George Balazs

The song of the turtle

Sea turtles have been around for 200 million years. Now, these antediluvian animals are threatened by foolish exploitation, but before they can be helped they must be understood

Dr Jeremy Cherfas reports from Washington DC

Sea turtles are easy meat. The female hauls out of the water and up the beach to lay her clutch of eggs, abandons them and heads back to the sea. She is vulnerable while she waits in the water offshore to emerge, and even more so when she comes up on land. The eggs, though she does her best to hide the nest site, are easy to find. As a result the turtle and her eggs have long been a valuable source of food in many countries with tropical coastline. Other, larger-scale, activities, however, have put increasing pressure on the world's sea turtle to the extent that six of the seven species are officially endangered (the exception is the small flatback turtle *Chelonia depressa*).

The plight of the turtles has now been taken up both by the international conservation community and by the enterprises that kill turtles (even accidentally—the US Fisheries and Wildlife Service is keen to end incidental catches of turtles in the nets of shrimp trawlers). The result was the recent five day World Conference on Sea Turtle Conservation in Washington DC. More than 300 representatives from over 40 countries discussed the ins and outs of turtle biology and turtle conservation. There were plentiful arguments on some aspects of conservation (see p 852) but the overwhelming conclusion of the meeting was that we really know very little about the biology of the sea turtles. This profound ignorance hampers rational discussion of the options, and must be rectified; some of the scientists presented the conference with results that point the way to the kind of study that will have to be done, and done quickly, if sea turtles are not to join the list of species exploited to the very edge of extinction.

A thorough understanding of an animal's life cycle is perhaps the most important prerequisite for any attempt at conservation. How fast does it grow? When is it sexually mature? How often does it reproduce? Do many of the young survive? When do they die? Answers to all these questions are vital. The common wisdom—based as much on preconceptions as on the results of tagging programmes—is that the turtle suffers high mortality when young, and that perhaps only one in a hundred hatchlings survives to maturity (about 60 per cent of the eggs in a clutch make it to become hatchlings). Once the turtles reach maturity, at about five years, they come to the beach and lay perhaps three or four clutches of about 100 eggs each in a season. The adults live for quite a long time and return to nest again every three years.

Not one of these assumptions went unchallenged.

George Hughes is a chief conservator with the Natal Parks Board and has worked with the sea turtles of South Africa for almost a decade, supervising one of the best tagging operations in the world. He is particularly worried about the assumption that turtles return to nest more than once. Tagging programmes have been running for 20 or 30 years, and they have provided evidence that some females do indeed return to the nesting beach in accordance with a more or less fixed cycle. At Tortuguero beach in Costa Rica, for example, Archie Carr's group has been tagging green turtles (*Chelonia*

David Hughes/Bruce Coleman

Top, a Hawaiian green turtle basks on the beach. An olive ridley, above, comes ashore to lay, keeping flippers off the hot sand

working in their own fields" (in the event, not strictly true, but never mind). And thus they printed, at the bottom of the front page of their programme, that the gathering had been "Approved by the DHSS under Section 63 of the National Health Service Act".

This last statement means that the DHSS would hand out a few pounds of taxpayers' money, by way of reimbursement of expenses to any NHS family doctor who might attend the show, and it is a clause in the act designed to encourage GPs to go to gatherings which might help them to "keep up" with advances in medical knowledge. No conventional medical meeting would need to be advertised in this fashion. We can assume that the sponsors of the "New approaches to cancer" seminar were immensely proud of the fact that their efforts had been "recognised" by the very Establishment that they are so eager to fault and criticise.

It was a mixed audience, consisting of, perhaps, a few GPs, and some nurses, and some psychotherapists, and some naturopaths, and some cancer patients, and some widows of cancer victims, but largely, I guess, of men and women who had no particular professional or personal interest in the disease under discussion, but who were there because they lusted after some kind of "revelation" about the nature of man and his flesh, and the burdens of the flesh, which they had not been able to discover through any of the "usual channels".

But the audience was not, by any stretch of the imagination, a gathering capable of understanding and assessing esoteric biological propositions and arguments. It was therefore both surprising and revealing to find that the longest and the loudest applause, and the commonest cause of admiring comment during "nutritional breaks", was a lengthy dissertation delivered by a Mr D. Lang Stevenson, a retired consultant surgeon, who once worked in an East London hospital. I found it extremely hard to follow his arguments, and I have had some training in the biological sciences, but I can quote some of his assertions, among which was the statement that "the brain is the greatest carcinogen of them all", and that "the fault, dear Cassius, lies not in your carcinogens but in yourself".

So far as I could understand his message, it was that cancerous growths are an expression of each individual cell's infelt need to be "born again".

There was a great deal of "science" in his presentation, and he had a lot to say about enzymes and molecular mechanisms, and I *think* that, at one stage, he was telling us that cells contain tiny lasers, which accomplish all manner of effects, and which, by their presence support the thesis that "Light is Life". I *think* he was saying that cancers are groups of cells which have "decided" that the body in which they exist is inimicable to their well-being and survival, so that they light off on their own, and make a kind of UDI (just like the Rhodesians), and I *think* he was suggesting that if a body harbouring cancer (and, particularly, the brain controlling that body) started behaving itself again, and became, once again, a satisfactory haven for the cells within it, then those cells would abandon their dissidence, and start behaving properly once more, and cancers would simply disappear.

But it was, as I have suggested, a confused and illogical presentation. That did not prevent an audience, most of whose members could hardly have understood a word of the arguments advanced, from cheering it to the roof.

Why did this happen?

I suggest that this is because there are a lot of people who have a "gut" feeling that the scientific approach is logical and right, but who don't like the answers which science propounds. And that is why they devote themselves to pseudo-science with such passion.

The conference wasn't all like that. The sponsors had imported, for example, from the United States, Dr Claus Bahnson, who is director of the Department of Behavioral Sciences at the Eastern Pennsylvania Psychiatric Institute in Philadelphia. This good man spoke for a very long time in a rather low voice about all the new considerable evidence suggesting that cancers are more frequent in our society among those who have experienced deep grief.

What he had to say well supported the view that the upper reaches of the brain, which are concerned with emotion and memory and imagination, have an influence upon the "lower" parts of that organ, which, in their turn, affect the activity of the endocrine glands, and the activity of autonomic system, so that thought processes do indeed moderate the workings of blood vessels, and the bone marrow, and the liver, and the gut, and all other parts and components of the body, and so that grief and despair and anxiety and frustration can reasonably be suspected as factors which may *sometimes* so distort the economy of the body that aberrant or "cancerous" cells which would otherwise have been destroyed by the immune system do, in fact, flourish and survive.

And so it may be.

Dr Dorothy Speed, who works at the Royal Marsden Hospital, described how she runs a ward devoted to the care of cancer patients who have been abandoned by the therapists. She tells how her part of the hospital takes over people for whom there is, apparently, no further hope, in any curative sense. But with sensible and compassionate help, many a cancer victim can go on living with the disease for a decade or more, finally dying (perhaps from cancer, and perhaps not) long after the making of the "mortal" diagnosis. Like the staff of the tragically few similar establishments in this country (such as the Marie Curie homes, and St Christopher's Hospice), Dr Speed and her colleagues have worked out a way that makes dying a painless and pleasant end to life.

Dr Speed's approach to this particular category of cancer patient was clearly regarded as unimaginative and old-fashioned by most of her listeners, rather than as the informed, humane, pragmatic and thoroughly beneficial response to a human need which it undoubtedly is. The audience wanted to hear of miraculous "insights" and "breakthroughs", and was in no mood to be reminded of the fact that refractory and intransient problems rarely yield to anything except patience and devoted effort.

Dr Speed had told, for example, how she had encouraged a young man under her care to go out into the Fulham Road and buy himself a steak from time to time, and to bring it back and cook it on the ward and then enjoy it, for she was concerned to make sure, so far as she was able, that her patients did indeed enjoy such life as might be left to them. But one participant (a self-confessed naturopath) got up and expressed his "outrage" at the fact that Dr Speed actually *encouraged* her patients to eat meat, because, according, presumably, to some received wisdom from the Lord (for I know of no controlled trials which could support his conviction), meat is terribly, terribly bad for cancer patients.

Meat is it—or enjoyment?

This man forces his cancerous clients to drink gallons of fruit and vegetable juices, which must be prepared according to a detailed ritual if they are to be effective, and which (according to another naturopath to whom I spoke during a nutritional break) must have been organically grown. The protestor also denies his patients coffee drunk in the usual fashion, but subjects his customers to a "coffee enema" every other day.

So, once again, we had a revelation of this underlying idea that pleasant experiences are corrupting, but that, if you can find a way of making them *thoroughly unpleasant*, then they will do you a power of good.

When I get "The Big C" God give me the care of Dr Dorothy Speed and to hell with coffee enemas. □

mydas) for over 20 years. By far the greatest proportion, 49 per cent, return after an absence of three years, with 21 per cent after two and 18 per cent after four years. Carr's tag returns make a good case for cyclical nesting.

What most people do not consider is that in the 21 years of its operation, the Tortuguero operation has tagged something like 12 000 females. The number that have returned in subsequent years is 1412, less than 12 per cent of the total. The figures for cycling are thus based on a rather small portion of the population. The tagging programme in Surinam has a high return rate of 24 per cent, but other green turtle tagging programmes have return rates that are close to 1 per cent, and other species, including Hughes's leatherbacks *(Dermochelys coriacea)* and loggerheads *(Caretta caretta)*, don't do much better.

The myth may be that turtles nest repeatedly, but as Hughes says, "turtles that are tagged and depart the nesting beaches as a single time nester never to be seen again far exceed those that return . . . in future years". Hughes seriously questions the myth, and thinks that most female sea turtles nest once only.

It is easy to measure turtle hatchlings as they scrabble frantically down the sand to the sea, and it's also easy to measure mature females as they lumber up the beach to nest. Between, the turtles are almost invisible. Nobody is sure where they go, or what they do, and herpetologists talk ruefully of the "lost years". Nobody knows, for example, how fast turtles grow or when they become sexually mature. George Balazs lives and works in Hawaii, and he has been tagging and measuring immature green turtles to try and get some answers to these questions.

The green turtles of Hawaii are unique for two reasons. One is that they occasionally crawl up on the beach to bask in the sunshine. They do this only on the remote beaches of uninhabited islands, and Balazs thinks that his basking turtles may be the last remnant able to carry on this tradition unmolested. The Hawaiian turtles are also unique because they provide possibly the best data on growth.

Fast growing off the big island

To date Balazs has tagged 629 immature turtles, and has managed to recapture 70 of these. Roughly half of these had grown measurably, but the rates of growth varied widely. The turtles grew most rapidly around the Kau district of the big island of Hawaii, where they averaged 0·38 to 0·52 cm per month. Contrast this with the turtles that lived around French Frigate Shoals; these grew between 0·02 and 0·13 cm per month.

The smallest turtle to nest in Hawaii measured 81 cm, and the average is 92 cm. Balazs's data suggest that it would take a 35 cm yearling 10·8 years to grow to 92 cm if it lives off Kau, a period that agrees with estimates of between 4 and 11 years based on rates of growth in captive animals. If, however, the turtle lives off French Frigate Shoals, it will take 59·4 years to reach average nesting size!

The fast-growing turtles off Kau have at their disposal large pastures of the alga *Pterocladia capillacea*, whereas those around French Frigate Shoals feed on other algae that are ignored by the turtles at Kau. Balazs thinks that the slow-growing turtles are eating second-rate food, and that these unpreferred foods may well be partially toxic. This would account for their slow growth, but it doesn't tell us much about other turtles, feeding on other plants in other localities. The possibility that a turtle may take more than 50 years to reach maturity means that the populations might be disastrously slow to respond to any help now.

One component of growth is the efficiency with which an animal converts food eaten into its own flesh and blood. Karen Bjorndal, a member of Archie Carr's group at the University of Florida, has done a beautiful study of the nutrition of the Caribbean green turtles that migrate between the nesting beach at Tortuguero in Costa Rica and feeding grounds off the coast of Nicaragua. The feeding grounds are large abundant pastures of the sea-grass *Thalassia testudinum* (turtle grass), which provides a constant source of food throughout the year. Surprisingly, few other herbivores take advantage of this ready supply, and less than 10 per cent of the leaves produced are eaten. One reason might be that turtle grass leaves contain 45 per cent (dry weight) cellulose, which animals cannot digest. Despite this, green turtles very evidently do use *T. testudinum* and Bjorndal has shown how they are able to do so.

The turtle has two prongs to its attack on turtle grass. The first is physiological. Animals cannot digest cellulose but microorganisms can. The guts of grass-eaters contain bacteria that break the cellulose down into components that the animals can utilise. The turtle is no exception; in its hind gut is a flourishing colony of microbes that ferment the cellulose into volatile fatty acids (acetate, butyrate and propionate) and the turtle appropriates these fatty acids for its own use. Fermentation in the caecum alone supplies 15 per cent of the turtles' energy needs, and overall the turtle is as efficient as the cow at getting energy from grass *(New Scientist*, 2 August, p 366). The turtles' second prong is behavioural. Rather than wandering aimlessly and eating as they go, the turtles consistently and repeatedly crop specific stands of sea-grass. The boundaries of these underwater pastures are clearly visible and although Bjorndal is not sure how the turtles establish these cropping areas, she is sure of the benefits they derive. Sea-grass that is being cropped will produce new leaves, and these young blades are much better for the turtle. They are more digestible, because they do not contain as much lignin as older leaves, and they are also more nutritious because they have 6 to 11 per cent more protein than the leaves in ungrazed stands of *T. testudinum*.

Even though the Nicaraguan green turtles have a plentiful supply of food, and can make the most of that supply by virtue of their physiological and behavioural adaptations, they are still limited by the overall low quality of their diet. One reason is that the large amounts of cellulose mean that the food takes longer to be fully digested. This long period for digestion restricts the amount that the turtle can eat each day without pushing the food through too fast to extract the energy from it. The result is that turtles can eat very little—somewhere between 0·24 and 0·33 per cent of their body weight—each day. Compare this with a terrestrial grazer, which might eat up to 8·3 per cent of its body weight in a single day. Another factor that limits the turtles' ability to use their food is that they are not very good at digesting protein. The average terrestrial herbivore digests 75 to 80 per cent of the protein it eats, but the turtles can manage only 50 per cent at most, and because the fermentation microbes are in the hindgut, the turtle has no opportunity to digest and use the bacteria.

So although the turtle is doing as well as it can on a constant, low quality diet, it is still limited by lack of nutrients. This makes for slow growth, delayed sexual maturity, and a low investment in reproduction. This last factor is both chilling and fascinating. Bjorndal made a series of calculations to compare her Nicaraguan turtles with others that nest in Surinam and feed on algae off the coast of Brazil. It turned out that the Nicaraguan turtles invest only 7·5 per cent of their annual energy budget in reproduction (only 3 per cent goes into the eggs themselves). Surinam turtles, with a migration over four times longer, are nevertheless able to channel 23·7 per cent of their energy intake into reproduction.

The alga on which the Surinam turtles feed is obviously a vastly superior source of nutrients than the turtle grass that the Nicaraguan turtles must make do with. And because the Nicaraguan turtles can spare so little for reproduction, they will be slow to respond to a decline in their numbers, even if fully protected from exploitation.

Food, and its limitations, are probably a prime factor in the delayed growth of some populations of turtles, as Balazs and Bjorndal emphasised. And if Hughes's disturbing thoughts on the frequency of nesting are correct, the turtles are indeed in grave danger. They simply will not be able to multiply quickly enough to ensure their survival unless all exploitation is immediately stopped. Of course, if eggs and hatchlings are suffering very high mortality, then one way to save the sea turtles would be to protect the eggs and hatchlings that would ordinarily die. This has been done at many turtle beaches around the world, and vast numbers of hatchlings have been released to the sea. Most of these have come from eggs taken out of nests and incubated in artificial plastic nest boxes.

Eggs from dead turtles

Sometimes the eggs are in "doomed" nests. These are nests built below the high tide mark; they would be flooded and the eggs drowned if not removed. Other eggs come from perfectly ordinary nests, dug up for profit by locals and bought back by conservation programmes, as at Trengganu in Malaysia. Or eggs may be taken from dead turtles, killed in their thousands before they have even had a chance to lay, as they are on the Pacific coast of Mexico (see *New Scientist*, vol 78, p 514). Wherever the eggs come from, it is a fond belief of those rearing them that they are adding to the stock of wild sea turtles when they release these saved hatchlings to the sea. This complacent belief was shattered by Nicholas Mrosovsky, of the University of Toronto. He told the conference of his work with C. L. Yntema, of the Department of Anatomy at the Upstate Medical Center in Syracuse, New York.

Most participants already had some idea of the results because Mrosovsky had given a foretaste of them in the extremely valuable *Marine Turtle Newsletter* that he edits. But the full shock had not, I think, penetrated to all. At worst, Mrosovsky and Yntema are saying that artificial incubation of eggs is a complete waste of time and resources; the reason is sex.

A turtle's sex is not obvious. There are ways to tell adults apart, but it is almost impossible to sex a hatchling. Not even chromosomes can help, for those of a female look the same as those of a male. It is, however, possible to sex a hatchling if you are prepared to cut it open and examine it histologically. The microscopic appearance of the gonads is very different in the two sexes, and when you have stained and sectioned the gonads and looked at them under a microscope it is not hard to tell them apart.

Back in 1976, Yntema had published a paper on the effects of incubation temperature on the sex of hatchling snapping turtles *(Chelydra serpentina)*. He found that the proportion of females in a clutch depended on the temperature at which the eggs were incubated. At 30°C, all the hatchlings were female. At 26°C, they were all male. And at cooler temperatures still, 20°C, the clutch once again gave rise to 100 per cent females. This is interesting, but why should it worry sea turtle conservationists?

Mrosovsky knew that the time it takes for a turtle egg to hatch depends on temperature—cool eggs take longer to develop. The average incubation time, for an egg at 30°C, is about 54 days, and a difference of 1°C alters the incubation time by about five days. He also knew that eggs incubated in plastic boxes often took longer to hatch than eggs left in nests. The delay varies, but in Surinam, for example, it is between 3 and 11 days, for green turtles. This implies that the artificial nests are between 0·6 and 2·2 degrees cooler than eggs in the sand. If the relationship between sex and temperature were as steep in the green turtle as it is in the snapping turtle, a drop of 2 degrees could produce an entirely male clutch. All those hatchlings, saved and returned to the sea, might well be males—good for the present but not for the future.

An experimental approach was clearly called for. Mrosovsky and Yntema obtained a clutch of 118 loggerhead eggs from a female laying on Little Cumberland Island, off the coast of Georgia in the US. Aliquots were incubated at different temperatures and the hatchlings sexed. As expected, temperature did affect sex. At 32° and 34°C, all hatchlings were female. At 26° and 28°C, they were all male. And at 30°C, 64 per cent were females.

Admittedly these results are based on one clutch from one species, but they are still worrisome. As Mrosovsky pointed out, before we continue or expand artificial hatching programmes we should answer several questions. What is the natural sex ratio in hatchlings? If we knew, he says, we could at least duplicate it by setting up the required proportion of artificial nests in warm and cool areas. We don't know the relationship between sex and temperature for different populations. For theoretical reasons it is clear that the pivotal temperature, which results in roughly equal numbers of males and females, will be close to the temperature at which the eggs normally find themselves, and there will be intense evolutionary pressure at different temperatures. In the turtle islands of Sarawak green turtles nest year round. Eggs laid in the summer hatch after 54 days. Those laid in February, during monsoon, can take 71 days to hatch. Does one get females in summer and males in the monsoon, or are the females that lay in summer genetically different from those that lay in the monsoon, so that each produces a balance between males and females?

We simply don't know the answers to these questions, and until we do, Mrosovsky cautions, we would do well to be conservative in our efforts at conservation. Arguing that the female knows best, Mrosovsky thinks that we should perhaps focus our efforts on protecting naturally dug nests, rather than struggling to hatch eggs artificially with essentially unknown consequences.

That turtles are in trouble in undeniable. Historical records tell of huge aggregations of the animals, and in the 16th century sailors lost in Caribbean fog could navigate to an island by following the noise of migrating hordes of turtles. A film made as recently as 1947 showed 40 000 Kemp's ridleys *(Lepidochelys kempi)* coming ashore in a single night. In 1979 there are probably less than 2000. The same general pattern holds for almost every other population of sea turtle and the reason, everywhere, is the same—overexploitation.

Turtles will always be easy meat, but they might never again be plentiful. Local people could continue to hunt turtles for personal use, but sustained large-scale commercial operations are now, and may always be, impossible. Sustained commercial use is certainly out of the question until we have the facts on which to base sensible management, but unless exploitation ceases the scientists may never have enough animals to discover the truth about turtle biology. □

David Hughes/Bruce Coleman