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EXPOSURE OF GREAT EGRET (*ARDEA ALBUS*) NESTLINGS TO MERCURY THROUGH DIET IN THE EVERGLADES ECOSYSTEM

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Abstract—We estimated exposure of great egret (*Ardea albus*) nestlings to mercury in food in the Florida Everglades, USA, by collecting regurgitated food samples during the 1993 to 1996 breeding seasons and during 1995 measured concentrations of mercury in individual prey items from those samples. Great egret nestlings had a diet composed predominantly of fish (>95% of biomass), though the species composition of fish in the diet fluctuated considerably among years. Great egrets concentrated on the larger fish available in the marsh, especially members of the Centrarchidae. The importance of all nonnative fish fluctuated from 0 to 32% of the diet by biomass and was dominated by pike killifish (*Belonesox belizanus*) and cichlids (Cichlidae). Total mercury concentrations in prey fish ranged from 0.04 to 1.40 mg/kg wet weight, and we found a significant relationship between mass of individual fish and mercury concentration. We estimated the concentration of total mercury in the diet as a whole by weighting the mercury concentration in a given fish species by the proportion of that species in the diet. We estimate that total mercury concentrations in the diets ranged among years from 0.37 to 0.47 mg/kg fish (4-year mean = 0.41 mg/kg). We estimated total mercury exposure in great egret nestlings by combining these mercury concentrations with measurements of food intake rate, as measured over the course of the nestling period in both lab and field situations. We estimate that, at the 0.41 mg/kg level, nestlings would ingest 4.32 mg total mercury during an 80-day nestling period. Captive feeding studies reported elsewhere suggest that this level of exposure in the wild could be associated with reduced fledging mass, increased lethargy, decreased appetite, and, possibly, poor health and juvenile survival.

Keywords—Mercury Wading birds Ciconiiformes Everglades

INTRODUCTION

Many studies have discovered mercury contamination in the tissues of wild birds, particularly carnivores and piscivores [1–6]. Birds often have been suggested as bioindicators of mercury contamination in aquatic food webs [7,8]. However, relatively few studies have estimated mercury exposure of wild birds through dietary intake, which is an essential first step in understanding both bioaccumulation and physiological dynamics of mercury in free-ranging populations of birds. Hoffman and Curnow [9] reported mercury concentrations in both adult black-crowned night herons (*Nycticorax nycticorax*) and their prey. Similarly, Gariboldi et al. [10] reported mercury content in the diet of nestling wood storks (*Mycteria americana*). Goutner and Furness [11] measured mercury in feathers and prey of little egrets (*Egretta garzetta*) in Greece. The results of all three studies demonstrated considerably higher mercury content in freshwater than in saltwater prey fish and concluded that large, predatory fish from freshwater areas constituted a significant source of mercury exposure to young birds. Hughes et al. [12] demonstrated that feather mercury concentrations of nestling ospreys (*Pandion haliaetus*) were related to interannual and site differences in mercury content of yellow perch (*Perca flavescens*).

The Everglades wetland mosaic of southern Florida has been recognized as having elevated mercury concentrations in tissues of most of the high trophic level predatory animals, including largemouth bass (*Micropterus salmoides*) [13], Florida panthers (*Felis concolor coryi*) [14], and wading birds (Ciconiiformes) [4,15,16]. Elevated mercury in the aquatic food web is thought to result from some combination of high atmospheric deposition and rapid methylation rates.

The purpose of this paper is to document the composition of the diet of great egret (*Ardea albus*) nestlings in the Everglades, to report mercury concentrations in prey animals taken as regurgitant from nestlings, and to estimate mercury exposure to nestlings by combining mercury concentrations in the diet with measurements of food consumption.

METHODS

During the course of a series of studies on the effects of mercury on wading birds in the Everglades ecosystem [6], we investigated the composition and mercury concentration of the diet of nestling great egrets in the central freshwater Everglades (Water Conservation Area 3 and northeastern Shark Slough; see Fig. 1) during the winter and spring nesting sea-

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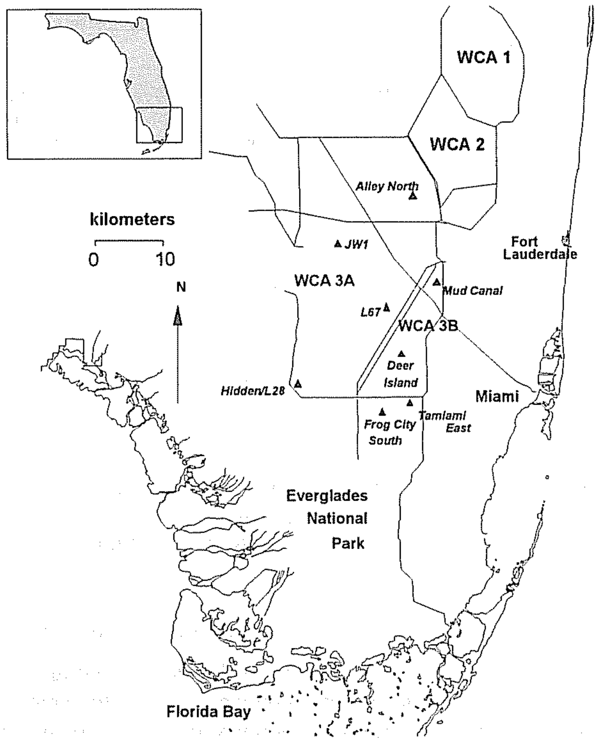

Fig. 1. Map of the study area in southern Florida, USA, showing locations of water management boundaries, major cities, and locations of wading bird colony sampling sites in the Everglades.

sons of 1993 to 1996. This extremely flat freshwater wetland habitat is composed of grasslands dominated by sawgrass (*Cladium jamaicense*) and wet prairie interspersed with higher elevation islands of tropical and subtropical tree species [17].

Food habits of great egrets

We collected regurgitated boluses from nestling great egrets at large colonies throughout the study area during April to June. The colonies were not always the same from year to year because some colonies were not active or because particular colonies were not accessible due to water conditions during that year. However, the colonies visited did represent the vast majority of the nesting population in each year.

During our visits to breeding colonies, we collected regurgitated food samples opportunistically from nestling and prefledging great egrets. These samples were collected from chicks of between 6 and 35 d of age that regurgitated spontaneously as we approached or that regurgitated while we were handling them. Marked regurgitant samples were stored individually in sealed plastic bags, iced in the field, and frozen for later analysis. Any regurgitation or series of regurgitations from the same bird on the same visit were defined as a single bolus.

Boluses were analyzed individually at the end of the nesting season (July–August). For all samples, individual prey items were identified, weighed to the nearest 0.1 gm (after patting dry with paper towel), and measured to the nearest millimeter (total length). Fish that were not intact (broken or partly digested pieces) were identified to species and their mass included as the total for that fish species. Unidentifiable fish were never intact, and their masses were combined for an unidentified fish category.

Mercury concentrations in fish

We selected a total of 52 fish from regurgitated boluses of great egret chicks collected during 1995 for later analysis of whole-body total mercury concentrations. The sampling among species was based on relative importance in the diet. For example, we chose to analyze larger numbers of centrarchid fish than any other group and relatively few smaller fish such as sailfin mollies (*Poecilia latipinna*) or killifish (*Fundulus* spp.). Specimens were chosen for freshness and completeness and to represent the size range of individuals most frequently taken by the birds.

Total mercury concentrations in fish samples were determined at the Florida Department of Environmental Protection Chemistry Section in Tallahasee, FL, USA. Individual whole fish were homogenized and a 0.25-g aliquot digested with trace metal grade sulfuric acid and nitric acid. Following digestion, 5% potassium permanganate was added to all samples. Samples were analyzed using a cold vapor atomic absorbtion spectrometer (Varian 30/40 with deuterium background correction, fitted with cold vapor/hydride generator using stannous chloride reductant, and automated with an SPS5 autosampler, Walnut Creek, CA, USA). A five-point calibration curve was created each day, and quality control samples for all runs included triplicate samples (rejection if agreement <10%), digestion blanks of deionized water, high (4 μg/L) and low (1 μg/ml) methylmercury choride sample matix spikes, fish tissue standards (DORM-1, 0.15–0.2 g), and a practical quantitation level (PQL) standard inorganic mercury solution (0.25 μg/L).

When expressing average mercury values, we averaged all sunfish (*Lepomis* spp.) to get an estimate of mercury content of unidentified sunfish and averaged the mean concentrations for all species to estimate a value for unidentified fish. Mercury concentrations in fish are expressed as total mercury in mg/kg (ppm) wet weight (wet wt) unless otherwise noted.

Food consumption

We measured food consumption of great egret nestlings using the labeled water technique [18], which relies on the fact that the main source of dietary water intake for nestling birds is their food. By measuring water flux using dilution rates of labeled water and knowing the water content of prey animals, prey consumption can be calculated with a minimum of 6% accuracy [19]. This accuracy is further enhanced by an age-specific calibration curve for egrets that we performed using captive animals. We measured water flux in wild birds by injecting chicks intramuscularly with 1 mci deuterium (1994) or tritium (1995) per kilogram of body mass, taking a reference blood sample, and returning for a second sample 3 to 5 d later. Water was later vacuum distilled from sealed blood samples, and tritium concentrations were determined using scintillation counts of the resulting body water. We then used measurements of water content in prey animals from Kushlan et al. [20] to convert water turnover into estimates of prey consumption during the nestling period. A detailed account of the food consumption measurements may be found in Williams [19].

We measured food consumption of a total of 39 nestlings in the field at 10 to 28 d of age in 1994 and 1995. In addition, we augmented these field measurements with direct measurements of *ad libitum* food consumption of six captive nestlings from 2 to 100 d of age [6].

We used chi-squared analysis to determine whether there were differences in prey composition among years. We used

Table 1. Total mercury concentrations (mg/kg) in whole-body samples of fish taken from regurgitated boluses of great egret nestlings during 1995, with average mass and length of each species

Species	n	Mean mass (g)	SE mass	Mean total length (cm)	SE length	Mean mercury (wet wt)	SE mercury	Mean mercury (dry wt)	Median mercury (wet wt)
Belonesox belizanus	1	9.1	NA[a]	8.0	NA	0.4	NA	1.9	0.4
Cichlasoma bimaculatum	5	7.3	3.1	4.9	0.7	0.1	0.0	0.5	0.1
C. urophthalmus	4	28.0	11.9	8.4	1.3	0.1	0.1	0.6	0.1
Lepomis gulosus	9	27.0	8.9	8.4	1.3	0.5	0.1	2.2	0.2
L. marginatus	3	NA	NA	NA	NA	0.1	0.0	0.4	0.1
L. punctatus	19	12.3	3.1	6.3	0.5	0.3	0.0	1.5	0.3
Micropterus salmoides	4	43.9	35.7	11.8	3.8	0.8	0.3	3.6	0.5
Poecilia latipinna	2	1.1	0.1	3.6	0.1	0.1	0.0	0.2	0.1

[a] NA = no data available or not applicable because of small sample size.

regression analysis (EXCEL 95, Microsoft, Redmond, WA, USA) to test for significant relationships between individual fish mass and total mercury concentration.

RESULTS

Food habits of wild great egret nestlings

In 1993, we collected at total of 21 regurgitated boluses from great egret nestlings at Tamiami East, Frog City South, Frog City North, and Hidden colonies (see Fig. 1 for geographic locations). In 1994, we collected a total of 24 regurgitations at Alley North, Deer Island, Frog City South, Hidden/L-28, JW1, L-67, and Mud Canal colonies. In 1995, we collected a total of 51 regurgitated boluses, predominantly at Hidden and Tamiami colonies, with small numbers from Alley North, JW1, Mud Canal, and L-67 colonies. We collected a total of 29 boluses at Hidden and JW1 colonies during 1996.

In the four years, fish comprised an average of 95% of the biomass in boluses (Appendix), with insects, crustaceans, and amphibians making up the remainder. Great egrets tended to eat relatively large-bodied fish, predominantly sunfish and largemouth bass (*Micropterus salmoides*) in the family Centrarchidae (between 41 and 80% of biomass). However, different species of centrarchids predominated in different years, with warmouth (*Lepomis gulosus*) being most prevalent in 1994 and spotted sunfish (*Lepomis punctatus*) most important in 1995 and 1996.

The diet fluctuated considerably across years. Using those species that in aggregate made up over 95% of the biomass of the diet in each year, we found significant differences in species composition of the biomass among the 4 years (X^2 = 968.5, df = 33, $P < 0.001$).

Mercury concentrations in regurgitated fish

We found total mercury concentrations in whole fish recovered from regurgitated great egret boluses to range between 0.035 and 1.4 mg/kg ww (Table 1). Among the fish species most frequently consumed by great egrets, we found average total mercury concentrations ranging from 0.05 mg/kg (sailfin mollies) to 0.79 mg/kg (largemouth bass) (Table 1). Using species-specific wet mass–dry mass conversions [20], we estimate that mercury concentrations in these fish averaged from 0.22 to 3.55 mg/kg dry weight among species. Combining all species, we found a significant relationship between mass of individual fish and whole-body mercury concentration (analysis of variance [ANOVA], $p < 0.0001$, df = 43; Fig. 2). We also found a significant relationship between mass and mercury concentration among the centrarchid sunfish (ANOVA, p = 0.00019, df = 25). Although there was no suggestion of a relationship between whole-body mercury concentration and mass in the cichlids, only nine individual cichlids were analyzed for mercury.

Mercury exposure of great egret nestlings through diet

We combined the information on fish species composition in diet with the species-specific concentrations of total mercury to estimate concentrations of mercury in the diet of nestling great egrets during the different years of study. The importance of each of the fish species in the diet (proportion of total biomass) was multiplied by either the average or median mercury concentrations (both are expressed in Table 2). These weighted concentrations were then summed over all fish species within any year to give an estimated annual mercury concentration in the diet. For this estimation, we used those prey species listed in the Appendix, which collectively accounted for 95% of the biomass of the diet in each year. We estimate that annual mean mercury concentrations varied between 0.37 and 0.47 mg/kg ww (mean across years = 0.41 mg/kg) in the diet of great egret nestlings over the course of the 4-year study and that median mercury concentrations varied between 0.21 and 0.30 mg/kg.

We then estimated daily and cumulative doses of mercury to great egret nestlings over the course of the 80-d nestling and preindependence period (Table 3). For these calculations, we assumed that modeled animals were receiving the average annual concentration of 0.41 mg mercury/kg dietary fish. Our estimation of total mercury accumulated during the nestling period includes the fact that great egret chicks in the Ever-

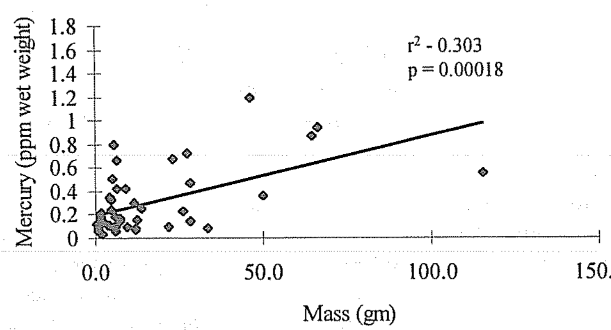

Fig. 2. Fish body mass versus whole-body mercury concentration, combining all species of fish for which mercury concentration was measured during 1995, in boluses regurgitated by great egret nestlings in the Everglades. The correlation is significant (ANOVA, p = 0.0001, df = 43).

Table 2. Estimated concentrations of mercury (mg/kg wet wt) in the diet of great egret nestlings by year and prey animal species as computed from species-specific prey mercury concentrations and representation of each species in the diet by biomass; results are shown using both mean mercury and median mercury values

Prey species	1993		1994		1995		1996	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Belonesox belizanus	0.063	0.063	0.013	0.013	0.008	0.008	0.000	0.000
Cichlasoma bimaculatum	0.001	0.001	0.000	0.000	0.005	0.005	0.000	0.000
C. urophthalmus	0.018	0.013	0.000	0.000	0.018	0.012	0.000	0.000
Lepomis gulosus	0.114	0.042	0.388	0.142	0.047	0.017	0.000	0.000
L. marginatus	0.005	0.005	0.000	0.000	0.002	0.002	0.000	0.000
L. punctatus	0.004	0.004	0.001	0.001	0.108	0.108	0.103	0.103
Micropterus salmoides	0.018	0.012	0.000	0.000	0.103	0.069	0.000	0.000
Poecilia latipinna	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
Lepomis spp.	0.094	0.061	0.002	0.001	0.004	0.003	0.050	0.032
Unknown fish	0.097	0.076	0.075	0.059	0.093	0.073	0.220	0.172
Total	0.415	0.276	0.479	0.216	0.389	0.299	0.373	0.307

glades begin life with an average of 0.40 mg/kg mercury ww as embryos (whole egg measurements, $n = 76$ eggs from the Water Conservation Areas of the Everglades, Dan Day, Biological Resources Division, U.S. Geological Survey, Patuxent Wildlife Research Center; personal communication).

Under these modeled conditions, daily mercury doses as a proportion of body mass are highest immediately following hatching and then decline over the nestling period, remaining largely in the range of 0.1 to 0.2 mg Hg/kg body mass/d (Fig. 3). At the rate of 0.41 mg Hg/kg food, we estimated that great egret chicks ingest a total of 10.49 kg ww of food and 4.32 mg Hg over the course of the 80-d preindependence period.

Since the regurgitant samples were taken from small and medium-sized young (to about 35 d) and since larger young might well take larger fish, we suggest that our estimates may be biased somewhat low for estimating actual mercury intake of prefledging great egrets in the Everglades. Similarly, these data were collected during three years when large fish were hypothesized to be relatively unavailable due to high water conditions [21], which would also have biased our measurements toward smaller fish of relatively low mercury concentration.

Using the modeling conditions described above, we also estimated mercury intake at two dietary mercury concentrations higher than those that we measured directly in the diet but that are probably quite possible in the Everglades (Table 3). The first is 0.6 mg/kg food, which is suggested by mercury concentrations in Everglades fish provided by W. Loftus (personal communication, [6]). The second is roughly three times that concentration (1.7 mg/kg food), which could be achieved if great egrets nestlings were fed only larger, predatory fish [13]. Such a diet is possible in a year in which much of the marsh surface is exposed through drying, making larger fish vulnerable to avian predation [22]. For example, during 1992, much of the marsh surface dried, and we noted very large centrarchid fish often spontaneously regurgitated by great egret nestlings as we worked in breeding colonies. We estimate that total mercury ingested over the 80-d prefledging period would be 6.53 mg per nestling at the 0.63 mg/kg concentration and 17.27 mg at the 1.76 mg/kg concentration.

Table 3. Estimation of total accumulation of mercury acquired through diet by great egret young during the nestling and prefledging period (<80 d) in Everglades

Mercury content of food (mg/kg prey)	Total mercury ingested (mg)	Average daily dose (mg)
0.41	4.32	0.05
0.63	6.53	0.08
1.76	17.27	0.22

DISCUSSION

We found that great egret nestlings are fed a diet dominated by fish. In the four years of study, fish comprised an average of 95% of the biomass in regurgitated boluses. The species of fish eaten fluctuated significantly from year to year, indicating very flexible dietary preferences. The larger species of fish certainly are favored by great egrets, especially the sunfish and the similarly shaped and sized cichlids. Centrarchids were clearly the most important group of prey animals, though two different species of centrarchids (warmouth and spotted sunfish) predominated in different years. This is of interest since the two species of fish are at markedly different trophic levels, as reflected in their mercury content. We also found large fluctuations in the proportion of the diet occupied by nonnative fish, ranging from 32% of the biomass in 1993 to 0% in 1996. Because water conditions remained similar over the 4 years (deep water, long hydroperiod) and freezes (to which nonnatives are very susceptible) were comparatively rare during this time, we are unable to invoke physical factors as explanations for the fluctuations in the consumption of nonnative fish by the birds.

Other studies have demonstrated both wider and narrower ranges of prey preferences for the great egret. In the Yucatan peninsula, Ramo and Busto [23] found that boluses regurgitated by nestlings were composed almost entirely of fish and almost entirely of a single species (*Astyanax fasciatus*). In a Puerto Rican estuary, Miranda and Collazo [24] found that 13 adult stomachs collected during the nonbreeding season contained a more varied diet, with at least seven species of fish about equal in importance. In addition, crustaceans and insects made up a significant portion of the diet in Puerto Rico, a feature not seen in this or other studies.

Our measurements of mercury content in prey animals utilized by great egrets agree in their range with those of other studies in the Everglades, ([13,25], W. Loftus, unpublished data) and are in the upper end of the range of mercury concentrations for freshwater fish, even for those found in contaminated areas [9,26–30].

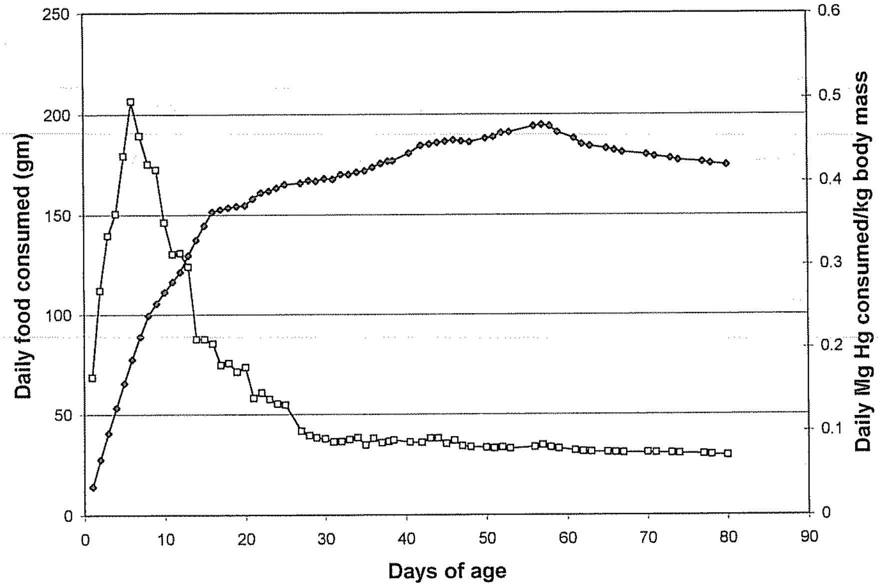

Fig. 3. Food consumed (solid diamonds) and mercury ingested per kilogram of body mass (open squares) by great egret chicks over the course of the entire nestling period, as modeled using 0.412 mg/kg as the average mercury concentration in prey items. Food consumption is modeled from a combination of data from both captive-raised birds and field measurements of food consumption.

Although mercury concentrations in Everglades fish probably are below the threshold for teratogenic effects or acute toxicity in fish, it is quite possible that they may cause sublethal effects in fish populations [29]. Our findings also demonstrate that, within the diet of great egret nestlings, mercury concentrations increase with size of fish. This leads to the prediction that mercury exposure in great egrets is likely to increase under any conditions (such as rapid drying of surface water) that allow birds to capture larger fish in the Everglades.

We predict that the relative dose rate for young great egrets (mg total mercury/kg body mass) will be highest shortly after hatching and will decline slowly until fledging. This prediction is unlikely to be strongly affected by changes in the actual mercury concentration or the size of fish captured because it is a mathematical result of the fact that chick mass increases rapidly in proportion to mass of food eaten as the chick grows. Daily exposure to very young chicks may, however, be overestimated because these animals probably will be fed smaller fish than those that we collected. In addition, it is likely that our estimates of mercury exposure in older chicks are biased somewhat low because we collected regurgitant during water conditions that made larger fish with higher mercury concentrations relatively unavailable to the birds.

Our estimation of total mercury accumulation from diet is at least qualitatively supported by variation in mercury accumulation rates in growing feathers of great egret chicks. Sepúlveda et al. [16] reported that age-adjusted mercury levels in growing feathers was higher in 1994 than in 1995 from great egret nestlings in all five colonies sampled in the freshwater Everglades. Although these findings with feathers agree at least qualitatively with our predicted exposure, further calibration is obviously needed before mercury exposure in the diet can be related to mercury concentrations in tissues in great egrets.

The effects of mercury exposure that we measured on young great egrets is difficult to predict. Scheuhammer [31] suggested that diets containing >1 mg/kg (ppm) ww total Hg posed a health risk to birds. In free-ranging great white herons (*Ardea herodias occidentalis*), Spalding et al. [15] found that post-fledging birds with elevated concentrations of hepatic mercury (>5 mg/kg total Hg ww) had more diseases than did their low-mercury counterparts. In captive-raised great egret chicks, Frederick et al. [6] and Bouton et al. [32] found that, at a dietary intake rate of 0.5 mg methylmercury/kg, great egret nestlings and fledglings displayed decreased appetite and strength, lower packed-cell volume, altered maintenance behavior, and some evidence of decreased motivation to hunt live prey. The methylmercury content of fish of both high and low trophic position in the Everglades food web is between 95 and 100% of total mercury ([25], Florida Department of Environmental Protection, unpublished data), so we may assume that our estimate of 0.41 mg/kg total mercury in the diet of wild birds is similar to the 0.5 mg/kg methylmercury diet fed to captives. This implies that the effects found in captive birds are on the same order of magnitude as what may be occurring in the field. We propose that the survival and health of great egret nestlings and juveniles in the Everglades may be affected by sublethal effects of chronic exposure to mercury through diet at concentrations that occur presently.

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APPENDIX

Relative importance of prey items in boluses regurgitated by nestling great egrets during 4 years in the central Everglades

	Proportion of	1993	1994	1995	1996
No. of boluses		21	24	51	29
Animals per bolus					
Mean		6.6	4.3	5.0	2.4
SD		4.83	6.04	5.54	NA[a]
Mass of boluses					
Mean		48.0	7.6	25.5	27.1
SD		32.13	15.60	10.88	NA
Vertebrata					
Osteichthys					
Unknown fish	Total biomass	0.07	0.07	0.07	0.50
	Samples	0.48	0.54	0.40	0.74
Erimyzon sucetta	Total biomass	0.00	0.05	0.02	0.00
	Samples	0.00	0.04	0.01	0.00
All Catostomidae	Total biomass	0.00	0.05	0.02	0.00
	Samples	0.00	0.04	0.00	0.00
Unidentified centrarchids	Total biomass	0.18	0.00	0.01	0.09
	Samples	0.57	0.04	0.09	0.37
Lepomis macrochirus	Total biomass	0.01	0.00	0.00	0.00
	Samples	0.14	0.04	0.00	0.00
Lepomis microlophus	Total biomass	0.05	0.00	0.00	0.00
	Samples	0.10	0.00	0.00	0.00
Lepomis marginatus	Total biomass	0.05	0.00	0.02	0.00
	Samples	0.10	0.00	0.09	0.00
Lepomis punctatus	Total biomass	0.01	0.00	0.33	0.31
	Samples	0.05	0.40	0.53	0.58
Lepomis gulosus	Total biomass	0.23	0.79	0.10	0.00
	Samples	0.19	0.41	0.09	0.00
Micropterus salmoides	Total biomass	0.02	0.00	0.13	0.00
	Samples	0.10	0.00	0.12	0.00
Elassoma evergladei	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.05	0.00	0.00	0.00
All Centrarchidae	Total biomass	0.56	0.80	0.59	0.41
	Samples	0.86	0.54	0.79	0.69
Unidentified *Fundulus*	Total biomass	0.01	0.00	0.00	0.00
	Samples	0.14	0.00	0.02	0.00
Fundulus seminolis	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.00	0.00	0.02	0.00
Fundulus chrysotus	Total biomass	0.01	0.01	0.02	0.00
	Samples	0.05	0.16	0.19	0.00
Fundulus confluentus	Total biomass	0.02	0.00	0.00	0.00
	Samples	0.19	0.00	0.00	0.05
Fundulus lineolatus	Total biomass	0.00	0.00	0.01	0.00
	Samples	0.00	0.00	0.11	0.00
Lucania parva	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.00	0.04	0.02	0.00
Belonesox belizanus	Total biomass	0.15	0.03	0.02	0.00
	Samples	0.24	0.04	0.12	0.00
Poecilia latipinna	Total biomass	0.00	0.00	0.02	0.00
	Samples	0.10	0.04	0.23	0.00
Gambusia holbrooki	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.05	0.16	0.11	0.00
Heterandria formosa	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.00	0.04	0.00	0.00
Jordanella floridae	Total biomass	0.01	0.00	0.01	0.00
	Samples	0.24	0.00	0.16	0.11
Unidentified Ictaluridae	Total biomass	0.01	0.00	0.00	0.00
	Samples	0.05	0.00	0.00	0.00
Unidentified cichlid	Total biomass	0.06	0.00	0.00	0.00
	Samples	0.10	0.00	0.02	0.00
Cichlasoma urophthalmus	Total biomass	0.13	0.00	0.12	0.00
	Samples	0.14	0.00	0.16	0.00
Cichlasoma bimaculatum	Total biomass	0.01	0.00	0.05	0.00
	Samples	0.10	0.00	0.11	0.00
Hemichromis letourneauxi	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.00	0.00	0.02	0.00
All Cichlidae	Total biomass	0.17	0.00	0.18	0.00
	Samples	0.43	0.00	0.30	0.00
All exotic fish	Total biomass	0.32	0.03	0.20	0.00
	Samples	0.57	0.04	0.42	0.00

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APPENDIX
Continued

	Proportion of	1993	1994	1995	1996
Amphibia					
Rana utricularia	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.05	0.00	0.00	0.00
Rana sp.	Total biomass	0.00	0.02	0.00	0.00
	Samples	0.00	0.04	0.00	0.00
Arthropoda					
Insecta					
Odonata adults	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.05	0.21	0.14	0.05
Unidentified insect	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.05	0.13	0.02	0.00
Crustacea					
Procambarus spp.	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.14	0.21	0.11	0.00
Palaemoenetus paludosus	Total biomass	0.00	0.00	0.00	0.00
	Samples	0.05	0.08	0.04	0.05

[a] NA = not applicable.