g. when –roughly- protection measures started to be in place?). And last regarding this issue, I don't understand why increased protection to buffleheads provides them a competitive advantage in the Bay. They increase in relative numbers, and therefore their rank position changes, but is this an actual advantage in the wintering area?

Response: This paragraph is only intended to be speculative about possible reasons behind these shifts. We did not explicitly test. It was an interesting discovery and we did not want to simply ignore it. We have added some text to this paragraph to make it clear that we are simply presenting some thoughts about what might be behind this pattern. Clearly more research is needed on this.

Competing Interests: No competing interests were disclosed.

Author Response 22 Oct 2015

Betty Kreakie, US EPA ORD, USA

I now realize that I should have waited to post the response after the new version was published. Version 2, which addresses your concerns, is now published. Sorry for any confusion that this may have caused.

Competing Interests: No competing interests were disclosed.

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General comments

Environmental monitoring means different things to different people. It always involves a long-term commitment – that is, a given system is followed up over time, years to decades – but how much this is

driven by hypotheses about what drive the changes of the system, and/or about the consequences of these changes, vary. One could use one of the most famous examples of environmental monitoring – the monitoring of CO₂ concentrations initiated by Charles David Keeling in 1958 at Hawaii's Mauna Loa observatory. Keeling was expecting a rise as a consequence of the combustion of fossil fuels, and there were different hypotheses regarding the rate of increase depending on in particular exchange between atmosphere and ocean (see e.g., Revelle and Suess 1957). Keeling concluded for example in 1960 "At the South Pole the observed rate of increase is nearly that to be expected from the combustion of fossil fuel (1.4 p.p.m.), if no removal from the atmosphere takes place" (p. 203; Keeling used measurements from both hemispheres, not just Mauna Loa). This was therefore a strongly hypothesis-driven monitoring – but that did not exclude surprises, in particular the large seasonal variations due to photosynthetic activity. But such surprises often came because there are rather precise expectations about possible changes (see Lindenmayer *et al.* 2010 for a related discussion). Many environmental monitoring programs, however, do not have such underlying hypotheses, and are often characterized as being more of the surveillance type (see Nichols and Williams 2006). The main goal is to identify changes – other than due to the stochastic variability of the system. This paper falls in this category – the main purpose is to describe waterfowl communities in a given area, the Narragansett Bay, and identify possible changes (as e.g., an upward trend in two species, Bufflehead and Hooded Merganser). Variables that could drive these changes, and with a relevance for local or regional management, are not included in the analyses – environmental data used refer either to site variables which are unlikely to change (latitude/longitude, bathymetry, area) or that rather reflect short-term temporal variation (wind speed on the day of the survey or just prior to it, North Atlantic Oscillation – a measure of regional atmospheric patterns – in the month of the survey or the months prior to it). That in fact identifying the causes of observed changes in waterfowl communities will be hard without having more explicit hypotheses is made clear in some parts of the discussion. How can we know for example if an observed increase in a wintering duck population is due to 1) improved reproductive success on the breeding grounds, 2) lower hunting pressure in the fall, and 3) change in wintering areas (these hypotheses are not exclusive, so the problem is to assess their relative importance, as for CO₂ concentrations: burning fuels, exchange atmosphere-ocean and photosynthetic activity all play a role). Monitoring environmental systems should, in my opinion, aim at characterizing the state of the system but also the drivers of changes (Yoccoz *et al.* 2001; Yoccoz 2012; see Lindenmayer *et al.* 2015 for a thorough discussion). Doing this without formulating hypotheses (and if possible quantitative models) is difficult. Even if the paper focuses on developing a baseline for environmental monitoring, it also proposes "a statistical framework for future environmental monitoring". I do not see how the proposed framework will allow for such a quantitative evaluation of hypotheses.

Another concern is the reference to a baseline – using the 2004-2011 data. It is most likely that waterfowl communities during that period have already been heavily impacted by important environmental drivers, either positively (think about the increase of some goose populations) or negatively. Taking those years as a baseline might lead to what Pauly (1995) in the context of fisheries call the "syndrome of shifting baselines" (see Clavero 2014 for an example with non-native species). What we see as a baseline is already very different from historical conditions – irrespective of the reference time used to define "historical". Monitoring requires we determine the state of the system, but calling it a baseline may be rather misleading without at least a comment.

A final general comment relates to waterfowl as "logical candidates for monitoring environmental health" (p. 2) because they respond to "a wide array of environmental stressors [...] at the local up to the regional scale". Clearly, what we monitor should reflect the changes we expect, but they should also allow for disentangling causes of change – for example if managers want to act on these causes. Knowing if for example causes are local or regional will determine where policy decisions should be made. Monitoring system variables, such as waterfowl communities, that are influenced by a large number of drivers at very

different scales may make them too “integrative” for management (or scientific) purposes. Of course, it may be that there will be a main driver of change (think of DDT and birds of prey) but that seems to be unlikely in this case. I personally think we should aim at monitoring directly state variables and rely less on indicators, but I understand also the practical (and financial) difficulties. But if one relies upon indicators, or surrogates, at least simple conceptual models linking indicators and state variables would help. It would also make transparent assumptions regarding the stability of the links.

To conclude, the authors have done a great job organizing and synthesizing a waterfowl survey over nearly 10 years. The next step – “future environmental monitoring” – should go further and provides us with a conceptual model of expected changes in the waterfowl community as stressors change at different spatial scales, and if one has the necessary information to assess the relative impact of these stressors.

Specific comments:

NMDS is one among many multivariate methods that can be used for analyzing spatio-temporal community data (see Legendre and Gauthier 2014 for a recent review). These methods do not make assumptions about the distribution of the data (p.2), but they all make assumptions about what is a “good” measure of e.g. community similarity (for example one could consider the number of species the two communities share, and how many species that are unique to each community, and combine these numbers in different similarity indices). If one wants to make inference (for the number of axes to be interpreted, or relationships with environmental variables), most analyses rely upon permutation tests which do not rely upon distribution of the data but may be sensitive to dependence among samples. Particularly to identify relationships with environmental variables, alternative approaches to NMDS such as Canonical Correspondence Analysis, would have been interesting to use (ter Braak 1987, Legendre et al. 2011).

p. 4, it is written that the choice of ancillary (environmental) variables was “hypothesis driven”. It would have helped to be more explicit about which component of the variation could be explained by these variables, and in what way it was related to the stressors described e.g. p.2. Clearly the first 10 variables (latitude to wetland area) are unlikely to change during the 8 years of the survey, so they would explain the spatial variation only. Wind speed the day of the survey might explain the day to day variation (but given there is no replicate survey within a year, it will be confounded with the yearly variation), whereas NAO.fall might reflect weather conditions during migration and early winter.

Table 2, p. 5: for counts with skewed distributions, the standard deviation (SD) might be a poor descriptor of the variability (the mean might also be a poor descriptor of location). It might be useful to give the range and median in addition to mean and SD.

Table 3: what is meant by “results”? Correlations? How are P-values calculated?

p. 7: *Bucephala*

p. 8: species’ life history strategies: use traits rather, you do not really investigate strategies here.

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I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Competing Interests: No competing interests were disclosed.

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General Comments

This study provides an excellent contribution to our knowledge of baseline species diversity and abundance for the waterfowl community in Narragansett Bay, Rhode Island. The authors analyze longitudinal survey data from the Narragansett Bay Winter Waterfowl Survey (NBWWS) in order to detect shifts in the species composition of the waterfowl community and to explore if environmental drivers might be driving any change. On a regional scale the study covers almost the entire bay, and considering the general paucity of such monitoring programs, this study is important in that it documents baseline knowledge of the species diversity and abundance of the areas waterfowl and seabird species.

Specific Comments

Introduction:

The main purpose of the introduction was to argue the need for baseline monitoring data for waterfowl communities. The authors do achieve this objective in first and fourth paragraphs, leading to the purpose of study in the last sentence of the fifth paragraph of the introduction. However, I did not find all the information in the introduction leading directly to the statement of purpose of the study, with this statement no matching what was stated in the abstract. The second and third paragraphs for example, include information that would be better suited for the methods. Also, while the authors do a great job in explaining why waterfowl are logical candidates for monitoring environmental health, I found the excessive references of the citations in the fourth paragraph a bit distracting. I am not certain of the editorial guidelines of *F1000Research* (I looked these up but failed to find the citation/reference guidelines), but I think a generally accepted rule of thumb is to not list more than three references per citation (although I could very well be wrong here). Nevertheless, when excessive references and citations are used it distracts the reader from the written message and disrupts the flow of the paragraph. I understand that you have to cite certain statements, but I would advice the authors to go through their citations and only cite essential sources. Doing so along with moving the information from the second and third paragraphs to the methods would help streamline the introduction.

Methods:

A general comment on the survey technique: As written, the survey methodology explains that complete counts are made in each of the areas corresponding to the site locations. It is not clear however, how observers would delineate the off shore boundaries of the survey areas, particularly those facing each other or off shore boundaries in general. How were these distances discerned? I am curious to how the observers gauged the distance from shore so that birds in the survey area from the opposite shoreline were not recounted. Did they use range finders? Adding some text explaining this would benefit the methods.

I downloaded the data that is made available with this study via the *F1000Research* website and found that in the data set describing the winter waterfowl survey ([10.5256/f1000research.6080.d42954](https://doi.org/10.5256/f1000research.6080.d42954)) the column corresponding to buffleheads is missing. Was a different dataset used for this study? If not, why are buffleheads not included in the dataset but in the result of the study?

First paragraph: In the fourth sentence the authors refer to "This area". I would suggest clearing up what 'area' is being referred to. Also, in the fifth sentence the authors state that the southern portion of the bay is deeper. However, they did not mention deeper 'than what'. Typically the reader expects to see the full comparison. I know these are nit picky grammar and style comments, but clearing these two minor points would make the paragraph read much better.

Fourth paragraph: In the first sentence the authors start by saying "Counting is completed" when the rest of the verbs in the paper are in the past tense. I think changing this to 'counting was completed' would be better. In the second sentence, the authors explain: "Every bird seen on the water surface or on the adjoining shoreline up to 50 m from the water is counted; when possible sex and age were also noted". Is this vertically or horizontally from the water? I am assuming that they mean 50 meters from the waters edge or shoreline – or along the coast. Please state this more clearly.

Seventh paragraph: Please explain why the data was transformed and why the Wisconsin double transformation was chosen. Because non-metric multidimensional scaling uses rank orders, it is not clear why the transformation was used. Stating this more clearly in the text would benefit the paper.

Eighth paragraph. In the last sentence, I would suggest using '>' instead of 'greater than'.

Results:

It is not obvious to the reader why the data presented in figures 1 & 2 show survey data up to 2012, while the ordination only used data up to 2011. Stating this reason more clearly in the methods would benefit the paper.

The legend of Table 2 is not clear. Changing the wording could help clear up the message of the legend. For example, the last two sentences state: “*Species making up less than 1% of the community, and considered rare. Trend analysis (Figure 3) were not be conducted on these rare species.” The tense is wrong here, please change analysis to analyses. Also I would suggest saying this a bit clearer using fewer words, with perhaps something like this? “Species with overall species compositions < 1% were considered rare and excluded from trend analysis”. On this note, if I understand correctly, the legend states that trend analyses were not conducted on rare species and then refers to Figure 3. Figure 3 however shows trends in rank abundance of all 23 species listed in Table 2. This is confusing. Clearing this up in the legend or text would benefit the paper.

Regarding the non-metric multidimensional scaling (NMDS), why were four dimensions chosen over two or three? Did solutions with fewer dimensions have too large stress value? Was this assessed with a scree plot? Stating these details would benefit the paper and help the reader understand why four dimensions were the best choice for the NMDS analysis. Furthermore, in Figure 4, where the results of the NMDS are first shown, it is not clear why are king eiders and long-tailed ducks not shown in the plot. I am assuming from table two that this is because these two species have proportions of the total waterfowl community abundance that are close to zero. Using this logic however, barrow’s goldeneyes should also be excluded from the plot—but they are not. As the NMDS analysis is the central component of the study, the authors should either include all 23 species or clearly state why only 20 were used. As is, the results are somewhat confusing and distract the reader from the overall message of the study.

The authors use Figure 5 to detect shifts in the waterfowl community structure of Narragansett Bay during the 8-yr period of the study (2004 and 2011). It is confusing why the NMDS plots in Figure 5 are different to those in Figure 4. I might be missing something, but should not the ordination plots in Figure 5 have the same points and axes as in Figure 4? Are these plots showing the other two dimensions of the ordination? The details of Figure 5 should be made more elaborate explanation in the text. I am assuming the plots in Figure 5 show the average ordination positions for each section-year combination, with these being color coded for each year. Instead of this exercise, I would suggest authors use analysis of similarity (ANOSIM) to tests hypotheses of community change in each of the sections or the entire bay throughout the 8-yr study period. In this way the authors could obtain an objective measure indicating if there has been community change (or no change) in the waterfowl of Narragansett Bay during the 8-yr study period. Using ANOSIM here would be analogous to using ANOVAs to assess before and after changes at certain breaks in the 8-yr study period. ANOSIM however, uses the same similarity matrices imputed into NMDS and is philosophically allied with NMDS ordination. The functions need to perform this analysis are included in the R vegan package, which the authors have shown to have an excellent handle on using. Including ANOSIM in the study to objectively assess temporal changes in the beta diversity of the Narragansett Bay waterfowl community would therefore fit in nicely in the study as as it complements NMDS.

In the last paragraph of the results the authors state: “it is thought that waterfowl communities in this part of the Bay vary greatly according to the intensity of winter and amount of ice”. This statement should have

a citation referring to the reference thinking or hypothesizing this mechanism.

Discussion:

First paragraph. In the first sentence, I would suggest replacing “expected” for “baseline”. In the third sentence the authors refer to NMDS as a monitoring tool. NMDS is an ordination analysis used to interpret ecological data, and not a monitoring tool. I think this statement could be reworded better saying for example: “Using NMDS to analyzing monitoring data is a valuable approach to assess...”

Sixth paragraph: Again, NMDS is not an approach—it is an analytical tool. Using this ordination technique is the approach the authors took to assess the community structure of the Narragansett Bay waterfowl community. Addressing and fixing this accordingly, will benefit the flow of the text.

The second objective of the of the study was to explore if environmental drivers that might be driving changes in the species composition of the waterfowl species composition. I think this objective needs to be addressed a bit more in the discussion. It is only touched upon lightly. Furthermore, what do the authors think is the reason why they found strong correlations of the average wind speed for the three days prior to survey, area, mean bathymetry of site and latitude with the ordination, and yet the wintering waterfowl species composition of the bay seemed to remain stable through time.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Competing Interests: No competing interests were disclosed.

Author Response 23 Oct 2015

Betty Kreakie, US EPA ORD, USA

We greatly appreciate your feedback on our manuscript. Your thorough and thoughtful review has allowed us to significantly improve the manuscript. Below are point-by-point responses to your comments. Your concerns will be reflected in version 3 of the manuscript. Thank you again for all your help. Please let us know if you have any additional concerns.

1. The main purpose of the introduction was to argue the need for baseline monitoring data for waterfowl communities. The authors do achieve this objective in first and fourth paragraphs, leading to the purpose of study in the last sentence of the fifth paragraph of the introduction. However, I did not find all the information in the introduction leading directly to the statement of purpose of the study, with this statement no matching what was stated in the abstract. The second and third paragraphs for example, include information that would be better suited for the methods.

Response: This concern was also expressed by the first reviewer of the manuscript. For version 2, we added considerable text to the introduction about how this method could have broader application. In the first version, you are correct in suggesting this text should be moved to the Methods section. However, the second version expands the statement of purpose. Hopefully these edits will address your concern.

2. Also, while the authors do a great job in explaining why waterfowl are logical candidates for monitoring environmental health, I found the excessive references of the

citations in the fourth paragraph a bit distracting. I am not certain of the editorial guidelines of *F1000Research* (I looked these up but failed to find the citation/reference guidelines), but I think a generally accepted rule of thumb is to not list more than three references per citation (although I could very well be wrong here). Nevertheless, when excessive references and citations are used it distracts the reader from the written message and disrupts the flow of the paragraph. I understand that you have to cite certain statements, but I would advise the authors to go through their citations and only cite essential sources. Doing so along with moving the information from the second and third paragraphs to the methods would help streamline the introduction.

Response: We completely agree that the amount of references were distracting. We have selectively reduced the number of citations in this part. Specifically, we removed several of the older citations. Most of the material from the older works was more comprehensively covered in the more recent work.

3. As written, the survey methodology explains that complete counts are made in each of the areas corresponding to the site locations. It is not clear however, how observers would delineate the off shore boundaries of the survey areas, particularly those facing each other or off shore boundaries in general. How were these distances discerned? I am curious to how the observers gauged the distance from shore so that birds in the survey area from the opposite shoreline were not recounted. Did they use range finders? Adding some text explaining this would benefit the methods.

Response: To clarify this issue, we added text the first paragraph of the Survey Method subsection of the Methods.

4. I downloaded the data that is made available with this study via the *F1000Research* website and found that in the data set describing the winter waterfowl survey ([10.5256/f1000research.6080.d42954](#)) the column corresponding to buffleheads is missing. Was a different dataset used for this study? If not, why are buffleheads not included in the dataset but in the result of the study?

Response: The wrong data set did get uploaded to the F1000Research page. Thank you for pointing out this mistake. The correct data are now available.

5. First paragraph: In the fourth sentence the authors refer to “This area”. I would suggest clearing up what 'area' is being referred to.

Response: We have changed to this text to “The land surrounding the northern portion of Narragansett Bay.”

6. Also, in the fifth sentence the authors state that the southern portion of the bay is deeper. However, they did not mention deeper ‘than what’. Typically the reader expects to see the full comparison. I know these are nit picky grammar and style comments, but clearing these two minor points would make the paragraph read much better.

Response: We have added “than the portion near Providence, Rhode Island.” Also, we completely agree that this paragraph now reads much better.

7. In the first sentence the authors start by saying “Counting is completed” when the rest of the verbs in the paper are in the past tense. I think changing this to ‘counting was completed’ would be better.

Response: This error has been corrected.

8. In the second sentence, the authors explain: “Every bird seen on the water surface or on the adjoining shoreline up to 50 m from the water is counted; when possible sex and age were also noted”. Is this vertically or horizontally from the water? I am assuming that they mean 50 meters from the waters edge or shoreline – or along the coast. Please state this more clearly.

Response: We have incorporated this recommendation into the text.

9. Please explain why the data was transformed and why the Wisconsin double transformation was chosen. Because non-metric multidimensional scaling uses rank orders, it is not clear why the transformation was used. Stating this more clearly in the text would benefit the paper.

Response: We have added text to clarify why this transformation was performed.

10. In the last sentence, I would suggest using ‘>’ instead of ‘greater than’.

Response: This change was added to the text.

11. It is not obvious to the reader why the data presented in figures 1 & 2 show survey data up to 2012, while the ordination only used data up to 2011. Stating this reason more clearly in the methods would benefit the paper.

Response: At the time of the analysis, all the environmental variables were not available through 2012. The waterfowl survey for 2012 was available and had gone through our QA/QC process. We decided to include another year into the population, since we were specifically looking for significant trends. We have added clarification to the text about this issue.

12. The legend of Table 2 is not clear. Changing the wording could help clear up the message of the legend. For example, the last two sentences state: “*Species making up less than 1% of the community, and considered rare. Trend analysis (Figure 3) were not be conducted on these rare species.” The tense is wrong here, please change analysis to analyses. Also I would suggest saying this a bit clearer using fewer words, with perhaps something like this? “Species with overall species compositions < 1% were considered rare and excluded from trend analysis”. On this note, if I understand correctly, the legend states that trend analyses were not conducted on rare species and then refers to Figure 3. Figure 3 however shows trends in rank abundance of all 23 species listed in Table 2. This is confusing. Clearing this up in the legend or text would benefit the paper.

Response: We apologize for the confusion. These was a change in approach that obviously did not get corrected in all parts of the final manuscript. Previous reviewers request that all species be presented in Figure 3 and therefor that figure was edited accordingly. The manuscript has been corrected to reflect the presented data.

13. Regarding the non-metric multidimensional scaling (NMDS), why were four dimensions chosen over two or three? Did solutions with fewer dimensions have too large stress value? Was this assessed with a scree plot? Stating these details would benefit the paper and help the reader understand why four dimensions were the best choice for the NMDS analysis.

Response: We explained our process for selecting the number of dimensions in the Methods (third paragraph of the Data Analysis subsection). In addition, we added text to the Results (second paragraph).

14. Furthermore, in Figure 4, where the results of the NMDS are first shown, it is not clear why are king eiders and long-tailed ducks not shown in the plot. I am assuming from table two that this is because these two species have proportions of the total waterfowl community abundance that are close to zero. Using this logic however, barrow's goldeneyes should also be excluded from the plot—but they are not. As the NMDS analysis is the central component of the study, the authors should either include all 23 species or clearly state why only 20 were used. As is, the results are somewhat confusing and distract the reader from the overall message of the study.

Response: All 23 species were indeed used to construct the plot. Both long-tailed duck and king eider plot very low on the y-axis. Since this is a very complicated plot, we decided to zoom in slightly to have a better view of the main cluster. This also allowed us to make our labels more legible. However, we failed to explain this in text. We have added text to the figure capture to explain this decision and to report values for long-tailed duck and king eider.

15. The authors use Figure 5 to detect shifts in the waterfowl community structure of Narragansett Bay during the 8-yr period of the study (2004 and 2011). It is confusing why the NMDS plots in Figure 5 are different to those in Figure 4. I might be missing something, but should not the ordination plots in Figure 5 have the same points and axes as in Figure 4? Are these plots showing the other two dimensions of the ordination? The details of Figure 5 should be made more elaborate explanation in the text.

Response: The subplots in figure 5 are the same plots as in figure 4. For figure 5 we greyed out the site locations, and added the average section location with a square symbol. However, as you pointed out, this is not intuitively clear. We added text in the figure caption to clarify this issue.

16. I am assuming the plots in Figure 5 show the average ordination positions for each section-year combination, with these being color coded for each year. Instead of this exercise, I would suggest authors use analysis of similarity (ANOSIM) to tests hypotheses of community change in each of the sections or the entire bay throughout the 8-yr study period. In this way the authors could obtain an objective measure indicating if there has been community change (or no change) in the waterfowl of Narragansett Bay during the 8-yr study period. Using ANOSIM here would be analogous to using ANOVAs to assess before and after changes at certain breaks in the 8-yr study period. ANOSIM however, uses the same similarity matrices imputed into NMDS and is philosophically allied with NMDS ordination. The functions need to perform this analysis are included in the R vegan package, which the authors have shown to have an excellent handle on using. Including ANOSIM in the study to objectively assess temporal changes in the beta diversity of the

Narragansett Bay waterfowl community would therefore fit in nicely in the study as it complements NMDS.

Response: We agree that ANOSIM would tell us if the groups are different and different by year. In figure 5 we are trying to show how the sections change through the years in context to the of the entire Bay waterfowl community. Hopefully, the additional text will clarify our intent to the audience. Additional, we added considerable text to the discussion in version 2 that adds to the interpretation of this figure.

17. In the last paragraph of the results the authors state: “it is thought that waterfowl communities in this part of the Bay vary greatly according to the intensity of winter and amount of ice”. This statement should have a citation referring to the reference thinking or hypothesizing this mechanism.

Response: This material was moved to the Discussion in version 2. We have added a citation to this state.

18. In the first sentence, I would suggest replacing “expected” for “baseline”.

Response: This concern was corrected in version 2.

19. In the third sentence the authors refer to NMDS as a monitoring tool. NMDS is an ordination analysis used to interpret ecological data, and not a monitoring tool. I think this statement could be reworded better saying for example: “Using NMDS to analyzing monitoring data is a valuable approach to assess...”

Response: In version 2, we added text to clarify how we feel that this method could have broader appeal. However, we do agree that the NMDS is an ordination analysis. We have edited the text to address this concern.

20. Again, NMDS is not an approach—it is an analytical tool. Using this ordination technique is the approach the authors took to assess the community structure of the Narragansett Bay waterfowl community. Addressing and fixing this accordingly, will benefit the flow of the text.

Response: See above for explanation about how this issue was corrected.

21. The second objective of the study was to explore if environmental drivers that might be driving changes in the species composition of the waterfowl species composition. I think this objective needs to be addressed a bit more in the discussion. It is only touched upon lightly.

Response: The first reviewer of the manuscript agreed with your concern. Therefore we add material to the Discussion in the second version to further explore our interpretation on the environmental drivers.

22. Furthermore, what do the authors think is the reason why they found strong correlations of the average wind speed for the three days prior to survey, area, mean bathymetry of site and latitude with the ordination, and yet the wintering waterfowl

species composition of the bay seemed to remain stable through time.

Response: As mentioned above, we did add text to Discussion about these issues.

Competing Interests: No competing interests were disclosed.
