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ADJUSTED DIETS OF BALD EAGLES (*HALIAEETUS LEUCOCEPHALUS*) BREEDING IN AN ALTERED ESTUARY

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Abstract.—Diet of Bald Eagles (*Haliaeetus leucocephalus*) in the Florida Bay estuary was determined from prey remains from nest sites and used to evaluate differences between two time periods, the 1972 and 1973 breeding seasons compared with 2009 and 2010. Between these two time periods, Florida Bay underwent a well-documented series of ecological changes beginning in the late 1980s, which significantly altered the ecosystem. To examine the hypothesis that ecological changes may have shifted Bald Eagle diets, we compared 571 remains (30 species) collected in 1972/1973 from 21 nest sites, to 419 remains (22 species) collected sites in 2009/2010 from 11 nest sites. Fish made up the majority of prey in 1972/1973 and 2009/2010 (80.7% and 69.5% by number, respectively) and birds were second (15.8% and 29.1%). Hardhead catfish (*Arius felis*) skulls made up the majority of individual prey remains in both time periods (55% and 54%). Bald Eagles also ate significantly larger catfish in the 1972/1973 seasons, as the mean total skull length was 10% greater and estimated biomass was 35.7% greater. There was no difference in overall prey diversity between the two time periods; however, analysis of similarities showed prey composition differed. Mullet (*Mugilidae*), jack (*Carangidae*), Double-crested Cormorant (*Phalacrocorax auritus*), and Red-breasted Merganser (*Mergus serrator*) were the species that contributed most to the dissimilarities between time periods. We suggest that Florida Bay's ecological and prey community changes during this time period influenced Bald Eagle diets.

Key Words: *Bald Eagle*; Haliaeetus leucocephalus; *hardhead catfish*; Arius felis; *diet*; *Everglades National Park*; *Florida*; *mangrove ecosystem.*

CAMBIOS EN LA DIETA DE *HALIAEETUS LEUCOCEPHALUS* QUE SE REPRODUCEN EN UN ESTUARIO ALTERADO

Resumen.—Se determinó la dieta de *Haliaeetus leucocephalus* en el estuario de la Bahía de Florida a partir de restos de presas obtenidos en lugares de nidificación. Se evaluaron diferencias entre dos periodos de tiempo, comparando las estaciones reproductoras de 1972 y 1973 con las de 2009 y 2010. Entre estos dos periodos de tiempo la Bahía de Florida pasó por una serie de cambios ecológicos bien documentados que comenzaron a finales de la década de 1980 y que alteró el ecosistema de manera significativa. Para evaluar la hipótesis de que estos cambios ecológicos produjeron un cambio en la dieta de *H. leucocephalus*, comparamos 571 restos de presas (30 especies) recolectados en 1972/1973 en 21 lugares de nidificación, con 419 restos de presas (22 especies) recolectados en 2009/2010 en 11 lugares de nidificación. Los peces constituyeron la mayoría de las presas en 1972/1973 y 2009/2010 (80.7% y 69.5% en cantidad, respectivamente) y las aves aparecieron en segundo lugar (15.8% y 29.1%). Los cráneos de *Arius felis* constituyeron la mayoría de los restos de presas individuales en ambos periodos de tiempo (55% y 54%). Los individuos de *H. leucocephalus* se alimentaron de peces más grandes en las épocas de cría de 1972/1973, ya que el promedio de la longitud total del cráneo fue un 10% mayor y la biomasa estimada fue un 35.7% mayor. No hubo diferencias en la diversidad total de presas entre los dos periodos de tiempo; sin embargo, un análisis de similitudes evidenció que la composición de presas difirió. Los peces de las familias Mugilidae y Carangidae, y las aves como *Phalacocorax auritus* y *Mergus serrator*, fueron las especies que más contribuyeron a las disimilitudes entre los períodos de tiempo. Sugerimos que los cambios ecológicos y de la comunidad de presas en la Bahía de Florida durante este periodo de tiempo influyó en la dieta de *H. leucocephalus*.

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The prey choice of raptors can be flexible and potentially representative of ecosystem conditions (Sonerud 1986, Preston 1990, Beier and Drennan 1997, Poole et al. 2002, Preston and Beane 2009). Ecosystem conditions influence the composition, abundance, and distribution of prey communities, which affects prey vulnerability to predation (Estabrook and Dunham 1976, Fryxell and Lundberg 1994, Schmidt and Ostfeld 2003). Changes in prey choice depend on the foraging strategies of predators, the diet of each of which responds differently to changes in prey communities. For example, a specialist that preys on a certain species may not respond to changes in the prey community, as long as that prey species is sufficiently abundant. Generalists, however, may or may not adjust their diet in response to a change in community structure, depending on abundance and availability of prey species. Monitoring changes in predator diets may inform our understanding of important life history traits, potential effects on fitness, and the corresponding influence of changing ecosystem conditions on prey communities. Monitoring changes in diet may also provide insight into the abundance of prey species and the ability of the predator to adjust its diet.

The Bald Eagle (*Haliaeetus leucocephalus*) is an opportunistic and generalist predator whose short-term diet usually reflects the local abundance of most available prey items (Buehler 2000, Thompson et al. 2005). Bald Eagle diet also varies when prey availability varies at the microhabitat level (Elliott et al. 2005, 2011), or when prey availability changes over time (Collins et al. 2005, Anthony et al. 2008, Newsome et al. 2010). This foraging strategy enables Bald Eagles to exploit a diverse assemblage of fish, avian, mammalian, and reptilian prey (McEwan and Hirth 1980, Hunt et al. 2002, Markham and Watts 2008).

The Florida Bay estuary holds the southernmost breeding population of Bald Eagles (Baldwin et al. 2012). Located at the southern tip of Florida, Florida Bay is a subtropical mangrove-dominated estuary that has been altered over time with documented changes in ecosystem conditions (Butler et al. 1995, Fourqurean and Robblee 1999, Hall et al. 1999). It has been protected as part of Everglades National Park (ENP) since 1947 and is dependent on freshwater input from the Greater Everglades Ecosystem immediately to the north. Florida Bay experienced dramatic ecological changes in the late 1980s due to changes in the amount and distribution of fresh water input, which subsequently shifted salinity, nutrient, and oxygen content away from historical levels (Fourqurean and Robblee 1999). Massive die-offs and redistributions of once-abundant seagrass habitat within Florida Bay were likely caused by these changes in water quality (Zieman et al. 1988, Robblee et al. 1991, Hall et al. 1999). Loss of seagrass, primarily *Thalassia testudinum*, increased suspension of sediment in the water (turbidity) and the frequency of algal blooms (Phlips et al. 1995, Boyer et al. 1999). These changes have affected multiple trophic levels in Florida Bay (Butler et al. 1995, Thayer et al. 1999, Powell 2003, Lorenz 2014), including Bald Eagles and waterbirds (Matheson et al. 1999, Crozier and Gawlik 2003, Davis et al. 2005, Frederick et al. 2009, Lorenz et al. 2009, Baldwin et al. 2012, Ogden et al. 2014).

Prey remains are commonly evaluated as a proxy for raptor diet (Mollhagen et al. 1972; Bosakowski and Smith 1992; Hunt et al. 2002) and have been used to monitor changes in prey communities and availability in eagles' local environments (Steenhof and Kochert 1985, 1988, Knight et al. 1990, Watson 2002). Although diets described by analysis of prey remains are somewhat biased (Simmons et al. 1991, Mersmann et al. 1992, Lewis et al. 2004), prey remains analysis is a useful strategy for examining raptor diets. Bald Eagle prey remains collected before and after local ecosystem changes in the Aleutian Archipelago, AK, differed significantly; declines of kelp forests and kelp-associated species affected prey communities and likely caused shifts in eagle diet (Anthony et al. 2008). Similarly, prey remains excavated from historic Bald Eagle nest sites in the Channel Islands, California (Collins et al. 2005, Erlandson et al. 2007) documented diet changes and suggested increases and decreases in availability of several prey types (Newsome et al. 2010).

There have been no published diet studies of breeding Bald Eagle populations in a subtropical mangrove ecosystem. Our objectives were to identify the prey of breeding Bald Eagles in Florida Bay and evaluate temporal differences. To determine diet, we analyzed prey remains from Bald Eagle nest sites in two time periods, prior to recent ecological changes (1972 and 1973 breeding seasons) and post change (2009 and 2010 breeding seasons). We hypothesized that the shift in ecological conditions in Florida Bay corresponds with changes in the type and size of prey of Bald Eagles.

Methods

We collected prey remains at the end of each breeding season in 2009 and 2010 at nest sites that were both accessible and successful (Baldwin et al. 2012) in that season, replicating methods employed by ENP staff in the 1970s (Robertson and Shea 1975). A territory was defined as successful if one or more young of fledgling size were present (Postupalsky 1974, Steenhof and Newton 2007). The eagle breeding season in south Florida is October through May (e.g., 1972 breeding season was October 1972 – May 1973) and ends when all young have fledged and are no longer receiving prey at the nest. Prey remains were collected from 22 successful nest sites in 1972 ($n=19$) and 1973 ($n=15$) by Robertson and Shea (1975). We collected prey remains at all accessible nest sites that successfully fledged young in 2009 ($n=7$) and 2010 ($n=6$) from 11 nest sites. Although not all territories were successful in both time periods, most territories examined in 2009 and 2010 overlapped spatially with territories examined in 1972 and 1973 (Fig. 1). Prey remains were removed from the nest sites for laboratory analysis. Remains were separated by class (avian, fish, reptile, mammal, other) and then by morphology unique to class (e.g., avian skulls, feathers, fish jaws, etc.). Remains were grouped into the lowest identifiable taxonomic level and the minimum number of individuals (MNI, highest number of a single prey remains per species) was determined. Recent remains, 2009/2010, were identified by comparison to museum specimens at the Florida Museum of Natural History, Gainesville, FL U.S.A.

We quantified prey remains as the MNI for each nest site and each taxonomic category. We compared composition of remains from all nest sites in 2009 and 2010 to the composition of remains collected in 1972 and 1973. We also compared nest sites in territories sampled during both time periods ($n=7$). We calculated individual species contribution to the overall composition of prey remains as the MNI for a given species divided by the MNI of all prey remains and compared these between time periods.

We defined nest site samples as the overall composition of remains (MNI of each species) per nest site per collection year. We excluded prey remains that were unidentifiable below class level

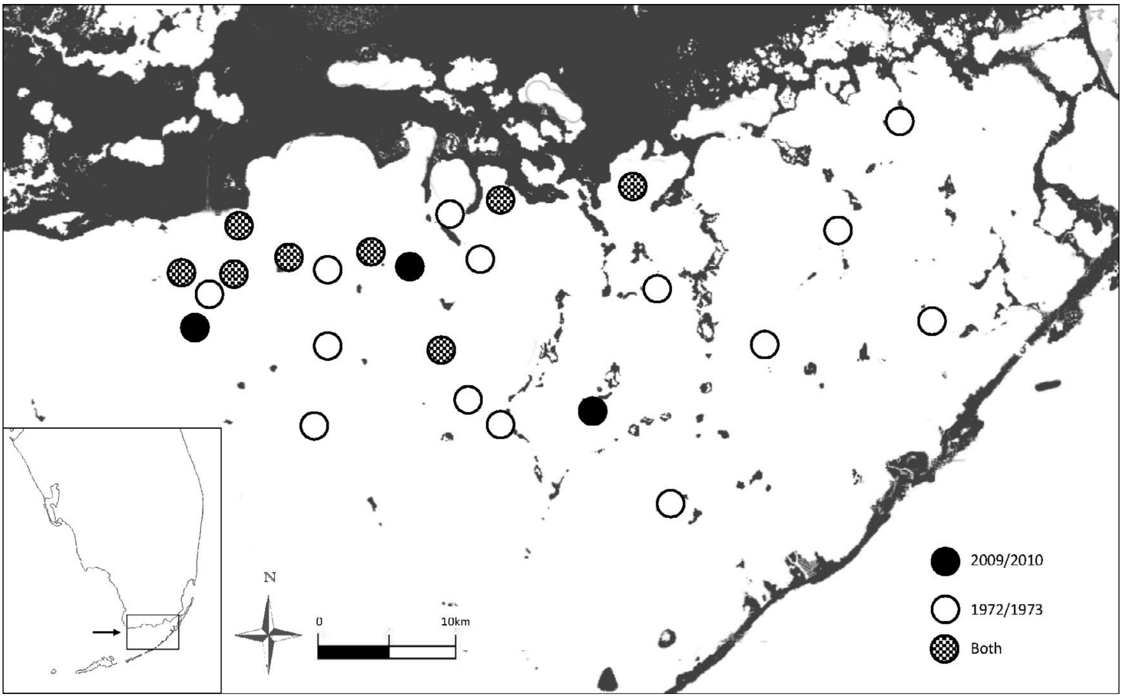

Figure 1. Map of Florida Bay, Florida, with locations of prey remains collections from 1972/1973, 2009/2010 and in both time periods.

from our analyses (2.7% of all remains). Some remains were only identifiable to a species group, and in this case, we divided these proportionally between the few possible species (e.g., small *Egretta* spp.). We standardized samples by sample total (each species MNI divided by total MNI for each sample, giving relative percentages) to control for varying sample sizes. Sample units were then transformed using log $(x+1)$ to lessen the influence of dominant and infrequent species.

We used a nonmetric multidimensional scaling (MDS) ordination technique to visually demonstrate differences in prey composition between collection periods. MDS is well-suited for compositional data because it makes few assumptions about the form of the data and can handle large and small numbers of species without having to delete species not represented in all samples (Clarke 1993, Clarke and Warwick 2001). MDS goodness-of-fit is indicated by the stress coefficient, ranging from 0 to 1, and represents how accurately the points in the plot represent the similarity between them. A stress coefficient <0.1 is good representation of the data, values between 0.1 and 0.2 provide useful ordinations, and values over 0.2 represent nearly random plots (Clarke and Warwick 2001). The 3D plot had considerably lower stress than 2D and so we used that for all further analyses. To test for differences in prey composition of samples between time periods, we used an analysis of similarities (ANOSIM), a multiple permutation procedure (Clarke and Warwick 2001). We calculated the correlation coefficient R and compared it to the distribution created from multiple random permutations. If R is close to 1 or –1, then group differences exist. If R is close to 0, then similarities among and within samples are the same on average. We determined significance if the observed R-value of prey composition did not fall within the 95th percentile of the random distribution of R-values, which were calculated using multiple permutations. We used PRIMER-E Ltd to perform the MDS and ANOSIM procedures (Clarke and Warwick 2001).

We calculated overall diversity for both time periods using Simpson's Index (D),

$$D = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

where p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), and s is the number of species (Solow 1993). We used a randomization test on the Simpson's indices to test for a significant difference (Solow 1993). To examine if species richness was influenced by the varying collection effort between time periods, we used rarefaction curves, which plot the number of individuals found or collections made vs. the species richness.

Hardhead catfish (*Arius felis*) remains (hard bony skulls) were commonly recovered intact. The catfish skulls were measured, using calipers, from the anterior end at the mesethmoid bone to the posterior end of the supraoccipital bone. We used an ANOVA to test differences in skull length between time periods. Using live-caught hardhead catfish ($n = 24$), we constructed a linear model:

$$f = 26599s + 37982; \qquad r^2 = 0.93$$

and extrapolated fork length (f, defined as the tip of snout to fork of tail, in mm) from skull length (s, in mm) for skulls collected from nests. Using the predicted fork length, we then estimated wet biomass of individual fish using a fork length-to-biomass conversion:

$$b = 7.189 \times 10^6 (f)^{3.116}$$

where b is the wet biomass (g; Armstrong et al. 1996). We compared mean estimated biomasses for catfish preyed upon in each time period using ANOVA.

RESULTS

The total MNIs of prey remains collected were 571 in 1972/1973 and 491 in 2009/2010. The remains in 1972/1973 contained 30 species, of which 17 were birds, 10 fish, and three other (one mammal, one reptile, and one crustacean); in 2009/2010 there were 33 total species, of which 20 were birds, 10 fish, and three other (one mammal, one reptile, and one crustacean; Table 1). Fish made up the majority of prey remains collected from Florida Bay from 1972/1973 and 2009/2010 (80.7% and 69.5%, respectively). Hardhead catfish were the most common species in the prey remains in both time periods (Table 1), 54.6% of all remains in 1972/1973 and 53.6% of all remains in 2009/2010. Birds made up the second largest proportion of the diet during the two time periods (15.8% and 29.1%) and the remaining classes (reptiles, mammals, crustaceans) made small contributions (3.5% and 1.4%).

Multidimensional scaling demonstrated compositional differences in eagle diet between the two time periods (Fig. 2). Analysis of Similarities (ANOSIM) showed prey remain compositions differed significantly between 1972/1973 and 2009/2010 ($r = 0.171$, $P = 0.024$). We also found a significant difference among territories in which collections were made from nest sites during both time periods ($r = 0.238$, $P = 0.007$). The Similarity Percentages (SIMPER) method showed that mullet (*Mugilidae*), jack (*Carangidae*), Double-crested Cormorant (*Phalacrocorax auritus*), and Red-breasted Merganser (*Mergus serrator*) contributed most to dissimilarities between time periods in each comparison (Table 2). In general, there was a shift to more mullet and Double-crested Cormorant and fewer jack and Red-breasted Merganser in the later period. The four most common avian species in 1972/1973 were Red-breasted Merganser, Horned Grebe (*Podiceps auritus*), Tricolored Heron (*Egretta tricolor*), and Laughing Gull (*Leucophaeus atricilla*) and in 2009/2010 were Double-crested Cormorant, Great Blue Heron (*Ardea herodias*), Great Egret (*Ardea alba*), and White Ibis (*Eudocimus albus*; Table 1). Hardhead catfish made up 67.7% of fish remains in 1972/1973 and 77.1% of fish remains in 2009/2010. After hardhead catfish, in order of rank, the three most common fish in 1972/1973 were jack, mullet, and mojarra (*Gerreidae*), and in 2009/2010 mullet, jack, and ladyfish (*Elops saurus*; Table 1).

There was no difference in overall diversity of prey species between the two time periods (Simpson's Index; 1972/1973 $D = 0.65$; 2009/2010 $D = 0.69$; $P = 0.296$). However, the rarefaction curves illustrated that collections in 2009/2010 led to much higher species richness with fewer collections (Fig. 3A). In addition, the cumulative curves of species richness as a function of the number of prey remains (MNI) increased steadily without reaching a plateau and may serve as better representation of prey diversity in the bay as a whole (Fig. 3B).

The most prevalent prey items, hardhead catfish skulls, were found in 93% of all nests, and

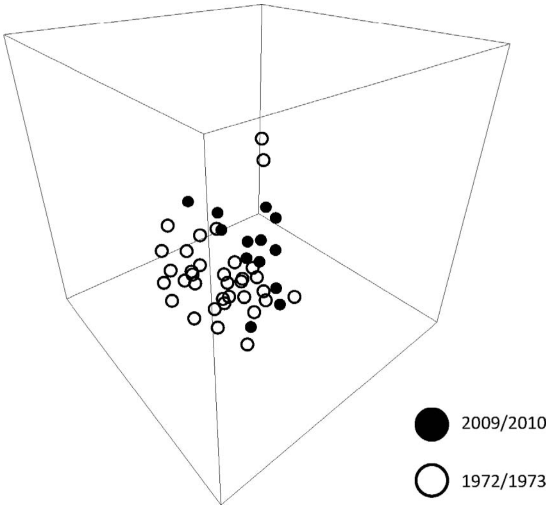

Figure 2. Three-dimensional scaling of prey remains compositions between 1972/1973 and 2009/2010 in Florida Bay for all nest sites; 3D stress = 0.14.

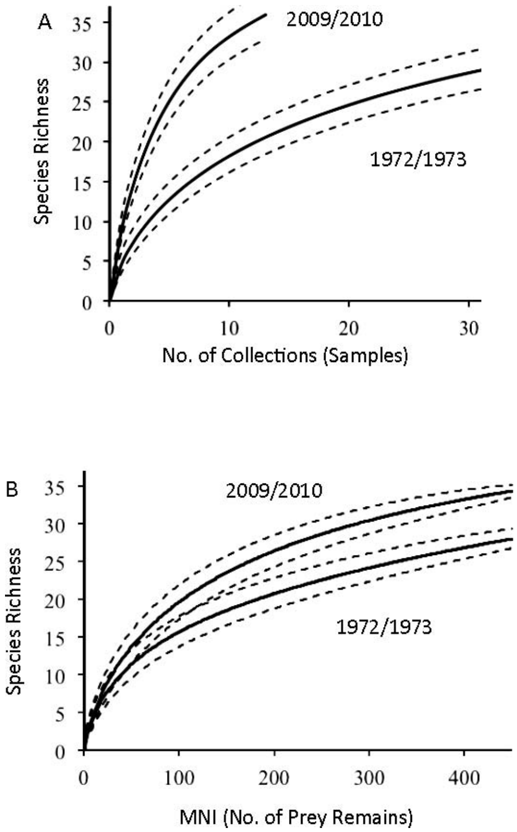

Figure 3. Rarefaction curves (solid lines) of species richness (A) per number of collections and (B) per MNI (number of prey remains collected) from Bald Eagle nest sites from 1972/1973 (lower) and 2009/2010 (upper) in Florida Bay, Florida. Dashed lines indicate 95% +/− confidence intervals.

Table 1. Contribution of each species found in prey remains from 1972/1973 and 2009/2010 from all nest sites and for breeding territories in which prey remains were collected in both time periods.

	ALL NEST SITES				SAME TERRITORIES IN BOTH PERIODS			
	1972/1973		2009/2010		1972/1973		2009/2010	
PREY TYPE AND SPECIES	*n*	% TOTAL	*n*	% TOTAL	*n*	% TOTAL	*n*	% TOTAL
Fish								
Hardhead catfish (*Arius felis*)	312	54.6	263	53.6	101	54	248	57.9
Crevalle jack (*Caranx hippos*)	62	10.9	22	4.5	30	16	18	4.2
Mullet (Mugilidae)	26	4.6	25	5.1	10	5.3	23	5.4
Striped mojarra (*Eugerres plumieri*)	19	3.3	-	-	7	3.7	-	-
Spotted seatrout (*Cynoscion nebulosus*)	11	1.9	8	1.6	5	2.7	5	1.2
Red drum (*Sciaenops ocellatus*)	-	-	4	0.8	-	-	4	0.9
Needlefish (Belonidae)	6	1.1	2	0.4	2	1.1	-	-
Ladyfish (*Elops saurus*)	-	-	11	2.2	-	-	9	2.1
Great barracuda (*Sphyraena barracuda*)	3	0.5	2	0.4	-	-	2	0.5
Sheepshead (*Archosargus probatocephalus*)	8	1.4	-	-	1	0.5	-	-
Snapper (*Lutjanus* spp.)	-	-	2	0.4	-	-	2	0.5
Oyster toadfish (*Opsanus tau*)	-	-	2	0.4	-	-	2	0.5
Filefish (Monacanthidae)	1	0.2	-	-	-	-	-	-
Burrfish (*Chilomycterus schoepfi*)	1	0.2	-	-	-	-	-	-
Unknown fish	12	2.1	-	-	4	2.1	-	-
Subtotal	**461**	**80.7**	**341**	**69.5**	**160**	**85.6**	**313**	**73.1**
Avian								
Red-breasted Merganser (*Mergus serrator*)	32	5.6	6	1.2	12	6.4	2	0.5
Horned Grebe (*Podiceps auritus*)	10	1.8	5	1	1	0.5	3	0.7
White Ibis (*Eudocimus albus*)	-	-	8	1.6	-	-	8	1.9
Tricolored Heron (*Egretta tricolor*)	9	1.6	4	0.8	2	1.1	3	0.7
Laughing Gull (*Leucophaeus atricilla*)	6	1.1	1	0.2	1	0.5	1	0.2
Double-crested Cormorant (*Phalacrocorax auritus*)	4	0.7	47	9.6	1	0.5	36	8.4
Great Egret (*Ardea alba*)	1	0.2	14	2.9	-	-	13	3
Roseate Spoonbill (*Platalea ajaja*)	3	0.5	6	1.2	-	-	5	1.2
American Coot (*Fulica americana*)	2	0.4	3	0.6	1	0.5	2	0.5
Scaup (unknown spp.)	2	0.4	-	-	1	0.5	-	-
Black-necked Stilt (*Himantopus mexicanus*)	2	0.4	-	-	-	-	-	-
Brown Pelican (*Pelecanus occidentalis*)	2	0.4	-	-	-	-	-	-
Pied-billed Grebe (*Podilymbus podiceps*)	1	0.2	-	-	1	0.5	-	-
Reddish Egret (*Egretta rufescens*)	1	0.2	5	1	-	-	5	1.2
Little Blue Heron (*Egretta caerulea*)	1	0.2	1	0.2	-	-	1	0.2
Fulvous Whistling Duck (*Dendrocygna bicolor*)	1	0.2	-	-	-	-	-	-

Table 1. Continued.

	ALL NEST SITES				SAME TERRITORIES IN BOTH PERIODS			
	1972/1973		2009/2010		1972/1973		2009/2010	
PREY TYPE AND SPECIES	*n*	% TOTAL	*n*	% TOTAL	*n*	% TOTAL	*n*	% TOTAL
Royal Tern (*Thalasseus maximus*)	1	0.2	3	0.6	-	-	1	0.2
Grebe (unknown spp.)	-	-	4	0.8	-	-	2	0.5
Wood Stork (*Mycteria americana*)	-	-	1	0.2	-	-	1	0.2
Great Blue Heron (*Ardea herodias*)	1	0.2	14	2.9	1	0.5	13	3
American Crow (*Corvus brachyrhynchos*)	-	-	1	0.2	-	-	1	0.2
Gull (unknown spp.)	-	-	2	0.4	-	-	1	0.2
Yellow-crowned Night-Heron (*Nyctanassa violacea*)	-	-	4	0.8	-	-	3	0.7
American White Pelican (*Pelecanus erythrorhynchos*)		-	1	0.2	-	-	-	-
Ring-billed Gull (*Larus delawarensis*)	-	-	4	0.8	-	-	3	0.7
Osprey (*Pandion haliaetus*)	-	-	1	0.2	-	-	1	0.2
Red-shouldered Hawk (*Buteo lineatus*)	-	-	1	0.2	-	-	1	0.2
Unknown wading bird	4	0.7	3	0.6	1	0.5	3	0.7
Unknown bird	7	1.2	4	0.8	3	1.6	3	0.7
Subtotal	**90**	**15.8**	**143**	**29.1**	**25**	**13.4**	**112**	**26.2**
Other								
Diamondback terrapin (*Malaclemys terrapin*)	17	3	5	1	1	0.5	1	0.2
Fiddler crab (*Uca* spp.)	2	0.4	1	0.2	-	-	1	0.2
Rat (*Rattus* spp.)	1	0.2	1	0.2	1	0.5	1	0.2
Subtotal	**20**	**3.5**	**7**	**1.4**	**2**	**1.1**	**3**	**0.7**
Total	**571**		**491**		**187**		**428**	

represented 55% of all remains. In comparison between time periods, Bald Eagle diets contained significantly larger catfish in the 1972/1973 seasons. The mean total length of skulls was 10% greater in the early period than in the later period ($F = 98.96$, df = 297, $P < 0.0001$, Fig. 4). Skull length was highly correlated with fork length and estimated hardhead catfish biomass per nest was 35.7% greater ($F = 107.94$, df = 297, $P < 0.0001$) in the early period (Fig. 4).

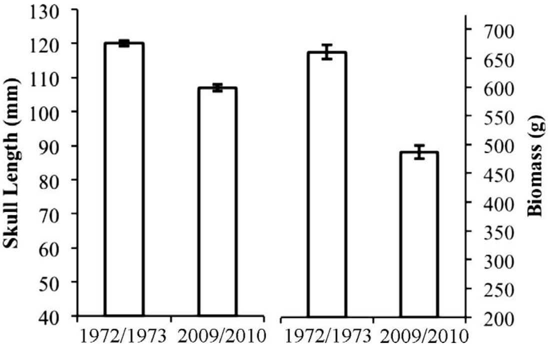

Figure 4. Mean skull length (mm) of hardhead catfish skulls collected from Bald Eagle nest sites in Florida Bay, Florida, from 1972/1973 ($n = 145$) and 2009/2010 ($n = 153$), and mean biomass (g) of catfish estimated from regressions. Error bars represent 1 standard error.

DISCUSSION

Composition of Bald Eagle prey remains changed in some ways between the time periods 1972/1973 and 2009/2010 in Florida Bay. Ecosystem changes have the ability to affect prey options of a predator (Reid and Croxall 2001, Diamond and Devlin 2003). Assuming Bald Eagles have not changed their basic foraging strategy, we conclude that the change in diet may be in response to changes in the prey community. Lorenz (2014) reviewed vertebrate species' population trends in Florida Bay and attributed the overall decline of many vertebrate species since 1984, including Bald Eagles, to upstream water management practices directing freshwater flow away from Florida Bay, resulting in

Table 2. Contribution to dissimilarities between compositions of prey remains from 1972/1973 and 2009/2010 for all nest sites, calculated using Simpson's Index.

SPECIES OR SPECIES GROUP	AVERAGE DISSIMILARITY	CONTRIBUTION %	+/− CHANGE IN CONTRIBUTION
Mullet	5.72	9.57	+
Jack	5.31	8.88	−
Double-crested Cormorant	4.4	7.37	+
Red-breasted Merganser	4.09	6.85	−
Hardhead catfish	3.1	5.19	+
Seatrout	2.9	4.86	−
Horned Grebe	2.86	4.78	−
Diamondback terrapin	2.8	4.69	−
Mojarra	2.18	3.65	−
Tricolored Heron	1.88	3.14	−
Great Blue Heron	1.76	2.95	+
Roseate Spoonbill	1.71	2.87	+
Needlefish	1.61	2.69	−
Ladyfish	1.57	2.63	+
Great Egret	1.5	2.51	+
American Coot	1.46	2.44	+
Ring-billed Gull	1.4	2.35	+
Royal Tern	1.36	2.27	+
Porgies	1.24	2.08	−
Pied-billed Grebe	1.18	1.98	−
Redfish	1.07	1.79	+
Barracuda	1.02	1.7	−
Laughing Gull	0.98	1.4	−
Yellow-crowned Night-Heron	0.66	1.11	+

declines in productivity at all trophic levels. The effects of long-term perturbations to hydrologic conditions have altered prey communities and Bald Eagle diets in a way that may limit their ability to maintain historic breeding population sizes.

Bald Eagles in Florida Bay consume mainly fish, followed by waterbirds, which is consistent with other studies of Bald Eagle diet (Dunstan and Harper 1975, McEwan and Hirth 1980, Haywood and Ohmart 1986, Brown et al. 1991, Mersmann et al. 1992). In some regions of North America, mammalian prey contributed more to eagle diet (Stalmaster 1987, Dominguez et al. 2003, Anthony et al. 2008). However, mammals are not very common on the small mangrove islands in Florida Bay (O. Bass, ENP, pers. comm.).

There was no difference in overall prey diversity between the two time periods; however, prey remains composition differed. In addition, analyses of within-time-period composition differences vs. among-time-periods showed the change was likely not a function of interannual fluctuations in prey communities or nest-site bias.

The ecological changes of Florida Bay between our sampling periods have affected fish communities (Matheson et al. 1999), which are dependent on the seagrass that characterizes Florida Bay (Sogard et al. 1989, Lorenz 2014) and influenced by altered water quality and changes in submerged vegetation (Zieman et al. 1988, Robblee et al. 1991). Populations of mullet are influenced particularly by salinity levels in Florida Bay (Sogard et al. 1989), as high salinity can affect metabolic rate and reproduction and decrease survival of *Mugil cephalus* (DeSilva and Perera 1976, Lee and Menu 1981, Cardona 2000). This may be why mullet, the second most common fish prey item, was the species that contributed most of the dissimilarity to overall compositions of Bald Eagle diets. Jack (*Caranx hippos*) and spotted seatrout (*Cynoscion nebulosus*) densities also vary with salinity levels and seagrass health and presence in Florida Bay (Thayer et al. 1999, Powell 2003, Neahr et al. 2010).

Catfish are a staple prey item for many Bald Eagle populations in North America (McEwan and Hirth 1980, Haywood and Ohmart 1986, Mersmann et al. 1992, Mabie et al. 1995, Watts et al. 2006, Viverette et al. 2007). In Florida Bay, the hardhead catfish, a strictly marine species found in seagrass habitats, was the most commonly recovered prey item, in both time periods. The abundance of hardhead catfish in remains did not necessarily mean that Bald Eagles had a strong preference for this species or that they were the most available prey type in Florida Bay, as prey remains may be biased toward larger and heavier-boned species (Simmons et al. 1991, Mersmann et al. 1992, Redpath et al. 2001, Marti et al. 2007). We believe hardhead catfish, representing more than half of the prey remains in both 1972/1973 and 2009/210, is likely overrepresented because of its relatively large and dense skull.

Despite its potential overrepresentation, hardhead catfish as prey demonstrated an interesting ecological trend, as the average skull length was significantly shorter in 2009/2010 than 1972/1973. Skeletal structures of fish have been previously used to document changes in growth characteristics of fish populations over long periods of time. Spines of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) collected from a 400-yr-old midden were compared to modern day spines, and showed that the modern population consisted of smaller and younger individuals, possibly a result of overharvesting and temperature changes (Balazik et al. 2010). Assuming Bald Eagles have not changed their preference toward smaller catfish in their diet, this suggests a change in the size structure of catfish in Florida Bay. In 1984–1986, hardhead catfish distributions within Florida Bay were not negatively affected by extreme salinities (Sogard et al. 1989). However, of the documented changes to water characteristics in Florida Bay, varying salinity levels, oxygen levels, and temperatures all can affect the growth and survival of many catfish species (Kilambi et al. 1970, Buentello et al. 2000, Bringolf et al. 2005, Copatti et al. 2011). The decrease in skull length of hardhead catfish suggested fewer older individuals, or a slower growth rate. The estimated 26% decrease in average catfish biomass indicated a reduced biomass delivered to the nest per successful foraging trip, especially if the catfish's actual contribution is near the 54% indicated by prey remains. The decrease in catfish biomass from 1972/1973 to 2009/2010 may explain the increase in the number of catfish deliveries (from 67% of fish deliveries to 72%), as more catfish captures were required to meet food demands of the young eagles.

In addition to changes in fish communities of Florida Bay, bird communities apparently were also affected by ecological changes (Lorenz 2014). Large predatory waterbird populations in Florida Bay decreased in abundance and distribution over time (Powell et al. 1989). For example, the nesting population of Roseate Spoonbills (*Ajaia ajaja*) in

Florida Bay decreased between our sampling periods, possibly in response to hydrologic conditions and salinity (Lorenz et al. 2009). Although we were not able to connect hydrologic conditions and salinity to prey availability of Bald Eagles, we did see changes in the bird species represented in Bald Eagle prey remains. Red-breasted Mergansers, the most abundant avian prey in 1972/1973 (35.6%) made up only 4% of avian remains in 2009/2010. In contrast, the Double-crested Cormorant was only 4% of avian remains in 1972/1973, but the most abundant avian remains in 2009/2010 (32.9%). These two species have some differences in foraging behavior and habitat use; mergansers specialize in their choice of prey and habitat. They prey on a fish in a narrow range of sizes (Titman 1999) and choose seagrass habitats over sand substrates. Change in extent and distribution of seagrass beds (Hall et al. 1999) may have changed mergansers' availability to Bald Eagles. Double-crested Cormorants prey on a wider size-range of fish and are characterized as opportunistic and flexible in their foraging habitat (Hatch and Weseloh 1999) and prey selection (Hobson et al. 1989; Blackwell et al. 1995). If Double-crested Cormorants in Florida Bay are better able to tolerate the ecosystem changes, their abundance may have increased relative to mergansers'.

To compare trends in occurrence of prey remains to surveyed prey populations, we used annual count data from the Christmas Bird Count (CBC, National Audubon Society 2010), as detailed population monitoring data of bird populations in Florida Bay is limited. The two survey routes closest to Florida Bay that have been regularly counted are Coot Bay (FLCE) and Key Largo (FLKL), which are located NW and SE of the bay, respectively, and roughly 40 km from each other. These counts occur during December or January, coinciding with the middle of the eagle breeding season. Only three of the five birds most commonly found as remains had similar trends in the CBC and prey remains samples. Double-crested Cormorants increased 150% in the CBC, but increased 650% in prey remains. Tricolored Herons decreased 7% in the CBC, but decreased 70% in prey remains. Red-breasted Mergansers decreased 6% in the CBC, and decreased 30% in remains.

Examining prey items of Bald Eagles breeding in Florida Bay from two time periods, separated by well-documented ecological changes, we found significant evidence for changes in the diet of breeding Bald Eagles, suggesting changes in prey communities. Although a change in diet does not necessarily result in harm to an individual or population, especially for opportunistic species that are capable of exploiting a wide range of prey, it has the potential for a negative effect on reproductive success and life histories (Penteriani et al. 2002, Rutz and Bijlsma 2006). Based on our investigation of Bald Eagle diets, we believe that the Florida Bay's ecological and prey community changes over this time period may have negatively influenced occupancy rates overall, although some territories still hold pairs that are successful in producing young, possibly as a result of an adapted diet. Bald Eagle breeding population size and territory occupancy rates in Florida Bay decreased from 1958–2010 (Baldwin et al. 2012), coinciding with the observed shift in diet. The percent of surveyed territories that were occupied (defined as a territory where a pair of adults was observed on at least one visit during the breeding season, or where at least one adult was seen and there was evidence of recent nest maintenance), decreased from 1972/1973 (93% / 93%) to 2009/2010 (63% / 57%). Breeding pairs apparently are not occupying historical territories, presumably as a result of the documented changes in the ecosystem.

Changes in prey diversity, availability, and distribution alter the proportion of eagles breeding and reproductive output (Steenhof et al. 1997, Whitfield et al. 2009, McIntyre and Schmidt 2012). Nesting success (defined as the proportion of occupied territories where one or more young fledged) was 37% / 42% in 1972/1973 and 69% / 33% in 2009/2010 (Baldwin et al. 2012). If Bald Eagles in Florida Bay occupied a breeding territory, their success rate was about the same (or better in 2009) as the historical rate, suggesting they were able to provide sufficient food for the young. In fact, the number of young/successful territory increased from 1972/1973 (1.40/1.45) to 2009/2010 (1.73/1.86; Baldwin et al. 2012), as it has in many other locations in the eastern U.S. As restoration efforts in Florida Bay continue, Bald Eagle occupancy and productivity should be monitored, because despite the increase in the number of young fledged per successful nest, the number of occupied territories has decreased, resulting in a reduced breeding population in Florida Bay.

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