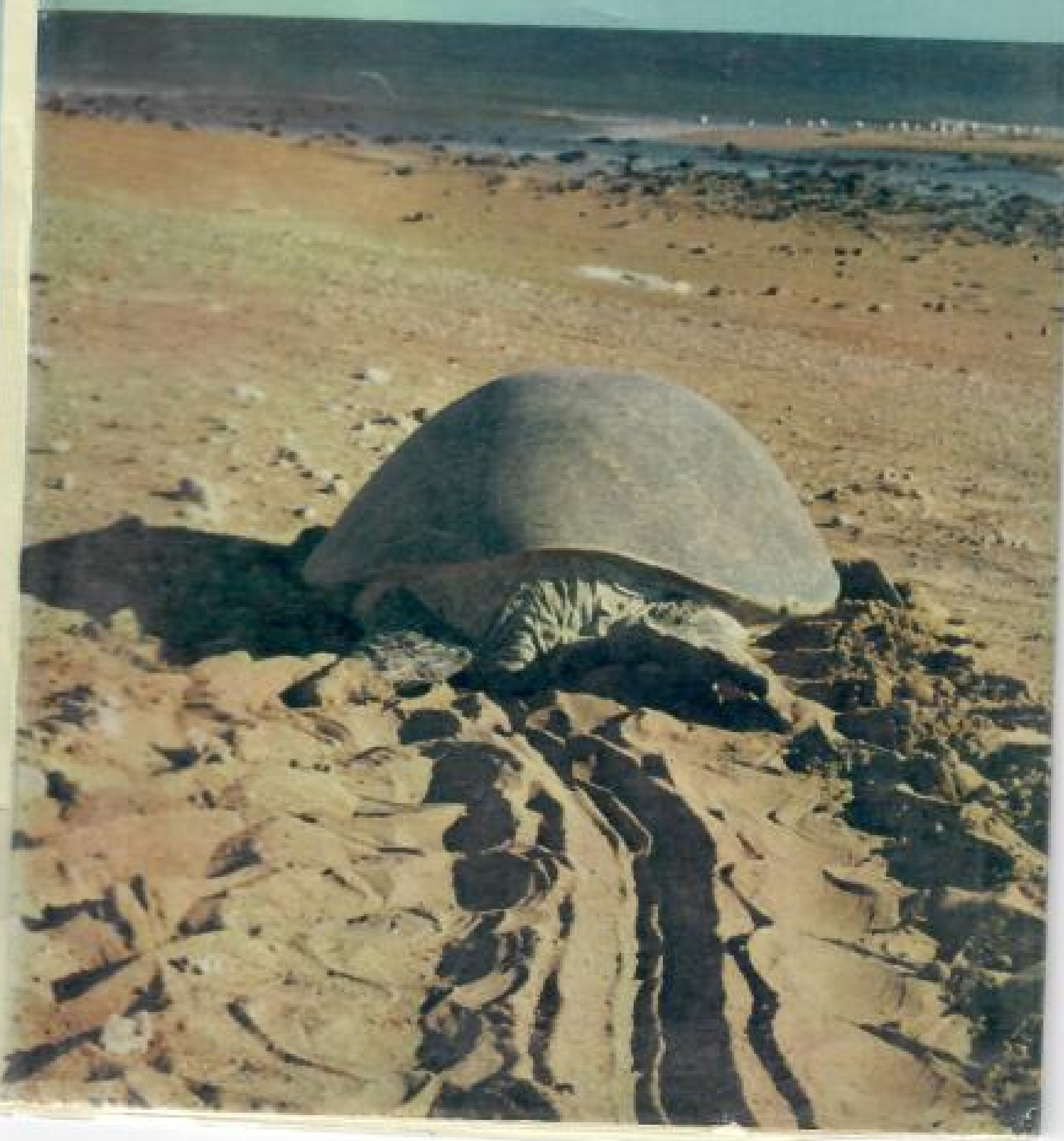
ROBERT BUSTARD

Sea Turtles

Their Natural History and Conservation



Robert Bustard **Sea Turtles**

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SEA TURTLES

particular interest because they indicate that large numbers of baby turtles are being transported by the prevailing offshore currents.

When green turtles are about three or four years old one commonly sees them on the reefs of the Capricorn–Bunker cays. However, by this time they are well on the way to becoming adults.

CHAPTER 9

Our Research Programme

OUR basic research programme has been centred on Heron Island in the Capricorns over the last eight summers. The work involves tagging and recapturing all the turtles which come ashore to nest during a specified period each summer. Associated with the tagging programme we have collected extensive information on egg production. We have also carried out work on egg physiology and the natural nest together with some work on hatchlings. These latter aspects have been discussed in Chapter 8 and in Bustard (1972) and Bustard, Simkiss and Jenkins (1969).

The tagging work is extremely laborious and its efficient operation requires a high degree of dedication by the staff. Since almost all the results are dependent on its being carried out with a very high degree of accuracy, and with virtually no turtles being missed, the procedure followed is described first.

Turtles are tagged so that we can positively identify them at a subsequent encounter. The tags serve the added function of informing anyone who may subsequently encounter the turtle that we have tagged it so that, hopefully, they will report its tag number to us. The tags we use are cow-ear tags, made of monel metal, to withstand long-term submersion in sea water. Their application to turtles was devised by Tom Harrisson in Sarawak and all turtle workers now use these. Some, however, prefer to have the tags made of plastic.

There are few places to tag a turtle. An examination of the carapace shows that it is a mass of minor abrasions and that anything affixed to it would soon be damaged or lost. Similarly, it would be unwise to fix anything to the plastron lest it be lost when the turtle is resting on the bottom.

When Professor Archie Carr started tagging turtles in the mid 1950s, he bored two holes in the rear of the carapace and fixed a metal label to the shell by monel metal wire passing through these two holes. He did not obtain any recaptures, but in time did recover turtles with holes bored in the carapace.

Having discarded the shell, one is left only with the soft parts, particularly the flippers. Harrisson picked on the front flippers, presumably since these are less frequently damaged, and selected the trailing edge. This proved to be an extremely wise choice. If one looks at a turtle during the nesting procedure, either when it is moving across the sand and/or negotiating rocks, or digging and subsequently filling in the nesting site, one is struck by the fact that only one area of the flippers is free from abrasion – namely, the trailing (rear) edge of the front flippers. The tag is best placed well in from the edge of the flipper. Different turtle workers, however, use different sites, some siting it well up the flipper near the 'shoulder' whereas we site it about mid-way.

Tags are applied using a specially designed pair of pliers. Once again practice here differs. Some workers prefer to make a hole first and then to insert the tag while the turtle is on its back awaiting the taking of various measurements. My own philosophy is rather different. As a population ecologist I like to think that I keep any possible effect on the animals I am studying to an absolute minimum. For this reason I never turn turtles over, and as described below, contact with them is reduced to a minimum. We apply the tag, which has a sharp piercing point, in one sudden motion. We do this just after the turtle has finished laying at which time it seems to be particularly insensitive to disturbance. Typically it either gives no noticeable reaction or shows a slight flipper withdrawal movement. Incidentally, it is extremely rare for any bleeding to occur when a turtle is tagged.

Let us now go back to explain the operation. Heron Island is some 1300 miles from my base (the Australian National University in Canberra). During the summer a number of assistants, usually promising zoology undergraduates or graduates, and myself, move up to live at the Research Station on Heron Island. Our first task is to become nocturnal since as mentioned in Chapter 4 green turtles do not leave the water during daylight hours. The task is somewhat more difficult than a straight shift of hours, since the work periods change virtually from night to night. On a coral cay with extensive associated reef, like Heron Island, turtles cannot come in on low or near low tides. The turtles show a well-marked response to the tide cycles, and about ninety percent come ashore between one hour before high tide to two hours after high tide. The time of nightfall and dawn are further complicating factors as the turtles show behavioural modification of the basic cycle firstly to avoid coming out of the water until it is dark and

secondly to reduce the amount of time they must remain ashore after egg laying in order to complete the filling-in process.

When high tide is about 11 p.m. we start work at 9.30 p.m. and patrol continuously round our area of beach. Patrols continue until we have tagged or noted the recapture of our last nesting turtle. However, the last patrol will not begin until at least 1.30 a.m. Clearly turtles which come in late or experience trouble in completing an egg chamber may keep us up most of the night.

When the time of high tide is between 3 and 4 a.m., a change in the beaching behaviour becomes noticeable in that turtles tend to come in rather earlier than one would anticipate. As high tides become later this trait becomes more pronounced so that when the time of high tide approximates dawn most of the turtles are up a couple of hours prior to high tide. On these tides we start work correspondingly earlier, and subject to turtle nesting activity, start the last patrol once it is broad daylight.

A similar phenomenon occurs in reverse when high tide is in the late afternoon before nightfall – turtles wait until it is dark to leave the water. Incidentally, there are three or four days in each fortnightly tide cycle when we have to work extremely long hours since turtles come in on both tides (there are two high tides every twenty-four hours). This is because one high tide occurs in the few hours preceding nightfall, and the tide is still high when darkness falls to activate turtles which are ready to lay. The other high tide, approximately twelve hours later, occurs in the early morning around the time of dawn bringing in turtles before first light. During these three days the turtles all switch over from the one tide to the next. The typical pattern is that on the first of the customary three days of 'double night tides' virtually all the turtles appear on the early morning high tide (which has been the only night high tide for about ten days). On the second day they are split fairly equally between this tide and the new evening tide, and on the third the majority come in on the evening high tide there being few on the morning tide. Since we are forced to follow the tides in order to see all our turtles, we work rather irregular hours, some days being up until after daylight and having worked through from sunset, perhaps with a rather annoying few hours' lull during the night. At other times we work in either the first or second half of the night depending on the stage in the fortnightly tide cycle.

The small size of Heron Island (beach perimeter just over one mile) means that two trained observers can operate the tag-recapture scheme. When turtles are seen for the first time they are tagged on the left front flipper after egg laying. The left flipper is selected since this is much easier for a righthanded person to tag. The tag bears a serial number on the upper side and a return address together with the word 'REWARD' on the lower side. Currently we pay a reward of four dollars (Australian) – about £2 Sterling – for the return of the tag together with date and the locality at which the turtle was caught, provided the turtle has been legally butchered. Under Queensland law only aborigines and Torres Strait Islanders can take turtles, and then only for their own use. The reward scheme does not operate in the Capricorn Group of islands and people are requested never to remove tags from living turtles. Since human population density is low in northern Queensland, there are few recaptures other than those we record ourselves back at the breeding beaches. This topic is discussed further below.

When a turtle is tagged, a record sheet is completed on the individual as follows; tag number, date of tagging, species, length and breadth (measured over the curve of the shell), presence or absence of barnacles and their location if present, injuries if any, notes on coloration, carapace shape and number of postoculars (in the green turtle), and number of marginals and inframarginals in loggerheads. Subsequently this information is transferred to a card in Canberra which is maintained for each individual tagged turtle. Each time the turtle is recaptured the date is noted together with other relevant information such as whether the turtle succeeded in nesting, and, if the individual is under detailed study, the number and weight of the eggs laid may be recorded.

During patrols, as far as possible, the operators move without lights, although they are issued with dim torches for writing and reading tag numbers when necessary. On most nights moonlight is quite adequate for normal activities. Great care is taken not to disturb beaching turtles, which sit at the water's edge and scan the landward horizon before emerging. Similarly, turtles moving up the beach are avoided by entering the vegetation zone and thereby bypassing them. Patrols are carried out by moving along the top of the beach adjacent to the vegetation zone. The best way to scare away turtles which are moving shorewards to nest is to walk along the water's edge where one is clearly silhouetted against the white coral sand. This process can be made virtually one

hundred percent effective by periodically shining a bright torch on the water.

The above statement brings me to a question I am frequently asked – the effect of tourists on turtles. It is impossible to generalise as there are many variables. However, we have extensive experience of the effect of tourists on Heron Island as this is a tourist resort. On the whole, tourists have not had a deleterious effect on the Heron turtles. Firstly, they only go out to see turtles on nights when the high tide is in the early evening – only the keenest turtle watchers are prepared to rise in the middle of the night! Secondly, and most important, the owners of the resort have been most conscious that the marine life is their greatest potential asset and have been keen to preserve it. They have worked in with us to advise tourists how to watch turtles without frightening them. We give talks to tourists, as does the resort management, and most tourists meet some of my assistants on the beach within minutes of going out turtle watching. However, it must be remembered that Heron Island is a small cay situated about forty miles offshore. All tourists (other than scientists visiting the Research Station) must live at the guest house as the rest of the island is a National Park and camping is prohibited. The effect would be quite different on the mainland where people could drive cars down on to the beach. Without a full-time warden, a mainland turtle National Park would serve little purpose if the public were granted unlimited entry.

Over the years we have guided very large numbers of tourists round the Heron beaches. We have certainly met many charming people and we send our publications to a number of these. Apart from everything else, we feel that this meeting ground is an excellent way of making people aware of the problems of conservation. Many people, who had never seen a turtle before, go away thinking it a very great shame that these huge, harmless beasts should be killed for soup in most parts of the world. Since these people all have votes, the conservation impact must be positive. Overall we feel privileged to be able to work in an environment where we meet such interesting people and are able to tell them about our work. Quite apart from discussions on the beach, when time permits, we hold weekly or twice-weekly informal talks with tourists and any questions they may have relating to turtles are answered to the best of our ability.

Many people think of a Barrier Reef island as being hot at night. In fact after nightfall there is frequently quite a cool breeze and I wear a jersey most nights. Popular imagination also tends to omit thoughts of rain, often torrential downpours which soak you to the skin in seconds, and which may continue for a large part of the night. This is particularly the case in the latter half of the nesting season (January, February). It is remarkable just how put out man is by rain. Work becomes much more tedious. Wet sand seems to get literally everywhere. Note taking is much more time consuming. It is interesting to note that this also reduces the turtles' 'efficiency'. If they are already about to lay or at a subsequent stage in the nesting process they do not appear to be disturbed. However, turtles coming up during or following torrential rain usually wander about aimlessly and often return to the sea without attempting to nest. They appear to require dry sand in order to start to dig. Since this is an impossibility on such nights digging attempts are scant.

Earlier I mentioned that turtles can be frightened away before beaching by shining bright lights on the water. Consequently, they are greatly disturbed by lightning. Prior to severe storms, dry storms with thunder and lightning often occur. If these take place before the turtles have emerged from the sea beaching is greatly impaired.

Our initial contact with the turtles gives us a mass of information on physical features. Furthermore, by plotting the numbers of newly tagged turtles each night throughout the time we are there, we can show that we 'tag out', that is tag all the individuals. This is accomplished after about one month, commencing with a completely untagged population. The time taken to tag the population is a reflection of the interval between laying (discussed below), since, until they have beached on the island in order to lay eggs, we have no opportunity to tag them. For this reason the work is restricted to female turtles. During the first cycle, if the nesting female population is a large one, we may be unable to cope with every turtle. Those missed are then all caught up with the next time round.

We have no data on weights because we have always felt that weighing constitutes a major disturbance to the turtle. Nevertheless, we now plan to weigh a small series for completeness of information on the population.

The 'green turtle' may constitute more than one species. Periodic attempts have been made to separate populations of this circum-

15. (a) Torres Strait Island turtle programme trainee, Nancy Pilot recording data on nesting loggerhead, Great Barrier Reef.

(b) Portrait of an old loggerhead. Note the pronounced 'beak'. Great Barrier Reef.

16.(a) Flatback (*Chelonia depressa*) emerging from the surf.

C. LIMPUS.

(b) Flatback (*Chelonia depressa*). Note the greatly flattened carapace, numerous small scales on front flippers and three large postocular scales immediately behind the eye.

global inhabitant of tropical and subtropical seas as a new species or subspecies. In view of this it is essential to have detailed information on the variation in features, which are used from time to time in attempts to separate populations, within individual populations. The shape of the carapace is one such feature which we have noted subjectively. For five years we recorded each turtle as having either a flattish, steeply rounded, or intermediately-shaped carapace. The information collected indicated that two-thirds of our green turtle population possessed intermediately-shaped carapaces with the rest split evenly between flat and steep. Of extreme interest was the fact that the percentages with each carapace shape varied greatly in different years. To demonstrate the significance of these variations a definite length/height ratio would need to be measured. Nevertheless, the crude observation made did not appear to be subject to bias especially since the same observers made the reports in several subsequent years and any new observers' data could be checked against this for bias. For instance, in years 1 and 2 the percentages with flat, intermediately-shaped and steep carapaces were 16, 35 and 49, and 25, 62 and 13 percent respectively – markedly different.

A feature often said to be diagnostic of the flatback is the presence of three scales behind the eye known as postoculars. Green turtles are said to have either four or five postoculars. This feature was checked in 1375 green turtles and 88 percent were found to possess four postoculars and seven percent possessed five. However, five percent possessed three as in the flatback. In a few individuals the postocular count differed between the two sides of the head.

In the loggerhead turtle populations a study was made of the number of marginal shields which edge the carapace and also the number of inframarginals which form the bridge joining the carapace to the plastron. A five-year count based on only 144 turtles indicated that 60 percent possessed 12 marginals, 22 percent 11 and 17 percent 13. Only one turtle was found with 10 marginals. The percentages varied between the populations visiting the island in different years. Twelve marginals was always the most common count but this varied from 51 percent in year 3 to 74 percent in year 5. The percentage of turtles with 11 marginals ranged from 12 to 32 percent and with 13 from nought to 37 percent. Eighty-three percent of the loggerheads examined in the five years possessed 3 inframarginals and 16 percent had 4. Only one turtle had an inframarginal count of 5. However, as in the case of the marginals, there were differences in the relative proportions of 3 and 4 between populations of different years. In years 1, 2 and 3 respectively the percentage with 4 inframarginals was nought, 10 and 4 percent respectively whereas in years 4 and 5 it was 40 and 47 percent! Differences of this nature would seem to be the result of distinctive populations nesting in separate years. This topic is taken up again towards the end of this chapter.

During routine observations on each turtle, presence or absence of barnacles, and the location if present, was recorded. In both green and loggerhead turtles there was not a marked increase in the percentage with barnacles with increasing size (age) of the turtle as one would expect if the incidence of barnacle infestation was cumulative. In the green turtle the figure was similar in all size-classes of breeding females. In the loggerhead the figure appeared to fall somewhat as the turtles became larger. In both cases this would tend to suggest that either barnacles are acquired at a specific immature stage of the life cycle only, or that incidence of acquisition is balanced by rate of loss, either through barnacle death, or loss when scutes are shed. As was the case with certain other features described above the percentage occurrence of barnacles varied considerably between populations in different years.

There are several factors which affect the number of turtles coming ashore to nest each night in addition to the aspects of weather referred to previously. In my experience green and loggerhead turtles dislike high winds, probably due to wind action on the sand. Winds of velocity above 25 knots cause the surface sand to become airborne. Since the experience is quite painful to bare skin if one sits on the ground, the effect on turtles' eyes is probably severe. Turtles that emerge under such conditions invariably change direction so as to put their backs into the wind and shield their heads. This behaviour often results in them moving parallel to the beach. They may return to the water without reaching the vegetation zone. On windy nights the majority of the turtles which would be expected to arrive on the windy side of the island move round to the lee side and nest there.

Numbers of nesting turtles also vary greatly but predictably during each tide cycle. On Heron Island with a large nesting population the peaks are around one hundred turtles per night and the troughs less than ten. This has important bearings on survey

work – one must be able to specify the state of the tide at the time of the work. It is extremely important if only a few nights' observation are carried out, otherwise one could come away with a completely unrepresentative picture of the abundance of turtles. In our experience, the greatest number of turtles usually beach on the second night following the end of the double tides. The following night numbers are often considerably less, but still high, and numbers then generally remain similar for several nights before starting to drop off. Numbers may reach a low point about midway through the fortnightly cycle or this may not occur until the double tides. The phenomenon is well illustrated in fig. 6 based on the Heron Island green turtle data for summer 1965–6.

We understand the fluctuations in number of nesting individuals of the much smaller loggerhead population at Heron Island less well. We have noted what we call 'loggerhead nights' on which a number of loggerheads come ashore to nest, whereas on adjacent nights there may be none. At the present time we are unable to explain these variations.

There is also a fluctuation in the number of turtles nesting throughout the season. Since all turtles do not arrive simultaneously, and depart together, there is a build up in numbers at the start of the nesting season and a gradual fall towards the end. The first green turtles to arrive are seen at Heron Island generally during the last week of October. For the first few days no nesting takes place, although some turtles may emerge from the water and crawl up the beach, only to return to the sea without making any attempt at nesting. By late November the population has built up to its maximum size and remains at this level until mid to late January when it starts decreasing. Some nesting, however, occurs until at least well into March and sometimes a few turtles are nesting until the end of April.

While on the subject of beachings it may be of interest to discuss exploratory beachings. This is the term we use for turtles which emerge, apparently to nest, but make no attempt to do so. Dampier (1697) noted the phenomenon. He wrote, 'sometimes they come up the night before they intend to lay, and take a view of the place, and so having made a Tow, or Semi-circular March, they return to the sea again, and they never fail to come ashore the next night, to lay near that place'.

These turtles frequently wander long distances in the course of which they often accidentally bump into other nesting turtles and

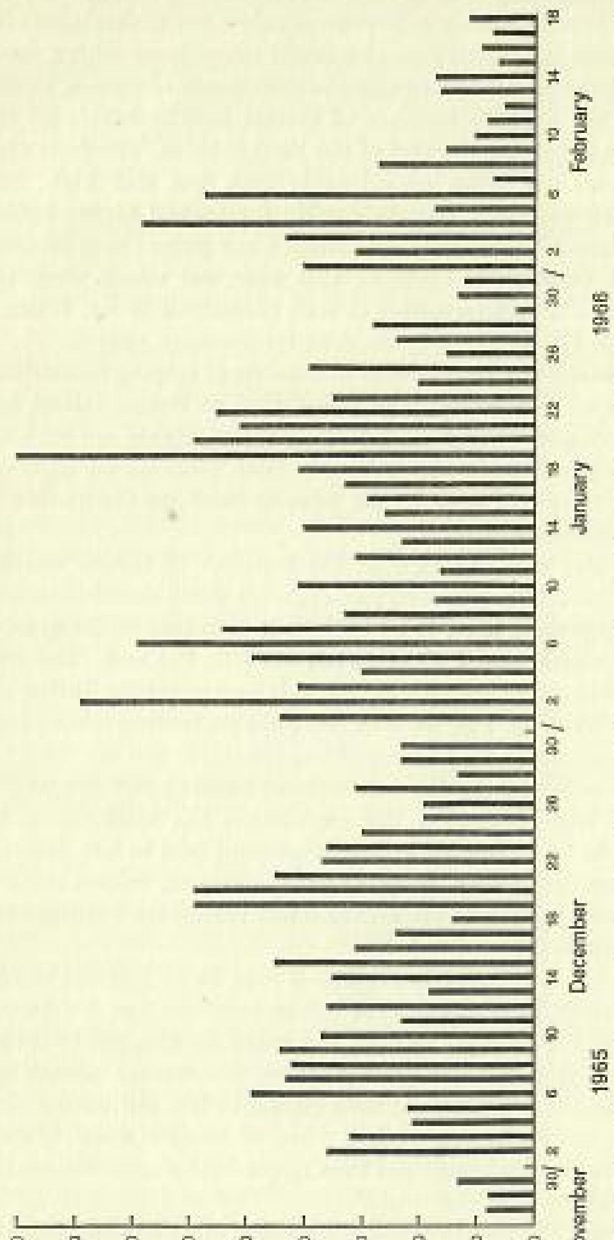


FIG. 6 Numbers of green turtles beaching nightly on the whole of Heron Island between November 1965 and February 1966 (see text).

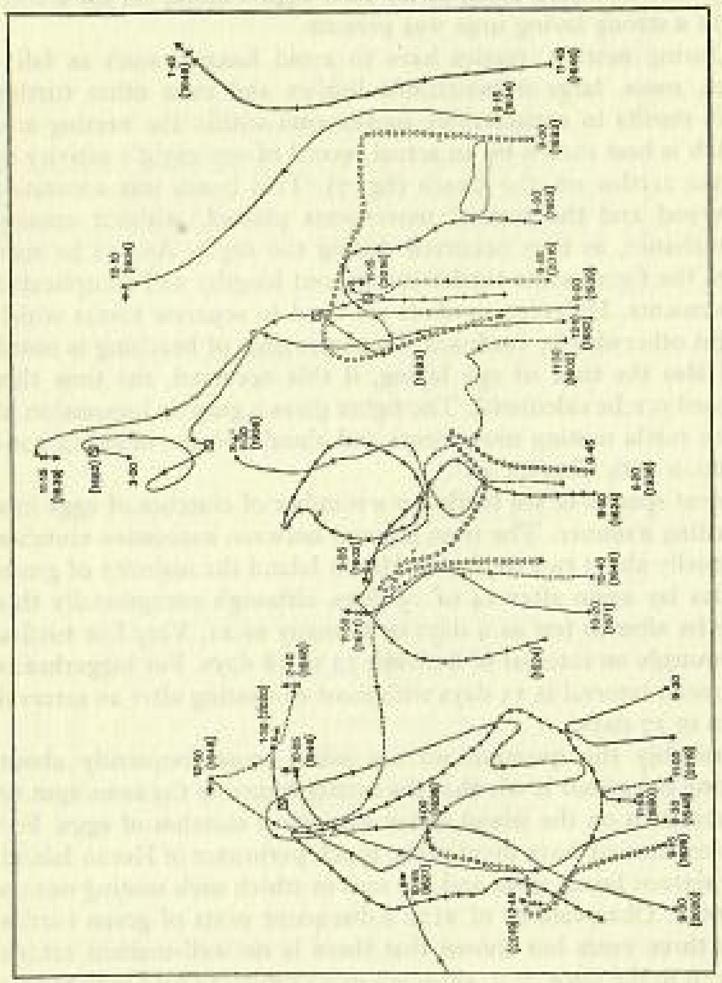
disturb them. During this wandering they either make no attempt to dig or make only cursory front flipper movements at a few sites before moving on again. Detailed observations have shown that these particular turtles almost always emerge again the following evening, haul-up just above the spring high-tide mark, and dig their nests at once with no exploratory activity. The marked contrast between the two nights' activity is most conspicuous. Provided weather conditions have resulted in the sand being suitable for nesting activity, we can only assume that on the first night they were not quite ready to lay their eggs whereas on the second night a strong laying urge was present.

During nesting, turtles have to avoid hazards such as fallen trees, roots, large impenetrable bushes and even other turtles. This results in considerable movements within the nesting area which is best shown by an actual record of one night's activity by all the turtles on the beach (fig. 7). This beach was accurately surveyed and the turtles' movements plotted, without causing disturbance, as they occurred during the night. As can be seen from the figure some turtles carried out lengthy and complicated movements. Different symbols are used to separate tracks which might otherwise be confused. Since the time of beaching is noted and also the time of egg laying, if this occurred, the time that elapsed can be calculated. The figure gives a graphic impression of green turtle nesting movements and should be examined in conjunction with Chapter 4.

Most species of sea turtle lay a number of clutches of eggs in a breeding summer. The time interval between successive clutches is usually about two weeks. At Heron Island the majority of green turtles lay again after 14 or 15 days, although exceptionally this may be after as few as 9 days or as many as 21. Very few turtles fall outside an interval of between 12 to 18 days. For loggerheads the mean interval is 15 days with most re-nesting after an interval of 12 to 17 days.

Probably the question we are asked most frequently about nesting behaviour is whether the turtles return to the same spot or general area on the island to lay successive clutches of eggs. For convenience we have divided the beach perimeter of Heron Island into sixteen beach areas and the area in which each nesting occurs is noted. Observations of 2120 subsequent nests of green turtles over three years has shown that there is no well-marked return pattern to the same area, although more return to nest in the same

FIG. 7 Turtle movements on an area of high beach platform at Heron Island on one night to show their complexity. Times at foot indicate emergence from sea, bracketed numbers are turtle tag number. 'X' indicates site of laying, time is given and the arrow shows direction of turtle's head. Square with diagonal line indicates unsuccessful nesting attempt. Records were made by watching turtles carefully at night.



area or area immediately adjacent thereto than would occur randomly. The figures recorded were as follows: returns to the same area 21 percent; to adjacent area 22 percent; to completely different area 57 percent.

Any mathematical calculations on the above data would be heavily biased by a number of factors. Firstly turtles do not beach randomly on Heron Island for nesting. Numbers are most dense in the Shark's Bay area where there is good access to deep water without intervening coral. On areas of the island where there is extensive beach rock (plate 1) the numbers nesting depends on the height of the night tide and, therefore, on the state of the tide cycle. When the tide covers the beach rock, nesting takes place at quite substantial density. However, when the high tide leaves large areas of beach rock exposed then much sparser nesting takes place in these sections of the beach. Green turtles will crawl across large areas of beach rock, but not unnaturally there is a tendency to avoid this where possible. Once they are on beach rock they will continue across it, but if the tide is below the start of the rock – which often makes climbing on to it difficult – they generally swim parallel to the beach rock looking for a way through. In our experience loggerhead turtles seldom cross beach rock, and since this occurs on a large proportion of the Heron beaches, their main nesting area is restricted to a small part of the island.

We have carried out considerable work on egg production by the green turtles at Heron Island. Production per female is the number of clutches produced in a season multiplied by the number of eggs per clutch. Information on the first is obtained as a result of the tag-recapture programme, but the latter requires counting eggs in successive clutches. Initially this work was greatly aided by the hatchery programme, described in Chapter 8, in which large numbers of eggs were collected from known females for hatchery incubation. All these eggs were counted during collection and a random sample from each clutch was weighed in order to establish the mean egg weight.

In the green turtle we have found that the mean number of clutches of eggs deposited differs between years. In three successive years it varied from between three and four to between five and six clutches. The third year was intermediate. In two of three years the greatest number of loggerheads were recorded only laying one clutch although some individuals laid as many as four or five times. In the remaining year most laid two or three clutches of eggs. At the present time we are not able to explain these inter-year population differences. The observation period was the same in each year and there is no reason to doubt the efficiency of the tag-recapture operation in any year. It may reflect population differences, or perhaps is a result of variation in the quantity and/or quality of food supply.

We found that a number of factors affect clutch size in the green turtle. One of these is the size of the turtle, larger turtles producing larger clutches of eggs. Carapace length is plotted against clutch size for the green turtle population at Heron Island in summer 1965–66 in fig. 8. As shown in the figure large turtles lay up to twice as many eggs in a clutch as small females. Since turtles, like other reptiles, commence breeding long before they have reached maximum size (most reptiles subsequently continue to grow slowly throughout adult life) 'small' is probably equatable with 'young' and 'large' with 'old'.

The average size of the eggs remains similar despite changes in size of the mother. That is to say, larger turtles produce a much greater mass (weight) of eggs. Clutch size, in the sense of biomass of the clutch, is probably a result of the physical space available to house the developing eggs as well as a result of the amount of reserves which the turtle can make available for egg production. Both these factors would promote larger clutches by bigger females. It is not surprising that average egg size remains similar, as this will be determined by natural selection at a size which produces the greatest number of surviving progeny, bearing in mind that the amount of egg material is fixed and, therefore, that if the eggs were smaller there could be more of them and vice versa.

In the loggerhead the relationship between clutch size and carapace length is much less pronounced than in the green turtle.

In addition to studying the turtles' way of life at the nesting beach, we are interested in where they go and what they do while at sea for several years between nesting cycles. Tagging helps to provide some data on this as recaptures give an indication of the distance moved. Carr (1968) has shown that the Costa Rican green turtle population moves as far afield as Mexico, adjacent to Yucatan, southern Florida and Isla de Margarita, Venezuela. Furthermore, work by Carr and associates discussed in Carr (1968) has indicated that Brazilian green turtles travel to Ascension Island in the mid-Atlantic to nest. This information was gained by tagging green turtles on Ascension Island, where there are no

nearby feeding grounds. Turtles tagged on Ascension Island have been recaptured on the coast of South America and have also been recaptured nesting again at Ascension after an interval of several years. The shortest distance between Ascension and the coast of South America is about 1400 miles. Navigational problems in the journey to a small island like Ascension must be immense but turtles appear to be adept at this.

Recaptures of Australian tagged turtles are shown in fig. 9. In examining the figure one must bear in mind that the human population in Queensland is heavily concentrated in the south-east of the State. There is accordingly marked bias in reporting recaptures in the south as compared to the north. The fact that

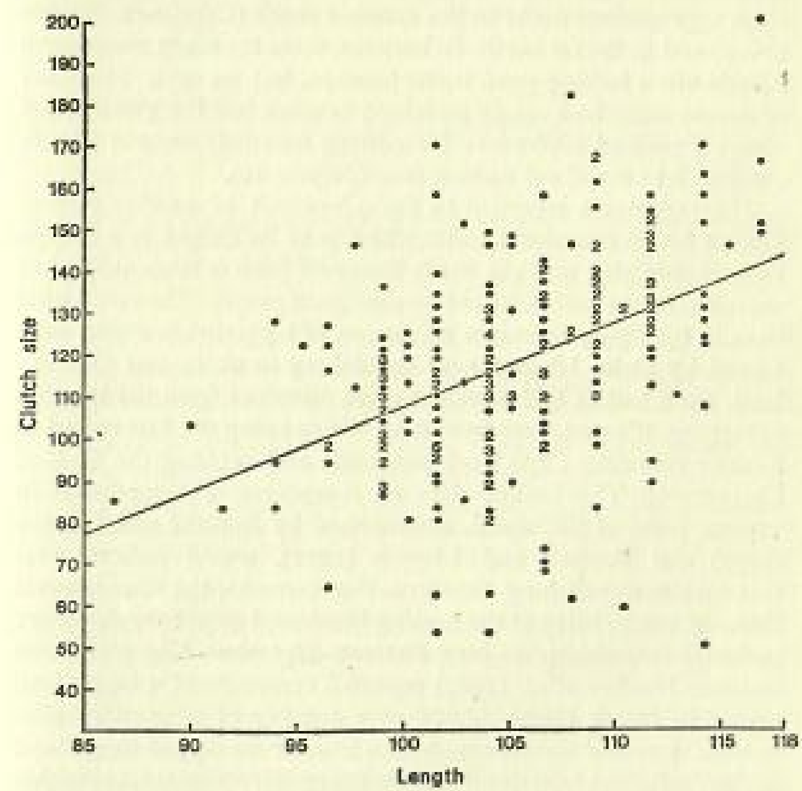


FIG. 8 Relationship between length and clutch size in a green turtle population at Heron Island showing that larger turtles lay appreciably more eggs. Numbers where several points are superimposed.

despite this bias most recaptures come from considerable distances from Heron Island is good evidence of lengthy migration by the vast majority of turtles. Apart from those individuals which move out into the Pacific (such as the three New Caledonia recaptures) the trend is unmistakably to move northwards. Some knowledge of local geography is necessary to appreciate this. The Capricorn–Bunker cays are situated astride the Tropic of Capricorn and as such are relatively far south for major green turtle rookeries. Certainly the major feeding grounds are well to the north. One might wonder why turtles feeding say, north of Townsville, would come as far south as Heron Island to nest. The reason for this is that cays which provide ideal nesting conditions for turtles are not common throughout the length of the Great Barrier Reef. The main aggregations occur in the extreme south (Capricorn–Bunker group) and in the far north. In between there are many continental islands often lacking good turtle beaches, but no cays. There are of course numerous sandy mainland beaches but the green turtle shows a marked preference for nesting on small isolated islands compared to mainland nesting (see Chapter 10).

The recaptures recorded in fig. 9 are not of nesting turtles. Except for an occasional turtle which may be caught in a net, its capture recorded and the turtle liberated (unless drowned), they are taken on the reefs for food by aboriginal people. The two dotted lines in the figure represent recaptures of loggerheads which were tagged by Colin Limpus near Bundaberg in south-east Queensland. Both turtles had travelled great distances from the location of tagging, the recapture from near Weipa being the first record of a turtle rounding Cape York peninsula and entering the Gulf of Carpentaria. The limited data on recaptures of loggerheads in various parts of the world, summarised by Bustard and Limpus (1970) and Bustard and Limpus (1971), would indicate that this species travels long distances. Furthermore, the time interval between last sighting at the nesting beach and recapture elsewhere indicates that deliberate long distance migrations take place. For instance Hughes *et al.* (1967) reported recapture of a loggerhead tagged in Natal, South Africa, at a distance of 1650 miles after only 91 days and the recapture of a Bundaberg tagged loggerhead in the Trobriand Islands off eastern Papua–New Guinea, a straight-line distance of 1100 miles, took place after a lapse of only 63 days. If, as appears likely, the turtle followed the coast for much of the way the distance covered would have been much greater – up to

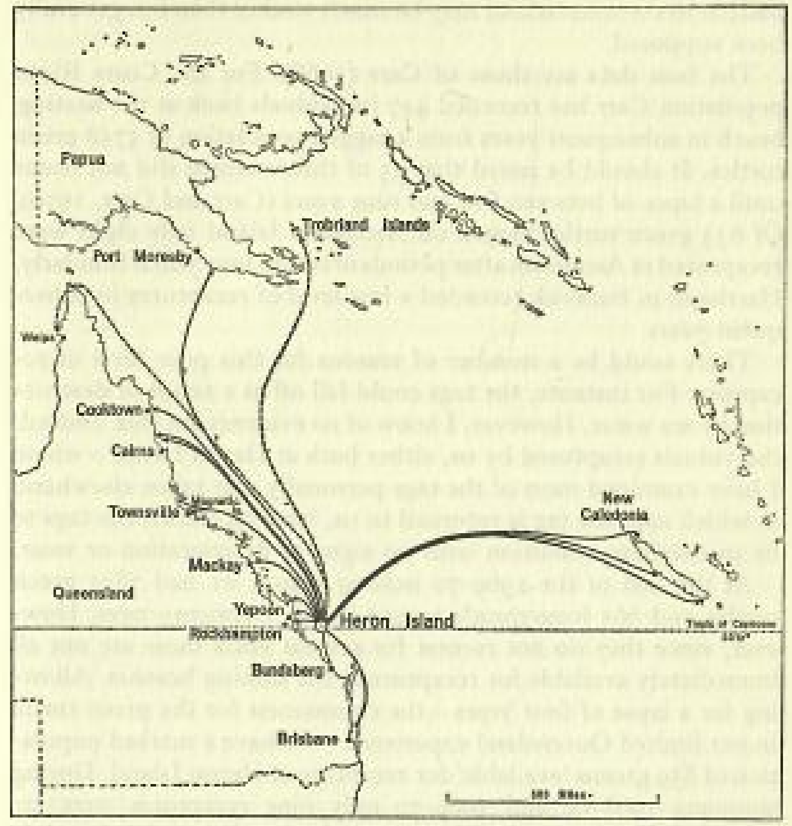


FIG. 9 Recovery sites of green turtles tagged at Heron Island and adjacent cays (continuous lines) and loggerheads tagged at Bundaberg on the mainland (dotted lines). The lines do not necessarily indicate the route followed.

2000 miles. Furthermore, at the time of year that the movement took place, the prevailing current is travelling southwards down the east coast of Australia, so, far from travelling on the current, the turtle would have to swim against it.

It has been known for many years that turtles may return to the same beach to nest in subsequent nesting seasons. This information has been substantiated by tagging programmes. However, most reports gloss over the very low proportion of returns recorded. The low returns are puzzling in view of the probable longevity of the adults and would tend to indicate that the return pattern to the same island may be much weaker than has generally been supposed.

The best data are those of Carr (1968). For the Costa Rican population Carr has recorded 447 individuals back at the nesting beach in subsequent years from a tagged population of 5758 green turtles. It should be noted that 55 of these returns did not occur until a lapse of between five and nine years (Carr and Carr, 1970). Of 635 green turtles tagged on Ascension Island only eight were recaptured at Ascension after periods of two to four years. Similarly, Harrisson in Sarawak recorded a low level of recaptures in subsequent years.

There could be a number of reasons for this poor level of recapture. For instance, the tags could fall off as a result of destruction by sea water. However, I know of no evidence for this. Indeed, individuals recaptured by us, either back at Heron Island – where I have examined most of the tags personally – or taken elsewhere, in which case the tag is returned to us, have all shown the tags to be in excellent condition with no signs of deterioration or wear.

At the end of the 1969–70 nesting season we had 3825 green turtles and 665 loggerheads tagged in the Capricorn cays. However, since they do not re-nest for several years these are not all immediately available for recapture at the nesting beaches. Allowing for a lapse of four years – the commonest for the green turtle in our limited Queensland experience – we have a marked population of 859 greens 'available' for recapture at Heron Island. During summers 1968–69 and 1969–70 only nine recaptures were recorded. It will be recalled that due to the small size of the cay it is easy to see all nesting turtles at Heron Island. Furthermore, the fact that it is an island means that turtles cannot be missed by beaching just outside the study area as could occur on the mainland.

In 1965–66 we tagged 139 green turtles on North-West Island, the largest of the Capricorn cays. In summer 1969–70, four years later, only two tagged turtles were present in the nesting population.

Loggerheads appear rather more prone to return to nest subsequently than greens but even with them the percent recapture rate is low. In our experience they nest again after intervals of two or three years. On this basis we had 153 tagged individuals available for recapture by summer 1969–70 yet recaptures totalled only ten. One loggerhead returned after one year and laid, and

this same individual was recorded at Heron Island for a third season two years later.

The geography of the Capricorns – there are seven islands in the group used by nesting turtles – provides some additional information of great interest. One reason which could be put forward to explain the small number of returns to specific beaches in subsequent nesting seasons would be that turtles have a tendency to return, not to the exact location of previous nesting – perhaps they have difficulty in locating it – but to the same general area. Hence there would exist not populations of Heron Island turtles but Capricorn cay turtles. Since the various cays are situated only 8 to 17 miles from Heron – quite trivial distances in view of migrations of many hundreds of miles from the north – they provide an excellent situation to test this theory. One would expect many 'misses' in which turtles tagged on one island return four years later to another cay in the general area. During summer 1969–70 we were able to test this possibility since we carried out tag-recapture operations on four of the seven nesting cays. During the summer all recaptures bar one were made on the island where the turtles were originally tagged. The sole exception, a loggerhead tagged on Heron, was recaptured eight miles distant on Wreck Island. Hence, there is no question of most turtles returning to the general area but using another island. If they returned to the general area they nested on the same cay used several years previously. Despite this we have several records of turtles tagged on one cay subsequently nesting in the same season on an adjacent cay.

As stated in Chapter 2 the past fifteen years have seen a tremendous advance in knowledge concerning sea turtle natural history, particularly as a result of the work of Carr. The following accounts are of particular interest: Carr (1962), Carr and Giovannoli (1957), Carr and Ogren (1960), and Carr *et al.* (1966). Other important accounts include Harrisson (1951, 1954 and 1956) and Hendrickson (1958).

Our major interest in Queensland has been to utilise the large unhunted turtle populations to carry out a detailed population ecology study. This would advance knowledge very considerably without merely repeating in Australia work carried out or in progress elsewhere. Queensland offers very great advantages for this work not enjoyed elsewhere which is why we started the programme there. Firstly the State is huge with a seaboard of 3250 miles. We have assumed that most of our tagged turtles remain within or adjacent to Australian territorial waters throughout their life. There is no European fishery for turtles permitted in Queensland (see Chapter 10) and the aborigines no longer take many. This means that marked animals are not subject to a substantial but imprecisely known predation rate as a result of human hunting effort as occurs in most other countries. Furthermore, the small size of our study area, together with the information given above that turtles returning to the Capricorn Group of islands in subsequent nesting seasons return to the same cay once again, allows us to effectively monitor a discrete population.

As detailed above the reproductive pattern is now fairly well known. It is interesting to note that the length of the nesting season differs considerably in various geographic locations probably as a result of latitude. As one moves towards the equator the nesting season is prolonged and in such areas as Sarawak some nesting occurs in every month of the year but with pronounced peaks in certain months. As well as the spread in nesting season, the number of clutches laid by each female also shows geographic variation.

In view of a presumed optimum size (weight) for the egg as a result of natural selection (see discussion above) it is extremely interesting to note that egg weight and, therefore, size of the hatchling, varies in different localities. For instance, Hendrickson (1958) gave a mean of 36 grams (range 28.6–44.7) for Sarawak which compares with 51.6 grams (range 44.0–60.4) for the Heron Island population. This very substantial difference could perhaps be related to differences in the mean number of clutches laid by a female in a nesting year, however, this is not borne out by Hendrickson's data.

An extremely interesting facet of the population ecology is the enormous numbers of individuals nesting at undisturbed rookeries. The discrete nature of these rookeries, combined with the limited area available for nesting – a narrow strip between the spring high-tide mark and the vegetation zone – results in many subsequent nesting females digging where a female has previously deposited eggs. Thus appreciable destruction of incubating eggs occurs, as was first pointed out by Moorhouse (1933). We have studied this situation on Heron Island and using computer studies have confirmed that nest destruction is dependent on population density (Bustard and Tognetti, 1969). It may be that this phenomenon is

important in limiting production of any one rookery and hence playing a role in population regulation. However, the situation is extremely complex as the density of hatchlings entering the sea has also to be taken into account. For some time I have seen the progressive build up of a rookery, with the resultant flood of hatchlings entering the water, as an important way of reducing neonatal predation by flooding the area with hatchlings. The hatchlings are most vulnerable when still in fairly shallow water on and around the reef platform – that is, during the first few hours of life. When a rookery produces more hatchlings per night than the carnivorous fish on the surrounding reef can eat, then clearly many will certainly survive and reach deep water. As long as the numbers of hatchlings are inadequate to feed the local fish then any hatchling entering the sea has a finite chance of being eaten while crossing the reef. Clearly there must be a population level at which the reef platform is regularly flooded with hatchling turtles. The relative importance of egg destruction by subsequent nesting turtles will depend at what adult turtle population size 'flooding' by hatchlings occurs.

Where two species of turtles share the same nesting beach, competition between them for nesting space may be important, especially if their behaviour differs sufficiently for one to be markedly adversely affected by the other. Bustard and Matters studied the interaction of green and loggerhead turtles nesting at Heron Island where the loggerhead population is always much smaller than the population of nesting green turtles. The field data were simulated on the computer to provide extensive quantitative information. Loggerhead turtles usually nest much nearer the sea than green turtles. At Heron Island they usually lay just above the low bank which encircles the island. Some green turtles nest in this zone but most move farther inland. Hence the nesting loggerheads potentially affect only a fraction of the green turtles. Furthermore, due to the small numbers of loggerheads their effect is minimal. However, although many green turtles move considerably farther inland before nesting, they frequently dig a first egg chamber in the main loggerhead nesting area. Naturally this results in a tendency to dig up and so destroy incubating loggerhead eggs. Since green turtles are proportionally much more numerous than loggerheads, and since the total loggerhead lay is aggregated in this narrow area above the bank, the effect of the green turtles on the loggerheads is proportionately large.

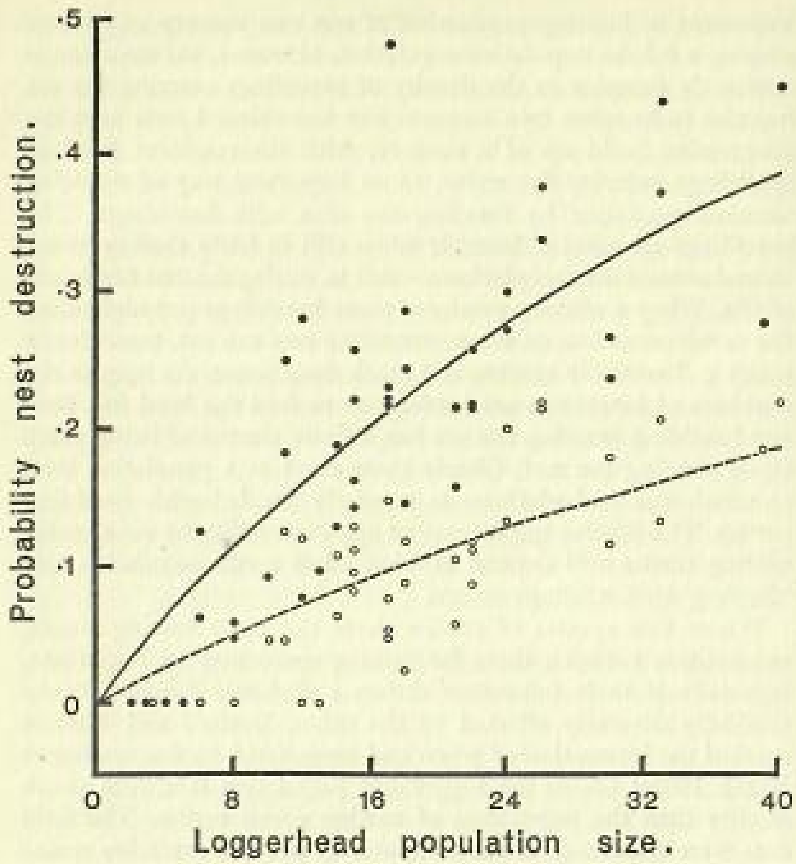


FIG. 10 The probability of nest destruction resulting from intra- and inter-specific competition for nesting sites on a cay (Heron Island). Graphed are the destruction of loggerhead nests by subsequent nesting loggerheads (lower broken curve) and total nest destruction suffered by the loggerhead population (upper continuous curve). The difference between the curves is the result of very substantial interaction (nest destruction) by a nesting population of green turtles.

The effect of this interaction is illustrated graphically in fig. 10 in which the probability of nest destruction (a figure of 1 would represent one hundred percent) is plotted against the size of the loggerhead turtle population. The lower dotted curve shows the loss of incubating loggerhead eggs as a result of destruction by

other nesting loggerheads, whereas the upper continuous curve shows the total level of egg destruction suffered by the loggerhead population. The difference is due to interaction with green turtles. As is shown in the figure the green turtle effect is substantial. For instance, with a loggerhead population of only 18 animals on the nesting beach studied, the probability of nest destruction by subsequent nesting female loggerheads is of the order of 1 in 10. However, the effect of the green turtles is to more than double the destruction to between 1 in 4 and 1 in 5. This is the same as saying that there is considerable competition between green and loggerhead turtles for nesting space and that the competition adversely affects the loggerhead population.

Growth is another fascinating topic about which little is known. A small number of turtles have been reared in captivity in various parts of the world. The resultant information is open to criticism on the grounds that there is no indication of the relationship of captive growth rates to growth in nature. Indeed it is known that captive growth rates vary enormously depending on the conditions under which the turtles are kept and the food supply.

On the basis of growth rates obtained by Les and Dorothy Tanis who provide ideal conditions for their turtles (see Chapter 10) I would give a tentative age at first breeding for Australian green turtles as not less than eight years. This is much slower growth than figures arrived at by Carr and Hendrickson and may merely reflect slower growth in captivity. Carr (1968) thinks that Caribbean populations of the green turtle reach maturity at about five years of age and Hendrickson (1958) has suggested between four and six years for Asian populations of the same species.

Turtles reared in captivity from hatching and then subsequently released into the ocean may maintain similar growth rates to captives kept under ideal conditions. Of a number liberated at the age of one year or more we have so far had only one recapture. The turtle was hatched on 24th March, 1965 and released at Heron Island on 9th January 1967. At the time of release it weighed $4\frac{1}{2}$ lb and had a carapace length of $9\frac{5}{8}$ inches. Another hatchling from the same clutch of eggs also reared in captivity weighed $9\frac{1}{4}$ lb and had a carapace length of $11\frac{3}{4}$ inches on 9th January. The foregoing turtle was recaptured on the reef at Masthead Island, Capricorn Group, on 6th May 1969 and sighted there again on 8th and 9th May. On 6th May it was measured, the length over the carapace being $19\frac{1}{2}$ inches. At this time the captive sibling had a carapace length of $21\frac{1}{2}$ inches. Hence, the overall difference in carapace length had remained similar indicating that the individual at liberty was showing a similar, or marginally better, growth rate to the captive individual.

There are no data as yet on growth to breeding size by wild individuals. In an attempt to get this information I operated a hatchery at Heron Island for three years from 1965–6. All hatchlings were marked immediately following hatching and then liberated into the sea at the water's edge. Recaptures will provide information on growth to maturity and hopefully also on survival. The hatchlings were marked by removing part of a marginal shield of the carapace. Evidence suggests that this does not regenerate well and that the clip can be picked out readily many years later. Use of a different marginal each year will allow us to age the individuals if these are subsequently recaptured.

On the Great Barrier Reef nesting female green turtles vary from 35 to 50 inches in carapace length (measured over the curve). The commonest size is about 42 inches, and above this size the addition of only one or two inches makes the turtle appear very much larger and greatly increases its weight. Tag recapture data can provide information on growth of these turtles between nesting seasons. Since reptiles, like other ectotherms, continue growth throughout life and typically reach sexual maturity long before attaining a 'maximum size' one would expect considerable growth to be recorded, at least among the smaller females. Once reptiles reach a certain size, often referred to as the 'adult size range', growth becomes extremely slow and indeed it may be difficult to measure. Young nesting female green turtles might be expected to show fairly rapid growth until they attain a size of 40 to 42 inches. Our very limited recapture data is extremely interesting but difficult to interpret. We have recaptured eleven green turtles after intervals of up to four years at sea. Nine of these definitely showed no measurable growth. In only one was there a strong indication of an increase of one inch, from 45 to 46 inches. The remaining individual apparently increased by 0.5 inches but since this is at the level of accuracy the apparent growth might have been due to experimental error.

The loggerhead recaptures provide similar information. In only two of eleven recaptures is there definite indication of growth. One increased by 1 inch from an initial carapace length of 41.5 inches and the other by 1.5 inches from 38 inches.

The above information can be interpreted as meaning that growth is generally extremely slow in both species once sexual maturity (minimum breeding size) is reached. On this interpretation large individuals are extremely old. On the other hand, the data can be taken to mean that there is markedly different growth during immaturity, perhaps as a result of food supply, with the result that size at sexual maturity varies widely. On the latter interpretation little growth would be expected after attainment of sexual maturity – only the extremely slow growth characteristic of reptiles throughout adult life. An age determination technique is required to settle this problem and we are currently investigating skeletal ageing techniques in sea turtles.

The frequent high density of nesting turtles on rookeries not subject to intensive human predation – which quickly wipes out the turtles if applied to the nesting females – leads to two important situations. Firstly one is usually struck by the shortage of nesting area. Only a narrow strip between the spring high-tide mark and the vegetation zone, the latter usually forms an impenetrable barrier, is available to the turtles. Furthermore, green turtles have a tendency to nest beside vegetation hence increasing egg destruction even further. It is possible to design an ideal beach which has a greater nesting area, with vegetation so arranged that the same area can support a much larger volume of developing eggs without a concurrent high rate of egg destruction by nesting turtles. Clearly this could have important practical applications. There is no question but that the productivity of most island (or mainland) nesting beaches could be increased at little cost. At the simplest this would involve removing debris in the form of tree trunks and the like from nesting beaches and laying areas. We have carried out an investigation of ideal nesting area configurations using computer techniques (Bustard and Matters, in prepn.). The other situation is beach erosion which was discussed in some detail in Chapter 3.

The relative occurrence of turtles of various sizes in the population provides additional information on the growth-age problem. In both green and loggerhead turtles at Heron Island there are extremely few individuals of about first breeding size, which may be young females breeding for the first time. This could suggest that few juveniles survive to join the breeding population which would, therefore, need to have a long life span. However, as mentioned above, it could merely mean that many females attain a considerably larger size before commencing breeding. The size-frequency distribution data, shown in fig. 11, also show a very small number of large individuals. This means that most individuals are lost from the population before they attain a very large size. On the other hand this could reflect a fairly rapid loss, so that even with a recordable growth rate adults tend to be lost before a large size is reached, or it could result from a slow growth rate with the result that the turtles seldom live long enough to attain these large sizes. Once again only an ageing technique applicable to adults will solve this problem.

Some information can be obtained, however, by an examination of the information on injuries grouped according to turtle size. A cursory examination of these data show that incidence of injury is definitely not cumulative throughout life as could be expected. Injuries are highest in the smaller breeding female green turtles. As the turtles become larger the percent with injuries drops steeply and then remains similar throughout life. The fall in percentage with injuries above this size grouping is clear evidence that there is considerable loss of young breeding female green turtles from the population and that a lower rate of loss occurs throughout later life (to offset those contracting new injuries) or that sharks seldom attack larger green turtles. Both factors may be important. In loggerheads, injuries reach a peak somewhat more than half-way through the breeding size range. This would tend to indicate that little loss from the population occurs prior to the size (age) class represented by the peak but that after this size (age) is attained substantial losses occur. The above statements will only hold good if the hypothesis that the larger turtles are older is shown to be correct.

The problems raised above show that a great deal remains to be elucidated about the lives of sea turtles. Their relative inaccessibility during their life at sea is largely responsible for this paucity of information. However, greatly increased tagging effort at many more locations should provide considerable information to fill present gaps in our knowledge. For instance I have remarked above on the poor recapture rates recorded back at the nesting beaches. Do these reflect dispersal to other nesting beaches or death? This is yet another problem which we are not able to answer at present. The definite characteristics of a nesting population in any one year, outlined earlier in this chapter, together with the fact that these characters tend to repeat themselves when that population would

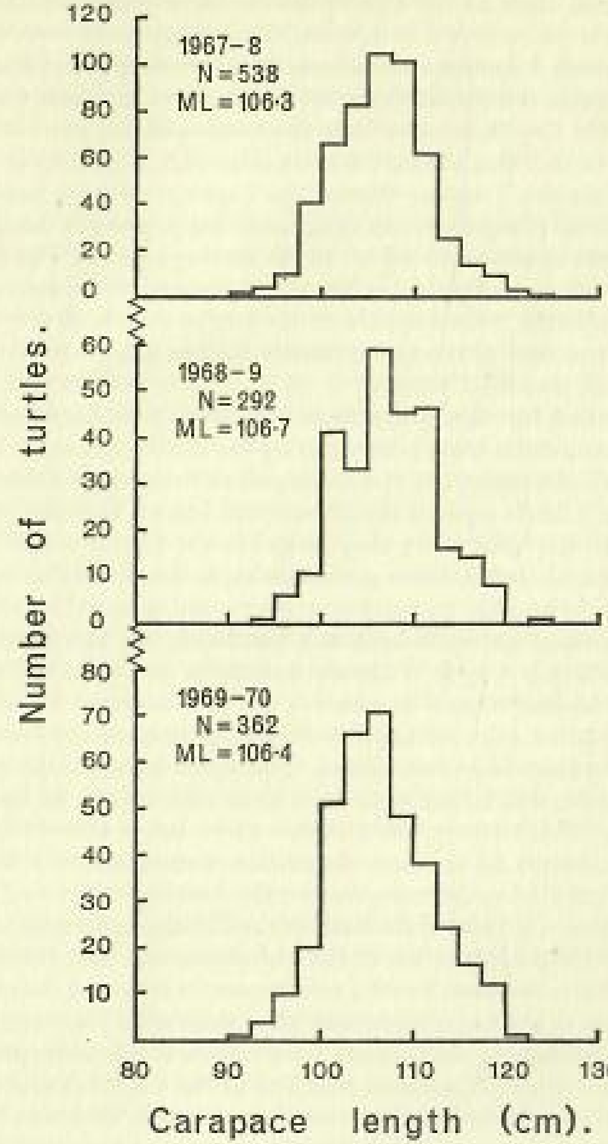


FIG. 11 Size-frequency histograms for three years' populations of the green turtle at Heron Island. The virtual absence of small breeding females (new recruits?) and the fall-off in size above about 105 cm (41.5 inches) should be noted.

be expected back at the nesting beach – four years later in the case of the green turtle in Queensland – suggests an interesting theory which I outlined tentatively in a review paper (Bustard, 1972). I pointed out that there are pronounced currents moving towards the Capricorn cays from the north and the north-east at the time of year that the turtles are presumably migrating to their nesting beaches. I wrote, 'Hence the Capricorn turtles could be parts of much larger populations which happen to get caught in this current and proceed with it to the nesting cays . . . The hypothesis raises a further question which cannot be answered at present, namely, what happens to the turtles which do not reach the southern area of the Great Barrier Reef in a nesting year? Do they breed, and if so, where?'

For several hundred years there have been periodic records of adult green turtles lying ashore during the daytime in areas of the Pacific (viz. Dampier, 1697). In one part of their range – the outer Hawaiian Islands – green turtles are well known to come ashore during the day time when they lie in the sun (Kenyon and Rice, 1959; Parsons, 1962). Since green turtles, as described above, take considerable trouble to carry out their nesting activities during darkness, observers have been at a loss to explain this behaviour and particularly why it is observed solely in areas of the Pacific. One would only expect to observe the phenomenon in isolated regions where turtles are not disturbed since they are shy creatures and very vulnerable when ashore. This could be sufficient reason for the trait, which may once have been widespread, to be little seen now. Furthermore, the evidence given below shows that the trait also occurs in northern Australian waters, and Mr Robert Poulson has seen numerous green turtles basking on the reef – out of the water – at Bloomfield Reef in the Capricorn Group.

The obvious explanation of the phenomenon is that the turtles are basking in the sun. Turtles are frequently recorded sleeping at the surface of the sea. Under such conditions their body temperature is considerably above water temperature due to absorption of radiant energy. Furthermore, heat loss to the water is reduced, as the surface waters are warmer than deeper down. However, basking opportunities are much reduced in the water compared to on land as heat loss to the surrounding water is always substantial. On land in the presence of a radiation source, heat loss is much reduced. Basking is well known in many reptiles as a means of elevating their body temperature. This can result in much faster

digestion. It would seem feasible, therefore, that after eating a large meal green turtles in remote areas haul out to lie in the sun in order to speed up digestion.

In 1969 the Lardil aborigines on Mornington Island told me that, during the winter, green turtles hauled ashore far from the settlement and lay on the beach during the day. In the course of a discussion I asked them why the turtles did it. Without hesitation they said the trait was only shown by females which came ashore to escape the attentions of the promiscuous males. I was most intrigued by this explanation which I had never heard advanced before and determined to investigate at the first opportunity.

In winter 1970 during turtle survey work I was flying over Mornington and neighbouring islands in the Gulf of Carpentaria and sure enough on the outer islands there were turtles lying ashore on the beaches. The following day we landed our light aircraft – a Cessna 182 – on the beach at Bountiful to investigate. I wandered up to two large turtles lying on the beach and to my disappointment both appeared dead. I gave one a push with my bare foot and to my surprise it quickly came to life, grunted and lumbered down the beach towards the sea. The other turtle responded similarly. Both were females. During our stay on Bountiful we walked right round the island's beaches and observed many turtles lying ashore in the sun often fifty to one hundred yards from the water. We were able to observe exactly what happened.

Firstly, we corroborated the Lardil story – all were females. In the morning we observed the situation just after the tide turned. High tide was about 8 a.m. Shortly thereafter turtles came up to the wave wash and generally turned round to face seawards where they remained stationary in extremely shallow water in which swimming was impossible. At this stage they were alert and the sight of humans sent them lumbering into deeper water where they swam out to sea. However, as the tide receded these turtles were left high and dry and by early afternoon many were considerable distances from the sea as we had observed the previous day. Since male turtles never leave the water there is no doubt about the efficacy of this behaviour against sexually active males. Indeed the females do not need to actually leave the sea to escape the attention of the males. Males cannot mount females unless they are in about two feet of water, and by resting in extremely shallow water in which males cannot swim, females can completely avoid their attentions. We observed many males swimming along parallel to the beaches, in water just deep enough for efficient swimming, undoubtedly looking for females. They passed a number of females at the water's edge without noticing them. The fact that the females become stranded at some distance from the sea is quite incidental – the result of the tide cycle. Unless the females keep crawling seawards to compensate for tide fall this is bound to occur. As a result of these observations I am now convinced that my aboriginal friends are correct.

We have seen many female turtles deliberately enter shallow pools which become cut off from the sea by the receding tide. There is no basking advantage in these pools as their carapaces remain covered or largely covered all the time, although the shallow water becomes somewhat warmer than the sea. This behaviour, like stranding, is clearly carried out to avoid male attentions. Sometimes several males enter these pools before the tide cuts them off. Females cannot subsequently escape and there is pandemonium until the tide comes in or darkness falls. One can tell at a glance if males are also present. If not, the females are all asleep often with part of the carapace completely dry and projecting from the shallow water. If males are present the females' carapaces are usually wet due to continuous assault, and activity in the pool is generally pronounced.

Remarkably little has been written about sea turtle courtship. Indeed I know of no detailed account for any species of sea turtle. Photographs of copulating turtles are fairly common, as are accounts of several males swimming around a single female in the water. On remote Bountiful Island I was lucky enough to observe courtship and copulation many times, often from a distance of less than six feet. Incidentally, I had never observed this at Heron Island. This is because the main mating areas are often at some distance from the nesting beaches. In the Capricorns, Broomfield reef is renowned as a mating area.

When a male green turtle first approaches a female it swims round to face the female and nuzzles her head, rather like rubbing noses. Usually the female shows no response whatsoever. After a short period of nuzzling, the male then makes 'bites' in the region between the female's shoulder and neck. Little attempt appears to be made to actually grasp the female in the jaws. Rather the process is an extension of the nuzzling first observed but now no longer directed at the head. Undoubtedly the procedure is intended to arouse the female. After a variable time the male then

swims to the rear of the female and makes some biting actions at one of the rear flippers. Sometimes the flipper is taken loosely in the jaws. At this stage the female frequently swims away at speed, chased by the male. In the sea males are never able to mount an unwilling female, but due to their persistence and the fact that many males are always looking for females they must have very considerable 'nuisance value'. Presumably this explains the female haul-out behaviour. However, in land-locked pools the female is less readily able to escape from the male although she can certainly frustrate actual copulation attempts.

If the female does not swim away when the male nuzzles and bites a rear flipper, the male then attempts to climb on top of the female. This manoeuvre is only possible if the water is somewhat deeper than the depth of the female's carapace. Due to the highly domed carapace of the female and the bony plastron of the male, the manoeuvre is difficult at the best of times. The male attempts to gain momentum and literally swim up, and on to, the female's back. Once there he hooks on with the large thumb claws of the front flippers. These are hooked over the front of the female's carapace between the shoulder and neck region. As a result of this, nesting females are seen with anterior marginal areas of the carapace chipped and the soft parts raw from the male's claws during copulation. The male also maintains his position on the female by hooking the horny end of his tail under the posterior marginals of the female's carapace. The greatly elongated tail of the male has a pronounced horn-like distal portion. Sometimes a male may go right over a female and, following a chase, not infrequently fails to approach from behind but makes a sideways approach. This results in the male not being able to maintain his position and he slides off to try again. Once a male has firmly positioned himself on a female, copulation can begin. As pointed out above, males never succeed in reaching a stage where copulation is possible unless the female is a willing partner to the act. The courtship behaviour is illustrated in plate 6/7.

In view of the general paucity of information on sea turtle biology in many parts of the world, the small number of scientific turtle workers have an obligation to set some time aside for investigations outside their main study region. The large gaps in our knowledge reflect lack of personnel just as much as lack of funds. Indeed it would seem that personnel are more at a premium than availability of funds. However, the two are often related.

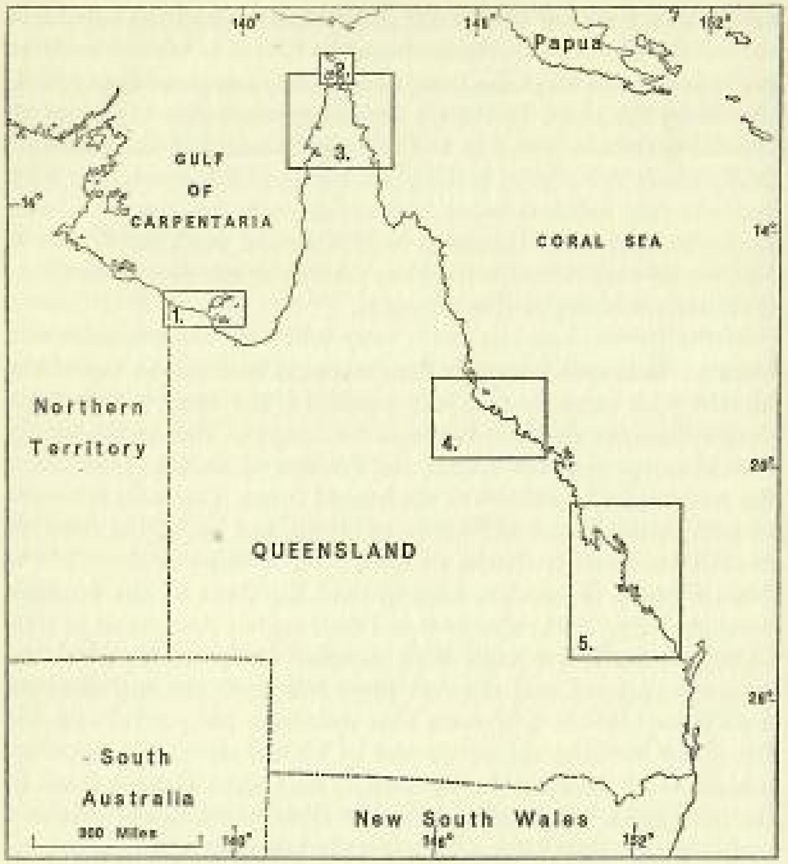


FIG. 12 Map of Queensland, Australia, showing areas (boxed) with turtle nesting aggregations in December 1969.

Perhaps it may be of interest to readers to know what we are doing in this regard. In June 1970, with financial support from the United States National Appeal of the World Wild Life Fund, we started an investigation of the sea turtle resources of the whole of Queensland. This work involved aerial surveys of all mainland beaches and off-shore islands together with extensive ground follow-up work and is expected to take about eighteen months to complete. When complete it will be written up as a report to the Government of Queensland and also published separately to act

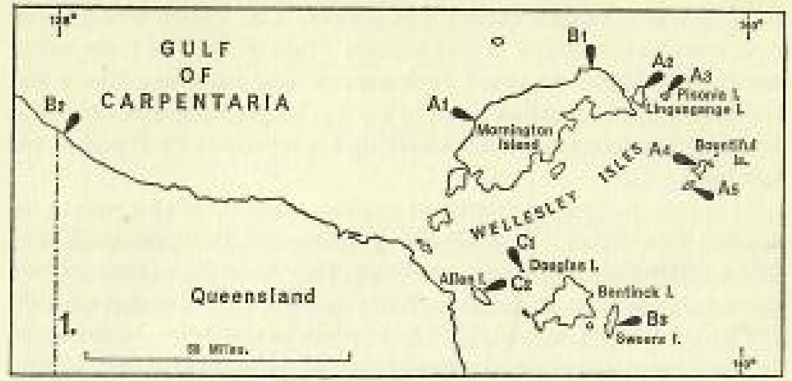


FIG. 13 Detail of area 1 of fig. 12 showing locations of specific rookeries, which are categorised A, B or C in descending order of importance. The Bountiful and Pisonia rookeries are large by world standards.

as a guide to others of how we feel this sort of work should be undertaken and the results evaluated.

It is readily possible from a height of about 500 feet to count individual turtle tracks from the air and usually to state the species involved. Before writing our report we will have seen all of the State's beaches and islands between three and six times from the air. Survey work has been arranged so that the various areas of the State are investigated at different periods of the breeding season since seasonal differences in time of breeding between species are known to occur.

A major result of the work so far has been to show that nesting only occurs to any extent in certain areas of the State and that, as anticipated the main rookery areas are closely circumscribed. This information has two important bearings on conservation or any rational exploitation schemes which may be investigated. It would be easy to virtually wipe out the present large turtle populations in Queensland. Alienation of only two rookeries – geographically very small – Bountiful and Crab Islands, would probably reduce the Queensland populations of green turtle – the economic species – by one half! On the other hand, since the important areas are small and remote, it would be a simple procedure for the Government to protect the turtle populations by declaring these remote areas, which form such key nesting rookeries, National Parks. In fig. 12 the main areas used by nesting turtles during the first surveys are indicated by boxes 1 to 5. Outside of these areas no nesting was recorded during this survey. The Capricorn–Bunker cays were not included in this survey. Maps of each of these areas are then prepared to cover each survey. For instance, area 1 for the June 1970 survey is shown in fig. 13. Major rookeries are indicated by the letter A, smaller nesting aggregations by B and some nesting by C.

It is extremely important that applied research of this nature be carried out. Since the scientific workers are the best qualified, and usually the only people available, they must be encouraged to participate wherever possible. After completion of our statewide investigations in Queensland, I have plans to carry out similar work in Western Australia and then in the Northern Territory. I have also been providing some help to other turtle bearing countries overseas. For instance, during 1970 I spent several weeks in Fiji investigating the status of sea turtles there (Bustard, 1970b) and also visited the Trengganu rookery of the leathery turtle on the east coast of West Malaysia to see what could be done to further safeguard the future of that population (Bustard, 1971a).

PART FOUR
Turtles and Man

CHAPTER 10 brings together the many facets of sea-turtle conservation, past, present and future. Our own experiences in Queensland are used to illustrate the sort of problems which one encounters in this kind of work since these are of universal occurrence. We differ in that we have been exceptionally fortunate in the enlightened attitude we have encountered towards turtle conservation by the Government of Queensland and its officers.

The chapter starts by reviewing past legislation. Current conservation achievements are then considered together with relevant background information. The chapter concludes with a species by species survey of the future of the world's sea turtle resources. Since turtle farming – by satisfying the demand for commercial turtle products – can greatly reduce the hunting pressure on wild turtles, and perhaps ultimately replace wild turtles as a source of commercial product, it is strongly linked to conservation in my view. Of course, the way in which the farms are run is vitally important and as always political considerations must also be borne in mind. Because of the future importance of turtle farming to turtle conservation, a section of Chapter 10 is devoted to this topic.

the reptiles with shells, tortoises live on land, rapins are amphibious, but turtles are rine. Like all reptiles they evolved on land, t they have reverted over their 90-million-year tory to an aquatic life (like the whales ong mammals). A small but fascinating group, gether they cover all the world's tropical and b-tropical seas. For their aquatic life turtles ve fused fingers into flippers, developed t-excreting glands around the eye (and so e seen to weep when caught) and streamlined d lightened the tortoise's high domed shell. s still an encumbrance, but also protects— eir only other defence against predators being swim away fast.

t as reptiles, turtles must lay their eggs on nd, and it is the story of their remarkable productive behaviour that is so fascinating.

rtles copulate at sea, but the female must en heave herself up above high tide-line on a itable beach at night; laboriously excavate ith her front flippers a deep wide hollow; lay r eggs in it, cover them up with sand (for olness and concealment) and get back to sea. he eggs look like ping-pong balls. The female ys up to 1000 in a season—because the ortality in baby turtles is so high. When ter 3 months they emerge, the hatchlings weigh ss than an ounce. They dig themselves out of e sand, also at night, and scuttle down the each to the sea (and it must be down; an tervening dune will disorientate them). But n the beach the ghost crab lies in wait, and in e sea a dozen other predators. One in a undred may survive.

n this book, Dr. Bustard, world famous for his ork on turtles of the Queensland coast, has ritten a definitive account for the general eader of the world's seven turtle species, their fe histories and conservation. It is illustrated ith many of his own photographs.

Robert Bustard is one of the world's leading authorities on turtles. Born and educated in Scotland, he moved in 1963 to the Australian National University in Canberra. He is now investigating turtle and crocodile farming with support from the Australian Commonwealth Government and by his own efforts stimulated the 1968 Queensland Sea Turtle legislation. The IUCN has declared this "by far the most significant legislation in turtle conservation that has yet been enacted anywhere in the world".

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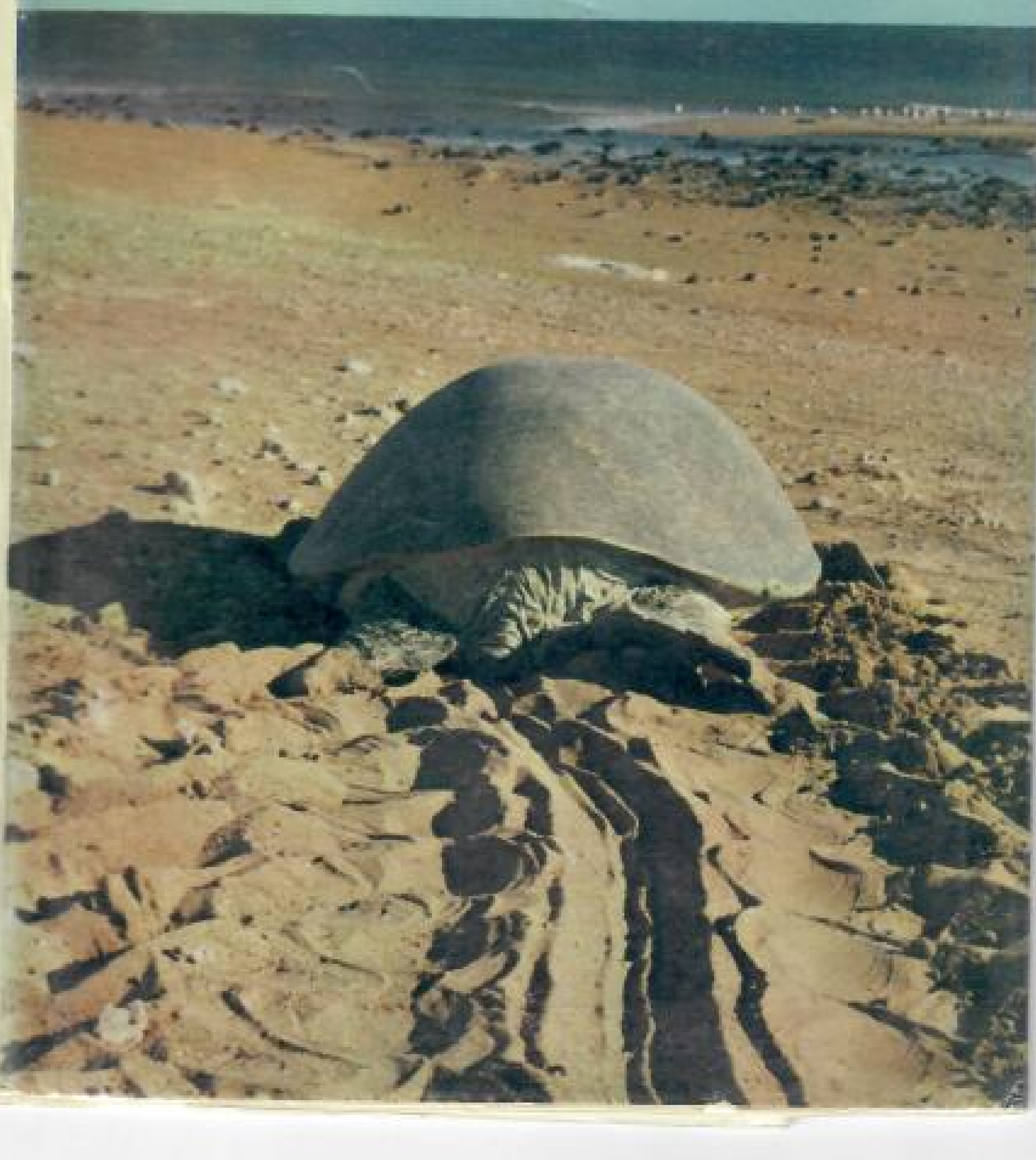
ROBERT BUSTARD

Sea Turtles

Their Natural History and Conservation



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