Crocodilians and other Reptiles: Bioindicators of Pollution

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The detrimental effects of environmental contamination and pollution (e.g. heavy metals, organochlorines, radionuclides) on wildlife are generally not well known or understood. Research is providing baseline information for various groups of animals, usually because of their sensitivity to changes in their environment (e.g. fish, amphibians), but also where there is a potential conservation threat (e.g. marine mammals). Little research has been directed at reptiles, which may be good bioindicators of their environment. Crocodilians in particular, because of their position in the food chain, aquatic habits and longevity (generally >50 years; Webb and Manolis 1989) may reflect changes in an area over longer periods (Burger et al., 2000). This paper provides a brief overview on environmental contamination and reptiles, with particular reference to crocodilians.

Lizards and Snakes

Lizards and snakes have been shown to act as indicators of environmental pollution, particularly organochlorines. For example, in the Canary Islands, where agrochemical use has increased dramatically over the last 20 years, the lizard *Gallotia galloti* was considered a better indicator of organophosphorus contamination than birds (Fossi et al., 1995). Bauerle et al. (1975) quantified lead and pesticide levels in the liver and fat respectively of Gopher Snakes (*Pituophis catenifer*) and Prairie Rattlesnakes (*Crotalus viridis*), and suggested that relatively low levels detected in these tissues were correlated with limited use in the study area. Radiocesium levels in nineteen snakes species from contaminated areas were found to be much higher than in those from uncontaminated areas (Brisbin et al., 1974). Detectable levels of plutonium (^{239}Pu) were reported in the liver and bone tissues of three snake species (*Coluber constrictor, Pituophis melanoleucus, C. viridis*) in habitats contaminated by plutonium-laden oil (Geiger and Winsor, 1977).

Turtles

The effect of contamination (particularly pesticide-related compounds) on freshwater turtles (e.g. *Chrysemys picta, Chelydra serpentina, Graptemys geographica, Terrapene carolina, Trachemys scripta, Trionyx spinifer*) has been investigated in detail, and their potential as bioindicators of environmental pollution has been discussed. For example, Snapping Turtle (*C. serpentina*) eggs from the St Lawrence River, Canada, reveal very high concentrations of organochlorine residues, indicative of significant contamination in the area (De Solla et al., 2001). Differences in contamination between eggs of Snapping Turtles and Herring Gulls were thought to be due to local sources of contaminants and diet (Bishop et al., 1996).

Slider Turtle (*T. scripta*) eggs laid in contaminated soils exhibited reduced embryo survivorship (Nagle et al., 2001). Although adult turtles from contaminated areas had high levels of As, Cd, Cr and Se in their tissues, only Se was transferred maternally to hatchlings at relatively high levels, and may have contributed to differences in physiology (fitness) between hatchlings from polluted and non-polluted areas (Nagle et al., 2001). The physiology of radium and calcium accumulation from the environment by Australian freshwater turtles has been investigated by Jeffree (1991) and Jeffree and Jones (1992).

Compared to freshwater turtles, research on contaminant accumulation in marine turtles has been limited to assessments of organochlorines and heavy metals in the eggs and/or tissues of free-living animals (*Caretta caretta, Chelonia mydas, Dermochelys coriacea, Lepidochelys kempii*) (e.g. Hillestad et al., 1974; Thompson et al., 1974; Stoneburner et al., 1980; Witowski and Frazier, 1982; McKim and Johnson, 1983; Clark and Krynitsky, 1985; Davenport and Wrench, 1990; Sis et al., 1993; Rybitski et al., 1995; Cobb and Wood, 1996).

Crocodilians

Brisbin et al. (1998) summarised the literature on organic, heavy metal and radioactive contaminants in crocodilians, most of which related to the American alligator (*Alligator mississippiensis*). The recent finding that the flesh and bones (osteoderms) of the saltwater crocodile (*Crocodylus porosus*) reflected the chemical characteristics of their environment (Jeffree et al., 2001) emphasises the potential importance of crocodilians as bioindicators of contamination. Twining et al. (1999) reported the first case of anthropogenically enhanced lead exposure in wild *C. porosus*, with increased levels being reflected in annual laminations of the osteoderms in the dorsal skin. Due to the lack of data on the toxicological effect of lead on crocodilians, the biological significance of this finding could not be assessed. Later research indicated high lead levels can be present without crocodiles exhibiting recognisable visible effects (Hammerton, this volume).

Elevated levels of lead were detected in the blood of farmed American alligators fed meat contaminated by lead shot, but levels in the muscle were very low, and did not pose a threat for human consumption (Camus et al., 1998). Cook et al. (1989) reported elevated lead levels in the blood of two adult False Gharials (*Tomistoma schlegelii*) and an adult Cuban crocodile (*C. rhombifer*), which were attributed to diet (pigeons). High plasma zinc levels were recorded in a Cuban crocodile which had ingested coins and other metal objects (Cook et al., 1989). Odierna (unpublished; cited in Brazaitis et al., 1996) investigated lead levels in two species of caiman (*Caiman crocodilus, C. yacare*) in Brazil, with only 18% of animals sampled having levels below the level of detection.

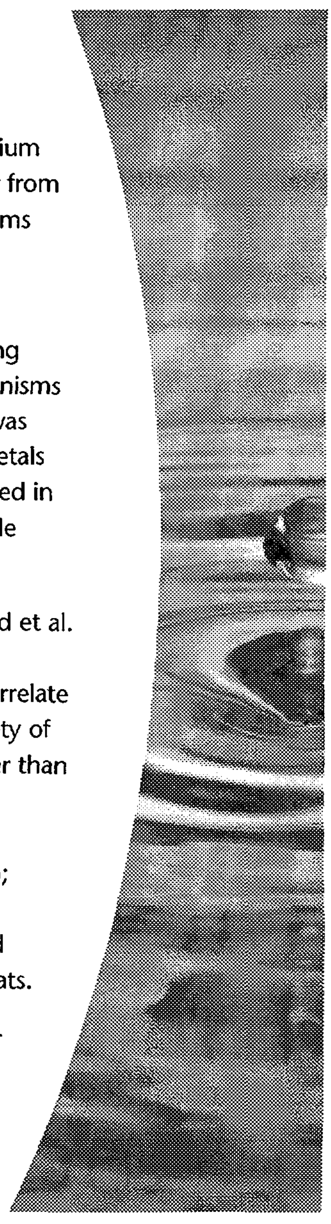
The possible health risks associated with local people eating contaminated crocodilian meat was highlighted by Brazaitis et al. (1996). The production of American alligator meat for human consumption in the USA has also prompted various studies to quantify mercury levels in meat (e.g. Delaney et al., 1988; Hord et al., 1990; Ruckel, 1993; Jagoe et al., 1998), with unacceptable levels for human consumption being recorded in some cases (e.g. Hord et al., 1990).

Radioactive contaminants are not generally encountered in crocodilian populations. Radiocesium levels in American alligators living near a reservoir receiving radionuclide-contaminated water from a nuclear reactor were quantified by Brisbin (1989); levels were lower than in various prey items (e.g. fish, waterbirds).

Xenobiotic compounds entering the environment are known to have a detrimental effect on wildlife. Guillette et al. (1999, 2000) summarised the effects of a range of endocrine disrupting contaminants on reproduction in the American alligator. The underlying physiological mechanisms associated with contaminant-induced modifications to the reproductive system of alligators was investigated by Guillette et al. (1995). Burger et al. (2000) suggested that levels of various metals (Pb, Cd, Se, Cr, Mn, As, Sn, Hg), lower than recorded elsewhere in Florida, were not implicated in reproductive impairment. Phelps et al. (1989) provided data on DDT residues in the fat of Nile crocodiles (*C. niloticus*).

The accumulation of contaminants in crocodilian eggs has received little attention. Woodward et al. (1993) attempted to correlate low clutch viability and high alligator mortalities with levels of contamination in the water and other factors. Heinz et al. (1991), however, was unable to correlate levels of organochlorines in the eggs to low clutch viability. Hall et al. (1979) detected a variety of organochlorines in the eggs of the American crocodile (*C. acutus*), levels of which were higher than in most birds, fish and invertebrates from the same area. Stoneburner and Kushlan (1984) investigated metal levels in American crocodile eggs. Organochlorine and metal levels in Nile crocodile and Morelet's crocodile (*C. moreletii*) eggs have been quantified (Phelps et al., 1986; Skaare et al., 1991; Rainwater et al., 1997). Concentrations of Cu, Zn, Cd and Pb in wild and captive-laid Chinese alligator (*A. sinensis*) eggs were quantified by Ding et al. (2001); high Cd and Pb levels are considered to be indicative of pollution in the few remaining alligator habitats.

Expanding our knowledge on the effects of contaminants on crocodilians has implications for crocodilian conservation [e.g. reintroduction programs with the Siamese crocodile



(*C. siamensis*), Chinese alligator (*A. sinensis*) and Philippine crocodile (*C. mindorensis*)], human health (consumption of crocodilian meat and eggs) and the crocodilian farming industry. Crocodilians may also enable long-term monitoring of the status of environments through their accumulation of elements.

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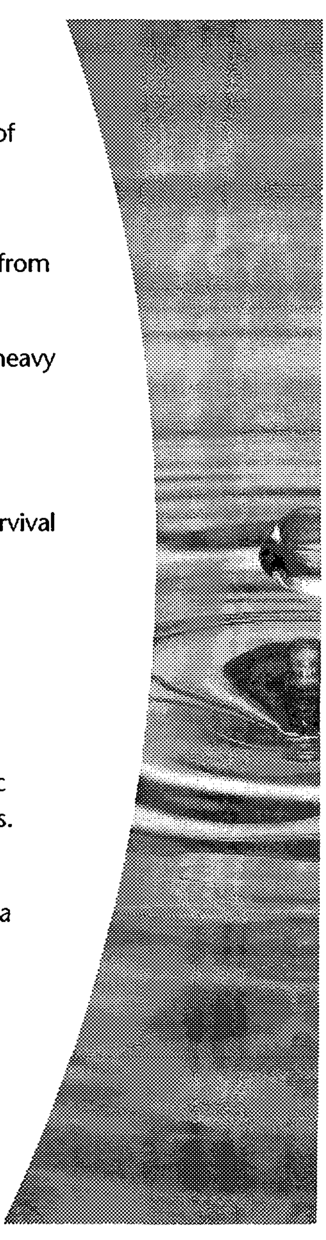

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