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Effects of Environmental Contaminants on Snapping Turtles of a Tidal Wetland

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Abstract. Snapping turtles (*Chelydra serpentina*) were collected from a brackish-water and a nearly freshwater area in the contaminated Hackensack Meadowlands of New Jersey and an uncontaminated freshwater area in Maryland to determine the effects of environmental contaminants on a resident wetland species. No turtles were observed or caught in the Meadowlands at two trapping sites that were the most heavily contaminated by metals. Snapping turtles from the brackish-water area had an unusually low lipid content of body fat and reduced growth compared to turtles from the freshwater areas in New Jersey and Maryland. Despite the serious metal contamination of the Hackensack Meadowlands, the metal content of kidneys and livers from New Jersey turtles was low and not greatly different from that of the Maryland turtles. Organochlorine pesticide concentrations in body fat were generally low at all three study areas. Polychlorinated biphenyls (PCBs) concentrations in fat were highest in male turtles from the New Jersey brackish-water area. Analysis of blood for aminolevulinic acid dehydratase, albumin, glucose, hemoglobin, osmolality, packed cell volume, total protein, triglycerides, and uric acid failed to reveal any differences among groups that would indicate physiological impairment related to contaminants.

Wetlands in highly populated coastal areas of the United States are subjected to disturbances of many kinds, including environmental contaminants. The effects of contaminants on animal populations can be difficult to separate from the effects of other disturbances, especially in the absence of reliable information on the past status of contaminants and animal populations. Species that are missing or present in abnormally low numbers might be indicative of poor environmental conditions, but establishing this relationship can be difficult (Cairns 1974). Our approach was to examine a species that exists in a disturbed area in an effort to identify the physiological stresses placed on the organism.

The snapping turtle (*Chelydra serpentina*) is a common resident of wetlands. The presence of this turtle in contaminated environments has been reported by others (Gibbons 1968; Graham and Perkins 1976; Stone *et al.* 1980; Helwig and Hora 1983; Olafsson *et al.* 1983). The latter three studies indicated that snapping turtles exposed to pollutants can accumulate high concentrations of substances such as polychlorinated biphenyls (PCBs), chlorinated pesticides, and metals, but no information on physiological condition was presented. Our objective was to compare growth, certain physiological functions, and contaminant burdens of snapping turtles from a contaminated coastal wetland and an undisturbed wetland.

Methods

The contaminated wetland consisted of several brackish-water locations (2.5–5 ppt salinity) in the vicinity of Moonachie Creek marshes, Mill Creek, and Berry's Creek drainage basin, and a nearly freshwater location (1 ppt; hereafter called freshwater), Kearny Marsh, in the Hackensack Meadowlands of northeast New Jersey (NJ) (Figure 1). The brackish-water locations in NJ consisted of tidal creeks (1-m tidal range) and drainage ditches that were either tidal or nontidal. Vegetation consisted almost entirely of dense stands of common reed (*Phragmites communis*). Kearny Marsh was a large, shallow (0.5–1.5 m) impoundment containing old drainage ditches and areas of open water. Common reed dominated the emergent vegetation but other aquatic plants, such as marsh-mallow (*Althaea officinalis*),

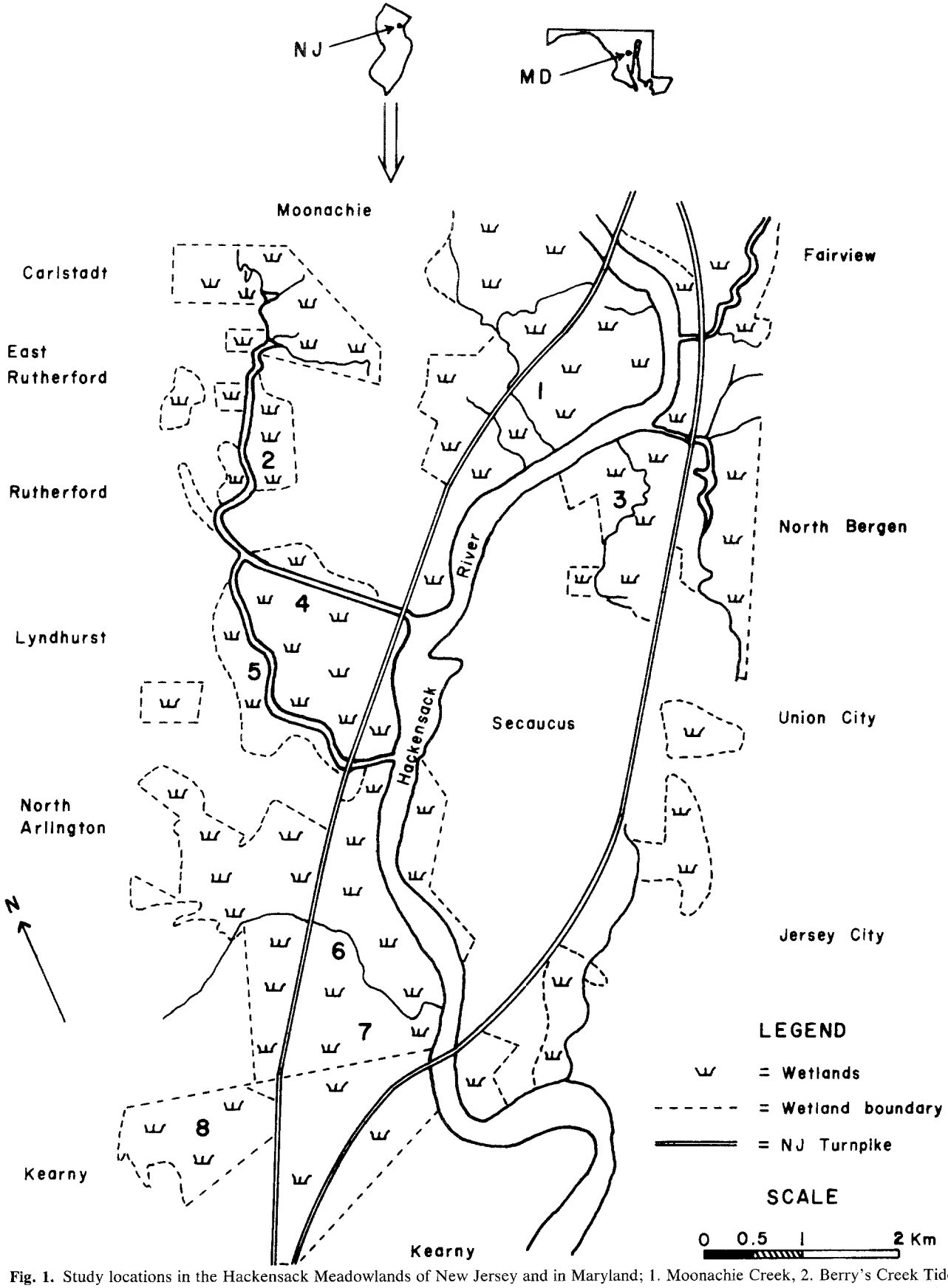

Fig. 1. Study locations in the Hackensack Meadowlands of New Jersey and in Maryland; 1. Moonachie Creek, 2. Berry's Creek Tide Marsh, 3. Mill Creek, 4. Berry's Creek Canal, 5. Berry's Creek, 6. Sawmill Creek, 7. Sawmill Creek Tide Marsh, 8. Kearny Marsh

duckweed (*Lemna minor*), and horned pondweed (*Zannichellia palustris*) occurred in varying amounts.

The Hackensack Meadowlands comprise 7,700 ha of brackish-water and freshwater marshes and creeks that are surrounded by residential, commercial, and industrial areas. The area is crossed by highways, railroads, and commercial barge traffic on the Hackensack River and has been the periodic target of large-scale drainage and reclamation efforts since the mid-nineteenth century (Hackensack Meadowlands Development Commission 1980). Large portions of the remaining wetlands are scheduled for future development (Mattson 1978). The Meadowlands have been subjected to contamination from residential landfills, municipal sewage effluents, industrial discharges, urban stormwater runoff, and airborne contaminants from auto and industrial emissions (Mueller *et al.* 1976; Meyerson *et al.* 1981).

Metal contamination is particularly serious in the marsh soils and stream sediments of the Meadowlands. Berry's Creek and Mill Creek contained high concentrations of metals; Berry's Creek averaged 107 ppm mercury in marsh surface soil and 66 ppm in channel surface sediments (nine samples), and Mill Creek averaged 4.5 ppm mercury (four samples) in marsh surface soil and 5.9 ppm (19 samples) in channel surface sediments (Galluzzi and Sabounjian 1980; McCormick and Assoc 1978). A channel surface sediment survey of a 5-mile portion of upper Berry's Creek averaged 16.9 ppm cadmium, 966 ppm chromium, 379 ppm copper, 289 ppm mercury, 68 ppm nickel, 256 ppm lead, and 3,200 ppm zinc for 25 samples (Galluzzi, unpublished). Metals, other than mercury, were found in similar quantities in the Mill Creek basin (McCormick and Assoc 1978). The Moonachie Creek marsh area averaged 2.7 ppm mercury in four samples of marsh surface soil and 0.4 ppm mercury in three samples of channel surface sediments (Galluzzi and Sabounjian 1980); no information was available on other metals. Kearny Marsh averaged 1.1 ppm mercury in four surface soil samples (Galluzzi and Sabounjian 1980) and averaged 3.3 ppm cadmium, 90 ppm chromium, 209 ppm copper, 75 ppm nickel, 686 ppm lead, and 472 ppm zinc in three surface soil samples (Galluzzi, unpublished). A survey of metals studies in estuaries and rivers in other parts of the world indicates that the NJ sites could be classified as seriously polluted for most of the metals (Essink 1980; Menasveta and Cheevaparanapiwat 1981; Millward and Herbert 1981; Smith *et al.* 1981; Zingde and Desai 1981; Nishida *et al.* 1982).

The undisturbed wetland consisted of shallow, freshwater impoundments (<0.5 ppt salinity) at the Patuxent Wildlife Research Center, Laurel, Maryland (MD). The impoundments were created in the 1950's from riverbottom woodlands and do not receive any industrial or municipal input other than from motor vehicles and aerial deposition from nearby metropolitan areas. The impoundments had a maximum depth of 1.5 m, contained numerous stumps and dead trees, and were characterized by moderate to dense mixtures of aquatic vegetation; e.g., white waterlily (*Nymphae odorata*), yellow pond-lily (*Nuphar variegatum*), watershield (*Brasenia schreberi*), swamp smartweed (*Polygonium hydropiperoides*), square-stem spike rush (*Eleocharis quadrangulata*), and hornwort (*Ceratophyllum demersum*).

Procedures

Turtles were collected with set lines baited with chicken necks; lines were checked at least once and often twice a day. All turtles were caught during the months of June, July, and August in 1981 and 1982. Turtles were transported to the necropsy site in feed sacks and weighed prior to removal from the sacks. The turtles were anesthetized by intramuscular injection of 11 mg/kg of Ketaset[1] (ketamine hydrochloride; Veterinary Products, Bristol Laboratories, Syracuse, NY) and 2.2 mg/kg of Rompun (xylazine; Bayvet, Shawnee, KS). After a 30-ml blood sample was drawn by heparinized needle and syringe from the vertebral sinus at the base of the tail, 0.3 mg/kg of T-61 euthanasia solution (American Hoechst Corp., Somerville, NH) was injected into the same needle. Whole blood samples for hemoglobin (cyanomethemoglobin method; Hycel Inc., Houston, TX) and aminolevulinic acid dehydratase (ALAD) determination (spectrophotometric) were placed in liquid nitrogen and processed at a later date. Packed cell volume (PCV) was determined by the microhematocrit method (Coles 1980, p 84). Plasma was separated from the remaining blood by centrifugation and stored in liquid nitrogen; the plasma was later transferred to storage at −80°C.

The weight of the turtles and the dimensions of the carapace were recorded. The eipidermal scales of the second and third right lateral bony plates of the carapace were cleaned with detergent and steel wool and the number of rings (annuli) were recorded (Sexton 1959; Hammer 1969; Christiansen and Burken 1979). Bone annuli (Hammer 1969) were also counted, but the carapace annuli method was preferred (Albers and Sileo, in prep.). Portions of the liver, kidney, and visceral fat were taken with hexane-washed instruments and frozen at −28°C for contaminants analyses.

Chemical, Blood, and Data Analysis

All chemical and blood analyses were performed in the chemistry and physiology laboratories of the Patuxent Wildlife Research Center.

Liver and kidney samples were homogenized in a blender. Five-g portions of each were placed in Vycor crucibles for cadmium, chromium (total), copper, nickel, lead, and zinc analyses, and separate 5-g portions of each were used for mercury analysis.

The aliquots for mercury analysis were digested and analyzed by the methods of Haseltine *et al.* (1980). Aliquots for cadmium, chromium, copper, nickel, lead, and zinc were digested as in Haseltine *et al.* (1981) and residues were determined by comparison with aqueous standards on a Perkin-Elmer model 5000 atomic absorption spectrophotometer. Except for the lead line of 217.0 nm, the standard conditions as published by the manufacturer were used. The lower limits of reportable residues, on a wet weight basis, were 0.1 ppm for cadmium, copper, nickel, and zinc; 0.05 ppm for chromium; and 0.02 ppm for mercury. Recoveries from chicken livers ranged from 83 to 110%. Residue levels were not corrected for recovery.

The visceral fat was analyzed for an array of organochlorine compounds. Sample preparation, extraction of a 2-g portion of fat, and Florisil® cleanup have been described in Cromartie *et al.* (1975). Silica gel (100–200 mesh, grade 923, Davison Chemical Division, W. R. Grace & Co) was substituted for SilicAR for the separation of pesticides from PCBs. Samples were separated into four fractions rather than three to facilitate separation of dieldrin and/or endrin in a discrete fraction (Kaiser *et al.* 1980). Fractions I and II were combined and were not analyzed for

[1] Use of trade names or names of suppliers does not imply endorsement by the federal government.

HCB and mirex. Residues were quantitated by electron-capture, gas-liquid chromatography (EC-GLC) using a 1.83-m long by 4-mm i.d., 1.5/1.95% SP-2250/2401 column. A 3% SP-2100 column was used to increase resolution of the chlordane isomers. Residues in 3% of the samples were confirmed with a Finnigan model 4000 gas-liquid chromatograph/mass spectrometer. The lower limits of reportable residues were 0.1 ppm for pesticides and 0.5 ppm for PCBs. Average percent recovery in fortified mallard tissue (*Anas platyrhynchos*) ranged from 80 to 100%. Residue levels were not corrected for recovery.

The blood serum was analyzed for albumin, glucose, total protein, triglycerides, and uric acid on a centrifugal analyzer (Centrifichem 500; Baker Instrument Corporation, Allentown, PA); procedures were according to manufacturers specifications. Osmolality was determined with an Osmette A (Precision Systems, Inc., Sudbury, MA).

Results of the organochlorine and metal analysis, whole blood characteristics, blood serum analysis, and the percent lipid of visceral fat were analyzed by one-way analysis of variance. Organochlorines and metals that were detected in at least 50% of the samples were subjected to statistical analysis. One half of the detection limit was substituted for a not-detected finding. Turtles were separated by sex for all data analyses. Variances were tested for homogeneity with Bartlett's test (Bartlett 1937); data sets failing the test were transformed to natural logarithms and re-analyzed by analysis of variance. All significant analyses of variance were subjected to multiple comparisons by the Bonferonni method (Neter and Wasserman 1974). Separate multiple comparisons were performed to test for an interaction between sex and location, a difference between sexes at a location, and differences between locations. If sexes were not different, then both sexes in MD and brackish-water NJ were combined for the test of location difference. The growth of male turtles from the three collection locations was evaluated by analysis of covariance; weight and carapace length were variates and shell age was the covariate (Gibbons 1968; Hammer 1969; Graham and Perkins 1976; Kiviat 1980). Contrasts on adjusted means were performed with an *F*-test. The level of significance used for all analyses was $P \leq 0.05$.

Results

Specimen Collection

Thirty-two snapping turtles were caught at the three collection locations, 13 in MD, 11 in the brackish-water NJ location, and eight in the freshwater NJ location. No turtles were caught in tidal brackish-water at the most contaminated sites, Mill Creek and the Berry's Creek drainage, despite 66 set-line days of effort; only one turtle was caught at other tidal brackish-water sites in 39 set-line days (4–5 ppt salinity). Ten brackish-water turtles were caught at nontidal sites in the Moonachie Creek marshes (46 set-line days; 2.5–5 ppt salinity). Turtles collected in MD and freshwater NJ required 4 to 6 set-line days per turtle.

Metal and Organochlorine Chemical Analysis

Chromium, copper, mercury, nickel, and zinc were detected in at least 50% of the liver and kidney samples; cadmium and lead were detected in less than 50% of the samples (Tables 1 and 2). All analyses of variance, except for mercury in kidney tissue, revealed significant differences among the groups. The only sex-related difference in metal accumulation was a significantly higher amount of copper in the livers of NJ brackish-water males than in the NJ brackish-water females. Quantities of metals in liver and kidney tissue from MD turtles were equal to or significantly less than those from NJ brackish-water turtles. Quantities of metals in liver tissue of MD turtles were equal to or significantly greater than those of NJ freshwater turtles, but metals in kidney tissue were equal to or significantly less than those of NJ freshwater turtles. Quantities of metals in liver and kidney tissue of NJ brackish-water turtles were equal to or significantly greater than those from NJ freshwater turtles. The general order of metal accumulation was NJ brackish-water > MD = NJ freshwater.

Oxychlordane, *cis*-nonachlor, *trans*-nonachlor, DDE, and PCBs were detected in at least 50% of the visceral fat samples (Table 3). Turtles from the freshwater NJ location contained the highest levels of DDE which were significantly higher than in the turtles from brackish-water NJ locations. PCBs were significantly higher in male turtles from brackish-water NJ than in male turtles from freshwater NJ and MD. The percent lipid of fat bodies was low for brackish-water NJ turtles. Male turtles from MD had significantly greater quantities of DDE in their fat than did the MD females. The combined males from the MD and NJ brackish-water locations had significantly greater quantities of PCBs in their fat than did the combined females of both locations.

Blood Plasma Analysis

Turtles from MD had significantly higher ALAD and significantly lower hemoglobin than turtles from brackish-water NJ, and significantly lower albumin, glucose, hemoglobin, and total protein than freshwater NJ turtles (Table 4). Brackish-water NJ turtles had lower albumin, glucose, and total protein than freshwater NJ turtles. Female turtles from MD had significantly higher levels of albumin and triglycerides than did the males from MD. Combined females from MD and NJ brackish-water locations had higher levels of total protein than did combined males from the same locations.

Table 1. Metal content of livers from snapping turtles collected at two sites in the Hackensack Meadowlands of New Jersey (NJ) and at an undisturbed site in Maryland (MD). Values are in ppm, wet weight; mean (SD). Mean percent moisture of groups from left to right is 75.6, 73.0, 78.0, 76.9, and 75.1

		Group (sample size)				
Metal	Frequency of detection (%)	MD male (7)	MD female (6)	NJ brackish male (8)	NJ brackish female (3)	NJ freshwater male (8)
Cadmium	28	0.07 (0.04)	0.06 (0.03)	0.10 (0.06)	0.08 (0.05)	0.08 (0.07)
Chromium	100	1.00 (0.76)A[a]	1.97 (1.48)A	0.60 (0.32)AB	0.60 (0.23)AB	0.36 (0.32)B
Copper	100	1.28 (0.52)A	1.57 (0.59)A	9.72 (4.61)B	5.17 (3.59)B	2.08 (0.63)A
Lead	6	0.07 (0.06)	ND[b]	ND	ND	0.12 (0.20)
Mercury	100	0.90 (0.48)A	0.46 (0.18)A	1.28 (0.79)B	1.27 (0.34)B	0.60 (0.40)A
Nickel	81	0.44 (0.36)A	0.99 (0.85)A	0.24 (0.15)AB	0.27 (0.15)AB	0.13 (0.10)B
Zinc	100	27.72 (3.25)A	29.29 (3.60)A	50.38 (23.74)B	38.95 (10.67)B	30.68 (4.44)A

[a] Means with different letters are significantly different, Bonferonni method; sexes from the same site were combined for analysis, except for copper. Sexes different for copper; within sex comparisons only
[b] ND = not detected

Table 2. Metal content of kidneys from snapping turtles collected at two sites in the Hackensack Meadowlands of New Jersey (NJ) and at an undisturbed site in Maryland (MD). Values are in ppm, wet weight; mean (SD). Mean percent moisture of groups from left to right is 83.9, 84.3, 83.8, 84.8, and 83.0

		Group (sample size)				
Metal	Frequency of detection (%)	MD male (7)	MD female (6)	NJ brackish male (8)	NJ brackish female (3)	NJ freshwater male (8)
Cadmium	41	0.07 (0.05)	0.07 (0.04)	0.24 (0.18)	0.30 (0.37)	0.09 (0.06)
Chromium	100	0.93 (0.47)A[a]	1.26 (0.73)A	2.97 (1.52)B	2.70 (2.18)B	1.13 (0.77)A
Copper	100	0.82 (0.28)A	1.07 (0.43)A	1.81 (1.20)AB	1.27 (0.38)AB	1.73 (1.01)B
Lead	41	0.07 (0.05)	0.16 (0.14)	0.19 (0.24)	ND[b]	0.10 (0.05)
Mercury	100	0.44 (0.14)	0.56 (0.44)	0.55 (0.26)	0.41 (0.13)	0.39 (0.22)
Nickel	94	0.35 (0.18)A	0.43 (0.27)A	1.24 (0.65)B	1.07 (0.91)B	0.45 (0.34)A
Zinc	100	8.80 (0.99)A	9.60 (0.88)A	9.93 (1.18)AB	9.79 (0.69)AB	10.51 (0.41)B

[a] Means with different letters are significantly different, Bonferonni method; sexes from the same site were combined for analysis
[b] ND = not detected

Growth

Growth rates differed by sex; seven male turtles from MD averaged 2.36 cm of carapace growth per year compared to 2.22 cm for six MD females. Regressions of the carapace length of male turtles from the three collection locations and age estimates had slopes that were not significantly different from a common slope. Contrasts on adjusted means showed that the male turtles from NJ brackish-water sites were significantly smaller for their age than were the male turtles from NJ freshwater or from MD. The contrast was similarly significant when combined MD and NJ freshwater males were compared with NJ brackish-water males. The analysis of covariance procedure using body weight instead of carapace length yielded identical results. Growth curves for NJ brackish-water males ($n = 8$, $r^2 = 0.73$, $Y = 13.53 + 1.18$ X) and combined MD and NJ freshwater males ($n = 15$, $r^2 = 0.76$, $Y = 8.19 + 9.89$ Ln X) (Figure 2) were compared with snapping turtle growth curves reported in five other studies (Figure 3). A regression ($n = 27$, $r^2 = 0.80$, $Y = 11.42 + 6.01$ Ln X) was used on data presented by Christiansen and Burken (1979) for male snapping turtles and a regression ($n = 38$, $r^2 = 0.84$, $Y = 8.54 + 6.62$ Ln X) was used for females. A growth curve for combined male and female snapping turtles ($n = 27$) was taken from Hammer (1969); the reproduced curve is an estimate because no statistical models or data accompanied the figure. Kiviat (1980) described a mean growth rate for immature (<20 cm carapace length) turtles of either sex ($n = 20$); the rate was plotted as a straight line function. Mean growth rates for adult males and females (>20 cm carapace length) were also determined and were plotted as straight line functions. The adult growth

Table 3. Organochlorine chemicals content of visceral fat from snapping turtles collected at two sites in the Hackensack Meadowlands of New Jersey (NJ) and at an undisturbed site in Maryland (MD). Except for percent lipid, the values are in ppm of lipid. Values are shown as mean (SD)

Organochlorine	Frequency of detection (%)	Group (sample size) MD male (7)	MD female (6)	NJ brackish male (8)	NJ brackish female (3)	NJ freshwater male (8)
Cis-chlordane	3	ND[a]	ND	ND	0.12 (0.20)	ND
Oxychlordane	88	2.00 (1.27)	1.53 (3.17)	9.33 (16.10)	2.12 (3.03)	1.30 (1.04)
Trans-chlordane	9	0.08 (0.13)	0.04 (0.09)	ND	ND	ND
Cis-nonachlor	59	0.59 (0.71)	0.31 (0.74)	3.53 (7.03)	0.64 (1.10)	0.31 (0.32)
Trans-nonachlor	53	0.87 (1.46)	0.34 (0.81)	4.01 (6.19)	0.93 (1.61)	0.68 (0.67)
DDT	0	ND	ND	ND	ND	ND
DDD	3	ND	ND	ND	ND	0.13 (0.34)
DDE	63	0.39 (0.31)A[b]	0.10 (0.16)A	0.16 (0.29)B	0.26 (0.44)A	2.03 (1.24)A
Dieldrin	13	0.03 (0.07)	ND	ND	ND	0.07 (0.10)
Endrin	0	ND	ND	ND	ND	ND
Heptachlor epoxide	25	0.17 (0.25)	0.04 (0.08)	ND	ND	0.38 (0.60)
Toxaphene	0	ND	ND	ND	ND	ND
PCB	100	41.20 (37.24)A	36.17 (81.16)A	291.13 (304.82)B	34.07 (15.56)A	23.55 (11.19)A
% lipid		63.29 (14.49)A	71.00 (9.76)A	13.88 (13.07)B	24.67 (18.82)B	73.38 (8.05)A

[a] ND = not detected

[b] Means with different letters are significantly different, Bonferonni method. Sexes from the same site were combined for analysis for % lipid. Sexes were different for DDE and PCB; within sex comparisons only

Table 4. Blood and blood plasma characteristics of snapping turtles collected at two sites in the Hackensack Meadowlands of New Jersey (NJ) and at an undisturbed site in Maryland (MD). Values are shown as mean (SD)

Blood or blood plasma characteristic	Group (sample size) MD male (7)	MD female (6)	NJ brackish male (8)	NJ brackish female (3)	NJ freshwater male (8)
ALAD[a]	186.57 (42.88)A[b]	190.92 (94.14)A	94.00 (55.06)B	113.50 (76.64)B	115.53 (32.38)AB
Albumin (gm/dl)	0.74 (0.17)A	1.22 (0.08)A	0.94 (0.18)A	1.03 (0.21)A	1.48 (0.23)B
Glucose (mg/dl)	56.43 (34.42)A	71.45 (27.89)A	52.68 (22.23)A	43.37 (15.64)A	100.20 (22.72)B
Hemoglobin (gm/dl)	3.60 (0.38)A	4.10 (0.94)A	5.83 (1.31)B	6.03 (1.07)B	7.04 (0.26)B
Osmolality (mOsm)	270.57 (15.81)	267.67 (7.89)	276.88 (29.00)	282.33 (24.83)	274.83 (3.66)
PCV (%)	18.14 (1.95)	18.33 (3.78)	20.88 (4.22)	20.33 (6.51)	25.14 (2.67)
Total protein (gm/dl)	3.29 (0.78)A	4.42 (0.54)A	3.25 (0.46)A	3.80 (0.44)A	5.10 (0.67)B
Triglyceride (mg/dl)	15.81 (9.11)A	204.20 (114.45)A	24.30 (30.27)A	94.20 (137.55)A	15.12 (5.14)A
Uric acid (mg/dl)	1.24 (0.34)	1.05 (0.30)	0.90 (0.36)	1.13 (0.60)	0.97 (0.08)

[a] A unit is 0.1 in absorbance/ml erythrocytes/h (38°C) at 555 nm with a 1.0 cm light path

[b] Means with different letters are significantly different, Bonferonni method; sexes from the same site were combined for ALAD, glucose, and hemoglobin. Sexes were different for albumin, total protein, and triglycerides; within sex comparisons only

lines do not exhibit age-related decreases in growth rates. Gibbons (1968) and Graham and Perkins (1976) estimated growth rates for young snapping turtles (1–6 years old) from a polluted river and a polluted marsh. A regression was used on the data means of Gibbons ($n = 6$; $r^2 = 0.99$, $Y = 3.60 + 3.21\ X$) and Graham and Perkins ($n = 6$, $r^2 = 0.98$, $Y = 2.60 + 2.55\ X$).

Discussion

Metals and Organochlorine Chemicals

The scarce literature on metals in turtles indicates that the cadmium, mercury, and lead concentrations in the livers and kidneys of snapping turtles in this

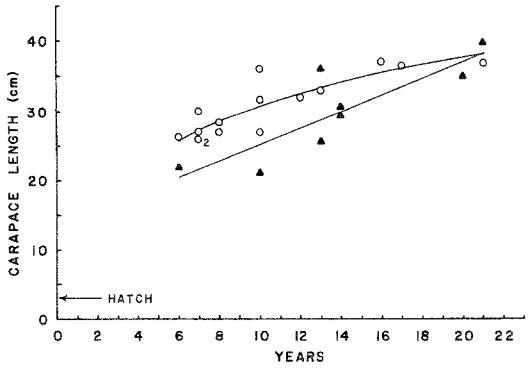

Fig. 2. Growth curves for snapping turtles (♂) from New Jersey and Maryland. ○ = Maryland + New Jersey freshwater. ▲ = New Jersey brackish water

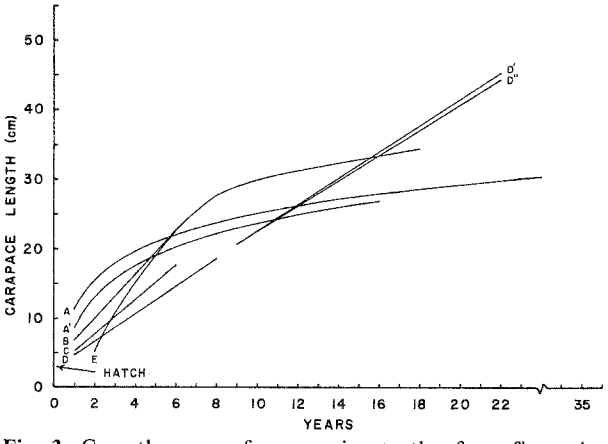

Fig. 3. Growth curves for snapping turtles from five other studies: A,A'. Christiansen and Burken (1979) (♂, ♀). B. Gibbons (1968) (♂ + ♀). C. Graham and Perkins (1976) (♂ + ♀). D,D',D'' Kiviat (1980) (♂ + ♀, ♂, ♀). E. Hammer (1969) (♂ + ♀)

study were low. Cadium was reported as less than 0.06 ppm in two snapping turtle livers from one site on the Hudson River and an average of 17 ppm for four snapping turtle livers from another Hudson River site (Stone *et al.* 1980). No cadmium was detected in the kidneys and livers of softshell turtles (*Trionyx spinifer*) from an uncontaminated portion of a Tennessee river but up to 9.9 ppm of cadmium was found in the kidneys of softshell turtles from a portion of the river below several metal plating facilities (Robinson and Wells 1975). The latter site was characterized by periodic fish kills but no dead turtles were observed. Softshell turtles fed 2 mg of cadmium acetate showed no visible signs of distress for four days after dosage (Robinson and Wells 1975). Two diamondback terrapins (*Malaclemys terrapin terrapin*) collected between Berry's Creek and Kearny Marsh contained 3.6 and 7.6 ppm mercury in the livers and 1.1 and 2.4 ppm mercury in the kidneys (Galluzzi 1981). Four box turtles (*Terrapene carolina*) collected near lead smelters in Missouri contained an average of 21.6 ppm lead in livers and 24.3 ppm lead in kidneys; four box turtles collected from a site in West Virginia, remote from industrial lead sources, contained an average of 1.2 ppm lead in livers and 1.8 ppm lead in kidneys (Beresford *et al.* 1981). No comparative information was found for chromium, copper, nickel, and zinc in turtles. Seven of the nine significant comparisons between MD and NJ turtles showed higher metal concentrations for NJ than MD, but the low quantities involved imply that either body burdens of metals in the NJ turtles were limited by metabolism and excretion or that much of the metal in the sediment and soil was biologically unavailable to the turtles. Similarly, Galluzzi (1981) found that the mercury content of mammals and birds collected in the Hackensack Meadowlands did not reflect the degree and geographic pattern of mercury contamination known to exist there. The small home range of snapping turtles (3–4 ha), except for some nesting females, assured that the turtles had ample opportunity to accumulate contaminants from the vicinity of the collection site (Kiviat 1980; Obbard and Brooks 1981).

If our success at catching snapping turtles was an accurate indicator of population density, then Berry's Creek and Mill Creek harbored few, if any, turtles. Trapping success was also poor in all brackish-water areas with tidal flow. Kiviat (1980) captured large numbers of snapping turtles in a freshwater tidal marsh on the Hudson River. Fiddler crabs (*Uca pugnax* and *U. pugilator*) were absent from Berry's Creek marsh (3–9 ppt salinity), but were abundant in Saw Mill Creek marsh (5–15 ppt salinity), less than 1 mile to the south of the junction of Berry's Creek and the Hackensack River (Breteler *et al.* 1981). The collection locations had essentially similar habitat but the mercury concentration of Berry's Creek marsh was more than 10 times that in Saw Mill Creek marsh.

Concentrations of DDE and dieldrin in snapping turtle fat were lower than those reported from heavily contaminated sites but comparable to those from agricultural sites. DDE and dieldrin in 20 fat samples from snapping turtles caught in New York State averaged about 11 ppm and 6 ppm on a lipid weight basis (Stone *et al.* 1980). Single turtles from the Hudson River and Lake Ontario contained 15 ppm and 87.6 ppm in the fat on a lipid weight basis (Olafsson *et al.* 1983). A single snapping turtle collected 15 months after a DDT spraying experiment contained 13 ppm DDE in the fat on a wet weight

basis (Meeks 1968). A single snapping turtle from an agricultural area of Iowa contained no detectable DDE or dieldrin in the fat on a lipid weight basis (Punzo *et al.* 1979), and eight snapping turtles from a tobacco growing area of North Carolina averaged less than 0.2 ppm DDE in the whole body on a wet weight basis (Reeves *et al.* 1977). No organochlorine insecticides other than DDE and dieldrin were sought in the previously mentioned studies. The relationship between tissue residues of organochlorine pesticides and PCBs and biological effects is not known for turtles (Hall 1980). However, organochlorine pesticide concentrations in fat from this study are much lower than concentrations reported for whole body analyses of *Chrysemys* thought to have been killed by organochlorine pesticides, and mostly lower than the residues found with several types of analyses in several species of live turtles collected in areas receiving pesticide applications (Hall 1980).

Snapping turtles from the Hudson River in New York State contained 306 to 7,990 ppm (mean = 3,047 ppm; n = 12, 2 pooled) of PCBs in the fat; turtles from other New York locations had concentrations of PCBs in fat ranging from 0.4 to 2,281 ppm (mean = 481 ppm; n = 10) (Stone *et al.* 1980; Olafsson *et al.* 1983). Fat samples from snapping turtles of the Mississippi River in Minnesota contained 1.4 to 60.5 ppm (mean = 27 ppm; n = 12, 2 pooled); fat from three turtles at other sites in Minnesota had less than 0.2 to 5 ppm and a mean of less than 2 ppm (Helwig and Hora 1983). In this study, snapping turtles collected in MD (mean = 39 ppm) and urban NJ (mean = 138 ppm) contained less PCBs than those collected in New York State but more than those collected in Minnesota. Organochlorine pesticides and PCBs are probably not a major factor affecting the survival of the snapping turtle in the Hackensack Meadowlands, however the presence of low to moderate amounts of PCBs and certain organochlorine pesticides in some sample groups raises the possibility that some turtles might be experiencing reproductive or other sublethal effects similar to those attributed to organochlorines in birds (Fox *et al.* 1978; Fleming *et al.* 1982) and bats (Clark and Lamont 1976).

Blood Analysis and Lipid Content of Fat

ALAD depression is normally associated with lead exposure; tissue lead levels are negatively correlated with ALAD activity in birds (Dieter and Finley 1979; Eastin *et al.* 1983) and mammals (Mouw *et al.* 1975; Buchet *et al.* 1976). The blood ALAD of NJ brackish-water turtles (10 of 11 taken within 150 m of the NJ Turnpike) was significantly less than that of MD turtles even though lead was detected infrequently and at low levels in both kidneys and livers. Detected concentrations of lead in the kidney and liver are considrably lower than those of box turtles from contaminated and uncontaminated areas in West Virginia (Beresford *et al.* 1981), and lower than those of mammals (Way and Schroeder 1982; Chmiel and Harrison 1981) and birds (Dieter and Finley 1979; Kendall and Scanlon 1982) collected in the wild or dosed with lead-shot. Although the concentration of lead in blood was not determined for the snapping turtles, the lack of a significant relationship between tissue lead and blood ALAD activity implies either a rapid excretion of ingested lead or a level of exposure insufficient for organ accumulation.

The significantly elevated total protein, albumin, and plasma glucose averages for NJ freshwater turtles is probably a function of age. NJ freshwater turtles averaged 7.5 years while NJ brackish-water turtles averaged 13.7 years and MD turtles averaged 12.8 years; all three plasma measures were negatively related to turtle age ($P < 0.05$, linear regression). The high protein requirement of rapidly growing animals might account for the differences in protein. Growth hormone is thought to produce elevated blood glucose in reptiles (Licht 1974) and snapping turtles grow at a more rapid rate at 7 years of age than at 13 years (Hammer 1969; Christiansen and Burken 1979).

The reason for the significantly higher amount of hemoglobin in NJ turtles and the parallel, but not significant, increase in PCV is unknown, but salinity could be a factor. Diamondback terrapins (*Malaclemys centrata*) have higher hematocrit when in a salt water environment than when in a freshwater environment (Gilles-Baillien 1974). Both NJ locations have salinities (5 ppt and 1 ppt) greater than true freshwater (<0.5 ppt).

All the blood composition and plasma values for our snapping turtles were similar to those reported in sources cited by Dessauer (1970, 1974) except for plasma glucose, which was considerably higher than that reported in the literature (mean = 33 mg/dl). Physiological stress can increase plasma glucose levels (Dessauer 1970); perhaps the stress caused by the collecting procedure in this study was responsible for the high overall glucose values.

The lipid content of visceral fat from MD and NJ freshwater snapping turtles was similar to that reported for snapping turtles from Minnesota (Helwig and Hora 1983); the significantly lower lipid content of the NJ brackish-water turtles would be unusual

in Minnesota also. The low lipid content was not correlated with differences in any of the blood and blood plasma characteristics.

It is not known if the lack of stored lipid affects the NJ brackish-water turtles during the winter and the spring arousal period, nor if it affects egg quantity and quality. High winter mortality and poor egg production caused by low lipid levels would be disastrous for a snapping turtle population subjected to the normal high incidence of predation. Nearly 71% of snapping turtle nests in South Dakota were partially or completely destroyed (Hammer 1969) and a mean of 93.6% of the eggs in clutches did not leave the nest as hatchlings during a 5-year study in Ontario (Obbard 1984). Kiviat (1980) reported that 40% of the nests in a Hudson River freshwater tidal marsh were opened by predators. Information on reproduction is not available for the Hackensack Meadowlands, but the primary egg predators, *i.e.*, skunks (*Mephitis mephitis*) and raccoons (*Procyon lotor*), are present, and opened snapping turtle nests have been observed (Don Smith, personal communication). If predation in the Meadowlands is lower than normal, any negative reproductive effects caused by salinity/contaminants could be neutralized. A reproductive study is needed to resolve this matter.

Growth

Rates of growth for male and female snapping turtles (Figures 2 & 3) are sufficiently different that comparisons between studies should take this into account (Hammer 1969; Christiansen and Burken 1979; Kiviat 1980; present study). Regional differences in growth, as exemplified by the difference between older (>6 years) snapping turtles in Iowa (Christiansen and Burken 1979) and those in South Dakota (Hammer 1969) might also exist.

Rates of growth for young snapping turtles (<6 years) varied considerably; turtles 1–3 years old were twice as large in Iowa (Christiansen and Burken 1979) as in the Hudson River of New York (Kiviat 1980). The accuracy of the left end of the growth curve reported by Hammer (1969) is questionable because the smallest wild turtle captured had a carapace length of 22.2 cm (8.75 in). Growth estimates for turtles younger than 6 years appear to have been derived from six hatchlings raised in captivity for varying periods of time up to 3 years. If this portion of the growth curve reported by Hammer is omitted, then the lower three regression lines represent polluted locations (a polluted river in Michigan, Gibbons 1968; a polluted wetland in Massachusetts, Graham and Perkins 1976; a polluted river [Hudson River] in New York, Kiviat 1980). Presumably, the turtles from Iowa (Christiansen and Burken 1979) represent a rural, agricultural environment with low contamination. If regional differences were not responsible for the growth difference, then toxic effects or a poor diet caused by environmental pollution might have been responsible for the low growth.

The analysis of covariance results of the present study indicate the absence of a significant regional effect on the rate of growth or the cumulative growth of older (≥6 years) turtles in MD in NJ. The significantly reduced cumulative growth of the NJ brackish-water males compared to the MD and NJ freshwater males appears to have been caused by some characteristic(s) of the location. Possible explanations for the reduced growth and reduced lipid content of visceral fat include (1) nutritionally inadequate food in the brackish-water habitat and (2) increased energy expenditure and/or interference with the biochemical conversion of ingested food to lipids. The NJ brackish-water turtles were all caught in a habitat dominated by common reed; the only aquatic animals observed were killifish (*Fundulus* sp.). Common reed was a common item in the gastrointestinal tract of the NJ turtles from both locations, but the amount of time that lapsed between capture and necropsy prevented any meaningful evaluation of food items. The salinity at the NJ brackish-water location or some contaminant(s) could be stressing the turtles. No other growth data on brackish-water snapping turtles has been reported, but the presence of some form of pollution at the three lowest growth sites for young turtles (Figure 2) implies that environmental contamination can, directly or indirectly, cause reduced growth.

Implications

Growth differences, differences in lipid content of body fat, and the inability of the investigators to catch turtles in some areas indicate that living conditions in some portions of the Meadowlands are having a negative impact on individual turtles. The results of the metal, organochlorine chemical, and blood plasma analyses failed to provide clear evidence of a stress sufficient to cause the reduced body weight and lipid content of fat bodies of NJ brackish-water turtles. The cause of the negative impact and its importance to reproductive success and population stability remain unknown.

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