Australian Natural History

Vol.21 No.5
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TASMANIAN TIGER SIGHTING/SEX CHANGE FISH

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from the INSIDE

To discover a new bird species is equivalent to a weekend fossicker finding a gem like the Hope diamond. In fact, only five species have been described from Australia over the last 50 years. This edition of *Australian Natural History* features another, the Eungella honeyeater, discovered in misty highland rainforest west of Mackay, Queensland. We also feature the investigation that followed the most recent reliable sighting of that mysterious marsupial, the Tasmanian tiger. Is this dog-like animal extinct or not? The evidence presented in this story might surprise you.

It's pleasing to announce the commencement of a regular *Letters* section. At *ANH* we believe that reader participation is a crucial ingredient to our continuing success. You provide the feedback and watch the magazine respond. This edition's *Letters* continues the controversy surrounding our last, widely publicised, cover story about kangaroo harvesting.

Our marine theme this edition examines the implementation of marine reserves, of which the Great Barrier Reef is Australia's finest example. To talk about the Reef necessitates the need to look at the crown-of-thorns starfish which has recently stepped up its onslaught on the Reef's beautiful coral formations. Is there a crown-of-thorns "plague" destroying the Reef? Our informed experts say *no*.

We look at two different types of marine-related invasions by introduced species which may well be threatening our native sand dune species and our local fish populations. As well, we take a trip to the massive green turtle and bird colonies of Raine Island, off north Queensland.

A new editorial team has taken over production of *Australian Natural History*. You will see in coming issues a magazine with more diversified editorial content, a greater emphasis on quality colour photography and the introduction of regular features concerning topics that you, the readers, have told us you would like to see included.

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COVER: Diver exploring a coral cave with sponges illuminated by photographer's flashlight. Photo: Kev Deacon

Letters

Last edition's (Vol. 21 No. 4) kangaroo harvesting story by Gordon Grigg from Sydney University attracted a vociferous response from the conservation movement.

More Than Just Meat, Skins And Profit

According to your magazine's editorial you have always presented the facts however it is unfortunate that Gordon Grigg has neglected to mention the following facts concerning the kangaroo issue:—

1. There are 10 species of macropods which are taken commercially. Excluding the red, eastern grey and western grey kangaroos, there are *no* population estimates for the remaining species.

2. The available research into the competition between kangaroos and domestic stock does not prove that kangaroos are large scale agricultural pests.

3. Farmers' organisations have yet to provide accurate estimates of the value of damage caused by kangaroos.

4. Commercial exploitation of the red kangaroo in the Northern Territory in the 1960s decimated the population and it has never fully recovered.

5. Victoria stopped commercial kangaroo killing in 1982 when it was shown that it was not abiding by the National Kangaroo Management Program. Since that time complaints from farmers re agricultural damage caused by kangaroos have not increased noticeably.

6. None of the States currently carrying out commercial killing of kangaroos have shown how they are abiding by the National Kangaroo Management Program.

7. The US Government recently reversed its decision to delist three species of kangaroo from the Threatened Species List under the US Endangered Species Act (1973) largely due to the effects of the last severe drought and because it was shown that the Australian Government had misled the US re kangaroo population figures.

8. Aerial surveys do not provide accurate information on sex, age ratios condition of individuals, environmental conditions and other biological data necessary for proper kangaroo management.

9. Euros are not counted with aerial surveys yet there is a quota of 77,000 total for 1984.

10. The value of the export market for kangaroo products has increased from about $2 million in 1975 to about $17 million in 1983.

11. In 1983 there were roughly 133 million sheep in Australia, 22 million cattle, 15 million humans and 10 to 12 million kangaroos. This is an important point when discussing kangaroo plagues.

As accurate aerial survey work on kangaroos only dates back to 1977, any longterm decline in populations may not show as yet for five, ten or 20 years. Grigg uses export figures for the last 50 years to say that there has been no sign of any diminution in kangaroo numbers but this is not an accurate method of proving that kangaroo numbers have not declined (or are declining) in the longterm and Grigg (as a scientist) should know better.

Concerning the moral arguments mentioned. Whether it is logically or morally right or wrong or whether Dr. Grigg likes it or not, people on the whole, do view animals in two ways — wild and domesticated. Whilst not trying to justify the killing of domestic animals it is fair to say that nearly all domestic stock would not exist in many places if it wasn't for their direct cultivation by people. In comparison, what effort do wildlife exploiters put back into the welfare of the species?

Kangaroos and all wildlife should not be regarded as human "resources" as they have their own rights to exist independently on this planet. To consider them so as useful only in a human way is an example of the greedy and exploitative nature of our species. The Australian and world communities consider kangaroos more important than just a source of meat, skins and profit.

—Trevor Daly
Kangaroo Project
Coordinator
Greenpeace.

Conservationist Views Distorted

I write to congratulate you on the very high standard of production of *Australian Natural History*. I always find the interesting articles exceptionally well presented. I also write to comment on Vol. 21(4) which dealt extensively with the kangaroo issue.

What was missing from this issue was a presentation of the views of the conservation movement.

As you would be well aware, it is always unsatisfactory to have one's views presented by someone else, and particularly by unsympathetic commentators or by the press, a point I stressed in a paper I gave at a public forum on kangaroos in Adelaide last year (see *Habitat* 11(5) pages 9—11). I presume you are referring to this when you say that "false and misleading statements have been widely reported in the media by individuals and conservation groups."

The distortions of the media clearly make it difficult to have an informed and constructive debate. The inference in the introduction to Gordon Grigg's paper that we believe harvesting is wiping out kangaroos is of course a distortion of our position.

A change in community values or ethics towards wildlife is a matter of major importance. The implication in your statement that this constitutes "emotive ravings, exaggeration or ill-informed arguments" does not do much to enhance serious discussion of such a change. One cannot help but feel that such a dismissive attitude reflects an unwillingness to face up to the facts.

You say that Barry Cohen, after promising to investigate kangaroo harvesting, supports the harvesting program. This statement is misleading, because it fails to mention the significant fact that the inquiry which represents the investigation referred to is still underway and no results are available from it yet.

J. G. Mosley,
Director, Australian
Conservation Foundation,
Hawthorn, Victoria.

I have been given the task of replying to these two letters in about 200 words. It is disappointing that Dr Mosley in his letter chooses to judge me unconcerned about the conservation of Kangaroos. There will inevitably be a diversity of views among conservationists and one can certainly be a conservationist without being an animal liberationist. The conclusions expressed in my article are in *no way* anti-conservation and are accepted by the many conservation societies which find a regulated kangaroo harvest quite acceptable.

I support much, probably most A.C.F. policy, but I do not accept most of the philosophy behind animal rights, or animal liberation. I do believe very strongly that humans have a duty and a responsibility towards animals, especially to avoid practices which either cause suffering or hasten extinction, but I do not accept that kangaroos have rights in the way humans do.

However, animal welfare groups increasingly recommend free-range management of domestic animals in order to give these animals a better quality of life, so the method of harvesting kangaroos seems to have a lot to recommend it.

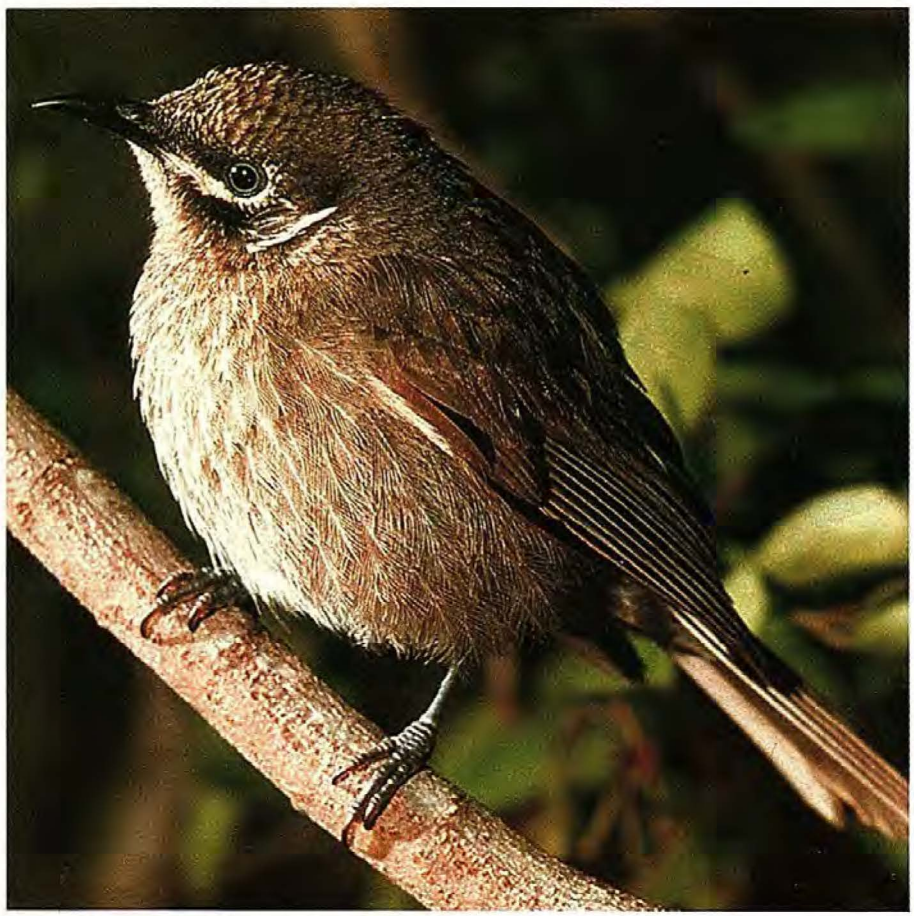
As far as the letter from Greenpeace is concerned, space prohibits the full discussion it deserves. I agree with some of the points raised. Some are partly right, some are wrong, some are matters of opinion rather than of fact and some are irrelevant to an article which dealt with only three species. However, Mr Daly's comments do not challenge the main point of the article, which is that scientific data and other evidence allows the confident assertion that regulated harvesting will not endanger or threaten these species, so that opposition to the industry must move away from the numerical and into the moralistic arena.

— Gordon C. Grigg

Discovery of New Rainforest Bird Species

EUNGELLA HONEYEATER

This exclusive story documents a significant milestone in ornithology, the discovery of a new bird species. Only five new species have been described from Australia over the last 50 years. This one, the Eungella honeyeater, was first found in rainforest west of Mackay, central Queensland. The author, wildlife ecologist Jim Shields, was intimately involved with the discovery.



Eungella (pronounced "Young-gel-la") honeyeater. This is the new species of honeyeater discovered near the Eungella National Park in central Queensland. It was found in rainforest in the Clark Range, 80 kilometres inland from Mackay.
Photo Jim Shields.

Just after sunrise on November 29, 1978, a small grey-brown honeyeater was removed from a mist net spanning Massey Creek in the highland rainforest west of Mackay, Queensland. This bird was the first individual of a then undescribed species (now known as the Eungella honeyeater *Meliphaga hindwoodi)* captured by a joint field trip from the Australian and Queensland Museums. The major purpose of the field trip was to confirm the existence of this suspected new species, and the capture of the first specimen insured success to the venture. It also gave just cause for celebration which belied the sober reputation that museum activities have acquired in the public eye.

The bird itself is simply a grey-brown honeyeater about 20 centimetres long, with a streaked breast, black bill and white "bridle" stripe from gape to ear coverts. It is a pleasant little bird, but far from a striking visual experience. Why, one might ask, should it inspire an entire field trip, or instill jubilation into well-travelled ornithologists?

The discovery of a new bird species in the 20th century is an unusual occurrence. To exaggerate the situation slightly, for the ordinary birdwatcher, finding a new species would be roughly equivalent to a weekend fossicker finding a gem like the Hope Diamond.

A species, in biological terms, is a population of actually or potentially interbreeding individuals which is reproductively isolated from other, similar populations. The field of biology known as taxonomy is devoted to the description and naming of such groups of organisms to facilitate reference and to give an indication of their assumed relationships.

To a large degree, the naming of new species of birds was accomplished during the age of European exploration. A naturalist was a standard part of the crew on voyages of exploration, sending specimens of new biological discoveries to workers in his home country. When the early scientist was confronted with the task of describing the fauna of a new area, it was natural to start with the birds. The ease with which they were observed allowed the first naturalists to collect, and ultimately describe, a large percentage of birds during the initial surveys of new lands.

The magnitude of this job was diminished by the fact that there is a comparatively small number of bird species. On a worldwide level, there are currently described about 20,000 bony fishes, 750,000 insects and 60,000 molluscs, while there are only about 9,000 birds. Each year, hundreds of new fish, insects and molluscs (not to mention species of other invertebrate

Above: The rainforest habitat where the first Eungella honeyeater was captured. The bird became entangled in the black nylon mist net (in the patch of sunlight) and was carefully removed for measurement and banding.
Photo Jim Shields.

groups) are described, while it is rare if even three new species of birds are discovered in a year; most of these come from remote sections of South America. The lot of the 20th century ornithologists has advanced to ecology, behavioural studies, physiology and higher level systematics. Dramatic and exciting discoveries of new species are few and far between — only five have been described from Australia in the last 50 years.

The trail to the discovery of the Eungella honeyeater (pronounced "young-el-la") began, not in the dark recesses of an unexplored rainforest, but in the naphthalene-scented atmosphere of the Australian Museum's Ornithology Department. Wayne Longmore, at the time a Lance Corporal in the Australian Army on leave to work as a volunteer in the department, was casually examining specimens in April 1976. As he was going through a tray labelled "bridled honeyeater", he came across a single specimen which looked different. It was the only bird in the series of specimens from the Clarke Range region of mid-east Queensland.

The bridled honeyeater *Meliphaga frenata* is a familiar and typical representative of the honeyeater family Meliphagidae. It feeds on nectar, fruit and insects, and has a down-curved bill and a brush-tipped tongue. It is distinguished by having a dark brown body, black head, whitish bridle stripe on the face, white and yellow ear tufts and a bicoloured bill (black on the tip, yellow at the base). Distributed along the coast and adjacent ranges of north-eastern Queensland, it is most common in the highlands. The single bird noted by Wayne had a solid black bill, was paler than the typical bridled honeyeater, and had definite white streaking on the body feathers.

Wayne measured this individual and found that the lengths of its bill, wing and tail were noticeably smaller than those of a series of bridled honeyeaters. Upon conducting a search of the scientific literature, he found only two major references to bridled-type honeyeaters in the Eungella region. An article by Mr. J. S. Robertson in a 1961 article of *The Emu,* the national ornithological journal of Australia, contained a description, measurements and a photograph of a bird from that area which resembled the specimen Wayne had picked out in the Museum, and differed from those of a true bridled honeyeater. These differences had never been discerned by anyone else, though quite obvious in the published photograph. Several years later, one of Australia's leading naturalists, Mr Alec Chisholm, had published a short note in the same journal. In it, he described his encounter with the "bridled" honeyeaters of the Clarke Range area but, like others, failed to recognise the dissimilarities.

Wayne followed up these findings with a survey of museum specimens in Australia and around the world. He discovered that the skin in the Australian Museum was the only specimen of "bridled" honeyeater from the Clarke Range region in existence. Subsequently, he became the individual most responsible for the confirmation of the existence of the Eungella honeyeater; in fact, while researching the subject of the still largely hypothetical species, his colleagues referred to the bird as "Longmore's honeyeater".

The specimen which focused attention on this group of birds was collected by Mr Rolf Lossin, a senior preparator at the Australian Museum. He was in the Clarke Range studying the fauna of Australian rainforests as part of a survey being conducted jointly by the Australian and Queensland Museums. He acquired the bird, an immature female, on April 5, 1975, just as the survey team was preparing to leave the area.

Walter Boles, a transplanted American ornithologist, now of the Australian Museum's Ornithology Department, also took part in the 1975 section of the survey which covered selected sites in mid-east Queensland. Taking up his position with the Museum earlier that year, he quickly found himself immersed in the survey, working with members of the Queensland Museum staff. When he caught a pair of medium-sized, grey-brown honeyeaters in his mist nets at one of the Clarke Range sites, he identified them from the available literature as bridled honeyeaters, banded them and released them, as the purpose of the mist netting operation was to assess bird populations, not to take specimens.

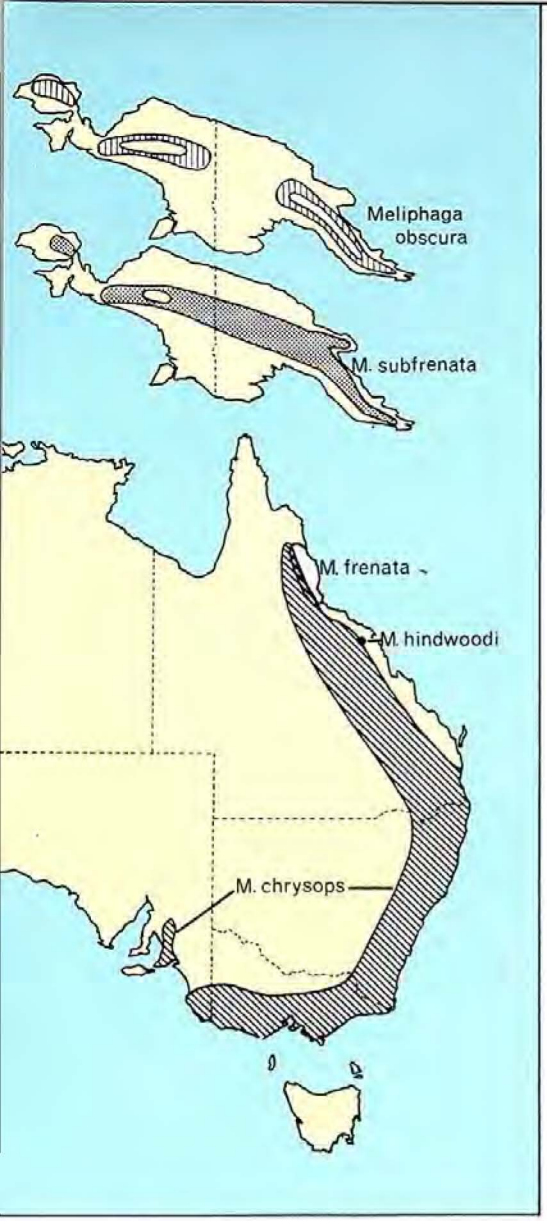
He found the birds to be common in the region. They were a noisy and obvious component of the site's avifauna. These observations became particularly intriguing when combined with Wayne's subsequent findings. By early 1978, there was considerable evidence that an undescribed form of honeyeater was living in the mountains behind Mackay. Preliminary trips to that area were made individually by Wayne, Terry Lindsey and myself during the period from May to July 1978.

Terry, an expatriate Canadian ornithologist, wildlife artist and associate of the Museum's Ornithology Department, had followed Wayne's research from the outset. He had lived on the Atherton Tableland for several years, in the heart of the "true" bridled honeyeater's range, and was familiar with that species' field appearance, songs and behaviour patterns. He was also the only one to have any success on the preliminary trips. Wayne and I had found no signs of the birds when we were in the area during different parts of July. When Terry was there in May, he heard a bird's song that was similar to, but noticeably different from a bridled honeyeater. Due to heavy rain, he was unable to locate the bird visually. Although disappointing at the time, these findings were not unexpected. The birds had been observed in the area only from October to April, and many rainforest birds exhibit population dispersions after this time.

It was decided to mount an official trip to the region during the summer, when the birds should be present and possibly nesting. Mr John Disney, then Curator of Birds at the Australian

Right top: Bridled honeyeater Meliphaga frenata, *a dark plumaged rainforest honeyeater similar to the Eungella honeyeater but differing in its darker plumage and bi-coloured bill. Photo N. Chaffer (NPIAW).*

Right below: Regent bowerbird, Sericulus chrysocephalus. *This male was captured in north-eastern New South Wales in the centre of the species range. A far northern population was encountered in the Clarke Range west of Mackay, Queensland. Photo Jim Shields.*



The group of species to which the Eungella honeyeater belongs, replace each other geographically along eastern Australia and in New Guinea. The distribution of the Eungella honeyeater is one of the smallest of any Australian species. Map by D. S. Kent.

Museum, and Dr Des Griffin, Director of that institution, helped make arrangements for a five week trip from mid-November to mid-December 1978. The Queensland Museum in Brisbane was consulted and it was agreed to make a joint venture of the expedition. Mr Glen Ingram would represent that museum. He currently holds the dual role of Curator of both amphibians and birds, but his interests and capabilities in natural history are ubiquitous, ranging from skinks to anthropology.

Glen would be picked up in Mackay by the Sydney team members who consisted Walter and Wayne from the Museum, myself as a volunteer trained biologist and ex-professional chef, and Terry, his wife Ann, herself an avid amateur ornithologist, and their 14 week old daughter Clair. On November 15, the expedition set out from Sydney, taking time to revisit several northeastern New South Wales rainforest sites from the previous survey, in particular, Terania Creek, near Lismore, and the Tooloom Scrub at Beaury State Forest, near the Queensland border. Two days after departing Brisbane, we neared the small known distribution of "Longmore's honeyeater", centred in the rainforest atop the Clarke Range, the escarpment west of Mackay.

The Clarke Range lies 80 kilometres west of a major birdwatching pathway between Rockhampton and the tropical rainforests of northeastern Queensland, including the popular Atherton Tableland. Between these two well-frequented birding stops are long stretches of highway travelling through dry, flat, and not particularly inviting countryside. Most people traditionally continued past the turnoff to the Clarke Range without a second thought.

Travelling up the road to the top of the escarpment, another reason became apparent why birdwatchers hadn't overwhelmed the place and made the Eungella honeyeater a matter of common knowledge. The road that ascends the 1300 metres between the coastal plain and the top is a ten kilometre stretch of steep, hairpin turns, literally hanging out into the void, capped at the crest by a turn so sharp that a mirror has been provided to give the driver a view of the road around the bend. It did not seem surprising that few serious ornithological activities had taken place on the top of the range before the 1975 survey.

Once up top, the weather belies the fact that the area is in tropical Queensland. It can get chilly in the morning, even in summer. The rains come often and the air is always damp. Fog, or clouds at ground level, often obscure the view (the word "Eungella" is of Aboriginal origin and means 'mountain of the mists'). On a clear day, however, it is possible to see ships in Mackay's harbour, from the veranda of the only hotel in Dalrymple Heights (or Eungella, as it is also known), the township perched right on the edge of the escarpment, overlooking the Pioneer Valley.

The eastern portion of the Clarke Range is covered by rainforest, giving way to drier eucalypt forest to the west. The establishment of Eungella National Park has preserved large tracts of rainforest on the eastern edge, down the steep slopes through some lush areas at the base of the range. Emergent trees loom to heights of 30 metres or more, and the understorey is made up of smooth bark palms and tree ferns five to ten metres tall. The tree ferns lend a definite primeval touch to an atmosphere that is still one of an unexplored wilderness. Many areas outside the park have been cleared for dairying. The pastures are brilliant green, but often slope so steeply that one fears for the equilibrium of the peacefully grazing Fresians. Dairying and timber production are the major local occupations. Other stands of rainforest are retained in State Forests and in uncleared back lots of private dairy farms.

Upon arriving at the top, we followed a dirt road north and west towards Mt William, the highest point, for 18 kilometres to the approximate area where Rolf Lossin had taken the original specimen. Here, Mr Graham Thurgood kindly allowed us to set up field headquarters on his property and to use a disused milking shed to supplement our tents.

The next day, Wayne and I reconnoitered the area, while the rest of the crew went into Mackay to meet Glen at the airport and to buy camp provisions. We began our reconnaissance by taking a walk down the track leading back to Dalrymple Heights. After a dull and disappointing start, we were finally rewarded with our first sighting of a live "Longmore's honeyeater". Typically for a honeyeater, it was feeding on blossoms about ten metres up in the lower part of the forest canopy. The flowers in which it was most interested were those of mistletoe, a parasitic bush which grows on the branches of trees. Later on, we discovered that mistletoe and honeyeaters seemed to go together — where one was found, it was likely to find the other. After a very brief stay, the bird we were watching flitted out of sight. Still, it was a relief to know that the birds we were searching for did exist and that they were present in the area.

Mr Thurgood volunteered to show us around his property and the general area. We took him up on the offer late in the morning and discovered the inner beauty of the rainforest, a charming little waterfall and a length of Massey Creek that ran through a corner of his property, used as a bathing pool by our honeyeaters. One of them flew down and had a splash literally at Wayne's feet. The presence of the water and a good supply of mistletoe drew the tolerant birds close enough for Wayne to pick their song on the pocket tape recorder he was using to take field notes.

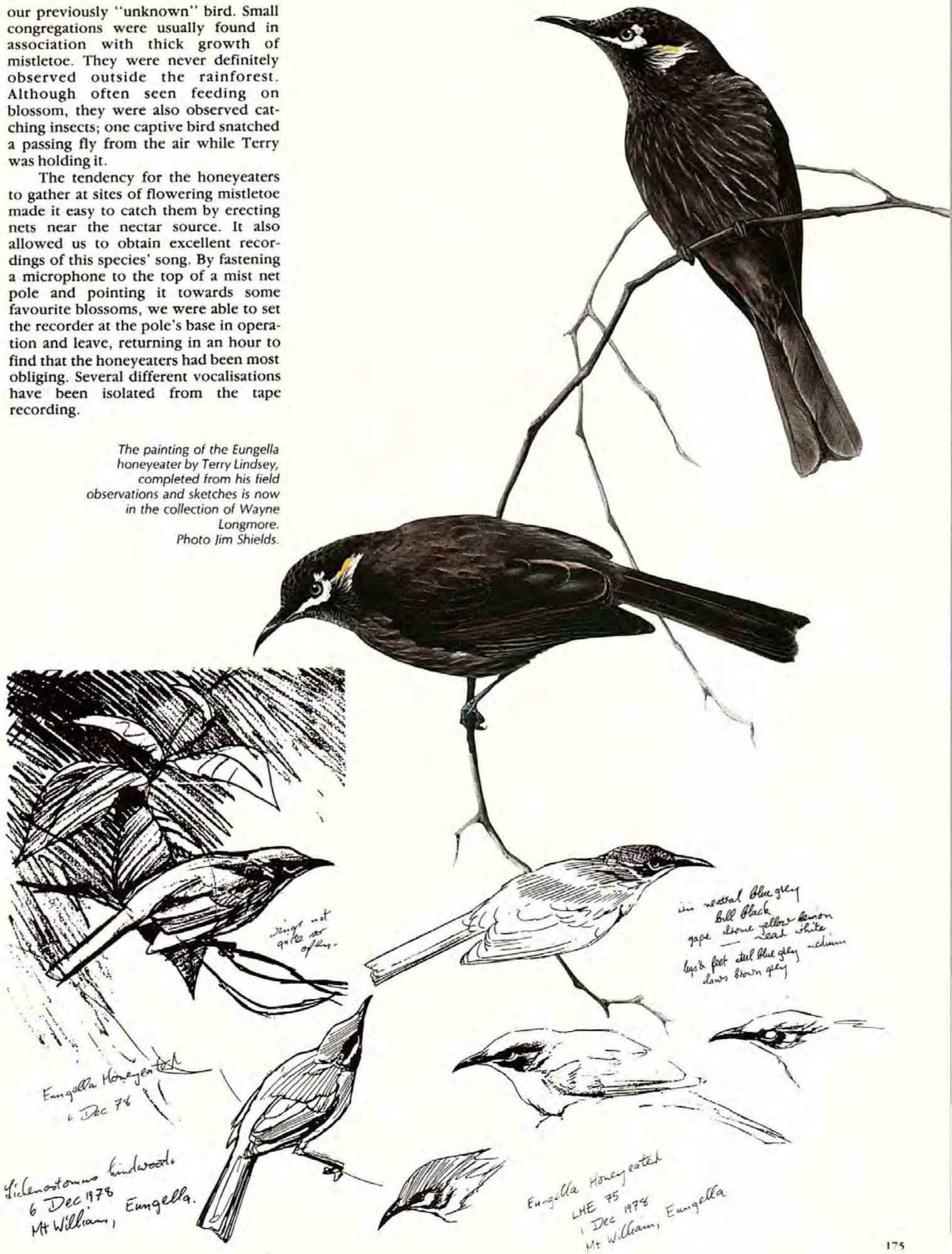
Recognising a good thing when we stumbled over it, Wayne and I returned to the stream in the afternoon to set up a mist net. Our plan was to stretch the net diagonally across the stream which involved taking off boots and stumbling about over sharp hidden rocks while we secured both ends of the net. Our pains were rewarded by the capture of an azure kingfisher *Alcedo azureus* which obligingly flew into the net before we had time to put our boots back on.

Our return to camp found the entire group assembled. Suitably impressed by our day's finding, Glen, Terry and Wayne drove over to check the net. They discovered our first specimen of the Eungella honeyeater entangled midstream, and insured the success of the expedition.

In the two weeks that followed, we became a great deal more familiar with

our previously "unknown" bird. Small congregations were usually found in association with thick growth of mistletoe. They were never definitely observed outside the rainforest. Although often seen feeding on blossom, they were also observed catching insects; one captive bird snatched a passing fly from the air while Terry was holding it.

The tendency for the honeyeaters to gather at sites of flowering mistletoe made it easy to catch them by erecting nets near the nectar source. It also allowed us to obtain excellent recordings of this species' song. By fastening a microphone to the top of a mist net pole and pointing it towards some favourite blossoms, we were able to set the recorder at the pole's base in operation and leave, returning in an hour to find that the honeyeaters had been most obliging. Several different vocalisations have been isolated from the tape recording.



The painting of the Eungella honeyeater by Terry Lindsey, completed from his field observations and sketches is now in the collection of Wayne Longmore. Photo Jim Shields.

Terry, the expedition's artist, made numerous sketches of the different species of birds and their habitat, but particularly devoted his time to the Eungella honeyeater. From these he produced a life size colour painting of the birds.

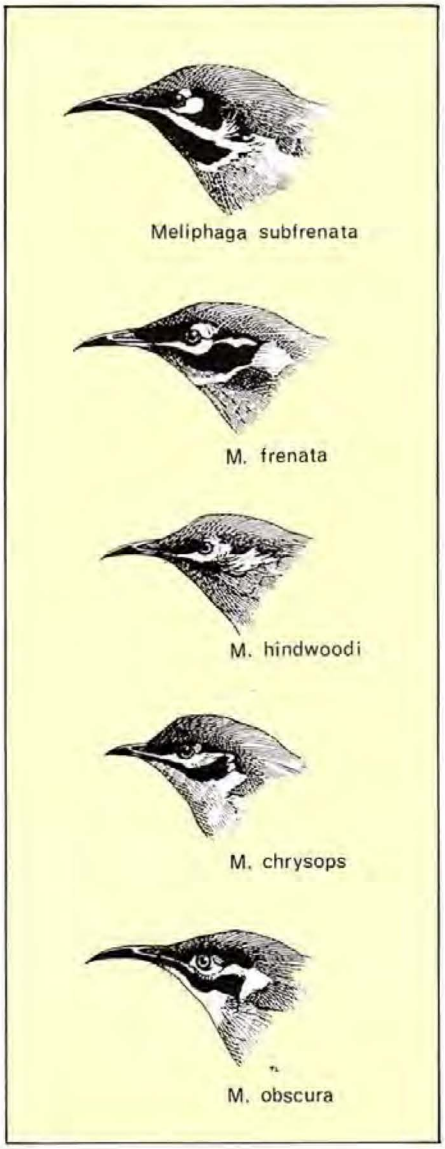
No colour photographs of this species existed. Using materials found in the dark recesses of the milking shed (cinder blocks and sheet metal), together with rope, clothes pegs and Walter's sacrificed mosquito net, a makeshift photographic studio was constructed. By placing a captive bird inside with a few twigs of mistletoe, Terry was able to obtain excellent photographs.

It was necessary to confirm that the newly found honeyeater was more than a distinctive local population of the bridled honeyeater, that is, were there sufficient reasons to believe that they were reproductively isolated from each other? Differences in size and plumage certainly seemed to indicate that this was the case. A further test was a comparison of the songs. To our ears, there were both notable similarities and obvious differences. Whether or not the birds themselves recognised differences would need to be tested. At the end of the visit to the Clarke Range, Terry and Ann proceeded to the Atherton Tableland. There they played calls of both forms to the local bridled honeyeaters. Hearing their own song elicited an instant and marked response on the part of the honeyeaters — they approached the tape recorder and called vigorously back. Playing the song from the Clarke Range birds, however, was met with complete disregard, a very strong indication that bridled honeyeaters would not recognise Eungella honeyeaters if they ever met. In retrospect, it seems curious that the differences between these species were not noted sooner.

To Wayne went the honor of choosing the scientific name by which this species would be known. His designation ***hindwoodi*** commemorates the late Keith Hindwood, for many years one of Australia's foremost ornithologists and the honorary ornithologist at the Australian Museum until his premature death in 1971. He was Wayne's mentor during the development of Wayne's interest in birds.

Though the attachment of a name to a description of the bird was an essential step, the task was still far from over. By comparing specimens of the Eungella honeyeater with those of other species in museum collections, hopefully its nearest relatives could be recognised. The possible evolutionary history and current distribution could then be related to geological and biological events in Australia's past.

Wayne and Walter identified a group of Australian and New Guinea honeyeaters that shared a number of characters, such as the bridle stripe, ear plumes, blue iris, etc., and which replaced each other geographically; as expected the bridled honeyeater is one of these. Others are the yellow-faced honeyeater *Meliphaga chrysops* of eastern Australia, and the obscure honeyeater *M. obscura* and black-throated honeyeater *M. subfrenata* of the New Guinea lowlands and highlands, respectively. Later, another probable member, the white-lined honeyeater *M. albilineata* of the Kimberleys and Arnhem Land, was identified. The distribution of this replacement series corresponded nicely with areas considered to have acted as refuges for wetter habitats during past periods of aridity on the continent.



The Eungella honeyeater and its relatives share many facial characters, one of the most notable of which is the bridle stripe extending from the gape to the ear region, ending in short plumes. Drawing by T. R. Lindsey.

The description and proposed name of the Eungella honeyeater were published in *The Emu*, together with a discussion of its relationships and evolutionary history. Accompanying the article were pen and ink drawings and the colour painting of the bird by Terry, reproduced here.

Aside from the Eungella honeyeater, we discovered or confirmed the earlier survey results of other interesting facets of a little known avian community. The local populations of both the white-throated treecreeper *Climacteris leucophaea* and brown thornbill *Acanthiza pusilla* have been formally named as new subspecies; other possible new forms await further study. The Clarke Range marks the limit of the distribution of several species not previously known to extend that far. One of these, the regent bowerbird *Sericulus chrysocephalus,* was located in several spots. Another, the diminuitive little kingfisher *Alcedo pusillus,* was captured in the original net across Massey Creek. It became obvious that this area was an interesting and understudied forest habitat, with a rich and varied bird community. To the north and south, the Clarke Range is separated from other highland rainforest areas by stretches of dry, low country. This isolation has contributed to the formation of the distinctive nature of the range's avifauna.

This distinctiveness is by no means restricted to the birdlife. The 1975 survey found several frogs and lizards which were also unknown. During our stay, Terry and Ann were joined by several geckos which belonged to an, at the time, undescribed species. Unnamed skinks roamed about the shed and new species of frogs called nightly from the dam in the adjacent paddock. Glen was kept busy spending nights searching for these elusive creatures with a head lamp, as well as contributing to the ornithological work during the day.

And of course, there is still much to be discovered about the Eungella honeyeater. We never found a nest or the eggs of this bird. What is the full extent of its distribution? It must rate as one of the most restricted species in Australia. In particular, a better understanding of the movements of this species is needed. Through a shorter visit in the winter of 1980 and from the observations of an ever growing number of birdwatchers now visiting the area, we now know that away from a flower source the honeyeaters sit quietly in the foliage. More recent observations have demonstrated that they will move to the rainforest at the eastern base of the range when sources of nectar are available.

It was both exhilarating and somewhat sad when our time was up. The search for a new species of "little brown bird" was over. It had taken two and a half years of research on Wayne's part, a 2,500 kilometre trip and a final joint effort between two research institutions. The resulting addition to our store of knowledge about a little known habitat and a new form of life will hopefully enable us to preserve and protect them better.

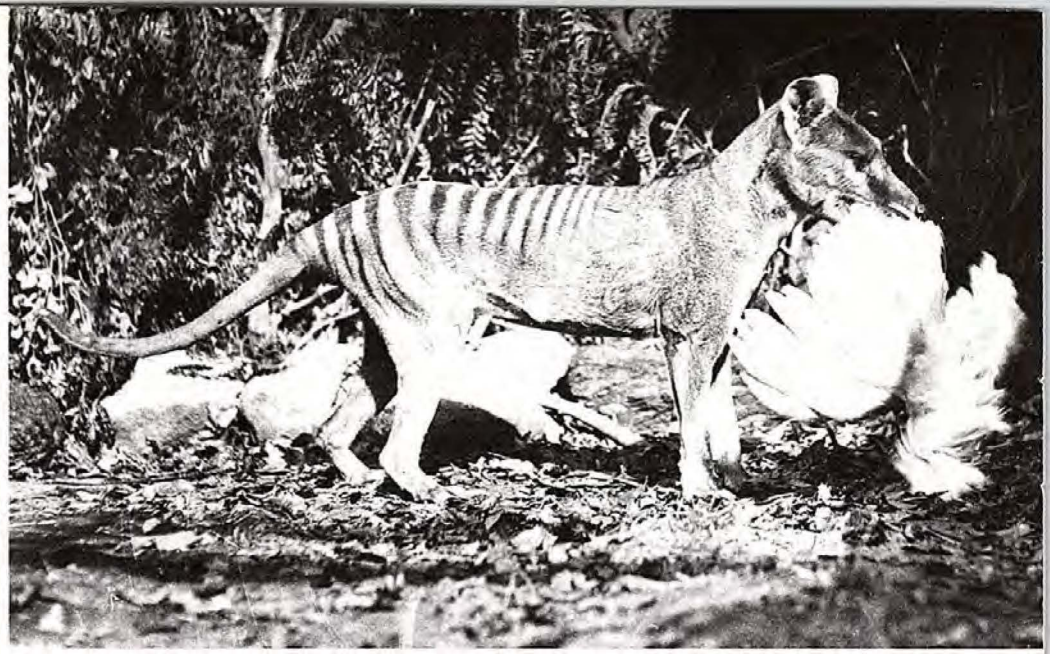
Tasmanian Tiger Sighting Casts Marsupial in New Light

Few Australian species have captured the imagination of the public as much as the thylacine, or Tasmanian tiger, a dog-like marsupial. Does it still exist? After being relatively common in some areas, particularly north-west Tasmania, the thylacine was virtually obliterated by bounty hunters around the turn of the century. Since then, only a few corpses have been produced, the last being in 1930. Persistent alleged sightings and even stories of captures have prevailed ever since. The most recent sighting, in 1982, led to a thorough, if unsuccessful, search for the animal. Nick Mooney, Research Officer for the Tasmanian National Parks and Wildlife Service, was involved in this most recent investigation and recounts here for Australian Natural History *readers what took place. He is personally optimistic that one day more of us will see the mysterious thylacine.*

The recently publicised sighting of a thylacine *(Thylacinus cynocephalus)* by a member of the National Parks and Wildlife Service of Tasmania has once again brought this elusive creature into the limelight. The sighting itself was one of the best on record. An account of the sighting (March 1982) helps to convey the excitement the Service felt at the time:—

> *"I had gone to sleep in the back of my vehicle which was parked at a road junction in a remote forested area in the northwest of the State. It was raining heavily. At 2.00 a.m. I awoke and, out of habit, scanned the surrounds with a spotlight. As I swept the light-beam around, it came to rest on a large thylacine, standing side on some six to seven metres distant. My camera bag was out of immediate reach so I decided to examine the animal carefully before risking movement. It was an adult male in excellent condition with 12 black stripes on a sandy coat. Eye reflection was pale yellow. It moved only once, opening its jaw and showing its teeth. After several minutes of observation I attempted to reach my camera bag but in doing so I disturbed the animal and it moved away into the undergrowth. Leaving the vehicle and moving to where the animal disappeared, I noted a strong scent. Despite an intensive search no further trace of the animal could be found."*

When the thylacine was spotted it was probably travelling along the road, came across the car and was investigating the area. Like most wildlife disturbed by a spotlight, it eventually moved off into the bush.



The animal concerned may have been travelling large distances in search of a mate, as March, the time of the sighting, is the beginning of the breeding season. Alternatively, its mate may have been present in the area but not located. Historically, adult thylacines were most often recorded in pairs. However, with their present rarity it is possible that normal social structures have changed, solitary animals being more common.

Observations of more than one adult have been extremely rare in recent years.

Immediately following the sighting NPWS officers and Dr Eric Guiler of the University of Tasmania commenced surveillance of the area using remotely triggered cameras, purchased in 1980 under a grant from the World Wildlife Fund (Australia).

After months of negative results, it was decided to use long term monitoring procedures over a larger area. The aims were to detect the regular presence of thylacines, determine their numbers and range and learn something of their general ecology. With this information it would be possible to take any immediate steps necessary to conserve the animal and its habitat and enable a long term study of the animal to be planned.

After close examination from the ground and air, an area of 250 square kilometres around the point of sighting was chosen for monitoring. Results of studies of dingo ecology in similar habitat indicate the area could hold several thylacine territories. Rainfall is heavy, exceeding 1500 mm per year. Habitat is diverse with areas of pasture, heath and sedgelands, sclerophyll forest and rainforest. Principal disturbing factors were road improvement programs in the months following the sighting and subsequent localised logging and regeneration which continued throughout the search period. The area has been logged selectively for many decades. As thylacines at least occasionally use the area (there have been good reports of sightings nearby) they must be tolerant of this disturbance to some degree.

It was necessary to make assumptions about the behaviour of thylacines, with frequent reference to the known ecology of large dog-like carnivores found in habitat similar to the search area. The most relevant information came from studies of dingos and Tasmanian devils, with assistance from a zoologist who had studied dingo ecology for eight years in temperate rainforest in New South Wales.

Sand or mud pits, soft areas of tracks and trails, road verges, creek edges and river bars were regularly examined for tracks. Where such pits did not exist, artificial ones were created. Aerial photos were used to ensure tracking pits were adequately distributed.

Altogether, 89 existing and 256 artificial pits were monitored. Three potential den sites were regularly monitored using tracking techniques and over 50 others checked for signs of occupation. On 37 occasions, road-killed wallaby and wombat were left on a forest track and surrounded by sand in order to record attracted predators.

Plaster of Paris casts were made of species' tracks. Some were so varied that they could potentially be confused with those of the thylacine in both size and shape (accepting that thylacines come in different sizes).

To identify thylacine prints reference was made to current identification charts and field guides, museum skins, photographs, and people who had seen actual tracks. Casts were taken of the feet of mounted thylacines.

A reference gait for walking thylacines was obtained from movie film of a captive animal.

Localities of any unusual calls could be examined using tracking techniques. Consistent descriptions of the thylacine's nasal, terrier like "yip-yip" have been made by bushmen. Reportedly, it is very distinct and is usually repeated at 20—30 second intervals while hunting.

Faeces of local carnivores were collected for chemical analysis. Theoretically, each species has a characteristic set of bile salts and scats that can be "fingerprinted". This technique requires further refinement to distinguish between the marsupial species, as Tasmanian devils and tiger quolls inhabit the area. There is also the problem of getting a type scat of a thylacine.

Collections of hair were made from scats (hair in scats is picked up from prey or during grooming). In the past, thylacine hair was not regarded as conclusively identifiable, but improvements in the techniques show promising results.

People who reported sightings in the search area were interviewed.

The result of all this work did not provide conclusive evidence of thylacines but several "possible" tracks were recorded. The prints were of the correct size but lacked the detail necessary for positive identification.

No gait comparable with that of the thylacine was recorded. However, in the best situations (long, muddy tracks) intensive Tasmanian devil traffic often masked other prints. This problem could only be overcome by:

a) Searching areas low in Tasmanian devil numbers. However, such areas may also be of low suitability for thylacines;
b) Removing Tasmanian devils from the seach area, an expensive option, but it could have other advantages. The large number of Tasmanian devils compared to thylacines may provide unacceptable levels of predation of competition. There are unsubstantiated historical reports of predation by Tasmanian devils on unattended thylacine pups in dens even when the former were relatively uncommon. The present high ratio of Tasmanian devils to thylacines may mean that predation levels are very high. From what we know of the historic diet of thylacines and the present diet of Tasmanian devils, it is apparent that the prey largely overlap. It could therefore be argued that the abundance locally of Tasmanian devils is potentially significant in controlling the recovery of thylacine populations.
c) Extending the search period to increase the probability of finding any resident thylacines. This option was chosen.

It was found that Tasmanian devils travel long distances. Several identifiable individuals were recorded over ten kilometres apart on consecutive nights. Tasmanian devils and particularly tiger quolls, often travelled several hundred metres up a game trail crossing the main track and then returned to the track, probably investigating a fresh scent or noise.

Most Tasmanian devils appear to travel between or within areas of high abundance of wallaby. They often used sandpits as defaecatory points and regularly crossed large rivers.

Much information was gained on the distribution of other species, their activity periods and their breeding seasons. There appeared to be no seasonal movement of detected predator or prey populations in the search area.

The collection of scats made during field work was subjected to chemical analysis. Bile acids were extracted from scats of Tasmanian devils, tiger and native quolls, domestic dogs and cats. All three species of marsupials contain-

Above: The most recent reported sighting of the Tasmanian Tiger was at the junction of forestry roads in sclerophyll forest in north west Tasmania. Photo TNPWS

Above left: A typical muddy track near the sighting point where tracking is easy but there is considerable risk of disturbing the animal.
Photo TNPWS

Top left and bottom right: photographs of the thylacine taken at the beginning of this century by Australian Museum staff member Harry Burrell.
Photo Australian Museum.

ed the three bile acids commonly found in eutherian mammals, namely cholic, deoxycholic and lithocholic acids. The small differences between species in the type and amount of bile acids present in scats and difficulties encountered in detecting them by thin layer chromatography precluded this as a satisfactory method of identification at the present time.

However, a method of bile analysis of scats using the greater sensitivity and accuracy of High Performance Liquid Chromatography is being investigated and the results from this work are more promising.

During the search period interviews were conducted concerning seven reports of alleged thylacines in the search area (four sight and three sound reports).

One sight report, two kilometres from the Ranger's sighting but three years earlier, was excellent. One other sight and two of the sound reports were also excellent.

The recent sighting confirms that the search area was used by thylacines at least irregularly up until autumn 1982. If irregular use was normal, this may not have changed. If regular use was normal, the only factor changing this would have been disturbance, such as intensified forestry. Historically, thylacines appeared tolerant of some disturbance, however present clearfelling techniques may be far more disturbing for thylacines than past selective logging techniques. Populations of all other forest species studied are apparently healthy despite present levels of disturbance.

Much of the search area remains as apparently suitable habitat for thylacines with an abundance of game, shelter and little nocturnal disturbance.

Despite the failure of this search to produce information on the ecology of the thylacine, certain conclusions are obvious.

Over 45 years have passed between the death of the last known thylacine and the 1982 sighting, far longer than the lifespan of such an animal. This alone means that thylacines must be breeding. From the distribution of alleged sightings of different sized animals (meaning different ages), it appears breeding occurs in several areas.

The problem of what should and should not be done is perplexing. Before rational decisions can be made, we must decide on certain basic facts about the animal. We know very little of its ecology. When the thylacine was common, all efforts were to kill or capture, not study it, a common attitude to predators in those days. We have little fact, much hearsay and some folklore. Unfortunately, most of the bushmen who had frequent first hand contact with the thylacine are now dead. Others have provided useful information.

What and how much habitat is required to support a viable population of thylacines? Although we have gained knowledge of its past distribution from journals, diaries and records of bounty payments and know what habitat was then in those areas, much has changed. What hasn't changed we can regard as potential habitat, and, from the best sightings, areas of actual distribution. Of this, obviously the breeding habitat is of prime importance. Unfortunately, recent sightings of dependent young are few. Most sightings are of single animals of a size where they would probably be independent. These animals may be transients, possibly accounting for sightings in some surprising places.

Since the thylacine has obviously not recovered from its population crash early this century, we must accept that it probably needs active management help. Just "leaving it alone" may not be good enough. The main aim of study would be to find out how much of what habitat the various parts of a population need. With luck, breeding populations of the thylacine will be found in areas already affected by man meaning they are tolerant of some disturbance. On the other hand, the breeding populations may be restricted to wilderness areas. If one is optimistic, sightings suggest both habitats are occupied but the importance of each is unknown. A pair may only need a small, secure area to breed but may use a larger, disturbed area for hunting. This is often the case with large, timid carnivores.

Study may reveal some critical specialisation holding back recovery of the thylacine population. There may be an unusual susceptibility to disease. Intolerance of competition or predation may have been heightened by the present high population of Tasmanian devils, something the thylacine did not previously have to contend with.

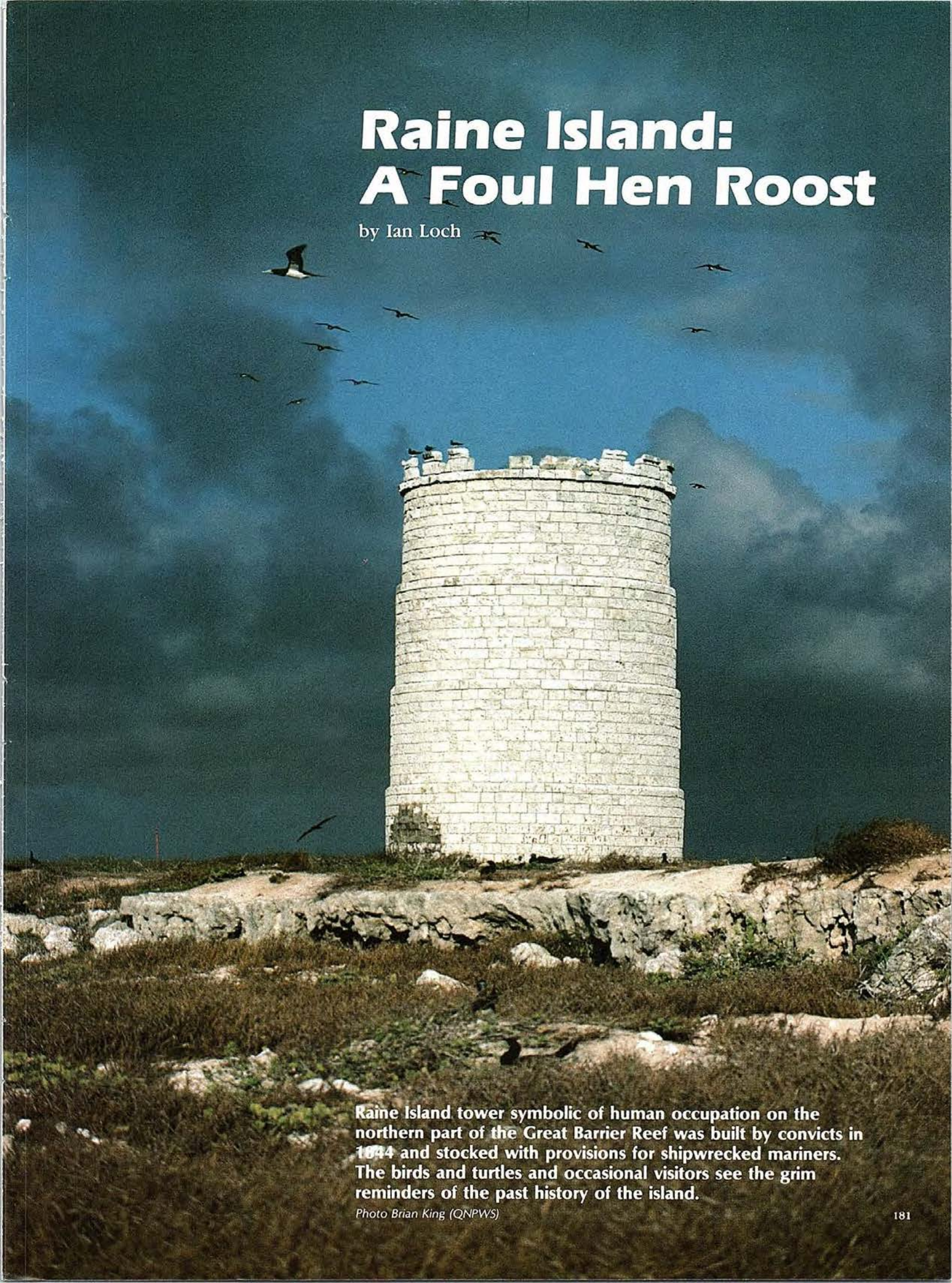
What of the value of wilderness to the thylacine? Historically, much of the rugged and remote areas now labelled "wilderness" were relatively poor habitat for thylacines and they apparently occurred there in low densities. Preferred habitat seemed to be eucalypt forests and coastal plains. However, as these areas were settled by Europeans, populations declined. Contrary to the popular belief that such persecuted animals are driven "back into the hills" it is known that those "in the hills", originally, are the only ones to survive. Animals holding territories (almost certainly the thylacine is territorial) for survival cannot move easily. The obvious conclusion is that "the hills" or "wilderness" may hold the remnant breeding populations (probably a number of near-isolated family groups). Careful management is needed if this situation is to be improved.

Before the word "study" conjures up fears for the animal, it must be pointed out that research will be conservative and, at some future date, only involve the capture, radio-tagging and release of an individual for the study of its movements. As with any species, the capture of animals by responsible authorities is only undertaken if it is considered that the population can tolerate that particular disturbance. The NPWS is principally interested in locating populations of thylacines only for census and assessment of habitat requirements. Obviously the potential effects of habitat alteration must be determined. One way is to compare disturbed and undisturbed populations.

What should the Government's approach be to the thylacine? Whether a "wait and see" policy or a more active long term searching policy aimed at active management should be adopted is under careful consideration. A contingency plan is being prepared in the event that elusive extant thylacines are finally found. Hopefully this will occur in secure areas involving sufficient numbers to allow study and a population recovery in the near future. Given the enormity and history of the problem, I prefer to throw frustrations aside and be optimistic that more of us will see this mysterious and beautiful animal.

Raine Island: A Foul Hen Roost

by Ian Loch



Raine Island tower symbolic of human occupation on the northern part of the Great Barrier Reef was built by convicts in 1844 and stocked with provisions for shipwrecked mariners. The birds and turtles and occasional visitors see the grim reminders of the past history of the island.

Photo Brian King (QNPWS)

A flat, treeless islet on a detached reef surrounded by 150 to 430 metres of water, 100 kilometres from the mainland, might be expected to have led a relatively undisturbed existence, but such has not been the history of Raine Island off Cape York Peninsula.

A "malignant typhus fever which raged with unprecedented fury throughout the ship" caused second mate Thomas Raine to be in command of the convict transport *Surry* as she and her people were quarantined on Sydney's north shore in July 1814. In 1815, Governor Macquarie sent the *Surry* to China and while sailing from the Coral Sea to the Torres Straits, Raine found an islet in the middle of an eight mile passage through the outer barrier reefs. This passage, increasingly desirable as the volume of shipping rose, and its islet and reef were named after Raine.

This question of safe passage to Torres Strait was emphasized by the wrecks of the *Pandora* (1791) with some of the *Bounty* mutineers, the *Flora* (1832), *Charles Eaton* (1834), *Ferguson* (1840) and *Martha Ridgeway* (1842) on reefs close to Raine Island. Earlier sporadic surveys through North Queensland by Flinders (1802—4), P. P. King (1819—20) and Wickham and Stokes in the *Beagle* (1837—43) were supplanted by more detailed work by HMS *Fly* and her attendant schooner *Bramble* which visited Raine in late July 1843. On board were the naturalist John Macgillivray, artist H. S. Melvill and geologist J. Beete Jukes who reported "the whole surface of the island was covered with old and young birds", and "stank like a foul hen-roost". They "dined upon young boobies and frigate birds and tern eggs — the latter were excellent, and the former very good, especially when cooked with a little curry powder." Some of the wild life returned the compliment and they "were covered with bird lice and ticks after sleeping in the sand". Although a few turtle tracks were seen, no turtles were taken, "though many dead ones were scattered about the island, their shells and skeletons remaining." From these remains and similar ones on Pandora Cay about 19 kms to the north, Jukes deduced "they come upon these banks to die on land."

From the 1843 survey, Captain Blackwood of the *Fly* recommended the building of a beacon on Raine Island to mark what he then considered the best entrance through the reefs, so the *Fly* and *Bramble* and the small colonial revenue cutter *Prince George* sailed north from Sydney with 20 convict masons and quarry men, tools, wooden houses and stores to build the beacon during the northern sailing season during winter when the south-east trade winds blew, and to carry out further survey work.

On May 27, 1844, the arduous task of landing stores from the *Fly* at her anchorage about 20 kilometres away to the south-west began. Prefabricated huts and tents were erected, a coral rock quarry begun, wells were dug yielding only brackish water suitable for slaking the lime made from burning the shells of the giant clams *Tridacna* and *Hippopus* from the surrounding reef. Timber for lime burning and cooking, and fresh water, were collected on islands near the mainland. Macgillivray calculated that at least 3,000 young terns and 17,000 of their eggs were consumed during June, "with an occasional turtle, now and then some fish." A kangaroo dog was used to kill large numbers of the edible land rail. From the reef eels they "found to be capital eating, and for this purpose killed great numbers with a bayonet fixed on the end of a stick". Thirty genera of "fine shells" were collected. The Victorian combination of sport, science and the table was a lethal one for the local fauna. Macgillivray recorded 18 species of birds, 30 insects and about 20 plants.

Similar effects were felt by the scanty flora, by the mechanical disruption of tower and tents, quarry and paths, the harvesting of "spinach" (a *Portulaca*) for the pot to combat scurvy, and the establishment of a garden of "pumpkins, maize, and other plants", including coconuts.

Revenge was taken by the parasitic arachnids from the birds which "fastening to our bodies while sleeping on the sand, caused very painful swellings, and occasionally even ulcerations".

By mid September the tower was completed. Designed by the *Fly's* carpenter Stephen Moore, it consisted of a circular stone tower 45 feet high, 30 feet in diameter at the base with walls 5 feet thick, topped by a wooden-framed, canvas-covered, domed roof surmounted by a similarly constructed black ball 6 feet in diameter, raising the tower to 63 feet above the ground. Inside were three stories, partially floored and connected by ladders. Beams for this were taken from the wreck of the *Martha Ridgeway* some 65 kilometres to the south, and her ship's tank was placed beside the beacon to collect rain water piped from the roof. Stores for shipwrecked mariners were left in the tower. The convict volunteers who had endured the arid, shadeless, lice-ridden island were granted six months remission of their sentences.

In February 1845 the merchant vessel *Heroine* called at Raine Island while beating her way south. Her Captain MacKenzie left rice with the emergency provisions, released a pair of goats and planted coconuts and other seeds, while "fourteen large turtles, each averaging four hundredweight, also an immense number of eggs" were collected and "the crew killed birds out of number"; a reasonable effort from daylight to 2 p.m. The water tank was full. Returning from Indonesia, the *Bramble*, on the morning of the 28th April, landed her invalids on Raine Island for recuperation, including the convict masons who had been "almost entirely on salt provisions for the last twelve months" and were suffering from scurvy, with a junior officer, a steward and the purser, John Sweatman, who recorded the visit. The beacon was in good condition apart from a slight leak in the wooden dome, the water tank was full, the goats were "frisking about", the coconut trees nearly four feet high, and weeds had obliterated the gardens. The three crew occupied the tower, along with crickets, and the convicts stayed in the old huts.

Their "first act on landing was, of course, to break every egg on the island so that all we collected afterwards were sure to be fresh". They ate 144 eggs each in 24 hours, and collected three casks full for the *Bramble* during their week ashore. Also consumed were "turtle soup, eels, mutton birds, fish, spinach and damper". Sweatman collected shells on the reef, and 14 turtles were turned at night. The *Bramble* also took a good supply of the *Portulaca* "spinach". Four more coconut trees were planted. If it seems that these naval crews were gluttonously destructive, the same purser Sweatman also recorded that the ship was overrun with cockroaches which ate 47 out of 112 pounds of ship's biscuit in three weeks at Port Essington in 1846. She was unloaded and scuttled on intertidal mud flats with the hatches nailed down. 500 gallons of drowned cockroaches were taken from her holds and as many were estimated to have washed into the sea or ashore where they were eaten by Aborigines.

Captain Mackenzie again passed in August 1845, reporting the coconut trees "were growing very fast and the goats had three young ones". On July 1850, the *Enchantress* was wrecked on Raine Reef but all made it to shelter in the beacon, from where they were taken the following day by the *Lady Margaret* which had been travelling in company. During the next decade a series of wrecks occurred in the vicinity of Raine Island and Great Detached Reef to the south. The *Rio Packet* 1852, *Bourneuf* 1853, *Stata* 1853, *Fatima* 1854, *Island Queen* 1854, *Cornelius* 1854, *Frances Walker* and *Sultana* 1854, *Chesterholme* 1858, *Constant* 1858, *Sapphire* and *Marina* 1859 all were lost. A few records of crew landing on Raine and subsisting on boobies' eggs exist but most attempted to make Booby Island at the western end of Torres Strait, where

most vessels called on passing. The shipwreck haven apparently had a short life. In 1860, Captain Denham of paddlewheeler HMS *Salamander* reported the wood and canvas dome (and water collector) had fallen in.

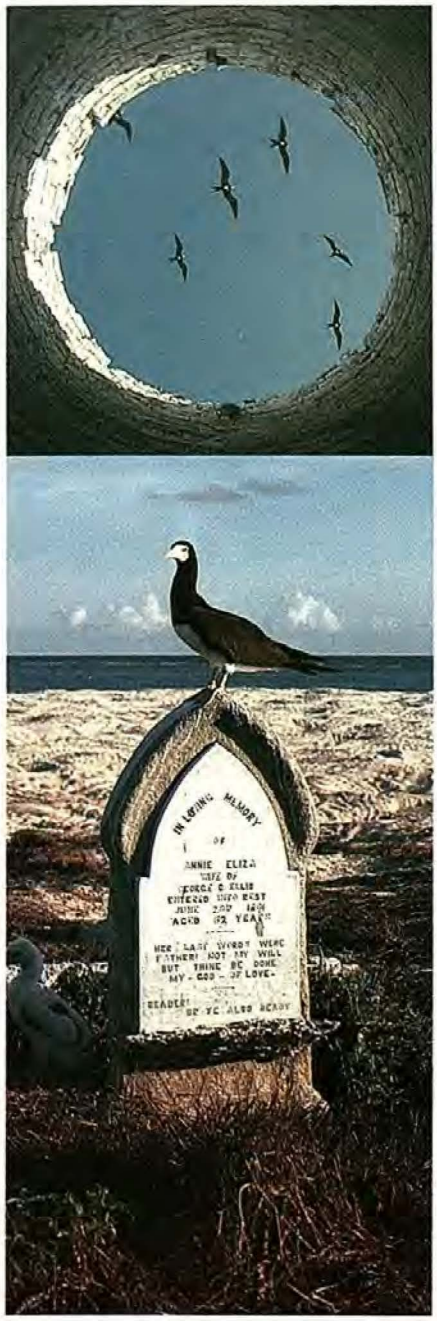
Leases for guano mining were granted for Raine and other Queensland islands in 1862, but Raine was not mined at this time. Commander Carnegie in HMS *Salamander* visited in January 1865 to assess the guano deposits and reported they weren't commercially viable. The lease was allowed to lapse. During the 1860s fisheries for pearl shell and beche-de-mer or trepang were established in Torres Strait. In 1873 the Palmer gold rush started. Steam was replacing sail and the inner reef route the outer Coral Sea one.

The visit of HMS *Challenger* in August 1874 was well recorded. Reports describe the most impressive thing as being the birds which "darken the air beneath as they fly overhead". The sailor's criteria of "easily knocked over on the nest with sticks "or" could only be obtained by being shot" were applied again. By now the woodwork inside the tower had fallen in and decayed, the water tank rusted out and no trace remained of earlier gardens, goats or coconuts. Undaunted, pumpkin, tomato, capsicum, water melon and cape gooseberry seeds were planted in "very good black vegetable soil". Eleven plants, some fungii, 11 species of birds, a locust and an earwig were recorded. Turtle remains around the little cliffs were again commented on.

Dredgings were obtained in 135 fathoms behind Raine and 155 fathoms between Raine and Great Detached Reef which yielded about 150 specimens of invertebrates and fish, comprsing "67 species, of which 47 are new to science; 39 of the new species were not obtained elsewhere." Although not all of these "new" species would be recognised today, it was still an impressive haul, and the first deep water dredgings on the Barrier Reef. A plankton net was also set the night before landing.

Raine Island became a site for fishing and processing trepang in the 1870s. Aborigines were employed to collect the holothurians, and in October 1879, a bloody incident took place on Raine when Aboriginal collectors killed a European, a Chinese and two Kanakas on the island and fled in a lugger. An archaeological excavation in the beacon in 1983 uncovered a layer of ash most probably from boiling operations of trepangers.

Disturbance on a large scale came in 1890 with the arrival of the J. T. Arundel Company to mine guano, with 100 Chinese and Malay labourers and ten European supervisors. Huts, a tram track with loco, and a jetty were constructed to enable the mining of "tens of thousands of tons" of phosphate. Mainland firewood for cooking and freshwater distillation for miners or trepangers was probably responsible for the introduction of the scorpion and centipede now found on the island.



An adult brown booby perches on top of Mrs. Ellis' headstone, while its chick shelters in the shade beside it.
Photo Brian King (QNPWS)

The tower dominates the island from every angle, lesser frigate birds fly past.
Photo Brian King (QNPWS)

Apart from the physical disturbance of mining, the gastronomic considerations of over 100 men had serious effects. The Chinese labourers anticipated Taiwanese clam boats by eating the two kilogram adductor muscle of large *Tridacna*. (A Taiwanese boat arrested at Raine was forfeited for clam fishing in January 1984). Also, the island was inhabited during the summer nesting season of the green turtle. One was killed every day in season for fresh food, perhaps not a great burden on a population which lost several every night through tumbling over little cliffs or dying of heat exhaustion when still ashore in strong sunlight. Albert Ellis, a guano miner, recorded "every few days a gang of Chinese would go round with ropes and pull these to the water. Then the sharks would seize the carcasses and tear them to pieces", hardly an edifying sight for men who were bathing in the sea daily to remove the dust of mining. Ellis estimated that more than a thousand a night came up to lay at the height of the season. After a shark-killing spree however, "dead turtles became so numerous at the water's edge that we were forced to realize that even the shark had its uses." Fish and shells were also taken. The land rails were in large numbers on their arrival, "and a welcome addition to the table they were. Their numbers were materially lessened during our occupation of the island, but some were left to carry on the restocking of that lonely spot." This species still exists there today.

In 1892, the guano miners left, taking their tram track, huts and jetty, leaving the grave of Ellis's mother who died during their two years on the island, still visible near the tower. The island reverted to the casual attention of the luggers in search of trochus and beche-de-mer. In 1910, 1911 and 1913 W. Macgillivray and others visited the islands to study seabirds. The trochus and trepang industries declined, to some extent replaced by fishing with the spread of refrigeration. The peripatetic David Attenborough visited for a few days in 1957 with a film crew. John Warham stayed a week in February 1959 observing birds at "probably the most important breeding station for tropical seabirds in Australian seas," and noting the base of the tower was decaying. This was repaired in 1961 by HMAS *Gascoyne*.

The pattern of brief scientific visits and long periods of relative quiescence was disrupted by an attempt to establish a turtle meat trade, but this failed because of marketing difficulties. In 1967 a lease was granted to mine the phosphatic capstone rock, but this lapsed for commercial reasons. A joint Royal Society and University of Queensland trip visited in James Cook University's *James Kirby* in November 1973 with one or two hundred turtles recorded nesting at night. Then in December 1974, the "*James Kirby*" returned, and an estimated 11,800 turtles came ashore in a night, the highest estimate of nesting turtles in the world. Raine Island was being rediscovered by the world of science.

Raine Island: Green Turtle Rookery of World Significance

Raine Island is one of the two largest green turtle rookeries in the world, and is also noted for its massive colonies of seabirds. This article was written by Raine expert Brian King from the Queensland National Parks and Wildlife Service.

Raine Island today presents a view that outwardly has changed only a little from our earliest records. When the boat's anchor is secure and the wind has blown away the last traces of exhaust fumes, the wind brings to us the smell of the island. The pungency comes from traces of ammonia given off by the deposits of guano that slowly accrete on the island; on wet days it is powerful enough to catch your breath.

A boat approaching the island is greeted by a variety of unusual birds flying out to inspect the new arrival. Flocks of red footed, masked and brown boobies wheel around the vessel, sometimes joined by a tropic bird, trailing its long scarlet tail streamers. In the thermal air streams that rise over and beside the island there is always a cloud of soaring frigate birds sliding effortlessly on wings spanning nearly two metres.

The frigates, both lesser and greater, nest on the ground of the treeless Raine. In mid year, the cloud of soaring birds are nearly all breeding adults, while in summer there is a preponderance of juveniles. The long, backwardly swept wings, deeply forked tails and mostly black plumage gives these birds a slightly sinister air, and their habit of stealing food from incoming birds of other species suits this appearance. Their shape is the result of a strong specialization for flight, and well developed flight capabilities, and an ability to outmanoeuvre and outrace any of their less aerobatic relatives, are ideal for gaining the free meals, which account for about ten percent of their food.

An incoming bird, heavy with prey in its crop, is selected by a soaring frigate and the chase is on. The victim, most popularly a masked booby, tries to escape by diving and wheeling and calling loudly, but is relentlessly harried by the frigate and forced down over the sea. Watch closely as the frigate dives from above, grasps its victim's tail in its bill and tilts the tail upwards so that the unfortunate booby nosedives into the sea. If the unlucky bird has not already regurgitated during the aerial chase, then this ignominious treatment does the trick every time. The frigate picks up its stolen meal from the surface of the sea and departs, leaving the loser to readjust its plumage and fly off to fish again.

The central depression, once mined for guano, is now the main breeding colony for thousands of seabirds, particularly brown and masked boobies.
Photo Brian King (QNPWS)

Right: Chick of the lesser frigate bird on Raine Island.
Photo Brian King (QNPWS)

Once ashore, it becomes obvious that humans have changed this remote cay. The ruined stone beacon serves as a convenient perch for seabirds, boobies and noddies. In mid year a hundred or so noddies nest on the narrow ledges that run round the walls at different levels. Many of these helpless chicks are doomed to die with one false step. The tower also produces a convenient updraft of wind that holds aloft a mixed flock of soaring birds, boobies and frigates. A surprisingly large number glide too close to the hollow inside the tower and, unable to escape, fall to the bottom. If uninjured they can walk out of the empty doorway to fly again, but eventual death is the only result of a bad fall. The bones of such victims lie on the floor, covered by guano.

Away from the beacon there are other signs of former human activities. Mrs. Ellis' grave has a headstone that throws a tiny patch of shade on the ground beside it, ensuring the survival of the chick of a pair of brown boobies that nest beside it every

Top: Immature red footed booby
Photo Brian King (QNPWS)
Below: Masked booby family portrait.
Photo D. Young

summer. Farther away lies the central depression — the legacy of open cut guano mining, done with pick and shovel some 90 years ago.

While the mining and permanent occupation of the island must have been disasterous for the fauna at the time, there was some benefit to the recolonizing birds. The flat, open central depression is exposed to the winds, making it a good place for frigate birds nesting on the rockpiles and for ground nesting boobies on the floor.

The boobies make full use of the depression. Up to a thousand or more pairs of masked boobies nest in the most open areas and a club of nonbreeding birds has its own separate area. Areas not favoured by masked boobies (uneven, rocky or vegetated ground) are colonized by brown boobies. Over 6,000 pairs of these nest at Raine and they utilize the entire vegetated area above the beach for their breeding. Most of the colony is to be found in the central depression, where over four thousand pairs of brown boobies pack around and among the nesting masked boobies. Where the two species overlap, territorial disputes are common and the much larger masked booby has all the advantages of greater size, weight and reach over its opponent, not to mention a formidable bill with razor-sharp edges that leave numerous surface cuts on the skin of any adversary.

On the ground, a masked booby is a formidable opponent, and not only to other boobies. Prospective seabird researchers quickly learn how to handle and avoid the weapons they carry. Careless handling can result in bleeding cuts from bites, and they also kick, scratch, struggle, regurgitate and defaecate while being handled. It is hard to be gentle with an uncooperative captive that can be nearly as large and as strong as a goose.

Brown boobies who do not occupy the favoured central depression breeding sites nest on the vegetated sand ridge that surrounds it. On the ridges, there are several disadvantages for breeding. Firstly, the dense mat of low vegetation impedes the movements of boobies on the ground and seriously hampers take off attempts, especially if the bird is startled and tries to flee in panic. Secondly, brown booby nests can only be built on bare ground which is scarce and the birds nest at a lower density than on the more open central depression floor. Thirdly, in the summer the prevailing south-easterlies are periodically replaced by days of calm or light north-westerly weather, with fine and intensely hot conditions, reaching 40° for most of the day. The only shade available for young booby chicks is that provided by their standing parents. On the hottest days this is inadequate, so that ground reflected heat kills some chicks. The problem is worsened by the southern ridge sheltering its southern face from the north-westerly breeze and being exposed to the afternoon sun. The open central depression receives whatever breeze is available and chick survival is higher.

Other eggs and chicks are lost due to the predatory activities of gulls and banded land rails that inhabit this island. Frigate birds and rufous night herons are also predators. However, in spite of these hazards, large numbers of brown and masked booby chicks survive to leave the island. Returns of banded chicks show that they move north and north-east from Raine, many to the Gulf of Papua and some to the islands north of the New Guinea mainland. Some brown and masked boobies have been recovered more than 1,000 kms away at New Ireland and New Britain.

The vegetated sandridge that surrounds the central depression is separated from the island's beach by what is loosely termed a cliff, in places merely a jumble of broken rocks less than half a metre in height, rising to nearly two metres. It consists of a soft conglomerate stone formed by the action of phosphates (from the ever-present guano) on the calcareous coral sand, and contains reef sediments, broken coral, shells and the fossilized remains of turtles that once nested on former beaches there.

The cliff, is largely broken and undercut forming numerous small caves and shelters with sandy floors that provide a nesting habitat for another pan-tropical oceanic wanderer, the red-tailed tropicbird. These truly beautiful birds nest here all year round, the population peaking mid year at around a hundred pairs. During the day, pairs and groups of birds perform graceful aerobatic displays above the beaches and cliffs. On the nest the birds are quite fearless of people and are, as our researchers have discovered, well equipped to defend themselves. Their brilliant

scarlet bills can deliver an immensely powerful bite. If approached, the sitting bird sits quietly, coldly watching the source of disturbance. A close approach is greeted by a threat display with raised wings, accompanied by a harsh scream of protest. Closer still, the bird screams again and lunges with a sharp thrust of the open bill.

Tropicbirds lay one egg, beautifully marked with reddish-brown. This hatches to a small chick, covered in thick grey down, with a temperament the opposite of its parents'. The chicks grow quickly and lose their down as they take on their first plumage. This is quite different from the adults', being white speckled all over with black. The bill is black, in contrast with the adults' red, and the juvenile lacks the long red tail streamers that contribute so much to the spectacular appearance of its parents. The juvenile continues to grow until it is heavier than its parents. Then, about three months after hatching, the chick, loaded with stored fat and unable to fly, leaves the nest. It shuffles across the beach, resting sometimes for long periods. When it reaches the sea it swims off. At Raine the journey can take over a day to accomplish, and occasionally a juvenile can be found resting quietly in the beach vegetation. Where they go to, nobody knows. No birds banded as chicks have yet returned as adults, neither have any adults banded on Raine been recovered anywhere else. What we have found is that many banded adults return to Raine to breed, some at the same time of the year for each of the last four years.

Tropicbirds do not have exclusive rights to the cliff habitat, but share it with several other birds. Wedge-tailed shearwaters sometimes nest in burrows in cave corners and occupy small holes and crevices that are inaccessible to tropicbirds. Banded landrails are often found skulking in the caves and under overhangs. Pairs of bridled terns occupy holes and crevices in the upper reaches of the cliff face — any cavity will suit them and a favourite nest site is in the carapace cavity of dead turtle skeletons. Occasionally a pair of rufous night herons will take up residence in a cliff cave and build their large stick-nest on the ground in a corner.

The activities of the night herons at Raine are surprising. These birds, usually so shy and secretive in their mainland haunts, come to Great Barrier Reef and Gulf of Carpentaria islands every year to breed. This may not seem unusual, but the birds here are timing their movements and breeding cycle to match the cycle of the food supply that supports it. This is the nesting of sea turtles, at Raine, the green turtle. Each summer, from October to April, female green turtles gather off their nesting islands. Every two or three weeks each female crawls ashore, digs a large body cavity in the sand above high water mark, then digs a second, small egg chamber with her hind flippers. The large excavation removes the upper dry sand until she finds sand of the right consistency beneath. The small cavity is to contain the hundred or more eggs she will lay. Once filled over, the clutch of eggs incubates at the correct temperature and humidity for two months, and then the tiny hatchlings dig their way to the surface, pause until darkness and escape from the sand. They head for the water, guided by differences in light on the horizon, and swim out to sea. Where they go then, and for how long, nobody knows as yet. It may take up to 50 years before some return as laying adults to this or another beach.

Many animals utilize the turtle breeding as a source of food. Fish and sharks reap a huge harvest of hatchlings in the water. Crabs and birds take them on the shore if any emerge before darkness falls. In large turtle rookeries, nesting females often dig up nests laid earlier in the season and scatter the eggs over the sand. Scavenging landrails and herons feed on these at night and gulls and turnstones finish them off next day. These eggs form an important food source for the birds that utilize them, especially the rails and herons.

But let us now return to the story of the rufous night herons. In mid year (a time of no green turtle nesting) the night herons are absent from the island, presumably living on the adjacent mainland. The turtles start laying in October and as their numbers increase through November, the herons start arriving. The number of night herons increases steadily through November and December, as the

Measuring a nesting green turtle at night when it comes ashore to lay its eggs. Photo D. Young

turtles approach their peak in laying numbers. The herons begin breeding in January or February, coinciding with the period of greatest hatching of turtles (when over a hundred thousand baby turtles may leave the beaches every night in big seasons).

In the early stages of this cycle the adult birds feast on discarded turtle eggs dug up and scattered by other laying turtles. Later, both the adult herons and their growing chicks feed almost exclusively upon turtle hatchlings. If you consider that there may be up to 1,000 pairs of herons, each with a family of up to three chicks, then the nightly harvest of hatchlings is enormous. It is quite likely that the herons can only exist there because of the turtles as a food source. During daytime low tides, hundreds of night herons stalk the reef flats and it is doubtful whether the reef can support such a number of predatory birds, let alone feed their young. When the turtles leave the island at the end of their breeding the herons also disappear.

When the herons are in residence the greater part of their activities are directed around the nightly nesting and hatching of the turtles. Every afternoon these shy, furtive birds move out of the vegetation or return from foraging on the reef flat and space themselves over the entire area of the island's beach. They stand patiently, lurking as only herons can, waiting for a turtle nest to emerge. Once spotted, often by slight sand movements, the herons gather round and by means of threats and fights compete for possession of the site. A turtle nest is no larger than 20 centimetres in diameter, allowing room for only one predator at a time.

As soon as a hatchling starts to emerge the heron takes it, then relinquishes the site to others and devours it. These then decide who will occupy pride of place at the nest site. Should the entire nest be disturbed enough to erupt, scores of herons swiftly move in. All that can be seen in the ensuring melee is a mass of herons, some threatening, some frightening, and bird after bird flying off with a struggling hatchling in its bill. The unlucky hatchlings are swallowed whole by the herons and later fed to their chicks.

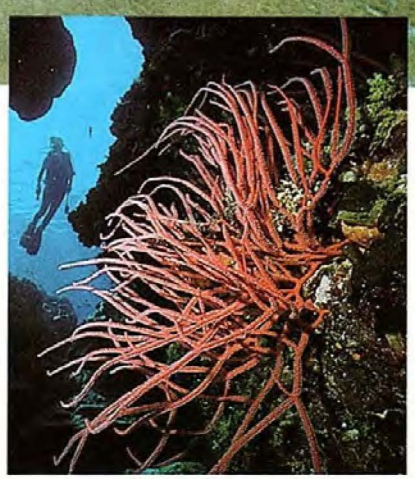
For every hatchling taken or egg lost, hundreds survive and escape out to sea. The proof is to be seen every summer when thousands of adult turtles return to the island to lay in the sand. Remember too, that turtles are a very old life form and have been breeding in this way for millions of years. Their natural losses on this scale can be coped with, but it's the additional burden imposed by human exploitation or indirect influence that usually tips the balance towards a decline.

The sea turtle population of Australia's tropical north is one of the last large populations of turtles on earth. Raine Island is a major breeding place for, perhaps a major proportion of the green turtles that live in the Torres Straits. Turtle harvesting forms an integral part of the culture of the Torres Strait people. Present harvest levels are restricted to local consumption among the island and coastal communities, but the formation of a large scale turtle industry, or the resumption of the turtle meat and soup trade, could spell the end of the Raine Island turtle rookery. Seabird rookeries too, are very vulnerable to human predation and visitor interference.

Is anything being done to preserve this fascinating place? Raine has always been partially protected by its remoteness, and it is beyond the reach of those who hunt turtles and seabirds, and is well away from the much used Cape York Peninsula fishing and prawning grounds. Because of its importance as a turtle breeding ground, Raine was declared a Reserve by the Queensland Department of Aboriginal and Islanders Advancement in 1977. Scientific attention to the island, sporadic in the past, was given a boost by the passing of the Raine Island Research Act of 1981 by the Queensland Government. Under the terms of this Act, a donated sum has been set aside and an organization created to manage the future of the island and to fund research activities there. In addition, moves have been made to declare the area a Scientific Purposes Reserve, to aid this endeavour. Visitor access has been limited and is now strictly controlled. Raine Island is therefore no longer open to all who wish to visit it. An attempt has been made to reserve one of the most interesting areas of the Barrier Reef in a state as undisturbed as possible for future studies into its populations and elements. It may be that in the future we will look to this area to measure the condition of the rest of the Reef. In a period when visitor pressure exploitation of reef resources is accelerating, this is a timely consideration.

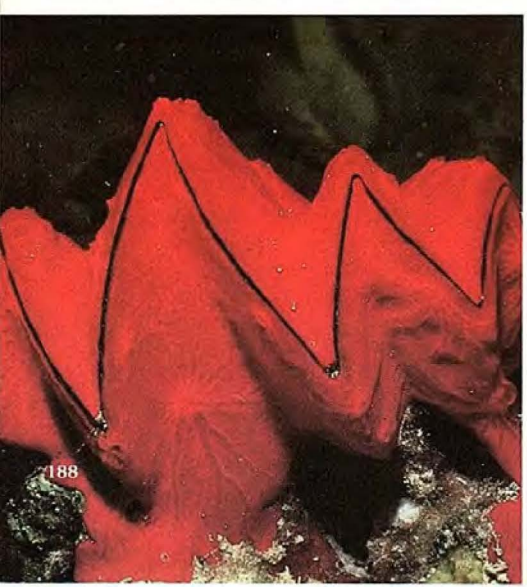
Exploring . . . The Great Barrier Reef

The Great Barrier Reef is a region of coral reefs and islands stretching from Cape York Peninsula in the north, to the islands of the Capricorn Bunker Group in the south. Within this area the reef structures have developed over a period from 15,000 years ago to about 6,000 years ago as the sea level rose gradually, some 45 metres. Reefs developed on the site of low, weathered, limestone hills, and as the sea level rose, so the reefs grew vertically upwards, towards the sea surface. Since the coral polyp requires the presence of algae in its tissues which can only grow where there is adequate light, the living part of the reef extends to about 40 metres.



The marine life of the reef comprises the diverse forms of coral: the branching corals like *Acropora* and *Pocillopora,* the brain corals like *Platygyra* and *Leptoria,* the plate corals such as *Turbinaria,* the mushroom corals, *Fungia,* and the encrusting corals characterised by *Montipora.* There are numerous shells such as the giant clam and over 4,000 other species. The fish are almost as diverse with 1,500 species including the pelagic species like marlin and mackerel, the reef dwellers like coral trout *Plectropomus,* red emperor *Lutjanus,* snapper and cod, while brightly coloured territorial fishes like butterfly fish and damsel fish defend a few square metres of reef. There are six species of turtle, the nesting sites of the green and loggerhead turtles are of world significance, while whales, dolphins and dugong also live in reef waters.

The reefs may form from radial growth when they are called platform or patch reefs, or from elongate growth when they may form wall reefs or fringing reefs. The calcareous skeletons of corals are the major components of the reef, but certain calcareous algae assist the process of consolidating the reef mass against wave erosion. On some reefs, particularly platform reefs, coral cays formed, from the accumulation of sand and rubble, and in time birds and salt tolerant plants became established. The nesting birds provide a layer of guano which aids the establishment of plants. The cay grows and with accumulation of more material, freshwater is trapped in the sediments floating on a layer of salt water.



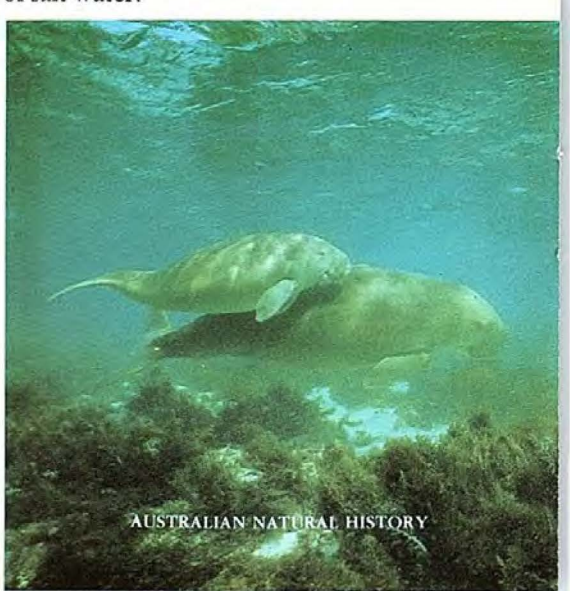


Photo GBRMPA
Scorpionfish Photo Kev Deacon
Photos Kev Deacon

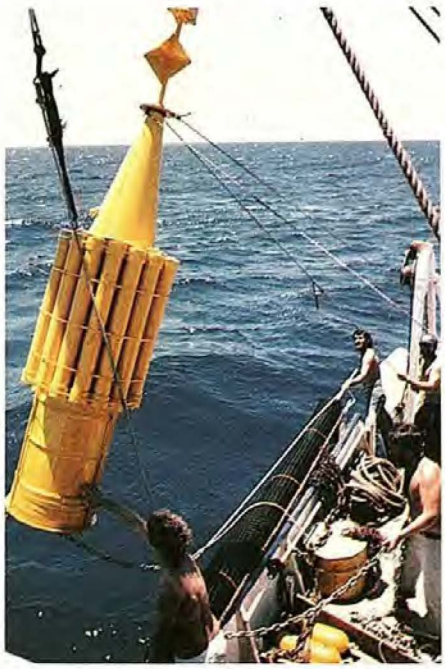
Boosting Fish Numbers with Artifical Reefs

The Japanese were the first to realise that fish are attracted to old wrecks, and to exploit this by creating artificial fish habitats. They began in 1775, with the fishermen of Manzai village in the Province of Awaji, south of Kobe, sinking large wooden frames mounted with sandbags intertwined with bamboo and wooden sticks into 60 metres of water on rather barren fishing ground. They were so successful that in the following ten years they sank several hundred such shelters.

In Australia, it wasn't until the 1960s that the idea of creating artificial fish habitats was investigated and it was found that the most effective material for their construction was used motor tyres. Accumulating as waste at a rate of two million a year, old tyres offered an abundant source of raw materials for reef construction. They were an environmental hazard on land creating air pollution when burnt, but were well suited to reef construction being resistant to salt water deterioration and providing shelter and a surface suited to marine growth.

Other materials are also suited to artificial reef construction. The first reef in Australia, in Victoria's Port Phillip Bay in 1965, used concrete pipes to which derelict boats and concrete rubble were later added, but they were unsuitable, became scattered and the pipes buried in the soft bottom. Derelict cars and old ships, as well as tyres and concrete rubble were used on another very early reef built in 1968 inside Moreton Island, southeast Queensland. Large populations of angling species now inhabit this reef.

Since the aim is to attract fish, how successful are artificial reefs? While it may appear that artificial reefs are often convenient disposal points for unwanted material when designed and constructed correctly, they are very successful. Overseas studies have shown a tenfold increase in fish species on an artificial (concrete block) reef site in the Virgin Islands. Another study in South Carolina reports a ten percent increase in gross economic impact of sport fishing on communities surrounding a reef composed of several thousand car tyres and four sunken vessels. We do not have the results of this type of study under Australian conditions, but observations of the tyre reefs, show a marked succession of inhabitants and good populations of angling fishes. By nine months after reef placement, there is a well developed invertebrate community and many fish are atracted to the reef for shelter and food. Even six months after placement, tyre reefs attract a variety of fish such as snapper, mullet, leatherjackets boarfish, bulls eye, silver drummer, sea perch morwong, pike and old wives in temperate waters. In northern waters, the variety of fish is much more extensive. Amateur anglers particularly benefit from the increased productivity which artificial reefs generate, but the indirect economic benefit to Australian seaside communities is less obvious.



Launching a mid-water fish attracting device (FAD) at sea.
Photo John Mathews

What are we doing to encourage the construction of artificial reefs and other fish attracting devices? The South Australian Fisheries Department has no objections to the installation of artificial reefs composed of old tyres, subject to the surveillance of an officer of the department. The most desirable criteria for artificial reef construction have been determined. Bundles of five tyres strapped together with rot-proof rope, each punctured to allow air to escape, are amalgamated into pyramids and placed on barren ground outside navigational or trawling areas. The depth of water (minimum ten metres) and the nature of the bottom are important in ensuring the reef remains intact. The location of the artificial reef must be easily determined and the reef available to be fished by anyone, not just to be considered as a private fishing area. A non-profit making company was proposed to dispose of unwanted car tyres in South Australia where the availability of suitable seafloor in the Gulfs is almost unlimited. Several large reefs have been constructed, one with 25,000 tyres off Glenelg, in which 7,000 tyres were installed by helicopter, and another large reef is under construction.

In Queensland, artificial reefs constructed with the help of the Army Water Transport Squadrons and the Citizen Military Forces, with private companies and community organisations involved, have provided artificial reefs at Moreton and Hervey Bays. The Moreton Bay reef, composed of four vessels and 7,000 tyres, is a popular spot with scuba divers and fishing is banned, in contrast to the other reefs where fishing is encouraged.

A large ship reef, being constructed off Long Reef, Sydney, began with the old Manly ferry *Dee Why* in 1976. Several other vessels have since joined her on the bottom and amateur fishermen report good catches of snapper, mulloway, teraglin and kingfish.

New South Wales Fisheries Division is now investigating mid-water fish attracting devices, anchored on the edge of the continental shelf. Baitfish soon abound near the devices, which attract schools of kingfish and dolphin fish circling within 30 metres of the attractor. While there have been few reports of commercial fishing, amateur catches include yellowfin tuna, striped tuna, tiger sharks, kingfish, dolphin fish and albacore tuna. Catch rates from trolling indicate the feasibility of commercial fishing, particularly when its considered that the fuel saving and search time are reduced by the devices.

Artificial reefs and fish attracting devices have been shown to increase the productivity of barren marine areas in Australia. Tyre reefs offer an environmental alternative to a major waste disposal and air pollution hazard, and community groups have demonstrated the practical application of their construction. When can we see more of them?

Written by ANH's Christine Deacon from information supplied by fisheries biologists Dave Pollard and John Mathews from New South Wales Fisheries Division.

CENTREFOLD 5

Clownfish

Anemone fish or clownfish live in close association with large tropical sea anemones. Equipped with specialised stinging cells or nematocysts, the anemone's tentacles can paralyse intruders, but the anemone fish is unharmed. It relies on the anemone for protection from predators. How is it immune to the anemone stinging cells?

After living two or three weeks in the plankton, the young fish searches for a suitable unoccupied anemone. Most anemones are already "saturated" with occupants and the fiercely territorial residents repel the intruder. If an unoccupied host cannot be found, the young anemone fish will eventually succumb to predators.

The young fish, when it finds an anemone, must gradually become acclimatised to the deadly tentacles. The fish makes only brief contacts at first, but after about 24 hours, it can safely remain among the tentacles. Researchers have set forth an array of theories to explain the process which enables the fishes to live safely within their dangerous host. Some scientists feel that an active part is played by the anemone in the acclimation process, that it becomes habituated to the fishes' presence, and in time no longer fires its nematocysts. Other scientists have shown that acclimation involves a chemical change in the mucus coat of the fish, which renders immunity by actually lowering the threshold of nematocyst discharge.

Anemone fishes belong to the large tropical reef fish family Pomacentridae. The 26 species which comprise the anemone fish genus, *Amphiprion,* are confined to the Indo-Pacific region, and 11 species inhabit Australian coral reefs. The pink anemone fish *A. perideraion,* our centrefold this month, is associated with Ritter's anemone *Radianthus ritteri,* which usually has an adult pair and three or four smaller fish, living amongst its tentacles. The adult fishes constantly harass the younger ones, establishing a "pecking order".

Typically, the fishes feed on minute planktonic animals a short distance above their lair. Copepods and other minute crustaceans form the main food. The fishes retreat to their anemone periodically, where they scamper over the oral disc and bathe among the tentacles. If approached by a diver or large predatory fish, they dash to their host, disappearing amongst the tentacles.

Recent investigations reveal that many anemone fish begin their lives as males and later transform to the female sex. The female is usually larger in size and spawns throughout the year at approximately monthly intervals. The eggs are deposited in a small nest at the base of the anemone and the male is very active in taking care of the nest, fanning the eggs with his pectoral fins and removing debris and dead or diseased eggs. The female spends most of her time feeding. The eggs hatch on the night of the seventh day of incubation. The lavae struggle to the surface where they are swept out to sea, spending two to three weeks in the plankton before they settle to the bottom and begin their life-long association with an anemone.

Juveniles grow at rates which vary from about two to seven millimetres per month and it requires one and a half to two years to reach sexual maturity, the larger species attaining a length of nearly 15 centimetres. There is little information about their longevity, but in the Noumea Aquarium at New Caledonia, anemone fishes have lived for more than ten years.

Gerald Allen, Western Australia Museum.

Centrefold: Anemonefish or clownfish Amphiprion perideraion *hide in the tentacles of Ritter's anemone* Radianthus ritteri, *the adult fishes harass the younger ones establishing a "pecking order". Above: The anemone holds fast to the coralline substrate, its tentacles waving in the current. Both photos by Kev Deacon.*

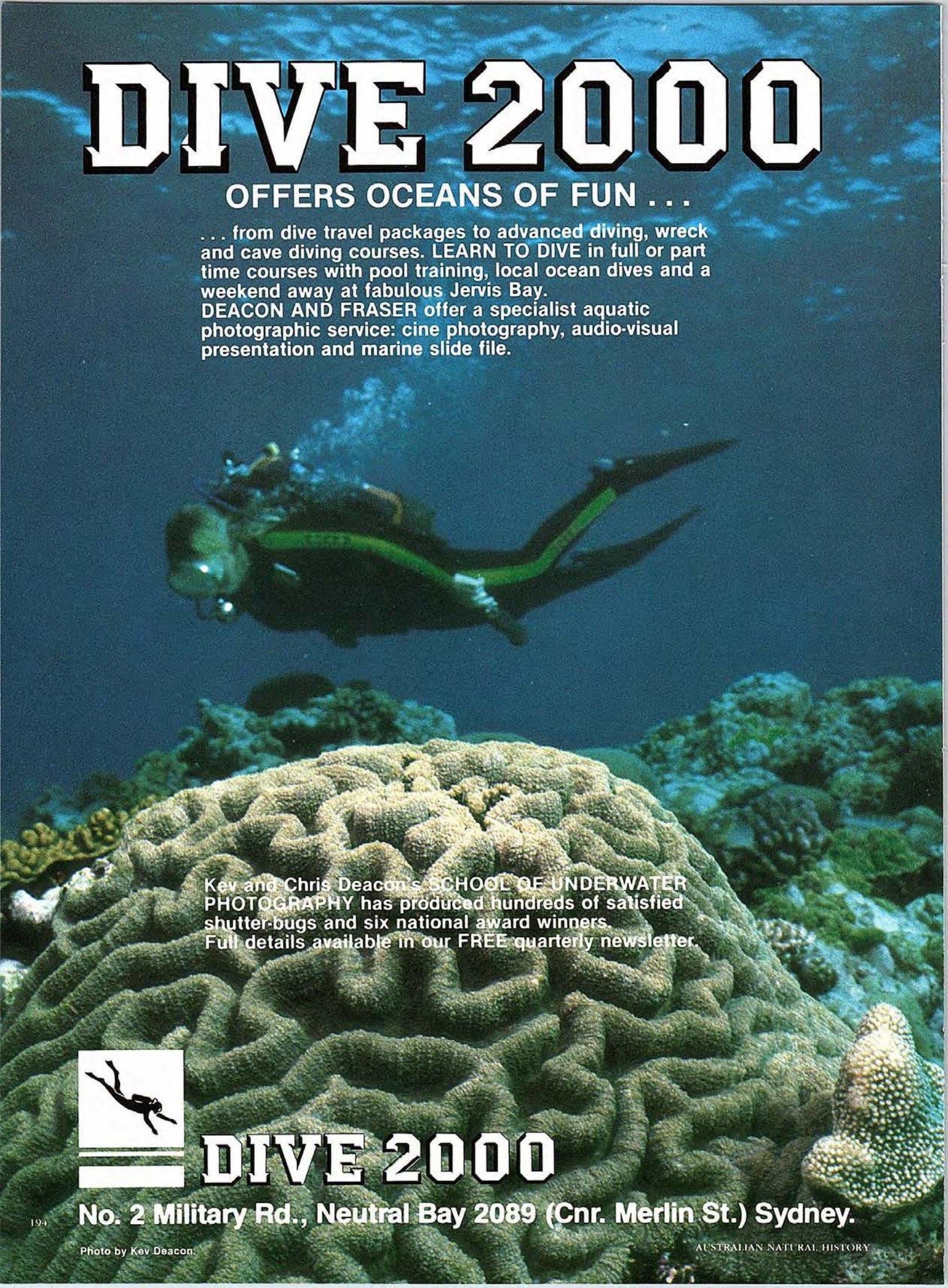

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Photo by Kev Deacon.

FORUM

Is the Crown-of-Thorns Ravaging the Reef?

The crown-of-thorns starfish extending its stomach to feed on coral polyps leaving a white coral skeleton.
Photo Kathie Atkinson.

The crown-of-thorns starfish has attracted considerable publicity in recent times. Media presentations have, in the main, portrayed the starfish as an agent of doom, which will eventually cause the destruction of the Great Barrier Reef, the associated tourist industry, and in the most extreme cases, the entire north Queensland coast. Sensationalist headlines have included "Threat To The Reef", "Reef Park A Farce In Face Of Starfish Threat", "March Of The Starfish" .....less emotive views have also been expressed. In seeking out an informed opinion on the current state of affairs, Australian Natural History *talked to Australian Museum staffer Dr Frank Rowe, an international authority on echinoderm systematics and distributions, and Mr Lyle Vail, an experienced biologist and diver, who has worked with Dr Rowe for the past three years, particularly on the Great Barrier Reef studying the biology of feather-star echinoderms towards his Ph.D thesis.*

What is the crown-of-thorns?

The crown-of-thorns starfish *(Acanthaster planci)* is a large, rather magnificent starfish of the phylum Echinodermata which inhabits coral reefs. Adults are typically 25 to 35 centimetres in diameter, but some are over 60 centimetres in diameter. It has up to 23 arms and is covered, on the top with long poisonous spines. Juveniles are rarely found because they are effectively hidden in crevices and under rocks and boulders on the reef. The starfish are not usually seen in any numbers until they reach about 15 to 20 centimetres in diameter, by which time they are about two to three years old and sexually mature.

How does it reproduce?

The crown-of-thorns has separate sexes which are indistinguishable without examining the gonads. On the Great Barrier Reef, reproduction has been shown to occur during summer months, when masses of sperm and eggs are released into the water. Fertilisation occurs and after a period of three to four weeks in the plankton, the tiny transparent larvae settle on the bottom, and metamorphose into tiny juveniles. The life span of crown-of-thorns is considered to be between three and five years.

How does the crown-of-thorns affect coral on the Great Barrier Reef?

The main food of the crown-of-thorns are the soft-bodied polyps of corals whose skeletons make up most of the reef. However, it does eat other animals, such as sea anemones and the polyps of "soft" corals, as well as algae. Very small juveniles apparently require algae for food, but gradually change their diet to coral and other foods as they grow. The food is enveloped by the stomach, which is extended out through the mouth. Juices from the stomach wall digest the food which is then absorbed by the stomach. When the starfish have fed, all that is left behind is the white coral skeleton.

Does the crown-of-thorns only occur in Australia?

No. It has a very wide distribution in the Indo-west Pacific region, from the red Sea, East Africa, east to Japan, Hawaii, the Society Islands, Pitcairn Island and tropical Australia. On the Australian coast the species occurs at least from Dampier Archipelago on the northwest coast to the southern end of the Great Barrier Reef, and to Byron Bay and the Solitary Islands and Lord Howe Island in New South Wales. A second species, *A. brevispinus,* discovered in the Philippine Islands has also been found, on the Great Barrier Reef as far south as the reefs of the Capricorn Bunker Group. This species lives in deeper water and on soft bottoms. It is not known to specifically attack coral. A third species, *A. ellisi,* is so closely related to the Great Barrier Reef crown-of-thorns that some scientists consider it to be the same species. It occurs in Baja, California and Panama and has similar living habits to the Great Barrier Reef *A. planci.*

When was crown-of-thorns "discovered" in Australia?

In Australia, the crown-of-thorns was first recorded from the northern end of the Great Barrier Reef in 1921. Subsequently, a single specimen was recorded from Low Island (near Cairns) in 1932. In 1961 Dr Robert Endean (Queensland University) recorded a single specimen from Heron Island. In 1964 Drs Barnes and Endean commented that it was "unusually prevalent" on reefs east of Cairns in 1962—3. Two years later (1966) Dr Barnes described aggregations of the starfish around Green Island. Dr Endean led an investigation into the problem and the first comprehensive report was published in 1969.

Is the problem unique to Australia?

Aggregations of the crown-of-thorns have been reported at a number of locations throughout the geographic range of the species, so Australia is by no means the only place that the phenomenon is known to have occurred.

What is an aggregation?
This is very difficult to define since most reefs contain a number of *Acanthaster*. However, aggregations have more often implied groups of hundreds, thousands or in extreme cases over a million starfish! In recent surveys carried out by the Great Barrier Reef Marine Park Authority (GBRMPA) the very low number of 40 or more starfish sighted in a survey of a reef has been used, as a benchmark, to record an "infestation" or "aggregation".

What causes aggregations of the crown-of-thorns?
No one knows for certain, although the available scientific evidence strongly supports the contention that increases in numbers are due to natural processes. A few scientists, believe, that agregations are the repercussions of human activities, in particular, the removal of predators of *Acanthaster*. Most scientists no longer accept this hypothesis.

What is the explanation generally accepted by scientists for these aggregations?
Recent investigations by Professor Charles Birkeland (University of Guam) and Dr John Lucas (James Cook University, Queensland) have led towards possible explanations. Professor Birkeland believes that heavy rains, following dry spells result in higher than normal levels of nitrates and phosphates being washed out into coastal waters. This higher nutrient level, in turn, results in the development of extra dense phytoplankton blooms which provide increased food levels for crown-of-thorns larvae. More larvae are able to survive and metamorphose into juveniles. The adults as we have mentioned earlier, are not seen until they are about two to three years old. Using this evidence, Professor Birkeland suggested that the reason for the outbreaks of *Acanthaster* on the Great Barrier Reef in 1962 lay in the fact that larvae survived more readily after the heavy rains washed nutrients out into coastal waters after the 1959 Queensland cyclones. Interestingly, Dr Lucas, using laboratory experiments, found that only a small percentage of larvae would survive in phytoplankton concentrations which are normally found in the waters of the Reef. According to Professor Birkeland, over a million eggs can be produced by a large female crown-of-thorns. An increase in survival as small as 1/10 of 1% might result, therefore, in an additional thousand offspring per female. Small increases in rates of larval survival have the potential, in later years, to be reflected in large increases of adult numbers.

What other factors affect the population size?
Various animals, such as puffer fish, trigger fish, grouper and the triton (a mollusc) have been observed feeding on *Acanthaster planci*. Despite claims to the contrary, the effectiveness of these predators, in controlling populations of crown-of-thorns, has not been demonstrated. However, populations of other animals on the reef do fluctuate. In a recent paper, Associate Professor Sale (Sydney University) has suggested that large fluctuations in numbers of reef fish is indeed a normal process. A phenomenon of "bleaching" in corals, which might cause death, at least in parts of a reef has been recorded by Dr Glynn (of the Smithsonian Tropical Research Institute, Miami) for reefs off Panama. This same beaching phenomenon has been observed by a number of scientists at various localities along the Great Barrier Reef. It is clear that fluctuations in populations of reefal animals are not unique events. Variation in the size of populations of *Acanthaster* might normally be expected.

Is there then, a crown-of-thorns "plague" which is destroying the Great Barrier Reef?
The answer is clearly and affirmatively no, although there are reefs, or portions of reefs, which are heavily infested from time to time. During 1983, survey records were obtained by the GBRMPA from reefs sampled along the entire length of the Reef. These showed that of 117 reefs sampled, 86% had between 0 to 39 starfish sighted on them. Aggregations of starfish (40 or more sighted) were recorded on only 14% of the 117 reefs. From extrapolations of these figures, it is likely that at the most, only 350, or so, of the 2,500 reefs along the length of the Reef would be affected to any degree. These results do not mean that we should be complacent about the problem. It does indicate that rather than creating alarm and despondency by predicting the imminent destruction of the reef, more energy should be put into examining the problem rationally.

Can the reef recover from crown-of-thorns attacks, and if so, how long does it take?
Dr Endean believes that in some areas recovery may occur in 20 to 40 years, although in other areas it may be delayed or even prevented altogether. On the other hand, Mr Pearson (Qld. Fisheries) found two to three years enough time for small corals and seven years for some larger corals to recover. He also believes that less than 20 years is sufficient time to restore species richness of the coral community. In a review of *Acanthaster,* Professor Potts (University of California) noted that present evidence does not indicate the permanent exclusion of hard corals from a reef damaged by the crown-of-thorns.

How long has the crown-of-thorns been on the Reef?
Dr Frankel (Queensland University) has found skeletal plates and spines of the crown-of-thorns on the Great Barrier Reef in sediment cores at 200 to 250 year intervals over the last 3,500 years (determined by using radio-carbon dating.) Professor Blake (University of Illinois) has found a fossil starfish from Mexican deposits about 36 to 58 million years old, which he thinks may be at least a forerunner to the crown-of-thorns. A number of sea-urchins living in Australian waters are also known from fossil deposits dating back about 15 to 38 million years. It is reasonable to suggest that the crown-of-thorns is at least as old, and probably older, than the present-day Great Barrier Reef which is only about 10,000 years old. Crown-of-thorns may have been associated with the Reef for as long as the reef has been in existence. The effect of *Acanthaster* on the reef as a whole needs to take this into account before claims are made about the immenent collapse of the Great Barrier Reef.

Are governments supporting research into the crown-of-thorns?
Yes. Research has been conducted by many government financed institutions around the world since the 1960s. In Australia the GBRMPA alone has spent over $300,000 since 1976 on research investigating various aspects of the crown-of-thorns. Research programs are currently being conducted by scientists at the Australian Institute of Marine Science and James Cook University in North Queensland. Nonetheless, many gaps in our knowledge concerning the biology and population dynamics of *Acanthaster* still remain.

Can we make management decisions on the control of *Acanthaster?*
Not yet. Indeed, there are doubts whether *A. planci* can be controlled at any level. What we see as essential is more combined research effort and the pooling of scientific knowledge. By this means, instead of a series of separate research projects being completed, integrated projects are planned which, when results are analysed, give a fuller understanding of this complex phenomenon. You can't make good management decisions on incomplete, disconnected information.

What would you see as an effective strategy in dealing with the crown-of-thorns?
An integrated program of multi-disciplinary short and long term projects carried out on the Reef. The logistics of such a program, involving scientists across a range of disciplines, will be costly. Far greater finance is required which should not be provided at the expense of research in other areas. What we need to remember is that the Great Barrier Reef is not only one of Australia's most important biological structures, but was placed on the World Heritage List in 1981. It is essential that research into this complex system be continued, in order to preserve the Great Barrier Reef.

Fish Populations Threatened

BY INADEQUATE QUARANTINE LAWS

by Lucy Parr

The N.S.W. Fisheries Division keeps records of estimates of catches by professional fishermen, calculated from measurements taken at the Sydney fish markets. In 1982, a Fisheries observer found an unidentified specimen, 370 millimetres long that had been taken from Pittwater, just north of Sydney. As it was so unusual to find such a large specimen not recorded from Sydney before, the fish was taken to the State Fisheries laboratories where scientists unsuccessfully attempted to put a name to it. Eventually, Australian Museum scientists identified the fish as *Lateolabrax japonicus,* the Japanese sea bass, previously known only as far south as Hong Kong.

A year and a half later another Japanese sea bass of slightly larger size was found and the ages of the two fish determined. It appears they were introduced into Australian waters at the same time (assuming they were introduced as larvae). The sea bass is not an aquarium fish and it is highly unlikely it would be accidentally or deliberately imported by an aquarium dealer. How could a large marine fish appear 5,600 kilometres to the south of its normal habitat?

Rob Williams, a N.S.W. Fisheries scientist, has been studying the problem of introduced marine species for several years. He firmly believes it is only a matter of time before a pest species becomes established in Australia. "We don't want marine rabbits in our estuaries," he says. The chances of this happening are increasing as more exotic species are being recorded, coinciding with the increase in international shipping traffic.

The presence of the Japanese sea bass is cause for concern as it is a carnivorous fish and grows up to one metre in length. The introduction of such a large species could have far reaching effects on the environment, and could adversely affect estuarine commercial fisheries. Mr. Williams is looking for more specimens of the sea bass to try to determine the extent of its distribution in Australia, and to find out whether the fish has established a breeding population or if the two records from Sydney represent an isolated introduction.

In its report to the Fishing Industry Research Committee in 1982, the N.S.W. Fisheries Division listed 19 species of marine animals that have been introduced into Australia from other countries. The report gave the results of a sampling program carried out in the ballast water tanks of ships, recently arrived in various Australian ports, from Japan. As cargo vessels often need to travel unladen between ports, it is necessary to add weight (ballast) to stabilize the ship. The added weight must be readily disposable when the ship is loading at its destination. Seawater would appear to be an inexpensive, convenient and pollution-free form of ballast, but ballast water may not be as harmless to the environment as was once thought.

The report shows that substantial amounts of live zooplankton were regularly found in the water and sediment at the bottom of ballast tanks. Although most of the crustacea were considered harmless to commercial fisheries, some species of polychaetes (worms) and pinnotherids (crabs) are parasitic or commensal with oysters and mussels. If populations of these animals become established in Australia they could provide a threat to the shellfish industry.

A further threat is indicated by the presence of bivalve veligers (larvae) in ballast water. It is possible these could include the larvae of the Japanese oyster *(Crassostrea gigas)* but, due to the difficulty of identifying veliger larvae to species, the presence of *C. gigas* has not been confirmed. The Japanese oyster is faster growing, but of inferior quality, to the Sydney rock oyster, and already poses a minor problem to oyster farmers along coastal N.S.W. Any expansion in the animal's distribution or numbers will adversely affect the industry.

Dr. Douglass Hoese, of the Australian Museum, has recorded the introduction into Sydney Harbour of two species of gobies, normally found in Japanese waters. In 1971 *Acanthogobius flavimanus* was found at Dawes Point. Seventeen specimens have been collected since then from other areas of Sydney Harbour and Parramatta River. It is highly probable that this species has established a viable breeding population, as it has where it was introduced into America in the San Francisco Bay area.

Tridentiger trigonocephalus was first recorded from Little Sirius Cove in 1973, and subsequently collected from Melbourne and Perth. It has been found alive in the ballast water of an Australian ship.

Gobies are small fish and probably do not have a major effect on the estuarine environment (although they may compete for food and space with the juveniles of some commercial species). However, they do show that animals can not only survive in ballast water, but can also be successfully transferred to a new environment.

So far it does not appear that introduced animals have greatly affected our marine environment. However, it has been shown that live animals are transported in ballast water tanks of cargo vessels and that these animals can be transferred to, and survive in, Australian waters. The frequency of introduction of exotic species will determine the number of successful colonizations. The amount of ballast water received in Australia is increasing as the bulk export of Australian raw materials increases. This trend is expected to continue yet there are no quarantine laws relating to ballast water.

A spokesperson for the Department of Health said: "as far as general quarantine is concerned there does not seem to be a problem". The department was unaware of the N.S.W. Fisheries Division report. They did express concern that all terrestrial pest species of animals and plants in Australia have been introduced from overseas, but seemed to think that, provided ballast water was dumped below low-tide level, there was no risk involved.

As international markets are becoming more competitive, it is unlikely that the Federal Government will impose restrictions on the disposal of ballast water, as any increase in shipping costs could discourage foreign trade. However, unless action is taken to ensure that water is treated before being pumped from ballast tanks, live, non-indigenous animals will be imported into Australia at an increasing rate. Will it be necessary to wait for proof that introduced species can damage Australia's marine environment, or will the Government realize that the costs involved in chemical treatment of ballast water would be minimal compared with the enormous cost of dealing with a pest species once it has become established?

Lucy Parr, Technical Assistant, Fish Department, Australian Museum

Marine Reserves

CONSERVATION OR RECREATION?

Right: A diver examines a giant clam Tridacna, *in the Great Barrier Reef Marine Park.*
Photo Kev Deacon.
Left: Lady Musgrave Island and the fringing coral reef and lagoon are part of the Capricornia Section of the Great Barrier Reef Marine Park.
Photo Kev Deacon

The key to conserving the marine environment is the preservation of representative habitats in prime condition. In marine areas such habitat include the underwater terrain as well as the water above it and the plant and animal life associated with both the bottom (benthic) terrain and the mid-water (pelagic) fish and plankton which are often transient occupants.

In the declaration of marine reserves, the size required may be complicated by what use the reserve will serve. Is it to be primarily for conservation, historic, scientific, educational, recreational or wilderness purposes? When the reserve is large enough, it is possible to zone areas for a variety of purposes and activities.

Conservational reserves are areas least affected by people and representative of different aquatic ecosystems. Nursery and breeding grounds for important commercial and recreational fisheries, such highly productive areas as mangroves and seagrass are of prime importance. When they are not already in declared reserves, in N.S.W. at least, development applications affecting mangrove or seagrass areas are viewed by fisheries authorities.

How does the present system of marine reserves in Australia measure up to conservation criteria? With several states without any marine reserve legislation, the biogeographic provinces are very inadeuqately represented.

In Western Australia several areas have been proposed as marine reserves; unfortunately, W.A. National Parks and Wildlife Service do not have legislative provision to declare them. The marine reserve of Ashmore and Cartier Islands in the Indian Ocean is representative of that biogeographic area. It has been gazetted under Australian National Parks and Wildlife legislation as Ashmore Reef National Nature Reserve. The reefs and islands comprise an External Territory of Australia which extends our marine boundaries. Indonesia is disputing our rights in the area, claiming traditional fishing rights. The boundary with Indonesia in this area is disputed, Australia claiming the Timor Trough forms a natural boundary; Indonesia claims a boundary equidistant from the two shores. Since discovery of the Jabiru oil field, it is crucial that aggreement on a boundary be reached, as it's anticipated other oil fields may be found in the Timor Sea.

The area is subject to an Agreement of Understanding between Australia and Indonesia which gives Indonesian fishermen access to two coral cays but there have been transgressions of the agreement. Indonesians have been camping on the islands and killing seabirds and turtles. The navy is patrolling the area and health and quarantine officials have issued warnings. A Marine Parks Act is currently under consideration to supplement present legislation; in Western Australia the Ningaloo Reef is proposed as a marine reserve including 200 kilometres of coastline off North West Cape. It represents a coastal coral reef system, averaging 2.5 kilometres from the coast, stretching for 260 kilometres. Tenure of the marine areas proposed for the marine park is vested in several State and Commonwealth bodies. Part of it is a military training area. The reserve's consideration appears to be stalled, with several other proposals including Rowley Shoals, Shark Bay and Broke Inlet also awaiting suitable legislation to be passed to give management of the areas under consideration to one administrative body. A problem has been the lack of Commonwealth legislation for marine reserves which would ensure a national management philosophy.

Lord Howe Island, the southernmost coral reef in the world and an area of great zoogeographic interest with particular marine importance, is not yet a marine reserve through it is under consideration, as is the Solitary Islands, off Coffs Harbour, N.S.W., with its interesting reef-building corals and mixture of tropical/temperate fuana. New South Wales has a fairly good record with establishment of marine reserves beginning with the proclamation of a marine extension of Bouddi State (now National) Park in 1971. An amendment to the Fisheries and Oyster Farms Act in 1979 enabled the establishment of Aquatic Reserves under New South Wales fisheries legislation. Aquatic reserves close to Sydney are at Long Reef, Bass Point, Shiprock, and in the northern part of Sydney Harbour. The Long Reef Aquatic Reserve was gazetted when it came under pressure from people collecting shellfish and sea urchins for food. It has been used as a field studies area for local schools and universities for over 50 years. Limited

collecting is allowed under permit from N.S.W. Fisheries Division. Near Melbourne is the Harold Holt Marine Reserve where the last remnants of seagrass habitat in Port Phillip Bay are included, providing waterbirds and fish species with an important nursery area.

South Australia has several Aquatic Reserves under its Fisheries Act, declared since 1971. Close to Adelaide is the Port Noarlunga Reef in St. Vincents Gulf, a sandstone reef about 1.5 kilometres long connected to the shore by jetty. Fish populations were decimated by spearfishing in the early 1960s, but since its protection, fish are plentiful and unafraid of divers. It is a fine example of an educational, recreational reserve. Ten kilometres south, is Aldinga Reef, an intertidal limestone platform which is primarily a recreational/educational reserve. Goose Island and some nearby islets in Spencer Gulf are primarily an educational reserve for an Adelaide school. There are several other conservational reserves in South Australia including most of that State's mangrove areas which have been protected by fisheries legislation.

There are no marine reserves in the Northern Territory nor in Tasmania, though there are several proposals in Tasmania including that discussed in the Port Davey article. The author of that article reports that an earlier proposal to have Ninepin Point Reef in D' Entrecasteaux Channel near Hobart gazetted, resulted in exploitation of the reef by fishermen with resulting depletion of fish stocks.

The first marine reserve in Australia was the reef surrounding Green Island, a small coral cay 20 kilometres from Cairns, north Queensland, which has been protected under fisheries legislation since 1938. Heron Island and adjacent Wistari Reef, 80 kilometres northeast of Gladstone were also protected under fisheries legislation. The declaration of the Capricornia Section of the Great Barrier Reef Marine Park in 1979 and the Cairns section in 1981, under the Great Barrier Reef Marine Park Act has redressed the inadequacy of protection afforded our greatest marine attraction. The significance of the region has been realised with the inclusion of the Great Barrier Reef in the World Heritage Listing. This international recognition has reduced some of the public criticism which regulation of the activities in the marine park generates.

The multiple use zoning plan, restricting various activities in certain areas, enables the protection of a buffer zone, allowing traditional fishing alongside commercial and recreational activities in other areas. The sections proclaimed in 1983, are Far Northern, Central, Southern, Inshore Southern, Cormorant Pass and Townsville. In addition there are 23 fish habitat reserves to protect inshore and estuarine habitats.

The area covered by the park is certainly representative of the Great Barrier Reef, in fact with 98 percent of the Great Barrier Reef region now in the park, the conservation of the reef is ensured. Recreation and education have quite different requirements. Accessiblity, interesting terrain, diversity of plant and animal life, and clear water are attributes which sport divers seek in a marine park. Facilities to enable the non-diving public to appreciate the marine environment, such as glass-bottomed boats, onshore aquaria and museums, underwater observation chambers and submersible vehicles enable them to gain an appreciation of the marine environment. For sport divers, marked scuba trails, notices indicating interesting fauna or geology and support facilities such as air compressors and even decompression chambers are highly desirable facilities.

The underwater observatory at Green Island and others operating on the reef have done much to enable visitors to appreciate the beauty of the reef, as have the glass-bottomed boats operating out of various resorts. These are all private enterprise ventures successful in promoting the reef in ways which are inaccessible to the public administrators. Encouragement of private enterprise offering facilities for the public which enhance appreciation of the reef becomes a desirable feature of marine park planning.

Marine reserves declared in Australia to date have been primarily conservational reserves. There has been difficulty in the present legislation between Commonwealth, State responsibilities; the proposed Australian Marine and Estuarine Reserves Act would provide a national marine reserves system. In Queensland, the Great Barrier Reef Marine Park operates in joint management between the Great Barrier Reef Marine Park Authority and Queensland National Parks and Wildlife Service, which provide rangers and field staff. In the Capricornia section of the park there are about 10 field staff working out of Rockhampton. To manage and implement policies over

such a large area, obviously requires more staff than is available, at present.

No marine parks in Australia have been specifically designed to enhance the recreational or educational potential as has been done in Japan or the United States. The Kushimoto Marine Park on the Kii Peninsula at the southernmost point of the Japanese island of Honshu, is headquarters of the Marine Parks Centre of Japan and its facilities include a large onshore aquarium, underwater observation towers which hold 40 people at a time, and glass bottomed boats which carry as many people on regular tours of the park's coral reefs. We do not have the system of marked scuba diving trails such as in the John Pennekamp Coral Reef State Park in the United States, yet with the finest coral reef system in the world, we have enormous potential to increase the tourist and educational facilities provided.

Written by ANH's Christine Deacon from material supplied by Dave Pollard and John Matheus of N.S.W. Fisheries Division.

Mating Behaviour of Fiddler Crabs

The author Professor Michael Salmon of the University of Illinois at Urbana-Champaign is a world authority on fiddler crabs and whilst in Australia, observed fiddler crabs at Townsville. He reports for Australian Natural History *on the way Australian fiddlers attract a mate.*

Fiddlers have intrigued naturalists because of their fascinating behaviour. They are commonly found between the low and high tide zones of mangroves and salt marshes around the world. About 60 species have been described, most of which are tropical. These animals play an important part in marine ecosystems, converting intertidal organic matter (diatoms, algae and nematodes) into small, bit-sized packages for many predators, both terrestrial (shore birds, mammals) and aquatic (marine crabs and fishes). They also release billions of their larvae into the planktonic community where they serve as both prey and predators for other species. Of the several crab groups adapted to life on briefly exposed intertidal flats (such as the soldier crabs of Queensland), none rival the fiddlers in sheer numbers of individuals or species.

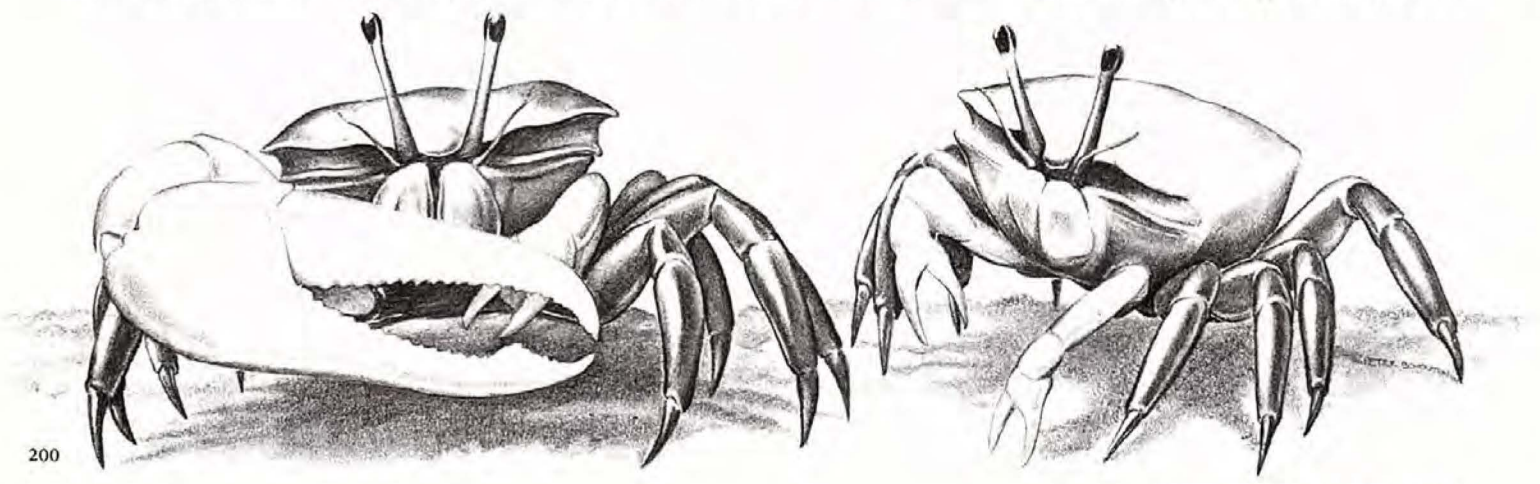
Fiddler crabs are typically social, living in large, often crowded, colonies, but each individual centres its activities around a protective burrow. During the breeding season, males court females by a repetitive "waving" signal, using their single enlarged claw. In some species, this gesture is accompanied by dance steps and sound production. When not waving, males use their large claw in fights with other male rivals. These resemble arm wrestling matches and are usually over rights to court local assemblages of females.

Many behavioural biologists have described these waving "displays" and agressive interactions and some have attempted to explain why they differ in complexity, form and social context from one species to the next. In the 1950s, Jocelyn Crane, an authority on the group, documented the strong correlations between structure, physiology and behaviour of fiddler crabs. She proposed that the "narrow front" species of the western Pacific, which inhabited burrows in the lower intertidal zone, were most primitive while the "broad fronts" of the Americas, which lived in the upper intertidal, were advanced. The "front" is the space separating the eyestalks.

This hypothesis seemed reasonable on two counts. First, fiddlers are derived from totally marine crabs which later became adapted to life within the intertidal. Those living in the lower intertidal are only briefly exposed, at low tide, to the extremes of temperature and dessication and therefore, have changed the least from their totally marine ancestors. Secondly, the social behaviour of the narrow fronts seemed less developed. For example, male waves were simple in form (a vertical lift, followed by a return) and often directed toward males as well as females. Waving, then, seemed to function more as an aggressive than as a courtship signal. Similar movements are also shown by many marine crabs when they fight. In contrast, waving by the broad fronts is complex, consisting not only of a vertical lift but also a lateral extension. Furthermore, waving went on for hours at a time and was most often directed toward females, suggesting that the display had become specialized for a new (courtship) function.

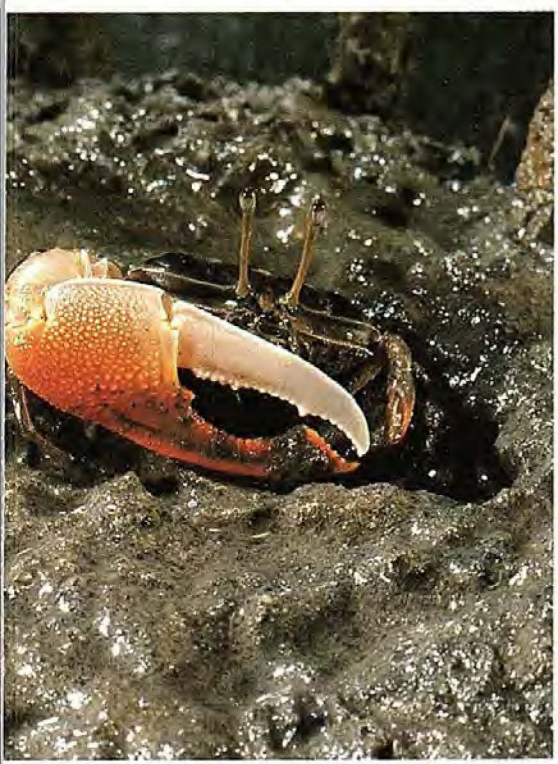
On the other hand, the narrow fronts exhibit most of the morphological specializations found in the broad fronts. They have a well

developed "lung" and strong legs repositioned under the body to support their weight on land. They are also abundant and flourish in the western Pacific. A few species of broad fronts also occur there, but they show no sign of competitive dominance or replacement of their more "primitive" relatives. These facts suggest that the two groups represent alternative modes of adaptation, not a primitive-to-advanced "continuum." Could this also be true of their reproductive behaviour? Until recently, this hypothesis could not



Fiddler crabs, Uca vomeris, the dark coloured female beside the burrow while the male displays his large coloured claw. Photo Kathie Atkinson

Drawing by Peter Schouten.



be tested because basic information was unavailable.

Within the last few years, scientists have studied the reproductive behaviour of animals from a broader perspective. It is no longer sufficient to describe male courtship in isolation from the ecological factors of importance to a species. Emphasis is now placed upon defining the environmental resources needed by both sexes for successful breeding and the techniques they employ to obtain these resources.

This approach leads to the definition of a mating system: the social relationships between the sexes during breeding in relation to their ecological breeding requirements. In the fiddler crabs, previous workers had emphasized differences in male courtship behaviour but omitted reference to resource requirements, especially for females. We now know that female requirements are most important because females invest the most time and energy in reproduction. Recent studies suggest that broad and narrow front females differ in where they live in relation to their food supply, and in their requirements for incubating eggs. These differences have caused males to alter their behaviour as they compete for matings, yielding broad and narrow front courtship "patterns." This new perspective suggests that the two groups might demonstrate contrasting mating systems.

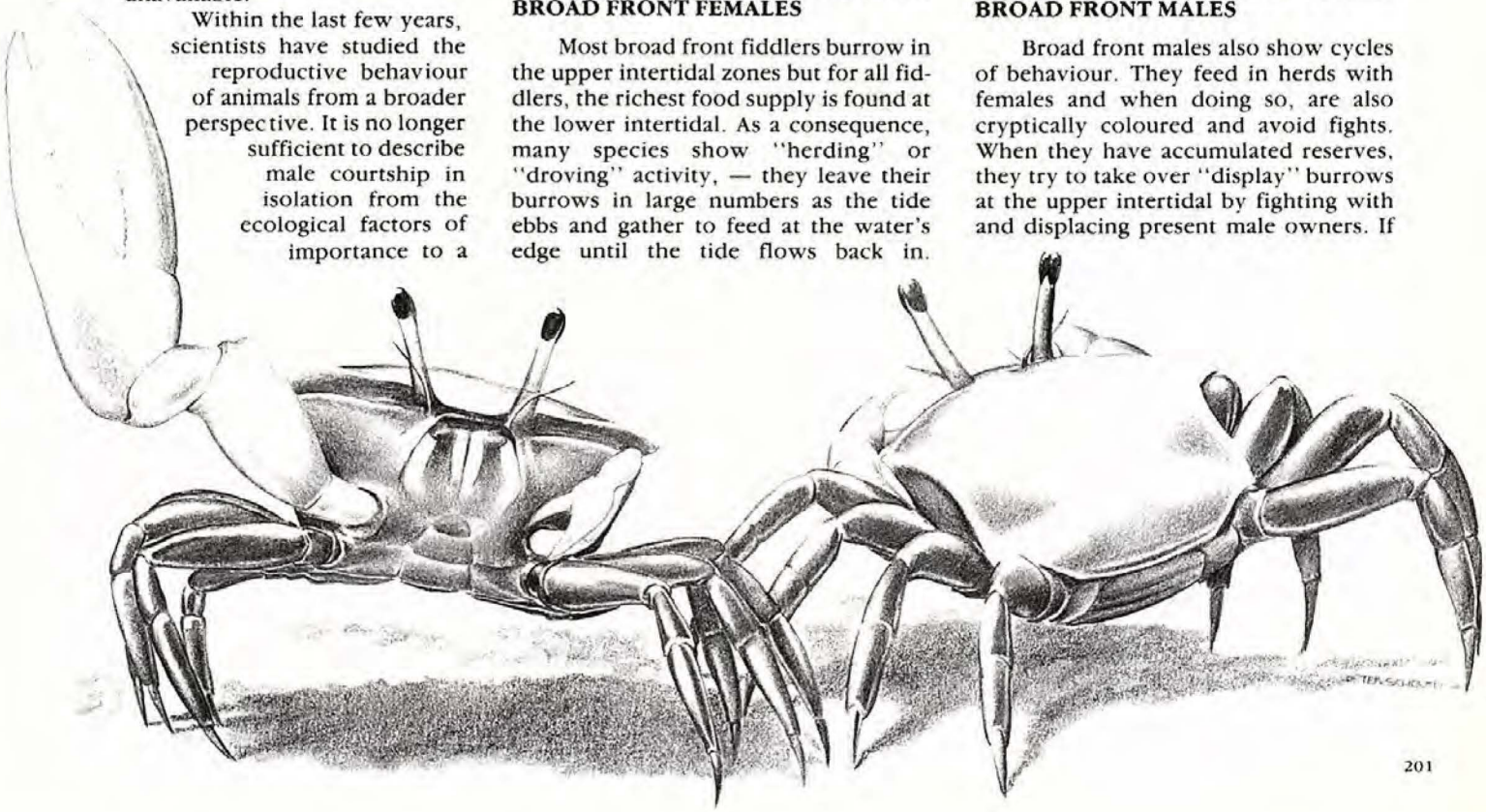
REPRODUCTIVE ECOLOGY OF THE BROAD FRONT FEMALES

Most broad front fiddlers burrow in the upper intertidal zones but for all fiddlers, the richest food supply is found at the lower intertidal. As a consequence, many species show "herding" or "droving" activity, — they leave their burrows in large numbers as the tide ebbs and gather to feed at the water's edge until the tide flows back in. Females do this every day until they accumulate sufficient reserves for a clutch of eggs. Typically, females are cryptically coloured minimizing the risks associated with feeding away from a protective burrow. When feeding, females do not fight because doing so makes the combatants more conspicuous to predators and takes time away from feeding. There are also no advantages gained by fighting over food since this resource is locally abundant.

About once every month, each female accumulates enough food to produce a clutch of eggs. She then becomes both physiologically and behaviourally receptive. The paired genital openings of female crabs are covered by opercula, normally hardened. Just before mating these become pliable and can be pushed to the side by gentle pressure. This allows males to transfer spermatophores during mating and, shortly afterward, permits the female to extrude her eggs to the abdomen where they form a "sponge." Females incubate their sponges for 12—14 days, then release their larvae into the water (spawning).

REPRODUCTIVE ECOLOGY OF THE BROAD FRONT MALES

Broad front males also show cycles of behaviour. They feed in herds with females and when doing so, are also cryptically coloured and avoid fights. When they have accumulated reserves, they try to take over "display" burrows at the upper intertidal by fighting with and displacing present male owners. If



successful, they become brightly coloured and spend most of the low tide period waving to females. They vigoroulsy defend their display burrows, both from neighbours and from other males seeking them. Receptive females prospect for mates from among this assemblage of often crowded, frantically waving males. Each female visits several males and their burrows until a "suitable" one is found. The chosen male closes his burrow entrance and the pair "honeymoon" together for about 24 hours.

SAND FIDDLER REPRODUCTION

In 1980, Dr. John H. Christy of Cornell University reported on the sand fiddler *Uca pugilator* a common species along the east coast of the U.S., that shortly after closing, the pair copulates and within hours, the female extrudes her eggs. Her mate waits for this process to be completed, thereby assuring his paternity. Then he seals the female into the what now becomes a brooding chamber, returns to the surface, and courts other females. He may succeed in attracting several females in succession, and will house each in a separate brooding chamber. But because his breeding burrow is located at the upper intertidal where there is no food, his reserves are eventually exhausted and he abandons his breeding burrow to feed for several days at the lower zones before the cycle is repeated.

Christy found that not all males were successful at acquiring mates. Some never attracted females because their display burrows were dug in areas where the substrate was "unstable": the burrows collapsed when inundated at high tide. Females require several hours to attach their eggs and this, in turn, means that the brooding chamber must not collapse. When females sample, they apparently are not scrutinizing males but rather, are assessing display burrow "safety." Unsuccessful males lose fights with competitors and cannot acquire good quality burrows. Females, therefore, reject them.

REPRODUCTION IN CRUSTACEA

In the vast majority of the Crustacea, males offer no resources to females during the parental phase. But in the sand fiddler (and a few species of crayfishes) males do participate, at least to the extent of providing suitable incubation sites. Now, the fighting, colour and waving shown by broad front males make some sense. Suitable brooding sites are resources often in short supply and males must compete to acquire and hold them. Once held, a male still needs to compete with neighbors for a female's "attention." Conspicuous, complicted waves and bright colors are his main aids. Finally, males have to advertize persistently because they can hold out only as long as their food reserves last. That is why waving goes on for hours at a time.

REPRODUCTIVE ECOLOGY OF A NARROW FRONT SPECIES

The mangrove fiddler, *Uca vomeris* is abundant along the east coast of Australia. I recently studied them adjacent to the Australian Institute of Marine Science, near Townsville, Queensland. This beautiful animal (orange, red and violet chelae; turquoise and chocolate body) thrives in the lower intertidal zones. I located a dense colony, surrounded it with a barracade, and marked each crab with a numbered tag so that its activities could be followed over several months. It soon became apparent that both males and females behaved very differently from the broad fronts. I decided to find out why, turning first to foraging and feeding patterns because these are especially critical for understanding female behaviour.

Since *U. vomeris* lives in the lower intertidal, food is locally abundant. Most crabs feed near their burrows. Herding is virtually absent and females, in particular, spend most of each low tide carrying parcels of food-rich mud into their burrows. My guess is that they feed on this stored material while covered by the high tide, certainly an important adaptation when exposure time is short.

Another major difference is in colouration. Neither sex shows crypticity, except for individuals too young to breed. In fact, both mature males and females are brightly (and identically) coloured. Similarly, both males and

females are aggressive to members of the same sex. Females possess a repertoire of 15 distinct postures and movements all used in threats toward, or fights with, other females. Females even wave, just like males! In both sexes, waving had no sexual function; it was clearly an aggressive display. Both sexes have agressive repertoires of about the same size but they consisted of different movements, probably because in males the enlarged claw is so prominently employed. I timed the fights and found that those between female combatants were, on the average, longer than those between males. Females fight to defend both their burrows and the foraging sites near the openings.

Females also continuously incubate clutches of eggs and do so while active on the surface, feeding. Incubation lasts about 14 days but within a day or two after spawning, each female extrudes a new batch of fresh eggs. Thus instead of dividing their reproductive cycles into separate phases of ovarian maturation and underground incubation, these processes occur simultaneously, with no period of prolonged underground incubation.

I found that females often copulated several times during one incubation cycle, always next to their own burrow entrances. They could mate repeatedly because their opercula were always somewhat pliable (which permitted spermatophore transfer), though only completely flexible just before ovulation. Because females were feeding and available each day, males courted them constantly. But, it was impossible for me (and presumably, a male) to tell if a female would be receptive. Each female had to be courted, one by one, and she mated with just a few of her many suitors. I calculated, based upon my data from marked females, that on the average each male had to visit at least 17 females to obtain a single mating! That statistic assumed no other male had gotten there first!

How did males increase their chances of obtaining matings? How did they outcompete other males striving to do the same? Fighting over burrows was obviously not adaptive since females did not use male burrows for reproduction. Similarly, waving to attract females would accomplish little; females stayed by their own burrows and males had to come to them. Persistence, coupled with efficiency, seemed to be the answer.

I found that successful males courted many females each day, visiting each for a brief (30 sec—2 min) courtship before moving on to the next. When they obtained a copulation they mated quickly (within 7 minutes), then left to court other females. Such males could, and occasionally did, obtain two matings within 15 minutes.

Successful males also obtained some matings by returning to females which had initially refused them. Females, in short, "liked" males who were persistent and avid courters. This preference probably exists because male courtship "technique" is passed on genetically from father to son. Thus, females whose sons are sired by persistent courters can expect to produce male offspring who will also be attractive, perpetuating their mother's genes through large numbers of grandchildren. Of course, each male can devote only so much time to courting females. He must also feed and channel energy into growth and "maintenance." Attractive males demonstrate a capacity to most efficiently balance these conflicting reqirements.

Finally, while males do fight, often fiercely, their fights are rarely over real estate. This, of course, makes perfect sense. Time spent fighting represents a loss of courtship time. I saw males fight when sallying through the same assemblage of females. The "loser", usually a smaller male, simply changed direction and courted another cluster of females. Alternatively, he retreated, waited for his larger adversary to leave, then began courting the same females. In either case, no male fought for more than a few seconds.

COMPARATIVE ANALYSIS OF MATING SYSTEMS

The studies Christy and I have done attempt to establish major patterns, or themes, which we presume characterize broad and narrow front mating "types" in relation to their ecology. The extent to which we have done so remains to be seen. It is clear, though, that in the sand fiddler, the mating system is polygynous, (one male mates with several females but females mate only once), and resource-based (each male provides his mate with a safe burrow for mating, ovulation and incubation), while in *Uca vomeris* the mating system is promiscuous (each sex mates multiply) and resource-free (neither sex provides the other with any resource other than sex cells). These differences can be understood as the consequence of variation in the resource requirements and reproductive physiology of females. As a result, the observed contrasts in behaviour make sense, given the options available to each sex.

Where do we go from here? To what extent are the differences in both species groups the result of responses to variation in their habitat, as opposed to genetic (evolutionary) divergence? The answers lie in the judicious sampling of other broad and narrow front representatives, especially those occupying ecological niches resembling those of the other. For example, what happens when broad front species prefer to reside in food-rich, lower intertidal areas? When narrow fronts prefer the upper intertidal zone? There are not many such species but some are present. Each should show some elements of convergence in behaviour and social organization but also, some conservative elements representative of genetic difference. Another equally informative approach centers around the flexibility shown by individual species occupying different niches in different areas. When these comparative analyses are completed, we will better understand relationships between genetic divergence, behavioural response to ecological variation and the evolution of behaviour in these marvelous animals.

The Sex Changing Coral Reef Fish

by Gillian Eckert

Moon wrasse male, a large terminal phase male in blue colouration, the dominant fish in the group.
Photo R. Kuiter

Many fish change sex as a normal part of their functioning life. The most common pattern is one of females changing into males (protogynous hermaphroditism). The tropical moon-wrasse has two types of males; some that are born as males and others that were functional females before they changed sex. What evolutionary pressures may have led to the coexistence of these different male forms in one species? A study of their mating behaviour in different habitats in their natural environment provides insights into this question.

The moon-wrasse, *Thalassoma lunare,* is an extremely common fish throughout the Great Barrier Reef. It is a member of the family Labridae, one of the most speciose groups of fishes which includes the cleaner fish, tusk fish, maori wrasses and the blue groper.

Fish are often thought to exemplify the simple life-style. A moon-wrasse in an aquarium does little more than eat and swim up and down the tank. In its natural habitat on a coral reef, however, it leads a very involved social life. Moon-wrasses come in two distinct colour phases. The large, brightly coloured individuals with long tail rays and bright pectoral fins are always males. These are extremely aggressive fish which dominate all smaller individuals. The rest of the adult population are smaller, relatively non-aggressive and drab green. These may be either males or females. This species is termed diandric because it has two different types of males: large bright Terminal Phase (TP) males and smaller drab Initial Phase (IP) males. All females are born as such.

On small reefs, where only a few individuals live, one can usually find a single large TP male and a group of up to 12 smaller drab IP fish. The smaller fish are all submissive to the big male, giving him priority of access to food and generally keeping out of his way. The male's daily cycle of behaviour centres around spawning time. Moon-wrasses spawn on the diurnal high tide each day in summer. Throughout the day, the male's colour alternates between green and a very bright blue. When he is green he spends his time swimming around and feeding. Instantaneously, without any obvious external stimulus, the TP male will change to a bright blue colour. Feeding ceases and he begins to attack every IP fish that he encounters; irrespective of its size. This aggressive behaviour usually lasts for about ten minutes. Equally suddenly, or at the sight of an interesting piece of food, the male will change back to green, stop attacking and begin feeding again. This cycle repeats itself about once per hour during low tide but, towards spawning time, the blue periods increase in frequency and duration and attacks on smaller fish become more intense. IP fish may be chased persisitently by the male until they are forced to take shelter under coral or in a hole.

About an hour before spawning, the blue colour becomes permanent and the TP male swims rapidly in large circles around the reef, interspersing this with attacks on IP fish. The male then begins swimming up towards the surface and down again; a practice known as looping. Soon after this the male begins his mating display. At a prominent point on the reef, he rises up into the water column and performs a rapid quivering of the body and tail while fluttering his bright pectoral fins. Females remain close to the bottom feeding. Eventually, one moves towards him, rises off the bottom and the two fish rush together towards the surface, release eggs and sperm and rush back to the bottom. Coral trout, which have been waiting nearby, often attempt to attack the spawning fish. The strong currents rushing off the reef just after high water assist in sweeping the vulnerable eggs away from the numerous egg predators and into the open sea. After all of the females have spawned, courtship ceases, the male changes back to green and the daily cycle begins again.

The TP male is at an enormous reproductive advantage over any of the females in his group on a small reef. They each spawn once but he is able to spawn with perhaps eight females, thereby potentially adding eight times as many of his genes to the next generation of moon-wrasses. Some of the IP fish in these groups are, of course, IP males. If an IP male makes any attempt to court a female, he is attacked severely by the TP male. These animals have no chance of spawning with any of the females because of the social control that the dominant TP male has over all other members of his group.

How does a fish become a TP male? This was tested experimentally by removing TP males from areas of reef. Although they are relatively non-aggressive, the IP fish do have a size-based dominance hierarchy among themselves. If the next largest fish in a group is an IP male, it quickly recognises that the dominant TP male is gone. It looks around the reef thoroughly to make sure that it isn't just feeding under a piece of coral. The IP fish then rapidly changes to a blue colour and begins attacking females. On the next high tide, it begins courting females and goes through the motions of spawning. At this stage its relatively inactive testes contain no motile sperm but they quickly develop and its tail fins grow longer and the general body colours intensify. The animal can now be classified as Terminal Phase.

If the largest IP fish happens to be a female, nothing obviously happens for a few days. After 10 to 12 days however, the female begins to show typically male behaviour. She becomes aggressive, adopts the blue colouration and actively courts other females at spawning time. If the female is then caught and dissected it is found that the ovaries are degenerating and testicular tissue is developing and producing motile sperm. The animal has functionally changed sex.

By becoming a TP male on a small reef, an IP fish dramatically increases its reproductive success. It can now spawn with all of the other females and fertilize many eggs. The only way an IP male can participate in spawning is if it lives long enough to become the TP male in its group.

On larger pieces of reef where many moon-wrasses live, things are rather different. In these areas, wrasses live in groups spread out over the reef, each with a dominant male. At high water all of the wrasses move to one spawning site; usually on the down-current side of a projection of the reef. Here, several TP males display to the females. Rather than there being only two or three IP males, however, there may be 20 to 30 of them. These IP males adopt a strategy of interference with TP males. They form together in a tight school and swim around the spawning site watching as the TP males display to females. Whenever a female moves towards a blue male to spawn, they rush towards him. The TP males attempt to chase the IP males away, but in this situation they are not able to effectively control the behaviour of these smaller fish. As the dominant male begins the spawning rush, they join in with him. The female, TP male and the whole group of IP males release their gametes together in a white cloud.

One or two of these active IP males were transplanted onto a small reef controlled by a dominant male. When they attempted to interfere with pair-spawning, they were attacked so severely by the large male that they soon give up even trying.

On very large reefs with extremely high densities of moon-wrasses, group spawning is the norm. In these areas, several hundred IP males may gather at the spawning site and form several groups which watch every TP male as he attempts to display. TP males here have no chance at all of having an uninterrupted pair-spawning. Many females, in fact, choose to spawn with the groups of IP males and don't even bother to go to the big blue males. The TP males, being so unsuccessful in securing females, frequently have to reverse roles and join in with the group spawnings of the IP males.

Moon wrasse terminal phase males with green colouration and smaller drab initial phase females and males.
Photo R. Kuiter

IP males are able, therefore, to fertilise some eggs in this situation. They don't, however, have the large advantage over females that TP males have on small reefs. The daily mating success of each IP male will approximately equal the number of spawnings it participates in divided by the number of males with which it shares each spawning. In other words, they will have the same mating success as a female if they spawn with as many females as there are members of their IP male group.

Individuals on large reefs don't improve their reproductive success by becoming TP males. One wonders why they bother to change sex at all on large reefs but the dominance hierarchy is so firmly a part of their social system that animals rapidly fill the vacated place of a TP male.

It is interesting to note that there is a balance between success of the two types of males on reefs of different sizes. The ability of large TP males to effectively prevent small males from mating, varies among the habitats described. TP males have a large advantage on small reefs where they pair-spawn with all of the females and prevent any IP males from reproducing. On small reefs, therefore, small males have no success in mating. Hermaphrodites who produce eggs when they are small and later function as TP males will contribute the most offspring to the next generation. In this habitat, sex-changing individuals will be favoured.

On large reefs, however, group-spawning with IP males is the main method of reproduction and pair spawning is almost impossible. IP males have a reproductive advantage in this habitat. Because the two types of males have differing success rates in different habitats, they both survive within one species.

Sex-reversal in itself is not such an unusual phenomenon. Instead it appears to be commonplace for many families of fishes. It has recently been shown to occur in most wrasses, parrotfish and angelfish and in many species of gobies, damselfishes, bream, snappers and emporers. Whether social systems as complex as that of the moon-wrasse mediate sex-reversal in all of these groups awaits further research.

Gillian Eckert, Zoology Department,
University of Sydney.
Completing a Ph. D
at the One Tree Island
Field Station, north Queensland

The Depths of Port Davey

ISOLATED S.W. TASMANIA DISPLAYS HOSTILITY AND BEAUTY

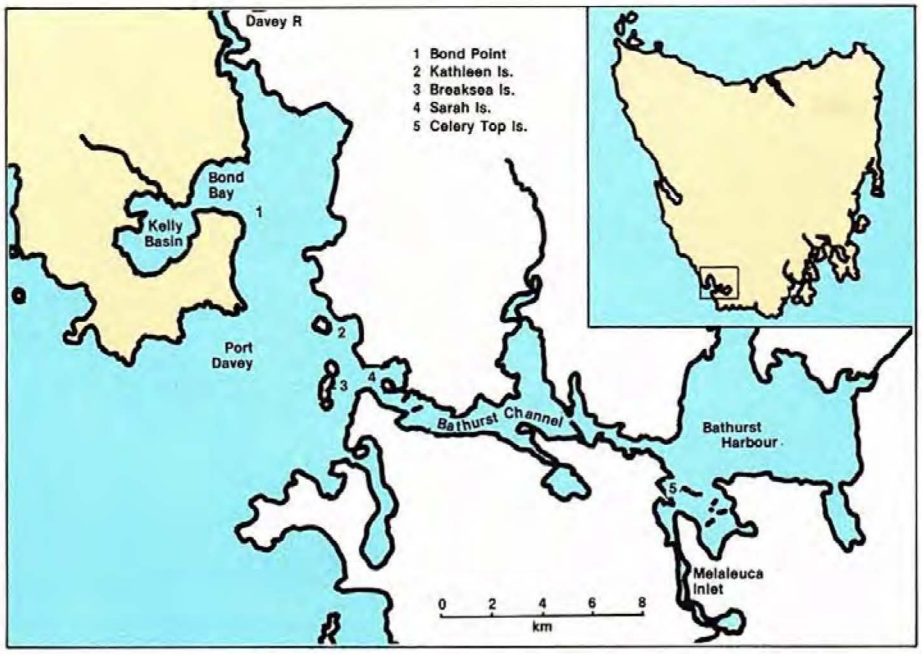
Biologist Dr Graham Edgar was contracted by the Tasmanian National Parks and Wildlife Service to investigate the potential of marine parks in southern Tasmania, and in particular, to weigh up the merits of declaring all or part of the remote Port Davey region a marine reserve. His decision was that the natural isolation of the area, the lack of fishing, and the protection afforded by South West National Park legislation precluded any immediate threats to the marine community. Read on for Dr Edgar's fascinating insights into the depths of Port Davey.

In the most inaccessible part of Tasmania, the south-west corner, lies a harbour with three unique features. Port Davey comprises the southernmost large embayment in Australia, it is the only drowned river valley which is affected by the dark, tannin-stained waters typical of buttongrass plains, and most importantly, it is the only harbour in southern Australia where marine and estuarine systems, and surrounding freshwater catchment areas, have not been greatly disturbed by humanity.

Two families of tin miners and a seasonally fluctuating number of bushwalkers and fishermen comprise the only inhabitants within a catchment area of nearly 2,000 square kilometres.

The population of Port Davey has not always been so small. A band of the south west tribe of Tasmanian Aborigines is believed to have occupied the area for most of the past 20,000 years. This band seasonally migrated as far as Cape Grim, the north-western point of Tasmania, and Recherche Bay in the south-eastern corner. In 1815 Europeans first entered the region — a short-lived voyage by Denis McCarty ending in shipwreck off Port Davey, followed by the discovery of the harbour itself by James Kelly a few weeks later. Kelly's voyage had been organised and financed by the Hobart merchant Dr Thomas Birch in the hope of finding the source of valuable huon pine logs which occasionally drifted ashore along the coast of south-eastern Tasmania. Dr Birch's efforts were rewarded with a year's concession to cut huon pine in the rich, newly-discovered forests of the Davey and Spring Rivers. Ever since, the history of Port Davey has been bound up with sagas of timber and whale exploitation.

The complete removal of the Port Davey Aborigines by 1833 coincided with an influx of piners, who established a settlement of over 50 people at the mouth of the Davey River by the early 1850s. This community was abandoned two decades later after timber supplies were exhausted. Whalers also created a settlement in Bramble Cove in the 1840s. This was short lived due to the rapid initial over-exploitation of the easily captured southern right whale



and the later decimation of the off shore sperm whale. Since 1891 when whaling ceased the only permanent occupants of the area have been miners working small tin concessions.

A complete absence of information about Port Davey marine life caused the Tasmanian Fisheries Development Authority to recently organise a five day survey of the region, with several biologists invited along, including myself.

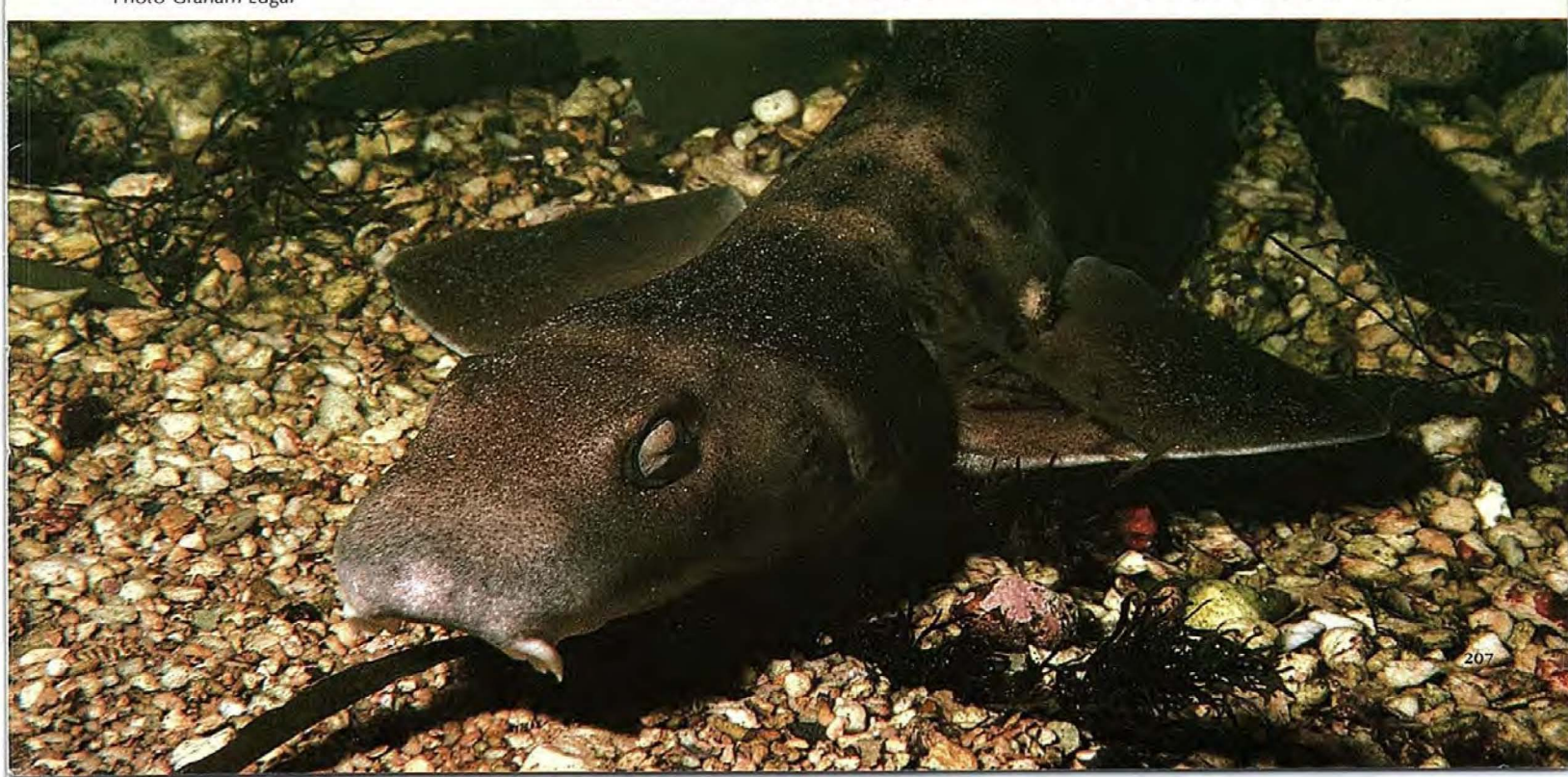
On arrival we anchored and established camp in Bramble Cove at the mouth of Bathurst Channel. Amid constantly alternating sunny skies and drizzling rain, we decided that the first survey sites would be along the western shore of Port Davey.

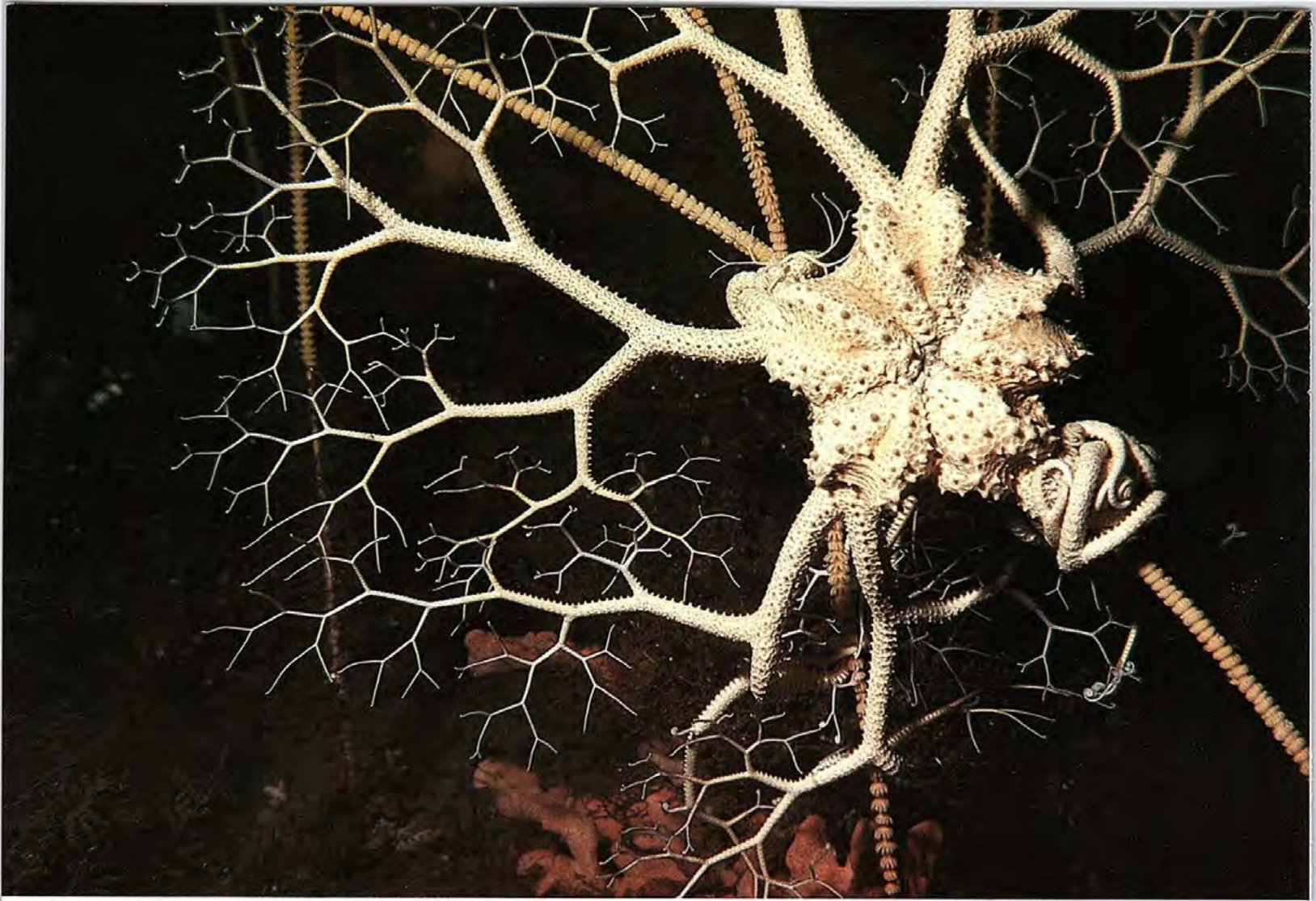
On the day after arrival we investigated the sheltered shore of Breaksea Island, which lies across the entrance of Bathurst Channel. From the dinghy the water appeared jet black, cold and unappealing. Once underwater, with the light shafting through it, the water took on an orange-brown hue. Despite my eyes taking time to adjust to the darkness at eight metres depth, the shapes of the benthic objects were immediately recognizable; they were animals not plants. Deep water species of gorgonians, seawhips, corals, sponges and bryozoans completely covered any available space. Torchlight would have revealed colours as varied, and shapes as diverse, as anything found on coral reefs. I settled down to photograph some of these creatures, taking as much care as possible to avoid crushing the delicate formations with my flippers, but immediately encountered a problem which confronts the underwater photographer all too infrequently. It was next to impossible to isolate a photographic subject from the mass of organisms.

The reason for the unusually shallow depth of this benthic community must lie in the light transmitting properties of the buttongrass water. The tannins in the water transmit the red end of the light spectrum, hence the orange-brown colouration, but absorb blue wavelengths. Conversely, seawater transmits blue and green light but absorbs red strongly. Thus, very little light of any wavelength is transmitted through water contaminated by tannins, and as algae rely on light for photosynthesis they do not extend to any great depth. Slow-growing colonial animals which are usually restricted to deeper water by competition for space can therefore move into the vacant areas generally occupied by plants at intermediate depths.

In order to map the vertical zonation of subtidal organisms, the next dive took place off Sarah Island, at the entrance to Bramble Cove, where the bottom in Bathurst Channel sloped steeply to depths exceeding 40 metres. Bull kelp *(Durvillaea potatorum)* extended to depths of two metres and the succeeding mixed algal community petered out at a depth of only four metres. Below this was a much sparser example of the colonial animal community seen at Breaksea Island. The water was now crystal clear, albeit very dark, because the buttongrass water exists in a discrete water layer less dense than seawater and does not extend far beneath the

Left: The entrance to Bathurst Channel with Breaksea Island on the right of the picture. Photo Graham Edgar
Below: The Tasmanian catshark Parascyllium *'erruginium, common at Port Davey is rare elsewhere in Tasmania, possibly as a result of gill-netting. Photo Graham Edgar*





Basket stars Conocladus australis, *contracted during the day expand their arms at night for filter feeding.*
Photo Graham Edgar

surface. At about ten metres depth the reef submerged under a layer of silt and few animals were present. A few metres deeper, convinced that I was wasting time in this barren area, I came on a sight I had never seen — an expanse of seapens *(Sarcoptilus grandis).* These feathery creatures, up to 50 cm in height, spread out to the limits of vision. They were spaced at regular intervals of about one and a half metres, and were each aligned in the same direction like a battlefield of toy soldiers. Unlike soldiers, however, they were directed towards the current, oblivious to the nudibranch mollusc *Armina,* which feeds exclusively on seapens.

Below the seapens the silt substrate sloped much more steeply and outcrops of reef reappeared. These reefs were covered by masses of pencil-thin, metre-long seawhips *(Primnoella australasiae),* many of which provided substrates themselves for basket stars *(Conocladus australis).* Somewhat surprisingly, the arms of most of these echinoderms were not extended in the night-time position for filter feeding but were largely contracted, probably a response to the slight glimmer of light penetrating from the surface.

A few days later it was decided to repeat this Sarah Island dive after nighfall. We were hoping that two species of fish collected earlier in the survey, the "living fossil" elephant shark *(Callorhynchus milii)* and an undescribed species belonging to the notothenoid (antarctic ice fish) group, might be approachable at night. There was nevertheless one fish we were hoping not to see; the three metre long, potentially dangerous, seven gilled shark *(Notorynchus cepedianus),* which was commony caught in nets set in the area.

Several species of nudibranch not seen during the day were wandering about in large numbers amongst the reef plants and animals in shallow water. Colonial animals appeared much as they did in daylight, although the polyps of gorgonians and the solitary coral *Balanophyllia bairdiana* were now extended. Fish were scarce, just as they were on the previous dive. Shortly after passing onto soft sediments I relocated the seapens which were still exposed in the same positions to the current. As I swam deeper amongst the seawhips, the environment was strangely disconcerting, particularly when a ghostly shape rising above me resolved itself as a giant kelp *(Macrocystis pyrifera),* which should not be growing from the soft substrate from which it arose. Then I found the holdfast sitting on, but not attached to, the silt. The plant had drifted in toto from elsewhere.

Night dives are not often like this but are generally completed with little fuss and little in the way of flights of imagination. The night dive at Sarah Island illustrates an unusual aspect which was common to dives in Bathurst Channel but is impossible to explain by reference to the plant and animal species present. That intangible aspect is best considered as the atmosphere of the dives. Perhaps the reason for this atmosphere relates to the thrill of exploring an unknown; perhaps it is caused by the cold, dark waters restricting the senses. Whatever the reason, the marine environment at Port Davey certainly reflected the same mixture of beauty and hostility which is found in the adjacent terrestrial environment but is lacking in more civilized lands. It is fortunate indeed that undisturbed environments such as Port Davey still exist and remain protected by their isolation.

There's a Frog in my Mouth

Amongst the rich and diverse fauna of Australia one species of frog is attracting worldwide attention. The frog is *Rheobatrachus silus*, otherwise known as the gastric brooding frog or platypus frog. It was described from the Conondale and Blackall Ranges in southeast Queensland by David Liem in 1973, and in the following year was discovered to be a gastric brooder — rearing its young in its stomach.

The stomach of *Rheobatrachus silus* is no better suited to serve as a uterus for babies than the stomach of any other animal. The stomach wall contains glands that secrete hydrochloric acid, and under normal conditions would digest material swallowed in a matter of a few minutes. However it appears that the jelly surrounding the eggs of *Rheobatrachus* contains a substance (named Prostaglandin E_2) which switches off acid production, and converts the upper half of the stomach into a transparent bag.

The eggs turn into embryos and develop slowly through a tadpole stage until they become baby frogs. At that stage the mother gives birth to them through her mouth.

When the first report of gastric brooding was published in 1974 it was treated with a mixture of incredulity and open disbelief. The habit was unique in the animal kingdom. Many people argued that the habit was impossible. Even when the first photographs of birth through the mouth were obtained and published in 1981, it was suggested that they were touched up in some way to create an elaborate hoax.

But in 1980 or 1981 *Rheobatrachus silus* disappeared without trace from its entire geographic range. Forestry, gold panning, poisoning, drought: all have been blamed as causative factors, but the reality is that the reason for the sudden demise of the species is not known. Tragically no one noticed at the time just what was happening, but a frog population that was abundant changed to a situation in which the species is very seriously endangered if not extinct.

The cause of the decline may never be known, but it is significant that the population numbers of several other forest frogs crashed simultaneously. Within areas where they were extremely abundant they are now encountered very rarely.

The gastric brooding frog Rheobatrachus silus *actually broods its young in its stomach, which its able to do because a substance in the eggs switches off acid production in the stomach. Photo Michael Tyler, from his forthcoming book "There's a Frog in my ~~Throat~~ Stomach" published by Collins.*

The demise of *R. silus* is particularly significant because an Adelaide medical research team is trying to establish just how the inhibition of gastric acid production is controlled. Such a phenomenon has substantial interest in the field of human gastric ulcer treatment. If acid production could be switched off with the speed and efficiency achieved by *Rheobatrachus* perhaps the treatment of gastric ulcers would be revolutionised.

For biologists the loss of an area of research of demonstrable potential practical application (beneficial rather than just academic) was also a tragedy.

Then in January 1984 a new species of *Rheobatrachus* was discovered in rainforest near Mackay by Michael Mahony of Macquarie University. It differs from *R. silus* in its larger size, brilliant orange-yellow markings on the undersurface, as well as features of the skeleton and chromosomes. It too broods its young in its stomach.

But the discovery in no way alleviates the demise and possible extinction of *R. silus*. It just reaffirms how poorly segments of the Australian fauna are known, and of our inability to monitor, let alone manage, vulnerable components of the fauna that we hold in trust.

Michael J. Tyler, Zoology Department, University of Adelaide, author of book
There's A Frog In My ~~Throat~~ Stomach
(published by William Collins Pty Ltd, $5.95).

The gastric brooding frog is one of the topics to be discussed at the 1984 Australasian Herpetological Conference to be held at the Australian Museum, Sydney, from 28th to 31st August. Symposium topics at the Conference include the ecological biogeography of the Australasian herpetofauna, the physiological ecology of aquatic reptiles, rare and endangered Australasian frogs and reptiles, population ecology of frogs and reptiles, husbandry and captive breeding, reproduction and development of frogs and reptiles, the phylogeny of Australasian elapid snakes, and chromosomes and evolution of Australasian frogs and reptiles.

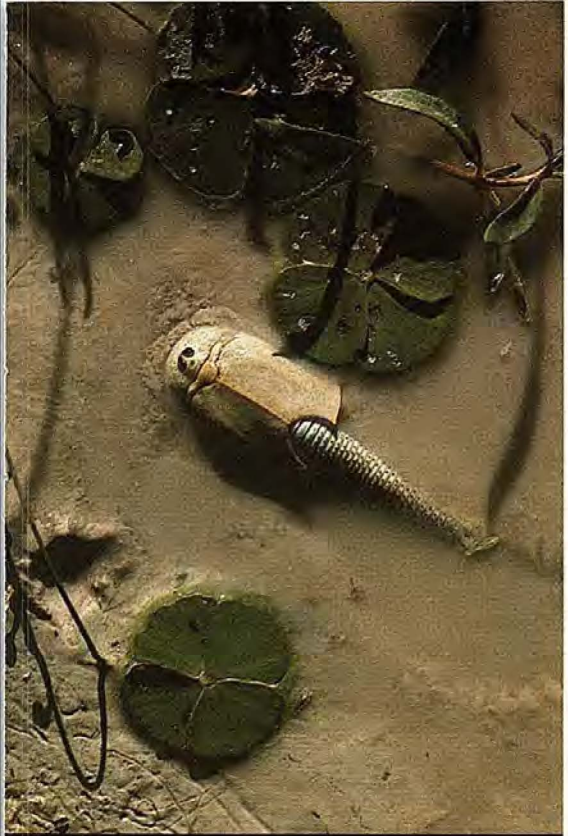
The keynote speaker will be Professor Carl Gans from the University of Michigan, an herpetological expert with a particular interest in animal mechanics.

Professional and amateur herpetologists are welcome to attend. For more information, contact The Organising Committee, 1984 Australasian Herpetological Conference, Zoology A08, University of Sydney, N.S.W. 2006.

Desert Pool Dwellers

by Pamela and David Maitland

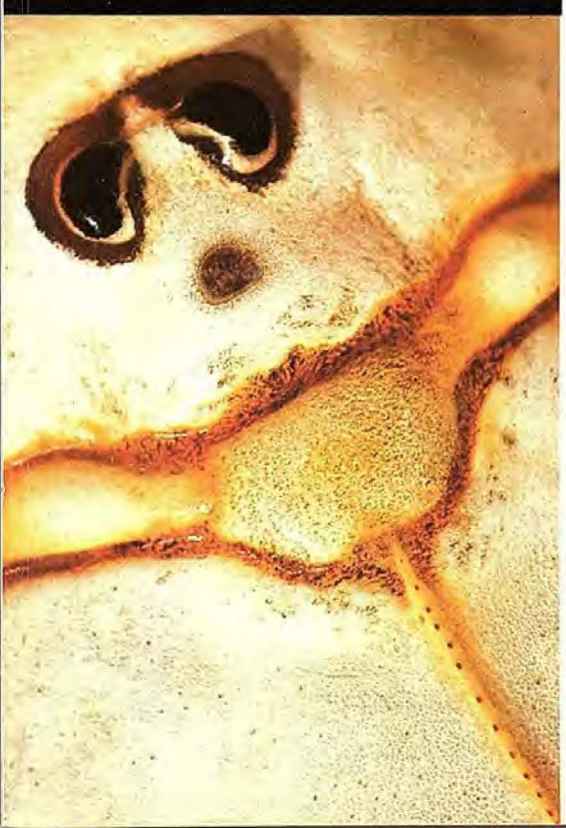
The word "ephemeral" conjures up images of ghostlike things, shimmering and glistening for a moment, then suddenly vanishing into thin air. The word is therefore well suited to describe small pools of water that are left in deserts after heavy rainfall, and which only last a few weeks before drying up in the sun. They, like ghosts, are temporary and transient.



The tadpole shrimp, Triops **at the edge of an ephemeral pool.**
Photo David Maitland.

A female fairy shrimp is red because of an increase in haemoglobin, a result of low oxygen content in the water of the pool from which she was taken.
Photo David Maitland.

The compound eyes of Triops *and the brown chitin-strengthened cuticle where the jaw muscles are attached.*
Photo David Maitland.



Australia has vast areas of desert and semidesert terrain where annual rainfall is only a few inches. When the rain does come it often falls within a couple of days, flooding the area. Most of the water disappears rapidly and soon only depressions and ditches remain, forming puddles. It is here that a whole world of animals hatch, develop, reproduce and die within three or four weeks. This is the world of ephemeral pools.

We were exploring a sheep station near Bourke in northwest New South Wales when we came across a shallow drainage ditch containing still, murky water, only a few inches deep, and teeming with life. This drought-stricken landscape had had its first rainfall for five years. A whole gamut of strange and wonderful animals; plankton, insects, insect nymphs and little pea-shaped crustaceans called clam shrimps, kept appearing and disappearing as they went about their business in the cloudy water. The clam shrimps are affectionately known as full-stops because they swim into view only to stop suddenly and disappear when they close their bivalve shells and sink.

Then we saw *Triops,* the tadpole shrimp, partially submerged in the mud at the edge of the pool with its two large eyes staring up from its surrounding shell. It looked like a small horseshoe crab (these are marine chelicerates, related to spiders) and was surprisingly large, all of three inches long, a remarkable feature considering the incredibly short length of growing time available to it.

No sooner was the tadpole shrimp discovered than another unexpectedly large crustacean was spotted. It was a fairy shrimp, two inches long and swimming legs up just beneath the surface of the water. All that could be seen of it was its numerous legs actively beating together and its forked-tip tail as it descended again into the murky water. Others were easily spotted due to the characteristic swirling currents they created as they swam just below.

The full-stops, the tadpole shrimps and the fairy shrimps all belong to one of the most primitive groups of crustaceans, the Branchiopoda:

The clam shrimp has a rounded bivalve carapace that encloses its body and numerous legs, while the fairy shrimp has none at all. The female fairy shrimp has long, flat membranous second antennae and an ovisac at the end of its thorax. The male has short stiff second antennae which are used to grasp the female.

The tadpole shrimp is the most striking, because of its size and unusual appearance. Its large, green shield-shaped carapace is attached only at the front and from it stare two large, sessile eyes. The carapace is pliable (not at all like the hard shells of crabs, for example) because it is only slightly impregnated with calcium. The jaws are strengthened however, as are the points on the carapace which anchor the jaw muscles, but these are toughened with chitin, not calcium. Projecting from underneath the carapace is a long segmented tail with a forked tip. When the animal is turned over, a large number of legs can be seen beating in perfect synchrony. Some of the legs are adapted for crawling but most are rather flattened structures, suffused with bright red blood. They serve not only a locomotive function but a respiratory one as well. The red colour is due to the presence of the respiratory pigment, haemoglobin (a similar pigment to that found in mammalian blood), which carries oxygen. In response to the decreasing availability of oxygen as the water becomes more and more stagnant, the animals produce more and more haemoglobin and their red colour deepens. Thus some individuals are dark red, while others are light pink.

The legs of all three crustaceans are important for feeding. The beating of their legs, so crucial to their breathing and movement, serves to waft particles of food along a groove running between the legs to the mouth. The ephemeral pools are formed in much the same place after each cycle of rain and drought. The dead organic material left behind when the previous pool has dried up provides abundant nutrients for a rich harvest of planktonic organisms.

Another problem facing these animals is surviving periods of drought which may last for years. The adult animals themselves cannot survive the dry spells because they are neither physiologically nor behaviorally adapted, but by developing numerous small eggs that are resistant to desiccation, they are able to survive from generation to generation. It is important that each species produces as many eggs as possible which will survive the inevitable drought.

The fairy and tadpole shrimps reach their respective sizes and are sexually mature within an incredible 20 days. In an ephemeral pool lasting only a few weeks it is likely that only one generation is present. The much smaller full-stops, however, reach maturity within a matter of days after hatching, and so several successive generations may live in a single pool. It makes one wonder what a high metabolic rate these creatures must have. Theirs is a frantic race against time.

Pamela and David Maitland are from the Department of Zoology, University of New South Wales.

Beach Invaders

SEA ROCKETS AND BEACH DAISIES THRIVE

by Petrus Heyligers

The author is a plant biogeographer with CSIRO Division of Water and Land Resources. His studies have included the interaction between native and introduced plant species and their succession on sand dunes, from aerial photographs taken over a 50 year period.

The beach daisy, *Arctotheca populifolia,* and the sea rockets, *Cakile maritima* and *C. edentula,* are all naturalised in Australia, and originally came from different parts of the globe. The beach daisy is a seashore plant from southern Africa, where it occurs from the semi-arid coast north of Cape Town to the subtropical coast of Mozambique. *Cakile maritima* is native to the shores of the Mediterranean, the Atlantic Ocean from the Strait of Gibraltar to the British Isles, and the North Sea, while *C. edentula* is indigenous to the Atlantic beaches of Canada and the United States, from the mouth of the St. Lawrence River to the outer banks of North Carolina. Specific common names for these sea rocket species don't exist and they are referred to as the European and American sea rocket, respectively.

Beach daisies and sea rockets are adapted to an environment dominated by salt-laden winds, shifting sand and intense solar radiation. Away from the upper beach and blowouts in dunes, they are poor competitors and do not present a threat to native plant communities, as is the case with boneseed, *Chrysanthemoides monilifera* in New South Wales and dune onion weed, *Trachyandra divaricata,* in Western Australia. On the contrary, because of their sand catching capacity in an environment where few native species are at home, they contribute to the early stages of dune formation, or at least to sand storage on the upper beach, and consequently play an albeit modest role in coastal protection.

SEA ROCKET HISTORY

Early botanical works do not mention beach daisies or sea rockets and the earliest known collection of a sea rocket in Australia was made in 1863 on Phillip Island, southeast of Melbourne. It was the American sea rocket, which probably had been introduced with ballast from ships of New England sealers. Ten years later a report from western Victoria mentioned that the sea rocket was spreading "through the sand down to the margin of the sea and promised to cover in a short time the whole of the sand patches on the coast".

On Kangaroo Island, the destination of the sealers, the earliest collection was made in 1881. The American sea rocket became widespread along the shores of South Australia, but it has never been collected further west than Eucla, just across the border with Western Australia. On the east coast this sea rocket was collected at Manly Beach near Sydney as early as 1870, but it was more than half a century later before it was recorded from Queensland, where in 1922 it was collected on Stradbroke Island.

In the meantime, the European sea rocket had gained a foothold in Western Australia, being collected in the summer of 1897—98 near Fremantle and Busselton. In his book on the vegetation of Western Australia, published in 1906, Diels wrote "Few plants are to be found established in the loose sand of the flat shore lines. *Cakile maritima* is usually the first to be met with". This shows that this species must have been quite wide-spread in the southwest at that time. From there it spread eastward. In 1918 it was collected in southeastern South Australia and four years later in Victoria near Melbourne. During its migration it intermingled with its American congener and within a comparatively short time of one or two decades the European sea rocket virtually replaced the other species along these sections of the coast.

The sea rocket, Cakile maritima, *a native of western European shores, is now naturalised in Australia, along with beach daisies from southern Africa.*
Photo Petrus Heyligers

The European sea rocket turned up on the South Coast of New South Wales in the early 1960s, about 40 years after its arrival in Victoria. Only on some beaches does it appear to have replaced the American species, but usually both species can be found together, albeit in various proportions of abundance.

A remarkably similar sequence of events happened along the Pacific coast of North America. No sea rockets were reported from this coast by the early explorers, but in the early 1880s the species native to the beaches of the Atlantic coast of North America appeared at San Francisco Bay and soon afterwards was reported to be common in the area. It rapidly spread, reaching British Colombia within 30 years. The migration southward was less dramatic and even today the American sea rocket does not occur south of the Mexican border. It was not until 1935 that the first collection of the European sea rocket was made on the Pacific coast, again near San Francisco. This species spread almost as fast as its predecessor, reaching British Colombia in the early 1950s, but migrated also into Mexico, where Cedros Island is its southernmost locality. By the late 1960s the American sea rocket had been virtually displaced from the Californian beaches by the European species, similar to what had happened along the southern shores of Australia about two decades earlier. However, further north, especially in Washington, the American sea rocket is still the predominant species.

And so the question arises: is the process of sea rocket species displacement still going on along the east coast of Australia as well as along the Oregon and Washington coasts of North America, or has an equilibrium been reached? Time will tell!

BEACH DAISY MIGRATIONS

The beach daisy turned up along the shores of southwestern Western Australia about 30 years after the arrival of the European sea rocket and soon became a common plant of the strandline community. The initial spread was mainly along the southern coast and Esperance was reached in 1950. However, by 1972 beach daisies were not only found on the beach of

Twilight Cove but also near Geraldton.

During the 1930s the beach daisy also appeared on the east coast of Australia and the localities of the earliest herbarium collections suggest that Newcastle was the port of entry. At present it is fairly common along the Central Coast of New South Wales and has been collected as far north as Kempsey and as far south as Dalmeny.

Between Twilight Cove and Dalmeny there is only one other known occurrence of the beach daisy, namely in a dune blowout near Coffin Bay, in the far southwest of the Eyre Peninsula, South Australia. It has never been found in Victoria, nor Queensland or the Northern Territory.

A CLOSER LOOK AT THE SEA ROCKETS

The story of these migrations leaves us with many questions. For instance, how did these species, once they had arrived on a foreign shore, manage to spread so rapidly? Why did the European sea rocket "push out" the American one? Is it likely that any of the three species will spread further? No explicit answers can be given, but a closer look at the plants and, in the case of sea rockets, results of several overseas studies, may point out some possibilities.

The European sea rocket and, to a lesser extent, the American species, vary considerably in size, branching characteristics, leaf form, flower size and fruit shape. The European sea rocket tends to be the larger of the two and to branch more profusely. Hence, it is a more efficient wind breaker and can accumulate higher mounds of sand.

As the European sea rocket has more branches and each branch carries more flowers, it has the capacity to produce many more fruits per plant than the American sea rocket. The sheer weight of numbers is often thought to be a sufficient explanation for the European species ousting its American congener from a particular beach in due time. However, other factors probably play a role as well, because the European sea rocket is not always a winner. Near ports along the east coast of the United States of America the European sea rocket may build up dense populations often mixed with the American sea rocket, the local native species, only to disappear after a few years.

No studies have as yet been undertaken to specifically compare the two sea rockets in their new territory although evidence suggests that the species differ in their life histories. Such differences could have an important bearing on survival rates during adverse events in critical periods in the life cycles. American observations show that buried seeds stay viable for about a year. Hence, there seems to be the possibility that, if a new generation is wiped out by a high flood before the fruits have matured, or much earlier, for instance in the seedling stage, a local population could be destroyed or at least seriously depleted. If there are differences between the species, and the European sea rocket has a slightly shorter growth cycle than the American species when grown in cultivation, these could have a selective advantage for one or the other of the species.

Even before having fully matured, sea rocket fruits attract various parrot species. Crimson rosellas, *Platycercus elegans,* slit open the fruit segments to gain access to the seeds and hundreds of split shells may be found under a single sea rocket 'bush'. Sea rockets are also a major food source for the orange-bellied parrot, *Neophema chrysogaster,* during its autumn migration from southern Tasmania to the salt marshes in Port Phillip Bay and southeastern South Australia.

Emus, *Dromaius novaehollandiae,* also forage on sea rockets, nipping off tops of branches, including buds, flowers and fruits. The result of this pruning is that the plants grow into very compact bushes. Not all seeds are digested by the emus and it is not unusual to find seedlings sprouting in emu pads along the beach. If some of the seeds eaten by parrots also escape digestion, then migrating birds could make a significant contribution towards long-range dispersal.

Birds, however, are only one of the agents of dispersal. When ripe, the upper fruit segments are easily dislodged and blown along the beach by wind. They may also be picked up by waves. Experiments have shown that these segments do not usually stay afloat for long, a week or two at best. However, even when submerged, the seed in the fruit remains viable for at least several months. The lower fruit segments remain attached to the branches and unless the whole plant is uprooted and washed or blown away, these provide the seeds for the next local population.

BEACH DAISIES IN FOCUS

Beach daisies have a sprawling growth habit. Seedlings grow into short plants with leaves spaced out in a rosette. When about a dozen leaves have formed stem forks the first set of flowers are produced in the axil of the fork. During the summer months flowering occurs within eleven weeks after germination. This branching is repeated when a further half dozen or so leaves form, and so on, while other branches develop from some of the leaf axils. In its way the plants may achieve a considerable spread within one growing season. In the mean time sand accumulates among the branches to a greater or lesser degree, dependent on the position of the plant in relation to other wind-retarding obstacles. If sand accumulation is heavy, a single plant may appear as a patch of rosettes. Adventitious roots grow from the buried stems. As the branches predominantly spread in horizontal directions, the mounds of sand tend to be low, but wide. This is in marked contrast with those built by sea rockets, especially the European species. As sea rockets have a more upright growth habit they accumulate rather high mounds, which have a trailing sand ridge at the lee side if there is a prevailing direction of strong winds.

After flowering the daisy heads bend over and often disappear under the leaves, only to straighten again when the fruits have matured. The fruits, 5mm long and 3mm across, are crowned with small scales and sparsely covered with hairs of varying length. Not adapted to be lifted through the air, they drop among the leaves or along the periphery of the plants, from where they can be shifted by wind and blown about on the beach. Fruits may also be transported by waves and long shore currents, as they stay afloat for three or four days. It is not known how long seeds submerged in sea water or buried in the sand remain viable, but it seems that the fruits of beach daisies and sea rockets are dispersed by wind and waves in similar ways.

SEA CURRENTS AND PLANT MIGRATION

As mentioned earlier, the fruits of beach daisies stay afloat for about four days, those of sea rockets usually up to two weeks. However, some fruits of the American sea rocket have been observed to float at least ten weeks. Submerged seeds of the sea rockets remain viable for up to three months, but longevity of beach daisy seeds is not known.

How far can a floating propagule be carried by sea currents in a limited number of days? Direct observations on fruits are lacking, but drift cards released from an oil rig in Bass Strait 23km offshore travelled up to 20km per day along the East Gippsland coast. Radio-tracked buoys off Western Australia have indicated speeds of up to 90km per day for the Leeuwin Current, while one such buoy in the Tasman Sea drifted from the latitude of Brisbane to Jervis Bay in 12 days (an average of 75km per day). These figures show that under favourable conditions fruits could be carried over considerable distances within a short time. These strong currents, however, run well out to sea, often along the margin of the continental shelf and become much weakened inshore. Moreover, for a propagule to come under the influence of these currents, it first has to be carried out to sea, while later it has to not only be thrown back onto the shore, but also encounter conditions favourable for establishment and survival.

Keeping these limitations and especially the odds against successful establishment, in mind, it is nevertheless compelling to compare the migration patterns of the beach daisy and the sea rockets, as revealed by studying the herbarium records and literature, with the sea current regimes

around the southern half of the continent.

Since the 1950s the oceans around Australia have been subject to intensive research by various Commonwealth and State organisations. The results show that the traditional current maps depicting a northerly flowing Western Australian Current and a southward-directed East Australia Current are misleading over-simplifications.

The currents in the Indian Ocean off Fremantle are very variable and appear to consist of eddies, 100km or so across, embedded in a broad, generally southward-moving water mass. From April till July the Leeuwin Current flows over the continental shelf between this eddy sytem and the coast. Originating in the tropics, it surges down the coast, probably triggered by the seasonal change in the monsoon climate, and follows the continental slope around Cape Leeuwin into the Great Australian Bight. The current is only about 20km wide and may reach speeds of nearly 4km per hour.

The West Wind Drift is the dominant force of the currents south of the continent. It flows in an easterly direction until finding the land masses of southeastern Australia in its way. When reaching the western shore of the Eyre Peninsula water is pushed northward and then westward along the shore of the Bight. Evidence of drift cards suggests that this current is also operative along the southern shores of Western Australia and that under influence of southwesterly winds it veers northward around Cape Leeuwin, only to taper off north of Fremantle.

Currents in Bass Strait are generally eastward as shown by drift cards released from oil rigs in the Strait. In the summer months, however, drift bottles released off western Victoria always float westward, presumably under the influence of prevailing winds. The eastward drift is initially maintained on entering the Tasman Sea and cards have been reported back from New Zealand, Macquarie Island and Chile, as well as from the east coast of Australia as far north as Cairns. The shortest time of a drift journey was 81 days and the card was found at Port Kembla. However no cards released from the oil rig closest to the East Gippsland coast, 23km out to sea, were reported back from the east coast — they were washed up at various beaches between Wilsons Promontory and Cape Howe, and it is presumed that none rounded Cape Howe.

The East Australian Current is a southward moving water mass near the edge of the continental shelf off southern Queensland and northern New South Wales, which may include large eddies, elongated in a north-south direction. Further south it veers away from the shelf and currents along the shelf edge become dominated by counter-clockwise flowing eddies with diameters of 200 to 300km and surface velocities of up to 8km per hour. Reverse northward flow between eddies can occur adjacent to the coast. Currents on the continental shelf are related to the currents along the edge, but are appreciably weaker.

Sea Current Flow Causes Slow Northward Migration Up East Coast Of Australia

Biologists assume that man's activities were responsible for the introduction of the beach daisy into Western Australia and New South Wales, the American sea rocket into Victoria and, possibly, New South Wales, and the European sea rocket into Western Australia, but that subsequent spread from the location of introduction was by natural means only.

Both the European sea rocket and the beach daisy first appeared on the beaches of Western Australia between Fremantle and Geographe Bay. Within a few years they became not only common in this area, but had spread along the southern shores as far east as Albany. This rapid spread seems to correlate with the occurrence of pronounced currents relatively closely inshore along this part of the coast — the Leeuwin Current during the autumn, when most fruits will be available, and a current in opposite direction during the rest of the year. The spread of both species to the north beyond Fremantle and further east along the shores of the Bight seems to have been slow and irregular. The beach daisy, collected near Esperence in 1950, 20 years after it was reported from Albany, only appears to have become common along the intervening beaches in the 1960s. As the dispersal in these directions would be largely against the prevailing current directions, it is again enticing to see here a correlation between migration rate and current regime.

About 20 years after its establishment the European sea rocket turned up in southeastern South Australia, supposedly carried straight across the Great Australian Bight by the West Wind Drift. Four years later it was also collected at Port Phillip Bay. The only known occurrence of the beach daisy on the eastern shores of the Bight is on the southwestern tip of the Eyre Peninsula. In view of the substantial population present there, the species must have arrived several years earlier; still, it is likely that at least 40 years lapsed between its establishment in Western Australia and its arrival on the Peninsula.

It is tempting to speculate that the time difference, 20 years for the sea rocket and 40 years for the beach daisy, at least to some degree reflects the differences in floating capability of their fruits. The beach daisy does not appear to have migrated further northward along the shores of the Peninsula, but both sea rocket species occur there. However, while the American sea rocket is known to occur as far west as the West Australian border, the European species does not seem to have migrated beyond Ceduna.

Any migration by off-shore currents along this part of the Bight may be hampered by the prevailing westerly and southwesterly winds, which tend to keep floating objects inshore and to lock them up in bays, which are a common feature of the very irregular coastline. This could mean that the European sea rocket is still catching up with its American congener, which — supposedly — arrived there much earlier.

Once the European sea rocket had crossed the Bight it spread along the shores of Victoria and adjacent South Australia and virtually replaced the American species which almost a century earlier had rapidly spread along these same shores in presumably much the same way. As in southwestern West Australia, the currents along these shores seasonally alternate in direction and this is likely to have promoted rapid dispersal. The fact that more than two decades lapsed before the European sea rocket was found on the beaches of New South Wales seems to be very much in line with the results of the drift card experiments — inshore currents do not round Cape Howe, while the time taken by floating objects to reach the east coast of the continent when carried by currents further off-shore is too long for the fruits to stay afloat.

It appears that the migration northward along the east coast of both the American sea rocket and beach daisy was rather slow, which could be due to the generally southward flow of the sea currents along this section of the coast. It took a decade for the beach daisy to spread southward along the central coast of New South Wales, another ten years to reach Jervis Bay and considerably longer to arrive at its present southernmost locality on the south coast. Meanwhile, the northward progress of the European sea rocket along this coast has been slow as well. As a result, migration rates along the central and south coast are markedly less than in southwestern Western Australia or along the Victorian coast, but comparable to those along the southern shore of Western Australia. It is possibly the result of a predominance of local inshore currents and wind regimes on dispersal, as the currents associated with the eddies off southern New South Wales are weak near the coast and vary in their direction.

Books

Reliving Krakatau: The Loudest Noise in Recorded History

KRAKATAU 1883 : The Volcanic Eruption And Its Effects
T. Simkin and R. Fiske
Smithsonian Institution Press
464 pages, paper $24.00.

Two Smithsonian volcanologists Tom Simkin and Richard Fiske (the latter also the Director of the American National Museum of Natural History) have compiled this source book on the 100th anniversary of the eruption of Krakatau. This volcanic eruption was the first stupendous event to occur after Europe was wired to Asia and North America with underwater telegraph cables.

The Krakatau eruption ejected four cubic miles of material, killed approximately 36,000 people and produced the loudest noise in recorded history, the main blast having been heard in Burma, South Australia and Rodriquez Island, 2,892 miles away in the Indian Ocean. News could travel quickly and the effects of the explosion in the oceans and atmosphere could be studied as they happened. Dutch and English scientists especially, prepared massive reports, and eye-witness accounts were assiduously collected.

Paradoxically however, much of that original information remains scattered in libraries and scientific institutions. *Krakatau 1883* brings together eye-witness accounts from survivors in Java and Sumatra as well as from seven ships in the Sunda Straits at the time and presents a monograph from a Dutch mining engineer, Rogier Verbeek, published less than two years after the event.

This account begins with the telegrams sent from Batavia (Jakarta) to Singapore. "Anjier, Tjeringin and Telok Betong destroyed". "Light houses, Straits Sunda disappeared". "Where once Mount Krakatau stood the sea now plays".

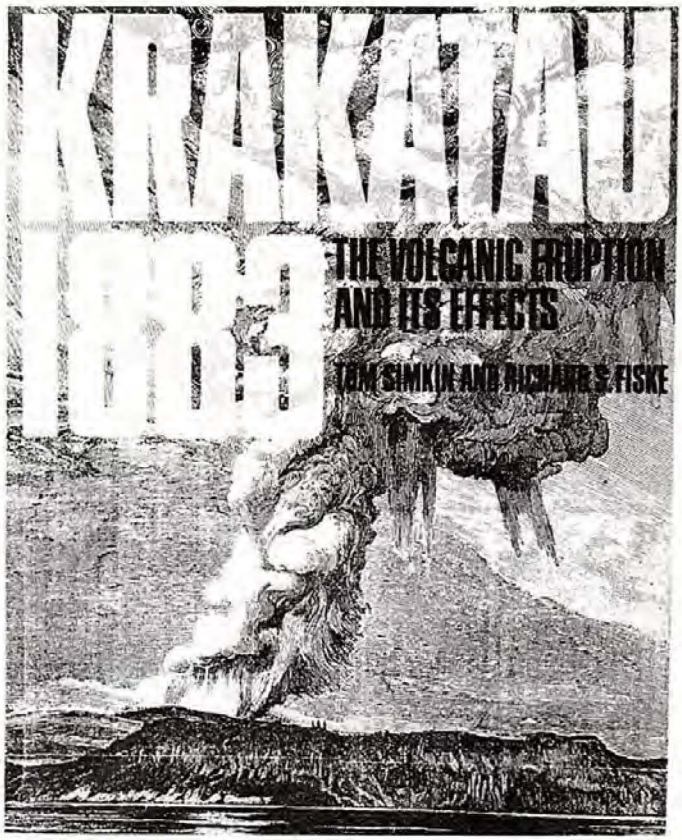
The human stories outdo anything Hollywood has come up with in disaster films. Most of the victims were overrun by Tsunamis, as high as 130 feet, that washed as far as five miles inland and then retreated, carrying the bodies of the drowned out to sea. Some were burned to death by the hot ash and rock that had been molten until it exploded upward and solidified on contact with the air. For 100 pages we read the first hand accounts of people running for the hills as the waves destroy everything on the coast. Sailors risk death to shovel tons of hot ash off the decks before the ship sinks. The water is choked with a tangle of trees, human bodies and pumice.

One report tape recorded in 1946 the recollections of a man who was an 11 year old on his father's ship near Sunda Straits when Krakatau blew.

Some reports come from places far from Indonesia. The air wave set off by the largest blast was recorded on every barograph in the world. Spreading out in all directions, the wave met itself on the opposite side of the world and bounced back to its origin. Here it rebounded outwards again so that some barographs recorded the wave seven times as it bounced back and forth between Krakatau and its antipode. Tsunamis reached Adin, 4,400 miles away, 12 hours after the blast. Rafts of floating pumice washed up in Africa and Melanesia many months later. Volcanic dust ascended high in the atmosphere and spread to higher latitudes causing intense sunsets around the world for many months. The fine particles filtered out enough sunlight to lower the global temperature by approximately one degree for a number of years.

Krakatau is an important milestone in the study of volcanoes, write the authors. It led to the understanding of caldera, the large circular depressions left by some volcanoes. Biologists learnt about how life recolonized devastated areas and how alien species were delivered on the floating islands of pumice to the shores of Africa.

The final section provides a sampling of scientific papers on the eruption from 1884 to

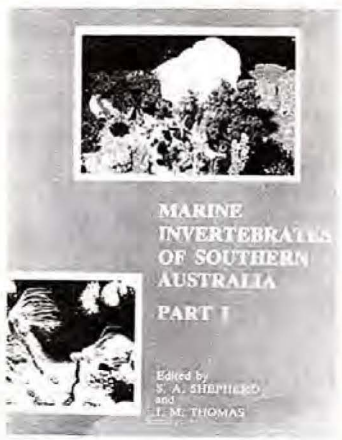


1982, showing how the interpretation and understanding of the event has changed over the years. The book has been written for the serious student of volcanology but the interested layperson will find much of interest especially in the eyewitness accounts of the survivors.

— Max Dingle

Marine Invertebrates of South Australia

Marine Invertebrates of Southern Australia Part 1
Edited by S. A. Shepherd and I. M. Thomas.
South Australian Government Printer
491 pages 32 colour plates. Text figures and B/W photographs. $17.00 and $21.00 on plastic paper.



This long overdue book is a most welcome addition to the list of handbooks on the flora and fauna of South Australia.

After a first chapter giving a general introduction to the marine environment, there follows a very useful chapter illustrated with simple food webs and giving the types of feeding utilised by invertebrates in the various habitats, such as sandy and rocky open coasts and sheltered bays and inlets.

The following chapters cover eight of the major marine phyla commonly found along the South Australian coast. Each phylum is dealt with by an authority on the subject. Each chapter has a key to the various orders of the phylum, and in some instances there is also a key to families and even to species. A comprehensive glossary and selected bibliography are given at the end of each chapter. Clear text figures throughout the book illustrate some of the more im-

portant features necessary for identification.

There is a certain imbalance in the various chapters, some being dealt with much more fully than others. However, this would appear to reflect the relative abundance of populations and paucity of information of the group in South Australia, together with difficulty in field collection and preservation, rather than omissions on the part of an author.

Colour plates are most helpful, sometimes almost essential, for easy identification of marine invertebrates by the non-specialist, and the greater number of plates appearing in the book will prove to be very useful. The reproduction, unfortunately, is not always sharp and clear, especially in the case of small species which are often extremely difficult to photograph.

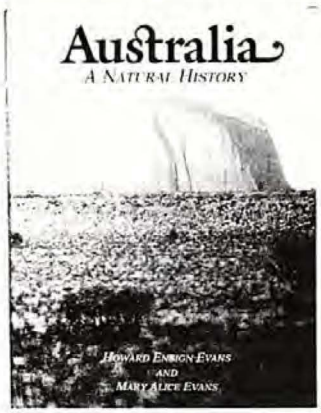
Undoubtedly this book will prove to be a most valuable reference for students and all those interested in the invertebrate animals of the seashore. The various authors have contributed information previously unknown or scattered in journals, and the editors are to be congratulated on bringing together, for the first time, the most important information known to date about these groups of animals. Theirs has been not only a tremendous task, but obviously a labour of love, based both on their own work and knowledge, and on their intense interest in marine animals.

— Isobel Bennett.

Oz Through American Eyes

Australia : A Natural History

H. E. Evans and M. A. Evans, Smithsonian Institution Press 208 pages, cloth $45.00, paper $25.00.



A wide ranging book which tries to capture the essence of Australia's history, climate, geography, flora and fauna. The authors, Howard Evans, an entomologist from Colorado State University and Mary Evans, from the same institution, in their words "ardent australophiles", have made three lengthy trips to Australia over a ten year span. (Their particular objects of study were Bembix sand wasps).

They write with enthusiasm and it is easy to enjoy their anecdotes, adventures and descriptions of Australia and its denizens, but let the Australian chauvinist beware it is written by Americans for the American market. Perhaps it was unfortunate I was confronted, on the first random opening, with a page describing the wombat as a "priceless novelty" reminiscent of the marmot or woodchuck of North America. There was some redemption in the lamenting of the lack of recognition of the wombat, accorded to koalas and kangaroos in advertising, and on coins and stamps. (One facet of Australian culture was missed by our intrepid authors, and that is the television soap opera, a "Country Practice".) Apart from the tendency to lapse into a "Disney" description of the occasional animal or town, the underlying attitude of the authors can be summed up in the following quotes.

"When the 'yanks' arrived, they came as saviours, bringing men, supplies and technical capabilities to build defences." "Currently, American satellite tracking stations dot the landscape here and there and there is almost daily talk of increased American Military presence in Australia". "(and yes, there are Pizza Huts, McDonalds and Kentucky Fried Chicken establishments.)"

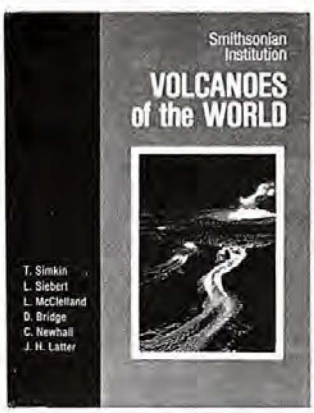
The book is well researched and the author's rave, judging from the quotes in the text and the extensive bibliography, reaches far and wide in their exploration of the subject. From the poetry of Judith Wright to the more obvious Hal Cogger's *Reptiles and Amphibians of Australia*. Patrick White is mentioned in the text, but not quoted, while James McCauley is quoted in the text but not mentioned in the bibliography.

Two criticisms I have are of captions to photographs, in all likelihood not the fault of the authors, the first being the transposing of two captions, so that the lace monitor on page 89 is a bearded dragon and the dragon on page 90 becomes a lace monitor. (A very easy mistake in the preparation of a book as can be seen in the recent *Complete Book of Australian Mammals* where the photographs of the leopard seal and the weddell seal have been transposed).

The other is a photograph of a flock of ibisis, captioned as being white ibisis, which, in fact, are straw necked ibisis. I hesitate in mentioning this last photograph as it is credited to the Australian Information Service!

In summation, an adequate introduction to the Australian continent, it's history, environment and flora and fauna, for an American reader with little or no knowledge of the subject.

— Max Dingle



Volcanoes of the World

T. Simkin et al
Smithsonian Institution Press
232 pages $35.00

Not for the general reader, this title presents computer generated tables of data designed to provide volcanologists with geographic, historic and volcanologic information on the world's volcanoes. The first 30 pages provide an explanation of the computer formt data tables and the balance of the book is in four sections. A directory of geographic data, morphology, activity status and known eruptive history of 1,353 volcanoes.

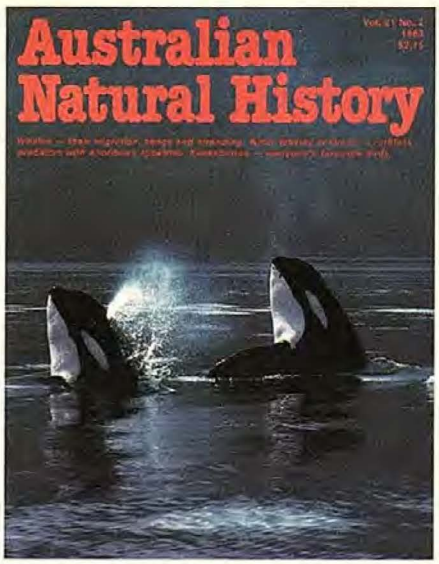
It includes a documentation of 5,564 eruptions in chronological sequence including, if known, start, duration, volcanoe name and subregion name. This displays all volcanism known to have taken place. Also there is a gazetteer of 5,342 volcanoe names and a bibliography of source documents.

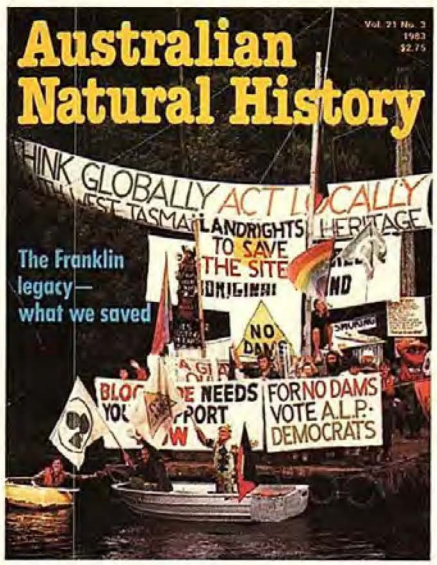
Read the Natural Authority

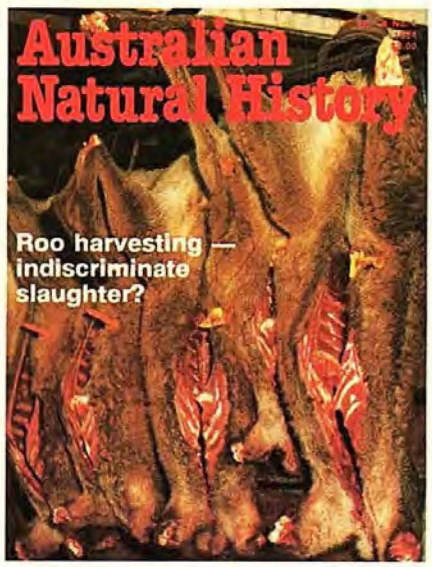
Vol. 21 No. 2. This issue of *Australian Natural History* (a whale mini-special) concentrates on some of the peculiarities of whales in Australian waters. As well as covering whale stranding, intelligence (are they really smarter than man?) and migration, the mini-special explores the mysteries of whales' enchanting songs and deals with that most famous of all cetaceans, the Killer Whale or Orca. There are also articles on the Kookaburra, a bird which has come to epitomise the Australian bush prehistoric animals of Australia, Sydney's famous Grey-headed Fruit Bat colony and the Middleton and Elizabeth Reefs — Australia's lonely atolls.'

Vol. 21 No. 3. In March, 1981, a small party of archaeologists from the Tasmanian National Parks and Wildlife Service and Australian National University's Department of Prehistory returned to a cave, then known as F34 or Fraser Cave. Intensive investigation revealed it to be one of the most important discoveries ever made of man's earliest history. This discovery, together with South West Tasmania's wild and beautiful landscape, catalysed the campaign to save the Franklin. This issue of the magazine looks at South West Tasmania, examining just what was saved and what the artefacts tell us about the lives of the people who lived in the region all those thousands of years ago.

Vol. 21 No. 4. Conservation groups are waging a campaign to stop kangaroo harvesting in Australia. Viewed as senseless slaughter that will wipe out Australia's best known mammal, kangaroo protectionists have been agressively waging this campaign against Federal and State Governments as well as the specialist scientists they employ. As a result, emotional and misleading statements such as "leading us along a path similar to that traversed by the American buffalo," and "killing a kangaroo every ten seconds: is our national conscience extinct?" have been widely reported.
In Australian Natural History, Professor Gordon Grigg reveals why kangaroo harvesting is NOT a threat to the survival of the species and outlines an objective rather than emotional approach to the kangaroo question. Also, Dr Harry Recher, one of Australia's leading ecologists, asks the question: "just how well are our diminishing forests being managed?" Come within striking distance of one of the insect world's fiercest predators, the praying mantis. Meet the remarkable and endangered malleefowl, as well as the manta or "devil" ray, the mysterious caped monster of the sea.







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All the more reason to subscribe to the Natural Authority

Australian Natural History

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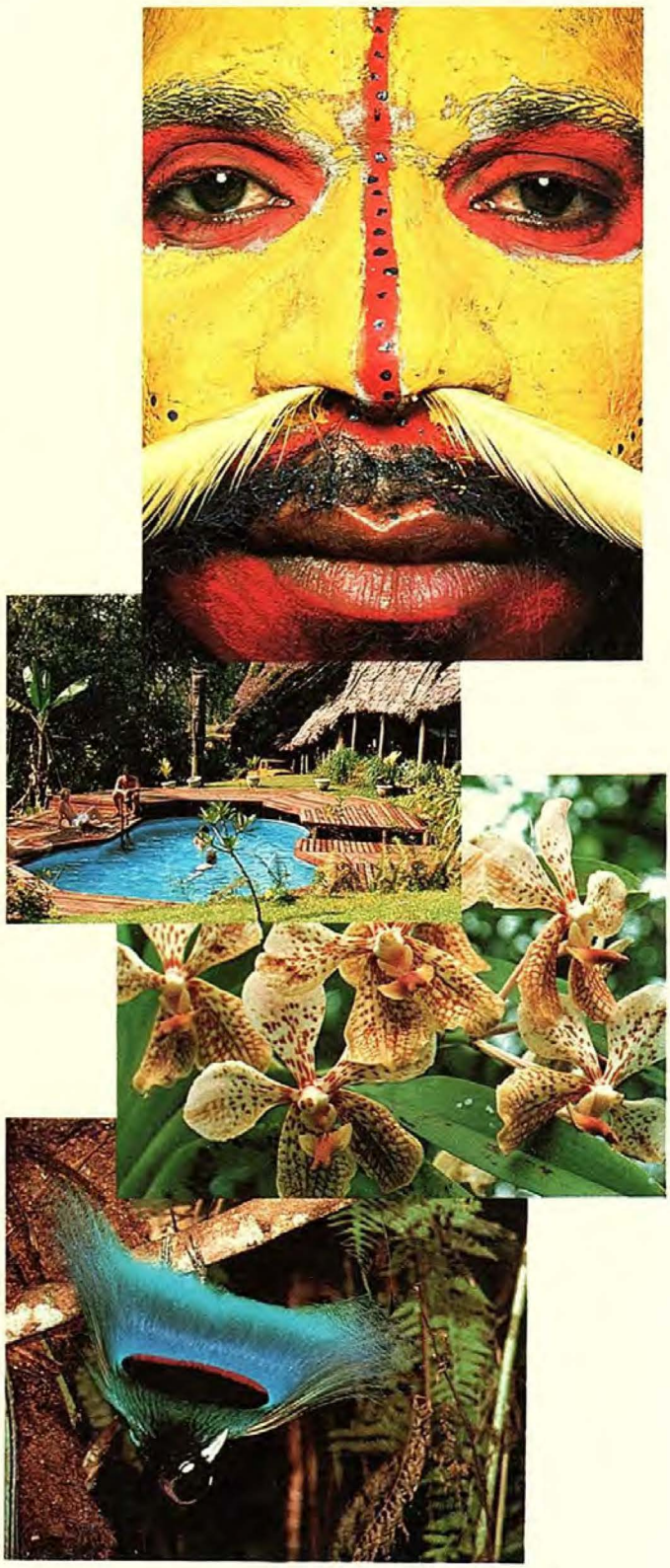

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