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Escalation of threats to marine turtles

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Many, if not all, marine turtle populations world-wide have become seriously depleted by the impact of numerous factors over the years. Populations of marine turtles are now classified as endangered or threatened. National and international legislation designed to protect sea turtles has been unsuccessful and, despite ever-growing interest, there is disturbing evidence of new and increasingly important threats: increased incidence of disease; oil and organochlorine contamination and marine 'macro-pollution'.

Introduction

Six species of marine turtles are listed as vulnerable or endangered by IUCN (IUCN, 1990) and are also listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Navid, 1982). These listings reflect the fact that it has long been recognized that marine turtles face many threats (e.g. Bjorndal, 1982). The threats include incidental catch in fisheries (NAS, 1990) as well as directed take of adults and eggs for subsistence and commercial purposes. Despite CITES listing, trade in turtles and turtle products still constitutes a major source of exploitation and cause of mortality (Groombridge and Luxmore, 1989; Milliken, 1990). A further well-established threat, and one of growing concern, is the disruption and destruction of nesting beaches (e.g. those in Greece described by Warren and Antonopoulou (1990)).

Legislation has been directed towards these threats – albeit with limited success. The substantial and apparently growing impacts on turtles of disease and various forms of pollution now deserve particular attention.

Fibropapilloma disease

Significant among these new threats is the increasing incidence of fibropapillomas. This disease often produces highly conspicuous symptoms: affected turtles exhibit large external tumours, which may impair movement or grow across the mouth or eyes, inhibiting feeding, breathing or vision, thus reducing or eliminating the turtle's ability to survive (Balazs and Pooley, 1991). Detailed disease histopathology has been given by Jacobson *et al.* (1989) and by Sundberg (cited in Balazs and Pooley, 1991), who noted that a number of turtles with superficial tumours, when necropsied, were also found to have multiple visceral (internal) lesions. It is not known whether the internal and external problems are related. Norton *et al.* (1990) found that, compared with clinically healthy green turtles *Chelonia mydas*, an individual with external cutaneous fibropapillomas (and the kidney nodules of 'renal myxofibroma') exhibited haematological and serum chemical abnormalities including severe anaemia. This lends evidence to the theory that the presence of external tumours may also indicate multiple internal problems.

Cutaneous fibropapilloma disease is reported to affect primarily green turtles and has therefore been referred to as 'green turtle fibropapilloma disease (GTFP)'. Three comparable fibropapilloma cases have also been recorded from loggerhead turtles *Caretta caretta*; two from the Indian River area of Florida in 1986 and one from Hutchinson Island on the Atlantic coast of Florida in 1987 (Harshbarger, 1991).

First described in 1938 as an occasional occurrence (Lucke, 1938; Smith and Coates, 1938), GTFP has now reached epidemic proportions in Florida (Jacobson *et al.*, 1989; Ehrhart, 1991) and the Hawaiian Islands (Balazs, 1991). Before 1982, although hundreds of green turtles were observed in the Indian River lagoon system, Florida, no papillomatous animals were recorded; one was seen in 1982, and between 1985 and June 1986, 30 out of a sample of 57 in this study area were found to be affected (Jacobson *et al.*, 1989). In the Hawaiian Islands the earliest confirmed case of GTFP was January 1958, although reliable information indicates that it was virtually non-existent prior to and during the 1950s and early 1960s (Balazs, 1991). Balazs (1991) reported that 31–53 per cent of stranded turtles examined each year since 1983 had GTFP. During 1989 and 1990 GTFP was present in 77 per cent and 85 per cent, respectively, of turtles stranded on the island of Maui. In Kaneohe Bay, 121 turtles captured alive from four discrete sites since February 1989 have shown GTFP rates of 49–92 per cent. The disease has also been identified in other locations, e.g. San Diego Bay, California (McDonald and Dutton, 1990), Puerto Rico and the Cayman Islands (Harshbarger, 1991), the Bahamas, Panama, the Netherlands Antilles, Trinidad, Belize, Australia, Malaysia and Japan (Jacobson, 1991). The world-wide distribution of fibropapillomas in turtles is shown in Figure 1.

The factors causing the disease have yet to be firmly established. The possible association between fibropapillomas and digenean trematode parasites has been investigated by Dailey (1991). Jacobson *et al.* (1989), however, argued for a viral cause, because no digenean eggs were observed in any of the 28 biopsies from six papillomatous green turtles in Florida. Inclusions of viral particles compatible with a herpes virus were, however, found in electron microscope studies of tissues from a fibropapillomatous turtle (Jacobson, 1991), but only in one area of one tumour out of 14 removed from a single turtle.

Other potential factors include environmental factors, such as pollution, food chain contamination by 'foreign' algae, aberrant wound healing, ectoparasites, transmission of non-

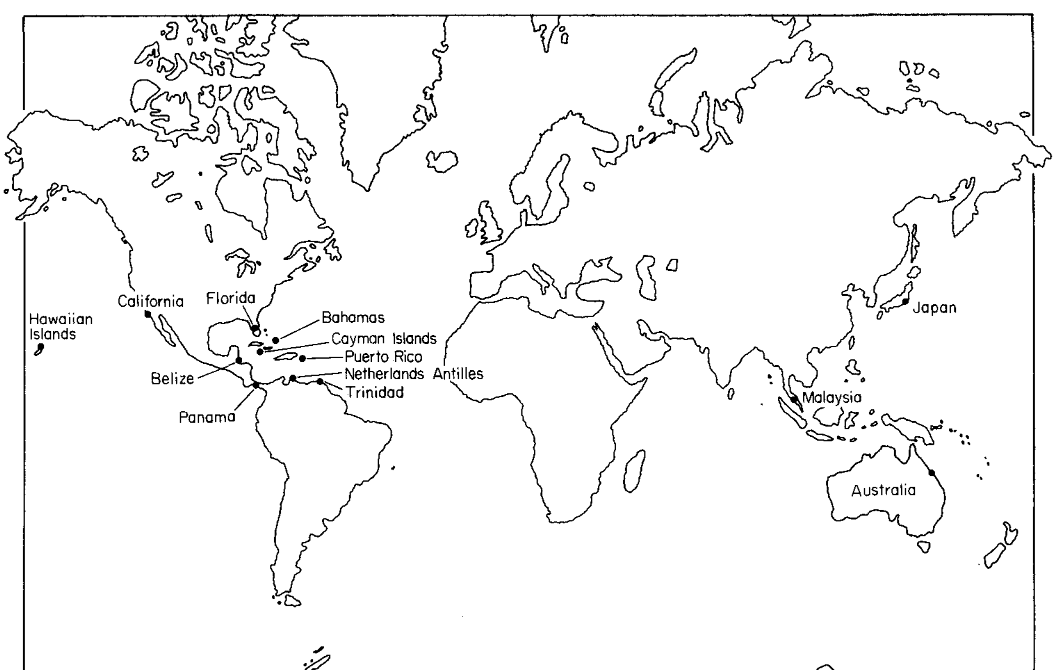

Figure 1. World-wide distribution of fibropapillomas in marine turtles (for sources see text).

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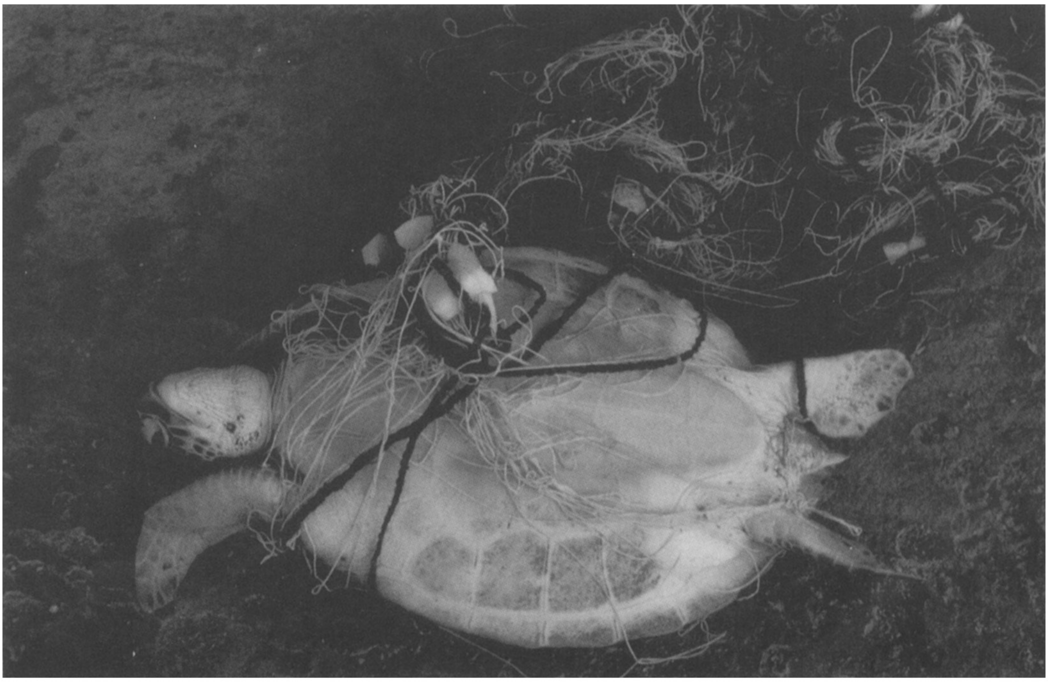

Turtle caught in net (*Greenpeace/Fretey*).

viral tumours through sexual or other direct contact, and weakness in immune systems, either genetic or resulting from viral infections, parasitic infections, environmental stressors and/or pollution (Balazs and Pooley, 1991).

Whatever the causes, the increasing incidence of the disease in recent years seems to indicate that there are new harmful factors in the turtles' environment, creating a new and significant threat to their survival and populations.

Organochlorine pollution

Investigations should shortly begin into GTFP in Barbados in relation to pesticides used on the island's sugar crop (Balazs and Pooley, 1991). Organochlorine compounds, such as pesticides and PCBs (polychlorinated biphenyls), are well known to have adverse effects upon animals (reviewed in Simmonds, in press). Reproductive failure and the suppression of the immune system are, for example, common results of exposure to these ubiquitous pollutants. Attention has recently started to focus on the measured and potential impact of organochlorines on fish-eating marine mammals. Body burdens of PCBs and DDT are correlated with reproductive failure in southern Wadden Sea harbour seals *Phoca vitulina* and, similarly, with gross blockages of the uterus in Baltic Sea grey seals *Halichoerus grypus* and ringed seals *Phoca hispida*, and grey seals in Liverpool Bay, UK. Experimental evidence indicates that, as reported for many mammals in laboratory trials, the consumption of PCB-contaminated fish also causes immunosuppression in harbour seals.

Levels of organochlorines in the seas are slowly rising. The total world PCB production (by 1989) was calculated to be 2 x 10^8 tonnes, of which 16–30 per cent was estimated to have reached the environment and 57 per cent was still in use (Klamer *et al.*, 1990). Because dispersal of PCBs into the ocean cannot easily be controlled, there is a serious risk that at least part of the total still in use will ultimately reach the world's oceans (Klamer *et al.*, 1990).

Marine predators are the ultimate destination of much persistent pollution passed to them by accumulating steps in the food chain. The significance of this for marine mammals has not been missed: 'If the increase in ocean PCB concentration continues, it may ultimately result in (their) extinction' (Klamer *et al.*, 1990).

However, only very few investigations have been made into the concentrations of such compounds in marine turtles. These involved analysis of organochlorines in eggs of green turtles (Thompson *et al.*, 1974; Clark and Krynitsky, 1980), eggs of loggerheads (Hillestad *et al.*, 1974; Clark and Krynitsky, 1980, 1985), and tissues from leatherbacks *Dermochelys coriacea* (Duguy *et al.*, 1980; Davenport *et al.*, 1990) (see Table 1).

Davenport *et al.* (1990) noted that the concentration of total PCBs (approximately 1.2 μg/g lipid) in the fat of a male leatherback was one to three orders of magnitude higher than the lowest reported levels for fish from the open north Atlantic, similar to the lowest concentrations reported for oceanic cetaceans, but most concentrations reported for coastal marine mammals and birds were one to three orders of magnitude higher than for the leatherback in their study. However, Duguy *et al.* (1980) noted that their results (data not given) showed that concentrations in the turtles were higher than those in bivalve molluscs and of the same order of magnitude as those of the Clupeidae (amongst the most polluted of littoral fish).

Although there is so little reported information, it is clear that marine turtles accumulate organochlorine compounds. We should anticipate, therefore, some impact on them—and judging from induced effects in other species, particularly impacts on reproductive success and/or immuno status; GTFP could be just such an effect. That organochlorines are transferred to eggs is of particular concern, because PCB-mediated effects have been shown in the young of many exposed species (see Simmonds, in press).

Macro-pollution

One relevant and perhaps unexpected source of PCBs may be plastic debris. Carpenter and

Table 1. Organochlorine concentrations measured in tissues of marine turtles

Species	Tissue type	Sample type	Contaminant and concentration (μg/g)	References
Caretta caretta Loggerhead turtle	Eggs *n*=not specified	Not specified	Total DDT (DDE+DDD+DDT) 0.058–0.305 Dieldrin trace–0.0564	Hillestad *et al.*, 1974
Chelonia mydas Green turtle	Eggs *n*=10	Wet weight	DDE nd*–0.009 PCB 0.02–0.22	Thompson *et al.*, 1974
Caretta caretta Loggerhead turtle	Eggs *n*=28	Wet weight	DDE 0.018–0.200 DDT nd–0.048 Dieldrin nd–0.028 Heptachlor epoxide nd–0.006 Oxychlordane nd–0.017 *trans*-Nonachlor nd–0.005 PCB (Arochlor 1260) 0.032–0.201	Clark and Krynitsky, 1980
Chelonia mydas Green turtle	*n*=170		DDE nd–0.005 DDT nd–0.042	
Dermochelys coriacea Leatherback turtle	Adipose tissue Adult male	Lipid weight	PCB approx. 1.2	Davenport *et al.*, 1990

*nd = not detectable

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Green turtle, Indonesia (*Greenpeace/Canin*).

Smith (1972) commented that many plastics contain considerable quantities of PCBs as plasticizers. These can be released from plastic during its breakdown and Ryan *et al.* (1988) established that levels of PCBs in sea birds were positively correlated with the amount of ingested plastics. The possibility of PCBs accumulating in sea turtles as a result of plastic ingestion does not appear to have been investigated.

Plastic debris in itself may be a substantial threat to marine reptiles. Balazs (1985) provided a comprehensive review of the incidence of sea turtle interactions with ocean debris (also known as macro-pollution), listing 79 reported cases in which turtles had ingested materials (including plastic, metal and tar balls), and 60 instances of entanglement. It is noteworthy that none of the cases recorded occurred before the 1950s and 95 per cent had taken place since 1970. Although this may be a result of previous lack of interest in recording such data, it may well reflect the increased use of synthetic materials since the 1950s. Debris found in the guts of turtles has included glass, metal litter, plastic bags and woven sacks, styrofoam beads, and monfilament fishing line (Mrosovsky, 1981; Fritts, 1982; Balazs, 1985; Gramentz, 1988; Plotkin and Amos, in press). Laist (1987) considered that the types of debris most dangerous to marine life are fishing nets, plastic strapping bands, plastic bags, synthetic rope and line, small plastic objects that degrade into small floating fragments, and raw plastic pellets.

Particulate plastic debris has been observed in surface waters of the Sargasso Sea (Carpenter and Smith, 1972) and the north-western Atlantic (Colton *et al.*, 1974). Wilber (1987) noted that, by comparison with reports of almost 15 years previously, there had been a fourfold increase in the total number of plastic pieces in the northern Sargasso Sea. He also commented that this increase might be the result of both increased inputs and the effect of oceanic circulation patterns. The oceanic transport and abundance of plastic particles has been studied by Gregory (1978). Oceanic convergences seem particularly important in their distribution.

There is evidence that both marine debris and hatchling turtles collect together in ocean convergences (see Carr, 1987), increasing the chances of turtles ingesting debris. Turtles apparently mistake plastic for edible items; small dead or moribund turtle hatchlings thrown up on coasts after storms frequently contain tar pellets and plastic beads similar in size and shape to the floating vesicles that readily fragment from *Sargassum* plants (Carr, 1987). Adult olive ridleys *Lepidochelys olivacea* and leatherbacks appear to feed mainly on the surface (Carr, 1987) and it is generally believed that they mistake plastic bags for jellyfish. Although chiefly benthic foragers, green turtles and loggerheads also exploit driftlines when jellyfish are abundant (Carr, 1987). Thus, like hatchlings, adults can be exposed, when surface feeding, to plastic and other debris, including floating tar balls and oil.

Oil pollution

Oil pollution is an increasing problem in the marine environment. A number of researchers have considered its significance to turtles (e.g. Fritts and McGehee, 1981; Hall *et al.*, 1983; Frazier and Salas, 1984; Balazs, 1985; Gramentz, 1986, 1988; Hirth, 1987; MEPA, 1989). Studies of sea turtle strandings in Florida (Vargo *et al.*, 1986) showed that, although more loggerheads stranded in total, green turtle strandings were the most likely to be oil-related (46 per cent as opposed to 22 per cent for loggerheads), and juveniles were affected more than adults; trends possibly explained by habitat preference and location of nesting beaches.

The physical effects of oil on sea turtles, such as the sealing of mouths and nostrils by tar, have frequently been noted (e.g. Witham, 1978, 1983; Balazs, 1985; Gramentz, 1988) but the physiological effects are not so well documented. Vargo *et al.* (1986) found that exposure of loggerhead turtles to South Louisiana crude oil induced a variety of responses, including an immune response involving a significant increase in white blood cell counts, and dermal effects including epidermal inflammatory cell infiltrates, epidermal thickening, oedema and haemorrhage. The immune response was found to be dependent on the duration of the oil exposure and, after a recovery period, the white blood cell counts returned to baseline levels. This immune response contrasts with that of birds, where white cell counts were reduced after dosing with oil (Leighton *et al.*, 1983, cited in Vargo, 1986). Vargo *et al.* (1986) noted that no information appears to be available regarding long-term effects of petroleum exposure on loggerheads and that, compared with laboratory conditions, additional stresses, e.g from disease and predation, would occur in the natural environment. They suggested that low-level chronic exposure to oil might result in breaks in the integument, which may result in infection. The proposal by Balazs and Pooley (1991), that immunosystem weakness and aberrant wound responses may be causal factors in GFTP, should therefore also be considered in relation to oil pollution.

Conclusion

Alongside the substantial threats posed by fisheries, directed take, trade, and destruction of nesting beaches, there is considerable evidence that sea turtle populations are now also being significantly impacted by plastic and other anthropogenic debris, oil and organochlorine pollution, and (in the case of green turtles, and possibly loggerheads) from fibropapilloma disease. It is suggested that chronic exposure of sea turtles to organic contaminants, particularly oils and organochlorines (and perhaps both acting synergistically) might well be contributing to the GTFP epidemics by reducing the immune response, directly damaging the integument and increasing susceptibility to infection by pathogenic organisms.

Each of these threats to marine turtles is a cause for great concern, but the probability that turtles are facing the combined effects of several new environmental stressors is even more alarming.

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