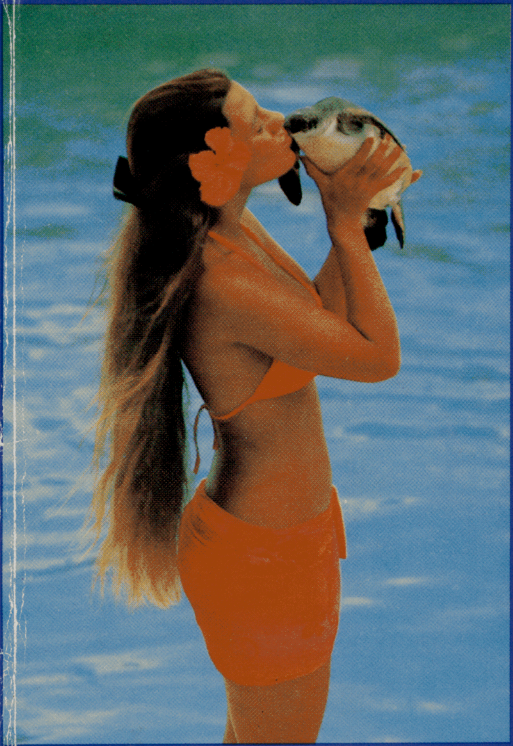
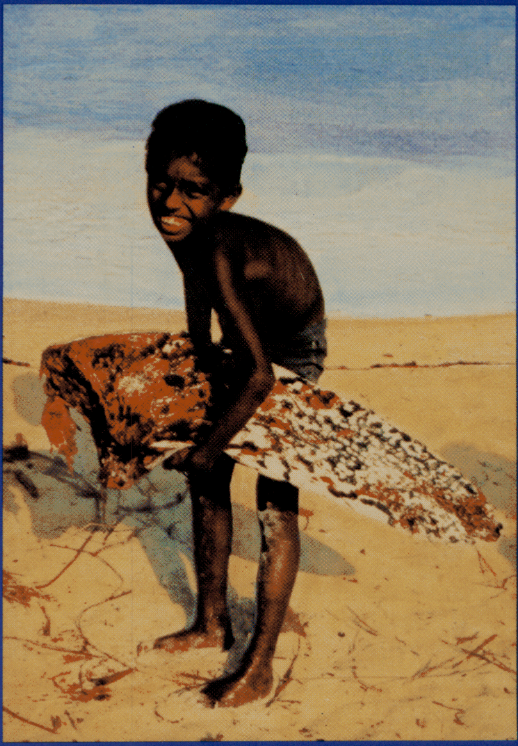
CONSERVING SEA TURTLES





N. Mrosovsky

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by

Nicholas Mrosovsky

Acknowledgements

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FOREWORD

One of the significant trends of the past thirty years has been the emergence of conservation of the world's fauna and flora as an active issue: not just the concern of a small band of committed naturalists, but a broadly-based ideal, shared by an increasing number of biologists and non-biologists alike. Few would now dissent from the general principle; but there is considerable divergence of views about the ways and means. Conservation problems are seldom straightforward. Often their solution requires that acceptable compromises be found between the conflicting needs of expanding human populations, with their demands for agricultural, economic and social development, and the maintenance of a place for the non-human inhabitants of the globe. The problems are intensified when the objects of concern are themselves an economic resource: should they be exploited, and if so, how and how much?

Marine turtles pose a considerable number of these kinds of problems. They are a resource, but they are also amongst the most spectacular of the world's fauna; they are exploited; and they are vulnerable. The debate about how they should be managed is keen. Articles on this subject have appeared in recent years in the *Marine Turtle Newsletter* and *British Herpetological Society Bulletin.*

This book is offered as a contribution to the debate. It seems particularly appropriate for the British Herpetological Society to sponsor its publication. Founded in 1947, it was one of the first national societies devoted solely to the study and wellbeing of reptiles and amphibians, and has actively encouraged conservation in all its aspects, particularly through its Conservation and Captive Breeding Committees. The success of its first volume *The Care and Breeding of Captive Reptiles* (edited by S. Townson, N.J. Millichamp, D.G.D. Lucas & A.J. Millwood) has encouraged us to feel that this is an appropriate means of disseminating ideas and information to our members, and to herpetologists in general. We hope that this volume will be equally successful.

Professor Mrosovsky's views are based on a thorough and longstanding knowledge of turtles and their problems, and his extensive knowledge of the literature. Not everybody will agree with everything he has written. The subject is highly controversial and emotive; commonsense and the animals themselves can often be the victims of human dissension, power and territoriality. However, the author has formulated his views with care and we would urge you to come to your own judgement, aided by the clarity of his arguments and the pains taken to be factual, so far as it is possible. If this volume increases general understanding of the very real problems which face those who have to make difficult decisions, which in turn may determine the fate of marine turtles over the next decades, we shall feel it has achieved its objective.

The Council,
British Herpetological Society

PREFACE

Sea turtles are beautiful complex creatures, mysterious enough to become addicting for the biologist, absorbing for anyone to watch, and of great value for their eggs, meat, shell and leather. This book is not concerned with demonstrating that sea turtles are worth preserving; that is taken for granted. It is concerned with the methods being used to achieve that end; it argues that much is wrong.

If my criticisms can be refuted, then current activities on behalf of the turtles—and the turtles themselves—will emerge all the stronger. If my criticisms stand, then it is time that a strong light was shone into the dark corners of the conservation biology of these species—and of others too perhaps. I am also convinced that the intentions of those active in sea turtle conservation are irreproachable. It is only the means of proceeding that I wish to debate.

I hope my colleagues will look at the matter in this way. But I expect that some of them will not. So I emphasize that listing their names here in no way implies agreement or support of what I have written, but is just part of the normal process of acknowledging exchange of information for which I am most grateful. For my part I hope that I have reciprocated over the past 6 years by circulating the Marine Turtle Newsletter to people whose attitudes and endeavours I respect though often disagree with. This book is to some extent a natural outgrowth of having been a vessel for information exchange over this period. But now I feel the time has come to go beyond the exchange of information to a tougher appraisal of what we are doing.

For providing information, then, I thank: R.G. Ackman, A. Carr, G.S. de Silva, A.W. Diamond, J. Frazier, J.T.V. Onions, P.C.H. Pritchard, H.A. Reichart, J.I. Richardson, J.P. Ross, J.P. Schulz, R.F. Scott, and J.R. Wood.

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N. Mrosovsky

To the seven—or maybe eight—species of sea turtle:

long may they live with us on this planet.

1. TURTLES ARE BIG

A few years ago, as the participants at an international conservation conference were rounding off their dinner, one leant forward over the drinks and said: 'Right now, you know, turtles are big. Whales, they've peaked now, yes ... but leaving behind a pretty packet for anything marine. You ought to go after it. For turtles. But big, big ...'

How right he was!

1978 saw the start of an ambitious plan to rescue Kemp's ridley, down to some 400 nesting females on a single beach in Mexico, from impending extinction: aeroplanes, telemetry and radio tracking, antibiotics, international co-operation between Mexico and the U.S.A., media coverage, marines armed with automatic weapons.

In the late seventies and early eighties, the National Marine Fisheries Service (NMFS) in the U.S.A. invested millions of dollars in the design of panels to exclude turtles from shrimping nets: underwater TV data collection, trials on shrimping vessels with observers, plans for international promotion. Alongside this went other attempts to mitigate the incidental catch of turtles by trawlers. Emergency regulations promulgated by NMFS (Federal Register, 1980, 45, 66460-1) required that comatose turtles caught in nets be turned on their backs and have their plastrons pumped up and down by hand or foot. When the turtles were to be released, even if they appeared to be dead, the engine gears should be in neutral and the turtles let go in areas where they were unlikely to be recaught by other fishing boats.

In Florida punishment for violation of the laws became severe. In 1980 two men were fined $4,000 each for killing a leatherback turtle. Not long after a man was sentenced to 359 days imprisonment for taking turtle eggs.

In New Delhi in 1981, the parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) removed an anomaly in their classification of turtles. The flatback turtle, previously lingering on Appendix II, joined the other turtles on Appendix I. The aim was to simplify enforcement by having all sea turtles subject to the stiffest constraints on trade.

Workshops and round tables proliferated: 1979 was a vintage year with the World Conference on Sea Turtle Conservation at the State Department, Washington, attended by several hundred people including delegates from Papua New Guinea, Indonesia, Turkey, Colombia, China, South Africa, Sri Lanka and many other nations. A second conference, on the Behavioral and Reproductive Biology of Sea Turtles, took place at Tampa, Florida, in the same year. The American Society of Zoologists devoted an issue of their journal to the proceedings.

Turtles featured on postage stamps in the Maldives (1980), the Dominican Republic (1980), Malaysia (1980), Pakistan (1981), Surinam (1982), The Philippines (1982), Mauritania (1982) and Mexico (scheduled for 1982). The Sea Turtle Rescue Fund in Washington, D.C., issued a sea turtle colouring book (1981) with English and Spanish texts.

A turtle hotline encouraged anyone finding stranded turtles along the coast of the southern states in the U.S.A. to call officials long-distance free of charge. And in 1980, at a cost of $350,000, more than 1000 loggerhead turtles were dragged out of a shipping channel leading to Cape Canaveral, snatched from the jaws of death before dredges moved in with their crushing metal scoops (Rudloe, 1981). Beside the cradle of the space age, the old turtles were holding their own.

Big, yes ... but, as Peter Pritchard (1980) of the Florida Audubon Society puts it, 'lest we get completely carried away by the conviction that our efforts are indeed saving sea turtles, and fail to maintain a constant critical appraisal of our efforts, it is worth reviewing the different things that people try and do to save sea turtles, to judge whether these techniques are indeed as purely beneficial as we might think.'

The next few chapters in this book look critically at some of the activities undertaken on behalf of turtles. The verdict: much is amiss. But before that comes a brief summary of the principal facts and mysteries about sea turtle biology.

2. A BRIEF LIFE HISTORY

There are 7 species of sea turtle. They are, in increasing order of size, the olive and Kemp's ridley, the hawksbill, flatback, loggerhead, green and leatherback (Table 1). Each has its own somewhat specialized strategy for survival so any account of sea turtles in general, including features from different species, as here, is more like a composite painting than an accurate photograph of any particular one. Fortunately, however, there are common themes running through the lives of all species of sea turtle, especially when they come on land.

Marine turtles spend most of their lives in the water, but they start on shore as hatchlings and later on, as adults, the females come back onto the beach to lay their eggs. These 2 occasions, brief though they be, are vital for reproductive success, for conservation and for learning about turtles. Starting from the turtle's point of view, after mating offshore, the females swim inshore, usually at night, climb out onto the beach and excavate a hole for the eggs with their flippers. After laying and covering the eggs, they leave them and return to the sea; the mothers do not guard the nest. This parental neglect has many consequences. The eggs are an easy meal for small keen-sensed mammals, like dogs and coatis, or for other larger mammals following the tracks left by the turtles and probing around the nest site with a stick. Ghost crabs burrowing down into the nest chamber are another effective predator. For those hatchlings that emerge about 2 months later and run down to the sea there are birds and fishes waiting. Against such odds, if even a few are to survive, a turtle must lay many eggs. Clutch sizes of around 100 eggs are common. But there are limits to how large a single clutch can be. The bony armour of a turtle is not like an expanding suitcase and can carry only so many fully formed eggs. And later on, when buried all together beneath the hot sand, a large mass of eggs may not get enough oxygen to develop properly (Ackerman, 1980). So marine turtles return to nest several times within a season, coming ashore at intervals of 10-14 days.

Another consequence of leaving the eggs unattended is that there is no opportunity to keep them at the right temperature by shading them, or exposing them to sunshine, as do mallee-fowl. Turtles must therefore select nesting sites and nesting seasons that provide suitable temperatures for the embryos. This limits rookeries to the tropics or to the summer months in temperate regions. Eggs do well at sand

Table 1. *The seven species of sea turtle with the approximate weight and length of nesting females.*

Common name	Scientific name	Weight (kg)	Carapace length (cm)	Further information
Olive ridley	*Lepidochelys olivacea*	35	65	Pritchard (1969)
Kemp's ridley	*Lepidochelys kempi*	40	65	Pritchard and Marquez (1973)
Hawksbill	*Eretmochelys imbricata*	60	80	Carr and Stancyk (1975); Diamond (1976); Hirth (1980)
Flatback	*Chelonia depressa*	70	90	Limpus (1971); Bustard (1972)
Loggerhead	*Caretta caretta*	110	95	Hughes (1974a&b)
Green	*Chelonia mydas mydas*	140[a]	105	Hirth (1971, 1980); Schulz (1975); Carr et al. (1978)
Green, East Pacific	*Chelonia mydas agassizi*	65	80	Pritchard (1971b)
Leatherback	*Dermochelys coriacea*	375	155	Pritchard (1971a); Mrosovsky (in press a)

[a] There is much variability between different rookeries. In Surinam the average weight is around 175 kg, in Costa Rica around 115 kg.

temperatures of 29°C. Some will still hatch at 22°C (after a prolonged incubation). Mortality is also higher if the eggs remain above 33°C for long periods, so they must be buried deep in the sand, protected from direct sunshine.

Suitably warm sandy beaches with easy access are sometimes far from feeding areas. This requires travel to and from the nesting beaches. How turtles navigate over long distances is unknown. So is the stimulus that triggers off these journeys. Many populations do not migrate to the rookeries annually but only once every two or three years. Perhaps it takes this long to build up sufficient reserves of fat to support both travel and egg production.

With long flippers and streamlined shapes, sea turtles are beautifully adapted for sustained travel through water. Their bony armour is less extensive than that of freshwater turtles and tortoises, making them more buoyant and agile but they pay a price for this. The limbs and head cannot be completely retracted within the shell and are vulnerable to shark attack. The slender flippers and flattened carapaces are also a liability on land. Here they move slowly and once turned over on their backs are seldom able to right themselves.

Being defenceless and cumbersome on land is to some extent compensated for by the selection of out-of-the-way places for nesting, small islands or beaches with swamps and lagoons on the landward side. This nest-site selection has served turtles well in the past. Some major rookeries have gone undiscovered even into the last decade. But the protection afforded by coming ashore in remote areas is now being swept away by the proliferation of outboard motors, one of the greatest threats to marine turtles. Nesting at predictable times of year on predictable beaches that can now be easily reached by small powerful craft, and the habit of congregating offshore for mating and then laying on land, are major disadvantages.

Yet they also provide a great opportunity for conservation. By patrolling limited stretches of coast, the whole breeding effort can be protected. The adults can be allowed to come and go unmolested and the eggs protected from predation by surrounding them with wire netting or by taking them when they are laid and reburying them in central hatcheries. When the hatchlings are released, people can be present to frighten off birds and crabs. Overall more baby turtles can be enabled to reach the sea than would have done so without human intervention. Terrestrial breeding presents people with easy ways to boost the reproductive output of turtles.

It also provides a convenient occasion for learning more about turtles. Although a turtle is easily scared when crawling up the beach or in the early stages of nesting, once she begins to lay her eggs it is difficult to stop her. Flashlights can be used with impunity; she can be inspected and measured. Even piercing a flipper for tagging does not usually stop her completing her task. The eggs can be counted and the nest marked with a stick for further observations. Incubation takes about 2 months. After breaking free from the eggshell, the turtles remain below the surface for a few days. Emergence above ground takes place under the cover of darkness when cool nighttime temperatures rouse the hatchlings from their daytime lethargy. In cloudy rainy weather it is sometimes cool enough in the day to trigger emergence. In these cases many hatchlings are snapped up by frigate birds, gulls or vultures. Those that escape dash to the sea, even though at turtle eye-level the water itself is often out of sight. This sea-finding orientation has been the subject of many experiments. Turtles head toward the centre of an open horizon and on most beaches with vegetation and a tree line, this means seaward. The mechanism involves a complex balancing of brightness inputs between the 2 eyes (Mrosovsky, 1978a). Altogether, much has been learnt about turtles by studying them on shore.

In general it has been found that the different species behave in remarkably similar ways when on land. But there are some differences. Nesting usually occurs at night but Kemp's ridleys lay by day, as do hawksbills in the Indian Ocean and sometimes flatbacks (Bustard, 1972). While most sea turtles strand singly or in small groups, ridleys come ashore in tens of thousands at a time, in huge 'arribadas' (Spanish for arrivals). Digging and laying are fairly standard but there are some idiosyncracies. The leatherback lets its tail hang down into the nest hole when depositing the eggs. The ridleys, after covering the eggs, rock from side to side on their plastrons (the base of their shells), thumping the sand down noisily. The other sea turtles are probably too heavy to do this. Clutch size varies from roughly 160 in hawksbills, 110 in loggerheads, greens and ridleys down to 85 in leatherbacks and 50 in flatbacks (see Hirth, 1980), though in the latter 2 the eggs are larger. There are other minor differences, in internesting interval and depth of nest for instance.

But the major differences between the various species of turtle occur when they are in the water. Green turtles are herbivores. They go primarily for turtle grass but will take some algae and also a little animal matter, most of it clinging to the plants they eat (Mortimer, 1981). To help them get the most out of a low-quality diet, they carry bacteria in the gut that help them digest cellulose and they forage in special ways. Instead of grazing on the tops of sea grass over a wide area, they keep small patches closely cropped (Bjorndal, 1980a). The young shoots sprouting at the base are more nutritious than the ends of larger plants. Pastures of sea grass thrive in shallow protected waters while places suitable for nesting with easy access are found where open seas throw up large sandy beaches. As a result many populations of green turtles are migratory.

Of the diet of flatbacks, virtually nothing is known. Seaweed and cuttlefish have been found in their stomachs (Worrell, 1963). They are also thought to eat sea cucumbers (Cogger and Lindner, 1969).

The other turtles are carnivores of one kind or another. The main item in the diet of the leatherback is jellyfish. The two sharp cusps on the mouth are good for seizing slippery prey. Because jellyfish drift with ocean currents, leatherbacks' food is dispersed far and wide and they must travel to find it. The longest turtle migration on record, 5,900 km, is by a leatherback (Pritchard, 1976). This species also has the largest range of any sea turtle, in fact of any reptile. For instance, it appears regularly in cool waters off Canada, Europe and Japan where jellyfish are abundant. To come so far from tropical breeding grounds, leatherbacks must be powerful swimmers. With the least armour and the longest flippers they are the most aquatic of the turtles. Their large size, thick blubbery layer around the body and special arrangements of blood vessels permit them to remain relatively warm-blooded even in water as cool as 8°C (Mrosovsky, 1980a).

Loggerheads eat snails, mussels, crabs and other hard-shelled marine animals (Hughes, 1974b). Their jaw structure tells the story. The head itself is massive, as large as that of the much larger-bodied leatherback, and the palate is thick. This is the mollusc-crushing apparatus. They also take softer invertebrates such as sea urchins, jellyfish and Portuguese men-of-war. Loggerheads are not known for spectacular migrations. Instead, in some circumstances at least, they bury themselves in the muddy parts of undersea channels and hibernate with body temperatures of around 15°C (Carr et al., 1980).

Hawksbills graze off sponges encrusting rocky areas. They also take sea squirts and molluscs and are thought to be fairly indiscriminate bottom feeders (Carr and Stancyk, 1975). Reefs are a preferred habitat and as these are often near small sandy cays, hawksbills should not have to migrate far for nesting. However, one tagged in the Solomon Islands was caught 1,400 km away in Papua New Guinea (Vaughan and Spring, 1980; see also Nietschmann, 1981). In general though, hawksbills nest in low density over wide areas with the consequence that their breeding is harder to protect and their biology harder to study. Rather little is known about this species.

Olive ridleys eat shrimp, jellyfish, crabs, snails and some algae. Kemp's ridleys have a similar diet; they take crabs, squid, fish, jellyfish and snails. Not enough is known to say if the feeding of the 2 ridley species differs in important ways. It is thought that Kemp's ridleys, with their more massive jaws, take more thick hard-shelled crabs than olive ridleys (Pritchard and Marquez, 1973; Pritchard, 1979a).

Most of the information on what turtles eat comes from analyses of stomach contents. These give a good idea of the principal items in the diet but to appreciate better how feeding specializations mould and constrain the life cycles of the various species much more than that needs to be known. There have been counts of the number of jellyfish captured in an hour by leatherbacks (Duron and Duron, 1980) and of the nutrient content and digestibility of sea grasses taken by green turtles (Bjorndal, 1980a), but these are exceptions. On the whole work on foraging strategies and quantitative data on food intake are almost entirely lacking. The trouble is that students of turtle behaviour are terrestrial while their subjects spend most of their time in the sea. We may be reaching the limits of what can be learnt about turtles by waiting for them to come ashore.

However, while most of the professors studying turtles have kept their feet firmly on the ground, 2 people with unremarkable academic credentials jumped into the water and showed how feasible and valuable work there can be. The first was Julie Booth. Concentrating on green turtles off the Great Barrier reef, Australia, she adopted the tactic of accustoming the animals to her presence, as Jane Goodall had done before so famously with chimpanzees. First the turtles were easily scared, then gradually they began to tolerate her, even when she swam nearby, and in the end they tried to mate with her. Though pleased by the compliment, she rejected the males' overtures by taking up the vertical refusal stance. This was one of the things she had learned by watching the turtles. She documented the behavioural details of courting and mating (Booth and Peters, 1972) and also discovered a vigorous competition for females. Sometimes as many as 5 'escort males' would attempt to dislodge the successful male who usually hung onto the female despite being wounded. Copulation could last as long as 6 hours at a stretch. But once the nesting season had begun, it became infrequent, suggesting that it served to fertilize eggs for the same year rather than for the future. Booth's work proved that reproductive behaviour of turtles can be studied in natural conditions but it remains to be followed up with more systematic data collection.

The other pioneer in observing turtles in their natural medium was Jane Frick (1976). She wanted to learn what the hatchlings did when, after running down the beach, they plunged through the surf and were lost to sight. Being a strong swimmer, she was able to do this simply by following them out to sea for several kilometres. She found that whether she released them on the north or on the south coast of Bermuda, they adopted offshore bearings. Initially these were like continuations of the sea-finding orientation that hatchlings show on land, away from the dark tree line and toward the centre of the open horizon. However, these bearings were maintained even when the turtles were out of sight of land. And by swimming ahead of the animals and noting how they dived under her and continued out to sea, she showed that her findings were not merely the result of the hatchlings being frightened away from her. Even steering a small boat by the turtles did not prevent them paddling out to sea; this has enabled Frick's direct tracking method to be used in shark infested waters. She also found that sometimes hatchlings rested in rafts of sargassum weed, thus giving substance to the theory that after the initial frenzy of offshore swimming takes them past the most dangerous concentrations of fish, the hatchlings simply drift with the current and feed on small invertebrates associated with floating algae (Carr and Meylan, 1980a).

Frick's original finding of offshore orientation by hatchlings has been extended with nighttime tracking assisted by ultrasonic transmitters attached to the turtles (Ireland et al., 1978). Booth's observations on mating behaviour have been confirmed at the Cayman Turtle Farm breeding pool (Wood and Wood, 1980), and various other studies of turtles in the water have begun. Capture and recapture projects show that turtles grow very slowly and may take as much as 30 years to become mature (Balazs, 1979a; Limpus and Walter, 1980).

Despite new directions being taken, research on turtles, especially at sea, is arduous and time consuming and much still remains unknown. A diagram of their life cycle, such as that in Figure 1, should not be taken too literally, but rather as a working model open to modification. But it sums up the best ideas of sea turtle biology available at present.

Starting at the beginning, when the newly-hatched turtles break the surface of the sand, they are very active. This 'juvenile frenzy' takes them rapidly through their sea-finding behaviour and then on out to sea. After a while they find mats of seaweed, or simply slow down and drift at the surface, feeding off small invertebrates there. The pale underside of the hatchlings, common in animals occupying the interface between sea and sky, is consistent with this interpretation. This part of the life cycle has been labelled the 'lost year' puzzle by Archie Carr, though exactly how long this presumably pelagic mode of existence lasts is not known. Turtles slightly larger than hatchlings are seldom seen. However, when turtles grow to about 35 cm in carapace length, they begin to appear inshore again (Limpus, 1980a). Here they become resident. The term 'resident' is appropriate as displacement tests show: juvenile green turtles released up to 7 km from where they were caught off Bermuda, soon swam home (Ireland, 1979). Whether there is one or several developmental habitats gradually merging with the adult feeding grounds is not known. It probably varies from species to species and leatherbacks anyway do not have circumscribed foraging ranges but follow the drift of jellyfish. After a long maturation period, both sexes migrate back to the rookeries where mating occurs. The females then lay several clutches of eggs and the life cycle is complete. However, after returning to the feeding areas, the females often breed again. Nesting turtles have been found after as much as 17 years back on the same beach where they were first tagged (Carr et al., 1978; Richardson and Richardson, in press). But most do not nest annually; intervals of 2-3 years between reproductive bouts are common.

Once again, it must be said, this summary is not all established fact. For instance, though it seems likely, it has not yet been proved that the adults return to their natal beaches for nesting. And while some green turtles (Felger et al., 1976), loggerheads and Kemp's ridleys hibernate, it is unknown whether this is a crisis response by individuals in particularly cold winters, or a regular part of the life cycle of

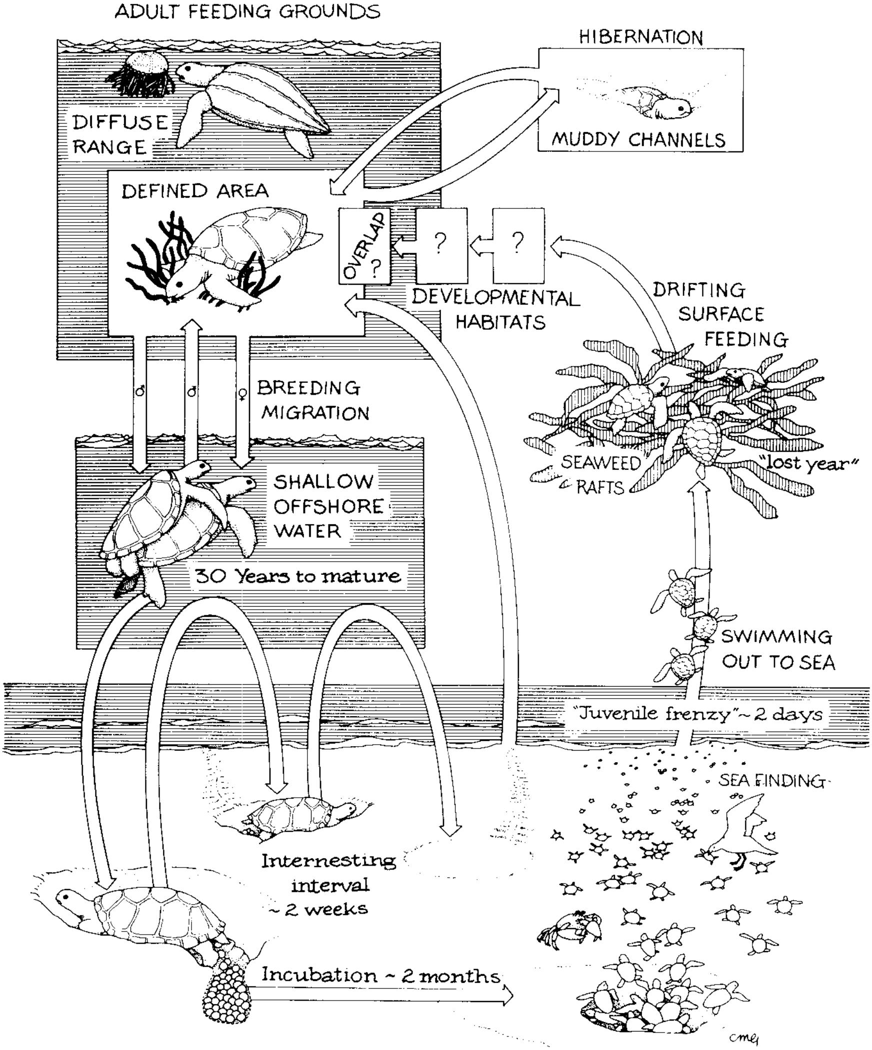

Figure 1. Simplified life cycle of sea turtles. Modified and elaborated from Carr et al. (1978).

most members of those populations. The diagrammatic life cycle includes many approximations and queries (Figure 1). This is acceptable and even useful when sitting in an armchair but when it comes to actually trying to do something practical, lack of a sounder data base can become a major obstacle. To be rational, conservation should be based on a thorough knowledge of the animal's life cycle and ecology. But where these are deficient, conservation programmes must incorporate scientific studies. Projects designed to increase the numbers of sea turtles should also provide a chance for gathering just the kind of information that is necessary to validate themselves. Conservation and science must go hand in hand. Without validation, we cannot be sure whether an endeavour is having a beneficial effect or whether the money and effort might be better spent on some alternative project. Is current conservation work on behalf of turtles based on those things we know for certain about them? Is it of high scientific calibre? Let us look now.

3. THE TAGGING REFLEX

The left hand lightly holds the front flipper, the right hand positions the applicator over the trailing edge and squeezes. The smaller and sharper end of the Monel metal tag bites through the flesh. The turtle winces. The left hand tightens its grasp, but the turtle struggles free, the tagger steps aside but this time not quickly enough; a flailing fipper grazes his shins, leaving marks of the profession. The tagger notes a number in his notebook, no. 98 for that night, loads a new tag into the applicator and walks on. Another turtle, its nesting finished, is crawling down to the sea. It is a large one and moving surprisingly fast on the sloping beach. The tagger runs up in front of it, digs his feet into the sand and braces his hands against the top of its shell, the carapace. The turtle cannot move but the tagger cannot tag. A tropical raincloud drifts away from the moon, the waves glisten and the sand brightens around the dark forms confronting each other. When the tagger moves round behind and tries to grab a flipper the turtle pulls free, the gradient in its favour, and heaves itself nearer to the water. Turning it, that is the only way. In front of the turtle again, the tagger seizes the firmer bony part of the flipper and, as the turtle lurches forward, expertly converts the forward momentum into an upward flip. Over on its back the turtle thrashes around for a few minutes, then rests exhausted. The tagger squeezes the applicator, turns the turtle the right way up again and watches it crawl into the surf, then plunge through the breakers.

After an exhilirating night on the beach, he returns to base camp and announces: 'Tagged 106 turtles tonight.'

Does a voice ask, 'And what did you learn?'

'Ah, that comes later of course.' The tagger is tired, in no mood for reflection. He has tagged more than 100 turtles, and broken his own personal record. He turns in for a well-earned rest with an unclouded sense of achievement.

What does come later? To start with half the tags fall off anyway.

As many as that? Yes, probably. Undoubtedly loss of tags is very frequent, but how frequent nobody quite knows and that is one of the most remarkable things about the tagging of turtles. The method is widely used yet has received minimal evaluation.

The attractions of tagging are obvious. Studying sea turtles in the water is difficult. Some species migrate over hundreds of kilometres.

Others are too sparse or too shy to permit collection of much data. It is much easier to watch turtles when they clamber ashore for nesting. Putting a tag on is especially simple. With identification numbers on one side and a return address on the other, tags can reveal many things including:

1. migratory paths and geographical range when tags are sent back from a distance;
2. breeding frequency, that is whether a female returns to nesting beach every year, every second year or every third year;
3. how often she lays within a season;
4. how accurately she returns to a particular beach or stretch of a beach (i.e., nest-site fixity);
5. longevity beyond the time when first tagged;
6. growth rates, if turtles are also measured on tagging and capture;
7. the population size, if certain assumptions are made.

If tagging programmes are to learn such things there are at least 2 good reasons why it is important that the tags stay on. First, there is the cost, the cost of transport to the rookery, patrolling the beach, paying assistants and much else. Halving tag loss doubles the amount of data obtained for those outlays. Second, if tag loss is high, returns will only tell one what turtles are capable of, not what the average turtle does. But many problems in turtle biology cannot be resolved without information about ordinary turtles, rather than just about the superstars. It may be that an individual female can nest 8 times in a season, but to calculate the population for a given beach from the number of nests laid there in a season, it is necessary to know how many times an average individual lays. If turtles are found to grow slowly, can one be sure that fast growing animals have not shed their tags? If most turtles are never seen again after tagging, does that mean few ever return to breed again or that their tags dropped off?

Designing a tag that holds up for many years in contact with sea water at one end and with flesh at the other may be troublesome. Non-corroding metals are expensive. If tags become worth too much they might not be returned so often. Plastic tags have also been tried and have their advocates (Siow, 1977; Green, 1979). But obliteration of the numbers and return address by colonizing algae or abrasion remains a problem (Green, 1979; Talbert et al., 1980). Susceptibility to tag loss might vary in different parts of the world, in different environmental conditions (Mrosovsky, 1976). So it is not really surprising that tags are often lost.

Nor has this matter been entirely repressed. In the first year of the programme at Tortuguero, Costa Rica, an obviously inadequate carapace tag was discarded in favour of the Monel metal cow ear tag attached to the flipper (Carr, 1967). This is much better but still far from ideal, as the collection of battered and corroded tags in the possession of George Balazs at the Hawaii Institute of Marine Biology attests. He has been investigating the use of a more resistant alloy, inconel (Balazs, 1977). Nevertheless tag loss continues; it is one of those seemingly trivial methodological problems that are a real impediment to scientific progress.

The next best thing to solving a problem may be to assess its scope. It may be very difficult to devise a cheap simple tag that stays on reliably, but better assessment of the frequency of tag loss would be easy and would permit sounder and more extensive use of data from tag returns. Double tagging is an obvious approach. From the number of turtles returning with only 1 tag an estimate can at least be made of the minimum tag loss. The real figure will be slightly higher as some turtles will lose both their tags and go unrecognized. If 3 or more tags were put on, then estimates based on larger samples would be possible, together with analyses of what was the best tagging site, the front or the rear flipper, the left or the right flipper. Just double tagging in an intensive short-lasting programme would be sufficient to vastly reduce the uncertainty about tag loss. Extrapolations could then be made over greater intervals. Of course a long-lasting double tagging programme would be better. But—and this will be one of the recurrent themes of this book—all too often some of those concerned with the conservation and biology of turtles devote little attention to evaluation of what they are doing.

At Tortuguero, where tagging has been the principal method of investigation for 25 years, the simple expedient of double tagging with Monel metal has never been tried, or if tried not widely reported. It is remarkable that it took 20 years before quantitative estimates of tag loss began. Finally, from 1976 to 1979, this information was derived from the frequency of scars left by tags that had fallen out (Carr, 1980a).

But even here the element of proof was lacking because tag holes might heal over without a trace. This possibility was recognized but dismissed as unlikely to account for the fact that most of the turtles tagged at Tortuguero were never seen again, the 'missing majority' problem (Carr, 1980a). It was even stated that it is incumbent for any tagging programme that expects to generate data for assessing population size 'to determine as carefully as possible the degree to which tag loss, and the failure of people to send in recovered tags, are factors in building up the "lost majority" ... .' But the tag scar method is not a good way of estimating tag loss because it lacks the essence of validation, the element of proof. Even leaving aside the question of what is a scar and how reliably 2 people agree on that on a rainy night in the tropics, and the possibility that a turtle with a callus on its flipper has lost a tag only once (Richardson, T. et al., 1978), for all we know most green turtles at Tortuguero shed their tags but heal rapidly. Those with detectable scars might be a minority. If the same applied to loggerheads, then discussions of population dynamics based on ratios of tagged and scarred remigrant turtles to untagged and unscarred supposedly new arrivals (Hughes, 1974b; Richardson, J. et al., 1978) become less satisfactory. Without information on scar healing, the 26.4% figure for tag loss from green turtles at Tortuguero (Carr, 1980a), despite an aura of precision, is at best unconvincing, at worst wildly wrong.

There is a reason for pointing out these things but it is not for the sake of criticizing the Tortuguero programme. That was a pioneering venture, initiated when many of the problems in turtle biology, including that of tag loss, were unformulated. It helped set the stage and define many of the questions conservationists needed to ask (Mrosovsky, 1980b). No research venture can or should try to tackle everything at once. Doubtless tagging at Tortuguero did uncover many valuable facts, even though the 'results are still inadequate to allow precise population estimates to be made' (Carr et al., 1978). Moreover, Carr (1980a) realizes as well as anyone that the lost majority problem might not be of biological interest but arise as an artifact of tagging methods.

But do other people think about these things enough? That is the reason for not getting starry-eyed about tagging. Many other turtle projects are modelled, either explicitly (Talbert et al., 1980) or implicitly on the Tortuguero programme. People read that 'more has been learned by tagging turtles than in any other way' (Carr et al., 1978) and that 'seldom can so much be learned from so little manipulation as a tagging project demands' (Carr, 1967). 'As a means of learning things about the life history of any animal that assembles in groups, as sea turtles do at nesting time, a simple tag is an important tool. It lacks the fascination of the gear of oceanographic research or of the apparatus of biochemical research, but it is an effective device all the same' (Carr, 1967). It depends on what is meant by 'effective.' Probably the man who made the first crude hammer and nails felt it was pretty effective if half of them went in straight. But new projects should go beyond the Tortuguero programme. Why are people tagging turtles all around the world? What are they hoping to learn?

A Sea Turtle Manual of Research and Conservation Techniques (Pritchard et al., in press), intended for those making a start on the subject, recommends tagging but gives practically no rationale. Specimen tagging data forms are reproduced, with places for recording other information to be collected at the same time, the weather conditions, and the width of the turtle's shell and much else. But it says nothing on how all these data are to be transformed into instructive knowledge or effective conservation. The neophyte turtle enthusiast is told how to tag turtles but not why or what to do with the data.

But what of monitoring the population, an important conservation activity? Is it not obvious that monitoring needs tagging? Not at all: if monitoring is the aim, tagging is not essential. One can monitor the population by counting the nests or tracks without ever seeing the turtles at all. Of course, because a female nests several times in a season, it is not possible to convert the number of nests in a season into the number of turtles making those nests, but it is possible to document declines or increases in reproductive output of the population over the years, and probably more cheaply than by tagging. All that is necessary is to visit the beach on a fair sample of nights throughout the season and count the number of nests. Flying over the beach early in the morning, before the fresh tracks from the previous night on the tidal stretch are obliterated, is another way of monitoring; in this case the need for occasional validation, ground truth, is recognized (Stancyk, et al., 1979), especially when the number of times a turtle returns to the sea without laying (false crawls) is high or variable. But tagging is not necessary for monitoring, and might even be a less satisfactory method than counting nests if tag loss is high.

Tag loss also means that some of the still unanswered and more interesting questions about turtle biology will remain unanswered. The simpler questions will be reanswered. For instance, it is easy to learn about the number of days between successive nestings by a turtle (the internesting interval) because the tag only has to stay on for a fortnight or so. But already there is a surfeit of data on this subject. Suppose it is found that the internesting interval of one turtle population is slightly longer than that of another, does that make anyone much the wiser? But to go beyond that, for example to the question of how many eggs a turtle lays in a season or in her lifetime, we need to know how many times an individual nests, and that means being able to identify it throughout those times.

The question of total output of eggs by an average turtle is an important one for conservation. In a stable population, to replace itself each female has to produce one female and one male, assuming a 1:1 sex ratio. Knowing the number of eggs a female lays naturally to ensure 2 surviving to maturity helps assess the levels of exploitation and the scope of measures designed to protect the eggs. Understanding reproductive output is also relevant in a resource management approach: is the turtle worth more as meat or as an egg-producing machine? To assess this it is essential to know how often she lays. And to tackle the question of how rapidly old turtles are replaced by new ones, how dynamic the population is, again we need tags that mostly stay on many years or, failing that, estimates of tag loss.

A good example of how the tagging method alters the conclusions comes from work on leatherback turtles in Tongaland. From the start of the tagging programme in the 1963-64 season till the end of the 1972-73 season, only 16% of the tags had been seen on turtles nesting again in a different season. This low recovery rate suggested that many leatherbacks 'nest only once in their lifetime' (Hughes, 1975). During the 1973-74 season the site of application of new tags was changed from the front flipper to a protected part of the hind flipper under the carapace. The recovery rate increased to 46% (Table 2).

A 46% remigration rate, with a tag that is still far from ideal, puts the view that leatherbacks only nest once in their lifetime in a very different and dim perspective. Unless there was a sudden increase in the tendency for the females to return to the same beach after the new procedure started, or some other unlikely coincidence, the new tag site was responsible for the higher recovery rates. A seemingly trivial change in the method results in a large difference in the inferences made about the turtle's life cycle. So, as Hughes (in press a) has said,

Table 2. *Known remigrations of leatherbacks to Tongaland for periods before and after changing tagging site from front to back flipper.*

Time span	Number of leatherbacks tagged	Number remigrating in a different season	Recovery rate (%)	Source
Until end of 1978-79 season	321	94	29	Hughes (in press a)
Until end of 1972-73 season	176	28	16	Hughes (1975)
Tag site changed during 1973-74 season				Hughes (1975)
From 1973-74 to 1978-79 season	145	66	46	Calculated by comparing data from sources given above

'it is ridiculous to spend thousands of man hours using an inferior tag which is giving inferior results.'

But of course tagging helps. It defines the units of study: are the loggerhead turtles nesting on the barrier islands along the southern United States all part of the same population or reproductively isolated? The finding that turtles tagged on Little Cumberland Island, Georgia, show up on the adjacent Jekyll Island (Bell and Richardson, 1978) suggests only modest nest-site specificity. Tagging also shows where turtles go when they are not breeding, where their feeding grounds are.

This may reveal distant threats to populations from turtling or incidental catch and give conservation an international dimension. Undoubtedly tagging can result in valuable information. Nevertheless, it would be reassuring to know that agencies or individuals initiating such programmes had spelled out the following:

1. What are the questions they are trying to answer?
2. Are there alternatives to tagging for addressing these questions?
3. Why is tagging the method of choice?
4. What kind of programme and which method of tagging is the most appropriate?
5. What provisions will be taken to collect and collate the data?
6. In what ways would the answer to the questions posed be likely to have an impact on conservation policies?

For instance if the aim was to discover where the non-breeding turtles go, then an intensive tagging effort lasting over just 1 or 2 seasons, with multiple tagging, might be indicated. Even then it could take several years before the answers were in. For other questions, with species that reproduce once every 2 or 3 years, and continue to do so, in some cases, for a decade or more (Carr et al., 1978; Siow, ca. 1980), research might take many years to come to fruition. Continuity of purpose is required if data are ever to be properly analysed and published.

Despite such difficulties, tagging will continue to have a role in turtle research. Fortunately a greater appreciation of tag loss as a problem has been developing recently. The matter has been featured in the Marine Turtle Newsletter. Several independent attempts have been made to alleviate its impact and assess its extent. In Surinam green turtles were marked with paint as well as with a Monel tag. Within only a month, at least 15% of the tags were gone (Schulz, 1975). Presumably more would have been shed later on but the paint did not last long enough to prove this. In the Galapagos the same species has been double tagged, a Monel tag in the front flipper and a plastic tag in the hind flipper. The plastic tag at the back stayed on much better and this helped show how often the metal tag fell off. Over the first few months loss of the metal tag was comparable to that occurring in Surinam. Over a span of almost 4 years, out of 116 turtles recaptured, only

67 had the Monel tag still in place, giving a tag loss of 42%. The true figure may well have been higher because although 4 turtles that had lost both tags (but were identified in some other way) were included in the 116, there may well have been other unrecognized turtles that had lost both tags; 42% is the minimum tag loss and it must also be said that most of these turtles were caught within the first year of the 4-year period. If only those turtles (n=17) that were recaptured after 500 days or more are considered, then tag loss of the Monel metal was 58% (Green, 1979). The figures apply to a resident population of turtles, caught for tagging in the waters off the Galapagos Islands. The figures for turtles tagged at nesting were still worse; only 2 out of 11 had Monel tags on when recaught within a period of 62 days, making an 82% tag loss. The sample is very small but the results were said to be typical of other beaches in the Galapagos and other years (Green, 1979). The high loss in this case was attributed to difficulty in pushing the tag through the thick flesh of the flipper, rather than to corrosion. Faulty tagging like this can probably be much attenuated by making a hole in the flipper before applying the tag, as is done at Tortuguero. It is still legitimate to ask how often such high tag losses, whatever the cause, occur in other programmes. Finally, in the Galapagos study, there were 7 turtles that were either recaught when nesting again after 2 years or along the coasts of South and Central America; 2 of these 7 were without their Monel tags, a 29% loss. In all comparisons the plastic tag on the hind foot held up much better. For example, over the 4 years, 8 out of 116 turtles shed their plastic tags, a mere 7% loss, even though the lettering on the tag was often obscured by algae.

So far the studies mentioned using double tagging, and some recent work on the west coast of Mexico (Pritchard and Cliffton, 1981) and Hawaii (Balazs, 1982), all concern green turtles. Perhaps the first, and most intelligently pursued, double-tagging project was with loggerheads; from 1968 onwards 2 tags have been attached to all females nesting on Little Cumberland Island, Georgia, U.S.A. (Richardson, T. et al., 1978). This not only enables more individuals to be identified but also reduces the problems in using scars as an indication of previous tags, the chance of 2 scars healing being less likely. Double tagging in fact provides an opportunity for validating the tag-scar method: a turtle returning with only 1 tag should always have a scar on the other flipper. Until this is looked at, relying on scars remains far from ideal. But if the probability of healing remains the same in different years, and if trends rather than the actual values in the ratios of remigrant to neophyte nesting turtles are emphasized, then the Little Cumberland Island programme may well provide circumstantial evidence of how long it takes for a hatchery initiated there in 1964 to take effect (see Richardson, J. et al., 1978). This could also give an idea of the maturation period. Elsewhere along the southeastern coast of the U.S.A. loggerhead turtles have been fitted with a stainless steel carapace tag as well as the usual Monel metal flipper tag (Hopkins, 1979).

Turning to leatherbacks, some have been double tagged in Tongaland but estimates of tag loss have not been derived (Hughes, 1974b). Tag loss from leatherbacks, with their ragged easily-torn flippers, is thought to be much higher than with other turtles, but nobody knows for sure (see Mrosovsky, in press a). Double tagging of olive ridleys, with plastic and Monel, has recently begun on the Pacific coast of Costa Rica (Cornelius and Robinson, 1981) and the same is being tried now with some Kemp's ridleys (Marquez, 1982). Hawksbills nesting in the Solomon Islands have been double tagged with Monel (Vaughan, 1981). Suddenly in the 1980s double tagging turtles seems to be becoming established. The new Sea Turtle Manual of Research and Conservation Techniques recommends it; but the emphasis is on increasing the number of returns rather than on how to use the data or arriving at a figure for tag loss and then using it in further calculations. If double tagging becomes a mindless craze, it will be little better than single tagging.

Probably many factors influence how well a tag stays in place, including the species, geographical area, type of tag, method of application, position on the turtle and how long the tag has been on already. These factors probably interact in complex ways. But as a rough generalization, on the basis of data from double-tagging studies so far, it is reasonable to assert that about 50% of front flipper Monel metal tags, the most widely used tags to date and those preferred by the Manual, simply fall off (Mrosovsky and Shettleworth, 1982). Tagging programmes are likely to discover facts already known, including that tag loss prevents unravelling the complexities of turtle population structure.

More has been relearned by tagging turtles than by any other method.

4. HEAD-STARTING: THE HEART HAS ITS REASONS

Head-starting turtles is the practice of raising hatchlings in captivity for a number of weeks, months or even years and then releasing them. The rationale is that they will then be larger and less vulnerable to predators than hatchlings growing in the wild and so contribute more to the population. The phrase 'head-starting' was first applied to turtles by Archie Carr at a meeting at Morges, Switzerland. Although he himself had reservations about the practice, the term had a convincing ring to it and it caught on. For North Americans it triggers associations with programmes for disadvantaged children; provision of extra opportunities for learning, cultural enrichment and health care give them, it is hoped, a head-start they might not otherwise have.

With turtles, however, the head-started are being taken out of an environment they are well adapted to and put into tanks. There they experience stimuli and conditions they would never encounter naturally, even in the best of circumstances. Perhaps head-starting is disadvantaging rather than benefiting them.

There are many worries. Head-started turtles might grow to like and come to depend on foods not readily available when they are released. However, there are now some data suggesting that preferences for the initial food can be lost rapidly (Owens et al., 1982). Another concern is whether there would be a proper development of the migratory guidance systems. It is widely thought, though not actually proved, that mature turtles come back to the beach where they hatched; this would be one way to ensure that they found a suitable nesting beach. Perhaps when very young they become imprinted on some characteristic of the beach. Perhaps they learn about the chemistry of the natal beach, its particular combination of vegetation and minerals, through a sense of smell, as do salmon (Carr, 1972; see also Owens et al., 1982). Alternatively, or additionally, swimming from the beach out to sea may be needed for the development of migratory behaviour. After the hatchlings plunge through the surf they paddle away on a bearing that takes them more or less directly away from shore, the exact path depending on the prevailing current (Frick, 1976). These bearings initially are extensions of the paths taken when the turtles crawl on land from the nest to the water's edge, and might be guided by the same stimuli, the more open horizon on the seaward side and the dark land mass. However, offshore bearings continue even when the turtles are several kilometres out to sea and the land is invisible at turtle eye-level. Perhaps magnetic (Perry et al., 1981), olfactory or other guidance systems are calibrated against the directions initiated when the turtles are on land, or in the immediate offshore region where brightness differs between the seaward and the landward directions (Mrosovsky, 1978a). Frick's (1976) paper mentions that 5 green turtle hatchlings, put directly in to the sea well offshore, did not head out to sea in the usual way. Unfortunately this experiment lacked a control group. It is possible that the particular batch of turtles were sick in some way, too lethargic to swim, or that conditions on that day were adverse for orientation. This important experiment should be repeated with 2 groups of turtles, matched for past history and time of testing. Turtles from one group should be set down on the beach, allowed to enter the water and swim away from the shore for several kilometres. Turtles from the other group should be taken directly to points, along the paths of the first group, that are out of sight of the land. Nevertheless, even without appropriate controls, Frick's data certainly highlight the possibility that the experience of swimming out to sea may be important.

Moreover, it may be important that such experience takes place at the right time. Just as children learn languages quickly when they are a few years old, so perhaps hatchling turtles have special abilities to learn about their spatial environment. There are many examples of the phenomenon of sensitive, even critical, periods for learning in animal behaviour. Making sure that head-started turtles are released on a beach might not be sufficient. It might be too late by then.

This brings up the whole question of where head-started turtles should be released. The most obvious alternative to the beach is to find places frequented by wild turtles of the same size as the head-started animals (Pritchard, 1979b). Perhaps appropriate food will be more plentiful there, but then on the other hand perhaps the turtles will be unable to find a suitable nesting beach later on.

Other problems arise even before the turtles are released, when they are still in the tanks. When unnaturally crowded they often bite at each other's necks or flippers. Fungal infection exacerbates the damage and whole limbs can be lost. Housing turtles singly is far more expensive. Disease in captive turtles is another threat, though some progress is being made in controlling pathogens with antibiotics (Leong, 1979; Glazebrook, 1980).

If these problems are overcome, the absence of predators may enable more animals to survive the hatchling stage. But this could turn out to be a mixed blessing if the turtles became so unwary that they failed to avoid sharks or people when set free later.

So altogether there are many doubts about head-starting turtles. Yet there are also considerable attractions in trying to get more hatchlings past the initial stages of greatest vulnerability to predators. With both doubts and attractions, obviously what is needed is a scientific evaluation of head-starting as a method of boosting turtle numbers.

Not only has no such evaluation been made, but formulation of how head-starting could be evaluated has been almost entirely lacking. That head-starting at present remains to be validated is understandable. At some point procedures have to be tried out, and with turtles taking a long time to mature it may take years before results become apparent. One cannot expect the results before an experiment is completed. But what is extraordinary is that some people have embarked on head-starting with so little attention to how it might be evaluated, whether it is possible to evaluate it at all. However, quite recently, this problem has been addressed and a few interesting suggestions have emerged.

Perhaps the best, the ultimate validation would be if after many years there was a greater percentage of head-started turtles among the breeding females than might be expected on the basis of the percentage of eggs taken for head-starting (Buitrago, 1981; Pritchard, 1981). For this it would be necessary to know not only how many eggs were taken for head-starting but also the percentage of the total laid that this take comprised. Working with a geographically well-defined population would be an advantage; all its nesting beaches could then be monitored. It would be necessary to check that the eggs of experimental animals were as viable and fertile as those of turtles with an ordinary upbringing. Finally, it would be essential to be able to identify breeding head-started turtles.

The collection of the data required for this level of evaluation is so demanding that it is unlikely it will ever be accomplished. The easiest part would be specifying the percentage of the eggs taken for head-starting. In Surinam there is good monitoring of the numbers of the nesting green turtles. The same is probably true in Florida. For Kemp's ridley in Mexico the single nesting population simplifies setting aside a known percentage of the eggs (Pritchard, 1981). But after that the difficulties become daunting. They arise from the long time turtles take to become mature. Nobody even knows how long this takes but rates of growth of juveniles, caught in the wild on 2 or more occasions, can be projected out to the size of a small nesting female. This procedure, applied to green turtles off Hawaii, Florida and Australia, suggests it takes 30 years or more before they breed (Balazs, 1979a; Mendonca, 1979; Limpus and Walter, 1980). Similar methods give 15-20 years for Florida greens in a different habitat (Witham, 1980) and 13-15 years for Florida loggerheads (Mendonca, 1979).

This way of estimating maturation time sounds reasonable. It is probably the best available at present but it too needs validating. Measuring the length of a turtle's carapace sounds the easiest thing imaginable. After tagging it is the turtle researcher's favourite activity. But there are some embarrassing instances of negative growth, to use a euphemism. Perhaps some mobilization of bone mineral and minor contraction of the carapace are possible, but can a turtle really shrink by more than 10% in less than a fortnight? A 35.6 cm (carapace length over the curve) green turtle released in the Torres Strait was 3.6 cm shorter when recaught 12 days later (Kowarksy and Capelle, 1979). In another case an adult loggerhead measured when nesting in Tongaland was 4 cm shorter when she returned 5 years later (Hughes, 1974b). In both instances the authors concluded that the data were unreliable. More worrying than unreliability in measuring is the possibility of systematic rather than random errors. In the Torres Strait study, 6 out of the 10 turtles measured on recapture had become shorter. Moreover those turtles were the 6 recaptured soonest. Most had been at sea only a few weeks. If their real growth had been minimal, then random errors should have given some positive as well as negative values. The probability that the first 6 turtles to be recaptured would all have errors pushing their true values in the same direction is less than 1 in 20 ($p= .032$, two-tailed sign test). In the Tongaland study, of the 14 turtles remeasured after 1 year, 10 were shorter, 1 was the same and only 3 were longer ($p= .09$, two-tailed sign test, ommitting 1 turtle whose length was the same). Perhaps then all turtles had been overestimated initially or underestimated when remeasured. Small systematic errors in growth rates when projected might add many years to estimates of the time to reach mature size. How consistent are carapace lengths measured by different people, or by the same person working on different occasions? It is to be hoped that, with large samples, estimates of maturity are fairly accurate. In the absence of anything better, as a working assumption, one has to accept the current view that turtles take a few decades rather than a few years to mature.

With a long maturation to contend with, any individuals embarking on a rigorous evaluation of head-starting need to have a head-start on the problem themselves. Even if one launched the project in one's mid-twenties, one might be approaching retirement age before data began accumulating. And any agency backing such a project would have to have unusual political and funding stability. But even supposing far-sightedness, funds and steadfastness of purpose were assured, there remains the not inconsiderable matter of recognizing head-started turtles when and if they come ashore to nest.

Tag loss, as Chapter 3 relates, is a major problem. The more tags that drop off, the lower the chances of demonstrating a successful outcome. Surely then head-starting programmes would make the maximum effort to mark their turtles in an enduring way. In Surinam there is some recognition of this problem: when turtles are released, 2 tags are attached through holes made in the marginal scutes of the carapace. The hope is that even if the tags corrode or are pulled out, the remaining holes or notches at the edge of the shell will provide a distinctive mark. Unfortunately this may not be a reliable method of marking because a notch might disappear as the turtle grows and because similar damage could result from natural causes (Mrosovsky, 1978b). This is a real possibility: of 1057 green turtles encountered on Ascension Island in 1973 and 1974, 8.4% had notches in their rear-marginal scutes (Simon and Parkes, 1976). As far as is known no deliberate notching has been undertaken there. So it is necessary to have baselines before such marking is instituted. In Malaysia, in 1976, 2 mm were clipped off the posterior tip of the carapace of 11,502 leatherback hatchlings before release (Siow, 1978) in the hope that enough would survive to be noticeable when they appeared in the nesting population and so provide data on maturation time. But even before 1976, and in other parts of the world, nesting leatherbacks were sometimes missing the end of their carapace. And in the Guianas about 25% of nesting leatherbacks have a blunted rather than pointed end to the carapace (Mrosovsky, unpublished). If the cut end of a hatchling's carapace were capable of growing out, it might end up not looking much different from that of some unclipped leatherbacks. Without quantification the Malaysian clipping project becomes much less valuable, possibly useless. None of the reports and papers from Malaysia mention such quantification.

Similar data, on the natural frequency of notches on adult turtles, are needed for Surinam. At least some effort is being made there to mark head-started turtles in several ways. But in Florida the head-starting programme only uses the same old unreliable Monel tag, on one flipper. There is even a footnote to a paper on this project pointing out that this tag is not endorsed by the Florida Department of Natural Resources (Witham, 1980). Head-started Kemp's ridleys have also been marked with this Monel tag (Klima and McVey, in press) though finally in 1981 an additional plastic tag was attached to some of the animals (Marquez, 1982).

But suppose, on top of the suppositions already made, that even despite tag loss more head-started turtles hauled ashore to nest than would be expected from the numbers of eggs taken earlier, would that validate the procedure? Suppose that head-starting were not only successful but also spectacularly successful, then perhaps the problem of tag loss over the years to maturity could be overcome. With many head-started turtles breeding, enough might still carry tags to prove success. Such an outcome would certainly be gratifying and would show that head-starting was more effective than leaving the turtles alone, but it would not establish that it was more effective than other conservation measures. A worthwhile evaluation of head-starting should go beyond trying to learn whether the procedure was better than doing nothing. It should also ask whether it was better than taking other actions to boost turtle populations. How much does it cost to raise a turtle in captivity to the age of one year or whenever it is released? Some of the other options are much easier and probably cheaper.

Perhaps the simplest is foiling predators by digging up eggs and reburying them elsewhere on the beach. In many parts of the United States racoons devour most of the eggs laid by loggerhead turtles. Probably racoons find the nest by the smell of sand moistened by the mucous secretions accompanying the eggs as they drop from the cloaca. Whatever the method, their depredations can be much reduced if the eggs are cleaned off and reburied close by. Care must be taken not to mix in sand from the original nest site and not to touch the sand at the new site with hands that have been in contact with the old one. Reburying eggs in this way on the night they were laid cut predation from 74% to 19% on Kiawah Island, South Carolina, in 1973 (Stancyk et al., 1980). This procedure has many attractions. It can easily be combined with saving clutches laid below the high tide line.

Introduction of unnatural stimuli is minimal. No equipment is needed, no radios, no telemetry, no tanks, pumps and filters. The only essential is a piece of cloth for carrying the eggs to a new site. A large cockle shell is handy for digging out the new nest hole.

> The transplantation method has great conservation potential on nesting beaches where erosion and predation by small mammals are important factors. Compared with other methods currently in use, transplantation is the cheapest, simplest and most natural way to avert predation that has yet been attempted. It requires relatively little labour and avoids many of the pitfalls of the other methods. Unless histories of individual nests are being monitored nest sites must be visited only once, when the clutch is buried. No chemicals are introduced, optimal beach sites can be chosen, and development in the natal beach takes place at normal beach temperatures. Hatching is not affected by human activities. What is needed now is for additional trials of the method to be carried out, in different parts of the world, where other species of sea turtles nest, and where different predators eat turtle eggs.
>
> (Stancyk et al., 1980)

Of course, unlike head-started yearlings, some of the hatchlings will be picked off by birds or crabs on their way to the water and others snapped up by fish lying offshore. Nevertheless with such a large reduction in initial losses on the beach, transplantation may well be a cheaper and less risky procedure. And if additional trials do not support the initial claims, then there are other uncomplicated ways of tackling the problem, such as intensive trapping of racoons at the start of the season.

Another simple conservation technique is to put wire netting around the nest, collect the hatchlings when they push up through the sand, take them out to sea in a small boat and release them beyond the zone of inshore predators. This was the practice for several years with leatherback turtles from the hatchery in Trengganu, Malaysia. Then it was stopped in case it might disrupt any imprinting and calibration occurring on the way out to sea. And so it might. But no attempts were made to discover the truth of the matter. Someone thinks that leap-frogging over the inshore predators is a good idea. So that is what is done. A few years later someone else thinks it too risky. So it is stopped. No progress is made. Formulation of how the practice might be evaluated, let alone any attempts to do so, are absent. Yet certainly following Frick's (1976) pioneering observations on the paths taken by hatchlings as they swim offshore, there are methods for studying at least some aspects of the problem. It remains possible that taking neonate turtles out to sea in a boat is no more damaging to orientation skills than releasing juveniles on a beach or elsewhere after a year or so in captivity.

Simple procedures like reburying eggs or leap-frogging hatchlings out to sea appear less risky than head-starting in that they involve shorter and less radical departures from the normal life cycle, but they are also difficult to assess rigorously. Permanently tagging hatchlings by conventional methods is even harder than tagging yearlings because the tags get sloughed off or incorporated as the animals grow. Perhaps then for all these procedures the hope of conclusive proof of success will have to be set aside in favour of interim evaluations, informed guesses.

For instance, if head-started turtles 'show up runted, diseased, or geographically displaced from where they should be, the program should be drastically revised or terminated' (Pritchard, 1981). This happened with laboratory-raised yearling green turtles released in the Gulf of Mexico. A few days later some crawled back onto land, hardly an appropriate place for animals of that age (Ehrenfeld, 1974). But if healthy turtles kept appearing in places frequented by other turtles of the same size, there would be grounds for optimism (Pritchard, 1981). And this seems to be the case with head-started Florida green turtles. They have been found widely distributed in the Caribbean and western Atlantic. Those that have been measured on recapture have grown, proving that they can adjust to finding their own food (Witham, 1980).

Such data are certainly encouraging; they show that head-started turtles can survive and grow after release. But they do not prove much beyond that. Do they survive better than ordinary turtles? In the Florida project there were more than 90 tag returns from more than 10,000 turtles released, about a 1% rate. Does this high recovery score mean that head-started turtles are doing well or does it mean that they are failing to evade capture and in the long run will contribute less to the population? Where are figures for the catch of normally developing turtles? Do the recaptures of the head-started turtles constitute an interestingly large percentage of the total captures? The head-started turtles are growing but are they growing as well as animals of that size with normal upbringing? There is no comparison group of wild animals so this cannot be assessed. The head-started turtles are widely distributed but how does this compare to the range of the Florida green turtle population? Are the head-started turtles likely to come back to Florida and reinforce the population there or go elsewhere? Nobody knows. And even if they did, that would not show that head-starting was more effective than other conservation techniques. What is the cost of raising a turtle in captivity for a year? Similar questions arise about the release of head-started turtles in Australia. Recapture of 14 out of more than 1000 greens and 53 hawksbills released tells one that some turtles can survive in the wild after a start in captivity, but little else (Kowarsky and Capelle, 1979).

Assessment based on what happens in the first few years after release may be the only feasible option at present. But even that is not easy. Interim assessments have to become much more quantitative and be founded on a better knowledge of the population under study before they become anything but minimally instructive. Even if a head-started turtle was found nesting, this would not show the method was superior to releasing hatchlings or other conservation measures. The event would doubtless be hailed as a milestone. In fact just that happened when a 7-year old head-started loggerhead was found nesting on Jupiter Island, Florida in 1979. The Florida Conservation News (September, 1979) ran an item entitled 'First Pen-Reared Turtle Seen Laying Eggs' and an enthusiastic letter followed in Oceans magazine the next year. Too bad that somewhere alone the line the tag number or records had been muddled and the whole thing had to be dropped.

Finally, on the question of evaluation, there is another event that would also doubtless be hailed as significant—and would certainly be pleasing—but would not prove that head-starting was effective: an increase in the population concerned. It would be particularly dangerous to argue from cause to correlation in this case because so little is known about long-term trends in turtle demography. About all that is definite is that there are huge and unpredictable fluctuations in numbers nesting from year to year (Carr et al., 1978; Kowarsky, 1978; Schulz, 1980). An increase, without demonstration that head-started turtles were responsible, would tell little. It might have resulted from changes in food supply, pollution abatement, long-term environmental trends and a host of other possible causes. Only by comparing 2 groups of separate turtle populations, some head-started, others not, might one begin to be able to randomize out such other factors. A group design of such size and multinational scope hovers between the unrealistic and the inconceivable.

But it should also be pointed out that if, after years of releasing tank reared turtles, a population crashed one could not justifiably point an accusing finger at head-starting. Without that the situation might have been much worse for all we know. Nothing that has been said so far in any way demonstrates that head-starting does not work.

What it comes down to then is that head-starting, as practised today, is a gamble, but a remarkable kind of gamble, one we may never know if we have won or lost—the wheel keeps spinning. In most gambling having a result is critical. But with head-starting all too often the motive behind the gamble cannot be the desire for an instructive outcome. For why then would some of the most obvious things be neglected, like putting 2 or more tags on the turtles in the hope that at least 1 would stay on, or researching tagging methods better before embarking on the main programme? Why is there so little formulation of the criteria of success? The driving force behind head-starting is not the overwhelming internal logic of the procedure nor the hope of external validation but its emotional appeal.

'In virtually all the popular romances between humans and originally wild animals there is a point at which the humans try and return their pets to the wilderness,' writes Alistair Graham (1973) in one of the few books that really search for a deeper insight into our treatment of wildlife. It is not necessary to agree with all of his interpretations, some narrowly Freudian, to be persuaded that attitudes towards animals are governed by many poorly recognized feelings. It might not be relevant to inquire into these feelings if the science of head-starting were more robust, but its weakness leaves a vacuum for the irrational and emotive. Releasing animals, releasing turtles, is pleasurable—watching how they crawl over the sand, struggle through the surf and breaking waves and then swim out beyond to the open sea. It is not so easy to define exactly why this is pleasurable. Perhaps it has something to do with the desire for a freer simpler existence, with an element of going beyond the present situation as well as back to childhood (cf. Graham, 1973). A whole novel, Turtle Diary, has been written about the release of turtles from the London Zoo. The story is really about people, how their lives expand, how they transcend their limitations, but freeing turtles is the vehicle for their aspirations:

> Could I be a turtle? Could I through an act of ecstasy swim unafraid and never lost, finding, finding? Swimming with Pangaea printed on my brain and bones, the ancient continent that was before the land masses drifted apart.
>
> (Hoban, 1975)

There must be many occasions when animals, especially birds, have been released as part of official celebrations. And private ones, too, such as when a couple instead of having a conventional marriage service marked the event in various other ways including buying a caged linnet and setting it free.

When animals are released in celebrations there is some recognition of the ritual element. The proceedings are not purely for the animals' sakes anymore than they are when animals are sacrificed. Head-starting too has a ritual element, covert, decked out in statements about conservation, the life cycle of the species, its numerous predators, but there all the same.

At Jensen Beach, Florida, in 1976, there was a release of head-started green turtles following the end of a conference on sea turtles. The serious valuable work of the meeting was over, the atmosphere was festive and relaxed, the weather perfect. The release took place during the day, not the time turtles would normally crawl down to the sea. Some were too hot and lethargic to manage it on their own, but conditions were excellent for the photographers. The officials talked to the press. With luck there would be a nice spread in the newspapers the next day explaining how the Florida Department of Natural Resources was helping preserve the natural heritage of Americans for future generations. A young wildlife biologist, as she lifted the turtles out of the carrying box, shut her eyes tightly and kissed each one .....

X X X

5. OPERATION GREEN TURTLE

Head-starting is not the only conservation measure involving the release of turtles. Another is to take hatchlings from their natal beach and release them on another beach in the hope that when mature they will return to lay there. The most celebrated translocation attempt of this kind was Operation Green Turtle: thousands of hatchlings, and also some eggs, were flown from Tortuguero, Costa Rica, to many different localities in the Caribbean and West Atlantic. In the words of Archie Carr (1967), who inspired and directed the operation, the aim was:

> to re-establish green turtle rookeries in places known to have once been nesting grounds. Batches of Tortuguero hatchlings are released, with the hope that they will grow to maturity imprinted by the smell, taste, or feel of the place where they entered the sea and will be instinctively drawn back there at breeding time, as the salmon is drawn to its hatching place.

Of course Carr knew this was a gamble. Turtles might behave differently from salmon. They might have an inherited and unmodifiable attachment to the natal beach. Transporting them elsewhere might even be so disruptive that they would not breed anywhere at all, and the endeavour would deplete rather than restore turtle populations. However, as only a few thousand out of an estimated million or more eggs laid at Tortuguero were taken each year, it seemed justifiable to try (Carr, 1979). So the idea that turtles return to the place of release was a hypothesis to be tested.

So far there is no evidence that the translocations were successful. The criteria for evaluation are much simpler than those for head-starting because the hatchlings were released in places that were not then nesting grounds for the green turtle. Yet old accounts of rookeries now wiped out in those areas demonstrated their ecological suitability. So if, after translocations, turtles began to lay eggs in places where there had been no recent nesting, then the inference would be that the operation had been successful. Certainly if nesting started up at a number of the release sites that would be by far the most likely explanation, if not the only conceivable one. But that has not happened, so the inference is that the hypothesis is disproved. It might be better to put it more cautiously: 'it cannot be proved that Operation Green Turtle restored any green turtle colonies' (Carr, 1979). This caution is appropriate because of the long time green turtles take to mature, maybe as much as 30 years. Operation Green Turtle began around the late 1950s so that it may be too early to be certain about the results till the end of the 1980s. But the signs so far are not encouraging.

So, though the record is not written yet, a provisional summary of Operation Green Turtle could be that as a conservation measure it was a failure but 'as an offbeat venture in public relations' it was a success (Carr, 1967) and as an experiment it was a heroic effort that gave negative results. Disconfirming a hypothesis is not a failure in science. On the contrary, it is sometimes considered the most instructive of outcomes.

But there is much more to an experiment than recording the results, or lack of them, and it is here that Operation Green Turtle is deficient. Its failure as science is not that the results are negative but something quite different: the lack of adequately reported details of what actually was done. It is like a scientific paper with no methods section.

If the analogy with salmon is to be taken seriously, then the details are the essence of the matter. In salmon there is a critical period for imprinting on the smell, the chemistry of the home stream. In coho salmon it lasts until the smolts begin their seaward journey (Hasler and Scholz, 1978). To be successful translocations of salmon would have to be made before then. The timing of this migration may differ from one year to another and between salmon populations in different streams. Of course Carr knew about critical periods and the shipment of eggs rather than hatchlings to Bermuda was designed to take this possibility into account (Carr, 1979). But how can the outcome of translocations to other beaches be evaluated, except in the most superficial way, with so little information on what happened. There are numerous questions. How long were the hatchlings held at Tortuguero before being flown out and under what conditions? Carr (1979) says: 'we usually kept them in tanks of sea water for a few days before the airplane arrived to distribute them,' implying that this was not always the case. Certainly in 1965 and 1966 some were kept longer. Maybe a trivial detail but who knows. If turtles began nesting at some of the release sites but not others it might be instructive to know if hatchlings had been shipped at an earlier age to the success areas. It would certainly be important to know how many hatchlings were released on the various beaches. And where are these beaches? In 1967 Carr mentions 22 different localities, in 1971 Hirth states there were 28, in 1972 (Carr) the figure mysteriously drops to 18 and in 1979 (Carr) it rises to 19, listed as Colombia, Trinidad, St. Vincent, Grenada, St. Lucia, Puerto Rico, Belize, Yucatan, Inagua, Bimini, Antigua, Nassau, Bermuda, Barbados and, in Florida, Cape Sable, Indian River, Dry Tortugas, Islamorada and Cape Canaveral. But Trinidad and the Yucatan are large places. Exactly where did the releases occur? What is the evidence that green turtles were not nesting on these beaches before Operation Green Turtle? A few turtles of this species do still nest in Florida (Sternberg, 1981; Witham, 1980). And what happened to the hatchlings when they arrived at their destinations? Evidently some were not set free at once. For instance, in 1966 at Key West (omitted for some reason from the list of release sites given above) they were kept for a year before being let go (Carr and Sweat, 1969). Does the 200 mentioned in this case refer to those arriving or the number surviving that year? On how many other occasions was head-starting combined with translocation? Even if, after waiting beyond any conceivable maturation period, no green turtles lay eggs at any of the release sites, information about the dates and numbers of translocated turtles would enrich a negative result like this. As we learn more about predation and survival of turtles of different age classes, it may be possible to say whether such an outcome could plausibly have resulted from too few having been released. And if transplants took at some sites but not others, then the numbers released and all the details would become vital.

Of course it is not easy to carry out projects of this nature in a precise way. At one time there may not be enough hatchlings, then suddenly there are so many that all efforts go simply on keeping them fed till the plane arrives. The vicissitudes of field work are compounded by tangles of red tape, getting permission for a plane to land in remote places in the Caribbean, and problems of finance. It is remarkable that so much was achieved.

Nevertheless, that as much attention has been given to the public relations side of Operation Green Turtle as to the procedural details, makes it legitimate to wonder where the emphasis was. Certainly there were times at Tortuguero when the plane arrived to pick up the hatchlings that cameras were far more in evidence than notebooks. Everyone seemed to be photographing everyone else and indeed it was a colourful event and remarkable mixing of cultures (see Carr, 1967). When a

United States seaplane touches down in a remote lagoon bringing only a cheerful crew intent on restocking turtles, it does capture peoples' imaginations, focus attention on the plight of the turtles and foster international goodwill. It is not downgrading such things to argue that if the hypothesis was worth testing, worth all the dollars that funding agencies poured into it, then surely some of the methods of that test should be in the mainstream scientific literature. Maybe all the details are tucked away in reports to the National Science Foundation, the U.S. Navy and the Caribbean Conservation Corporation, or tabulated elsewhere, but they should be more readily available. Or was the emphasis really on the process rather than on laying the foundations for an instructive experiment?

The importance of the process of trying to conserve sea turtles rather than the results, shows up elsewhere. A research worker in the Solomon Islands, after pointing out that head-starting turtles is a dubious procedure, quotes Carr's words about fostering goodwill and then goes on to say:

> I believe that a well run headstarting programme can serve a similar, if more modest, function in Solomon Islands. A batch of young turtles is the perfect starting point and prop for a discussion of conservation and it shows that we are doing more than just making laws which say people can not kill turtles.
>
> (Vaughan, 1981)

Of course public relations have to enter into many conservation projects, but sometimes they seem to dominate scientific considerations. The most extreme example is the ill-fated Torres Strait turtle farming venture. Originally backed by the Australian government in 1970 as a way of providing work for aborigines who had few other employment opportunities, it was also intended to protect both the indigenous people and their resources by following sound management procedures (Onions, 1980). Unfortunately it was launched without thought for the details and without an adequate environmental impact statement (see Carr and Main, 1973). Perhaps it was good politics and public relations when it started, but as management of an endangered species it produced the most startling folly ever in turtle conservation: feeding baby turtles with chopped-up adult turtles (Anon., 1973). The Torres Strait islanders were charged with keeping the young turtles alive and growing but lacked facilities. Sometimes they had no more than a few old oil drums at their disposal. Fetching enough sea water to keep the tanks clean and finding enough food to keep the turtles from biting at each other was a lot of work. So occasionally people would feed them whatever came to hand, meat from adult turtles, from dugongs (sea cows) too, animals classified as vulnerable in the IUCN Red Data Books. Those inheriting the farming scheme in 1973, Applied Ecology, did their utmost to stop this practice, but close supervision of a project spread out over many remote islands was impossible. Their newsletter of February 1979, circulated to all turtle farmers, warned: 'once again I must remind you that it is absolutely forbidden to feed either turtle meat or dugong to our farm turtles. Anyone caught doing this will lose his job immediately.'

Well, they would all lose those jobs anyhow, because in 1979 Applied Ecology advised the Minister for Aboriginal Affairs, Senator the Honourable F.M. Chaney, that the Torres Strait farming project was unlikely to become a commercially viable operation, and he decided to phase it out (Chaney, 1979). But the need for assisting the aborigines was not forgotten. Applied Ecology proposed to enlarge its emu farming project instead. Perhaps the emus will be blessed with better science and less public relations than the turtles.

6. THE STYROFOAM BOX STORY

Among the most widespread and simple tools of turtle conservation is the styrofoam box. A container suitable for carrying a picnic or iced drinks, about 36 X 21 X 23 cm, with extra air-holes punched in the side also serves admirably as an incubator for turtle eggs. First a few cm of sand are spread on the bottom, then the eggs are put in until the box is almost full, then a piece of gauze to stop grains from a second covering layer of sand falling between the eggs. With the lids on, these boxes are then arranged in rows on shelves in a shed on the beach. Except for occasional moistening, nothing has to be done until hatching. This is easily detected by listening for the turtles scrabbling against the walls.

Incubation in styrofoam boxes has many attractions. It affords better protection against predators than leaving the eggs in the sand. Even with a wire netting around, a nest in the sand is occasionally penetrated by a burrowing crab or persistent racoon. In a shed the eggs are much safer and can even be kept under lock and key if need be. If eggs are to be moved from where they were laid, it is easier to put them in a styrofoam box than to dig another hole in the sand. Within a box they can be inspected at any time during incubation by gently pulling back the gauze. If only a few turtles hatch, it is simple to separate the live animals from the rotting eggs. Styrofoam boxes are washable, stackable, not too expensive and, most important, the hatch rates are good, at times superb at around 95% (Woody, 1981). Some direct comparisons have been made to hatch rates of eggs left in the sand: boxes gave a 10% improvement with Kemp's ridley in Mexico (Marquez, 1978). In Surinam hatch rates for green turtles in boxes (80-92%) are similar to the best rates (85%) obtained from various samples left in the sand (Schulz, 1975). For leatherback clutches in styrofoam boxes, the rate was 54%; the best of the sand samples was 50% (Schulz, 1975). When predation is great, as on some leatherback beaches in French Guiana, the chances of eggs surviving in boxes are considerably greater (Fretey, 1981).

So it is not surprising that the styrofoam-box method of incubation, devised by Robert Schroeder in his own work (Simon, 1975) and later elaborated on when he was first technical director of Mariculture Ltd., the forerunner of the present Cayman Turtle Farm, has been widely copied. It has been used on both coasts of Mexico, in the

U.S.A., Surinam, French Guiana, the Grenadines, and probably other places besides. What could be more satisfying to park wardens or conservation officers than releasing a clutch of struggling baby turtles that they know would have had less chance of being alive if the eggs had been left in the sand? The thought that they may be biasing the sex ratio in favour of males is probably far from their minds. Only 10 years ago such an idea would have seemed almost inconceivable—to some people it still does. And yet this is what happens. There is now evidence that incubation in styrofoam boxes above ground, at least in some circumstances, increases the numbers of males in the clutch (Mrosovsky, 1982; Morreale et al., 1982).

It all goes back at least to 1966 when Charnier, working not with sea turtles but another reptile, the common agama lizard, reported that incubation of the eggs at 29°C resulted in predominantly (81%) male offspring while at temperatures only 2.5°C lower there were hardly any males (2%). There was minimal failure of the eggs to develop and although some details of his experiment are not given, the results seem clear cut. But his paper aroused little interest. Published in an obscure journal, that of the West African Society of Biology, probably few people ever read it. Fortunately studies of the effects of temperature on sexual differentiation were taken up by another Frenchman, Pieau (1971). Working with the eggs of the freshwater pond turtle, *Emys orbicularis*, and the European tortoise, *Testudo graeco*, he found that he could produce either males or females by varying the incubation temperature. In this case, however, it was the lower temperatures that resulted in males. As is often the case with pioneering endeavours, there were some alternative explanations, such as differential mortality between the sexes at high and low temperatures; this could not always be completely ruled out, and Pieau's work does not seem to have had the impact it deserved. But his findings were extended to the snapping turtle, *Chelydra serpentina*, by Yntema, at Syracuse, N.Y., with studies that put the phenomenon on a firmer basis and also brought it to the attention of a wider audience through publication in the Journal of Morphology in 1976.

At that time sexual differentiation in sea turtles had not been studied. Indeed nobody knew how to determine the sex of a hatchling sea turtle.

As Ogden Nash has written:

> The turtle lives 'twixt plated decks
> Which practically conceal its sex.

Actually it was worse than that, because even on dissection it was impossible to tell by just looking whether the immature gonad of a hatchling was a testis or an ovary. However, around 1976 some curious observations at the Cayman Turtle Farm made it likely that sexual development of sea turtles was also temperature dependent. In batches of turtles that had survived for a few years, and were large enough to sex, the ratios of males to females were highly skewed, but in ways that were different for different batches. Since there was no reason to suppose that disease had carried off the females in one batch and the males in another, the most probable explanation was that the conditions of incubation, modified over the years, were responsible. These findings were reported by Owens at the Jensen Beach Conference in 1976 (Owens and Hendrickson, 1978).

Beginning then with obscure papers tucked away in the French scientific literature, there was a gradual growth of knowledge, and by the late 1970s some collective awareness that the sex of sea turtles might be dependent on incubation temperature.

This had serious implications for conservation practices, particularly for the use of styrofoam boxes (Mrosovsky, 1978c). Eggs incubated in styrofoam boxes generally take longer to hatch out. Longer incubation times imply cooler temperatures and it has now been confirmed that temperatures within styrofoam boxes are lower on average than in the sand at the depth of turtle nests (Marquez, 1978; Mrosovsky, 1982). Cooler temperatures are masculinizing for various freshwater turtle species. Therefore using styrofoam boxes might bias the sex ratio of sea turtles in favour of males. But at that time it had not actually been shown that the sex of sea turtles was determined by temperature. There was an obvious need for scientific study. Were sea turtles like the other species studied before? If so, how sensitive were they to temperature? Would the 2°C or so temperature drop in the boxes be enough to affect sex ratio? The leading authority in the U.S.A., perhaps in the world, on the embryonic development of turtles then was Professor Yntema at Syracuse. Fortunately it was possible to interest him in the problem and also secure the co-operation of people in Florida to supply loggerhead turtle eggs. The stage was all set for a scientific evaluation of the problem. Then the Florida Department of

Natural Resources refused to grant permits for the eggs to be taken. Evidently there were other considerations to be taken into account.

A complicating factor was the necessity of killing the hatchlings to discover their sex. The only reliable way known at present to sex a hatchling sea turtle is to prepare thin sections from the gonads and look at them under a microscope: if a germinal layer is present they are female, if seminiferous tubules they are male. Now the Florida Department of Natural Resources is concerned with the conservation not the killing of turtles. Allowing them to be taken for some scientific investigation, however strong the case, might not be a good public relations risk, especially at a time when pressure was being put on the shrimping industry to reduce their incidental catch of turtles, those drowned in nets during long trawls. If the authorities allowed scientists to kill hundreds of turtles, then why should the shrimpers take the matter seriously? This is about the best interpretation that can be put on the position adopted by the Department. But there is plenty that can be said on the other side.

To start with, a few hundred hatchlings may sound like a lot but probably represents only a fraction of an adult. Sea turtles lay many eggs in a lifetime. The exact figures are not known, but with clutch sizes of around 100 and several nestings in a season, and at least some turtles returning for several seasons, 1000 or 2000 eggs in a lifetime is not an unreasonable guess. For the population to remain stable each female need only have 2 offspring survive to maturity, assuming a 1:1 sex ratio. Suppose a female lays 1000 eggs, then each egg only represents .002 of an adult turtle. Whatever the exact figures and the sex ratio, it is clear that sea turtles normally lay many eggs and that few survive. Taking a few hundred hatchlings is an insignificant drain on most populations, certainly on loggerhead populations in the United States where racoons dig up vast numbers of eggs anyway, often more than 50% and on some beaches as many as 90% (Stancyk et al., 1980). And it is very different from drowning thousands of much larger turtles in shrimping nets each year. It should have been possible to explain this to the public. Furthermore, offers were made to more than compensate for the numbers taken by paying a student to spend a week warding off racoons from newly laid clutches, but to no avail.

In this case the price of knowledge was not large but the cost of ignorance might have been. If styrofoam boxes were producing more males, in the worst instance nearly all males, nobody knew at the time, then conservation efforts not only in Florida but also in some other parts of the world might even be doing more harm than good. The authorities should have been delighted at the chance of having experts such as Professor Yntema work on the problem. The most they allowed was analysis of specimens from green turtles that had been incubated in styrofoam boxes but died later during head-starting. However, as these were not preserved appropriately nothing much was learnt. Permits for the kind of study that would have provided really useful information on temperature effects on sexual development were refused.

Even so, needed as such studies were, it could still be argued that reducing the incidental catch of turtles was more important; if so, anything that could conceivably jeopardize progress on the latter should be rejected. One of the most promising developments in turtle conservation is the progress in devising nets that do not entangle turtles but still catch as many shrimp (Seidel and McVea, in press; Anon., 1982). In 1979 this work was in a preliminary stage and beyond that the problems of persuading fishermen to accept new gear seemed formidable. If there really had to be a choice between studying sex ratio and preserving an appropriate public relations climate for tackling the incidental catch problem, then perhaps on balance the refusal of permits was justified. It also has to be remembered that Florida has a tradition of sea turtle conservation going back to the 1920s. A dedicated and effective team in their Department of Natural Resources had made considerable progress, in some cases despite political opposition. Undoubtedly the preservation of the turtles was the goal of this department. Their aims were mutually compatible with those of the investigators asking to study sexual differentiation. The differences lay only in the weighting to be attached to the various factors.

But—and this is the most revealing part of the story—the matter did not end with the refusal of the permits. A member of the Florida Department of Natural Resources (whether acting on his own or officially is not important here) went on beyond this to distribute a paper attacking the need for taking eggs or hatchlings for work on temperature and sexual differentiation (Futch, ca. 1979). This opposition made it harder to obtain eggs in other places in the U.S.A. because under the Endangered Species Act permits were required from Washington as well as from the state authorities. The 'presumptive experiment,' as it was called, involved the sacrifice of large numbers of turtles and failed to take account of 'existing knowledge on the genetic basis of sex determination.' Perhaps temperature was less important than it seemed. Sex might be genetically determined, its expression in the animal temporarily overridden by temperature but later the form of the turtle might revert back to that appropriate to its genetic sex. This possibility could not be incontrovertibly discounted but it was unlikely and the onus of the proof should be on those who propose unlikely things. Why, for instance, should the testes, once seminiferous tubules had formed, revert to an ovary, unless it really is no more remarkable to change sex twice than not at all?

Yet by letter Professor Yntema was advised that neither his competence nor the importace of the work was in question. If he could discover the sex without killing the hatchlings, the project would meet with approval. Determining whether the animal was male or female by taking only a small sample of tissue and looking for sex chromosomes was suggested. That would let the scientists do their studies but keep the turtles alive, a nice compromise. But there was just one tiny microscopic absolutely fundamental problem: it is no good trying to sex turtles by looking at their sex chromosomes because turtles do not have sex chromosomes, or not ones that can be told apart. At that time the chromosomes of more than 30 species of turtles, in more than 20 genera, had been studied. In the vast majority it was impossible to discern sex chromosomes (Stock, 1972) and not surprisingly this proved to be true for green turtles (Bickham et al., 1980). Only in 2 species of musk turtles had heteromorphic sex chromosomes been found (Bull et al., 1974).

Eventually, of course, it is to be hoped that a way will be found of telling the sex of a hatchling sea turtle without having to study the structure of the gonads, though almost certainly any new method would initially have to be validated against the old one. If a non-destructive way of sexing hatchling turtles had been available in the late 1970s, of course it would have been used. But meanwhile many turtles were being incubated in styrofoam boxes, including a sizeable proportion of the eggs from the remnant population of green turtles nesting in Florida. And members of their Department of Natural Resources had heard Owens' paper at the Jensen Beach Conference. So to suggest that sex should be determined by looking at sex chromosomes and that more account should be taken of the genetic basis of sex determination completely missed the aim of the proposed experiments: to ascertain whether sexual differentiation in sea turtles was environmentally rather than genetically determined. There is no necessary reason why genetics have to determine whether a creature develops into a male or female. Indeed in some circumstances it would be adaptive to have this depend on the environment (Charnov and Bull, 1977). Moreover, even if it turns out that incubation temperature does not initially determine sex but reverses or upholds a genetically specified sex (Engel et al., 1981), for a conservationist it is not likely to be very profitable to search for subtle differences in the staining pattern of sex chromosomes or study immunological sex differences (H-Y antigen) when these characteristics do not predict as well as temperature whether a turtle hatches with a testis or an ovary.

The scientific opinions of the Florida Department of Natural Resources in this case are not of particular interest in themselves. But that someone should obstruct investigations is worth noting as it is an example of a more general problem in wildlife management. It is not only that scientific evaluation is often low in the priorities of those concerned with wildlife management, there is also sometimes a vein of active rejection and hostility towards science (see also Graham, 1973).

But there were other elements in the situation, other opinions. The story has a happier outcome. The project was delayed but not stopped. Persistence and negotiation were rewarded. Eggs of loggerhead turtles nesting outside of Florida were obtained, in small numbers, but sufficient to show that temperature did affect sexual differentiation (Figure 2). With each new finding the idea that incubation temperature might have a dominating influence on sex ratio became more acceptable. The phenomenon was extended to green turtles in Australia (Miller and Limpus, 1981) and on the Cayman Turtle Farm (Wood and Wood, 1982). The Surinam authorities encouraged studies at hatcheries; samples were flown past the permit-stingy bureaucracies in the U.S.A. to Canada for analysis. The first results showed that there were indeed more males produced in styrofoam boxes than in the sand (Figure 3). At 23% more males, the difference, though large, was not as great as had been feared (Mrosovsky, 1982). But much more work needs to be done still; 23% is only a first approximation based on a small sample. Much may depend on the exact construction of the shed housing the styrofoam boxes, how shady it is, (Morreale et al., 1982) and on how much air reaches the eggs.

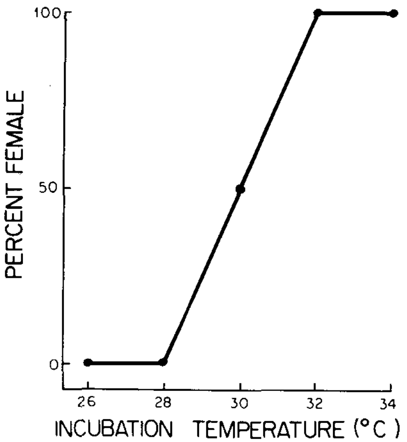

Figure 2. Percentage of females (turtles with ovaries present at hatching) as a function of incubation temperature. Eggs of loggerhead turtles were incubated at constant temperatures in the laboratory (data from Yntema and Mrosovsky, 1979, 1982).

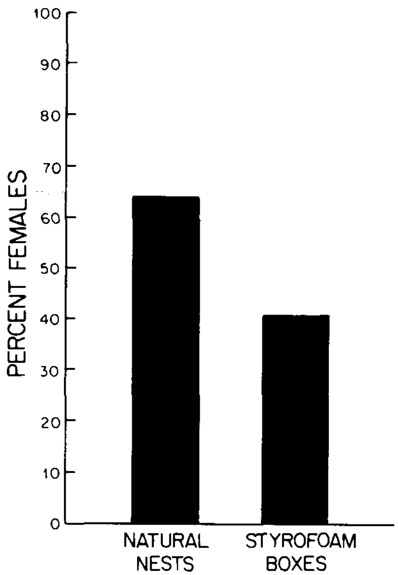

Figure 3. Percentage of females (ovaries present at hatching) of green sea turtles from natural nests and from styrofoam boxes. All samples were collected in Surinam during one part of the season; sex ratios are not therefore necessarily representative of the whole season. Data from Mrosovsky (1982).

But the implications of temperature determination of sex go beyond using styrofoam boxes to hatchery practices in general, and beyond that still (Mrosovsky and Yntema, 1980). For example, on Pulau Selingaan, Malaysia, boxes are not used; instead many clutches are moved from where they were laid and reburied in a fenced-off hatchery. There they lie in well-labelled neat rows in a cleared sunny area where they can easily be seen and cared for. Many of these eggs came from nests originally laid under trees, in the shade. On other of the Sabah Turtle Islands the undergrowth has been cleared to combat mosquitoes and make room for planting coconut palms. As even a small change in temperature can influence sex ratio (Figure 2), perhaps unnaturally high proportions of females are being produced. This may be preferable to masculinizing populations with styrofoam boxes but there could also be dangers in having too many females. Observations at the Cayman Turtle Farm show that female green turtles are more likely to nest if they have spent a long time in copulation previously. The percentage of females nesting reaches 94 only for those that have mated for a total of more than 5 hours (not necessarily all in one bout!). If cumulative copulation time is 1 hr 40 min or less, then only 20% of the turtles nest (Wood and Wood, 1980). Would a few males in an unbalanced population have the time to accomplish their long job? What is needed as a start is information on the ratio of males to females at the hatching stage in natural circumstances. This can serve as a baseline against which to compare data from hatchery procedures, even those as apparently innocuous as reburying eggs in an open sunny area, or in batches different from natural clutch sizes. When it comes to transplanting eggs from Costa Rica to Bermuda in the hope of re-establishing the former breeding colony there, it is imperative to consider thermal influences on sexual development. Perhaps also deliberately increasing the production of females would be beneficial in areas where they are subject to heavy onshore predation (Mrosovsky, 1981). To assess the opportunitites and dangers in managing animals whose sex ratio can so easily be manipulated, there is an obvious need for extensive detailed investigations.

Fortunately opinion in the United States, with its vast reservoirs of scientific expertise and facilities, is now changing. Permits were issued for taking more than 1000 eggs or hatchlings from Costa Rica to the U.S.A. for studies on the sex ratio and some more limited sampling within the U.S.A. has also been allowed. But there may be things that once determined are even more resistant to change than the sex of a sea turtle. Up to 1982 at least, the use of styrofoam boxes continued.

7. KEMP'S RIDLEY IN A TECHNOLOGICAL FIX

Combine the unknown with the unproven and you have an appealing plan for action. Head-starting is unevaluated, hard ever to evaluate. Translocations like those of Operation Green Turtle have not worked, at least not yet. So a combination of head-starting and translocation surely adds up to an effective conservation strategy. Two queries make a plus. That seems to be the rationale behind present attempts to save Kemp's ridley--with incubation in styrofoam boxes thrown in for good measure.

Kemp's ridley is the most seriously endangered of any species of sea turtle. It has only one nesting ground of any consequence, at Rancho Nuevo in the State of Tamaulipas on the Atlantic coast of Mexico. Occasionally individuals come ashore elsewhere (Pritchard and Marquez, 1973) but the validity of some reports is difficult to assess. The number of females laying at Rancho Nuevo has fallen from around 40,000 a year in 1947 to some 1,200 in 1974 (Carr, 1977, 1979) and then to 500 or so in 1977 (see Mrosovsky, 1978d) and has hovered around that level since then (Marquez, 1978; Mrosovsky, 1979; Anon., 1981a; Klima and McVey, in press). This precipitous downward trend to the present low numbers and the restricted breeding range make Kemp's ridley critically endangered.

This is undisputed and is the basis of action by the IUCN, the Instituto de Pesca in Mexico and various United States' agencies. Ridleys from Mexico come into U.S. waters for feeding; drowning of these turtles in shrimping nets there has probably contributed to their decline (Pritchard and Marquez, 1973).

As the plight of Kemp's ridley has worsened and become more widely known, following initiatives by Archie Carr, René Marquez, Peter Pritchard and a world-wide letter-writing campaign (Mrosovsky, 1977) and behind the scenes consultations, there have been renewed attempts to pull it back from the brink. Starting in July 1977 there have been additional regulations in Mexico, for example a ban on commercial fishing in the immediate offshore zone from April to August. In 1978 a joint U.S.A.-Mexico Recovery Team for the species began operating. The plans of the Recovery Team included attempts to establish a new rookery of Kemp's ridley on Padre Island, Texas, a head-starting project and better protection on the beach at Rancho Nuevo.

The Padre Island project comprises various stages. First sand from the island is sent in containers to Rancho Nuevo. Newly-laid eggs are placed in these containers. They are then returned to Padre Island where the eggs are artifically incubated in styrofoam boxes. The hatchlings are permitted to crawl over the sand to the surf but then are scooped up and taken to the NMFS facilities at Galveston, Texas, for head-starting. About 2,000 eggs a year go toward starting this new rookery (Marquez, 1978).

Another 2,000 eggs or so are also set aside for head-starting, but these are incubated at Rancho Nuevo in sand on the beach there. After the hatchlings crawl over the beach to the water's edge they are taken to the head-starting tanks at Galveston.

The Padre Island translocations differ from most of those in Operation Green Turtle in that eggs rather than hatchlings are moved. They are exposed to sand from the intended future nesting beach very soon after being laid. If imprinting occurs very early on in development, in the eggs, this procedure is an improvement, unless the embryos become attached to something about styrofoam boxes. But suppose that learning about the smell and chemistry of the natal beach does not occur in the egg but later on, as the turtles swim offshore, or in the first few days they spend at sea, then perhaps the tanks at Galveston should be filled with Padre Island water. It is not easy to cover for every unknown. Sending eggs from the natal beach to another place for incubation, then on to a still different place for head-starting and then again to yet another and fourth place for release inevitably gives the turtles experiences differing from those they receive when travelling their normal migratory paths.

But perhaps the differences will not be critical and doubts will prove misplaced. It remains conceivable that head-starting will confer significant advantages, that the favoured turtles will return to the desired beach and breed in large numbers, that enough tags will stay on to prove it, and that all the details of the numbers head-started, the places and dates of their release, and the percentage of eggs taken for head-starting will be in the public domain to permit independent confirmation. That would be a brilliant vindication of the gamble, giving Kemp's ridley a boost and supporting the imprinting hypothesis.

Let us hope it works out that way if these projects continue. But another approach would be to stop any gambling with such a critically endangered species as soon as possible, even gambling with only a part of its reproductive potential. Even if the 4,000 eggs or so represent only in the order of 5% of the eggs laid at Rancho Nuevo, maybe less some years, those extra few eggs might be what pulls the ridley through. Of course gambling must involve risks, but why take such risks before the results of previous gambles are even in? In the later stages of Operation Green Turtle eggs were sent to Bermuda (Carr, 1979); perhaps some were also head-started. If details were obtained it should be possible to calculate when results might be expected, given present day estimates of maturation time. Why not wait till then? It is not as if there are no alternatives to translocating and head-starting Kemp's ridleys. Both increased beach protection and breeding in captivity to obtain extra eggs involve fewer unknowns.

Beach protection is of course an important part of the Recovery Team plan, as mentioned before. Just having people on the beach at Rancho Nuevo collecting and incubating the eggs for head-starting scares off some of the poachers. And there are further disincentives, there are patrols of armed Mexican marines and guarded central hatcheries to stop people and animals taking the eggs. Nevertheless, beach protection on paper differs from beach protection in practice. In 1978 the marines arrived late, the first arribada had already come in and 45 clutches, just over 25% of the total for that arribada, had already been taken by local residents (Wauer, 1978). In 1980 the turtles came ashore further north than expected and more were taken by poachers (Anon., 1981a). It may therefore reasonably be asked if the money spent on translocating and head-starting 5% of the turtles would be better spent on extra beach protection. How much does it cost to head-start a Kemp's ridley at Galveston, including the cost of food, pumps, filters, electricity, antibiotics, salaries of pathologists and other personnel, administrative overheads, and the boat time and radio telemetry tracking when the turtles are released? What would that money buy in terms of beach protection? An earlier start to the operation? An extra camp at the northern section of the beach? Better defence of hatcheries against high seas and rainfall? As many as 13,130 eggs have been destroyed in a single year by hurricanes, that is 14% of the season's total reproductive output for the species (Marquez, 1982). Even offshore patrol boats might not be as expensive as head-starting and could perhaps save adult turtles from entanglement in nets and permit them to breed another year. Certainly there are informed people who consider that stepped-up protection at the breeding area is the most important aspect of the recovery plan. Carr (1979), after pointing out that 'neither head starting nor hatchling transplantation are proved management techniques' and that 'no new sea turtle colony has ever been provably established anywhere,' goes on to say that 'as to the urgent need for the other phase of the Rancho Nuevo project—U.S. participation in the surveillance of the beach—there can be no doubt at all.' Others concerned with the project have expressed similar opinions, have indicated, unofficially, that the spectacular technological translocation project was only reluctantly agreed to as a way of getting U.S. funds for the less glamorous work on the beach. A memo defending the Galveston project noted that 'we may find that the support for the Mexican beach patrols (which I believe we all agree are necessary) is linked to the support for the Galveston program; and if we cut off the one we may lose the other' (Pritchard, 1979c).

There is no doubt that much will be learned from keeping ridleys at Galveston. Much has already been learned about maintaining them in captivity, their diseases, growth rates; and radio tracking of tag returns will help plot the movements of head-started turtles (Klima and McVey, in press). But as science there are also drawbacks to a multifaceted rescue attempt: it confuses evaluation of the recovery effort. Suppose, as we hope, that ridleys suddenly become numerous again at Rancho Nuevo, then unless the tags stay on much better than there is reason to expect at present, it may be impossible to tell why things took a turn for the better. Would it be the head-starting or the increased beach protection? It has been argued that Kemp's ridley is an especially appropriate species for learning about head-starting because there is only one population, and this is well monitored. It is possible, therefore, to take a known proportion of the eggs for head-starting (Pritchard, 1981). But with protective measures also taking place on the beach, the baseline against which to assess head-starting changes. If those other measures are very successful, it would be harder to demonstrate that head-starting was working well. But if those measures were counter-productive, conceivably by artificial incubation methods biasing sex ratios (Chapter 6), then there would be a better chance of head-starting looking good.

The attempt to establish a new colony of Kemp's ridleys on Padre Island also combines variables. If it fails, it may be impossible to know whether it was the head-starting or the transplantation that did not work (Ehrenfeld, in press).

Perhaps as conservation it is wise to try some of everything in the hope that the ridley can be saved. This may be a case where good science and good conservation cannot run side by side and where the science should give way. But then any intention of proceeding scientifically and aiming for unambiguously interpretable results should be dropped.

And now another ingredient may be thrown into this already confused brew. The Kemp's ridley seems to have survived the IXTOC 1 oil blowout of 1979 but oil came up on its nesting beach and hatchlings had to be flown out to sea and released in areas free of the worst slicks. The incident was a reminder of the vulnerability of a species with a single breeding aggregation (Delikat, 1981). With only some 500 females coming ashore a year, it is not merely pessimistic but also prudent to wonder if Kemp's ridley can survive in its natural habitat. If not, then it might be wise to establish a small captive breeding stock as an insurance policy. This could serve as a gene bank until prospects were better for the species in the wild and knowledge of its biology advanced enough to make reintroductions possible.

It is known that green and loggerhead turtles will breed in artificial conditions (Wood and Wood, 1980; Wingate, 1980). Although Kemp's ridleys are more irascible and snap more at each other when crowded (Pritchard et al., in press), it is likely they would breed also. A number of concerned people have thought it worth a try at least. And if the attempt fails, the turtles could always be released. Reintroducing the species into nature after it had become extinct there might present more problems. If eggs laid on artificial beaches were flown to Rancho Nuevo and buried there, with only a few generations of domestication, the chances are good that the turtles would behave normally. But reintroductions somewhere else—if Rancho Nuevo became unsuitable, an oil boom town perhaps—might be more difficult. Also there is a danger that the fertility of a captive herd might drop if it became too inbred. How serious a problem this is depends on how the captive ridley herd is used. It might not arise at all if the same animals are kept for many years to produce eggs or hatchlings that are returned to the wild where, it is to be hoped, they will intermingle genetically with other animals. Such releases from yet another source would, however, further complicate evaluation of population trends at Rancho Nuevo. If ridleys became extinct there, then inbreeding remains a problem to be guarded against. It is not necessarily insuperable. Populations of animals as small as 50 may be able to survive while those in the order of 500 probably also preserve the capacity for evolutionary change as circumstances alter (Franklin, 1980). The best use of captive stock must depend on what happens to wild ridleys and how fast the science of restocking turtles advances. The immediate aim is simply to get a breeding herd established. With only limited options for doing much about the species in the wild and the very low numbers remaining, the idea of some insurance against possible disaster has attractions.

When taking out an insurance policy, people think about the costs as well as what it covers. The suggestion was not to take more Kemp's ridleys from the wild but rather to divert some from the Galveston head-starting operation, or use aquarium stock and accidentally caught individuals (Brongersma et al., 1979; Balazs, 1979b). The ridleys at Galveston already provide some insurance against environmental disasters (Klima and McVey, in press) but they are not a breeding stock. If 1,000 hatchlings from Galveston were set aside, or the yearlings surviving from that number, it would represent 25% of the head-starting project, and for one year only moreover. That does not seem a major commitment. Nevertheless the proposal ran into considerable opposition. But the principal disagreement was not about the concept of a gene bank. It was about who would be the banker.

Two different suggestions were made in 1979. The first plan was to keep the animals at the Cayman Turtle Farm, on the Grand Cayman Island in the West Indies. The Farm has extensive facilities for holding turtles, much expertise in breeding green turtles, and it offered to cover the costs for the first year in captivity. A number of biologists and Farm personnel signed a Statement of Intent, supporting this plan in principle (Brongersma et al., 1979).

The second proposal came from George Balazs (1979b) of the Hawaii Institute of Biology. His idea was to send a few hatchlings to each of some 50 aquaria, zoos and other institutions in the United States, Mexico and elsewhere for rearing and subsequent breeding. The dispersal of the stock would safeguard against disease, vandalism and other disasters. When the turtles matured, they could presumably be swapped between the various facilities for breeding.

These 2 plans are not mutually exclusive, except perhaps in so far as there might be constraints on how many animals could be spared from the Galveston head-starting operation. On the contrary, they could complement each other very nicely. Zoos could loan the Farm a few adult ridleys to cut down on the time it would take to get production of ridley eggs in captivity started. The Farm could provide zoos with hatchlings. The advantages of a dispersed stock without the costs of building breeding facilities could be beneficial to both projects, as could the exchange of information and animals.

But this has not happened. Both plans have gone ahead independently with neither getting off to a good start. The clue to the trouble comes in a curious passage in the Statement of Intent to the effect that the Cayman Farm would not use the help it was giving for promotional purposes. At that time the Farm was appealing decisions in the United States to ban the import of its products there (Chapter 8). The fear was that any conservation projects on the Farm might create favourable publicity and influence the courts in the United States. Such was the opposition there to the Cayman Farm, and to any international trade in sea turtles, that without this disclaimer it would have been more difficult to launch the captive breeding herd on the Cayman Islands. So the farm agreed not to advertise the project. Does this mean the Farm was so dedicated to conservation that it was prepared to support it even without deriving benefit from it, or does it mean, as cynics would argue, that it hoped to make a favourable impression even without striving for publicity? Perhaps the motives were mixed, but whatever the interpretation, it makes for a remarkable situation. It is hard to imagine the World Wildlife Fund (WWF) remaining silent about its conservation initiatives and why should they? It might be better to advertise the captive ridley stock at the Farm to promote the whole venture. For instance a special viewing area could be set up, with filmloops showing the former mass nesting of the species, 40,000 in one arribada. Visitors could be explained that this was their chance to see some of the few remaining Kemp's ridleys and that the extra charge they would have to pay to do so would go toward the maintenance of the captive stock.

But instead of co-operation between the Farm and zoos, and a campaign to fund a gene pool, both projects have got off to a poor start. There are a few adult Kemp's ridleys at the Miami Seaquarium but there is little action by zoos at the moment. In July 1980, 100 yearlings from the Galveston laboratory were moved to the Cayman Turtle Farm. By September 1981, 62 of these were still alive; 17 had died either during or within 10 days of transport and 21 died later. This high initial mortality probably was exacerbated by unfortunate travel arrangements.

The turtles could not go direct from Galveston to Grand Cayman, or even by good connections via Miami, because the legal battle (Chapter 8) between the Cayman Farm and U.S. government agencies prevented the 2 sides from negotiating. Instead the Mexican authorities, who still owned the turtles, had to request their return and they went to Cancun where they tangled with the labyrinthine Mexican bureaucracy. Some hatchling Kemp's ridleys from Mexico were also sent to the Farm but most died before they ever reached the Cayman Islands. The circumstances have not been reported fully.

By now there could have been a vigorous attempt to establish a captive breeding herd, using adults already in captivity to start things off at the excellent facilities already available on the Cayman Islands. If there is anywhere in the world qualified to breed turtles in captivity it is the Cayman Turtle Farm. But the Farm is anathema and must be denied publicity. And all too often the battle for publicity dominates scientific considerations.

8. THE ANATHEMA OF FARMING

> The one move that appears most promising as a way to accomplish the dual aim of feeding people and saving natural turtle populations is to set up turtle farms. If the teeming people of the future are to have turtle products—tortoise-shell, calipee, meat, soup, hides—these should come from captive stock.
>
> (Carr, 1967)

> A form of 'ranching' is what I had in mind—not farming.
>
> (Carr, 1979)

Of all the subjects most likely to stir the passions of people interested in the conservation of sea turtles, that of farming is foremost. Differences of opinion are expressed even at a national level: the United States prohibits the import of products from the Cayman Turtle Farm, the United Kingdom allows them. How often the question is asked: are you for or against turtle farming? And how quickly it is assumed, if the merest hint of something positive about farming is aired, that the speaker is pro-farming. How difficult it is to occupy the middle ground, to be neither for or against farming, but to be for keeping informed and to be against taking up inflexible positions.

There are many contentious issues. Will high-quality dependable supplies from turtle farms take the pressure off wild populations or will they increase it by promoting consumption of turtle products and expanding markets? Will meat and shell from captive-raised turtles be superior or inferior to that from free-ranging animals? Will it ever be possible to keep a herd of breeding adults large enough to make turtle mariculture self-sufficient, or will commerce always depend on taking eggs from the wild? Would continued egg collection constitute a serious drain on natural populations or could it be arranged so that only eggs that would have been eaten by predators or washed away by high seas, the doomed eggs, are taken? Will farms be able to compensate for what they take by head-starting, financial support of conservation programmes or other measures? Will one successful turtle farm encourage others to start up, taking more and more eggs off the beaches, or will new ventures have a model that permits launching with minimal seeding from wild stock? Should turtle products be sold on luxury markets or reserved for local use, providing protein for people who need it most? Would international trade help some countries by generating employment and money or would it, in the long run, be a poor option? Would such trade make impossible any effective enforcement of trade restrictions on products from wild-caught animals? Will keeping green turtles in tanks and feeding them expensive high-protein diets instead of sea grass ever be commercially viable? Will research on how to maintain and breed turtles in captivity result in useful knowledge that helps conservation efforts in the future, or will this be precluded by a too narrow commercial focus?

There are good reasons for remaining open-minded on these issues. The farming of turtles is a very new venture and changing the whole time. It was only in 1968 that Mariculture Ltd. began housing turtles on Grand Cayman Island in the British West Indies. They installed tanks, pumps and expensive equipment for maintaining many green turtles in captivity. The principal products were turtle steak and soup. At that time the operation was not a true farm, it was not closed cycle but relied on taking eggs from the wild. It was therefore really a ranch not a farm (Hirth, 1971).

Since then there have been major changes. In 1976 the company came under new ownership and management as the Cayman Turtle Farm. They established that they could breed turtles, something widely doubted originally. Since 1978 no more eggs have been taken from the wild to bolster output. Another significant change is that the emphasis has shifted from the meat to the shell. This may require rearing the turtles to a different size. It also raises new questions. One of the persistent worries about commercial mariculture of turtles has been that it would boost demand for green turtle products such as soup. These would necessarily be expensive to cover the capital outlays and cost of high-protein diets. There would then be increased incentives for poachers and others taking wild turtles; they could reap the benefits of the high prices without having made any initial investments. This is a legitimate worry. But the shift toward producing shell could perhaps now also provide conservation advantages. Traditionally turtle shell (often called tortoise-shell) comes from hawksbills, not green turtles whose shell is too thin to work easily. New methods of strengthening green turtle shell by infusing transparent plastic have been devised and attractive jewellery and boxes are now being made from the combination. Possibly then these artifacts could take some of the pressure off hawksbills, generally held to be by far the more seriously endangered of the 2 species (Carr, 1972; Bustard, 1972). It is too early to know whether the Japanese tortoise-shell industry and others will find this substitute acceptable. But it is at least legitimate to consider the possibility. New developments give rise to new questions. It is inappropriate to oppose the Cayman Farm on the basis of the way it was run in the early years.

Since that time a number of things said about the farming of turtles have proved to be wrong. In 1974 an influential article by Ehrenfeld questioned whether commercial mariculture could help conserve green turtles. 'Let us assume,' he wrote, 'the most favorable case for mariculture: that all captive females will be selected or induced to breed every 2 years, and that each will lay 500 eggs during a breeding season.' From these assumptions he went on to discuss the difficulties of keeping a large enough breeding herd to make infusions of eggs from the wild unnecessary. In fact these 'most favorable case' assumptions have been far surpassed. Turtles at the Cayman Farm often nest in successive years: 70% of the interseasonal intervals are only 1 year. In Surinam and Costa Rica intervals of 1 year constitute only about 5% or less of the total number of intervals. Captive turtles also nest more times within a breeding season. Overall, captive wildstock produce 2-5 times more eggs than green turtles do in the wild (Wood and Wood, 1980). A female that lays at the Farm produces an average of 493 eggs each year. So turtles could be selected to form a breeding-herd laying about twice as many eggs as Ehrenfeld's most favourable assumption of 500 every other year.

At this point anti-farmers may protest that many of the eggs are not fertile. Pro-farmers may counter that fertility rates are increasing, especially when you consider farm-reared stock that have bred over several years. Tempers rise and the debate is on. But hold it please! All that was being said was that scientific predictions are fallible, that farming turtles is a developing skill, it is still new, there are many things still to try out such as artificial insemination and hormone manipulations. Any it-can't-be-done attitude is an unimaginative basis for opposing farming. The work of discovery taking place at the farm, revealing new things about the reproductive physiology of turtles, is altering the very assumptions on which it might be attacked and is one of the reasons for staying open-minded. Much has already been learnt at the farm, and with controlled conditions, scientific facilities and animals of all ages on hand there is the potential for much more to come.

How ironic then that one of the worries raised about mariculture was the 'issue of secrecy, which may be necessary to a commercial operation, but which is repugnant to scientists who are thus obstructed in their efforts to learn more of the physiology, behavior and management of sea turtles' (Ehrenfeld, 1974). Now this kind of worry assumes there is something to be secret about, that commercial enterprises can make valuable scientific contributions. In recent years probably more has been learnt about the physiology and management of turtles at the Cayman Farm than anywhere else. As to the charge of commercial secrecy, that could perhaps be levelled at the new turtle ranch on Réunion Island for not revealing the composition of its diet (Anon., 1980a) but it does not apply to the Cayman Turtle Farm. Although some of the details of their techniques may not have been printed and circulated, much has been made available. Up to the end of 1982, there have been more than 40 published papers, and a number of theses and abstracts, that have either been based on work at the Cayman Farm (or Mariculture Ltd.) or depended on material, information, facilities or financial support supplied by them.

In addition to the ability to produce about twice the natural number of eggs, the following findings at the Farm are of particular interest. The longer mating continues, up to a cumulative total of 5 hours, the more likely that successful nesting will follow. The nesting usually occurs about 4 weeks after mating, dispelling the view that sperm storage from matings in a previous year (Carr and Hirth, 1962; see also Ulrich and Parkes, 1978) is of much importance. The minimum age to become mature for green turtles is 8 years (Wood and Wood, 1980). Though the average on the Farm is a few years longer, it is still much shorter than the 30 years or so estimated for free-living green turtles (Balazs, 1979a; Limpus and Walter, 1980). A series of papers published in the Journal of Zoology, London, give data on mating, hatch rates and clutch sizes. They discuss set-backs and difficulties as well as providing practical details such as that cleaning of eggs in sterilized water does not affect hatch rates either way (Ulrich and Parkes, 1978).

In addition to work by Farm personnel themselves, many other projects have taken place at the Farm or relied on material it supplied. Using extracts from pituitary glands, Licht (1980) and his associates have made radio-immuno assays for a number of the reproductive hormones, prolactin, luteinizing hormone (LH) and follicle stimulating hormone (FSH). The development of these assays has in turn made it possible to describe the changing hormone profiles when the turtle lays. And this in turn has made it possible to predict whether she will lay again. The surge in LH and prolactin 6-9 hours after laying is absent in turtles that do not lay again that season. More is probably known now about reproductive hormones in green turtles than in any other reptile. Besides this, the observations of skewed sex ratios in different batches at the Farm stimulated work on temperature and sexual differentiation (Chapter 6) and were later followed up by experiments there showing that temperature determines sexual differentiation in green turtles (Wood and Wood, 1982) as it does in loggerheads. Whether styrofoam-box incubation is retained, abandoned or modified, learning about reactions to temperature bears on other conservation practices, for instance the siting of hatcheries in open sunny areas (Chapter 6).

Another and particularly original project on which the Cayman Farm is co-operating is the development of 'living tags.' Government agencies in the United States are also supporting the same experiment on other turtle populations. The idea is to graft pieces of pale plastron from the underneath of hatchling turtles onto the dark carapace on the top. Being paler than the carapace tissue, the patches of plastron should be readily recognizable. The initial results, 10 months or more after the first transplants, are encouraging as the grafts seem to be growing in proportion to the adjacent tissues (Hendrickson and Hendrickson, 1981). Conventional tags attached to hatchlings either slough off or become incorporated as the turtle grows. Various other methods including tattooing (Balazs, 1978), injecting rare elements such as europium (Shoop, 1978) or inserting pieces of metal into the body (Hughes, 1971a; Schwartz, 1981) have either failed or provided a tag that can only be detected with special equipment or at dissection. Not being able to mark small turtles is one of the critical barriers to validating head-starting, assessing survival rates, discovering whether turtles return to their natal beaches and answering many demographic questions. Whether the living tag works or not, it is certainly worth a try.

Yet another line of investigation, supported by the Farm, concerns the ultrastructure of turtle eggshells and the ways in which mould penetrates through them. In the tropics each year thousands and thousands of eggs simply rot away, both in sand and in styrofoam boxes. If the mechanisms and predisposing factors for mould penetration were known, counter measures might be devised. Conserving turtles needs as good a factual base as it can get. Far from obstructing scientists in their efforts to learn more about turtles, the Cayman Farm has supported, stimulated and helped them.

But recognizing that the scientific benefits of the Farm are one of its strong points does not necessitate favouring farming of turtles on balance. There are legitimate worries on the other side of the scale. The possibility of stimulating demand for turtle products without being able to satisfy it with farm products has been mentioned already. Another concern is the difficulty of distinguishing farm products from those of turtles taken illegally elsewhere. Pieces of turtle steak look much the same whatever their origin. This is the 'look-alike problem' in the conservationist jargon, and it complicates enforcement of any prohibitions on non-farmed products. Yet another fear is that any success or approval of the Cayman Farm may lead to new farming ventures. The Cayman Farm is finally closed cycle, but new farms will have to take eggs or adults from the wild to start up.

Many negative and unpleasant things have been said about the Cayman Farm and its predecessor, Mariculture Ltd. Their initial breeding successes were discounted as the result of sperm storage by turtles that had mated before being brought into captivity (Johnson, 1980). Yet, there never has been any evidence that sea turtles store sperm for long periods. The idea was floated as a speculation (e.g. Carr and Ogren, 1960). Then, without further data, statements implying that sperm storage was a fact began appearing (Carr and Hirth, 1962; Ehrenfeld, 1974; see Frazier, 1971, for a discussion). This 'fact' was then used as a weapon against the Farm. There were others equally dubious. At the Washington turtle conference in 1979 they were accused of purveying laundered turtle products that had come from outside the Farm, but this charge was withdrawn (see Cherfas, 1979; Pickett and Townson, 1980a; Johnson, 1980). But the main doubts about turtle farming remain the stimulation of world trade, the accompanying look-alike problem if any trade is permitted and the spectre of a proliferation of farms draining rather than substituting for natural populations.

These are principally fears about what might happen in the future. There does not seem to be evidence that markets supplied by the Cayman Farm have stimulated new illegal trade. It is possible that this may have happened in some places but hard to find the evidence. Nor has turtle farming proliferated, not yet at any rate, and for a good reason: it is expensive. In Australia the cost of feed per kilogram of turtle meat produced was estimated at $6.00 Aust. (Onions, 1980). When wages, administration and transport are taken into account, the cost must be much higher. The Australian farming project was not as efficient as that on Grand Cayman. Nevertheless, it remains to be shown that turtle farming anywhere is a sound way of making money. As it stands at the moment, in 1982, the Cayman Farm is not taking turtles from the wild. It is even releasing surplus stock (Chapter 9).

In the past, of course, both eggs and adult turtles have been taken out of the wild to the Cayman Islands. It might have been preferable if the operation had begun on a much smaller and more experimental stage (Mrosovsky, 1972), only taking many eggs from the wild when methods of keeping turtles were better worked out and successful breeding accomplished. Taking 117 adult turtles from Mexico in 1976-1977 rather made a mockery of the idea that this was a farm at that time. Nevertheless, whatever the rights and wrongs in the past, in 1978, with court battles looming over the question of whether their products could be imported into the U.S.A. under the Endangered Species Act, the Cayman Farm signed an affidavit that it would take no more eggs or turtles from the wild, except possibly to prevent inbreeding.

There are things that could have been done better in the past, especially when Mariculture Ltd was starting up on the Cayman Islands. There are fears about what might happen in the future. But right at the moment the Cayman Farm is having no more than a marginal impact on turtle populations.

Even so, it might be best to strangle turtle farming in its infancy before it becomes a monster. If that is the correct conservation strategy, then maybe every means to further it should be employed including retrospective legislation. It may be that turtles have bred and laid eggs on the Farm, but under new CITES regulations adopted in Costa Rica in 1979, for Appendix 1 species to qualify for exceptions it is necessary to demonstrate the capability of reliably producing second generation animals in captivity. The first time turtles laid at the Farm was in 1973 (Simon et al., 1975) and the first time turtles raised from eggs collected in the wild laid eggs there was 1975 (Wood and Wood, 1980). With a minimum maturation period of 8 years, the earliest possible dates for second generation animals are 1981 and 1983. More probably this event would occur a few years later, around the mid 1980s, as the average time to mature is longer than 8 years. Even then, most of the turtles on the Farm would not themselves be second generation captive animals, even though no more were being taken from outside. So a legal case could be marshalled against allowing the Cayman Farm to trade Appendix 1 species. The intention of the 1979 CITES meeting was not to apply new definitions retroactively. Whether the Cayman Farm has been the victim of retrospective legislation is a moot point because individual parties to CITES are always entitled to adopt regulations more stringent than those required by the convention. Certainly the Farm has been subjected to changing standards. In 1978 the United States Department of Commerce prohibited import of all its products. An appeal by the Farm was turned down on 25 May 1979, so the ban went into effect on this date. The sentiment, expressed by Carr (1979), that the main hope of saving sea turtles lies in stopping international commerce in their products, probably has many adherents in the U.S.A. But the issue has been contested. In October 1982 a congressional sub-committee held hearings on the matter; possibly the ban on Cayman Farm products in the U.S.A. will be lifted.

In other places different attitudes towards international trade have found expression at the national level. Demonstrating the value of a renewable resource by controlled commercial harvesting could be an excellent way to ensure its preservation. The IUCN World Conservation Strategy (1980) recognizes this. Ensuring sustainable utilization of species and ecosystems that support rural communities as well as major industries is one of their objectives. And international trade often makes a resource even more valuable. There is nothing inherently better about eating turtle than selling it to someone else and using the money to buy food. The world is too complex for a simple dichotomy between subsistence hunting and commercial hunting or farming. Really there is a continuum of options as explained by Frazier (1980a):

> 'Subsistence hunting' is not easily defined. The goal of hunting is to provide food for personal use, and it is commonly assumed that the hunter will catch only what he can consume. 'Commercial' hunting is the antithesis of this approach, and here the hunter uses 'modern technology' to catch as much as possible for sale to a buyer or market. The two stereotypes are differentiated morally as well; in the paradigm of the 'noble savage' the traditional hunter is naive, innocent, and praised, the commercial one is tainted and

> denounced (although the majority of writers and critics participate eagerly—if unwittingly—in commercialized society). This dichotomy beween 'subsistence' and 'commercial' hunting is in such common usage that it affects legal regulations. Aboriginal rights in salmon fishing or Bowhead whaling are examples in which ethnic groups, because of traditional practices, are allowed to catch animals that their neighbors are prohibited from exploiting.
> However, rather than two mutually exclusive options, there seems to be a spectrum of conditions ranging from the self-sufficient hunter who consumes what he catches to the community in which different individuals with specific roles hunt, process, and distribute the catch, all based on a money economy. The extreme condition of market dependence is when the hunter will not eat his catch because it is 'too valuable' when sold. Hunting for monetary returns could be excluded from the definition of subsistence hunting, but as long as an action provides means for supporting life, it is a form of subsistence. Hence, population dependence and market dependence are not mutually exclusive.....
> An example of subsistence hunting, dependent on a market, is an incidental fishery for tortoise shell; the product is not edible and is useful only in the hands of an artisan. Yet, income from the sale of tortoise shell could provide the fisherman with funds to buy nets, boats, cloth, or grain—all necessary for subsistence.

Those hopeful about conservation through utilization may look at turtle farming rather differently. They may wish to allow it a reasonable time to become closed cycle. There has already been remarkable progress in that direction. The Cayman Farm no longer takes eggs from the wild and it shows every sign of being able to produce second generation animals in the mid or late 1980s. If this does not happen, the situation can be reassessed then. After all, the Farm was conforming with the pre-1979 CITES regulations. Those said nothing about second generation animals but only required that the animals be 'bred in captivity.' This phrase was not defined. Further confusion arose from the wording 'élevé en captivité' in the French text of the convention; this would not necessarily exclude collecting eggs from the wild and then rearing the offspring in captivity. It was excellent that the 1979 CITES meeting adopted more precise definitions of farming. Nevertheless a good case can be presented that the Cayman Farm was operating within the rules set by the convention and should not have been penalized when those rules were altered. An article by the chief executive of the

Cayman Farm, headed with the words 'The Crock of Gold' begins:

> Many people have heard the apocryphal story about the examination for a finals Economics Degree, when it was drawn to the attention of the examiner that the questions were identical to those set the previous year. 'Quite true' replied the examiner, 'but this year the answers are different.' We are reminded of these changing standards when looking at the battle Cayman Turtle Farm Ltd. has had ...
>
> (Johnson, 1980)

Whether sensitive to the unfairness of retrospective legislation or for other reasons, which doubtless included the fact that the Cayman Farm provides jobs and attracts tourists, the British government do permit import of their products.

With different countries adopting such different attitudes to the Cayman Farm, the international conservation movement gets the worst of both worlds. Any simplifying sweeping abolition of trade in sea turtles is thwarted. But at the same time the adversary litigious atmosphere sours the co-operation with the Farm. There are numerous benefits that a more positive approach might bring. These include not only expansion of scientific research using the Farm facilities but also co-ordinated efforts to control international trade. The Farm supports CITES; obviously it is in its interest to prevent competition from illegal exploitation of wild populations. It may never be possible to stop smuggling altogether, but it can be made more difficult and reduced. Customs or other officials from the importing country could be stationed on the Cayman Islands when packaging occurred. There could be agreements about restricting shipping to only one port of entry in each country. More intensive efforts to devise methods of marking turtle products distinctively, perhaps biochemically, might be helpful. And apart from regulating trade itself, there are more direct conservation possibilities such as close collaboration on Kemp's ridley between the head-starting operation at Galveston and the attempts to build up a breeding herd on the Cayman Islands. These suggestions are not inclusive or definitive, but just possible examples where co-operation might be valuable. But at present there is neither a united opposition to the Farm nor an atmosphere conducive to co-operation.

Nor is this situation likely to change much, unless perhaps the Farm goes out of business, until the whole matter of trade in endangered species is resolved. The issue of farming turtles cannot be settled in isolation. For instance what is decided about the culling and ranching of turtles is particularly relevant. There is really a continuum here from culling to ranching to farming. With culling, animals are not maintained in captivity; it is a matter of harvesting a quota from the wild. With ranching, animals are collected from the wild and then kept in captivity for a while but there is no attempt to propagate them there. With farming, animals remain in captivity throughout their life cycle. Except for starting up a farm, or to provide occasional infusions of genetic diversity, animals are not taken from the wild.

A current example of culling an endangered species is the vicuna programme in Peru. In the Pampa Galeras in the Peruvian Andes the vicuna population has built up from around 1000 in the mid-1960's to many thousands. Some culling took place but was vigorously opposed by various organizations and by Felipe Benevides, the foremost Peruvian conservationist. The controversy has ranged from the question of whether present numbers are overgrazing the Pampa Galeras reserve to an attempt by WWF headquarters in Switzerland to deny WWF Peru use of the organisation's name and panda symbol. On a loftier plane, the IUCN Bulletin (Anon., 1981b) notes:

> The debate highlights some important and as yet unresolved dilemmas in the conservation movement. Back in the mid-1960s ..... building up numbers to a point where exploitation could resume seemed an impossible dream. Could it be that some of those who are today responsible for all the sound and fury were only paying lip service to this concept? IUCN/WWF have backed the idea of sustainable utilisation from the start knowing full well that from time to time it will provoke criticisms from certain protectionist and animal welfare groups.

In fact there has not been any real challenge to the idea of culling if the vicuna population builds up sufficiently. The argument is about whether that has happened yet, and when it does who should benefit, and whether excess animals should be taken to reserves in other parts of South America before harvesting starts. The debate has become public and emotional (Sitwell, 1981), partly because of lack of firm biological data. Estimating vicuna populations is even more inexact than estimating turtle populations. In April 1980 a survey indicated that there were about 15,000 vicuna in the Pampa Galeras. Not long after another estimate gave a figure of 48,000. Virtually nothing seems to be known of the species' population dynamics and nutritional requirements. Without a higher priority for biological studies the issue is likely to remain even more contentious than it need be. Nevertheless it is accepted that the vicuna on the Pampa Galeras have recovered remarkably well. Some culling, whether now or later, should be possible.

Moving on from culling to ranching, there is the 'turtle town' at Matapica, Surinam (Schulz, 1980; Reichart, in press). Here green turtle hatchlings from nearby beaches are raised till they are a few years old. Some are taken to supply luxury hotels in Paramaribo. Some are released for head-starting. How the others will be used has not been fully settled yet. Procedures at the ranch are evolving, it is still very much in an experimental stage. However, some international trade is contemplated.

Ranching turtles in this way has a number of attractions. Capital investment for creating enclosed artificial beaches and for raising turtles for long periods till maturity is unnecessary. The use of fenced-off corrals in a creek rather than tanks offers further possibilities for economy. Tidal flushing substitutes for pumps and the initial impressions are that the turtles in the corrals are healthier (Schulz, J.P., personal communication). There are still problems to overcome. Catfish find their way in and steal some of the turtle food. More work is required to find the best local plant food to substitute for some of the Purina turtle chow or other expensive diets. Overall, however, ranching is probably much cheaper than farming. But data on the costs of different procedures are much needed. It might even be that keeping turtles in a tidal creek for a few years, without worrying about breeding, would be so much cheaper than farming that some of the money saved could support conservation work on the beach far outweighing the number of hatchlings taken for the ranch. Closed-cycle operations are not necessarily better conservation. It has to be demonstrated.

The Surinam turtle ranch is of some importance because it is one of the developments that has stimulated CITES to consider the ranching of endangered species. Is it just a coincidence that in Surinam, the country in South America with the most long-standing and effective conservation programme for turtles, covering all major nesting beaches, is also using this resource by culling the eggs and by ranching? Is there any reason why a country that is protecting, even building up its renewable resources should not reap some of the benefits by international trade? To prevent this would remove a major incentive for conservation (Reichart, in press). Recognizing this, the parties to CITES have been grappling with the problem of ranching. In 1981, at New Delhi, they drew up procedures for trade in products from ranched Appendix 1 species. It remains to be seen whether these will be used in a sensible way or to provide further bureaucratic hurdles by those opposing commercial turtle ranching. The Surinamese seem unsure about this; at any rate after the 1981 convention they entered reservations on their green and leatherback turtles. This means that, while still party to CITES, they reserve the right to trade in those particular species. It is widely accepted that the Surinam turtle programme is effective. If trade in such instances is banned, it will discredit CITES; and it would have a salutary effect if Surinam withdrew altogether from the convention.

But if ranching is allowed, then what of farming? It would be a strange anomaly if trade were permitted where animals were being taken from the wild, however cautiously, but not from a closed-cycle operation. So the issue of farming cannot be addressed satisfactorily without considering other questions. What happens when conservation is successful, when endangered species are pulled back from the brink, like the vicuna, or are well protected like the Surinam turtles? Is it possible to devise sufficiently good marking and documentation to permit regulated trade in such cases? Perhaps then it would be wise to focus not on turtle farming but on these wider questions.

Nevertheless, at meeting after meeting the farming issue, either explicitly or implicitly, dominates the proceedings, distracting attention from other more immediately menacing situations. The Cayman Farm has not made serious inroads into natural populations. From September 1969 to April 1973 the Farm took 79 adult green turtles, from Surinam, Guyana, Nicaragua, Costa Rica and Ascension Island (Simon et al., 1975). Another 14 were taken from Costa Rica in September 1973 (Ulrich and Parkes, 1978). Then 25 were obtained from Mexico in 1976 and another 92 from the same source in 1977 (Wood, J.R., personal communication). Perhaps there were a few others that have been unrecorded. A total of 250 adults is a conservative figure. That is very little compared to the estimated 10,000 turtles killed each year by the islanders of Torres Strait in northern Australia (Parmenter, 1980a, 1980b; Limpus, 1980a) or the 40,000 or so ridleys slaughtered at Escobilla, Mexico, in 1977 (Cahill, 1978). In 1979 alone, in Ecuador, 93,232 olive ridley turtles were killed for leather (Green and Hurtado, 1980); for a single year only this is more than 300 times the number of all the adult turtles ever taken by the Cayman Farm, and many of those are still alive, some laying eggs.

The Cayman Farm has also taken eggs from the wild. Unfortunately the precise number is not known because records from the first 6 collecting trips were inadequate or lost (Simon, 1975). Assuming the average for those trips was the same as for the next 7 trips, for which data are available (188,568 eggs), a total of 350,197 eggs were collected for 1968-1973. Over the next few years egg collection dwindled: 19,814 eggs were taken from Ascension Island and 60,650 from Surinam in 1974, none in 1975, then 42,830 from Surinam in 1976 and a further 33,609 and 28,173 from the same source in 1977 and 1978 (Wood, J.R., personal communication). In March 1978 egg collecting stopped. Overall in round figures some 550,000 eggs have been taken, at an average of 50,000 a year, before the operation became closed cycle. The Réunion turtle ranch is taking about 20,000 hatchlings each year now, and the Surinam ranch about 10,000 (Reichart, in press).

These may sound like large numbers, but they are unimportant compared to the natural wastage of eggs. At Les Hattes, French Guiana, at the height of the season, about 10% of nesting leatherbacks dig up eggs left by other turtles previously (Fretey and Lescure, 1979). With around 10,000 nests on that beach in 1979, and 84 eggs per clutch, that comes to a loss of 84,000 eggs. And that is just for one year and for one of the beaches in French Guiana. Turtles destroy many of each others eggs in other places in the world, on Europa Island in the Madagascar channel and at Nancite, Costa Rica, for example (Cornelius, in press). Besides this wastage, many eggs are washed away by high seas. In the Guianas about 40% of leatherbacks coming ashore site their nests below the high tide line (Mrosovsky, in press b). With green turtles the figures are not so high, but are nevertheless considerable. As a result, in Surinam, about 285,000 eggs per year would be destroyed by high tides if left where they were laid (Schulz, 1975). Many of these poorly-sited eggs are moved. In other parts of the world they may be lost. On Bramble Cay, Australia, 40% of the clutches are lost through erosion, an estimated 100,000 eggs a year; limited observations on other cays suggest similar rates of destruction (Parmenter, 1980b). So for the whole of Australia, a loss of half a million to a million eggs is not unlikely. In other places, in the southeastern United States and in the Oman for instance, many nests are inundated by high seas during hurricanes. Worldwide then the number of eggs wasted each year must run into millions. This has far more potential for conservation than worrying overmuch about the numbers of eggs taken for mariculture operations.

Moreover the numbers taken do not tell the whole story. Many of the eggs collected went toward working out turtle husbandry methods, others for scientific research and for making turtles that were later eaten. They also provided a number of jobs on the Cayman Islands. They were not wasted in the same way as eggs washed away by high tides.

Also many of the eggs taken would have been washed away had they been left in place. They were 'doomed eggs.' However, the practice of taking doomed eggs requires careful assessment. It is conceivable that scavengers subsisting off eggs exposed by high tides would be forced to raid viable nests if doomed eggs were removed. Probably most species lack the necessary flexibility in feeding methods; for instance black vultures eat exposed turtle eggs but have not been seen excavating nests. However, some species might be able to make the switch. More study of the exact fate of doomed eggs would be desirable.

A more worrying problem is that while counts of doomed eggs may look clear enough on paper, when it comes down to it, on the beach itself, it is not so simple to tell which nest is doomed and which will thrive. In only the minority of cases is it so obvious that there is no difficulty—when the turtle scoops out the nest chamber so near the sea that water seeps into it and the eggs drop in with a splash. But many nests are sited around the high tide line. Those that are below the line are in grave danger but perhaps they will only be washed over a few times and still survive, or perhaps the water will not come up so high again. Many turtle beaches are dynamic, changing even from day to day. As parts erode or are built up, waves break on them in slightly different ways. The complex interaction of beach profiles, wind conditions and tides determine how high the water actually comes. There is a high probability that a nest laid just below the last high tide line is doomed but not certainty. Under the pressure to fill a quota on a collecting trip it would be easy to err, on a dark night, in the direction of doom. That could be unfortunate not simply because viable eggs were collected but because *those particular eggs* were collected. Why should turtles swim for hundreds of kilometres and then squander their reproductive effort by not crawling a few more metres up the beach? Why, if laying eggs too near the water is as maladaptive as it seems, would it remain at such a high level in the population after millions of generations of natural selection? Laying below the high tide line is a biological puzzle. One proposed explanation runs as follows. It is true that laying near the water is a liability, but laying too far inland is also dangerous. More eggs are damaged by roots forcing their way into the nest if it is sited high up on the beach near vegetation (Caldwell, 1959). Hatchlings emerging from nests laid inland have further to travel to reach the sea. They are more liable to encounter obstructions and have difficulty orienting seaward (Mrosovsky and Shettleworth, 1975). They will therefore be exposed to predators for longer. The adults too have more trouble returning to the sea if they go far inland; sometimes they wander into hot saline lagoons behind the beach or become tangled in driftwood (Fretey, 1977). The ideal then might seem to be to lay above the high tide line but only just above it. But this too would pose problems. First, if other turtles also laid in that narrow zone, then the chances of a female having her eggs dug up by others would be greater. Second, it is very hard to predict, for the reasons mentioned, exactly how far up the beach water will come on the high tide. Faced with the pressure for not laying too far inland and the pressure for not laying too near the water, and being unable to select a spot just out of the water's reach, turtles have adopted, it is suggested, a scatter-nesting strategy (Mrosovsky, in press b). Some nests are laid too near the water and will be destroyed, others are laid too far inland and the hatchlings will be picked off by predators before they ever find the sea, but others will be just right. Perched on the crest of the beach, wetted once or twice but not enough to stop the embryos developing, the hatchlings will emerge later with only a short unobstructed stretch of sand to cross.

If this explanation is correct, then using the last high tide as a criterion to define doomed eggs might result in removal of some clutches that have a higher chance of survival than those laid further back. And if the scatter-nesting hypothesis is not correct, or only partially correct, and some individual turtles nest on average nearer the water than others, then by collecting more of their eggs, one may be imposing a selection pressure against those kinds of turtles and their genes. Until the scatter-nesting hypothesis is investigated and more is understood about laying below the high tide line, it is safest to collect only unquestionably doomed eggs. Fortunately this can sometimes be done. For instance when nests are laid at the base of a steep flood cliff and far below the high water mark, it is certain they will be washed away. Also in the mouth of the Marowijne River, separating Surinam from French Guiana, there are beaches where the water comes right up to a dense tangle of mangrove roots. With this degree of erosion there are no suitable nesting places. Yet many turtles still nest there (Schulz, 1975).

In practice, if a quantity of eggs is needed at a particular time when transport is available, collecting just doomed eggs may pose logistic problems. Sometimes, as in Surinam, it is more convenient to move poorly sited clutches as they are laid and take others for mariculture or to the market place. Biases could then arise if particular harvesting schemes were practised over many years. With possible differences between individual turtles in their selection of nest sites, and possible differences in the sex ratio as temperature varies within a season (Mrosovsky and Yntema, 1980), any non-random egg-collecting procedure has to be thought through. Probably over the relatively few years that the Surinamese have supplied eggs to the Cayman Farm and to their own markets in Paramaribo, any detrimental consequences have been far outweighed by the support for their conservation programme that these sales have provided.

Overall then, considering the help given to the Surinam conservation programme, and the knowledge that has eventuated, and that some of the eggs were doomed anyway, the numbers taken by the Cayman Farm probably have had at worst only a minor impact on present populations of green turtles. Perhaps any new farms would need to take fewer—if they did not go straight to adults, perhaps hiring them from the authorities for a limited period till their production lines were running. But some sense of proportion should be maintained. In the decade before the Cayman Farm declared itself closed cycle, it has taken a few hundred adults and about half a million eggs. Each year, however, millions of eggs are wasted naturally and maybe a few hundreds of thousands of adults killed. Conservationists should devote more meetings to such depredations and natural losses. The issue of turtle farming has been much overemphasized. And if a more positive approach to resource utilization developed, it may become still less important.

9. FOUR THOUSAND UNWANTED TURTLES

In 1980 the Cayman Farm found itself with a larger stock of yearling green turtles than it wished to hold. Changes in production schedules and the ban on imports of its products to the U.S.A. required streamlining their operation. Thinking that releasing some 4000 turtles would be preferable to killing them, Judith Mittag, one of the owners of the Farm, wrote to the IUCN advising them of their plan and asking for guidance on the release of these head-started turtles. Here is the correspondence.

DR. MITTAG VERWALTUNGSGESELLSCHAFT MBH
Düsseldorf, August 5, 1980

Mr. Robert F. Scott
Executive Officer
Survival Service Commission/IUCN
CH-1196 Gland

Dear Mr. Scott,

This is to inform you about and to ask your advice on a particular aspect of the present position of Cayman Turtle Farm.

In the near future we will most probably be faced with a certain surplus of hatchling turtles—farm reared animals, of course,—which we will have to dispose of in some way. Rather than kill them we would much prefer to sell or to release them from Cayman.

If you have any comments on this matter, we would be pleased to hear from you.

Yours sincerely,

Dr. med. Judith Mittag

INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES
Survival Service Commission
9 September 1980

Dr. med. Judith Mittag
Dr. Mittag Verwaltungsgesellschaft mbH
Am Bonneshof 30
D-4000 Düsseldorf 30
Federal Republic of Germany

Dear Dr. Mittag,

This is in response to your inquiry of 5 August 1980 on release of surplus hatchling turtles. This exemplifies one kind of problem that farming wild species generates. The present one may appear trivial, but to those who are concerned over the elementary state of sea turtle taxonomy it does not seem so. If the Cayman release were successful, it would add to the difficulty of determining affinities and differences among the green turtle populations of the western Atlantic. If the hatchlings to be released are from captive-reared females, they could be hybrids of the three Atlantic breeding colonies: those of Ascension Island, Suriname, and Costa Rica, all of which, at one time or another, have been present in the Cayman breeding crawl. The release might thus involve turtles that would either fail to breed, or would modify the natural West Atlantic strains, and thus exacerbate the troubles facing any effort to use modern, fine-scale taxonomic procedures in the systematic study of the group. Nevertheless, if the release were certain to be a single isolated exercise one might say go ahead with it—believing that so few of the hatchlings would grow to maturity that even the most discriminating biochemical tests of affinity would not be biased by their presence in the population. But there is also the precedent to consider. There are aspirant turtle farmers all over the world, and the kind of zoogeographic disarray that they could produce by indiscriminately releasing farm-bred hatchlings could completely block any effort to sort out the green turtle stocks of the world.

Perhaps the first questions to be asked are whether the genetic background of the stock to be released is known, how many turtles are involved, and what their age is? A few hundred very young hatchlings might not be worth worrying about. A few hundred yearlings of mixed origin probably would be. Situations in between those extremes would require more pondering.

Clearly the answer to your question is not simple!

Sincerely yours,

Robert F. Scott
Executive Officer
Survival Service Commission

DR. MITTAG VERWALTUNGSGESELLSCHAFT MBH
Düsseldorf, September 15, 1980

Mr. Robert F. Scott
Executive Officer
Survival Service Commission
International Union for Conservation
of Nature and Natural Resources
Avenue de Mont-Blanc
CH-1196 Gland

Dear Mr. Scott,

Thank you for your interesting letter of September 9, 1980.

In response to the question raised at the end of your letter please be informed that the excess number of turtles we are talking about is between 3,000 and 5,000 yearlings.

We are sad to learn from your comments that, with such a number involved, you would advise against releasing these turtles into the wild. At this stage, we do not have the possibility to either sell these excess animals or further keep and maintain them, so that we must otherwise dispose of them. We understand from your letter that, paradoxically enough, the killing rather than a release would be regarded as a tribute to conservationist goals which seem to focus more intently on a 'systematic study of the group' than on measures resulting in restocking of an endangered species.

Sincerely yours,

Dr. Judith Mittag

In a later letter, sent February 1981, IUCN stated that these issues were being discussed further. Indeed IUCN is still wrestling with the general subject. One danger is that precedents are set: what may be appropriate for one species in one set of circumstances may be contra-indicated for another in different circumstances. Introducing and re-introducing species to the wild have long been a concern of IUCN. An article in their Bulletin outlines some of the complexities (Anon., 1968). The reply from IUCN about the release of turtles from the Cayman Island should be assessed in the context of this official policy statement (Anon., 1968). This gives a number of examples where introductions have been calamitous. Although introducing a race or even a closely related species into an area where the local race has become extinct is comparatively free from risk, perhaps the greatest worry is that dangers are not always predictable. All the same, it is ironic that when Operation Green Turtle took green turtles from their natal beach in Costa Rica and set them free outside their normal range it was hailed as an ambitious and courageous experiment but when the Cayman Farm proposed a similar venture they were warned of causing zoogeographic disarray. Operation Green Turtle ran that risk too. It released turtles along the west coast of Florida (Witham and Carr, 1969) and on Bermuda (Burnett-Herkes, 1974), places outside the migratory range of Tortuguero green turtles as judged by tag recoveries (Carr et al., 1978). And as part of other research some hatchlings from Tortuguero, on the Atlantic coast of Costa Rica, were even taken over to the Pacific side and let go there (Carr and Ogren, 1960). Only about 20 animals were involved and the experiment proved instructive. All the same, imagine the problems for some systematist of the future if they establish a colony there. Other releases in Operation Green Turtle took place within the range of the Tortuguero colony but nevertheless some of the turtles ended up further afield. For instance a yearling released off Key West was later caught off Cape Hatteras, North Carolina (Carr and Sweat, 1969). As for those released in Bermuda, some stayed there, at least for a while (Burnett-Herkes, 1974) but for all we know others might have entered the Gulf Stream and crossed the Atlantic. Nor can the numbers of turtles involved in Operation Green Turtle, in as far as they are recorded, be automatically dismissed as trivial in their potential to affect studies of systematics. For instance, with only a remnant of green turtles nesting in Florida even a few hundred Costa Rican turtles might be enough to bias biochemical profiles if they entered the population. A recent paper (Smith et al., 1977) documents the high degree of genetic variability (strictly heterozygosity) in the enzymes of turtles collected from a beach on Hutchinson Island, Florida. It notes that Operation Green Turtle released turtles in the Indian River nearby. The implication is that conceivably some of the variability might have arisen from mixing of the stocks. Whether this is actually true or not, whether Costa Rican animals from a 1964 release would have matured by the time of the enzyme study, 1973-1975, is beside the point. Costa Rican turtles from earlier releases might have, or such turtles might in the future mingle with the Florida population. Operation Green Turtle released turtles outside their normal range or in places they would not have been at that age. These translocations, although generally less in terms of distance than those proposed by the Cayman Farm, certainly also ran the risk of causing zoogeographic disarray.

But two wrongs do not make a right. And perhaps not all conservationists agree about the merits of Operation Green Turtle and some may have changed their minds. It might be more constructive to set aside the precedent of the releases of Tortuguero turtles and ask simply whether a release now of 4,000 turtles from the Cayman Islands would or would not be desirable. It depends of course on priorities. If sorting out the taxonomic relationships of different turtle stocks is of overriding importance, then no further risks should be taken. If, however, the green turtle really is endangered, as conservationists assert, then building up stocks may be worth the risk of spoiling studies of systematics. The mixed origin of the Cayman Island animals might even be an advantage. Genetic variability is often considered desirable in restocking programmes and may help boost reproductive rates (see Smith et al., 1977).

For people living on the Cayman Islands even a remote chance of re-establishing a colony of green turtles nearby has many attractions. The islanders have a long tradition of turtle fishing, going back to the seventeenth century (Nietschmann, 1979). Without cogent demonstrations of the benefits of sorting out the taxonomic affinities of various turtle populations, releasing thousands of yearlings is obviously the preferable option to the islanders.

The idea of setting turtles free also appealed to wildlife enthusiasts, so much so that they were prepared to support it financially. The sentiments expressed by Mr. John Stoneham when he purchased a turtle from the Cayman Farm and then let it go were probably not untypical

(Anon., 1980b). He called it Sarah, after his wife, and released it with a tag inscribed: 'My name is Sarah, please put me back in the ocean where I belong.'

So altogether it was not surprising that His Excellency the Governor of the Cayman Islands, Mr. Thomas Russell, was on hand when the release took place in October 1980. A total of 1,074 turtles were liberated then. About half of these were simply set free by the Farm. For the others residents and tourists paid $5.00 for the privilege of releasing a turtle. Over the next 10 months another 897 turtles obtained their freedom in this way, making a total of nearly 2,000 (Wood, 1982). But with U.S. markets closed off and large numbers of turtles building up in the tanks, public response was insufficient for a further 3,700 excess animals. After keeping these for another 6 months, till they were about 18 months old, they were processed by the Farm in an effort to recover some of their costs (Wood, J.R. personal communication).

There remains, though, the inconsistency of conservationist opinions. When it comes to head-starting or Operation Green Turtle people are prepared to gamble. When the Cayman Farm proposes something similar, then suddenly the need for caution becomes paramount. More pondering is in order. If it is thought fit to 'commend Bermuda,' using eggs from Costa Rica and Surinam, 'for its support of the experimental effort to re-establish its extinct green turtle rookery' (Sea Turtle Conservation Strategy, 1980; see also Chapter 12), why not commend the Cayman Islands also? Such inconsistencies suggest a lack of interest in reaching conclusions on the basis of scientific considerations. Too often the science, such as it is, becomes a weapon in an underlying battle for other things. Publicity is one of those things. Perhaps jealousy comes into it also. Of course the Farm invited the media to their release of turtles. Releasing turtles, as we have seen, makes powerful appeals to the emotions. These things have to be denied to the Farm because the Farm is anathema.

10. DANGEROUS CATEGORIES

In some years the nesting of green turtles on Raine Island, Australia, is so dense that the easiest way to walk around the island is on the backs of the turtles. That is how Colin Limpus of the Queensland National Parks and Wildlife Service described it to a meeting of turtle biologists in Toronto in 1978.

Recent estimates put the number of leatherbacks coming ashore along the west coast of Mexico at 30,000 a year (Pritchard, in press). In French Guiana on the beach at Les Hattes 10% of leatherbacks dig up and destroy clutches laid previously by other females (Fretey and Lescure, 1979).

In Orissa, India, around 150,000 olive ridleys nest each year (Kar, 1980). There are also great arribadas (mass nestings) of this species in Costa Rica; within a few days more than a million eggs may be crushed by the turtles themselves, 15-30% of the total laid during a large arribada (Cornelius, in press).

Of course, numbers are not everything. Passenger pigeons were so numerous in North America in the last century that when they came in to roost the sky became dark and when they left the dung on the ground lay several centimetres deep. These sights were witnessed and recorded by, among others, James Audubon (1831):

> Every thing proved to me that the number of birds resorting to this part of the forest must be immense beyond conception.....The sun was lost to our view, yet not a Pigeon had arrived..... Suddenly there burst forth a general cry of 'Here they come!' The noise which they made, though yet distant, reminded me of a hard gale at sea, passing through the rigging of a close-reefed vessel. As the birds arrived and passed over me, I felt a current of air that surprised me....The Pigeons, arriving by thousands, alighted everywhere, one above another, until solid masses as large as hogsheads were formed on the branches all around. Here and there the perches gave way under the weight with a crash, and, falling to the ground, destroyed hundreds of the birds beneath, forcing down the dense groups with which every stick was loaded. It was a scene of uproar and confusion. I found it quite useless to speak, or even to shout to those persons who were nearest to me. Even the reports of guns were seldom heard, and I was made aware of the firing only by seeing the shooters reloading.

Well, they went on reloading all over North America and before long the passenger pigeon was extinct.

With turtles mere numbers are particularly deceptive as populations fluctuate erratically from year to year (Carr et al., 1978). The 1975-1976 season was a very poor one for turtles throughout much of Australia (Kowarsky, 1978). And yet that vast breeding aggregations can occur, in Australia, India, Costa Rica and Mexico, for instance, makes it at least respectable to question whether turtles really are endangered.

But what does being 'endangered' mean? There are 2 senses of the word. There is the general sense with which we are familiar and there is the endangered category enshrined by the Red Data Books of the International Union for Conservation of Nature and Natural Resources (IUCN). In Volume 3 (1968-1970, covering Amphibia and Reptilia), endangered was defined as follows:

> In immediate danger of extinction: continued survival unlikely without the implementation of special protective measures.

When this volume was revised in 1975, this definition was replaced. It was no longer necessary for the danger of extinction to be immediate. Endangered now meant:

> Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating.
> Included are taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction. Also included are taxa that are possibly already extinct.

A footnote pointed out that in practice the endangered category may include, temporarily:

> taxa whose populations are beginning to recover as a result of remedial action, but whose recovery is insufficient to justify their transfer to another category.

This definition is much broader than the previous one. It encompasses species possibly already extinct, those in immediate danger of extinction, those in danger at some later time and those beginning to recover. Therefore to say that a species is endangered may suggest urgency but is not very informative. With sea turtles, leaving aside the perilously diminished Kemp's ridley, considered earlier in Chapter 7, when the details are examined there are reasons for doubting that most are in immediate danger of extinction. Let us look at them in turn.

Green turtle *(Chelonia mydas)*

Estimates of turtle populations are best given in terms of adult females. These can be counted when they come ashore to lay their eggs. Males are seen much less often and nobody knows what the sex ratio is. There are also many juveniles and hatchlings, especially just after the nesting season, but these are seldom observed after they enter the water. The number of breeding females, or adults of both sexes, assuming a 1:1 ratio, can still be used to compare different areas and species, and to assess population trends.

For the green turtle this can only be done on a regional and limited basis. There are not even semi-solid data on world populations. In 1974 Ehrenfeld estimated there were between 100,000 and 400,000 adult males and females. Five years later, Pritchard (1979a) suggested that they might number in the millions. Most probably there are now more than 400,000 mature green turtles. Assuming a 1:1 sex ratio, in the Arabian area alone there are thought to be around 109,000 mature green turtles (Ross and Barwani, in press), in the western Caribbean another 63,000 (Carr et al., 1978). Then there are the massive green turtle populations in Australia. But more important than there still being a fair number of these turtles is that their nesting beaches are widespread. They have not, like the passenger pigeon, put all their eggs into 1 or 2 national or environmental baskets. An atlas of sea turtle nesting beaches issued by the Sea Turtle Rescue Fund shows 144 nesting sites for green turtles; 41 of these are considered major (Sternberg, 1981). The atlas is careful to point out that it is not definitive. It is vague on what constitutes a major and minor nesting site and also on what constitutes a site; nesting at several points along a coast line could be scored in various ways. Nevertheless, without putting emphasis on the precise figures, it is incontrovertible that the green turtle still nests in many different parts of the world.

But there are more cogent reasons, beyond the numbers left and the widespread nesting, for thinking that the green turtle is not in immediate danger of extinction. Like some other sea turtles, it is not a species whose hold upon this Earth is especially precarious. Despite intensive exploitation over several hundred years in the Caribbean there are still some green turtles left there. They have been drastically reduced, to be sure, but the real wonder is that there are any left there at all. They are survivors against great odds (Hughes, 1979). Laying so many eggs, sometimes on remote islands or inaccessible beaches contributes towards this biological resilience. Of course if all breeding females are killed year after year, then populations can soon be wiped out. Coming ashore to lay eggs is a liability; sea turtles are not aggressive and can easily be killed or turned over and dragged away. Turtles cannot withstand that kind of pressure any more than other species. There are limits to their resilience.

Finally, it should be remembered that green turtles will breed in captivity (Wood and Wood, 1980). They will sometimes lay eggs in zoos, and even in places as seemingly unpropitious as the cave at Devil's Hole Sink in Bermuda (Wingate, 1980). Their requirements for nesting areas are not dauntingly stringent. Mating may sometimes present more problems but there is the possibility of artificial insemination, now being studied at the Cayman Farm. Breeding in captivity does not necessarily safeguard the species. Captive stock have to have sufficient genetic variability to be viable. There are dangers of disease. But at least it is something to fall back on if the species really plunges to dangerously low levels in the wild.

In summary then, green turtles still exist in fair numbers, spread out in different parts of the world. They are biologically resilient and they breed in captivity. These points are well known and hardly add up to an immediate danger of extinction. Yet the public are told otherwise. A pamphlet sent out by the Sea Turtle Rescue Fund in 1981 says that the slaughter of sea turtles is of 'such magnitude that extinction looms only a few years away' and that sea turtles other than the flatback 'without immediate help will soon disappear from the face of the earth.' According to material accompanying a 1980 Cleveland Museum of Natural History exhibition of confiscated wildlife products, 'if present trends continue, this sea turtle [the green turtle] will become extinct by 1983.'

What about trends then? There may still be plenty of green turtles left, but if they are declining very rapidly, if the present 'causal factors continue operating,' then there might soon be none and an alarmist position would be justified. Trends in turtle populations are difficult to assess because of the huge fluctuations in nesting from year to year and because few colonies have been monitored for long enough. The best studied green turtle populations are at Tortuguero in Costa Rica and in Surinam. If anything there are upward trends at both these places (Figures 4 & 5), but because of the problem of erratic fluctuations a more cautious statement is preferable: between 1971 and 1980 there was no downward trend in the numbers nesting at Tortuguero (Carr et al., 1978) and between 1968 and 1978 there was no downward trend in Surinam either (Schulz, 1980). There is no way that projections of regression lines for these data would intercept zero in a few years.

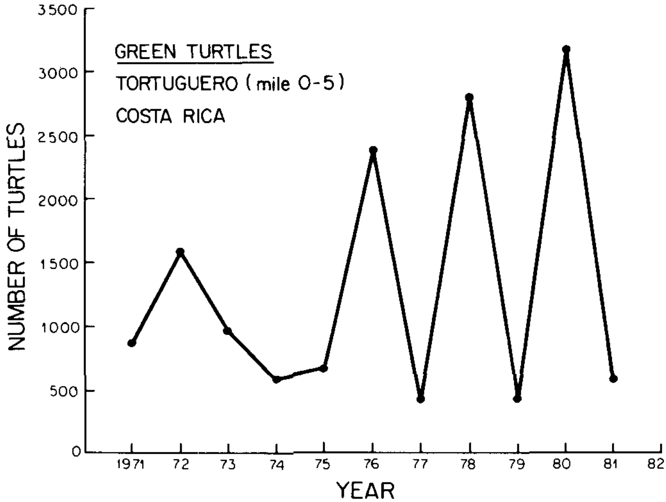

Figure 4. Numbers of green turtles (tagged remigrants plus newly tagged recruits) emerging on a 5 mile study area at Tortuguero, Costa Rica (data from Carr et al., 1978, Carr, 1980b and personal communication). The 5 mile (8 km) stretch is part of a 22 mile (35 km) long beach. The numbers nesting over the whole beach are much greater; for example in 1980 it was estimated that 52,046 turtles nest over the whole beach (Carr, 1980b). Because such estimates involve assumptions, data for the 5 mile stretch are better for showing trends.

But not too much faith should be placed in trends with species that mature slowly and live long. To take an extreme example, suppose from a certain day, forever after, every single egg laid on a given beach failed to hatch. With continued breeding by already adult turtles and with hatchlings and juveniles from previous seasons coming along, it might take years before counts of nesting turtles revealed the disaster. By the same token, of course, stable or even declining nesting on beaches where turtles have been afforded protection could conceal a dramatic upsurge around the corner. So ideally information about population dynamics and age structure is needed to interpret trends. In an attempt to go beyond counts of nesting females, Bjorndal (1980b) has calculated the chances of adult green turtles at Tortuguero surviving in successive years from 1959 to 1972. The increasing death rate in recent years suggests that the situation there is less sound than the trends might indicate. However there are difficulties in assessing survivorship. Turtles not seen again, when remigrating to the beach or when caught elsewhere with a tag later, were assumed to have died in the first year after nesting. But they might have lost their tags or they might have nested again on the long sections of the Tortuguero beach not routinely patrolled (Pritchard, 1980). Turtles do not always return to exactly the same spot for nesting and with changing beach topography nest-site fixity might vary in different years. Nor can it be assumed that different teams working the beach in different years apply tags with equal skill. With slopes of survivorship curves depending so much on the relatively few turtles seen again, such factors could become important. Certainly the number of nests over the years does not tell the whole story, but what it does tell is relatively free of assumptions. In 1980 Tortuguero had its best year ever since monitoring began. That does not suggest a population heading toward extinction.

Information for a number of other important green turtle rookeries is less adequate. There have been several expeditions to Europa Island, in the Madagascar channel, but methods, months of the year covered and extent of the island surveyed differed. In a recent study there, the mosquitoes proved too nasty for the investigators and night work was limited. The numbers of new tracks seen each morning were the main data. As turtles often come ashore and return to the sea without laying, tracks cannot be equated with nests. Nevertheless, track numbers can be used for comparative purposes. The number of tracks made on the Plage de la Station for the month of November, near the height of the nesting season, for different years was:

1970:	52 per 24 hr	(Hughes, 1974a)
1973:	6 per 24 hr	(Servan, 1976)
1978:	24 per 24 hr	(Lebeau et al., 1979)

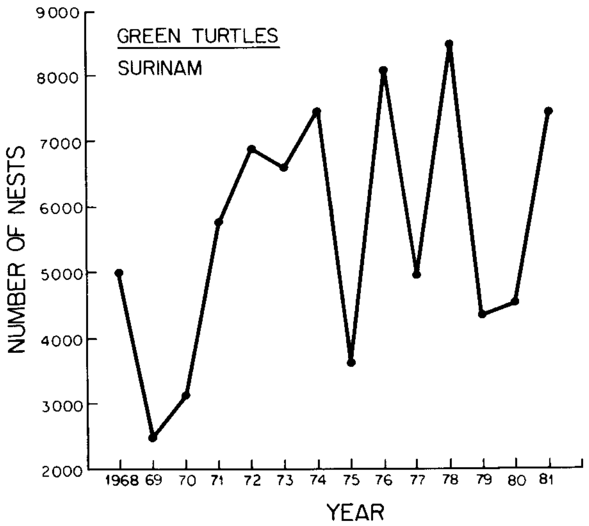

Figure 5. Numbers of green turtle nests on all the main nesting beaches in Surinam. Data from Schulz (1980) and Reichart, H.A. (personal communication). Individual turtles lay several times in a season so the number of turtles is less than the number of nests.

It is impossible to say whether these figures are just part of the now expected year to year fluctuations in nesting populations or whether, with an estimated 7,000 turtles of all sizes being taken each year around southwestern Madagascar (Hughes, 1971b), there has been a decline. The number of turtles emerging each night on the whole of Europa Island is more than 10 times the number of the Plage de la Station (Hughes, 1974a; Servan, 1976) so there were still many turtles left in 1978. Although recently some hatchlings have been collected for ranching, in the order of 20,000-30,000 a year (Chapter 14), the available data for this colony do not demonstrate a sustained decline.

The same is true of Raine Island, Australia. In fact in Australia as a whole, there is no reason to suppose that green turtle populations are crashing (Limpus, in press). Consideration of these few areas alone is enough to show that disappearance of the green turtle in the next few years is unlikely.

But that does not mean that everything is satisfactory, far from it. Even if over the last 2 decades or so some populations have held their own, others have declined dramatically in historical times. Audubon (see 1926), as well as writing about passenger pigeons and other birds, left accounts of green turtle nesting in Florida. 'Great numbers,' he wrote, 'are killed by the Turtlers and Indians, as well as by various species of carnivorous animals, as cougars, lynxes, bears and wolves.' He also described the activity of 'Eggers' and the construction of crawls to keep the turtles alive until they were wanted. Clearly there was a major green turtle resource in Florida in the last century and this is now virtually gone (Rebel, 1974). The same has happened in the Seychelles. In the early 1900s, on Assumption Island, 200 or more green turtles came ashore in a single night (Hornell, 1927). Now there are only about that number of nests in a whole year (Frazier, 1975). And numbers are down throughout much of the western Indian Ocean. It is estimated that fewer than 5,500 green turtles nest annually in an area of more than a million square miles (Frazier, 1975). Attempts to portray these declines quantitatively for a particular island, Aldabra Atoll, have been made (Frazier, 1974, 1976) but criticized as being much exaggerated (Stoddart, 1976). Because beaches were not patrolled over a number of years, accurate assessments of what happened may never be possible. But to present some balance to the apparently healthy state of the Tortuguero and Surinam green turtle colonies, Figures 6, 7 & 8 show the declines in export of green turtle products from the Seychelles and the decline in egg production on the Turtle Islands in East Malaysia. Even in places where turtles are still taken in large numbers there may be hidden problems. For instance the annual catch of green turtles around St. Brandon, Mauritius, held up surprisingly well from 1937 to 1971 (Hughes, 1976), but if the figures have been maintained by increased and more efficient fishing, as seems likely, then they conceal a population decline. And East Pacific green turtles nesting in Mexico are currently under severe pressure (Pritchard and Cliffton, 1981). So there certainly have been drastic declines and some colonies of green turtles may soon be lost completely. But even if they are, with some 144 nesting sites at present (Sternberg, 1981), this would not put the species in immediate danger of extinction.

As to less immediate danger, the 'if the causal factors continue operating' part of the Red Data Book definition of endangered, this too is debatable because some of the present factors affecting green turtles

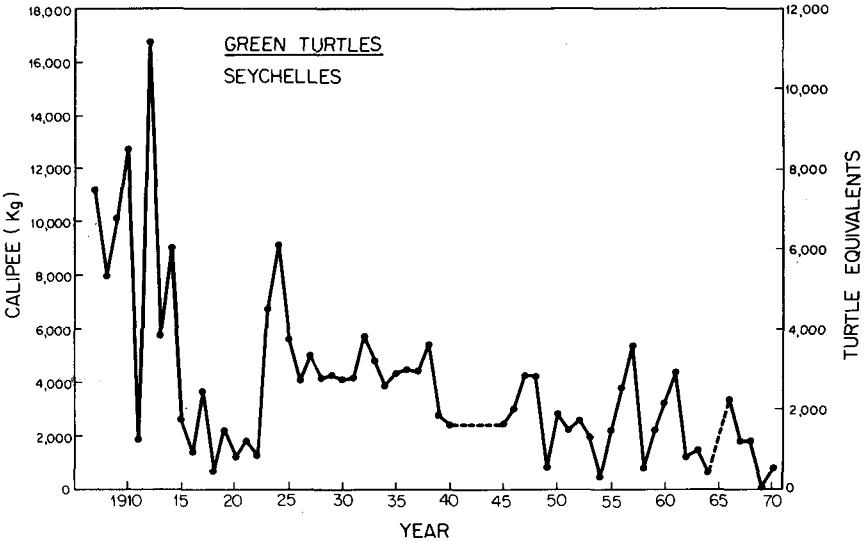

Figure 6. Exports from the Seychelles of calipee (part used for making soup) and equivalent in green turtles assuming one turtle provides 1.5 kg of calipee. Data from the Blue Books, Trade Reports, Seychelles, cited by Stoddart (1976).

are favourable. Some major populations of the species, in Costa Rica, Surinam, Europa Island, Australia, Malaysia and the Galapagos Islands receive at least a measure of protection. Tortuguero is a national park though fishermen are allowed to harpoon turtles beyond a certain offshore limit. In Surinam most of the turtles nest within the boundaries of nature reserves; populations are monitored and quotas of eggs taken and sold in the market can be adjusted accordingly. Europa is protected as much by the island's inaccessibility and fiendish profusion of mosquitoes as by regulations, though these exist. In Australia aborigines have traditional rights but otherwise taking turtles is illegal; the Raine Island green turtle rookery, the most important nesting site for green turtles there, lies among poorly-charted reefs way out in the Torres Strait and is difficult to reach (Lavery et al., 1980). There is no evidence that numbers of green turtles at any of these places are declining. If whatever causal factors responsible for this situation continue

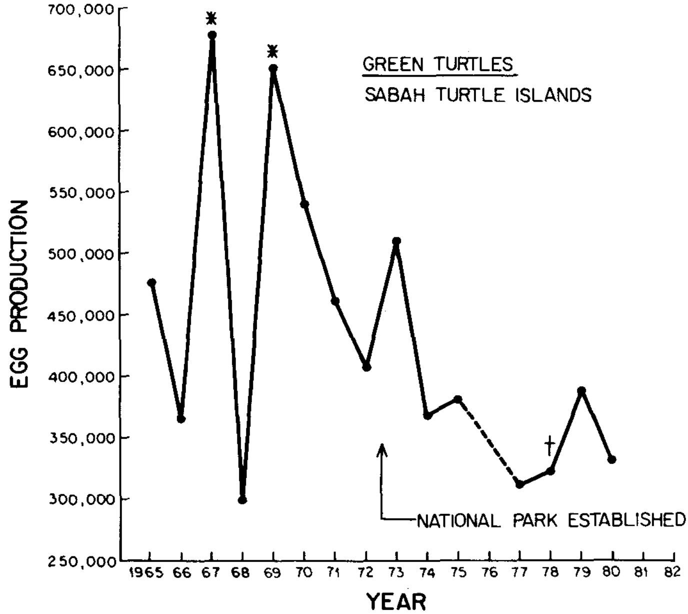

Figure 7. Egg production on 3 of the Sabah Turtle Islands (Selingaan, Bakkungaan Kecil and Gulisaan). Nearly all are from green turtles but a few from hawksbills may have been included. Prior to 1973 eggs were harvested under licence; a small percent were put into hatcheries. Some figures may be inaccurate because licencees tend to under-report the number of eggs they take. After 1973 most eggs were transplanted to hatcheries. *harvest checked by government personnel. †some stolen eggs not included. Data from de Silva (in press, personal communication).

operating, what is the basis for the IUCN Red Data Book classifying this species as endangered? In fact, a draft version (1982) for a revised data sheet for the green turtle tentatively changed its status to vulnerable, but after some debate the latest Red Data Book (1982) edition left this species in the endangered category.

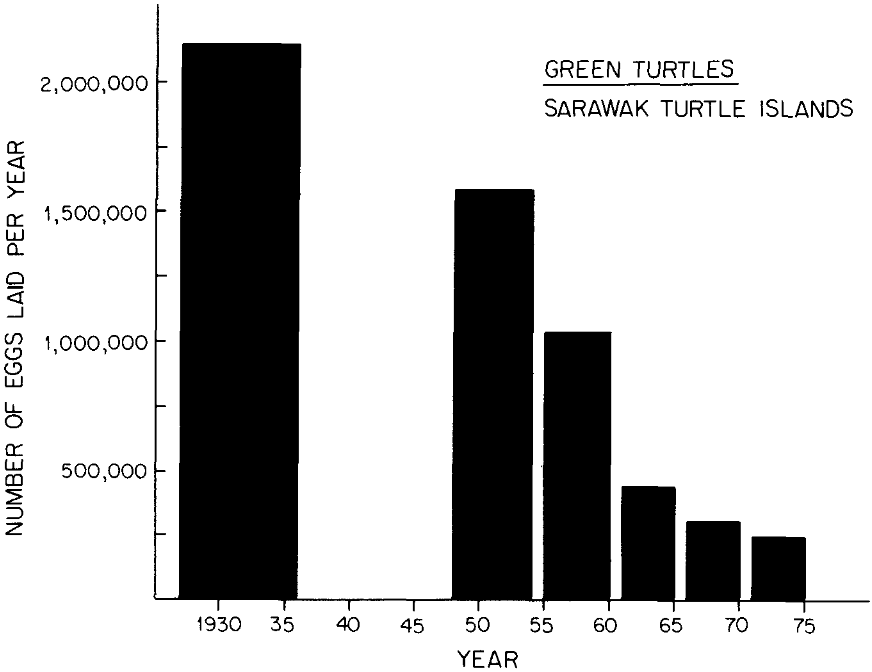

Figure 8. Number of eggs laid on the Sarawak Turtle Islands, East Malaysia. Each bar shows annual averages based on different number of years. Data from Harrisson (1976).

Hawksbill *(Eretmochelys imbricata)*

The hawksbill is also currently listed as endangered by the Red Data Book and was so even in 1970, before the definition of this category changed. This implies that the hawksbill is considered in immediate danger of extinction, unless the prospects for this species suddenly happened to brighten around the time the definition of endangered changed in 1975, and nobody has asserted that.

The main demand for hawksbill stems from the value of its shell. Japan imports large quantities, for instance more than 40,000 kg a year from 1976 to 1979; this is equivalent to more than 44,000 animals a year (Anon., 1977; Mack et al., in press). The meat is also sometimes eaten but there have been a number of cases of poisoning, some fatal, and so the hawksbill is not as widely sought after for food as the green turtle.

Hawksbills often nest on small beaches on islands or isolated coves. There are no historical accounts of huge breeding aggregations of this species, though it may well have nested at greater densities than is common today. Perhaps the largest remaining populations are in the Torres Strait where rookeries with up to 100 turtles emerging on a single night have been mentioned (Bustard, 1974). But no further details were given and on most of the islands along the Great Barrier Reef only a few hawksbills nest each night (Limpus, 1980b). Elsewhere 'major' hawksbill colonies today only have in the order of 100 turtles nesting over the whole season (Ross and Barwani, in press). Sparse scattered nesting makes it harder to protect the species' breeding but it also makes it harder to exploit and exterminate whole colonies rapidly. However with increasing availability of outboard motors and current prices for the shell, it is easy and profitable for individuals to search for hawksbills in remote places. In the Seychelles a good-sized animal sells for the equivalent of a labourer's wage for a whole month (Garnett, 1978), so pressure on the species continues.

Has this brought it to the verge of extinction yet? Because of their low nesting densities, hawksbills are not attractive for investing time in the kinds of long-term detailed studies that have been made on the other sea turtles. So, for example, there are few data on nest-site fixity and it is not possible to assess what the likelihood is that following elimination of hawksbills from one area others will move in from adjacent places. Population estimates also become exceedingly difficult.

Nevertheless, even if not numerous, the hawksbill still occurs in many parts of the world. Sternberg's (1981) atlas lists 95 nesting places. As with green turtles, the exact number is not important because it depends on definitions, but it is clear that hawksbills still breed in many parts of the world. With this kind of distribution, even if some colonies disappeared altogether, the species could still survive. 'Immediate danger of extinction' seems rather an exaggeration.

As for trends, detailed data of the kind obtained for some green turtle rookeries, spanning a decade or so, are only available for 2 hawksbill breeding areas, both protected. In neither are declines evident (Figures 9 & 10). But hawksbill nesting in Surinam is minor; and on Cousin Island the increase since a resident warden was installed could be the result of turtles moving in from other areas. Hawksbills do not always nest on the same island in the Indian Ocean (Diamond, 1976). Yet that nesting on Cousin Island has not actually decreased is encouraging because protection there is only partially effective and many reproductive females are killed throughout the Seychelles, as many as half the breeding population each year according to some tentative estimates (Garnett, 1978). Despite these pressures the latest surveys find that hawksbills are 'still relatively numerous' in the Seychelles (Mortimer, 1982).

However, if one bases more on general reports of declining numbers of hawksbills throughout the world, and if the demand for shell goes unabated or undiverted, then there is some danger the species will become extinct. Certainly control of exploitation of the hawksbill is urgently needed.

Olive ridley *(Lepidochelys olivacea)*

The nesting strategy of this species is very different from that of the hawksbill. Instead of scattering over wide areas, it specializes in huge arribadas of thousands and thousands of animals all stranding at the same time. Synchronous nesting makes the olive ridley a tempting target for exploitation and poachers. As many as 500 a day have been killed at Escobilla, Mexico, as they gather offshore for nesting (Cahill, 1978; Pritchard, 1978). Even away from the nesting grounds many olive ridleys have been taken in recent years, in the order of 100,000 a year in the late 1970s by the Ecuadorian leather industry (Green and Hurtado, 1980). That Ecuador was a member of CITES did not prevent the products being exported.

Many eggs have also been taken. Prior to 1967 nearly all of those laid at Eilanti, Surinam, were collected by Carib Indians who divided up the beach among themselves for this purpose. Competition for eggs was so intense that the proprietors of a particular section used to go out with brooms and sweep the beach clear of any debris that might discourage turtles from nesting there. Many eggs have also been taken in Mexico. Mass nesting also attracts animal predators. Coyotes, racoons and opossums dig up the eggs; black vultures and ghost crabs attack the hatchlings. On the 1,300-m beach at Nancite, Costa Rica, there are about 2,800 ghost crabs large enough to catch a hatchling; that means there is a crab for every half metre of beach (Hughes and

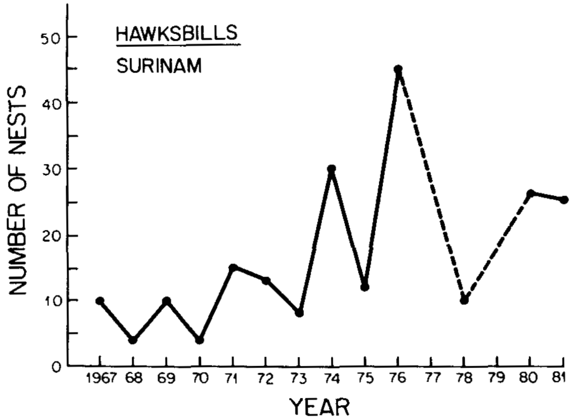

Figure 9. Number of hawksbill nests in Surinam (Bigisanti and Galibi beaches). Data from Schulz (1980) and Reichart, H.A. (personal communication).

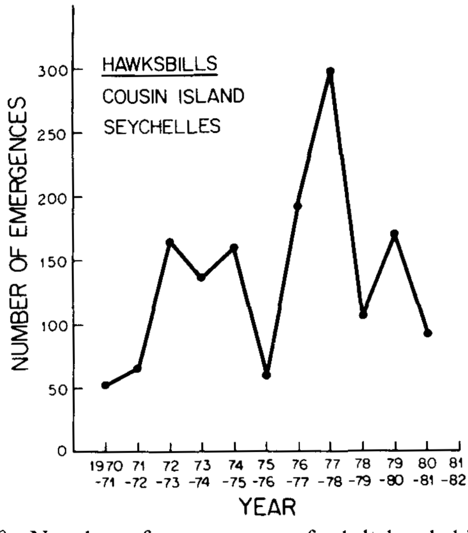

Figure 10. Number of emergences of adult hawksbill turtles on Cousin Island, Seychelles, since a resident warden was installed there by the International Council for Bird Preservation (ICBP). Both the number of nests and the number of turtles making those nests are smaller because turtles often return to the sea without laying and individuals can lay several times. Data from Garnett (1978), Diamond (1976 and personal communication) and reports of the Scientific Administrator (ICBP), Cousin Island. There are some minor discrepancies between these sources. The main nesting season is from September to February each year.

Richard, 1974). But with the vast numbers of baby turtles emerging, some manage to reach the sea. Satiation of predators is presumably the survival value of arribadas. The ridleys put all their eggs into one basket, but they make it so heavy that the thieves cannot carry it away, or not all of it.

But as a strategy to satiate predators mass nesting may perhaps have a serious biological weakness. Going back to pigeons for a moment, the courtship displays of the male bird are able to initiate ovulation in the female (Erickson and Lerhman, 1964). Such stimulation, and this is speculation, could have been especially important in triggering and synchronizing breeding in the passenger pigeon. If so, once their numbers fell below a certain threshold value, even though they were no longer worth going after with guns, there might have been too few to create the necessary excitement for breeding, and recovery would have been impossible. Perhaps something like this occurs in turtles. It is not known whether the timing of arribadas depends on propitious weather or on some kind of agreement among the turtles offshore, some urge to move inland that is induced by the very intensity of stimulation from the great numbers of other turtles. Strong offshore winds have been thought to be involved (Pritchard, 1969; Schulz, 1975), but their association with arribadas does not hold up in Costa Rica (Hughes and Richard, 1974; Cornelius, in press). Moreover the arribadas at Nancite and Ostional occur at different times, even though these beaches are only a 100 km apart and subject to similar tidal and weather regimes (Hughes and Richard, 1974). It is conceivable therefore that despite their great numbers, even because of them, olive ridleys have a more precarious hold on Earth than hawksbills. However, ridleys do come ashore in small clusters or individually in places, for instance at Bigisanti in Surinam and at Nancite, though in the latter case the number nesting singly or in small groups is less than 1% of that at arribadas (Hughes and Richard, 1974). But it is disquieting that despite having received considerable protection since 1967 (Pritchard 1979a; Schulz, 1975), the number of Surinam ridleys is dwindling (Figure 11). Is incidental catch by shrimping vessels taking more than protection on the shore saves? Or, following erosion of the beach at Eilanti (Schulz, 1975), have they moved not to other beaches in Surinam but elsewhere? Or have they fallen below a critical number necessary to sustain themselves? But too little is known about arribada formation to pursue these speculations.

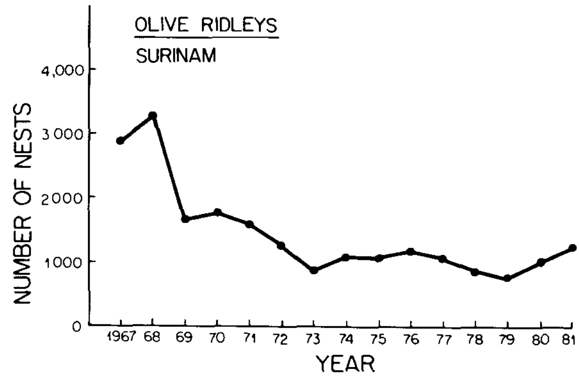

Figure 11. Number of olive ridley nests in Surinam (Bigisanti and Galibi beaches). Individual turtles sometimes lay more than once in a season so that the number of turtles is less than the number of nests. Data from Schulz (1980) ant Reichart, H.A. (personal communication).

Whatever is responsible for arribadas and whatever untoward is depressing the Surinam ridleys, there remain huge numbers elsewhere. At the Gahirmatha rookery in Orissa, India, there are 100,000 nesting turtles a year (Kar, 1980) and at Nancite, Costa Rica, 96,000—the average of 3 arribadas in 1971 (Hughes and Richard, 1974). These estimates may be inflated by some turtles returning to the sea without laying and then reappearing on shore the next day (Cornelius, in press). The multitide of turtles arriving at the same time saturates the biologists as much as the predators and makes it impossible to keep an accurate tally on everything. Even so, there are surely tens of thousands of individual females nesting at Gahirmatha and Nancite and another huge arribada in Costa Rica at Ostional (Richard and Hughes, 1972). Reports are just coming in of a second mass nesting site in Orissa (Kar, 1982) and there are 45 other places in the world where the species nests in lesser numbers (Sternberg, 1981). To call the olive ridley endangered is a poor way of reflecting these facts.

Nevertheless, even if the species is not about to become extinct, there are serious problems. True, the arribadas at Nancite and Ostional

(Robinson, 1982) benefit from a considerable measure of protection; and at Gahirmatha egg collection has practically stopped but adults are still being taken at sea there (Kar, 1980; Bhaskar, in press). Further north, at Digha in West Bengal, large numbers of ridleys are being slaughtered (Bobb, 1982). Altogether there is a flourishing illegal fishery of ridleys off the coast of West Bengal, Orissa and Andhra Pradesh (Bhaskar, in press). In Mexico, at Escobilla, there is a huge harvest of breeding females and many biologists consider the quotas far too high (Chapter 14). In Ecuador the ridley leather industry was officially closed in 1981 (Hurtado, 1982) and exports are well down from the record high of more than 130,000 in 1979. However, in 1981 skins from more than 56,000 turtles were still exported from Ecuador; it appears most of these originally came from a turtle fishery in Colombia (Hurtado, 1981). Many of these developments are recent and their outcomes unsettled. With vast numbers of olive ridleys still remaining, there are tremendous and pressing opportunities for conservation.

Leatherback *(Dermochelys coriacea)*

In the 1960s the leatherback colony at Trengganu, Malaysia, was the only known one of any importance. With that running at only 1,000-2,000 nesting adults a year, it was felt to be the species' last stand against extinction (Wyatt-Smith, 1960). Since then many other breeding populations have been discovered, some of them far larger than that at Trengganu. In French Guiana 5,500 females nest each year (Fretey and Lescure, 1979), in Mexico as many as 30,000 (Pritchard, in press). A new colony has just been found in Irian Jaya, Indonesia, rivalling the one at Trengganu in size (Salm, 1981). There are numerous minor nesting sites. Sternberg's (1981) atlas lists a total of 64 leatherback beaches.

Obviously the critically endangered three-star listing of 1968-1970 for the leatherback is no longer appropriate. But there remain at least 5 prominent adverse factors for the species:

1. The discovery of the huge breeding aggregation off the west coast of Mexico has a darker side: several hundreds of nesting females are being killed on the beaches there each year (Pritchard, in press).

2. Contrary to what has been often said and thought, leatherback meat is widely eaten (Mrosovsky, in press a). There is even a village, perhaps several, in Indonesia where a subsistence culture revolves around hunting leatherbacks: at Ohedertutu, Kai Cecil, the islanders kill about 100 adults a year (Compost, 1980). However, although leatherbacks are widely sought at local levels for their meat and oil, there are no large-scale commercial operations for their products.
3. In addition to the excessive egg harvest in Malaysia, leatherback eggs are collected on many other beaches.
4. Like other sea turtles, they are victims of accidental entanglement in fishing gear and many are drowned.
5. Unlike other sea turtles, leatherbacks are exceedingly difficult to keep in captivity. Self-inflicted injuries when they swim incessantly against the walls of their tanks are a particular problem. It is unrealistic to think that breeding leatherbacks in aquaria or farms is anything to fall back on if disaster overtakes them in the wild.

To what extent these adverse factors are depressing leatherback populations is unknown. In 2 places where leatherbacks are protected and have been studied for a number of years, Tongaland (South Africa) and Surinam, numbers nesting are stable or even increasing (Figures 12 & 13). But not too much should be made of these cases. The Tongaland rookery is a minor one, right at the southern edge of the species' breeding range, and the Surinam leatherbacks cannot be considered in isolation from those in French Guiana because there is interchange between beaches in the 2 countries (Schulz, 1975). Monitoring on the French side has not been going on for nearly as long as in Surinam (Figure 13). Moreover, the Tongaland and Surinam cases can be offset by a probable decline of leatherbacks in Malaysia. It is impossible to assess the situation there accurately because much is based on reports from the licensed egg collectors and they have reasons for falsifying the data: if their stretch of beach yields fewer eggs they may be able to hire it for less the next year. However, one estimate gives a 66% decline in egg production between 1956 and 1978 and there are reasons for thinking that this was not just because 1978 was a poor year (Siow and Moll, in press; Mrosovsky, in press a).

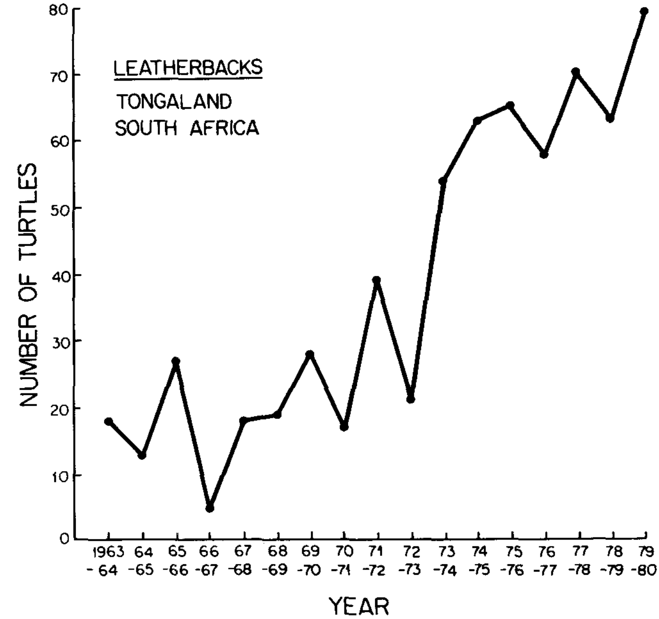

Figure 12. Number of leatherback turtles (remigrants plus new arrivals) seen in Tongaland, South Africa. The main nesting season is October-January. In 1969 the area routinely patrolled was increased from 32 to 56 km. Data from Hughes (1974b, in press a and personal communication).

With a generally positive situation in Tongaland and Surinam and a deteriorating one in Malaysia, and trends elsewhere mostly unknown, it is fair to say that 'certainly it is impossible to document an overall decline, and indeed the more we seek them, the more leatherbacks we find' (Pritchard, in press).

Although little is known about trends, there are now 2 recent estimates for the total number of mature female leatherbacks in the world, 115,000 (Pritchard, in press) and 70,000-75,000 (Mrosovsky, in press a). Agreement is somewhat better than for vicuna population estimates and quite encouraging considering different assumptions were made in deriving total numbers of individuals from numbers of nests in one year. The agreement on the numbers of nests in a year is closer.

So we have a species with many and widely distributed nesting sites, not demonstrably declining, and a world population in the order

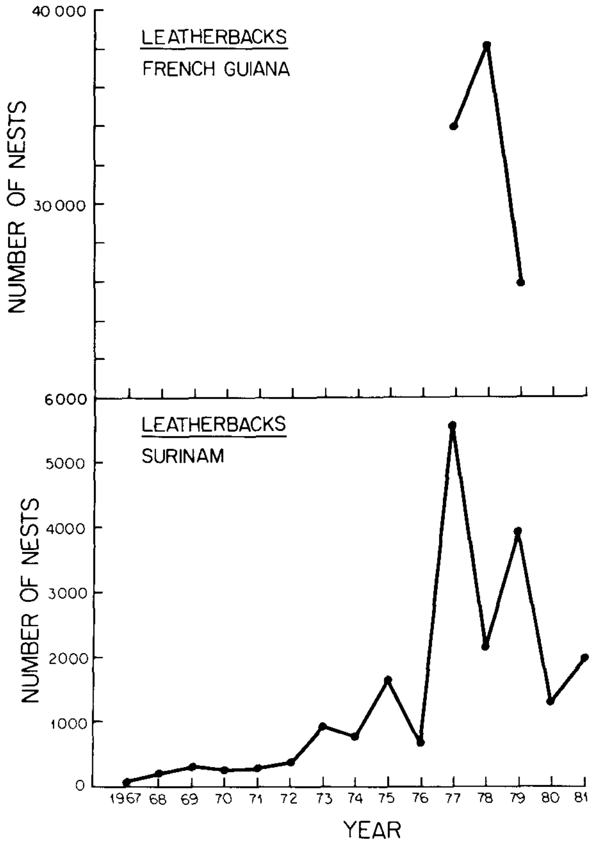

Figure 13. Number of leatherback nests in Surinam (data from Schulz, 1980 and Reichart, H.A., personal communication) and in French Guiana (data from Fretey and Lescure, 1979). Note that the scale for the two areas is not the same.

of 100,000 mature females. Endangered?

Yes, says Pritchard (in press), though tentatively: 'on consideration of all available data, I am inclined to believe that endangered status for the leatherback is still justified.' No, contends Mrosovsky (in press a): the appropriate category is vulnerable, not endangered. The 1975 Red Data Book defines vulnerable as follows:

> Taxa believed likely to move into the endangered category in the near future if the causal factors continue operating.
> Included are taxa of which most or all the populations are *decreasing* because of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously *depleted* and whose ultimate security is not yet assured; and taxa with populations that are still abundant but are *under threat* from serious adverse factors throughout their range.

The last sentence sums up the leatherback's present predicament, as far as it is known, and also that of some of the other sea turtles. But the latest edition of Red Data Book (1982) retains the endangered status for the leatherback.

Loggerhead *(Caretta caretta)*

The loggerhead is also classified as vulnerable and rightly so. It does face several threats. When feeding off crustaceans and molluscs on the bottom of the sea it comes fairly close inshore and is liable to be swept into shrimping trawls and held under water. Off the coast of Georgia, U.S.A., an estimated 778 turtles were drowned in 1976 (Hillestad et al., in press). This figure does not even reflect catches by vessels fishing off Georgia but unloading elsewhere. If 778 turtles are drowned off just one state, then shrimping in the U.S.A. as a whole, including the Gulf of Mexico, probably accounts for several thousand loggerhead turtles each year. Most of these are sub-adults.

Loggerhead nesting habitat is also being destroyed by sea walls, motorways and condominiums. 'Photic pollution' disorients the hatchlings. Many eventually find the sea but others are attracted inland and crushed on the highways (Mann, 1978). Even in more isolated areas such as Little Cumberland Island where turtles have been totally protected for almost 20 years and many eggs saved from racoons, nesting has not yet obviously increased (Figure 14). Perhaps this is only because a long maturation time has delayed the appearance of the beneficial effects of the conservation programme there (Richardson and Richardson, in press).

If these various threats cannot be kept in check and numbers nesting decline, the option of transferring the species to the endangered category remains. But at present the loggerhead is widely distributed with 64 listed nesting beaches (Sternberg, 1981). Most of these are in

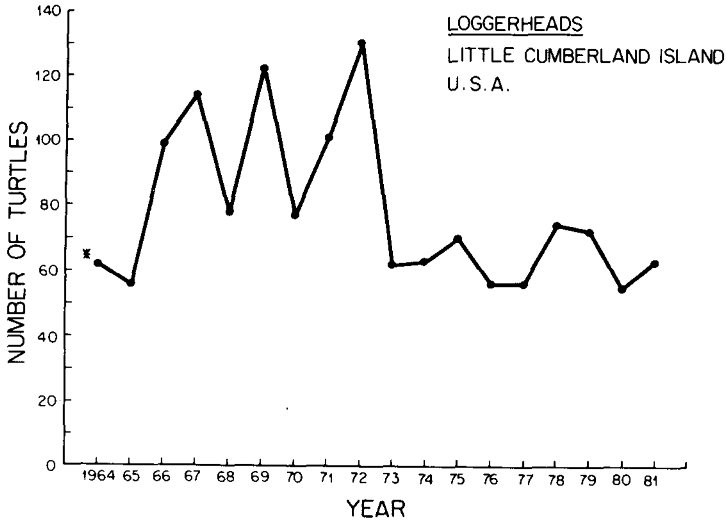

Figure 14. Number of loggerhead turtles emerging (remigrants plus new arrivals) on Little Cumberland Island, Georgia, U.S.A. *tagging only started 6th July, well into the season. Data from Richardson and Richardson (in press and personal communication).

the temperate rather than the tropical zone. This fortunate nesting preference has placed loggerheads in a number of countries that are able to afford total or considerable protection. Sizeable loggerhead populations occur in Australia, the United States, Oman and South Africa. And the numbers nesting in South Africa are either level, as level as is ever the case with turtle populations, or even creeping upwards (Figure 15). The loggerhead rookery on Masirah Island in Oman, probably the largest in the world for this species, has about 30,000 turtles nesting a year; many eggs are carried away by high seas but exploitation by people there is minimal (Ross and Barwani, in press).

Flatback *(Chelonia depressa)*

Flatbacks nest only in Australia. They are not uncommon in the Torres Strait and off Queensland but the 1975 Red Data Book listing of 'rare' is appropriate because of their limited range. The 1982 Red Data Book does not include the flatback, but nevertheless protection in Australia is essential to its survival. Fortunately the main flatback beaches are in sparsely inhabited regions. However, the aborigines have

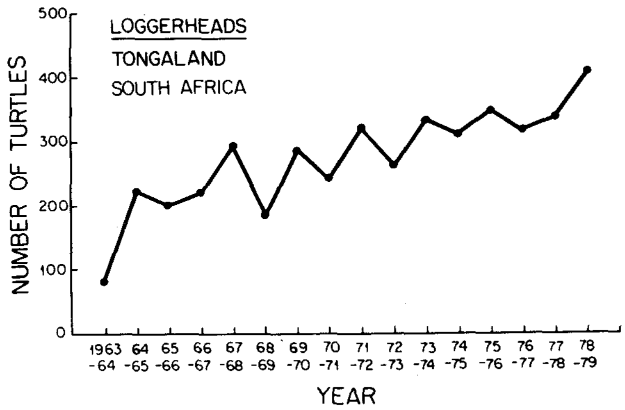

Figure 15. Number of loggerhead turtles (remigrants and new arrivals) seen in Tongaland, South Africa. The main nesting season is October-January. The low figure for 1963-1964 reflects less systematic study that year. In 1969 the area routinely patrolled was increased from 32 to 56 km. Data from Hughes (1974b, in press a).

traditional hunting rights and many now own outboard motors. Sometimes they take nesting females, more often the eggs, especially on Crab Island, the largest known rookery for flatbacks. But how many are collected each year is uncertain (Parmenter, 1980a,b). With a restricted range, excessive harvesting of eggs, or a deterioration in food supply or some other environmental change could be disastrous. So although at present there need be no special concern about losing the species, better monitoring of populations and more research are needed. There may come a time when aboriginal hunting rights should be curtailed.

In summary then, except for Kemp's ridley, and conceivably the hawksbill, none of the sea turtles are *at present* endangered in the Red Data Book sense of that word. This is not necessarily a criticism; it often takes time for new findings to be assessed and for information to reach the compilers of these volumes. It would only be discreditable if revised editions failed to reflect the current situation as accurately as possible, failed to make allowance for new discoveries and accumulating data on trends of numbers nesting at various breeding sites. The Red Data Books are admirable in intention and often, in the face of great difficulties, in execution too. They provide officials and others with a synopsis of data and current opinions on the survival outlook for various species. They are a useful starting point for environmental impact studies. But they are not the Koran, they are not sacrosanct. The people who originally produced the Red Data Books recognized their temporary and shifting nature from the outset and they embodied this recognition in the design of the books. These are not bound but consist of a red folder and loose-leaf sheets that can be unclipped or replaced. The time has now come to unclip, modify and replace a number of the pages categorizing sea turtles as endangered.

It would not be worth arguing about the matter, about the subtle differences between being endangered and being vulnerable, any more than it is worth arguing about the precise rating of some rare wine, were these categories not used as a basis for action. People often take the word 'endangered' as sufficient without going beyond it into details. Categories like 'endangered' have their uses as starting points, or quick summaries, but they become a liability if they become autonomous from the facts, with an existence of their own. It is facts we need as the basis for action. Labels have their uses but sooner or later we have to unpack the parcel and see what is really there.

The real situation is that most of the sea turtle species are not in immediate danger of extinction, nor even, probably, in danger if the factors presently affecting them continue operating. Nesting is widespread and some sizeable rookeries remain. But overall numbers are far less than they were in former times and some populations are under great pressure and may soon disappear. This should be the starting point for formulating conservation measures, not misleading alarmism, nor the previous IUCN endangered label which for all but one of the sea turtle species is now questionable.

In a more general sense of the word, of course, turtles are endangered. So are many species if human beings continue to breed so rapidly and destroy habitats and spread chemicals around the world and release radioactive wastes. Some conservationists may still wish to use the endangered label as they do a preventive medicine or as a self-negating prophecy. If you call a species endangered, then it can be saved. If you do not call it endangered, then it will be. But there should also be room for a scientific approach, for starting not with fear but with facts.

11. THE ALARMIST STRATEGY

Conservation biology has some strangely unscientific manifestations. One is to start with convictions and then produce authoritative-sounding assertions to support them. The alarmists, it seems, start with the conviction that killing turtles and trade in their products should be stopped. They then produce assertions to support this position: the green turtle will be extinct by 1983 if present trends continue (Cleveland Museum exhibit, 1980), turtles will be wiped from the face of the Earth in a few years. The 1981 pamphlet of the Sea Turtle Rescue Fund is rich in this kind of material (Chapter 10). Such assertions are false.

So are others, some appearing in reputable conservation publications. In 1978 an article with the title 'Sea-turtle Faces Extinction in India' was printed in Environmental Conservation (Davis et al., 1978). In this it was said that in 1977 not a single turtle nested at Gahirmatha, the main beach for olive ridleys in Orissa. A similar article (Davis and Bedi, 1978) appeared in Environmental Awareness, and this was the basis for further reports in Hamadryad and in the Marine Turtle Newsletter. But ridleys did nest at Gahirmatha in 1977, more than 150,000 of them. Apparently Davis and Bedi had only been on the beach for a few hours (Kar, 1980). Certainly the colony was not wiped out because the following year more than 200,000 nested there, and more than 100,000 in the year after (Kar, 1980).

An article in the IUCN Bulletin (Anon., 1979) on the killing of olive ridley turtles in Mexico stated that there was no arribada in 1978 in Oaxaca and that ridleys were almost rare in these waters. On the same page a caption to a photograph said that during the 1978 season 350-550 ridleys a day were processed by the Pesquería Industrial de Oaxaca (PIOSA) plant at San Augustinillo. This IUCN article was later criticized for containing 'totally inaccurate doomsday cries' (Frazier, 1981, 1982).

A letter by biologists active in sea turtle conservation in Mexico stated that: 'with the exception of those in Australia, all six species of sea turtles in the world are in imminent danger of extinction.' Referring specifically to Mexico's great sea turtle herds they said: 'if their reprieve does not come before the next breeding season -- summer 1978 -- turtles will disappear from Mexico's seas within three years' (Felger et al., 1978).

Why don't conservationists always start with the facts and formulate their plans accordingly rather than adopting this apparently unscientific reversal of the process? Out of ignorance? Perhaps in some cases that is the answer. Another interpretation is that they are often well aware of the facts but sometimes use hysteria about extinction as a weapon to achieve their aims. By making people think all sea turtles are about to disappear forever they might be able to better the survival prospects for some of the truly endangered populations. It is difficult to stop trade in some turtle products from some parts of the world while permitting it from other places. Turtle steak from one species, or even shell sometimes, resembles that from another species. Enforcement is simpler with blanket restrictions on all turtle species and products. Whatever the reason may be for the appearance of exaggerated statements about the precariousness of sea turtles, there can be no doubt that they are sincerely motivated by a desire to save these species and backed by much hard and unglamorous work. Perhaps on some occasions they are even effective in saving turtles. It is nevertheless legitimate to question whether such exaggeration is ultimately of value.

The main drawback of alarmism is that it focusses attention on the wrong issues. The real issue here is that it is difficult to distinguish turtle products from each other. Perhaps this situation can be ameliorated if it is not neglected. It may be difficult to solve the problem altogether, just as there will always be an arms race between the mint and the forgers, but much could be done with better marking systems, limitations on ports of entry for turtle products, tighter documentation and research in biochemical methods of identifying meat and shell from different sources. Some retailers will prefer reliable legal delivery, even if more expensive, to cheaper but riskier shipments of illegal produce (see also Pickett and Townson, 1980b).

The alarmist strategy may work for a while but it is dangerous. What will people think about assertions that sea turtles are in danger of extinction in the next few years if they read about the breeding colonies of green turtles in Australia and Europa Island and the arribadas of olive ridleys in Costa Rica, and learn about the measure of protection these populations are receiving? They may not care to believe anyone who is talking about the biology of turtles, or of other animals for that matter (Frazier, 1980b). It would be ironic if this happened to the Sea Turtle Rescue Fund, one of whose main aims is public education, public awareness they call it.

And just who in this case is most in need of that extra measure of awareness? Convictions in various parts of the world may be rather different from those animating people in North America. In many places people do not want a hands-off type of conservation or bans on trade. On the contrary they need trade, sometimes desperately. Trade can be part of subsistence. And in formulating where use of resources can be supported and under what conditions and where sanctuaries are essential, people need accurate dependable information, not misleading alarmism. Help in management techniques and biology from places with the expertise are more likely to be appreciated and more likely to be effective than any 'international action and awareness campaigns', any I'm-more-environmentally-conscious-than-thou attitude.

12. PROBLEM RESOLVING

The Sabah Turtle Islands lie out in the Sulu Sea some 30 km from Sandakan, East Malaysia. If you want to watch green turtles nest there, you sail out of Sandakan harbour, past the corrugated iron roofs of the kampong with its maze of interconnecting planks and wharfs, past the large boats with black and rust-coloured hulls, and the medium boats with wooden deck houses and the small boats with nothing but an awning and a put-put-put engine, past the gaunt rock face of Berhala and then out to sea. There the poisonous-looking orange-brown water of Sandakan gives way to blue. Around the horizon are many dark little patches, mostly craft of varying sea-worthiness on errands of varying legality, but others gradually become larger, more stable—these are the Sabah Turtle Islands. But make sure you have a good chart or are with someone who knows the region. Make sure you go to Selingaan or Little Bakkungaan, not to Big Bakkungaan Island because that belongs to the Philippines, not Malaysia. The turtles don't know that of course. They nest on islands in both countries, sometimes moving from one to another within a season. That is the problem. Taking of eggs and turtles is prohibited on the Sabah Islands and this is reasonably well enforced there by the presence of wardens. But these efforts are undermined by the uncontrolled situation on the adjacent Philippine Turtle Islands. So some joint management and enforcement programme is needed. Easier said than done! The government of the Philippines is more concerned about rebels than turtles. The region is politically unstable: with a large Moslem population in Sabah there have been fears of secession from Malaysia and union with the Moslems in the Philippines. There is smuggling, lingering piracy and general lawlessness on the Sulu seas. Park wardens need backing to be effective. Their boat has come under fire on occasion. A government licensed egg collector was killed in 1964 and in 1977 on one of the turtle islands there was a battle between pirates and police (de Silva, 1969, in press).

Undaunted by such details, sitting in the comfortable chairs of the State Department at Washington, the delegates to the World Conference on Sea Turtle Conservation voted for the following Action Project:

> Urge the governments of the State of Sabah, Malaysia, and the Republic of the Philippines to jointly establish an international turtle sanctuary embracing the Sabah Turtle Islands National Park and the Philippine Turtle Islands to conserve sea turtles of all species in areas to be demarcated.

No laughter in the back row please, this was one of the more realistic resolutions! It was actually accompanied by some recognition of costs and difficulties:

> IUCN and World Wildlife Fund should provide support for a working group from the Philippines and Sabah to meet in early 1980 and discuss the procedures or requirements necessary for the implementation of an international turtle sanctuary between the two countries.

But the essential requirement for establishing such an international sanctuary is already perfectly obvious: goodwill and political harmony between Sabah and the Philippines. And with that lacking, not surprisingly nothing has happened.

There is a great vogue among conservationists at present for planning and for strategies. In the last few years there has been the Marine Programme and the World Conservation Strategy, and all the associated national conservation strategies and action plans. Action is one of IUCN's favourite words. Action priority. Action point. Action plan. Perhaps it creates some comforting illusion.

At the Washington sea turtle conference, as the delegates rushed breathlessly through some 90 resolutions on the last afternoon, encouraging, commending, urging, recommending, a lone voice was raised: who was going to pay for all these projects? What about implementation? Well, the strategy had anticipated that. It had included a section in which UNEP and FAO were 'encouraged to provide financial and programmatic support to this global conservation program.' Besides there was to be a standing committee to monitor and facilitate implementation. The committee would meet in New Delhi before the CITES conference in early 1981 and prepare a report on progress. That never happened.

Perhaps it is wise to have documents of this kind, to have even seemingly unattainable aspirations down on paper. It may help give people a sense of purpose. It may help someone raise money for a project if they can say it was recommended by a conservation strategy. And yet there is also an aura of fantasy about such proceedings, and about 'ecocrats' travelling around the world commending, recommending and resolving, talking to themselves.

Here are some more of the resolutions adopted by the World Conference on Sea Turtle Conservation:

> Rapidly establish complete protection for *Chelonia m. agassizi* in all its habitats in east Pacific waters (e.g., Mexico and Guatemala).

But those actually working on the west coast of Mexico will be doing well if they manage to establish a 750-m stretch of beach as a reserve area (Pritchard and Cliffton, 1981). Most Mexicans probably do not want complete protection anyhow.

> Develop realistic population models for the Pacific green turtles and olive ridleys being exploited by Ecuador and Mexico.

This proposal is equally futile. After years of tagging and study at Tortuguero and at Little Cumberland Island and at Trengganu, there are still no adequate population models (Carr et al., 1978; Pritchard, 1980). Perhaps what is meant is that unrealistic population models should be discarded.

> Urge all workers in sea turtle research to publish their tagging results on a frequent and regular basis.

Now there is an interesting one. The problems of expensive research going to waste because data are not published, and of notched turtles being released without the details being put on record, are very real. The editor of the Marine Turtle Newsletter has also for some time been doing some urging and encouraging on the matter of lost data but at best with only modest success. But here the Washington meeting achieved something far beyond the scope of its resolution. What biologists or government departments would want an account of their conservation programme omitted, simply not mentioned in the proceedings of the World Conference on Sea Turtle Conservation? By holding out a carrot to investigators who prefer walking the beach to writing up their results, the conference organizers obtained not only tagging results but a wealth of other data and findings, conveniently assembled in one volume (Bjorndal, in press), a spectacular success.

13. SPLITTING: STRATEGY OR SCIENCE?

Suppose that green turtles, what we call green turtles today, are not just a single group but are really composed of several genetically different forms, then the number of animals in any particular group must be less than the total in all the groups. If so, then statements that green turtles are widespread and still quite numerous (e.g., Chapter 10) appear in a different light. Even when a particular form is abundant locally, if it is different from other green turtles and cannot be replaced, then its status becomes more precarious. So it is not surprising that a handout to delegates at the start of the World Conference on Sea Turtle Conservation listed the splitting of turtles into sub-groups, the 'Taxonomic problem', as one of the most pressing:

> --how to deal with the status of separate populations of the 'same' species, especially in the case of the green turtle. Lumping all populations into the same statistic is dangerously misleading because we have not been able to restore extinct populations by transplantation of individuals from other populations. Even if we could, we would be dealing with a biologically different animal.
>
> (Ehrenfeld, 1979)

Probably later opposition to the Cayman Farm release of yearlings stemmed in part from worry that it could make splitting more difficult (Chapter 9). At the conference itself, however, the taxonomic problem received minimal attention and that is not surprising because it is a difficult one.

The ingredients of the matter are:

1. There are differences in size, shape, colour and behaviour of different populations of green turtles. Some are quite obvious, some subtle and hard to discern.
2. Female turtles return to the same nesting beaches. For example, green turtles tagged at Tortuguero have never been found nesting in Surinam or on Ascension Island, even though all 3 populations share sea-grass pastures off Brazil for feeding.

The questions to be answered are:

1. If green turtles nesting on a particular beach are wiped out altogether, can they be replaced there by other forms?
2. Should some populations of green turtles be designated as sub-species, or even be accorded full species status?

The present position on these problems is:

1. Nobody knows if a colony can be re-established once it is gone. Operation Green Turtle has not given positive results, not yet at any rate, but with other methods transplanting might perhaps be successful.
2. There is a consensus that the East Pacific green turtle, with its smaller size, darker almost black colour and more domed carapace merits sub-species status. It is called *Chelonia mydas agassizi* to distinguish it from other green turtles, *Chelonia mydas mydas.*

This helps: in the 1975 Red Data Book the East Pacific green had its own page. But it still does not go very far toward fractionating the green turtle complex. Although there are some size differences, for instance Ascension Island and Surinam green turtles are large, 'the amazing thing about the remaining populations--for example those of Costa Rica, the Seychelles, the Great Barrier Reef, and the Sarawak Turtle Islands--is how very similar they are; what differences may exist have yet to be elucidated' (Pritchard, 1979a). People have been sniffing around the problem for some time without coming up with anything definitive.

In 1975 Carr proposed, as an interim measure till careful taxonomic work was done, that green turtles should be divided into 4 subspecies:

1. *agassizi*, in the eastern Pacific, Galapagos and Hawaii;
2. *japonica*, in the western tropical Pacific and Indian Ocean;

3. *mydas*, the Ascension Island population;
4. *viridis*, in the western Atlantic.

Referring to small differences in structure, behaviour and physiology, he added:

> Once these have been clearly demonstrated, and trenchant differentiation of the Ascension and Tortuguero green turtles is shown, the latter will be designated *Chelonia mydas viridis* (Schneider) and both it and *mydas* will automatically lay claim to endangered status.

This was written before the green turtle was transferred from the depleted to the endangered category, but the thrust of the argument is the same:

> It seems clear that if *Chelonia* is to get its share of concern as a group of vulnerable, threatened and endangered forms of life, the composite nature of the *mydas* complex must be made known to conservationists and legislating governments.
>
> (Carr, 1975)

How impressed governments will be with sub-specific differences is uncertain. Many biologists at least do not take sub-species designations very seriously as they do not imply genetic isolation between the various forms. In the case of turtles there might be a single population with different local forms, either genetic or depending on available diet, that interbred at their margins. In the Galapagos paler turtles with *mydas*-like characteristics occur as well as the typical darker *agassizi* form (Pritchard, 1971b). There is no evidence that they do not interbreed.

But, *if* there was *no* gene flow between populations, if they could be accorded full species status, then the whole argument would become more compelling. If, for instance *viridis* and *mydas* were as different from each other as loggerhead is from the olive ridley, then there would be all sorts of possibilities for generating interest and funds. There could be extra support forthcoming, international concern, a *viridis* recovery team. The easiest first step, however, toward giving various of the green turtles full species status, is to elevate the East Pacific green and make *agassizi* a full species. It is the form with the most obvious external differences from other green turtles. It is a tempting idea and one that cannot readily be disproved. So it should not be altogether surprising that in 1982 there appeared a poster, sponsored by the Sea Turtle Rescue Fund and the National Marine Fisheries Service, showing 8 species of sea turtles, with *Chelonia agassizi* as the newcomer. Proclaiming new species by public poster is not the most orthodox scientific way of designating them but never mind, the East Pacific green looks rather more different from the other green turtle than does the Kemp's ridley from the olive, and doubtless the public will be convinced. Few will pay attention to the note: 'Not universally recognized as a separate species.' Then what? Well, then there could be a 9th species. And why stop there?

But wait a moment please! We never did get that careful taxonomic study, that 'trenchant differentiation' needed to establish even sub-species differences. So before becoming too sure that the East Pacific green is a separate species, let us return to basics: for species status we need evidence that it is reproductively isolated. When we look for that in this case we find there are hints but no proof.

The dark *agassizi* form, with its high domed carapace, only occurs in certain parts of the world, it is true. It is not found in Surinam or Costa Rica, for instance. But, even assuming that no males, about whose movements we know nearly nothing, sneak over to other rookeries now and again, the dividing line between the dark and the pale forms is blurred. Green turtles with somewhat dark *agassizi*-like characters nest on the Lacépède Islands off western Australia (Carr, 1975), and in the Galapagos, as mentioned, dark and pale turtles are found alongside each other. The data on the distribution of *agassizi* do not preclude gene flow between the forms.

But if the *agassizi* form was so clearly different in structure, behaviour or biochemistry from the other green turtles, then that could constitute evidence for reproductive isolation, even if their distributions overlapped geographically. The question then is, just how different is *agassizi*, or more generally, how are differences between animal groups quantified? To go to an extreme example, confronted with an ostrich and an ocelot, one can be pretty certain just by looking at them that they belong to different species. But with animals resembling each other more closely, like the various forms of green turtles, it is necessary to study a large number of specimens. Armed with an appreciation of the variation in colour, and of other characteristics too ideally, one can then go on to ask if the differences between the East Pacific and the other green turtles are as great as the differences between known species, between the green turtle and the flatback, for instance. If they are, it becomes reasonable to call the East Pacific green a different species too. But such extensive detailed work has not been done yet, and it is definitely necessary because colour variations within populations of green turtles nesting in the same area are known to be considerable (Frazier, 1971).

A similar systematic approach is needed for the hawksbills in Australia. In the wake of the ill-fated Torres Strait farming venture (Chapter 5), it was noted that shell patterns and pigmentation of hawksbills from different islands were strikingly different (Carr and Main, 1973). To be sure that the forms from various islands are truly different, there should be data on the variation of patterns within single islands. If too few animals from each island are examined, with some of the specimens from a given island coming from the same clutch perhaps, then differences between islands may appear larger than they really are.

Returning to green turtles, suppose after extensive measurements and systematic work it was shown that the East Pacific form was as different from other greens as they are from flatbacks, the difficulties in demonstrating reproductive isolation might not be entirely at an end. Differences between *agassizi* and other greens, especially those in colour, might result from the environments they encountered in their respective areas rather than from genetically different constitutions. Perhaps something in its diet makes *agassizi* darker. When some hatchlings on the Galapagos Islands were examined and measured, they were rather small but their colour was not markedly different from that of other green turtles (Pritchard, 1971b). Nor are hatchlings from the Lacépède Islands superficially remarkable (Carr, 1975). However, again it is necessary to study a large series of animals, from different clutches, before drawing definite conclusions.

None of this disproves that the East Pacific green is a full species. It looks more or less different, breeds in different places and might be reproductively isolated. Sometimes there are no easy ways of telling whether animals are separate species or not. These points are not made to deny *agassizi* species status but to emphasize that the data are not yet in to clear up the matter either way. Suppositions become statements of fact and statements of fact become weapons all too easily. That is what happened with the idea that sperm storage from one season to the next was important in fertilization (Chapter 8). There are temptations to endanger turtles by dividing them into sub-groups, but if the strategy of splitting outran the science too much, it would be no more truthful than alarmism.

Nor should the problem of replacing former turtle colonies be tied too closely to the species question. Transplantation of breeding populations from one beach to another is an empirical matter. The experience of Operation Green Turtle suggests it cannot be done quickly or easily. Transport of eggs rather than hatchlings may be a better approach. This is being tried with green turtles, loggerheads (see Pritchard, 1980) and Kemp's ridley. Some biologists would have preferred to concentrate on the more abundant species and not to experiment with Kemp's ridley (Chapter 7). Nevertheless if a new colony is established on Padre Island, regardless of whether that is the best or most cost-effective way of saving the species, it will be instructive.

The outcome of such experiments will depend on what it is that keeps turtle populations apart in their breeding. If this occurs because the migratory instructions are ineluctably handed down by the genes, unsusceptible to modification by anything the animal experiences, then transplantation would not work, except through the slender chance of some fortunate mutation arising. But if return to the natal beach depends on some imprinting early in the animal's life, then it might be possible to re-establish turtles in areas where they bred formerly. They would probably not be exactly the same kind of turtles. That again depends on how reproductive isolation is brought about. If different early imprinting experience was the only important factor, then transplanted populations might be very similar to the old ones. But that is rather unlikely. More usually there are several barriers keeping populations apart. In addition to imprinting as an isolating mechanism, the genetic make-up might contribute towards differences in feeding patterns, in how much fat was put on before migration started, in the timing of migration, in selection of nest site on the beach, in pivotal temperatures for sex determination and much else. The transplanted turtles might then be unable to make the best of their new breeding area. Even if turtles nested again on the site of a former colony, there could be a loss of genetic diversity and the new population would be different.

But, it may be protested, giving sub-groups of turtles different names is precisely a way of emphasizing such population differences, of pointing out that with green turtles we are dealing with a composite group; conservationists are not just concerned with preservation at the species level but with populations too. If a particular distinct breeding aggregation is wiped out, that is a tragedy, whether it is a species, a sub-species or different in ways that cannot be easily categorized. There is a decrease in genetic diversity in each case.

Yes, of course populations should be saved. Nor has any objection been made to splitting if it is scientifically based. Splitting could be valid science *and* a conservation strategy. But will it be? There are indications that this difficult matter might be prejudged by a particular approach to conservation.

And anyhow the effectiveness of this approach toward saving the sea turtles may be overrated. *Japonica, agassizi, mydas* and *viridis*, these are lovely poetical names, but the authorities in some countries may be rather less impressed by the sonorities of scientific nomenclature or the slight genetic idiosyncrasies of their turtles than by demonstrations that preserving them has cash value.

14. AN EGG-LAYING MACHINE

> Sustainable utilization is somewhat analogous to spending the interest while keeping the capital.
>
> (World Conservation Strategy, 1980)

The reader may have formed the impression, perhaps justifiably, that so far these reflections on conserving sea turtles have been rather negative and pessimistic in tone. In one sense that may be true. Pulling down obstructions, clearing away undergrowth, sweeping out cobwebs are destructive but in another sense they are positive actions, based on optimism. If we reject the spread of semi-science and repudiate the tactical hoax—if that is what it is—that most turtle species are at present in danger of extinction, we find a situation that, though serious, has many hopeful elements, a sky full of lowering clouds but enlivened by patches of sunny blue.

In the long run man's dominance on Earth restricts the kinds of creatures that will survive here. Animals that are dangerous, physically or economically, are under the greatest pressure. This is the predicament of so much of Africa's wildlife. With human populations expanding and needing more and more space for crops, the clash between animals and agriculture has become so intense that for some conservationists only one option remains:

> ... wildlife in Africa should be commercialized in many places—exploited for every last nickel of income. In certain key ecological areas, it should be totally protected. Elsewhere, the sooner Africans enjoy gazelle goulash and wildebeest casserole, and the sooner the trade in zebra skins is regulated and expanded—rather than decried and suppressed—the sooner a more hopeful era will dawn for African animals.
>
> For those Africans who try to live alongside wild animals, there are sizeable personal costs. The only way these people can be persuaded to live and let live is for them to realize some personal benefits as well.
>
> Wildlife in Africa is being elbowed out of living space by millions of digging hoes—a far greater threat than the poachers' poisoned arrows. When zebras chomp up livestock's grass, when elephants drink dry savannahland water supplies, when buffalo herds trample maize crops and when lions carry off prize steers,

the animals must go—unless they can pay their way.

(Myers, 1981)

This may sound offensively radical but the realization that national parks alone are inadequate and that utilization helps preserve species like antelopes and gazelle is becoming widespread (see Hughes, 1979; Coe, 1980; Worrall, 1981).

But what of the sea turtles? Their prospects for living alongside mankind are really very good. The turtle is gentle and unaggressive, it does not trouble campers as do bears, it carries no known diseases, it does not interfere directly with agricultural efforts as do rabbits and woodchucks, or compete with domesticated herds for pasture as do vicunas; although it sometimes takes food eaten by man, such as shellfish and jellyfish, it does not raid and trample his crops as do elephants. Besides that, a nesting turtle is an intriguing sight to watch, an attraction for thousands of tourists (Fretey, 1981; Siow and Moll, in press), safe for children. But most important of all perhaps is the food turtles provide. They arrive on our shores at predictable seasons and places and leave behind protein in convenient packages, all ready for handling and marketing (Hendrickson, 1958). Turtles are magnificent egg-producing machines. This is their best hope for survival.

It has been said that the green turtle is the most valuable reptile in the world (Carr, 1952). But in cash terms it is only valuable if exploited. Its exploited value provides the incentive for producing more turtles for future exploitation. Exploitation and conservation go hand in hand. The best hope for sea turtles is to concentrate on the positive aspects of the situation, principally their uses. The priority should be to demonstrate how much money or nutritional value can be derived from turtles by managing them as a renewable resource. This will be more effective than shedding tears about how numerous turtles were in the days of Christopher Columbus.

But devising management methods brings us right back to practical considerations. It is all very well to say that conservation and exploitation should go hand in hand but how exactly are utilization and protection to be balanced? What percentage of eggs can be safely harvested? 10%? 50%? 90%?

Suppose, as commonly happens on turtle beaches, that many eggs are taken by predators or washed away by high tides, then could one go far wrong by saving as many as possible of these from destruction and allowing some to augment the naturally surviving eggs and keeping others back for human consumption? More hatchlings would reach the sea than without this human intervention. But there might well have to be additional provisos about the harvesting. Not all eggs should be collected from one part of the beach or at one time of year otherwise spatial and seasonal temperature differences, however slight, might bias the sex ratio of the embryos in the remaining eggs. For similar reasons the incubation of eggs kept for conservation should be as natural as possible. Simple protective measures such as disguising the scent or other cues by reburying the eggs close by on the night they were laid might be favoured. Who would have thought, 10 years ago, that temperature could determine the sex of sea turtles? The lesson to be drawn from this is not just the need to check on the thermal aspects of artificial incubation methods but also to accept that a natural environment may be important in ways of which we have no conception. Perhaps characteristics of the sand other than temperature contribute to optimal development. To allow for our ignorance, the balance between protection and use should be struck in a conservative way. Just as an engineer, after calculating the stresses and strains on a dam or bridge, doubles or even triples the strength of the supports, so of all the eggs saved from destruction more than twice the number taken for consumption should be set aside for the conservation programme.

A programme incorporating both collection of eggs and transplantation of doomed eggs has been operating for more than 10 years in Surinam. In the last few years about 250,000 green turtle eggs have been harvested annually (Reichart, in press). Formerly more than 400,000 were taken each year (Schulz, 1975). There are, very roughly, about 250,000 doomed green turtle eggs in Surinam (Reichart, in press). For the years 1970-1973, 284,500 per year (37% of the total) were laid below the high tide line (Schulz, 1975). So currently there is an approximate match between the number of doomed eggs and the number harvested. But there are some problems nevertheless. The quota has been arbitrarily set (Schulz, 1975), not indexed to the number of eggs transplanted. And although the logistic achievement of putting beach patrols on all the major Surinam beaches has been accomplished, in fact doomed nests are not always transplanted. Finally, there is no safety factor to guard against the unknowns of transplantation and selective egg collecting; ideally the number of eggs saved should exceed the number sold. So, quantitatively, the Surinam programme is not—or not yet—a completely satisfactory model.

Therefore a hypothetical example of how an egg harvesting scheme might operate will now be considered.

Along the eastern seaboard of the United States racoons dig up many nests of loggerhead turtles. In some places as many as 93% of the eggs are destroyed, in other places it is much less but still high at 55% (Stancyk et al., 1980). Eggs are also washed away by high seas, in South Carolina as many as 10% of them at Cape Romain (Caldwell, 1959) and 25% at Sand Island (Hopkins and Murphy, 1981). On some beaches there are already protective measures. For instance on Little Cumberland Island, Georgia, the residents' association organizes a hatchery and monitors the population. With people wanting to support total protection there is no need for selling eggs. But in other places the racoons are going unchecked. Suppose on a particular hypothetical barrier island racoon predation is estimated at 75%, then if this could be eliminated altogether, 25% of the eggs could be harvested leaving an additional 50% in the ground. The money from selling the eggs would go toward the conservation programme. Of course the details of the costs would be critical. There are some simple ways of protecting turtle eggs such as surrounding the nest with wire netting, taking the eggs to a central hatchery or reburying them in the sand close to where they were laid. Such measures do not demand great skill but need only the wages for a reasonably conscientious person who likes walking the beach by night. With no costs for feeding, battery cages, lighting or medication, it is not unreasonable to think that turtle eggs obtained in this way might compete successfully with hens' eggs. People in North America would probably pay more for turtle eggs, as they do in other places. In Malaysia leatherback eggs cost five times as much as hens' eggs (Siow and Moll, in press), although they are less than twice as large. Even the smaller ridley eggs sometimes fetch as much as a hen's egg (Carr, 1952).

Even if economically viable, there could still be some technical problems in the actual harvest. In theory, in the hypothetical example proposed, it may be that if protection is given to 50% of the eggs, then another 25% can be safely collected, but how does a person on the beach coming across a newly laid clutch know if it is one of the 75% that would have been taken by racoons? If all the nests found were automatically given protection against racoons, some additional allowances in setting the quota for harvesting might have to be made for eggs that did not need that protection and might have done better without it. Merely moving eggs from one place to another reduces hatch rates in some circumstances (Limpus et al., 1979). Also some procedures afford only partial protection. For instance Stancyk et al. (1980) found that reburying eggs close by reduced racoon predation to only 6-19% but did not eliminate it altogether (in this case hatch rates of the transplanted eggs were not lowered). So if reburying eggs was the conservation method of choice, then perhaps only 18% (75-19=56; divided by 3=18) of the eggs should be taken for human use. Also the more nests that are left on the beach, the greater the chances are that a turtle arriving later in the season will dig some up. If, on the other hand, some clutches are moved off the beach, then denying these eggs to predators could increase the pressure on other eggs.

Adopting a conservative balance between protection and use, such as the 2:1 ratio proposed above, provides some safeguard for these kinds of contingencies. Even so additional precautions would be desirable. There should be monitoring of population trends. If there was a sustained crash, the quota could be adjusted or suspended, even though the reasons for the decline were unconnected with the harvesting. Plotting long-term trends is easily combined with egg collecting simply by recording the number of nests laid each year (Chapter 3). Finally, leaving some areas as nature reserves, without intervention, would serve as a small insurance policy and would provide a reference site against which to compare the situation on managed beaches. If numbers rose and fell on both the managed beach and the reference area, it would be unlikely that the harvesting was responsible.

A combination of monitoring, a few reserves and putting back twice as many of the eggs saved from predators or high tides as one takes is a very conservative exploitation policy. Nevertheless, there will doubtless be objections to the idea of legalizing the sale of turtle eggs in the United States, even with careful controls. The sentiment there seems to be more for severer penalties for poachers. Trying to clamp down on poachers, blaming wildlife problems on poachers, is a common attitude among conservationists but there are few examples where it is successful (Graham, 1973). Perhaps one will be the activities at Rancho Nuevo on behalf of Kemp's ridley. With so few animals left there, stringent control of poaching is essential. But in the United States putting people in jail for taking turtle eggs or fining them several thousand dollars may provide a few symbolic victories, but it is illuminated expressways and buildings, high tides and racoons that are the worst enemies of turtles nesting there. Escalating the penalties on poachers is of marginal value. Developing conservation through use is likely to be much more effective in the long run.

And in parts of the world where poaching is considered to be a major problem, it has to be asked which of the following is more likely to be successful: having national parks without funds to ensure adequate enforcement—and that is often the reality with wildlife sanctuaries—or putting officials on the beach to organize egg harvesting and protection? Simply having more people on the beach discourages poachers, and egg sales could also subsidize enforcement directly. Where possible, of course, controlling access to the nesting beach and selling eggs only at government-licensed outlets may be useful adjuncts. Even so, it is seldom possible to eliminate poaching altogether. But it is not obvious that allowing some eggs to be sold makes it any worse. Poaching and black markets thrive on scarcity and bans; the seller has to set a price commensurate with the risks incurred. When a commodity is available at a reasonable price the incentive to steal may be reduced. In the villages in Surinam, a green turtle egg sells for less than a hens' egg. In 1982 the equivalents in U.S. currency were respectively about 6 cents and 10 cents, and the turtle's egg is barely 20% lighter. Not surprisingly poaching there is of minor importance.

There are several other things to note and further attractions of putting more effort into developing procedures for egg harvesting. To start with, taking eggs is compatible with having tourists on the beach. Only minimal restrictions are needed: the turtles should not be molested and flashlights should only be used sparingly. What a fantastic tourist attraction the great ridley arribadas could be! Thousands and thousands of turtles crawling out of the sea and nesting all at once! And, with the actual day of the arribada being unpredictable, what money could be made in charges for accommodation and drinks while people waited! But there is more than a financial harmony between turtle watching and egg collecting. Many wildlife enthusiasts may dislike talking about turtles as egg-laying machines or swimming meat deliveries. They may prefer to think of them as bearers of ancient biological traditions and representatives of life forms as good as ours, or to dwell on their mastery of spectacular navigational skills. They may prefer to describe them as wonderful mysterious gentle creatures—and so they are, so they are. This really is one of the few cases where one can have it both ways. Collecting a quota of eggs is compatible with a respect for another mode of existence. This is obvious in Malaysia where there are long-standing traditions against killing adult turtles. Egg collecting is institutionalized, controlled by the state. At the same time each year many Malaysians go to the Trengganu beaches simply to watch the giant leatherbacks haul out of the sea and lay their glistening eggs and put on a spectacular show of sand-flinging. The people enjoying these sights there are by no means only affluent tourists from northern countries.

Even the proponents of animal liberation allow for taking their eggs. With chickens, 'assuming you can get free-range eggs, the ethical objections to eating them are relatively minor. Hens provided with both shelter and an outdoor run to walk and scratch around in live comfortably. They do not appear to mind the removal of their eggs' (Singer, 1976). Far less objectionable still then would be the taking of eggs from turtles living their full lives in freedom and returning to the sea without ever seeing their eggs.

Killing adults when they gather to breed is very different. Butchering a turtle is a messy business. After stunning or cutting the throat, it is necessary to saw through or otherwise sever the bony junction between the plastron and the carapace; inside the tenacious heart goes on beating and blood and eggs slop around in the bowl of the upturned carapace, the contribution to the next generation unfulfilled. Even turning a turtle over and hauling it off to a discreetly located slaughter house is a sight some tourists will not appreciate.

Another point about harvesting eggs is that it is unlikely to endanger any other species. There are no known animals that eat turtle eggs exclusively. With nesting being seasonal it would be difficult for such a species to evolve. An extreme example is an arribada where laying is confined to a very short period: this satiates predators at one time but denies them food at other times. Once the season is over, crabs, coyotes and vultures have to survive on other fare.

Even in places in the tropics where laying occurs all year round, it is much more frequent in certain months (Hendrickson, 1958; Servan, 1976). It remains conceivable that removing and protecting many clutches might deprive a predator of nourishment at a time of particular need in its life cycle. Perhaps there are places where monitor lizards need turtle eggs to breed successfully. Of course when any intervention on behalf of a particular species is contemplated, as much consideration as possible must be given to possible interactions with other species.

However, at present there is nothing known to suggest harvesting turtle eggs would upset the 'balance of nature'. Some of the major egg predators like racoons and ghost crabs are hardly endangered species. If, along with harvesting, conservation measures were successful, then rivalry between increased numbers of turtles and other species might result. In the case of green turtles at least, the carrying capacity of sea-grass pastures is probably far in excess of the present day reduced turtle populations (Bjorndal, 1980a), so that competition with other grazers like dugongs is only a remote possibility.

Next, and this is essential, operating an egg harvesting and protection scheme does not preclude conservation measures aimed at other stages of the life cycle. On the contrary it should encourage them. The fewer adults killed, the more eggs will be available. And the more eggs saved from the tides, the more hatchlings can be released and the more the pressures on the adults mitigated. As an example, accidental drowning of sub-adult and adult turtles is common off the U.S.A. If the attempts to develop nets that allow turtles but not shrimp to escape prove successful, perhaps one of the few cases where a technological fix will be the solution (Anon., 1982; Seidel and McVea, in press), the benefits would not be lessened by taking eggs from racoons on the beaches and selling them to people. But to argue that eggs should not be harvested because many turtles are being killed by trawlers would be to miss the point of the present proposals: by diverting losses from predators and tides and linking harvesting to conservation, the turtles should be better off than before. By studying the number of clutches destroyed by animals or high seas, egg collection and conservation can be balanced in a rational way, and in a cautious way that allows for some of the minor uncertainties mentioned.

By contrast, there are egg collecting schemes where this balance is more arbitrary. In Trengganu, Malaysia, most of the eggs laid by leatherback turtles are taken, as they have been for decades. The state authorities there sell the rights to collect eggs on particular stretches of beach. The fees received from the licensed egg collectors go toward running a hatchery and looking after part of the beach set aside for conservation and tourists. People making a living collecting eggs obviously do not want the turtles disturbed while nesting and have an interest in the success of the conservation project and biologists from the Fisheries Department are able to influence events at the rookery. The whole social machinery is excellent: the problem is that nobody knows at what level to set the controls. The aim (not usually achieved) is to incubate about 15% of the leatherback eggs in a central fenced-off plot and release the hatchlings. But without knowing how many eggs are doomed naturally on the beach, many assumptions enter into setting the quota. It might be that losses of hatchlings in the first few days at sea outweigh losses to predators on the beach; high tides destroy very few nests on this beach (Mrosovsky, in press b). Allowing only 15% of the eggs to incubate, with a hatch rate of around 50%, might result in fewer baby turtles reaching the water than would occur if people left the rookery alone altogether. Or it might be that 15% was more than enough to sustain the population. There is no way of telling at present because there are no reference areas here to assess natural losses. In the long run the health of the rookery might provide some sort of answer, though with the longevity of the adults unknown, when that will be is anyone's guess.

Guesswork, arbitrary quotas, gambling on the future—these are far too frequent in turtle conservation already. They must be replaced by cautious management procedures that link use and protection in a logical way. Countries with a combination of funds for wildlife, scientific expertise and large sea turtle populations could take the lead. Australia is even better placed than the U.S.A. Several species of turtle nest in considerable numbers on its shores and some 40% of their eggs are inundated by high seas (Parmenter, 1980b). To what extent this results from erratic storms or from turtles laying below clearly visible high tide lines needs documenting. Unpredictability of egg loss, in place or time, would influence harvesting methods. There would probably also be difficulties in transporting eggs from remote islands. Development of new ways of handling and preserving eggs may be required. Perhaps pickling or freeze-drying would enable them to be kept near the beaches and collected en masse later in a single trip. It would be foolish to attempt precise suggestions without having a detailed knowledge of the situation. But it can confidently be asserted that with 40% of the eggs gobbled up by the seas there must be some room for organized egg harvesting in a way undetrimental to the turtles. If the Australian authorities worked out procedures, then they would not only obtain extra food for their own people but could also provide less fortunate countries with a helpful example of cautious sound use of this renewable resource.

An added advantage of exploiting eggs is that in some places it could be instituted rapidly. Giving people a stake in conservation while there is still something left to conserve may well be a more robust form of protection than protracted surveys and attempts to cut down on exploitation. For instance, in French Guiana it is already known that laying below the high tide line is responsible for many doomed eggs, probably more than 30% of the total for leatherbacks (Mrosovsky, in press b). Also stray dogs from nearby Indian villages create havoc digging up nests and devouring hatchlings (Fretey and Frenay, 1980). Nearly 15 years after the discovery of the French Guiana turtle rookeries, there are still no reserves, no regular beach patrols. The World Wildlife Fund and a few dedicated individuals cannot fill this gap adequately. Some government-sponsored protection is needed. Starting immediately personnel could be paid to rebury some of the eggs in fenced-off areas above the high water mark and take the rest, at the same time recording data on the frequency of misplaced nests on different stretches of the beach and in different months of the season. The same could be done in Oman on Masirah Island where about 40% of the loggerhead nests are destroyed by high seas (Ross and Barwani, in press).

Where eggs are to be taken mainly from predators rather than the seas, it may take longer for baseline studies to be completed. More than one year would be best in case numbers of predators fluctuated. Also there may be interactions between different factors affecting the chances of successful hatching (Hopkins and Murphy, 1981). When storms are few, there will be more eggs available for racoons. When racoons are few, after extermination programmes for instance, there will be more eggs for high seas to wash away. If a complete reserve area of comparable habitat to the harvested area was set aside for continuing studies this could be helpful. But it should not be necessary to wait a decade before exploitation began. On some beaches predation rates have already been investigated, for instance at Tortuguero, Costa Rica. Collecting eggs at Tortuguero? In a national park? How shocking! Again it must be repeated that what is advocated is more use of eggs that are lost anyway. At Tortuguero more than 40% of the eggs are lost to predators and high tides (Fowler, 1979). Feral dogs do most of the damage. A programme to control them has begun but it is not effective yet. Keeping dogs away and routine protection of eggs costs extra money. Selling some of the eggs could assist such endeavours and still leave more hatchlings entering the sea. After all the park at Tortuguero was created largely for turtles, not for dogs, coatis and vultures. But it is not worth debating here whether this is a place where more use should be made of doomed eggs or whether it should be kept as natural as possible as a reserve.

The more general point being urged here is that it is time to examine some of the currently cherished notions about sea turtles. Are they really endangered? Is there more room for using them? What is conservation for? In the early 1960s having the answers to these questions was not so pressing. Far fewer turtle rookeries were known then, and some that were seemed in a precarious state. A hands-off conservation ethic, or restricting use to very local levels, seemed most appropriate then for turtles. But now the situation is different. The numbers of turtles nesting at various well-studied beaches have not plunged (e.g., Figures 4, 5, 13 & 15). Huge new rookeries have been discovered, in Australia, India, Mexico, the Guianas, Costa Rica, Oman, Indonesia and on Europa Island, besides many minor ones elsewhere. And not all these countries appear to be intent on wiping out these resources in the way the Americans did in the time of Audubon.

Some of the bitterest arguments within conservation circles arise when protective measures are successful, when endangered species become numerous. National parks in Africa allow elephants to build up to such densities locally, that they destroy their own habitat, trample it down. Many elephants have been shot. This arouses passionate protests (Graham, 1973). The vicuna saga, already discussed in Chapter 8, is another case. This is not the place to debate whether the vicuna has yet reached numbers where culling is appropriate, or whether more animals should be transported from the Pampa Galeras to other areas. Better agreement between population estimates would certainly help in making such decisions. But sooner or later, if the vicuna conservation programme continues to show results, then use of the animal, and not just its wool, is almost inevitable. This will require the emotionally difficult transition from protecting individual animals to killing them. Whatever the reasons, it seems that success creates more dissension among conservationists than failure.

With turtles, perhaps partly because of some success in arresting declines in various areas, and increased public participation and new laws, and surely partly because of revised estimates of the numbers of turtles and their breeding places, we are now entering this controversial phase. So it is unlikely that some of the suggestions in this book will be universally acclaimed. But the sea turtle situation today is so completely different from that in the 1960s that it is time to re-examine every assumption, both about the biology and the use of these animals.

It is often thought a grave handicap that sea turtles are tied to their ancient habit of coming ashore to nest. Both the adults and the eggs and hatchlings are so vulnerable there. But in a humanized world this is their best hope for survival. If turtles laid their eggs in the sea, or carried their young within their bodies, protection of their reproductive efforts would be much harder. As it is, turtles adopt the strategy of laying vast numbers of eggs to overcome the odds against survival of any individual egg on land. This creates an opportunity for greatly boosting turtle populations. It is almost as easy for people to prevent eggs being taken by animals as to take them themselves. By ensuring that many more turtles survive at the early stages in their life cycle, populations can be raised to the limits imposed by nesting space, feeding habitats and other drains on the adults. And at the same time people can put food on their own plates.

Another assumption: it is often deplored that turtle eggs are mistakenly thought to be aphrodisiacs. In the short run this belief does increase pressure on the turtles, but in the long run perhaps this delusion might even be an advantage. Perhaps after a meal of turtle eggs the anticipation of extra sensations is enough to create them. If people are prepared to pay more for turtle eggs than warranted on a strictly caloric basis, then it would assist the operation of management schemes based on use of the eggs.

More generally, if the eggs are highly valued, for whatever reason, it simplifies setting the balance between protection and utilization because the main doubts about harvesting sea turtle eggs along the lines suggested above are these: maybe a turtle is worth more as meat than as an egg-laying machine and maybe its shell and leather are worth far more. If so, this would entail an altogether different approach to utilization because it would be much harder to forge a rational link between culling and conservation. In the proposal to set aside twice as many eggs for conservation as one takes for human consumption, there is at least some element of logic in the link. If many eggs are destroyed naturally, it is not especially risky, with the provisos mentioned and perhaps others also, to take some eggs and save others. But if it is a matter of culling adults, how many can be taken? What should be done to compensate for each turtle taken?

By far the easiest way of reimbursing the population would be to augment the numbers of young starting out by protecting eggs and hatchlings on the beach. But how many extra eggs have to be added for each adult turtle that was taken for its meat or shell? An empirical answer, even assuming there was a method of putting a mark on hatchlings that lasted till adulthood, would take decades to obtain because of the long maturation period. There are 2 ways, theoretically, of answering the question but at present both are dubious in practice. The first is to start with rates of predation at each stage of the life cycle, for the eggs in the nest, for the hatchlings on land, for the hatchlings when they enter the water and so on, and then calculate, given these rates, how many eggs are needed to produce an adult. This has been tried by Hendrickson (1958) for the Sarawak green turtles but he considered his figures to be only 'within the range of possibility.' The trouble is that predation rates, especially in the water, are little more than guesses. The second approach is to start with the number of eggs that an average female lays in her lifetime. To replace herself in a stable population she must produce one adult female and one adult male. So by dividing the lifetime output of eggs by 2, one arrives at the number needed to give one adult. This assumes a 1:1 sex ratio, but worse than that it requires knowledge of how many eggs an average turtle lays—just the kind of data that tag loss prevents one obtaining. Instead, from information about how many eggs can be laid by certain frequently seen tag-retaining turtles, one has to guess what the average turtle does, and that is an unsatisfactory procedure. So if adults are to be exploited, it is difficult to balance this with appropriate intervention on behalf of the turtles, and therefore it becomes all the more important, in thinking about resource utilization, to know whether it really is better to harvest the eggs or the adults.

The case for harvesting eggs has been developed by Hendrickson in 1958 in a paper that for its insights and range of information still remains essential reading today. He supported taking eggs rather than adults in 3 ways: with historical arguments, on general biological grounds and with specific calculations. First he claimed that in parts of Asia where the Muslim tradition of leaving the adults alone prevails, the numbers of turtles had declined far less than in parts of the world where mature turtles are slaughtered. This is hard to substantiate though. Not only is there a scarcity of quantitative data about the abundance of turtles in former times but any method of exploitation can be overdone. Even if there are more green turtles remaining in the South China Sea than the Caribbean, that does not in itself prove that egg collection is inherently superior. Nevertheless, proved or not, Hendrickson may well be right because there are general biological reasons for supposing that it is far safer to exploit the eggs.

> The individual *Chelonia mydas* female has a high reproductive potential and the species is adapted to sustain enormous losses at the very early stages of its life history. The small proportion of individuals which survive the early period of high mortality mature rather slowly and presumably remain reproductively active for a considerable number of years. In maintenance of the population, each adult female is of equal value to several thousands of eggs. The harvesting of eggs constitutes exploitation at that stage of the life cycle where the species is adapted to sustain high losses in the natural course of events. A very large portion of the eggs collected represent, not new losses to the population, but diversion of losses which would have occurred even if there had been no intervention by man. The slaughter of grown turtles, on the other hand, is a direct threat to the dynamic equilibrium of the population, and it would appear that the species is ill-adapted to sustain such losses. It is obvious that flesh and fat are the biologically more expensive food form to be obtained from Green Turtles, while eggs are biologically cheap. Given nutritional equivalence between eggs and flesh in terms of kilograms of edible protein per year, exploitation for eggs is the logical choice.
>
> (Hendrickson, 1958)

This last point was supported quantitatively. Green turtles in Sarawak 'usually lay' 6 or 7 times a season. With more than a 100 eggs per clutch, it is not unreasonable to suppose that production of 600 eggs per season is common. Assuming the turtle breeds in 3 separate seasons, it provides a total of 1,800 eggs weighing about 60 kg in all. An adult turtle in Sarawak weighs about 120 kg. If half of this is edible, it yields 60 kg of flesh and fat for consumption. This means that in terms of weight of food provided a turtle has only to breed for 3 seasons for the eggs to be worth as much as the turtle itself. And there always remains the possibility that it will come back in subsequent years to breed yet again.

If that was all there was to it, the case for leaving the adults alone and taking some of the eggs would be strong. But, as Hendrickson realized, the situation is complicated by the fact that a small strip of gelatinous tissue in the green turtle, the calipee, used for soup, is worth a sum out of all proportion to its weight or nutritional value. He believed, however, that even if the cash obtained by killing the turtles and selling the calipee was converted back into food by the vendor there would still be a net nutritional loss. In 1958, however, turtle leather was not fashionable and the shells were worth much less as souvenirs than they are now. Today these items fetch huge prices and it is unrealistic to ignore this. A further complication is that the value of different parts of the turtle varies widely between the different species. It may be best though to begin with a simple case.

The leatherback turtle, despite its name, is useless for leather. The flippers lack a cornified skin; their oily rubbery covering is difficult to preserve even for museum specimens. Nor does the carapace make a good souvenir. Instead of the usual turtle scutes there are only tiny bones embedded in a thick blubbery fibrous layer. Oil from leatherbacks is used in some parts of the world for varnishing boats, medicinal purposes and in lamps, but as there are other sources of oil in most of these societies and as it is hard to find a cash value for leatherback oil, for the sake of simplicity it is ignored here as of minor importance. That leaves only the eggs and the meat. So it is likely that arguments Hendrickson gave for harvesting the eggs of green turtles, based on comparisons of the weight of their eggs and meat, would today apply better to the leatherback. When similar calculations are made, based on the cash value of eggs versus meat, it turns out that a leatherback has only to lay for about 2 seasons for the value of the eggs to equal that of the meat (Table 3).

Of course, these calculations involve assumptions and should be refined as better data become available; they should be reworked for caloric and protein values as well as cash values. It might be that this would decrease the relative value of the eggs. But, on the other hand, it is improbable that an average leatherback only lays for 2 seasons. It would be odd for an animal after a long maturation period to breed once or twice only, especially when it is as swift and strong as a leatherback and has so few natural enemies. Killer whales take them sometimes, sharks inflict wounds, and jaguars occasionally kill them when they nest but at weights approaching 400 kg they are impervious to most predators (Mrosovsky, in press a). And indeed there are data showing that some individuals return to lay as many as 15 years after first being seen nesting (Hughes, in press a). Probably many leatherbacks produce thousands of eggs over a number of seasons. So killing the adults is neither good biology nor good economics. They are more valuable as egg-laying machines.

At the other end of the spectrum is the hawksbill turtle. Although its flesh is sometimes toxic and rarely eaten, its hide makes good leather and its shell is especially sought after; a single hawksbill may bring a fisherman as much as $60 U.S. (Nietschmann, 1981) or even $200 U.S. (Carr and Meylan, 1980b). It has displaced the green turtle as the world's most valuable reptile. With these kinds of prices there is little incentive to leave these turtles to lay eggs. Even a decline in numbers, which normally protects species by making it less worthwhile to go searching for them, may not save them. In the Caribbean divers hunting on reefs for lobsters or snappers will spear an animal worth $200, even if they did not set out specially to look for it (Carr and Meylan, 1980b). And with the hawksbill habit of nesting here and there in small numbers over large areas, it is difficult to protect its breeding and augment the numbers of hatchlings reaching the sea. Certainly it is hard to argue, as with the leatherbacks, that it is better as a matter of self-interest for a society to leave adult hawksbills alone.

Some conservationists believe that the only hope for the hawksbill is clamping down on all international trade in its products—by banning it, by fining violators, by discouraging consumers from wearing hawksbill jewellery, by Greenpeace-type gestures, by any means possible. Would that work? It might help but it is significant that Japan is the major importer of hawksbill shell. Making ornaments for officers' uniforms out of tortoise-shell and combs and pins for ladies goes back many centuries there. Formerly, these decorations were confined to the aristocracy and officials; exquisitely worked pieces were much prized. Now use of tortoise-shell products is more widespread but they still have auspicious and ceremonial connotations. It is significant also that Japan has recently joined CITES but has entered an exception for hawksbills. This means that while supporting the general aims of CITES, it is not prepared to renounce commerce in this species. France also has a reservation on this species. With such nations insisting on the right to trade, it would be optimistic to think that an international ban is going to be effective. Continued outcry over many years

Table 3. *Value of eggs and meat of leatherback turtles in Mexico* (adapted from Mrosovsky, 1981).

Data	Basis for assumptions and comments
Value of meat	
Carapace length = 147 cm	Mean over-the-curve measure for Tierra Colorada (n=13, Mrosovsky and Marquez, unpublished)
Weight = 295 kg	Pritchard (1971a) reported that a leatherback with a 149 cm carapace weighed 295 kg. Since his measure was straight line, it is not likely a 147 cm over-the-curve leatherback would weigh more.
Weight of meat = 103.2 kg	Rebel (1974) states that the flesh of a green turtle, including the muscles, constitutes about 40% of the body weight. At the Cayman Turtle Farm a 100-150 kg green turtle yields about 20% steak (Wood, J.R., personal communication). The latter figure may be more accurate but a leatherback with a less bony carapace and plastron and on a less rich diet probably has more of its weight as meat—at a guess 35%. If the flippers and fat are eaten, perhaps an even higher figure should be taken.
Price of meat = 60 pesos/kg	As reported by people at Tlacoyunque, 1978. Cliffton et al. (in press) state that the value of the meat is negligible. Nesting leatherbacks are sometimes killed for their oil and sometimes by egg poachers who do not want to wait for the turtles to lay. So often the potential value of a slaughtered leatherback is not realized.
Value of meat = 6192 pesos	

Value of Eggs

Clutch size = 70

Mean for Tierra Colorada (n=11, Mrosovsky, unpublished).

Cost per egg = 8 pesos

As reported by people at Tlacoyunque, 1978. Cliffton et al. (in press) give a value of 10-12 pesos per egg for 1978.

Value for 1 clutch = 560 pesos

Number of times a leatherback has to lay for the value of the eggs to exceed the value of the meat

Assuming 1 clutch is collected when turtle is killed for meat.

$$= \frac{6192 + 560}{560} = 12.06$$

Number of breeding seasons a leatherback has to stay alive for the value of the eggs to exceed that of the meat

Assuming the average leatherback lays 6 times in a season. Even if it lays only 5 clutches per season, the figure is still close to 2.

= 2

has not yet stopped the Japanese from whaling, although the International Whaling Commission recently voted to phase out commercial operations by 1985. Turtles are not likely to arouse the public as much as whales.

Is there any way to take the pressure off the hawksbill other than a confrontation between conservationists and the Japanese tortoise-shell industry? One possibility that merits consideration is farming, or ranching. Indeed the Japanese are already looking into this (Uchida, 1980). Perhaps a co-operative attitude that seeks to influence how mariculture operations are established would be more productive than a frontal attack. Suggestions about ways of compensating for the take of animals from the wild might then be better received. With farms and ranches there are feasible and rational ways this can be done, the very same ways that have been proposed for egg harvesting. The number of eggs taken for starting up a farm or maintaining a ranch should be balanced by twice that number being protected from predators and tides on the beaches. For instance, if the Australians were selling the Japanese hawksbill eggs, the price should be set so that it could cover beach patrols and staff sufficient to relocate and guard twice that number of doomed eggs. The attraction of linking commerce to conservation in this way is that commerce pays nature in the same currency as it receives, and it pays right away. Payment in other currency is more arbitrary, more controversial. When Mariculture Ltd. started up in the Cayman Islands, it intended to compensate for the eggs it took by head-starting some of the yearlings later. It may well be that protection at the juvenile stage is a better way of exerting upward leverage on a turtle population than increasing the output of hatchlings on the beach (cf. Richardson and Richardson, in press). Some of the extra hatchlings will only go to feed the fishes anyhow. But at present far too little is known about predation in the sea and about head-starting to make this anything but a gamble. How much is a head-started turtle worth? Is it worth anything at all? Nobody knows.

Another option is for commerce to take adult or sub-adult hawksbills for their shell and compensate by protecting eggs on the beach. But without data on how many eggs the average turtle lays it is difficult to know how many eggs should be saved. And in any case those eggs will only create adults in the future. But if the hawksbill trade begins with eggs and pays in protected eggs, then it is the other way round. Commerce pays nature at once but receives its profits later, when the shell is marketable.

There are additional potential advantages in farming or ranching for hawksbill shells. By varying the diet or genetic background it may be possible to produce animals with especially prized markings. Perhaps these would be readily distinguishable from most shells from the wild. Perhaps, if a more positive approach toward mariculture prevailed, the entrepreneurs would be willing to co-operate with scientists and wildlife departments in introducing some biological marker into the diet that lodged in the shell and could be used by customs officials to distinguish captive-raised from wild stock. Analysing the amino-acid composition of the shell is one approach to this problem (Hendrickson et al., 1977). Perhaps even better would be to introduce a synthetic fatty acid into the diet (Ackman, R.G., personal communication). The structure could be altered every few years, like changing a code number. This could be invaluable because however many farms or ranches there are, the incentive to take hawksbills from the wild will remain. Someone spearing a hawksbill on a reef has paid nothing for feeding the animal or keeping its water clean. To propose farming or ranching is not to deny that restrictions on trade in wild hawksbills are still needed. It is based on the hope that, even if farms do not remove all the incentive to take wild hawksbills, they will reduce the pressure on them by supplying a sizeable slice of the market with a dependable and perhaps superior product.

Here we come to the stale and unanswerable conundrum: will mariculture operations for turtles saturate the market or will they stimulate it? If ranching is linked to conservation in a logical careful way with a well-marked product, it is unlikely that hawksbills will be worse off, except to the extent that new markets for shell are developed and advertising stimulates consumers into a buying frenzy. If that happens, then supplies from maricultured turtles might be unable to meet the demand and the incentive to take hawksbills from the wild might become even greater. This is a legitimate fear; it cannot be dismissed. Even with better figures on the total world use of hawksbill shell, and estimates of how much farms might provide, there would be the intangibles of fashion and of how well any plans actually work in practice. Yet it is equally impossible to dismiss the hope that maricultured products would reduce the pressure on wild hawksbills.

Despite these acknowledged uncertainties, much can be said for establishing at least one fairly large scale hawksbill farm or ranch, to investigate mariculture methods for this species and to see if the products could cut into the market. Whether the hawksbill is endangered or only vulnerable, its situation is serious, there is agreement on that. Creating more reserves and more local protection for hawksbills would be helpful, but with their widespread nesting enforcement is difficult. Moreover, the main threat stems from the demand for their shell. Any solution getting at the root of the problem has to tackle this. An international ban on trade is unlikely to be effective. By taking out a reservation under the CITES convention, the Japanese have made it clear that they are not about to renounce this trade. The outcome of a world-wide campaign against hunting and consumption of hawksbills, on a scale similar to that on behalf of whales, is just as uncertain as is the effect of mariculture on demand. The Japanese Tortoise Shell Association already seems to be moving in the direction of farms or ranches. It realizes that ransacking the oceans for hawksbills cannot go on indefinitely. The conservation community will soon be forced to adopt some attitude to these initiatives. Perhaps attempts to influence them, to inject balancing conservation contributions, would be more productive than a repeat of the drawn-out battle with the Cayman Turtle Farm. That did not demonstrably increase populations of turtles in the wild and it may have diverted attention and energy from more productive activities (Chapter 8). Finally, there is at least a hint that mariculture operations might be able to supply a sizeable portion of the market. According to compilations of government statistics (Mack et al., in press), exports from the Cayman Islands accounted for about 1/10th of the imports of raw tortoise-shell to Japan from January 1977 to October 1979. There are, of course, numerous problems with such trade figures. Imports and exports do not always match up. From the figures alone it is not certain that the exports from the Cayman Islands all or mostly came from the Cayman Turtle Farm. Some estimates coming from the Cayman Farm itself (Wood, J.R., personal communication) give lower figures for sales to Japan than the official customs statistics. Possibly some turtle shell is re-exported from the Cayman Islands by other entrepreneurs. But lacking anything better to go on, it does appear possible that the Cayman Turtle Farm may be supplying a significant part of the Japanese market. Another way of assessing the capability of farms to supply this market is to compare the total imports of shell to Japan with the production potential on the Farm. From 1976-1978 an average of 44,265 kg a year of raw tortoise-shell was imported by Japan (Mack et al., in press). On the Cayman Turtle Farm the usable carapace shell from a green turtle is .9% of its body weight and production on the Farm has exceeded 500,000 kg of turtle in the past (Wood, J.R., personal communication). The Farm therefore is capable of producing 4,500 kg of shell a year, close to 1/10th of the 44,265 kg annually imported by Japan.

The Farm does not deal in hawksbills but in substitute shell from green turtles. It is too early to know how important this development will be. But even if green turtle shell did not become widely accepted in Japan, it is still notable that a single farm seems to supply or is capable of supplying 1/10th of this market. If that really is the case it only needs 10 hawksbill farms of equivalent scale to satisfy the whole industry there. If conservationists and industry could work together toward a situation where the Japanese Tortoise Shell Association bought only from farms or ranches that had been established from eggs in ways not detrimental and even helpful to the wild stock, as suggested above, then—maybe, maybe—the prospects for the hawksbill would brighten. It is at least worth serious consideration, as an alternative to the present impasse.

Turning to the other species of sea turtles, the green, the flatback, the loggerhead and the olive ridley, in terms of the value of their eggs relative to their other parts, they lie somewhere between the leatherback at one extreme and the hawksbill at the other. In a few cases, perhaps, collecting the eggs may be the most attractive way of exploitation but probably more often, especially if the vogue for turtle leather continues, there are considerable temptations for individuals to get rich quickly by killing as many animals as they can and banking the profits. What happens when these temptations go virtually unchecked by the government is evident in Mexico. Already 3 major arribadas of olive ridleys on the west coast have been reduced to a remnant. These occurred at Tlacoyunque (Guerrero), Mismaloya (Jalisco) and Chacahua (Oaxaca). It is difficult to find details and documentation about these arribadas, presumably because they were drastically exploited before biologists had a chance to study them. But people who have visited the area attest these arribadas once existed and this has not been disputed (Marquez et al., 1976; Pritchard, 1979a; Ross, 1980, Frazier, 1981; Pritchard and Cliffton, 1981). The largest remaining arribada at Escobilla (Oaxaca) is under great pressure (Cahill, 1978; Frazier, 1981). In a single week thousands of turtles are killed as they assemble offshore for breeding. The operation is run by co-operatives who have permission from the Instituto Nacional de Pesca to take a certain quota each year. There is also some protection on the beaches for those females that make it to the shore to lay. From those that do not, when they are slaughtered, the eggs are removed from the oviducts and put into styrofoam boxes. However, these measures bear no rational relationship to the number of adults taken. How possibly could they? With no reliable information on longevity, reproductive output, survivorship of the young and years to maturity for ridleys, there is no rational way a quota could be set. Moreover, hatch rates from oviductal eggs are poor; figures of 37% and 7-22% have been quoted (Pritchard, 1978, 1979b; Cliffton et al., in press). Also artificial incubation probably biases sex ratio. That the resulting hatchlings compensate for the adults taken is no more than a guess. The huge quotas and harvesting arrangements at Escobilla are not grounded on biological considerations but on something else:

> Coastal Oaxaca is a long way from Mexico City, and there is no real possibility of fielding a large crew of federal enforcement men in this remote area. Consequently, if PIOSA had not been allowed to have a quota as high as, or nearly as high as, it requested, such a harvest would simply have taken place anyway, with no real possibility of control. By granting one company a monopoly to purchase all turtles caught by the local cooperatives, it was hoped that the legitimate cooperatives and the PIOSA field men would act as unofficial enforcement agents, ensuring that no one else would dare get in on the act. This interpretation may reflect pragmatic reality, but also makes it clear that the quotas are set by commercial pressure rather than by any biological insight into what the populations can stand.
>
> (Pritchard, 1978)

On top of all this there is a major problem with incidental catch of turtles off the west coast of Mexico. In some areas the average catch per boat each working day is thought to be 20 turtles, green turtles as well as ridleys. More than 35 green turtles have been caught in a single trawl (Pritchard and Cliffton, 1981).

There are, nevertheless, those who go along with the quota system in Mexico for pragmatic reasons. At least it provides the co-operatives with an incentive to stop poachers and they have in fact intercepted illegal traffic on a number of occasions. The former owner of the turtle processing plant in Oaxaca, Sr. Antonio Suarez, is quoted as saying 'the surest way to drive a species to extinction [in Latin America] is to give it total protection' (Cliffton et al., in press). Some quotas are better than none and if the authorities set too small quotas the system would collapse and there would be a free for all. Even minimally effective conservation measures, such as trying to keep a 750 m stretch of beach as a reserve for green turtles in the State of Michoacan, might be seeds that one day will grow into broad protective shields (Pritchard and Cliffton, 1981). One cannot but admire people who work for wildlife in such an unpropitious environment and hope not to say anything that will upset their efforts.

But at the same time it is necessary to denounce the mad destructiveness of killing thousands of adults when they assemble for breeding, bearing ready-formed eggs. If Escobilla is not to go the way of Rancho Nuevo and Mismaloya and Tlacoyunque, as yet another example of how to destroy a resource rapidly, even before its potential is fully assessed, then biological considerations will have to replace political ones.

Fortunately, a number of countries are taking a saner and firmer approach to their newly-found turtle rookeries. But that should not prevent them from benefiting from these resources, and rapidly too. Without endangering and even perhaps augmenting their endowment, they can use the wasted eggs, either directly, or indirectly, by converting them into adults on farms or ranches. An interesting new example in the latter category is the Saint Leu turtle ranch (CORAIL) on Réunion Island in the Indian Ocean (Lebrun, 1975; Anon., 1980a). According to a 1977 prospectus, 30,000 green turtle hatchlings a year would be taken from Europa and Tromelin. That may sound like a large number but it is only 2% of the estimated total for those islands. Moreover there is a high natural wastage. When hatchlings emerge by day, as they do sometimes, most are carried off by frigate birds. Many of the hatchlings collected for the new ranch have been from such daylight emergences (Hughes, in press b). Also at the height of the nesting season on Tromelin around 40% of the nests (107,000 eggs) are dug up by the turtles themselves (Anon., ca. 1977). This leaves plenty of scope for augmenting the number of hatchlings reaching the sea, and the proposal was to compensate for the turtles taken by protecting some of the other clutches. Among the measures suggested were putting nets over the beaches to stop frigate birds swooping down on hatchlings emerging by day, and carrying hatchlings out beyond the coral reefs to avoid inshore fish predation. Whether these particular measures are the best is debatable. Maybe frigate birds just take an equal number of hatchlings from the surf instead of from the beach. Maybe the experience of swimming out to sea is important for orientation (Chapter 4). Also it would be rash to endorse the Réunion ranch without having more information on how the average numbers of nests each year are estimated, on the welfare of the animals in captivity (Fretey, 1978), on how many clutches are protected and by what means and on many other details. Even then in such remote places as Europa there need to be safeguards that conservation and collection procedures are adhered to. But whatever the actual practices may be—and there is little firm to go on at present—the principle is sound: linking the quantity of turtles taken to compensatory and even overcompensatory conservation, measured *in the same units* of hatchlings or eggs.

Whether ranching of this kind is sound economically is much less certain. Raising turtles in tanks for a few years is elaborate, costly and long-term. Until turtle mariculture becomes less experimental, it will often be more desirable to concentrate on using eggs as food and to turn away from the possibly more lucrative but riskier markets of luxury items made from leather and shell (see also Diamond, 1976). Ultimately, and this would take many years even with sounder tagging methods, when population dynamics of turtles are better understood, it should be feasible to offset a specified cull of adults from the wild by protecting an appropriate number of eggs. When ways of determining age are discovered, turtles could be taken at or toward the end of their reproductive lives (Hendrickson, 1958).

Meanwhile, it is wiser to exploit them as egg-laying machines. The idea of permitting and regulating egg harvesting is not new (see, for example, Hendrickson, 1958; Harrisson, 1962; Schulz, 1975, 1980; Diamond, 1976; Cornelius, in press), but too little has been done toward actually instituting such schemes or improving the few that exist. For the next few decades at least, conserving turtles needs re-orienting from sanctuaries, bans, alarmism and wailing about the past, to the benefits of managing and maximizing the eggs delivered so freely to our shores. What a wonderful opportunity sea turtles provide for us to pay with protection for what we take. If we cannot work out ways of living alongside the turtles, with such propitious circumstances, then what hope is there when it comes to the wildlife of Africa and the vicuna?

The biology of turtles, with their gentle demeanour, terrestrial breeding and huge output of eggs, many of them naturally doomed, has all the ingredients for an exemplary balance between profiting from and preserving wildlife, between taking and leaving, between use and admiration, between commerce and conservation.

ABBREVIATIONS

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CORAIL	Compagnie Réunionnaise d'Aquaculture et d'Industries Littorales
FAO	Food and Agriculture Organization of the United Nations
IUCN	International Union for Conservation of Nature and Natural Resources
NMFS	National Marine Fisheries Service (U.S.A.)
PIOSA	Pesquería Industrial de Oaxaca (Mexico), Sociedad Anónima
UNEP	United National Environmental Programme
WWF	World Wildlife Fund

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