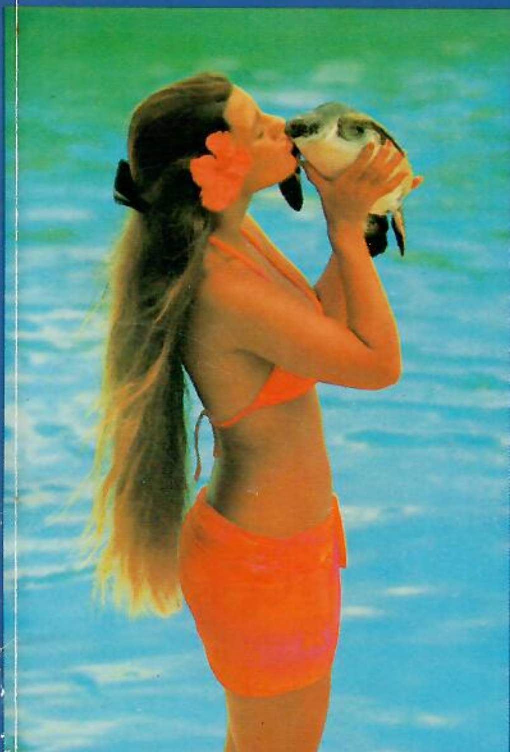
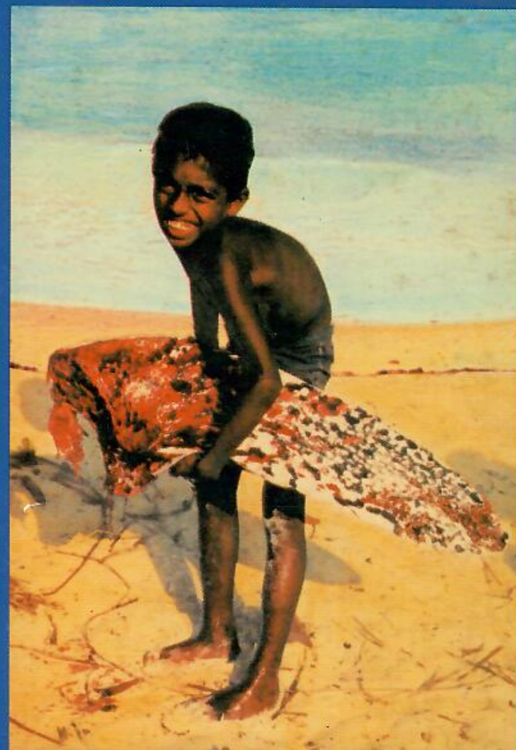
CONSERVING SEA TURTLES





N. Mrosovsky

This volume is the second in a series of miscellaneous publications issued by the Captive Breeding Committee of the British Herpetological Society, and was produced on behalf of the Society by Simon Townson and John Pickett.

First Edition, February 1983

Published by

The British Herpetological Society
c/o The Zoological Society of London
Regent's Park, London NW1 4RY

ISBN 0 9507371 1 9

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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.

For commenting on the manuscript, I thank: S. Kingsmill, K. McLean, S.J. Shettleworth and A.C. Whitaker.

For help in typing, drawing figures and preparing this book I thank: R. Cernavskis, C.M. Godkin, R. O'Grady, K. McLean, G. Richardson, J.J.B. Smith, H. Spencer, D. Trueman and R. Taylor.

Finally, I thank J. Pickett and S. Townson of the British Herpetological Society for their encouragement and help, and the Natural Sciences and Engineering Research Council of Canada for supporting my research on sea turtles.

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

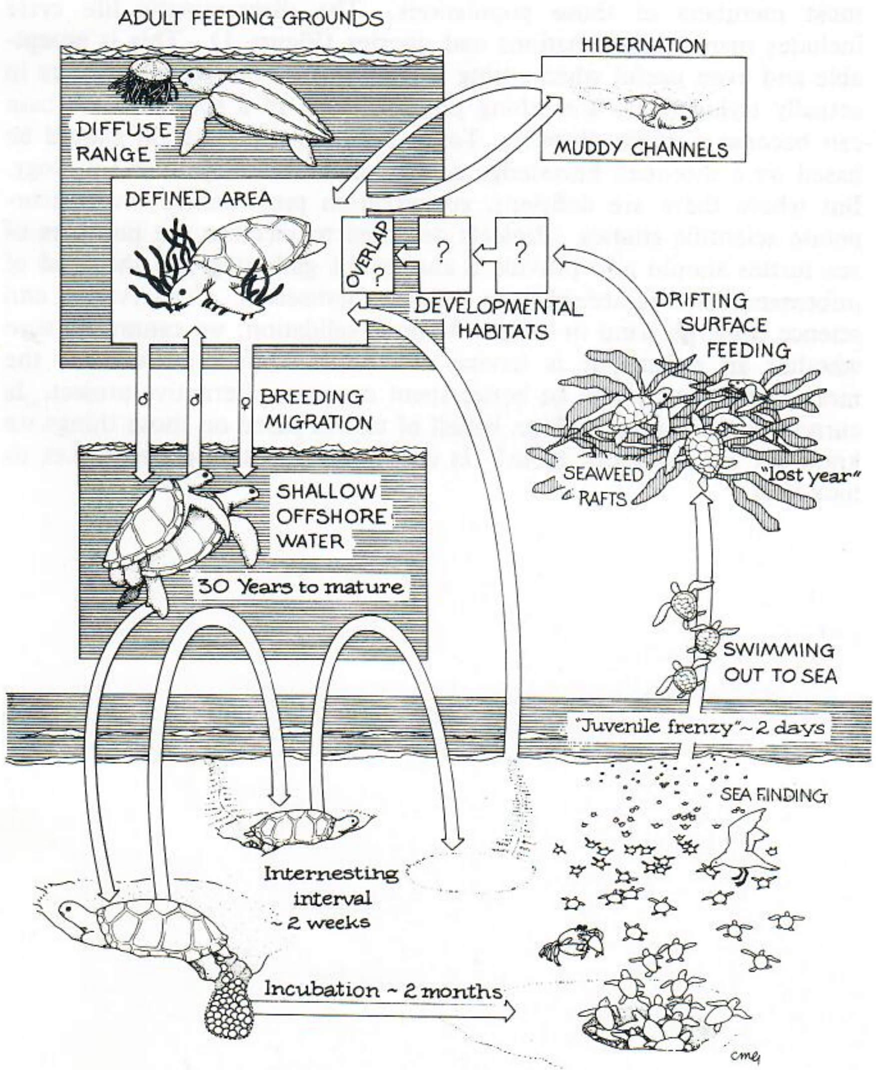

Figure 1. Simplified life cycle of sea turtles. Modified and elaborated from Carr et al. (1978).

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.

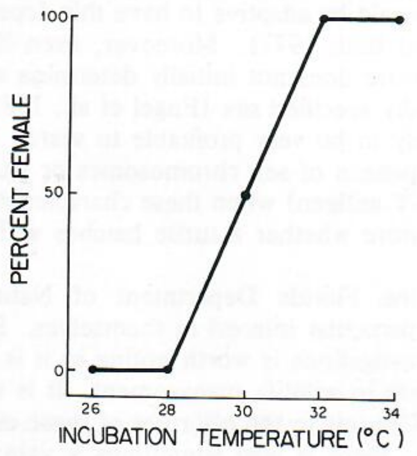

Figure 2. Percentage of females (turtles with ovaries present at hatching) as a function of incubation temperature. Eggs of loggerhead turtles were incubated at constant temperatures in the laboratory (data from Yntema and Mrosovsky, 1979, 1982).

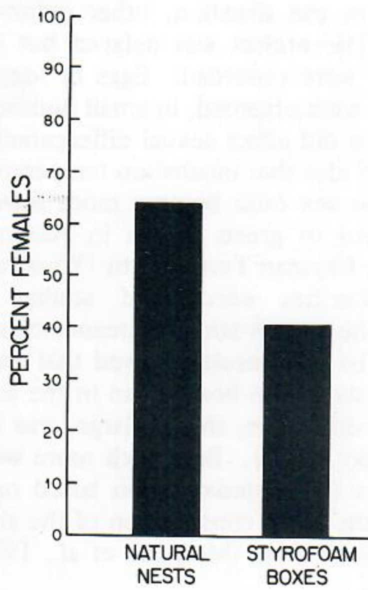

Figure 3. Percentage of females (ovaries present at hatching) of green sea turtles from natural nests and from styrofoam boxes. All samples were collected in Surinam during one part of the season; sex ratios are not therefore necessarily representative of the whole season. Data from Mrosovsky (1982).

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.