Geographic variation in mercury concentrations and C and N stable isotope ratios in American alligators

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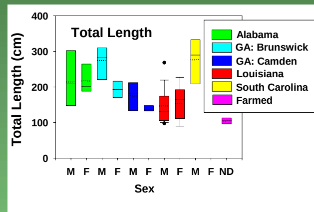
ABSTRACT

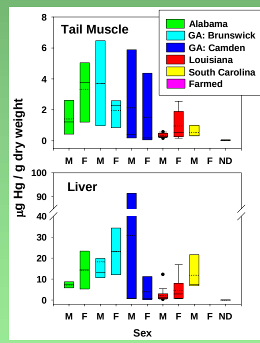
Alligators (Alligator mississippiensis) are long-lived apex predators in southeastern U.S. ecosystems, and can potentially accumulate considerable amounts of biomagnified contaminants such as methylmercury. We expected a positive correlation between trophic position (which can be estimated from 15N ratios) and mercury concentration. Because alligator diets are known to include both aquatic and terrestrial animals, we also expected that tissue mercury concentrations might be related to the relative contributions of these sources to the diet (which are potentially identifiable from tissue 13C ratios). To test these hypotheses and assess geographic variation in these parameters, we sampled liver and tail muscles of alligators (total length 90-350 cm) from Alabama, Georgia, South Carolina, and Louisiana. Tissue mercury concentrations were positively correlated with alligator size, but did not differ between males and females when size was used as a covariate. There were significant differences among locations in tissue mercury and both C and N stable isotope ratios. The highest mercury concentrations in both liver (geometric mean: 16.0; 95% confidence interval: 9.90-25.9 mg Hg kg-1 dry mass) and tail muscle (2.02; 1.13-3.62 mg Hg kg-1 dry mass) were in alligators from Glynn County, Georgia, which are in proximity to a mercury-polluted Superfund site. The lowest mercury concentrations were found in the Louisiana wildlife refuge and in the farmed alligators. Both liver and tail mercury concentrations were predictable (R2 > 0.55) from a combination of 15N and (to a lesser degree) 13C. Both liver (r = 0.64) and tail muscle (r = 0.60) 15N ratios were correlated with mercury levels. Total body length and 15N values were also correlated. This suggests that, as expected, larger alligators occupy higher trophic levels and thus also accumulate the most mercury.



Introduction

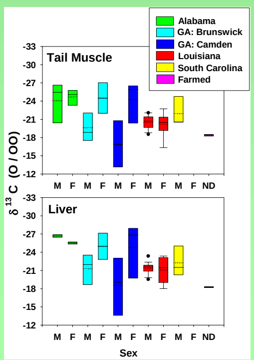
Environmental contaminants are a growing concern in the conservation and management of several crocodilian species. In the southeastern US, Hg represents a serious environmental threat to fish and wildlife. Adult alligators are top predators in freshwater wetlands across the southeastern US. Some persistent contaminants, including methyl mercury, biomagnify (increase in concentration with trophic level) so alligators could accumulate significant concentrations. A number of studies have shown that crocodilians are capable of accumulating Hg with dietary exposure, sometimes to levels that exceed U. S. Food & Drug Administration (FDA) limits for human consumption.

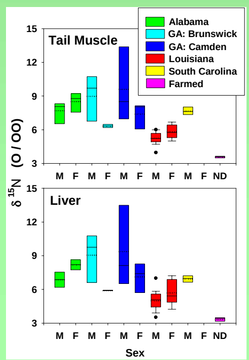
The ratio of the stable nitrogen isotopes $^{14}N/^{15}N$ can be used to infer trophic position; $\delta^{15}N$ typically increases 3-4 ‰ for each trophic level. Mercury concentration and $\delta^{15}N$ are positively correlated in many fish and mammals. Similarly, the ratio of carbon stable isotopes $^{12}C/^{13}C$ can be applied to differentiate carbon sources in a food web, and to infer whether an animal is feeding in marine, freshwater and terrestrial environments, and between agricultural and native plant carbon sources. Previous work has examined relationships between mercury and N and C isotopes in Alligators in Florida. In this study, we examine mercury $\delta^{15}N$ and $\delta^{13}C$ in American alligator tail muscle and liver tissue across the remainder of the southeastern US. Our objective was to determine potential links between trophic level and mercury concentration and to differentiate differences in mercury concentration associated with animals feeding in agricultural, terrestrial and aquatic food webs.



Materials and Methods

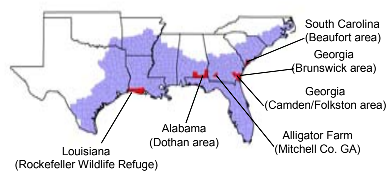
Liver and tail muscle samples were taken from wild alligators collected by nuisance trappers in Alabama (n=10), Georgia (n=16), and South Carolina (n=3) and by refuge personnel from Rockefeller Wildlife Refuge (RWR), Louisiana (n=27). Alligators were also sampled from a farm in Mitchell County, Georgia (n=4). Alligators were sexed, weighed, and total length was measured at time of capture. Samples taken from each alligator were stored individually in sterile Whirl-Pak bags, freeze dried to constant weight and mechanically homogenized before analysis. Total mercury was measured by thermal decomposition, gold amalgamation and CVAA spectroscopy (EPA method 7473) using a DMA-80 Analyzer (Milestone, Inc, Monroe, CT). Replicates, blanks and standards of similar matrix with certified Hg concentrations (DOLT-2, DORM-2 and TORT-2, National Research Council of Canada, Ottawa) were analyzed with each set of samples for QA/QC purposes. All samples contained detectable Hg (> 15 ng/g), and Hg data are presented on a dry weight basis. For isotope analyses, lyophilized samples were extracted in 2:1 chloroform:methanol, and dried. A continuous flow isotope ratio Delta+xls Mass Spectrometer (Finnigan-MAT, San Jose, Ca), with a Carlo Erba NC2500 Elemental Analyzer was used to measure C and N isotope ratios. .The results of the stable isotope analyses are presented in per mil units (‰) using standard δ notation. Working standards of DORM-2 and DOLT-2 were used and reproducible to $\pm$ 0.15 ‰ for $\delta^{13}C$ and $\delta^{15}N$. All data were tested for normality and log transformed when necessary. Differences in mercury concentration and stable isotope signatures between sexes and among locations were examined using analysis of covariance (ANCOVA). Tukey's multiple comparison procedure was used when significant differences were detected with ANCOVA. Relationships between variables were examined using Pearson and Spearman correlations. Statistical results were considered significant when $P \leq 0.05$.





Map Showing the Range of the American Alligator (in Blue)

counties where samples were collected are shown in red

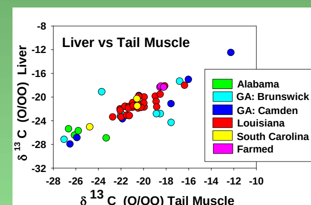


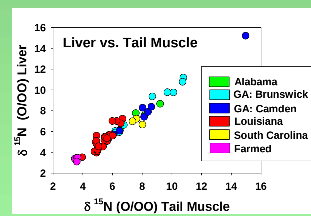
Results

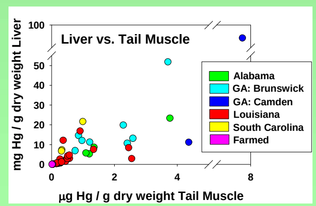
Alligators sampled were adults; most ranged in size from 1.5 to 3 meters. The farmed alligators were smaller, about 1 M in length. The largest specimens were nuscance gators from Alabama, Georgia and South Carolina

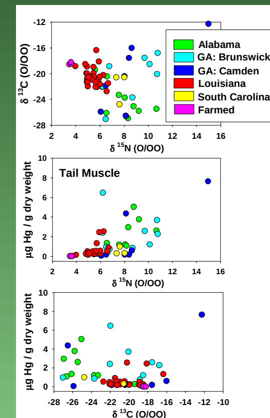
There were significant differences in mercury concentrations among locations. The farmed alligators contained the lowest mercury concentrations, followed by those from the Louisiana refuge. Highest mean and median values were at the Georgia and Alabama sites. The highest concentrations were found near Brunswick, GA, the location of a Superfund site that is heavily polluted with mercury. Liver concentrations were higher than tail muscle concentrations Concentrations were correlated with alligator size, but did not differ between males and females at most sites. This could reflect small samples sizes for some sexes at some sites

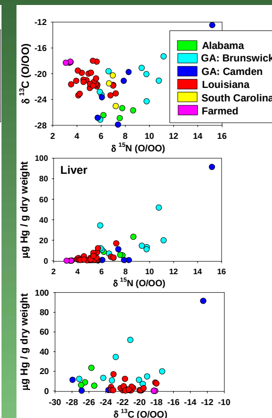
Stable N and C ratios also differed among sites. $\delta^{15}N$ values were highest in the GA samples, suggesting these animals were feeding at higher trophic levels. Farmed alligators had relatively high $\delta^{13}C$ values, as did those from Georgia, especially the Camden/Folkston area. Body length was correlated with $\delta^{15}N$, supporting the idea that larger alligators feed at higher trophic levels. $\delta^{13}C$ was not correlated with body size











Stable isotopes of C in tail muscle and liver were correlated, as were stable isotopes of N (Figures to left). Mercury concentrations in livers were more variable than those in tail muscle, and mercury in theses two tissues were not well correlated.

Liver and tail muscle δ 13C and δ 15N were correlated with Hg concentrations in these tissues (r = 0.64 and 0.60, respectively; Figures above). A regression model incorporating both N and C isotopes predicted about 55% of the variability in tissue mercury concentration.

Conclusions

As long-lived apex predators, alligator accumulate persistent contaminants such as methyl mercury. Our results, along with those of others who have examined this species, indicate the utility of alligators as biomonitors of mercury pollution. There appear to be geographic differences in mercury exposure and accumulation across the alligator's range. Farmed alligators, fed on agricultural products, have relatively low mercury concentrations. In contrast, wild alligators, especially larger and older adults, may contain potentially harmful mercury concentrations in edible tissues.

As expected, we found trophic position, as inferred from d 15N values, is related to mercury concentration in tissues. To a lesser extent, tissue mercury is related to carbon sources, as inferred form d 13C. Larger alligators have higher d 15N values, indicating that they feed at higher positions in food webs. These findings are consistent with current knowledge about crocodilian biology and ecology, and with studies that have investigated relationships between stable C and N ratios and mercury concentrations in other taxa.

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