Vol. 17 No. 4 DECEMBER 1971

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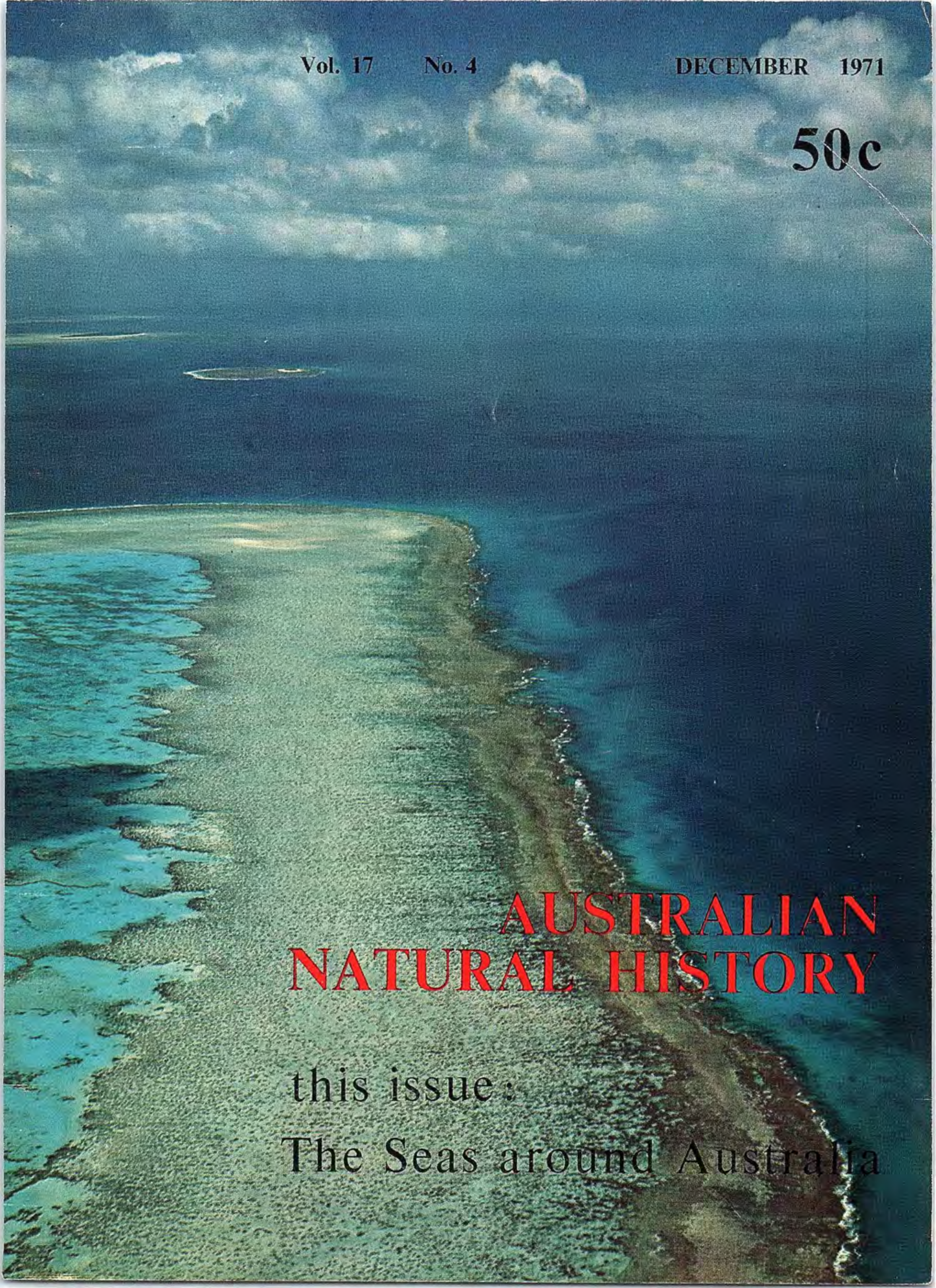

AUSTRALIAN NATURAL HISTORY

this issue:

The Seas around Australia

AUSTRALIAN NATURAL HISTORY

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This issue is devoted to the natural history of the seas around Australia. It contains 20 extra pages.

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● FRONT COVER: An aerial photo of part of the Capricorn Group, Great Barrier Reef, Queensland, showing coral reef edge and a lagoon in the foreground, coral cays in the distance, and the ocean at right. The Capricorn Group of islands is off Gladstone. [Photo.: Keith Gillett.] BACK COVER: BHP and Esso's Halibut platform, in Bass Strait, off the coast of Gippsland, Victoria, during development drilling. The platform is about 40 miles offshore and in 241 feet of water. The Halibut oilfield contains an estimated 440 million barrels of recoverable oil. An article on petroleum beneath the sea-floor appears on page 113. [Photo: BHP Oil and Gas Division.]

Live-bait pole-fishing for Southern Bluefin Tuna off the south coast of New South Wales. [Photo: Australian News and Information Bureau.]

Australian Commercial Fisheries

By PETER C. POWNALL
Editor of "Australian Fisheries", Canberra, A.C.T.

FISHING was a major pursuit of Australia's original inhabitants, the Aborigines, who fashioned simple hooks from bone, and spears from wood, and erected barriers or traps by rivers and lakes and along the seashores, to catch fish for food.

Today fishing in Australia is an important commercial enterprise which is earning millions of dollars in export income and provides a livelihood for more than 16,000 fishermen and several thousands more people associated with the industry. More than 9,000 fishing boats of all sizes, up to ocean-going trawlers, fish the waters around our 12,446-mile coast. They catch about 92,000 metric tons of fish a year, which is small when compared with that of Peru, the world's top fishing nation. Its annual catch is more than 8 million metric tons, although most of it is anchovy, which is made into fish meal and is fed to animals and poultry and not to humans.

The Australian continent is surrounded by some of the world's largest oceans, but no rich ocean currents, like those which give rise to the huge Peruvian anchovy fishery, impinge our shores. Also, our continental shelf is not as extensive and the range of commercial fish caught on it is not nearly as wide as is the case off other large land masses, particularly in the Northern Hemisphere, where cod, herring, haddock, and flatfish make a big proportion of the catch.

More than 2,000 species of fish have been

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Laying batten rock-lobster pots in the shallows off North Island in the Abrolhos group, Western Australia. The deckhand is using a glass-bottomed plastic bucket to locate a suitable spot to set a pot. [Photo: Australian News and Information Bureau.]

recorded from Australian waters, but fewer than 10 per cent of these are of commercial value to fishermen.

There is only one native fish of the salmon group caught in Australia. This is the Tasmanian whitebait, and it has diminished to insignificant proportions in recent years. (The so-called Australian salmon is a perch.) In the cod group, Australia has only small quantities of two species of minor importance. There is a total lack of ganoids—the group which includes the sturgeon. Of the teleostean flatfishes, Australia possesses commercial quantities of only small flounders and soles, whereas in the Northern Hemisphere large flatfishes, such as the Pacific halibut, grow to 200 pounds and the Atlantic halibut to 700 pounds.

Despite these limiting factors, Australian commercial fishermen have more than doubled their total catch in the past 10 years and the value of production to them rose to a record $63 million in the 1969–70 fiscal year. The most spectacular growth has been in fisheries based on exports. These include the rock lobster, prawn, abalone, and scallop fisheries, which are the backbone of the Australian fishing industry. (Though the word "fisheries" is used, lobsters and prawns are crustaceans, not fish, and abalone and scallops are molluscs.) In 1970–71 exports of these products were worth $60 million—more than treble their value 10 years ago—placing Australia among the top dozen fish exporting nations in the world.

Rock lobsters

Nine species of rock lobsters are found in Australian waters, and four of them are fished commercially. They are (in order of importance): Western (*Panulirus longipes cygnus*), Southern (*Jasus novaehollandiae*), Eastern (*Jasus verreauxi*), and Tropical (*Panulirus ornatus*) Rock Lobster.

Western Rock Lobster are found only in Western Australia, where they are caught over an area of about 8,000 square miles —generally within the 45-fathom line along the coastline north from Bunbury to Shark Bay and among the reefs fringing the Houtman Abrolhos islands, off Geraldton.

The Western Rock Lobster can be identified by its uniform reddish colour and continuous simple grooves across the segments of the abdomen. It feeds nocturnally and is omnivorous. During the day it shelters in crevices in limestone, sandstone, granite, or coraline reefs. It grows during the summer in a series of "moults", juveniles moulting at least five times a year. Adults moult only once or twice a year as their growth-rate slows.

The Southern Rock Lobster is found in

cooler waters of Australia. The main fishing grounds are rocky coastal waters off South Australia, Victoria, and Tasmania, and around the islands in Bass Strait. This lobster is red in colour, and has a characteristic "pavement" patterning on the abdomen.

The Eastern Rock Lobster is caught along the New South Wales coast in small numbers, and can be distinguished by its green coloration and smooth abdomen.

The Tropical Rock Lobster is found in northern Australia and in Papua-New Guinea and can be identified by its smooth abdomen, with obvious spots on the sides and a blotchy carapace. It is fished commercially by divers from Thursday Island in Torres Strait. Because it will not enter the conventional baited pot it is speared or caught by hand. The annual catch is not large.

Female lobsters mature at 3 to 4 years of age, mating taking place during the winter. Eggs are laid in the spring and are carried on the female's abdomen for about 10 weeks until the tiny larvae hatch. After release the larvae float to the surface and drift in the open ocean for a year before settling to the bottom again on inshore reefs. After 3 or 4 years they mature and move out to deeper reefs.

Large numbers of immature Western Rock Lobster on coastal reefs moult in November each year. After they shed their shell they have a light-pink appearance. During this stage they are known as "whites" and they leave the shallow on-shore reefs and move seaward. Their colour slowly deepens until the normal "red" appearance re-appears.

Big annual catch

Australia is the world's biggest producer and exporter of rock lobsters. The annual catch is between 25 and 30 million pounds, and exports are worth more than $25 million a year.

Lobster fishing in Australia dates back to last century, and until the 1940's nearly all the catch was sold locally. In 1947 the first consignment of frozen lobster tails was shipped to the U.S.A. This signalled the beginning of a spectacular period of growth for the industry, which today is Australia's most valuable fishing operation. Its prosperity is based almost entirely on exports; the U.S.A. is the main market, more than 90 per cent of exports going to that country.

Western Australia, with a fleet of 840 licensed boats, is the top rock lobster producing State in Australia, South Australia, Victoria, Tasmania, and New South Wales being next in importance.

To protect their valuable lobster fisheries all States and the Commonwealth have introduced management measures of some kind. The most comprehensive are in Western Australia, where they include a restriction on the number of boats in the fishery, the compulsory fitting of escape gaps in pots, a limit on the number of pots per boat, minimum legal lengths, and closed seasons. South Australia, Victoria, and Tasmania also have licence limitation and other regulations, similar to those in Western Australia.

Western and Southern Rock Lobster make up the bulk of the Australian catch. The Southern Rock Lobster grows to a larger size than the Western. Its average carapace length is 115 millimetres or about $4\frac{1}{2}$ inches (compared with 83 millimetres for a Western Rock Lobster), its maximum carapace length is 200 millimetres (115 millimetres), and the average tail-weight is 8 ounces (6 ounces).

The annual Western Rock Lobster catch represents about 60 per cent of total Australian lobster production, and in the past 10 years has risen as high as 21 million pounds.

The annual Southern Rock Lobster catch in Australia is about 12 million pounds.

Rock lobsters are caught in pots and traps and by hand. There are four types of pots and traps in commercial use—beehive pot, Western Australian batten pot, east coast D-shaped trap, and the east coast rectangular trap.

Prawns

Prawns have been caught along the east coast of Australia since the beginning of the century, but it is only in recent years, when profitable overseas markets have opened up, that the fishery has expanded. The fishery originally was estuarine, but oceanic fishing, which started in 1948, is continually being expanded seaward and northward into tropical waters.

Prawning spread to Western Australia in 1962, since when fishing has extended gradually northward from Shark Bay. In northern Australia, exploratory trawling in the Gulf of Carpentaria between 1963 and 1965 revealed the existence of twenty-two species of prawns, of which seven are fished commercially in other areas of Australia. In the past 5 years there has been a rush of trawlers to northern waters, which this year are expected to produce more than 20 million pounds of prawns. More recently, promising prawn grounds have been developed in South Australia.

Seven species of prawns make up the bulk of the Australian commercial catch. They are: Eastern King Prawn (*Penaeus plebejus*), School Prawn (*Metapenaeus macleayi*), Greentail or Bay Prawn (*Metapenaeus bennettae*), found in New South Wales and southern Queensland; Brown Tiger Prawn (*Penaeus esculentus*) and Banana Prawn (*Penaeus merguiensis*), fished in Queensland, northern Australia, and Western Australia; Western King Prawn (*Penaeus latisulcatus*), fished in Western Australia and South Australia, and Endeavour Prawn (*Metapenaeus endeavouri*), fished in north Queensland and northern Australia.

Australian commercial penaeids, with the exception of the inshore Greentail Prawn, are inhabitants of the open sea and spawn in offshore waters. They are present in estuarine waters for only the early part of their life-cycle and leave for ocean waters as they near maturity.

The life-cycle of prawns is short. Most species are believed to live little more than a year, but a small number of individuals could live as long as 2 years. The ultimate fate of prawns is not known. They may die after spawning, or perhaps, in their weakened condition, they fall prey to the innumerable predators in the ocean waters. Prawns are not only eaten by most marine animals, but are preferred to other foods.

King, Banana, and School Prawns are present in estuarine waters from post-larval stages in late autumn to adolescent stages the following midsummer—when they leave the estuaries and move into ocean waters to complete their growth and development. Then they congregate in dense schools on mating and prawning grounds in ocean waters. Breeding grounds of King Prawns are believed to be as deep as 50 to 70 fathoms. The School Prawn is believed to mate and spawn in ocean waters at about 30 fathoms.

Estuarine environment is believed to be most favourable for post-larval and juvenile prawns, but offshore species can complete their life-cycle in ocean waters, and some never enter estuaries.

Demersal and pelagic fish

The main commercial trawl fishery for demersal (bottom-dwelling) fish is located on the continental shelf in eastern Australia between Crowdy Bay (N.S.W.) and Lakes Entrance (Victoria). The main species caught are tiger flathead (*Neoplatycephalus richardsoni*), morwong (*Nemadactylus* species), snapper (*Chrysophrys auratus*), redfish (*Centroberyx affinis*), gurnard and latchet (*Triglidae*), John Dory (*Zeus faber*),

Sorting the catch aboard an Australian prawn trawler. This haul shows the variety of sea-bed life and "trash" fish encountered by prawners. [Photo: *Australian Fisheries*.]

The skipper of a South Australian shark boat gaffs a School Shark caught on a long line. [Photo: Australian News and Information Bureau.]

leatherjackets (*Aluteridae*), and school whiting (*Sillago bassenis*). The grounds were found between 1909 and 1915 by the Commonwealth fisheries research vessel *Endeavour*.

Fishery resources in rivers, estuaries, bays, and brackish-water lakes around the Australian coastline have been exploited for more than 100 years. It is only in comparatively recent years that operations have been extended offshore.

Gear used in the estuaries and coastal fisheries includes hand-lines, set-nets, drag-nets, gill-nets, and traps. Fish caught include bream, mullet, whiting, garfish, flathead, and tailor.

Numerous species of fish abound along the Great Barrier Reef in Queensland, and about sixty of them are caught commercially. The most popular fishing method is hand-lining, but other methods include trawling, beach seining, trolling, gill netting, potting, diving and spearing. Spanish mackerel is the most important commercial fish, annual production being about 1 million pounds. This is not a reef or demersal fish in the true sense, but it is caught near emergent reefs or above submerged reefs, both close to the mainland and near the main Barrier Reef. Other reef fish caught in commercial quantities include coral trout, sweetlip, emperor, and cod.

Pelagic (surface-swimming) and midwater fish are abundant in Australian waters. There is a substantial stock of Southern Bluefin Tuna, and it is believed to extend from the Indian Ocean south around Australia then eastward to New Zealand. They are fished commercially by pole and live-bait fishermen off southern New South Wales and in South Australia.

There are also stocks of Striped and Yellowfin Tuna in Australian waters, but these are not caught in large quantities as yet. The same applies to Jack Mackerel in southern waters.

The annual tuna catches fluctuate, according to the season, and can be as high as 6,000 tons a year.

Australia "salmon" (*Arripis trutta*) is next in importance to tuna as a commercial pelagic fish. The catch varies from 3,000 to 6,000 tons a year, and the fish are caught in beach seine nets in Victoria, Tasmania, South Australia, and Western Australia.

Shark fisheries

There are about eighty species of shark in Australian waters, and two of them—the School or Snapper Shark (*Galeorhinus australis*) and Gummy Shark (*Mustelus antarcticus*)—are the basis of a substantial commercial fishery. Both species are harmless to man, although they are related to some of the larger man-eating species.

School and Gummy Sharks, which are found along the eastern and southern seaboards of Australia and off Tasmania in water from 8 to more than 100 fathoms, grow to a length of 6 feet and are caught on long-lines and in gill-nets.

As with other sharks, the breeding habits of School and Gummy Sharks are somewhat different from those of other fish. Instead of releasing thousands of unfertilized eggs into the sea for chance fertilization, female sharks produce small numbers of eggs which are fertilized internally, and the young are born in a highly advanced state.

Tagging experiments have shown that there is only one stock of School Sharks in the southeastern Australian region, but they move freely between Tasmanian, South Australian, Victorian, and New South Wales waters.

In recent years commercial shark fishing has increased considerably in intensity in southern waters, particularly in Bass Strait, and fears have been expressed by fishermen that stocks may be depleted. Research officers in South Australia, Victoria, and Tasmania are examining the situation.

The shark fishery is Australia's fourth most important fishery, the annual catch being about 17 million pounds, worth $19 million.

Abalone and scallops

Abalone, a shellfish found on submarine reefs around Australia, is an important seafood, exports of which were worth more than $5 million in 1970–71.

Abalone has a single saucer-shaped shell and a large meaty foot, which attaches the animal and its shell to the rocks. It is this foot that is marketed. Abalone are collected by scuba and hookah divers operating from small powered boats based at ports in Victoria, Tasmania, South Australia, and Western Australia.

Fifteen species of abalone are found in Australian waters, but only four are exploited commercially. The Black-lip or Red-ear (*Notohaliotis ruber*) and the Green-lip or Mutton-fish (*Schismotis laevigata*) are the most common.

Australia is currently the second largest producer of abalone in the world, and most of its catch is canned or frozen and exported to the Far East.

Scallops of commercial importance in Australia are *Pecten alba* (found in Victoria), *Pecten meridionalis* (Tasmania), *Pecten fumata* (New South Wales), *Amusium balloti* (Queensland and Western Australia), *Amusium pleuronectes* (Western Australia), and *Chlamys asperrimus* and *Equichlamys bifrons* (Tasmania).

Tasmania and Victoria are the two leading scallop-producing States, but their fisheries have been marked by dramatic rises and falls in catches.

Scallops are dredged in New South Wales, Victoria and Tasmania and trawled in nets in Western Australia and Queensland. Most of the catch goes overseas, and in 1970–71 exports were worth more than $2 million.

For more than 100 years Australians have been drawn to the sea to catch fish, but experience has shown that, in many areas, as demand increases so do the size and number of boats in the fishing fleet. The result is that traditional grounds are often subjected to intense exploitation.

Today there is a growing realization that the sea must be harvested like the land, and fishery resources exploited in a responsible manner. To do this requires detailed research into the life-history of various fish species, and their migration patterns, while new grounds need to be explored and fishing techniques and gear improved. In the past 5 years there has been an upsurge of interest in fisheries research in Australia. Four States have established new marine laboratories, and others are planned, two large and a number of smaller fisheries research vessels have been built and funds have been set up to support research programmes. This increasing tempo is likely to continue in the 1970's.

A typical bag of game-fish off Sydney—several tuna, a marlin, and, at the extreme right, a dolphin fish (not a dolphin). [Photo: Graham Shepherd.]

Fishing for Sport

By HANK NEWMAN
President of the Amateur Fishermen's Association of New South Wales

SINCE most sport-fishing is only a matter of a baited hook and a line, it should follow that fishing methods are identical all over the world, but this is not so. Whether the difference in techniques should be attributed to the fads and fancies of anglers or to the tastes of their quarry is highly debatable; the pelagic species most certainly strike at the same artificial lures in America as they do in Africa. Even when using natural baits, there really isn't any difference between the cunjevoi of Australia and the red bait of South Africa, but since the vast majority of amateur anglers use natural baits it is surprising to find that methods vary, not only from continent to continent, but even over 100-mile stretches of coast. Australia, with its vast littoral, is a good example of this.

There is no doubt that anglers in the far north of Australia have a wealth of superb fishing at their doorsteps, from the exotic barramundi, bonefish, and tarpon, to the more common surface feeders of the tuna and billfish families. The capture of these specimens is so easy, in comparison to fishing further south, that Queenslanders, particularly, are not so fussy when it comes to bait, either natural or artificial.

Great sport on the Gulf

On a trip to Karumba, Gulf of Carpentaria, a few years ago, a party of Sydney anglers greatly amused the locals with their efforts to catch Threadfin Salmon (*Polydactylus sheridani*). To the locals these were just another fish, taken in great numbers with anything from a fillet of catfish to a slab of squid, but to us visitors they provided great sport on the light tackle used; a 15-pound fish which takes off like a kingfish, bores for the depths like a tuna, and, on surfacing, leaps to a height which would shame a trout, is indeed a worthy adversary for the most blasé fisherman. In our ignorance we stumbled on the giant prawns of the Gulf as being the best bait; indeed, we caught practically everything in the Norman River on this bait. The expensive and flashy-looking surface lures of the "killer" family were completely ignored at Karumba, both by the anglers and the fish.

The same story prevails from Cooktown to Tweed Heads, where no angler worth his salt would use a "shop bought" lure. They all make their own, except, of course, at Cairns, where a style of fishing has been developed which has put Australia on the world fishing map and where the first game fish over the 2,000-pound mark will eventually be boated. Game fishing at Cairns owes its existence almost 100 per cent to George Bransford, an American airman who was stationed there during the Second World War and who immediately saw the potential for the capture of giant Black Marlin, probably the most sought after of all game fish. When catches of Black Marlin of 1,000 pounds and over became quite commonplace, Cairns became the visiting ground of many experienced, and wealthy, American anglers, who, of course, usually brought their own tackle to Cairns. The results have been many new Australian records and three world records, the best of these undoubtedly being Ed Seay's 1,124-pound Black Marlin on a line of 50-pound breaking strain. Bigger fish, some of them well over that elusive 2,000-pound mark, have been lost, but this type of fishing is not the only attraction Cairns, indeed the whole of the Barrier Reef area, has to offer. Cobia, dolphin, barracuda, sailfish, tuna, and sharks are present in profusion and can be caught on light gear from small boats within the reef.

Voracious tailor

From the southern part of Queensland right down to South Australia fishing techniques vary again, the Queenslanders in the main staying with their side-cast reels and rangoon rods and catching huge bags of tailor (*Pomatomus saltatrix*) from the shore. Indeed, the tailor is a world-famous light-tackle fish, known in America as the bluefish and in South Africa as elft or shad; it is so prevalent as to be both the small boy's delight and the tyro's main catch. I wonder how many anglers started their fishing careers on tailor. In the underwater war of eat or be eaten, the tailor is a fish which will slash at anything which moves, long after its voracious appetite has been assuaged. This is a fish which seems to like killing just for the hell of it; consequently, when a shoal moves within reach of the angler, huge catches are the order of the day. Whether the bait

The author with a snapper caught off Long Reef, near Sydney. [Photo: Vincent Young.]

is the time-honoured garfish or an artificial lure doesn't seem to matter. The small boy experiencing the powerful run of his first "real" fish cannot be more excited than I was on hooking my first elft many years ago in one of the few tidal estuaries on the South African coast.

Further south fishing techniques change again, and the angler fishing for luderick (*Girella tricuspidata*) in New South Wales, with his extremely delicate tackle, need stand back for no trout-fishing purist, for here is fishing ability at its best. With a main line seldom more than 6-pound breaking strain, a centre-pin reel, and a long, very flexible rod (a cross between a fly and salmon rod), and terminal tackle consisting of a very light float, a small split shot and a tiny No. 10 hook baited with a morsel of weed, every fish becomes an adventure. Since most luderick fishing is done in the vicinity of cunje and barnacle covered reefs, the odds are heavily weighted in the fish's favour.

With the luderick is usually found the Silver Drummer (*Kyphosus sydneyanus*), and, when one of these 10-pound to 15-pound whoppers grabs at a bait intended for the smaller and not so burly luderick, the result is inevitably a smashed line. It is not surprising, therefore, that the Australian angler, with typical Aussie expressiveness, has dubbed the drummer "pig". Why a fish which grows to 20-pounds should be so maligned and a fish which does not average much more than about a pound should be sought after is beyond me, but that's the fisherman for you. They say you don't have to be mad to be a fisherman, but it helps!

Outstanding sporting fish

Without doubt the most outstanding sporting fish on the east coast of Australia is the salmon (*Arripis trutta*). It is not a salmon at all—in fact it is not even vaguely related to the true sea-run salmon—but it is a fish which really separates the men from the boys. If these fish grew to 50 pounds they would never be landed; in fact I heard one angler comment that they would probably leap from the water, tear your arms out at the shoulders, and beat you to death! A poor eating fish perhaps, but, pound for pound, it has no equal as a fish

The author with a Lord Howe Island kingfish. [Photo: Don Fleming.]

which never knows when it is beaten. Fisheries boffins maintain that there are two distinct colonies of salmon—the one found mainly in Western Australia, the other extending over most of the eastern Australian seaboard. Be that as it may, our salmon and the kahawai of New Zealand are not only a most spectacular sporting fish, but, as they will strike at practically any bait or lure, a sophisticated approach is not necessary to catch them. As a matter of fact, a strip of coloured cloth on a bare hook is usually sufficient to bring them into a feeding frenzy. On the many occasions when shoals of salmon are sighted but will not bite, the use of a diving board or some other paravane system of getting the lure to run a bit deeper will overcome their natural suspicion and they will strike savagely.

Lord Howe Island

Discussion of salmon leads inevitably to memories of Lord Howe Island. Although geographically 430 miles northeast of Sydney, it is still politically part of New South Wales, and with its crystal-clear, unpolluted water it provides fishing the like of which I have not seen anywhere in the world. Very large salmon are caught there, most of them ignominiously hauled aboard on 200-pound handlines, and a lot more would be caught if the Yellowtail Kingfish (*Regificola grandis*) were not first at the bait. Lord Howe Island is a popular resort for honeymoon couples, many of whom fish there for the first (and usually the last) time. Fishing is very simple and huge bags would be the order of the day if there were a greater demand on the island for fish for eating. As it is, an empty 44-gallon drum serves as a repository for the catch; when the drum is full enough fish have been caught, and I have seen five anglers fill a drum in 20 minutes. The technique is to troll, usually with a scraggy-looking piece of squid, until a kingfish strikes at the bait. The boat is stopped immediately, the fish is held in the water, and the rest of the school follow up until anglers on the boat can just drop a bait down the nearest throat. When the shoal disappears trolling is resumed until another fish takes a bait, when the process is repeated.

Were it not for the usually very shallow water around Lord Howe Island every record in the book would be beaten, for, underneath the school kingfish of 4 to 12 pounds, can be seen the giant "greenbacks" of 100 pounds and up. When these monsters are hooked, usually on a small live kingfish, they dive straight for the bottom and saw off the line, 200 pounds breaking strain regardless, on the nearest reef. Nevertheless, by brute strength and a fair amount of luck, several kingfish over the 100-pound mark have already been caught at Lord Howe Island.

Fishing in Western Australia

The best sport-fishing in Australia is undoubtedly on the west coast. Quite apart from the variety of fish there, there are not huge metropolitan concentrations resulting in shoulder-to-shoulder fishing conditions. The further north one travels from Perth the larger are the fish which are encountered, and boat fishermen, particularly, can expect to catch Spanish mackerel, mulloway, sailfish, marlin, salmon, tailor, dolphin—in fact, the whole gamut of the world's most prized game fish. In view of our very limited knowledge of a fish's reasoning power, I would hesitate to say that fish get used to baits, etc., and that where little fishing is done results are ipso facto better, but there is no doubt that our highly-populated and largely over-polluted eastern seaboard does not provide recreational fishing anywhere as good as western fishing spots which are off the beaten track. Perhaps in my own advancing years I like my fishing easy, and there is hardly any fishing spot on this great continent which does not provide this.

FURTHER READING

Big Fish and Blue Water, by Peter Goadby, published by Angus and Robertson, 1970.

Fish and Fisheries of Australia, by T. C. Roughley, published by Angus and Robertson, 1953–61.

The Family Fisherman, by Vic McCristal, published by K. G. Murray, 1969.

Sea Anglers' Fishes of Australia, by Arthur Parrott, published by Hodder and Stoughton, 1959.

Guide to Fishes, by E. M. Grant, published by the Department of Harbours and Marine, Queensland, 1965.

BOOK REVIEW

WILDFLOWERS OF WESTERN AUSTRALIA; WILDFLOWERS OF THE EAST COAST; WILDFLOWERS OF THE NORTH & CENTRE; all by Michael and Irene Morcombe. Periwinkle Colour Series, Lansdowne Press, 1970; $1.50 each.

These little books are in essence a breakdown into individual regions of Morcombe's larger work, *Wildflowers of Australia*, which dealt with the flora of the continent on a six-region basis. Not all of the colour plates are the same as in the larger work, though they display the same master hand and are of the same superb quality. About eighty species are illustrated per book. The text consists principally of a chapter, identical in each book, written for students and contributed by Dr John Child, describing the structure of flowers and fruits, the principles of taxonomic classification and of the identification of plants, and giving a diagram of the plant kingdom, descriptions of inflorescences, fruits and leaves, and a brief outline of vegetation types. The student is thus given all the basis he needs for identification of flowers found in the field, and, having read thus far, may imagine that he is all ready to do this with the aid of keys, etc., in the rest of the book. But no! He is told that "the simplest and surest way to identify a plant is to consult a government herbarium or professional botanist". The remainder of the volume is just another picture book. Too bad. In most regions of Australia it is regrettable how little information is available to the amateur to enable him to identify native plant species.—*J. S. Beard*, *Royal Botanic Gardens and National Herbarium*, *Sydney*.

A geologist sampling rocks on the sea floor, at a depth of about 120 feet, off Kangaroo Island, South Australia. [Photo: John Mitchell.]

MINERAL RESOURCES OF THE CONTINENTAL SHELVES

By REG. C. SPRIGG
Geosurveys of Australia Pty Ltd, Adelaide, South Australia

AUSTRALIA'S continental shelves, by and large, have evolved since Middle Mesozoic geological times. That is, a new and dominating phase in the outgrowth of the continental margins by primarily sedimentary processes developed in consequence of the final breaking-up of Gondwanaland (the Great South Continent) about 150–160 million years ago. Australia separated away from Antarctica, lying to the south, leaving a widening chasm that left steep rift-like continental slopes on its south margin. In addition, to the northwest and west India and Madagascar and, more distantly, Africa separated off, also with steep sub-sea breaks that tended to follow earlier lines of weakness and trough formations that dated back into the Permian (about 250 million years ago) and even earlier.

The ancient "neo-Australian" coasts of Gondwanaland were those of the north (actually within Papua) and eastern Australia, except for a missing slice in the extreme southeast that is now part of New Zealand.

As Australia migrated to the northeast away from Antarctica, successions of younger Mesozoic and Tertiary sea floors were in turn pushed up in a series of mountain and extensive sub-sea island arcs. Mostly these disturbed zones of folded sea floor are the sites of extensive volcanic outpourings, and exclusively lie beyond the coast of what is now continental Australia.

All of this may seem a long way from the consideration of sub-sea mineral resources, but it is not. The modern geologist can, in fact, deduce much from this history, particularly as to the petroleum prospects, and the age, nature, and mineral potential of deeper sediments likely to be encountered in exploration.

Sediment types of continental shelves and slopes

Practically the whole of the Australian continental shelves and slopes are made up of relatively young sediments. Older "hard" rocks, such as granitic or metamorphosed ("schistose" or indurated) bedrock, rarely occur except in nearer-shore situations or linking to Papua. Ancient consolidated sediments (about 700 to 1,000 million years old) do persist short distances seaward in the submarine outcrops of the Kimberlies, Arnhemland, southwestern Australia, and Eyre Peninsula, and it is about the latter only that sea-floor hard-rock mineral concentrations have been found (e.g., the scheelite deposits of Reevesby Island in the Sir Joseph Verco Group, South Australia).

The southern continental shelf is dominantly one of calcareous shelly sediments—coarse shell sands—near shore, becoming finer towards the shelf edge where coarse bryozoal and solitary corals with coarse shell fragments come to dominate again. Over the shelf edge, fine calcareous silts grade into more muddy silts reaching extreme depths.

Sediments of Bass Strait and about Tasmania are more variable in composition, and below 20 fathoms large areas of the sea bed are covered by carbonate sands and gravels derived from skeletal parts of marine organisms. Quartz sands, some carrying tin values, occur in shallower zones, particularly opposite the mouths of the more energetic rivers.

Much of the southwestern sea floor of Western Australia is dominated by calcareous dune sands similar to the southern Australia situation. To the north, however, while carbonate sediments still overwhelm all others, foraminiferal sands and muds are most prevalent. Submarine banks tend to be of coarse shell debris and carbonate detritus and grade into reef developments. Quartzose sands occur only nearer in-shore.

On the Arafura Shelf, shallow quartz sands give way to muddy shell sands and muds over most of the area, but coarser shell sands occur to the west. In the Gulf of Carpentaria, however, the greater part of the sea floor is of green clayey muds, although in the central area these give way to calcareous oolites.

A geophysicist metering sea-floor gravity in Spencer Gulf, South Australia, in a search for dense bodies likely to relate to ore bodies. [Photo: Mrs J. Watson.]

Northwest Queensland harbours the environment of the Great Barrier Reef, and as such is dominated by coral and algal detrital limestones and living calcareous growths. Fine calcareous detritus slumps into great depths down along the continental slope, whereas shoreward the carbonate sands give way to calcareous muds and clayey muds and finally quartz sands. Off the big rivers, clayey muds are prevalent and in intervening near-coastal areas coarse sands are well developed. These latter extend into the New England area and harbour deposits of rutile, zircon, gold, and other heavy minerals. Comparable detrital sea-floor sands also appear off the south coast of New South Wales and carry gold values in some situations.

Wide variety of minerals

Mineral deposits of the sea floor cover a wide variety. Other than petroleum, which is dealt with elsewhere in this issue, the best known are sea-beach and riverine detrital deposits relating to former lower levels of the sea. These include diamonds, heavy minerals, and the sedimentary mineral deposits such as phosphorite, manganese nodules, glauconite, and limestone. Manganese nodules rich in iron, cobalt, nickel, copper, vanadium, and rare earth minerals are restricted almost exclusively to deeper ocean waters and consequently are of little or no concern in the present context. Sea-water itself contains an enormous variety of minerals and elements and, in this respect, constitutes what is really an enormous ultra-ultra-low-grade ore-body. Salt, gypsum, potash minerals and bromine and iodine derivatives have, however, been recovered for centuries by solar evaporation from such sources. Inevitably, at some not distant future date, new chemical and biological extractive processes will extend this range into metallic elements such as copper, cobalt, and nickel, but these are beyond the scope of this discussion.

Coal and gold were the first minerals mined at and beyond the shoreline in Australia. Gold has been panned from beach sands along the north and south coasts of New South Wales, and coal has been mined in depth out under the sea from Newcastle.

Let us now review the more obvious economic possibilities of the immediate future.

Detrital (heavy mineral) deposits of "drowned" rivers and sea beaches

The processes of gravity concentration of heavy minerals by the action of currents and surf are well enough known not to require description here. Australia is probably the most fortunate country in the world for the richness of its ocean beaches in valuable heavy minerals such as rutile, zircon, ilmenite, and monazite (thorium). These are concentrated in the active surf zone to form the familiar black sands that occur so prolifically about the north coast of New South Wales and the Bunbury area of southwest Australia in particular. These are normally beautifully concentrated along with fine quartz sand that is easily separated to high concentrations by further gravity separation and various magnetic and electrostatic techniques. Garnet is a common by-product of the process, and at one time was recovered for the manufacture of garnet sandpapers. Gold has been recovered in some of those beaches, also.

The point of interest here is that most of these heavy minerals have been introduced into the beach environment by rivers, and that the beaches as we now know them are by no means fixed in position. The sea-level during the last million years or so has fallen by several hundred feet (about 350 feet) possibly many times, and returned. Higher windiness and greater rainfall during these "glacial" lower sea-level phases undoubtedly led to even richer beach and riverine mineral deposits being formed at much lower levels than today, but these are now deeply submerged. The extended search for and exploitation of these "drowned" deposits are undoubtedly the next important area of exploration, and this has already arrived. Indeed, considerable probing has already been undertaken in offshore New South Wales for the minerals mentioned. Similar exploration can be expected in southwestern Australia, principally for ilmenite (a lower grade titanium mineral than rutile), exploitation of which can be expected somewhat later than the New South Wales operation.

In Tasmania, tin (cassiterite) is likewise concentrated in coastal river and beach deposits, and these, too, have recently been explored quite seriously, but as yet unsuccessfully, out under the waters of Bass Strait.

Off northern Australia the underwater search for tin tungsten (wolfram) and tantalite-columbite has been attempted unsuccessfully off Bynoe Harbour, Northern Territory, and possibly also in Western Australia. Only a significant rise in the price of gold would re-open the search for this element in all of the foregoing areas.

Scheelite (calcium tungstate) has been found in sands on Reevesby Island, off Eyre Peninsula, South Australia, and there have been moves to sample the local sea bottom for more prospective accumulations.

Sea-floor deposits

Limey sands and muds make up much of the sea floor of the southern Australian continental shelf. As with the Great Barrier Reef, these represent enormous accumulations of limey material of continuing interest in cement manufacture and flux materials for blast furnaces. The problems of environmental protection are now well enough known not to be commented on here.

Of course, siliceous sands and calcareous shell-sand predominate in beach deposits, but, as these are usually still more adequately concentrated and sorted by wind, all such requirements for the foreseeable future are available in backshore dunes—providing environmental requirements do not prevent their exploitation completely.

Clays, sharp building sands, and gravels also occur widely in the shallower sections of the sea, and increasing attempts will be made to win these prosaic deposits from the sea floor as the needs of the building industry grow more rapacious.

Sea-floor phosphorite (phosphorous) and glauconite (potash) are deposits demanding increasing attention by oceanographers. Sea-floor glauconite has been recorded locally in South Australia, and occurs widely in such remote southwestern Pacific areas as the Chatham Rise. None of it approaches commerciality at this stage. No useful concentration of sea-floor phosphorite has been found around Australia, although serious submarine searches have been conducted about northern Australia and along the outer edges of the southern Australian continental shelf. Elsewhere in the world, nodules of phosphorite occur in monolayers on the sea floor and provide grades of 25 to 30 per cent P_2O_5 over enormous areas. As with manganese nodules occurring at still greater depths in the Pacific and elsewhere, completely new technologies of dredging have still to be perfected to make their recovery payable. Many new dredging techniques are being checked out experimentally, and the advent of practical exploration submarines is assisting. Solution of the problem of the economic recovery of manganese nodules—as may still be located in the Tasman Sea

A drilling vessel, *Offshore Driller II*. [Photo: Planet Metals Ltd.]

Collecting rutile samples from beneath the sea floor on board a drilling vessel. [Photo: Planet Metals Ltd.]

(deep) and elsewhere—could make a major contribution to the world supply of manganese, iron, nickel, copper, and cobalt. Dr John Nero, for example, has estimated that there are 1,500 million million tons of these manganese nodules on the sea floor alone. They grade as high as 50 per cent manganese, 2 per cent nickel, 2·6 per cent cobalt, and 2·5 per cent copper.

Undersea bauxite

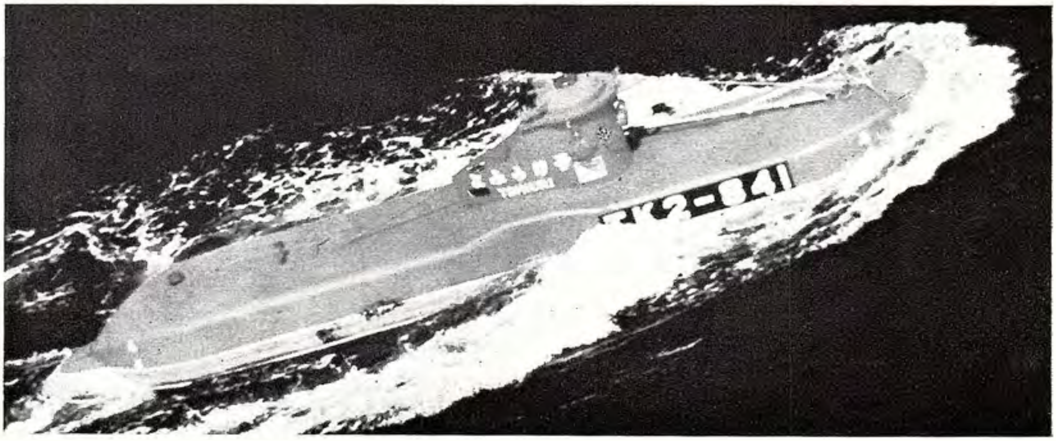
In a special category of its own is the search for undersea bauxite in the Gulf of Carpentaria, Queensland. The largest bauxite deposits in the world occur at Weipa on the east coast of the Gulf, and to the west are those of Gove, Northern Territory. As some geologists believe that the Gulf has downwarped below sea-level since the bauxites were formed in early Tertiary times, it is not surprising that enterprising companies are now probing for extensions of the known deposits in the local seas. If they are found, and lack serious overburden, then a new sub-sea mineral will be added to the already long list of potential Australian sub-sea mineral deposits.

Sub-sea oil and gas are already major income earners in the Australian sub-sea field, and the largest fields possibly still lie beneath the northwest and northeast continental shelves. Heavy mineral deposits such as rutile, zircon, monazite, ilmenite, and possibly tin can be expected to join this category later in the century.

Silica sands, limey shell sands, and gravels are capable of economic extraction in shallow subcoastal areas, and will be drawn on increasingly as industrialization demands. Economic concentrations of phosphorite and potash (glauconite) minerals have been explored for in deeper waters, but as yet with little success. Bauxite is being sought in sea-floor Gulf of Carpentaria.

Solar evaporation of sea-water for the

recovery of common salt is widely practised in southern and western Australia, and in Queensland. Attempts have been made to recover bromine economically, but without success. Ultimately the whole body of sea-water must be regarded as one enormous ultra-low-grade ore-body. New chemical and biological extractive processes must and will ultimately be perfected to make this the final great provider—assuming, of course, that the environment can be adequately protected.



The 40-foot, 35-ton research submarine *Yomiuri*. [Photo by courtesy of *Yomiuri Shimbun*.]

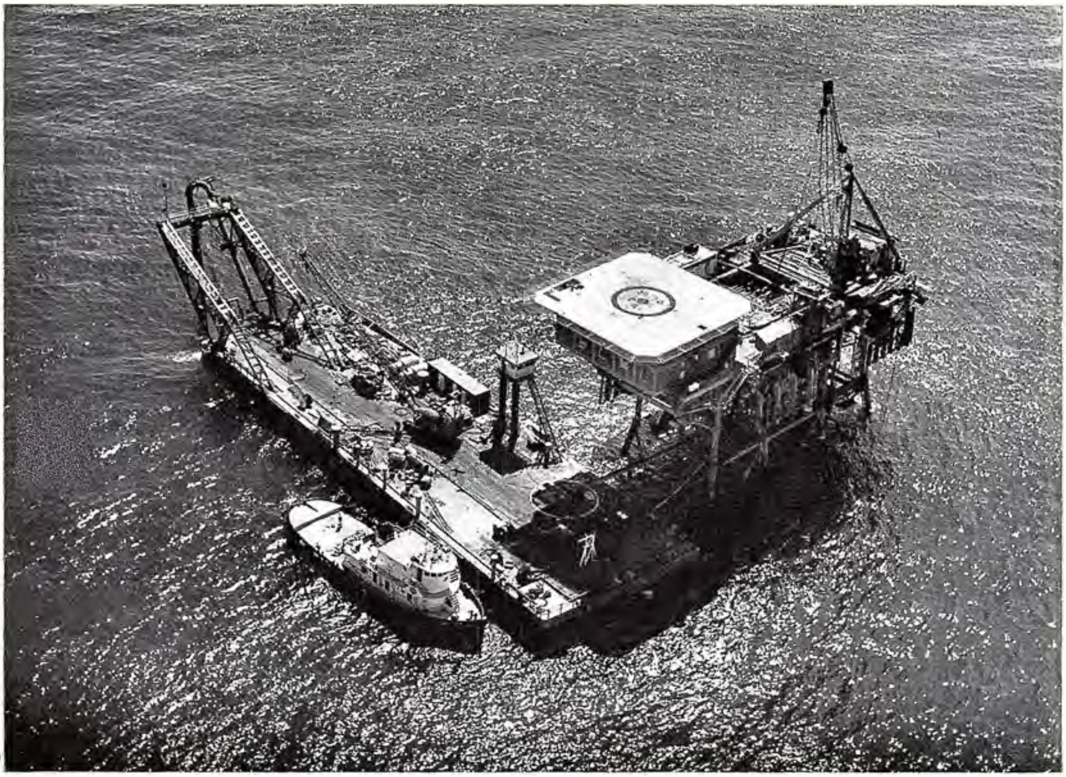
Small Submarine Aids Research

The Japanese research submarine *Yomiuri* spent 6 months in Australian waters during 1969, conducting studies in various areas of the marine environment. Accompanied to Australia by the mothership *Yamoto*, with a total crew of 24, the *Yomiuri* is capable of taking two scientific observers and her crew of four down to 1,000 feet for up to 4 hours. She is equipped with six viewing windows, a mechanical arm and an outside basket, and selected specimens of rocks and sedentary animals can be returned to the surface for further study.

The submarine worked in waters from Brisbane to Darwin, spending considerable time on the Great Barrier Reef and in the Arafura Sea; twenty-one Australian and four Japanese marine scientists participated in a total of 18 dives in Australian waters. A survey of reefs in conjunction with research on the Crown of Thorns Starfish was made, allowing the observing biologists to cover much more territory than with conventional scuba gear. Marine biologists studied plankton populations near the reef and also observed reef fish distributions at depths below the capabilities of scuba diving. Marine geologists were able to ascertain old wave-cut terraces formed during a period of low sea-level, deeper than previously suspected. Geologists also surveyed material of the sea-beds in Torres Strait and the Arafura Sea. In Japan the *Yomiuri* has been involved in surveying potential fishing grounds for commercial fisheries.

When one enters the vessel for the first time, it appears small and somewhat cramped. One is soon engrossed at the scene outside the window, and the fact that the submersible has accomplished more than 1,000 dives helps dispel any feeling of discomfort. The ship is 40 feet long and displaces 35 tons. It moves along the bottom about 1·5 knots during survey work, but is capable of 4 knots. Travel from one research area to another is made under tow by the mothership.

Marine research in the future will surely continue to utilize submersibles like the *Yomiuri*. While scuba divers now live for weeks at 50 feet and below, research submarines remain the best method for observation below scuba limits and are superior to remotely controlled television cameras. Unfortunately, the *Yomiuri* sank in a typhoon (without loss of life) last year. It is hoped that a vessel like the *Yomiuri*, with her hospitable and helpful crew, will be able to return to Australia and participate in the future exploration and study of our marine environment.—*John R. Paxton, Curator of Fishes, Australian Museum.*



A work-barge helping to complete the erection of a production platform in Bass Strait. [BHP photo, by Val Foreman.]

Petroleum Beneath the Sea Floor

By JOHN A. W. WHITE
Supervising Petroleum Technologist, Bureau of Mineral Resources, Department of National Development, Canberra

AUSTRALIA joined the world-wide search for offshore petroleum on 27th December, 1964, when the drill-ship *Glomar III* spudded Esso's Gippsland Shelf No. 1 well off the coast of Victoria. This well proved to be the discovery well for the Barracouta gasfield now supplying Melbourne with natural gas.

Offshore drilling started very modestly in the United States of America in the 1940s, using ordinary land-based drilling rigs mounted on barges or on jetties built in shallow water. The success of these early ventures led oil companies to move into deeper waters, and specialized drilling units first came into existence about this time. Basically, two types of units developed. The rig mounted on a jetty developed into the very large and very expensive drilling platform which can today be designed to operate in waters up to 350 feet in depth. They are generally used where a field has been proved to exist, and can be used as production platforms for a number of wells.

The other development was for the barge-mounted rig to be incorporated into a vessel capable of trans-ocean towing (many are

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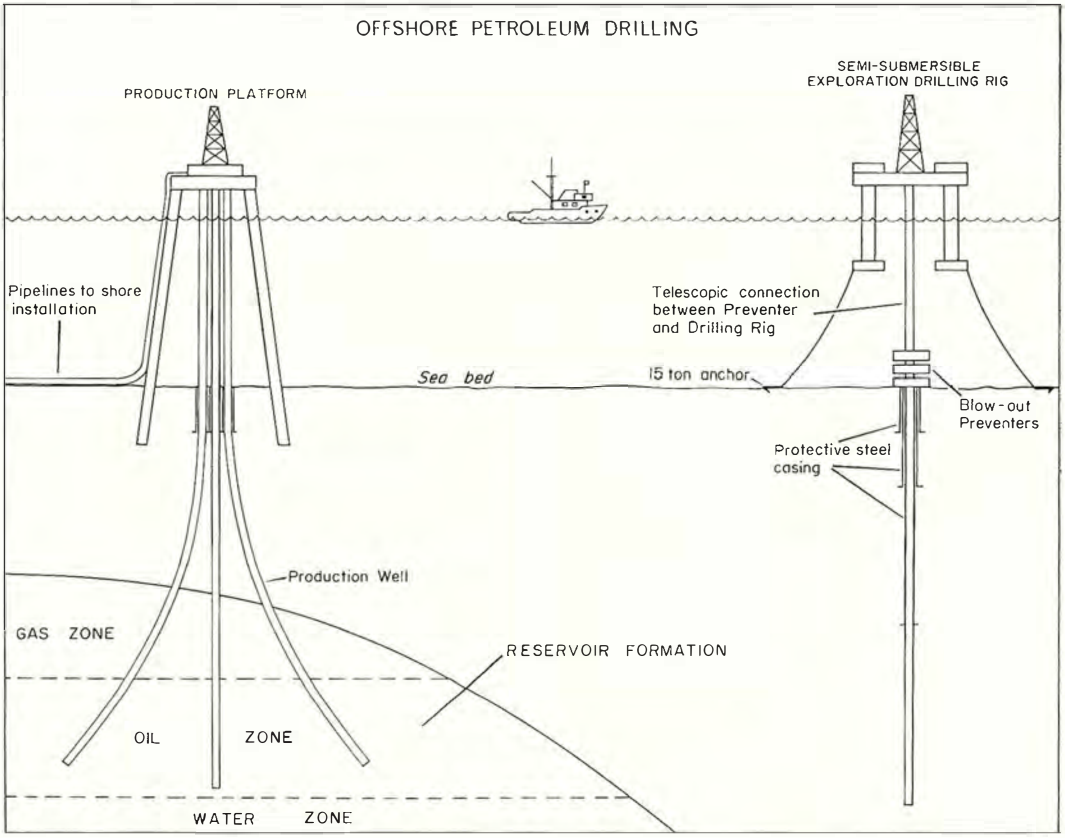
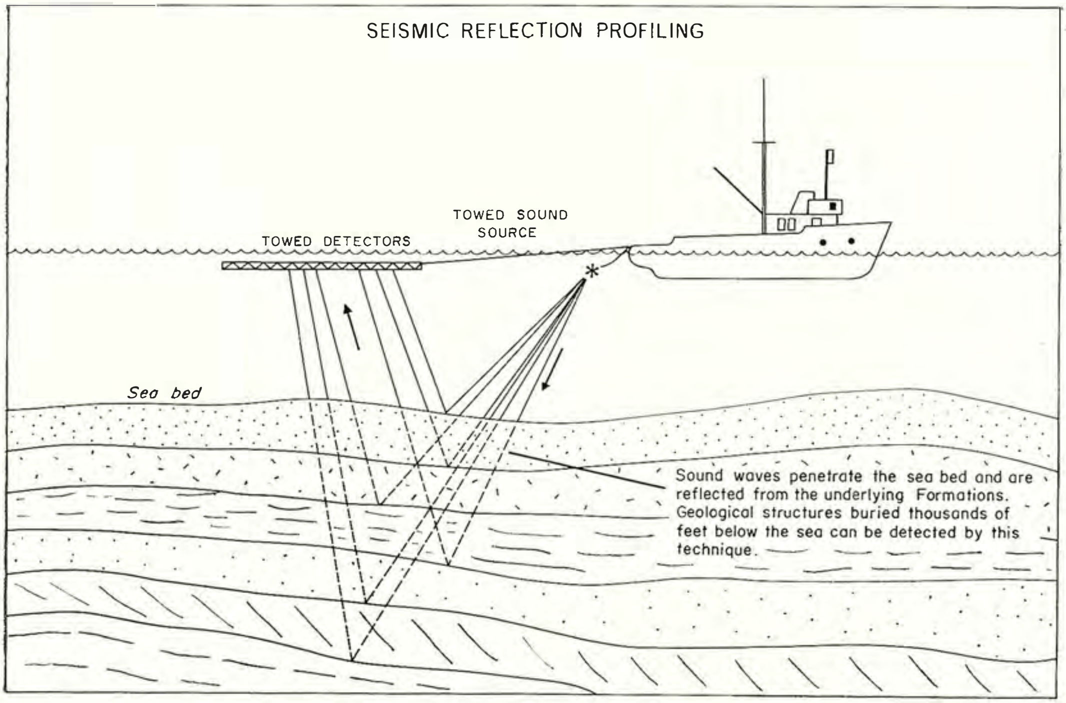
now self-propelled) and able to drill in waters up to 600 feet deep and able to withstand weather conditions up to and including hurricane-strength winds. The *Glomar III* is one such vessel.

A variation on this second category is the jack-up rig. Long legs are attached to the corners of the drilling barge and, when on location, these legs are lowered to the sea-bed and the barge then "climbs up" the legs until it is completely clear of the water. This provides a very stable platform for the subsequent drilling operation.

The drilling machinery used offshore is similar in every way to that commonly in use onshore. The drilling bit is rotated by a steel pipe (called drill pipe) and mud is pumped down the inside of this pipe to remove the rock cuttings produced by the bit. After washing past the bit the mud returns to the surface between the drill pipe and the hole being drilled, the cuttings are sieved out, and the mud is then pumped back down the drill pipe by powerful pumps. Initially, a very large hole is drilled (commonly 36 inches in diameter) and heavy steel casing 30 inches in diameter is then lowered into the hole and surrounded with cement to fix it permanently into place. In a similar way successively smaller strings of casing are cemented into place as the hole is deepened. The reason for this expensive casing being cemented in this manner is to protect the upper portion of the hole and to provide a foundation for the large valves, known as blow-out preventers, which are generally installed at the sea floor; they may be installed above



Note the bent or deviated holes drilled from the production platform. This method enables the oilfield to be drained by a minimum of platforms. [Diagram: Department of National Development.]



A seismic profile being run. The depth of the various rock formations can be calculated from the time taken by the sound waves. [Diagram: Department of National Development.]

the surface of the sea in the case of a well drilled by a jack-up rig.

Where to drill?

I started by describing drilling operations —this is the spectacular part of the discovery of oil or gas, but one must not forget the painstaking work which must precede the selection of a drill site. Initially, all available geological information on a selected area is assembled and geophysical surveys are carried out to determine the structure of the geological formations beneath the sea-bed. Commonly, an aeromagnetic survey is run first which can show the thickness of sediments existing and may also give an indication of the type of geological structure that may be expected. This is generally followed up by seismic surveys, in which specially equipped boats trail a long string of geophones or hydrophones in the water and shock waves are transmitted from an emitter on the vessel. These shock waves can be generated by one of many different methods, including explosives, electrical discharge, or mechanical means; perhaps the most popular these days is the compressed-air gun. From the results, the geological structure can be determined and the most favourable location for a drill site can be selected.

Oil and gas are very common minerals in the earth's crust, but the real problem is finding a commercial accumulation of them which is capable of being exploited. In favourable circumstances oil and gas can be found trapped in a porous sandstone or limestone reservoir rock, sealed in place by an impervious overlying layer (called a cap-rock). The reservoir formation obviously should not be in direct contact with the surface, otherwise the oil would escape; this is the reason geologists look for suitable rock structures, such as an anticline, where the oil may be trapped.

Many of the sedimentary basins of Australia extend onto the continental shelf around our shores, and, in fact, approximately one-third of the total sediments of the Australian continent lie offshore. It so happens that these offshore sedimentary basins are rich in the younger sediments (compared to onshore), and it is these younger sediments which elsewhere in the world provide the bulk of the world's petroleum. This is one of the reasons for explorers moving offshore even though exploration and development costs offshore are commonly many times higher than those onshore.

A total of just over 100 exploration wells have been drilled so far off every State except New South Wales, resulting in the discovery of several commercial fields off Victoria and many very promising shows of oil and gas off Western Australia, the Northern Territory, and Papua. Current exploration activity off Australia's coastline remains at a relatively high level compared to the current slump in onshore exploration. This offshore exploration work has been carried out by no fewer than eight different offshore drilling vessels, in water depths ranging from 34 feet to 466 feet and with well depths ranging from 1,900 to 15,520 feet.

Offshore production

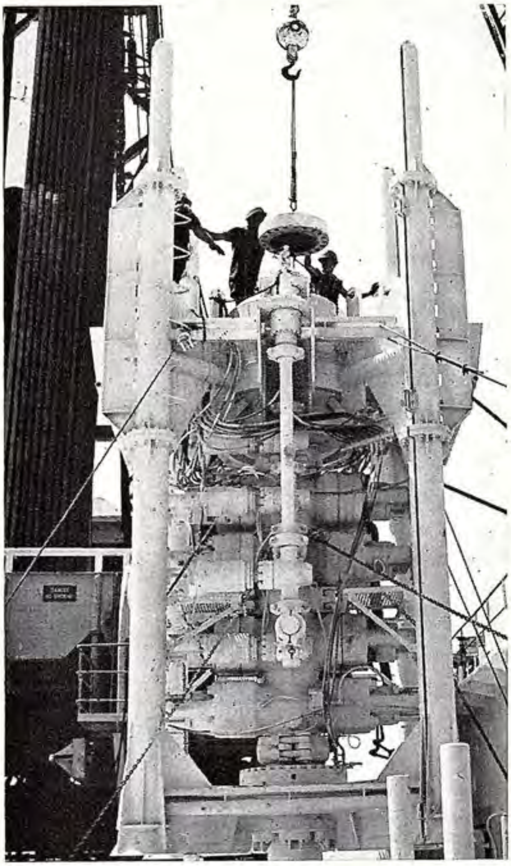
When a discovery has been made there comes the problem of getting the oil or gas out of the ground and then to market. The petroleum comes to the surface from the producing formation through a steel pipe (called tubing) which is hung inside the casing. This tubing is hung from a so-called Christmas tree, which may be either on the sea bed or, more commonly, on a production platform. From the well-head, the petroleum enters a pipe-line for transfer to the shore or, in the case of very isolated areas, the oil may be transferred directly into tankers.

Why the search for offshore oil?

So far, I have talked about how to find oil: perhaps a more important question is why? Petroleum is Australia's biggest single mineral import, and in the 1969 financial year oil imports cost $254 million. Australian discoveries to date are already making a very important contribution to the economy. This year we can expect to save about $225 million through the production of Australian crude oil, most of it offshore, instead of importing an equivalent amount. As well as the economic desirability of having home-produced petroleum, it could also be considered important from the defence point of view not to have to rely on overseas sources for such a vital product.

In the future it is likely that the import bill for petroleum could increase very dramatically unless further oilfields are discovered. Production from the Bass Strait oilfields will soon start declining as fields are depleted, and will drop to zero in about 30 to 50 years. With consumption rising at the rate of about 9 per cent per year and with the prospects of overseas petroleum prices increasing substantially in the coming decades, Australia's import bill for oil could rise very steeply in the years ahead.

It has been estimated that Australia must spend on petroleum exploration more than



Valves known as blow-out preventers being prepared for installation on the sea-bed. [Photo: Department of National Development.]

double the current $90 million a year if sufficient oil is to be found to satisfy Australia's requirements.

All petroleum drilling around Australia's shores is being carried out by private enterprise. Obviously their motive is to make a profit, and, while large profits are possible, it must not be forgotten that a company may spend, say, $30 million without finding a single drop of producible oil. Australia is politically stable and this is another incentive for oil companies to spend their exploration dollar here even though the success ratio is not perhaps as high as, for example, the relatively politically unstable Middle East.

The Commonwealth Government subsidizes petroleum exploration to a maximum of 30 per cent of the cost of the operation. However, subsidy is only paid to those companies offshore which have Australian participation. The effect of this subsidy is to make exploration cheaper and to increase the work done for each dollar spent by the company.

Environmental pollution

Pollution is a subject everyone is concerned about these days; what are the dangers? While drilling, an exploration well may blow-out, resulting in an uncontrolled escape of oil or gas; this is very unlikely, but is nevertheless a possibility. Without going into the mechanics of it, it is much more likely that such a blow-out would be of gas (with no pollution problem) rather than oil —in fact, oil blow-outs are extremely rare. In the United States in 1968 there were 714 reported oil spills, of which only two came from offshore oil wells. A total of 347 spills were from vessels, and, of the remainder, nearly 300 were caused by shore facilities.

On the credit side, exploration everywhere in the world has shown that fishing improves around offshore petroleum installations. Around the production platforms in the Gulf of Mexico catches have just about doubled since the first platform was installed several years ago. The platforms provide shelter for the fish, and also provide a "toe-hold" for molluscs upon which the fish can feed.

Offshore oil exploration has certainly come to stay with us in Australia, and we can expect to see a continuing programme into the foreseeable future. It will help the Australian economy in no uncertain way and could well mean the development of new ports, new towns, and new industries wherever large reserves of gas or oil are found.

FURTHER READING

Fortune in the North Sea, by P. Hinde, published by G. T. Foulis & Co. Ltd.

Oil and Australia 1970, published by the Petroleum Information Bureau (Australia), 227 Collins Street, Melbourne, Victoria 3000.

BOOK REVIEW

HOW TO FIND AUSTRALIAN GEMSTONES, by Derrick and Doug Stone; Periwinkle Books, Lansdowne Press, Melbourne, 1969; 144 pages; price $1.50.

The main chapter of this book, entitled "Where to find gemstones", is arranged according to States and is set out in tabular fashion under four headings—Gemstones; Location; Occurrence; Associated Gemstones. This arrangement, while it presents the information clearly, suffers because of a great degree of repetition. For instance a locality like Beechworth, Victoria, where a variety of gemstones and ornamental stones have been found, is listed eighteen times. Condensation of the information without omitting anything of importance could be achieved by including a subject index or a geographical index, or both. There is no index in this book. Another defect of this method of presentation is that emphasis is not laid on the most important localities.

The list of localities is comprehensive, as one would expect, since the authors acknowledge their indebtedness to records of the various State Geological Surveys for much of their information, but there are some omissions. The Oberon and Crookwell districts in New South Wales are a happy hunting ground for gem collectors but they are not mentioned. In Western Australia there is a vague mention of waterworn pebbles of amethyst in the area of the Murchison and Ashburton Rivers, but nothing is written about the source of this amethyst in quartz veins at Wyloo, one of the outstanding occurrences of amethyst in Australia. In the same State, Byro, some considerable distance to the north-west of Geraldton and noted as a source of ornamental common opal for many years, is not mentioned. Ornamental stones other than the silica varieties, such as alunite, prehnite, rhodonite, and malachite, are not included.

The chapters on rock types and physical properties of gem minerals and the glossary are quite useful. The chapter on mining for gemstones, particularly precious opal, and the use of the prospector's pan and sieve in recovering gem minerals from alluvial deposits will be of great use to the beginner.—*R. O. Chalmers.*

GIANT PYROSOMA SEEN IN NEW ZEALAND SEAS

By ROGER V. GRACE
University of Auckland, New Zealand

IN October, 1969, while diving at the Poor Knights Islands on the east coast of Northland, New Zealand, students from the University of Auckland came across a large white cylindrical object drifting just below the surface of the water. On close examination it was recognized as a giant pelagic tunicate or salp, a type of free-floating colonial sea-squirt, but much larger than any previously found in New Zealand. Others were seen in northeastern New Zealand during the following week or two, and they were subsequently identified as *Pyrosoma spinosum* Herdman, a species not previously recorded from New Zealand waters (as stated by A. N. Baker in the Records of the Dominion Museum, Wellington, N.Z., 1971).

Pyrosoma spinosum has also been seen by divers off the New South Wales coast, but the interesting feature of the New Zealand specimens is their enormous size, colonies up to 60 feet long having been seen.

Pyrosoma colonies are hollow cylinders made up of thousands of animals embedded in a cellulose wall. One end of the cylinder is closed, the other open. The colony grows by budding off new individuals from a single individual at the tip of the pointed, closed end. Each of the individual animals, or zooids, has a mouth opening to the outside of the cylinder. Water is sucked in through the mouth, and microscopic plankton is filtered out as food. The filtered water passes to the inside of the cylinder and eventually out the open end, thus acting as a weak propelling jet for the whole colony. This water jet is so weak that the colony is completely at the mercy of tides and ocean currents. It is thus a true member of the plankton, although much larger than the animals we normally think of as plankton. These giant *Pyrosoma* colonies are also one of the largest invertebrate organisms in existence. Tunicates have an interesting life-history, with a larval form shaped like a small tadpole and having a strengthening structure rather like a primitive rudimentary backbone.

Anterior view of a giant colony of *Pyrosoma spinosum*, 30 feet long, near the Poor Knights Islands, New Zealand. This specimen had a "tail" a further 30 feet long, the first few feet of which are visible at right, extending from the posterior end (the open end). The "tail" was structurally the same as the wall of the colony, with zooids, the individual animals making up the colony, occurring right to the tip of the "tail" process. [Photo: R. V. Grace.] See, also, photo on next page.

All species of *Pyrosoma* are noted for their luminescence. The zooids have special light organs which produce an eerie bluish-white glow. Seeing one of these giant colonies on a night dive would be a fantastic experience indeed.

Side view of a *Pyrosoma spinosum* colony, about 12 feet long, at the Poor Knights Islands. Note the pointed anterior end, at which the colony is growing by budding from a single zooid. [Photo: R. W. Fullerton.]

BOOK ON OPALS REVIEWED

AUSTRALIAN OPALS IN COLOUR, by N. and R. Perry; A. H. and A. W. Reed, Sydney, 1969; 112 pages. Price, $3.95.

The authors have made a commendable effort to cater for the varied interests of readers. For those who like to go out prospecting for opals there is a description of the geological occurrence of opal in the sedimentary deposits of arid inland Australia. This could have been enlarged on. Semi-mechanized methods of mining such as "puddling" are described. So also are the techniques using large earth-moving equipment to strip the overburden and reveal the opal-bearing horizon—a technique of doubtful value, in the opinion of this reviewer.

Those sections of the book with greater appeal for the reader, especially those thinking of venturing out and trying their luck for the first time, will be the description of the time-honoured, primitive method of mining opal by individual effort and the description of the various fields, their location, and their accessibility. Useful information on vehicles is given—notably on the necessity to carry spare parts, additional petrol, and water—and there is advice on how to extricate onself from difficult situations, such as being bogged in sand.

Apart from a passing mention in the introduction the authors have inexplicably failed to include White Cliffs, west of the Darling, in New South Wales, the first of the productive fields. White Cliffs is not the ghost town that many imagine it to be. There is some small-scale commercial production at present, there are amenities, and there are an increasing number of visitors, mainly from Victoria and parts of South Australia, for whom it is the nearest of the opal fields.

An informative section on the correct theory of the cause of the play of colour in precious opal is contributed by P. J. Darragh and A. J. Gaskin, of the CSIRO Division of Applied Mineralogy, where experimental work on precious opal was carried out.

The book is profusely illustrated, mostly in colour. The colour in some of the scenes of the opal fields is not correct, but all the plates of actual specimens, both cut and in the rough, are of high quality.—*R. O. Chalmer.*

SEA BIRDS

By VINCENT SERVENTY
President of the Wildlife Preservation Society of Australia

AS I have spent a great deal of time watching sea birds and gathering information about them, it is obvious that I find the group particularly interesting. This springs from the fact that the sea and the desert are two environments I find most exciting. Occasionally, sea birds can be found in both places. A few weeks ago, when the Georgina River flooded areas between the red sand-dunes of the Simpson Desert, I had the pleasure of seeing hundreds of Silver Gulls, Whiskered Terns, and Gull-billed Terns fishing desert pools. The Silver Gull is a bird of the sea which will penetrate deeply inland, even reaching Alice Springs. The Gull-billed Tern is both a coastal and inland species, while the Whiskered Tern is a bird of the inland and freshwater lakes. So the term sea bird, expressed scientifically, may not mean that a particular species is found near the sea at all, just as the term kingfisher includes birds such as kookaburras and Red-backed Kingfishers, to which a fish is a rare article of diet.

Normally the term sea bird is restricted to penguins, albatrosses and petrels, tropic-birds, frigate-birds, gannets, pelicans, cormorants, skuas, gulls, and terns. Shore birds or waders, though some are even more creatures of the sea, are not included in this listing.

Breeding seasons

A look at the map of Australia shows that the biggest development of continental shelves is in tropical Australia, while the cooler southern half has about half the shelf area, though it has a 50 per cent greater coastline. Similarly, the tropical regions carry twice the number of islands than the southern. All these are factors in determining the distribution of our sea birds and their ability to breed. Roughly speaking, we have about forty species breeding and slightly more coming as regular migrants or occasional stragglers.

The breeding seasons of these birds are interesting as well as puzzling. Southeastern

A Red-tailed Tropic Bird hovering over its nesting site. [Photo: Author.]

and eastern Australian birds are mainly spring and summer breeders, and the same holds for southwestern Australia and coastal Queensland. However, in the northwest autumn and winter are the main seasons, while on the west coast the zone in between has both spring and autumn breeding populations. On the Queensland outer islands, autumn breeders also occur.

It has been found that the following species have a double nesting season in various localities—Lesser Frigate-bird, Red-tailed Tropic Bird, Brown Booby, Masked Booby, Red-footed Booby, Pied Cormorant, Pelican, Caspian Tern, Crested Tern, Lesser Crested Tern, Sooty Tern, Roseate Tern, Bridled Tern, Fairy Tern, Common Noddy Tern, Silver and Pacific Gulls.

Conservation

Sea bird conservation is an aspect which has given concern over the years. We have, in the Short-tailed Shearwater, better known as the Tasmanian Mutton-bird, a bird which was saved by slaughter. This paradox arose as follows. The first "mutton-bird" was the Brown-headed Petrel, the Bird of

Sooty Terns nesting on Michaelmas Cay, off the coast near Cairns, north Queensland. [Photo: Author.]

Providence of Norfolk Island. This was exterminated by hunting. The same fate seemed likely for the Tasmanian Mutton-bird, but it occurs in such vast numbers that it may well be Australia's most abundant bird. The most intensive hunting in the last century could not wipe it out. However, destruction of habitat is the main danger facing any animal species, but it was the very presence of a mutton-birding industry which prevented the major rookeries being handed over to farmers. (The trampling of sheep and cattle, besides killing nesting birds, also hardens the ground, making further burrowing difficult. Burning tussocks can lead to soil erosion and a loss of burrows.) So the setting aside of the breeding grounds for the industry saved the birds in the last century. More recently, strict controls based on knowledge obtained from research means that the Mutton-bird is safe enough. Or at least until a few years ago we thought it was. Today, the effect of persistent pesticides on bird populations and mass destruction by oil spills are new factors which must be taken into account in a conservation programme and which temper our conservation optimism.

On tropical islands colonies of Sooty and Noddy Terns were wiped out, before the birds were protected, by the heavy taking of eggs for use in the manufacture of biscuits and cakes. Less severe damage has resulted from fishermen taking nesting birds for food. Today, legal protection for most sea birds has, in some cases, led to colonies on devastated islands regaining something of their old strength.

Island reserves

At present, it can be said that the conservation position in most States is satisfactory. Increasingly islands are being set aside as total reserves, and we hope this will become the pattern for the whole of Australia. The effect of Aboriginal hunting before the coming of the white man is hard to assess, though no doubt colonies on islands near the coast were wiped out. This hunting continues to the present day in parts of northern Australia. It is time that Governments took a new look at the traditional rights of Aborigines to take protected species, both inside and outside reserves. When this leads to the killing of

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The once-famous gannet rookery on Cat Island in Bass Strait, about 15 years ago. Today, the grass tussocks have invaded the nesting area, leaving only a tiny patch for the nesting pairs. The mounds in the foreground are nests. [Photo: Author.]

Red Kangaroos in Ayers Rock National Park and forays by dozens of boats to the sea-bird islands of Torres Strait, other methods must be found to provide alternative foods for these people.

Asian and white fishermen are also a problem. Crayfishermen are often the worst offenders, fairy penguins, gannets, cormorants, and shearwaters being killed for bait. Although these killings do not have any overall effect leading to the extinction of a species, they can mean that in certain areas the bird disappears.

Cat Island gannetry

A classic case of this is the Cat Island gannetry in Bass Strait. Here was once the largest of our five gannetries, carrying a nesting colony of possibly between 2,500 and 3,000 pairs. It was also the only easily-reached gannetry and so of great value to naturalists and tourists. It was this ease of access which led to its destruction. It has now been almost entirely destroyed because of the short-sighted greed of fishermen and the apathy of Governments towards providing ranger protection during the breeding season. This is a case of what I call "visual extinction", where, though the species survives for the average person it is extinct in so far as a chance to observe it is concerned.

Despite these blots on our conservation record, if we could be as happy about the general conservation of Australian wildlife as we are about that of our sea birds it would be a wonderful state of affairs.

FURTHER READING

A Handbook of the Seabirds of Australia, by D. L. Serventy, V. N. Serventy, and H. J. Warham. (A. H. and A. W. Reed.)

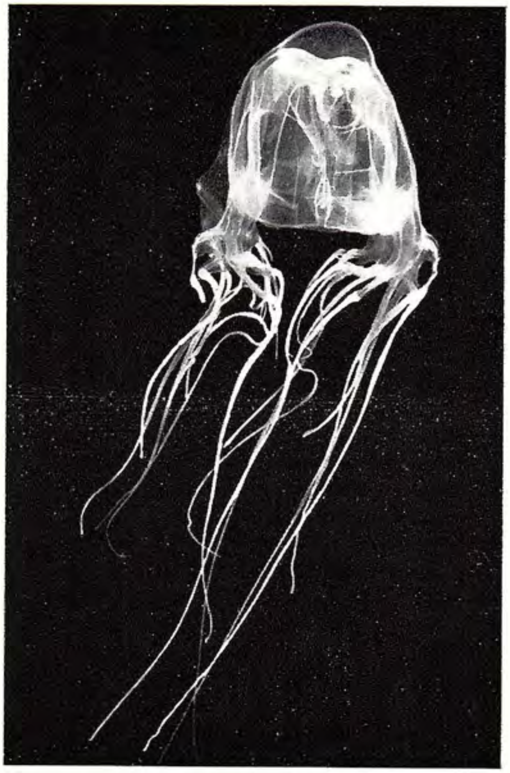
THE BOX-JELLIES OR SEA-WASPS

By RONALD V. SOUTHCOTT
Honorary Zoologist, South Australian Museum, Adelaide

IF asked to name the world's most venomous animal, most people would probably suggest one of the more deadly snakes, such as the king cobra or one of the larger Asian vipers; an Australian might suggest the taipan. However, each of these fearsome serpents is surpassed in poisonous potential by a far more primitive creature, a jellyfish known commonly as the box-jelly or sea-wasp, found in the tropical seas along the north of Australia and across to Asia, whose scientific name is *Chironex fleckeri*. It belongs to a somewhat specialized group of jellyfish known technically as the Cubomedusae. A fatal stinging commonly lasts about 3 minutes, and deaths at even greater speed are on record, down to as short a period as about half a minute. In a laboratory animal, the injection of *Chironex* venom into a vein causes death in seconds.

Little-known to the general public—and even to many zoologists—until comparatively recent years, the Cubomedusae have received increasing attention since it has been realized that along the shores of northern Australia they are a significant hazard.

Their shape is rather cuboidal or box-like in a number of species, the general structural plan being a four-sided one. From each of the four corners of the base of the bell the jelly-substance projects into a blade-like arm or process known as the pedalium. This may carry a single tentacle, in the simpler members of the group, or, in the more complex, it may be divided into as many as fifteen processes or claws, each of which carries a tentacle, the larger of which may be as thick as an earthworm. It is in these tentacles that most of the toxic potential of the animal resides.



The many-tentacled lethal box-jelly (also known as a sea-wasp) of northern Australia, *Chironex fleckeri*, in a swimming attitude. [Photo: Keith Gillett.]

Owing to the varying state of contraction of the tentacles, there is no standard way of measuring their length. Nevertheless, in the usual swimming posture of these animals the tentacles are observed to be several times as long as the bell of the animal, and it may be calculated that a large *Chironex fleckeri* swimming along may present 200 feet (about 60 metres) of trailing tentacle in a volume of sea-water, say, a cylinder less than a foot across and 3-6 feet long. Observations on victims of fatal stings indicate that only a small fraction of this (about 20 feet, or 6-7 metres) in vigorous contact with the skin is sufficient to cause death.

The four-tentacled box-jellies *Carukia barnesi*, the "Irukandji jellyfish" (left), and *Carybdea rastoni* (two specimens). [Photo: Author.]

Ecology—the place of the box-jellies in nature

The simpler four-tentacled forms are to be found in both tropical and temperate waters, but the dangerous many-tentacled forms are exclusively tropical.

The larger many-tentacled species of Cubomedusae all belong to the family Chirodropidae, with the genus *Chirodropus* occurring along the tropical west African coastline, *Chiropsalmus* occurring in both the tropical Atlantic and Indo-Pacific, while *Chironex* is found in the Indo-west Pacific tropical marine zone. The four-tentacled Cubomedusae belong to the family Carybdeidae; this family's larger members, with the bell the size of a hand or larger, favour tropical waters, while smaller species, with the bell the size of an egg-cup or smaller, are found in temperate as well as tropical seas. One small form, with its bell smaller than a thimble, is *Carukia*, which is found purely in tropical Indo-Pacific waters, while *Carybdea*, for example, occurs in temperate as well as tropical waters.

The box-jellies are exclusively marine. Some are found in open oceans, while others, particularly the largest kinds, show a marked preference for sheltered beaches and shallow waters. It is this last characteristic that makes the large many-tentacled box-jellies such a hazard on many otherwise attractive tropical beaches in northern Australia, as well as further north across to the Asian mainland and as far as the northern Philippines, and west into the Indian Ocean.

Seasonal appearances

The appearances of the box-jellies, at least in coastal waters, show a marked annual periodicity. Thus, the coming of the "sea-wasp season" to Darwin is an important annual event to the local swimmers, upon which formal public announcements are made by the local health authorities some time each year between October and December. In the following April or May the "season" is usually considered as over, although the author has received medium-sized specimens from Darwin waters in April. A somewhat similar periodicity for the mature four-tentacled *Carybdea rastoni* in the summer months is observed in the sheltered waters of St Vincent Gulf, South Australia. In the waters around Cairns, Queensland, *Carukia barnesi* begins stinging about early December, and continues until about mid-February.

So far, however, no detailed numerical study on the seasonal frequency of any cubomedusa in any body of water in the world has been published; this is clearly a subject worthy of further investigation. A research student could also very well spend several years in studying details of life-history, behaviour, and environmental preferences.

Motility

The Cubomedusae are rapid and powerful swimmers, shooting forward by "jet-action" when the bell contracts and impels a body of water backwards. The four sides of the bell are connected by a nerve-ring, and differential contraction of the impelling musculature around the bell outlet allows the jellyfish to move towards prey, or to take evasive action against a possible enemy. At times these jellyfish are recorded as breaking the surface of the water, causing a ripple, and frequently they have been observed swimming in a horizontal or oblique posture in the water, this having been observed for Australian, Japanese, and African Cubomedusae.

Feeding habits

The box-jellies live by preying upon small crustaceans and fish, and sometimes specimens of these medusae are caught with quite large fish, compared with their own size, attached to their tentacles or in their stomach. The large many-tentacled Cubomedusae of north Queensland have been stated to feed mainly upon the small shrimp *Acetes australis*. This predation of these medusae upon tough-skinned and well-muscled marine creatures explains why a powerful and almost instantaneous toxin needed to have evolved. The tensile strength of fish, for example, is considerable, as is also their muscular power—far greater, in fact, than that of a jellyfish of comparable size. Without such a powerful poison, and yet with good adhesion between predator and prey, the jellyfish would rapidly be torn apart. The alternative biological option would be for the jellyfish, if it had a less powerful poison, to have large numbers of finer tentacles which would deliver a greater volume of poison, possibly combined with greater fragility of substance, so that they could be torn away without damaging the bell from which they are suspended. Precisely this solution appears to have been adopted in the case of *Cyanea*, the hair-jellyfish. Another available option would be for using only smaller animals as prey.

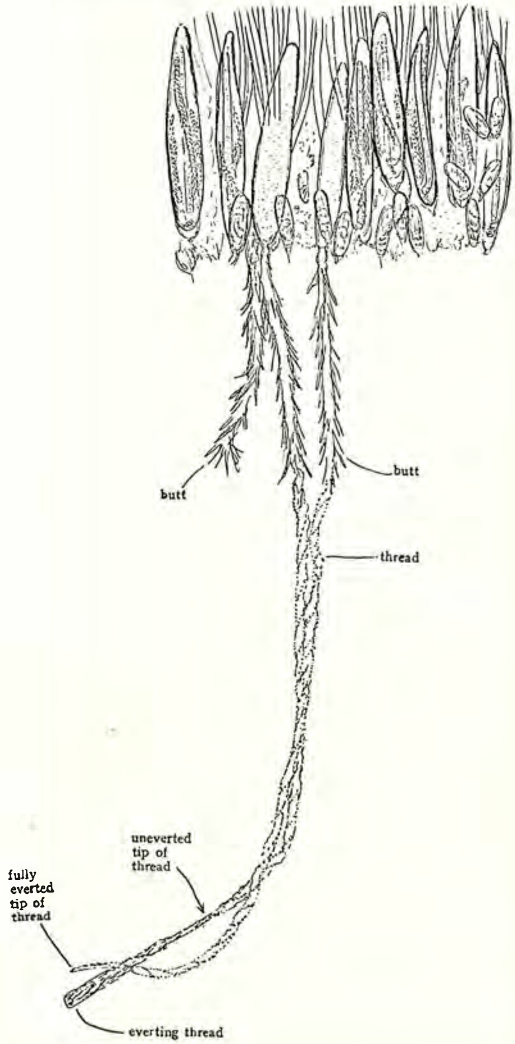
Response to light

A response to light intensity is an important behaviour characteristic of many marine creatures. This is the case with fixed or attached creatures, as well as for the zooplankton, the unattached marine fauna that swims in or is carried passively by the water. Among the Cubomedusae the light responses are important. In Japan it was recorded many years ago by Uchida that the common Pacific four-tentacled cubomedusa, *Carybdea rastoni*, is attracted at night to fishermen's fires, i.e., the traditional wood fires in iron baskets suspended over the sea to attract fish. In South Australian waters it is stated by scuba divers that this same species forms a thick bank on the sea-bed in shallow waters (6–30 feet) when the light is bright, as in the middle of the day, but with lower light intensities they tend to disperse through the water.

Examination of the sense organs of these creatures shows a well developed system which includes on each of the four sides of the bell a small cavity with a suspended sense organ giving information on position, as well as some sort of vision. This small organ carries six eye-spots, one of which is capped by a biconvex lens. All of the four sense organs are connected by a nerve ring that goes right around the bell. This well-developed optical system, at least for so primitive a creature, explains the ability of the animal to take evasive action promptly when danger threatens.

The stinging mechanism

The name "sea-wasp" was originally mentioned by Mayer, an American author, for some of the sharply-stinging Cubomedusae found in the Caribbean waters of North America. The stinging mechanism is, however, not fundamentally different from that of the other coelenterates (or cnidarians)—the group which includes all the jellyfish, as well as sea-anemones, corals and related forms, including also the hydrozoans, such as the fixed hydroids, and *Physalia*, the Portuguese Man-of-war or "bluebottle". The stinging apparatus, or nematocyst, is a small organ-like structure or organoid which is developed within a specialized cell known as a cnidoblast. There are a number of different kinds of nematocyst, even within the same coelenterate. Nematocysts are classified according to their structure and function. Some have the function of grappling, by a clockspring-like coiling, with small hairs or other projections of potential prey, while others are adherers by a mucinous substance, which serves the same purpose. In these last-named two forms the ejected



Nematocysts on a tentacle of *Chironex fleckeri*. Some are undischarged, and two are fully or nearly fully discharged. [Drawing by the author.]

thread is closed. Those nematocysts that inject poison into prey have an open thread-end when it is finally turned inside-out, and are known as "injectors"; when the thread is fully discharged poison flows from the open end. Even the injector-type nematocysts have nearly a score of different kinds with differing details of structure.

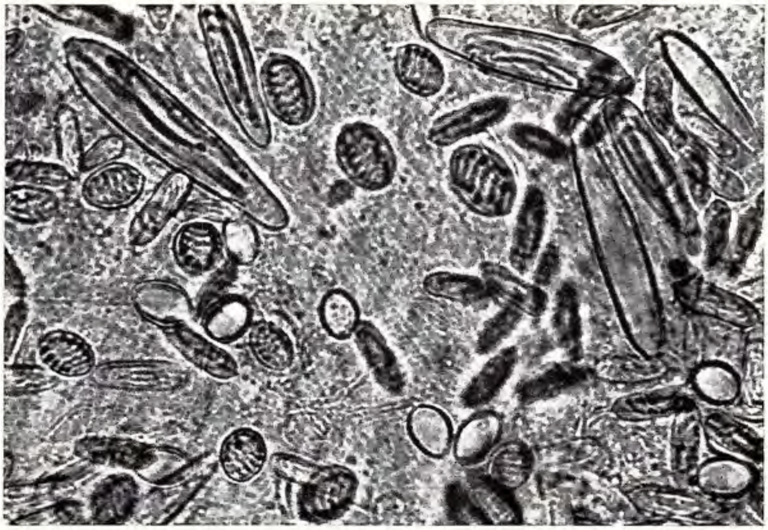
The method by which the injector type of nematocyst discharges is as follows: Inside the capsule is a coiled thread, lying in a pool of poison. Under the appropriate conditions, which include physical contact with prey and the correct chemical stimulus from potential food, the discharge mechanism is actuated. The coiled thread is attached to a precise place on the inside of the capsule, and may be compared to a turned-in finger of a surgical glove. When pressure is applied to the contents the attached finger or thread turns inside-out, or evaginates, thereby orientating itself into its functional position. The energy for this process is released from the absorption of water into the capsular contents, including the thread. This absorption results in the rapid rotation of the thread as it elongates and expands, punching and cutting through its quarry. Although in some nematocysts the threads are unarmed, in many kinds the threads carry a treble dextral spiral which may carry spines, and, as these appear at the turning-over and rotating edge of the advancing thread, it could be expected that this armament would aid the penetration and adherence of the thread. When fully everted the poison flows through the small open end of the thread, its ultimate volume being several times that of the original undiluted contents. At this stage the total thread length is many times the length of the original capsule. The firing of thousands or millions of these threads serves to anchor the prey to the tentacle, and, as further movements of the quarry in relation to the jellyfish bring more of its tissue into contact with more tentacle or nematocyst-bearing area, more and more capsules are discharged, until either the prey succumbs, the numbers of available capsules are exhausted, or the quarry manages to escape, tearing away threads, nematocysts, or even whole tentacles. Injector nematocysts, even if they do not succeed in penetrating into the quarry's tissue, where the toxin will cause significant harm, may nevertheless cause adhesion;

this accounts, for example, for the feeling of adhesion obtained on touching many anemones with the fingers. In the case of the more powerful nematocysts, the thread penetrates into living tissue. Its penetration into the superficial cellular layers of the human skin, for example, will cause pain. Deeper injection, through the cellular layer of the human skin into the dermis, allows the injection of poison where it may be absorbed into the circulatory system, and hence carried to distant vital centres as well as causing local effects.

Medical effects of Cubomedusae stings

Nearly all Cubomedusae cause pain and wealing when their tentacles touch average human skin—for example, that of the trunk or the back of the hand. With the larger box-jellies the penetrating power of the nematocysts is much greater, and some have been recorded as capable of penetrating even the skin of the palm, as has also been recorded by some authors for *Physalia*. The effects of the venom of the larger many-tentacled box-jellies are severe. Their venom is considered as containing three distinct actions: neurotoxic or lethal factor; skin-destroying (dermatonecrotic) factor; and haemolytic (blood-destroying) factor. The effect of a stinging depends upon many variables, but among the most important must be the amount of venom injected compared with the weight of the victim. Even with the large many-tentacled box-jellies, the majority of encounters with man are minor, and even considerable contact is not necessarily fatal. With minor stingings, or stingings in which the victim recovers more or less promptly, little more will be heard, and only the very severe or numerous stingings, or stingings with fatal outcome, are likely to get much publicity. In moderate stingings by many-tentacled box-jellies the victims may receive a painful wealing on the legs, with death of the skin underneath, and ultimately leaving a depressed scar. The neurotoxic element is the important one, and may cause death by paralysis of the vital centres for respiration and circulation at the base of the brain, and may damage local nerves, such as cardiac.

Emergency treatment in such severe cases should include assisted respiration, and the use of a local tourniquet could be helpful. Some progress is being made in the development of antitoxins, but at the time of going to press these are still under trial and have not been generally released. However, it must be realized that in a very severe stinging, with a fatal outcome likely to ensue in a few minutes, even if such an antitoxin were fully available its practical use would be very restricted. More hope appears to exist for possible future use of a prophylactic, by which those who insist on swimming with a large amount of skin



Nematocysts seen when a piece of *Chironex* tentacle is squashed on a slide. [Photomicrograph: Keith Gillet.]

exposed in dangerous waters could be immunized by toxoid, but this is still at the experimental stage.

One cubomedusa from restricted tropical areas, but occurring in the inshore waters around Cairns and Darwin, is a small box-jelly known as *Carukia barnesi*, the cause of "type A" or "Irukandji" stinging, now known formally as carukiosis. In that illness, contact with the jellyfish in the water may either go unnoticed or cause only a minor local stinging, usually on the trunk of the swimmer. Inspection of the area shows only a minor pink flush about the size of the palm of the hand. About 25 minutes later, on the average, the victim is seized by backache, abdominal pain, vomiting, muscle ache, and joint pains, increasing rapidly in intensity, with some cough, fever, and possibly headache. This acute illness lasts about 24 hours, with the victim recovering fully. Such stings are also recorded for New Guinea and Fiji, in a series of scattered tropical localities.

First-aid treatment

For minor stings, or even major ones, after the victim is removed from the water, the most important first-aid treatment, apart from taking care of any respiratory difficulties, consists of the rapid removal of tentacle. In fact, it could be argued that this is of paramount importance, as the prevention of further injection of toxin is possibly critical. Removal of tentacle is greatly expedited by the free application of methylated spirits or some other form of alcohol, e.g., anti-stinger lotion, which causes the tentacle to contract and makes it easy to remove. The dehydration from the alcohol will also inhibit further nematocyst discharge. Any available method to remove the tentacle should be used, such as rubbing it off with dry or damp sand, or using clothing, rag, fishing net, a knife or stick, or anything else available.

Respiratory failure should be treated by assisted respiration. Any obstruction to the airways should be corrected. If there is a centre where antitoxin and other medical attention is available the victim should be taken there as quickly as possible. In the meantime, artificial respiration should be continued in such major stingings while any hope remains.

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Southcott, R. V., 1967: Revision of some Carybdeidae (Scyphozoa: Cubomedusae), including a Description of the jellyfish responsible for the "Irukandji syndrome". *Australian Journal of Zoology*, 15 (3): 651–71.

BOOK REVIEW

AUSTRALIAN CRUSTACEANS IN COLOUR, by Anthony Healy and John Yaldwyn; A. H. and A. W. Reed, Sydney, 1970; 112 pages, 57 figures, 52 plates; price $3.95.

This book is a welcome addition to the rapidly growing series on Australian natural history published by A. H. and A. W. Reed. John Yaldwyn's intense interest in the subject shows in the wide-ranging and carefully checked text. Anthony Healy's photographs are excellent, but it is a pity that many of the plates are badly trimmed or bound—parts of legs or bodies are chopped off or are so close to the edge of the page as to spoil the appearance of the picture. The text is accompanied by a number of excellent drawings by Brian Bertram which illustrate details of anatomy and morphology.

There are many thousands of animals in Australia belonging to the class Crustacea, and this book deals with all main groups from small water fleas to the large crayfish and crabs. Unfortunately, little is known about many of the small forms, such as copepods, amphipods, and isopods. This is reflected in the fact that more than two-thirds of the book is devoted to the generally large shrimps, crayfish and crabs (Decapoda) which together probably comprise less than one-third of the total number of species.

The book opens with a general account of the structure and relationships of Crustacea. In the following pages there are accounts of the habits of the most notable Australian representatives. There is an explanation of the apparently sudden appearance, at times of rain, of shield shrimps (*Triops*), a review of the barnacles important in intertidal zonation, a summary of the life-cycle of prawns, accounts of shrimps that perform dances as part of their courtship, others that hide under sponges, and crabs that move around in "armies".

I can find only one error of fact. In the account of the way in which shrimps change colour it is stated that the hormones which control the size-changes of the chromatophores are produced in the eyestalks. Studies in the late 1950's showed that these hormones are stored in the eyestalks but produced in the central nervous system.

This book, covering some of Australia's most interesting and commercially important animals, will undoubtedly prove useful to all naturalists and to students interested in natural history.—*D. J. G. Griffin, Australian Museum.*

The East Australian Current

By B. V. HAMON and D. J. TRANTER
Research Scientists with the Division of Fisheries and Oceanography, CSIRO, Cronulla, New South Wales

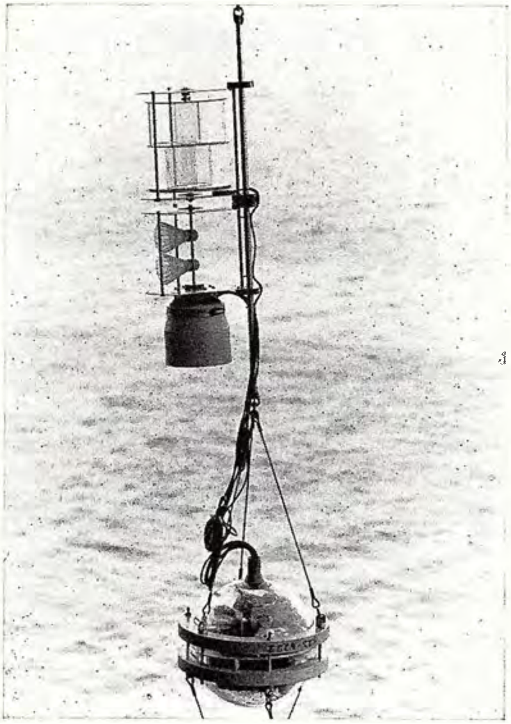
IN many and various ways the East Australian Current influences the entire southeastern seaboard of the Australian continent. We suspect that it determines the productivity of our fisheries and the nature of our climate. There seems little doubt that the tropical flora and fauna found in isolated pockets along the coast of New South Wales are maintained by this warm current from the north. The coral reefs of Lord Howe Island, 31½° S. latitude, are located much further south than other Pacific coral reefs, and it is thought that their continued existence depends on the current and its associated countercurrents and eddy systems.

Unlike the Gulf Stream of the north Atlantic and the Kuroshio Current of the north Pacific, the East Australian Current dissipates on leaving the coast. The pattern of this dissipation is constantly changing, and it is believed that the variations in the current system may play an important role in determining the variations in the rainfall in southeast Australia, the area where the greater part of the population is concentrated.

For these reasons the Division of Fisheries and Oceanography of CSIRO has carried out special studies on this oceanic system, a system whose complexity constitutes a challenge to Australian oceanography. These studies will be extended when oceanographic research ship facilities are provided.

Origin of the current

The East Australian Current is born in the region between the Great Barrier Reef and the Chesterfield Reefs of the Coral Sea. It is here that waters pile up under the influence of the trade winds and are constrained to flow southward by the land barriers of New Guinea and Australia. The current draws its water from the easterly Trade Drift for the greater part of the year. Between January and March, however, equatorial waters driven by the monsoon winds move southward around the northeast coast of New Guinea, enter the source area,



A current meter used by the CSIRO in studies of the East Australian Current. [Photo: CSIRO, Cronulla.]

and are caught up with the current. The stream narrows to the north of Fraser Island, and there draws further water from the lagoon of the Great Barrier Reef. Full velocity is reached in the area off Cape Byron; thence the current flows along the edge of the continental shelf, veering out to sea somewhere between Sydney and Eden.

Early knowledge about the current came from mariners. They found a southerly "set" near the edge of the continental shelf (100-fathoms line), from off Rockhampton to off Sydney. The current was first charted from ships' logs accumulated for over a century, with the result shown in fig. 1.

But this is only an average picture. The detail, at any one time, is much more complex and interesting. Navigators have known for years that the current is variable; this is specially noticeable on southbound passages between Brisbane and Sydney, where frequent fixes against landmarks lead to a more detailed picture of current structure than can be found when navigating out of sight of land. Ships coming south, near the 100-fathoms line, are often in the current for 100 miles or so, then suddenly they are out of it. Many captains use water temperature as an indicator; if the temperature drops suddenly, they assume they have lost the current, and may alter course away from the coast to pick it up again.

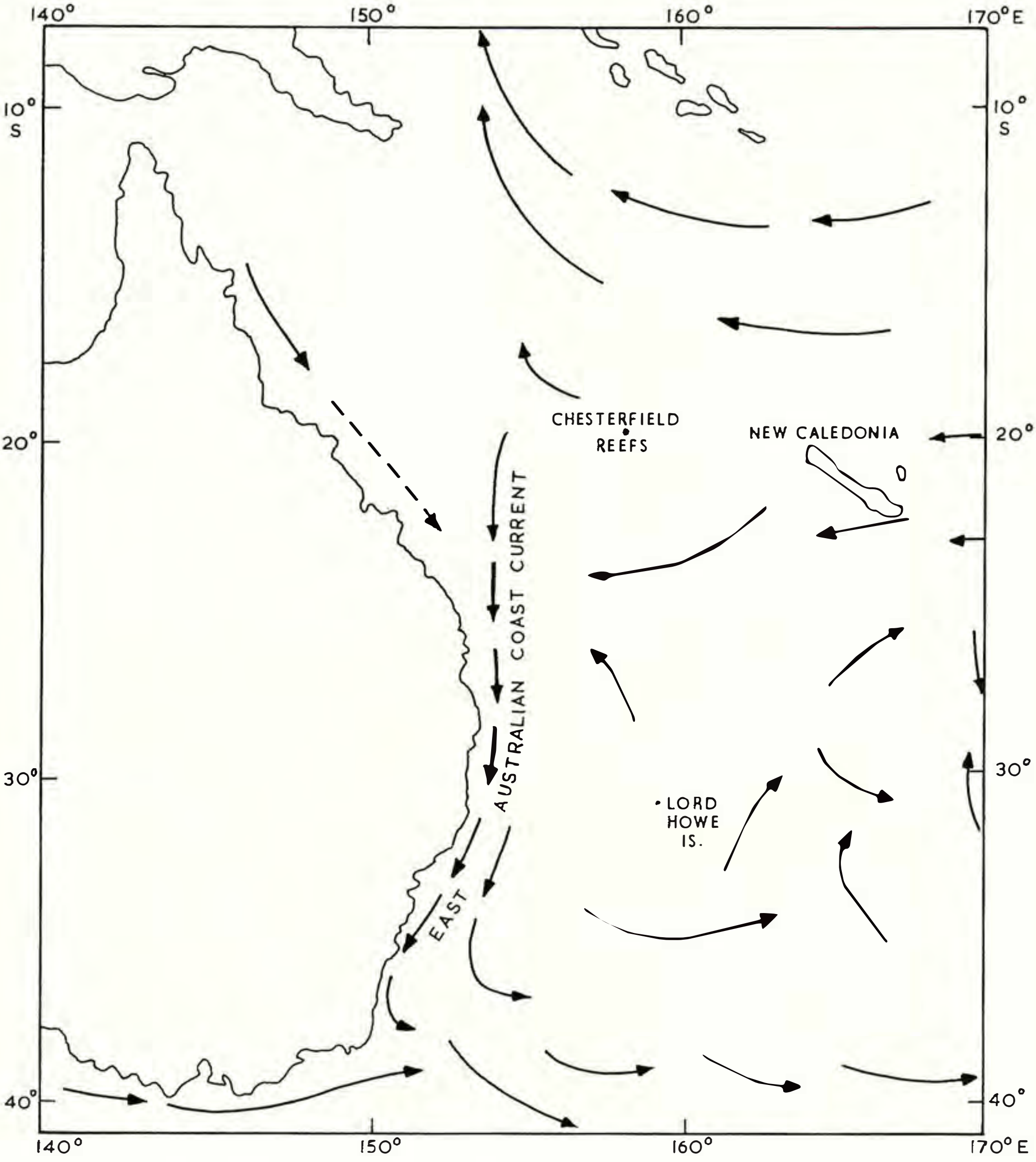


Fig. 1.—Surface circulation in the Coral and Tasman Seas, December–February, adapted from *Australia Pilot*, Vol. III (British Admiralty, 1960).

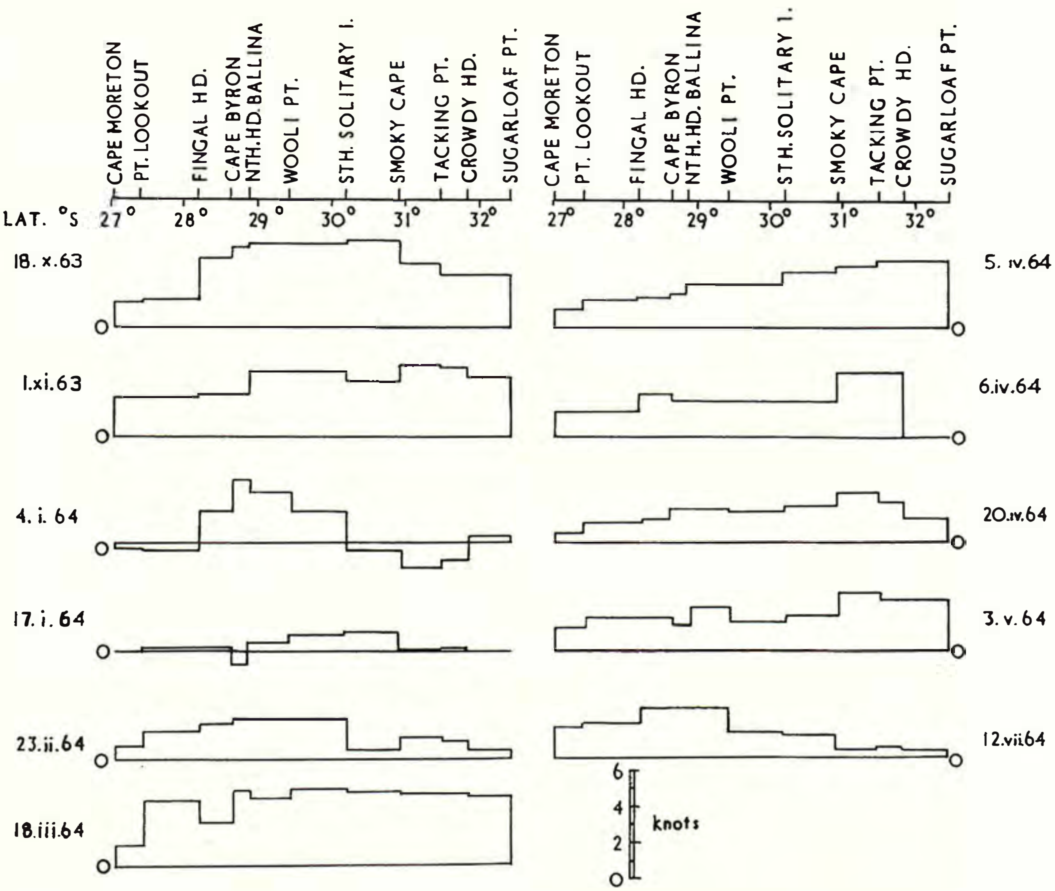


Fig. 2.—Currents near the 100-fathom line, between Cape Moreton and Sugarloaf Point, for 11 southward passages in 1963–64. Currents above zero line flow south, those below zero line flow north. [Diagram by the author.]

CSIRO recently collected ships' navigation logs for a year, to look at the current in more detail. Fig. 2 shows the currents between fixes from Cape Moreton (Brisbane) to Sugarloaf Point (near Port Stephens) for a number of passages down the 100-fathoms line; note how seldom the current looks anything like a steady stream over this distance.

The Division of Fisheries and Oceanography of CSIRO commenced its investigations in the East Australian Current area in 1954, working from a schooner, the Fisheries Research Vessel *Derwent Hunter*. This continued until 1959. Since 1960 the Division has been looking at the current in more detail, using H.M.A.S. *Gascoyne*, a frigate made available for oceanographic work by the Royal Australian Navy. This work led to our first coherent picture of the current away from the coast.

Assessing ocean surface height

On *Gascoyne*, we usually steamed a grid pattern, and measured temperature and salt concentration (salinity) down to 5,000 feet at stations 50 miles apart. Water density was worked out from temperature and salinity. We were then able to work out the height of the sea surface, since the average density is found to vary from station to station. "Light" (less dense) water stands higher than more dense water, just as kerosene stands higher in one limb of a U-tube if there is water in the other. The height differences found this way are up to about 2 feet. Knowing the heights at a grid of stations, we can draw contours of equal height, like isobars on a weather map. Fig. 3 shows an example.

What do these surface-height maps tell us? They have much more than a superficial resemblance to weather maps. Just as winds blow parallel to isobars on a weather map, we find that currents flow parallel to the contour lines in fig. 3. The arrows give the direction. Currents are stronger where the lines are close together. A few current strengths have been entered on the figure.

Eddies and countercurrents

Fig. 3, and a dozen or more similar charts from ten years' work on *Gascoyne*, show some surprising things. First, there is always a strong current to the north, if one goes far enough offshore. We have been calling this the "countercurrent". Second, there are often strong anti-clockwise eddies, about 150 miles in diameter. The near-shore edges of these must often be confused with the East Australian Current, and their eastward parts with the countercurrent—in fact, it is not clear if we should keep trying to attach separate meanings to the three terms "current", "countercurrent", and "eddy". It often appears to us that the so-called East Australian Current is really made up of a number of large anti-clockwise eddies. Third, the "shape" of the current at any time is often very complex (note the curious loops in fig. 3).

Transport of water by current system

There is good evidence that the current system brings water from the Coral Sea down along the east coast. In view of the countercurrents and eddies, how does this water get carried down, and at what rate? We are by no means sure of answers to these questions. At present we think the transport is by the bodily drift of complete eddies. We have some evidence that they move south, and even a little evidence about their speed—about 50 miles per month. But attempts so far to show that the water in an eddy is different from the water outside have failed. There is nothing to prevent an interchange of water between eddy and surrounding ocean.

Surface speeds go up to about 4 knots. Half the surface speed is found at 800–1,000 feet depth, and the current is still measurable at 5,000 feet.

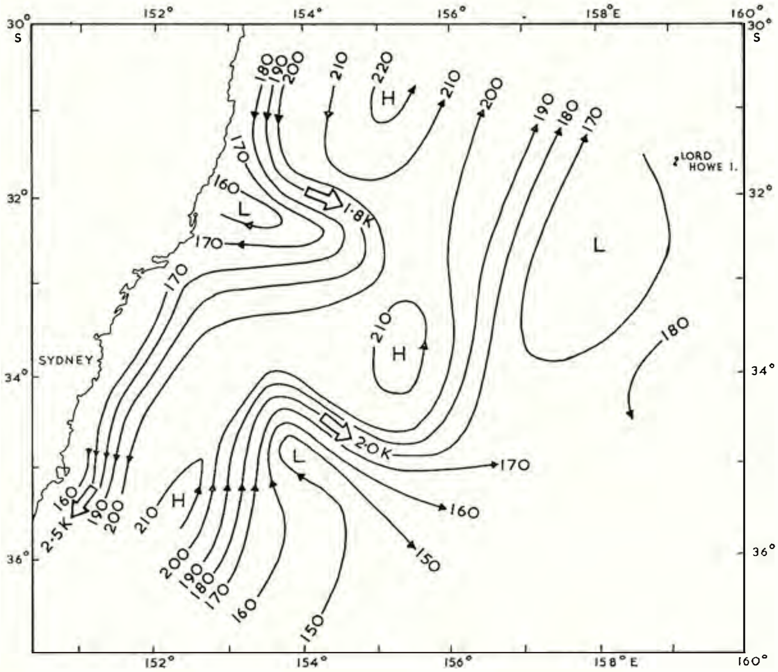


Fig. 3.—Contours of height of the sea surface, at 10-centimetre intervals, as worked out from water density. Height numbers are referred to an arbitrary zero. Some surface currents (in knots) estimated from the contour spacing are shown by the broad arrows. H, high sea-level; L, low sea-level. [Diagram by the author.]

The total flow of water around an eddy is about half that of the Gulf Stream. (It could fill Lake Eucumbene, New South Wales, in two minutes!) But the net southward transport would be much less than this, and has not yet been estimated.

Blooms of plankton

We have known for more than 30 years that there are blooms of plankton on the continental shelf of New South Wales in the spring of nearly every year. Spring blooms are well known in other regions of the world, but here they have a quite different origin. They appear, in some way that we do not yet fully comprehend, to be related to the East Australian Current. So far as we can determine, periodic changes in the velocity of the current and in its proximity to the coast allow cold deep water from the continental slope to penetrate the waters of the shelf. The mineral nutrients that these slope waters carry enrich the sunlit waters of the shelf and become available for the use of planktonic algae. Algal blooms are the inevitable result. These upwellings are better developed in some areas than in others. They are usually confined to the inner 10 miles of the shelf.

The details of this annual enrichment are not yet understood. Many questions remain unanswered. Which particular nutrient triggers off these algal blooms? Is it nitrate or is it silicate? Nitrate is sometimes used to exhaustion, but individual pulses of nitrate-rich water are not well-correlated with individual plankton blooms. Silicate levels fall very low during the spring, but remain both low and steady even though phytoplankton blooms come and go.

As Professor Dakin observed many years ago: "It is a difficult region, for we are probably sampling in a slow stream . . .". Maybe the algal blooms and swarms of zooplankton that we observe each spring off Sydney are the downstream consequence of upwellings further north. Maybe our coastal waters should be regarded as a river that changes speed, course, and direction in response to forces that we have yet to determine.

A strong upwelling is known to take place each year at Laurieton, near Port Macquarie, New South Wales. From August to October of this year (1971) the Laurieton upwelling was continually under observation. Moored current meters (see photo) recorded speed and direction of the current. At the same time a programme was carried out using ships which happened to be in the area. Commercial ships plying between Sydney and Brisbane noted changes in speed and track due to the prevailing current. Concurrent observations were made downstream of the upwelling in the area off Cronulla, near Sydney, to see whether the same body of water passed by, and, if so, what changes took place in the plankton community in the intervening period. We are trying to determine, in effect, whether the algal blooms and swarms of salps that characterize the Sydney area are the downstream consequence of upstream enrichment.

These are the sort of questions we are seeking to answer. In such a complex system as the East Australian Current there are sure to be many surprises.

FURTHER READING

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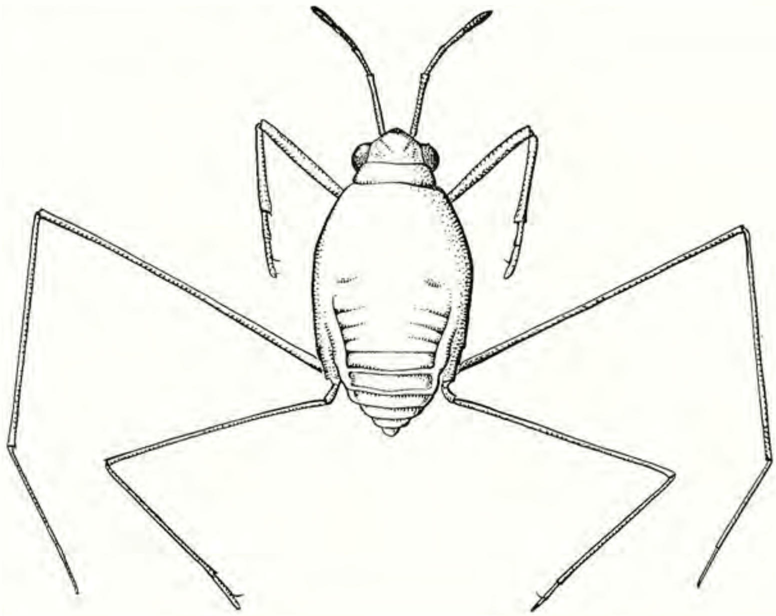


The water-strider *Halobates hayanus*, from the Low Isles. [Drawing by S. R. Curtis.]

AUSTRALIAN MARINE INSECTS

By ELIZABETH N. MARKS
Senior Research Officer, National Mosquito Control Committee, Brisbane

THE saltwater coastal environment grades from estuaries and salt marshes through mangrove swamps and sandy beaches, rocky shores and coral reefs, to the open sea. We might class as marine insects those that spend all or most of their life-cycle in the intertidal zone or beyond it. However, when considering marine insects in relation to seas around Australia, one's mind turns to the rocky shores and coral reefs, pounded by violent waves, or to wide expanses rich in animal and plant life exposed at the lowest tides, and it is mainly with the insects of these habitats that I will deal.

On Australia's rocky shores insects of the orders Hemiptera, Coleoptera, Diptera, and Trichoptera occur, as well as the primitive hexapods Collembola (springtails), mites, and a spider; all but Trichoptera are recorded also from coral reefs.

I should like to trace with you my own introduction to marine insects, because this is how any observant naturalist might encounter them if he or she sets out deliberately to look for them.

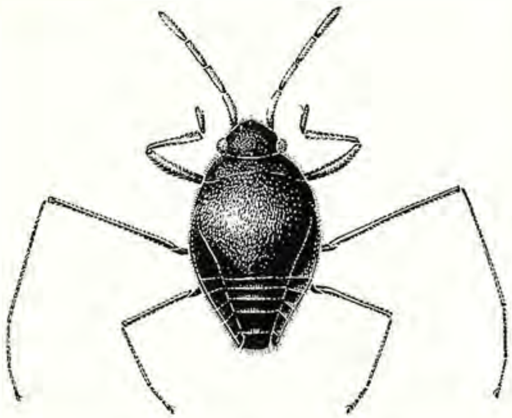
In August 1954 Dr M. J. Mackerras and I were members of a scientific party organized by the Great Barrier Reef Committee, which spent 2 weeks on Low Isles, 9 miles northeast of Port Douglas. These are two small sandy islands near either end of a horseshoe-shaped reef opening to the northwest, where, in 1928, a scientific expedition led by Dr C. M. Yonge spent a year in intensive study of corals and the ecology of the reef. They recorded a marine spider, *Desis crosslandi*, but no marine insects. Marine biologists do not look for insects in marine habitats, and entomologists rarely seek them there.

We went to Low Isles armed with some literature, so that we knew a little of the types of insects we should look for and were usually able to identify them to family and sometimes to genus. We later identified the Diptera ourselves and obtained expert identification for most others. We had waternets, glass vials and alcohol, and a x20 hand lens. We also had a low-power microscope which helped with the very small specimens. Whenever tide and weather allowed we spent most of our time searching for marine insects and observing their habits, and altogether collected five species of bugs, two beetles, and three flies, as well as one collembolan, two mites, and the spider previously recorded.

Full moon was on the 14th, and new moon on the 28th of August. Collection dates are given because the tide or phase of the moon may be significant, particularly in relation to marine midges.

On our first day, the 13th, with a 6-inch tide soon after mid-day, we collected three species of water-striders (Gerroid bugs) skimming over pools on the inner and outer reef, including two long-legged species, one with the underside of the abdomen partly or wholly white (*Halobates hayanus*), and one we called "short-tail" with abdomen scarcely visible (*Hermatobates* species); the third was a smaller, shorter-legged species (*Halovelia* species). These three bugs were frequently encountered thereafter. Under one lump of coral near the outer edge of the reef was a spider (*Desis crosslandi*) and under another a small beetle (*Polypaea coralli*) which we did not find again. A large plum-coloured collembolan was common on and under lumps of hard coral, and 2 days later we found it on soft coral at the reef edge only a foot above the lowest tide level. It appeared to carry an air bubble between the bases of its legs.

On the 15th we saw a few tiny, delicate, pale animals darting about on the surface of some coral pools. In the laboratory these were identified as males of the fly *Pontomyia*. We knew *Pontomyia* had been found in association with the marine plant *Halophila*, and collected a bundle of it. When, next day, this was washed out with sea-water, numerous dead *Pontomyia* males and male and female pupal skins were obtained. On the 16th and 17th we made many more observations of *Pontomyia*, especially over the *Halophila* area and over some large colonies of the coral *Porites*, and found females, mating pairs, and larvae, but after that we saw them no more.



A species of *Halovelia*, from Heron Island. [Drawing by S. R. Curtis.]

On the 19th, minute bugs (*Corallocoris marksae*), a small beetle (*Dicranolaius alleni*), and two species of mites (one was *Bdellodes pacifica*) were found emerging from crevices in beach rock as the tide receded. On the 21st (after a strong southeaster had been blowing), and later, another long-legged water-strider with underside of the abdomen uniformly black or dark reddish (*Halobates sericeus*) was collected, mainly near the outer edge of the reef.

On the 24th we saw great numbers of small black flies, the size of biting midges, flying low against the wind across the reef towards the cay; they were particularly easy to see over the yellow soft corals when the tide was right out. We found these were males of two species of *Clunio*, easily distinguished from one another on the relative lengths of the antennal segments. Next day mating pairs and the probable larvae were collected over *Porites* colonies. *Clunio* males and the water-striders became entangled in the frothy scum edging in over the reef after the tide turned, and many specimens were collected by gathering this scum and later extracting them from it.

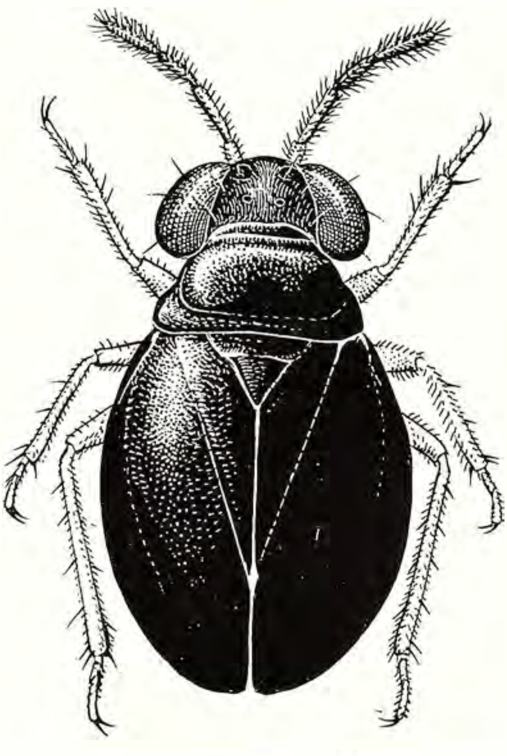
Let us see now what is known about these Low Isles species and other insects of the seas around Australia.

Hemiptera

The genus *Halobates* (Gerridae) is circum-tropical in distribution and includes the only truly oceanic insects. Several species spend their whole lives on the open sea and are apparently taken in shore collections only after storms or gales. The early naturalists who voyaged on sailing ships were keenly interested in these bugs, and their mapped distribution bears some relation to the routes of certain ships, as well as to prevailing winds and currents.

The genus and three species (including one, *H. sericeus*, that we took at Low Isles) were described in 1822 by the Esthonian naturalist Eschscholz, who collected them on the round-the-world voyage of the *Rurik*, 1815–18. Murray, on the voyage of the *Challenger*, observed that some of them fed on dead *Porpita*, *Physalia*, and other animals floating on the sea. *Halobates* eggs have been found attached to many kinds of floating material, such as seaweed, cuttlefish shells, and wood, and even on the tail feathers of a living noddy tern.

There are two ecologically distinct groups of *Halobates*—the open-ocean group of widely distributed species, and the coastal group, some of which apparently have a very restricted distribution; some of these latter lay their eggs in intertidal rock crevices.



A minute bug, *Corallocoris marksae*, from Heron Island. [Drawing by S. R. Curtis.]

Nine species are recorded from Australian seas and shores. The adults are about 4·5 millimetres long. Of the open-ocean species, *H. micans*, which is circumtropical, has been recorded near Sydney; *H. sericeus*, a common species of the north and south Pacific, has been recorded from the east coast between Low Isles and Sydney; and *H. germanus*, a species of the Indian Ocean and southwest Pacific, from our northern coasts. A coastal species with a wide distribution is *H. hayanus*, which occurs round Malaysia and New Guinea, as well as Torres Strait and Low Isles. *H. mjobergi* is recorded from Broome and Monte Bello Island, *H. darwini* only from Darwin, *H. regalis* from Monte Bello Island to Torres Strait, *H. zephyrus* from the vicinity of Moreton Bay, and *H. whiteleggei* from Moreton Bay to Port Hacking; some of these are associated with mangrove areas.

Whereas *Halobates* are clothed with a pile of velvety hairs that make them practically unwettable, and apparently live entirely on the water surface, *Hermatobates* and *Halovelia* retreat into crevices in the coral as the tide floods in. *Hermatobates* (doubtfully placed in Gerridae) can climb and walk rapidly on dry coral. Three species are recorded from northern Australia —*H. weddi* from Monte Bello and Heron Islands, *H. walkeri* from Guichen Reef in the Arafura Sea, and *H. haddoni* from Monte Bello Island, Guichen Reef, and Torres Strait, as well as from New Caledonia, Marquesas, Ryukyu Islands, and Philippine Islands.

Halovelia (Veliidae) includes nine species, of which two are recorded from northwestern Australia—*H. hilli* from Monte Bello Island and *H. maritima* from Cartier and Pelsart Islands. Two other species have been taken in New Guinea. *H. hilli* feeds on *Clunio*, and possibly also on Collembola.

The intertidal dwarf-bug *Corallocoris marksae* is known from Heron Island (the type locality) and Low Isles, and also from New Caledonia, Samoa, and Singapore. These bugs are black, about 1·5 millimetres long, flightless, but strong jumpers. The forewings are convex and toughened, and cover the abdomen, giving the insect a beetle-like appearance; probably air bubbles are held beneath them. As the tide recedes, the bugs, which are carnivorous, emerge from tiny crevices to forage under the rocks. They have been found in volcanic rock and in granite, as well as coralline beach rock. The eggs are relatively large and are glued to the substrate deep within the crevices. *C. marksae* has been reared in captivity, and its biology is much better known than is that of the other bugs listed. Two other species of *Corallocoris* are recorded, one from Nauru Island and one from Japan.

Coleoptera

Polypaea coralli (Staphylinidae), found at Low Isles, was described in 1878 from Aru Island. Another staphylinid (genus near *Quedius*) is recorded from upturned coral on the outer reef at Heron Island.

Dicranolaius alleni (Melyridae) occurs in beach-rock crevices at Low and Heron Islands. The larva is bright pink with a black head, and G. B. Monteith has observed it at Heron Island preying on an even smaller beetle (Limnichidae) about 1 millimetre long, which also inhabits crevices. These little animals and *Corallocoris* can be collected by taking pieces of rock that have been submerged by the tide, breaking them open, and washing out the cavities.

Diptera

There are marine species of *Idioglochina* (Tipulidae) in the Pacific Islands, and it is likely that two species of this genus known from northern Australia breed in the intertidal zone.

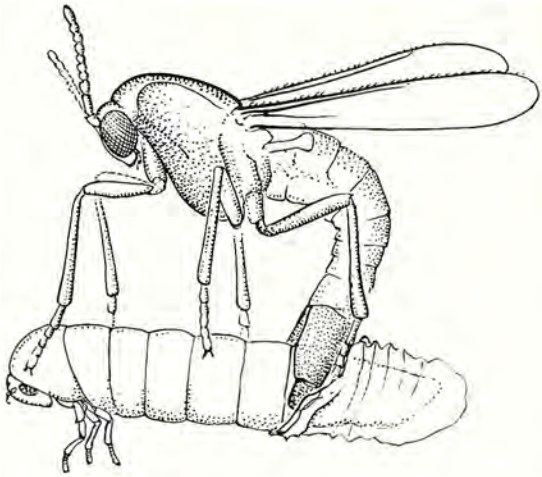
Pontomyia and *Clunio* (Chironomidae) are marine midges which pass their whole adult life in the couple of hours between outgoing and incoming tides. Both have typical Chironomid larvae, cylindrical, segmented, with a distinct head and a small prothoracic proleg. The larvae dwell in tubes which they build by binding algal debris and sand particles with sticky saliva, but tubes of Australian species have not yet been seen. The pupae, which lack respiratory horns, remain in the larval tubes until ready to emerge. Both genera have wingless grub-like females; female *Pontomyia* have only vestiges of mid and hind legs, but female *Clunio* have six short functional legs and are able to crawl about. In both genera females emerge full of developed eggs and, after mating and fertilization, lay them almost immediately in the algal mat.

Males and mating habits of these genera are very different. *Clunio* males are stoutly built, not unlike a biting midge, but are characterized by relatively enormous claspers representing about half the length of the abdomen. Detailed accounts are available of Japanese and European species. The pupae are non-motile. When ready to emerge, at an ebb tide, gas is formed in the body and they rise to the surface. Males emerge at once and take to flight; within a couple of minutes their terminalia have rotated 180° and they are ready to mate. Females cannot emerge independently, and the female pupa floats at the surface until a skimming male touches it with fore and mid legs, stimulating splitting of the skin. He then mounts it, pulls the pupal skin back with his claspers from the female abdomen, and mates. The female is dragged about for a while, trailing behind (such pairs are collected for definite association of the sexes of one species). Then she separates, deposits her egg-mass among the algae, and dies.

The species from Low Isles were close to *C. setoensis* and *C. tsushimensis* var. *minor* from Japan; the second of them has been collected south to Moreton Bay and *C. pacificus* has been reported from New South Wales. The genus is large, with a worldwide distribution.

Pontomyia males are delicate pale insects with peculiarly modified wings, narrow and with the apical third bent at an angle. The pupae swim actively to the surface and the female emerges unaided to float passively until clasped by a questing male, which then drags her about in end-to-end position. (We watched mating at Low Isles.)

Buxton, who collected the first known *Pontomyia*, *P. natans*, with a tow-net over *Halophila* in Samoa during nocturnal low tide, was convinced that the males use the wings to swim under water. Wassell collected *P. natans*? in a plankton haul in Princess Charlotte Bay, where they came to a strong light, and he, too, thought they swam beneath the surface. Tokunaga studied a Japanese species, *P. pacifica*, and



A *Clunio* species, near *setoensis*. The male is removing the female pupal skin prior to mating. [Drawing, in part after Hashimoto, by S. R. Curtis.]

concluded that the wings were used in a fluttering motion like oars to propel the insect skimming over the surface, the legs merely acting as supports. Later, he found *P. natans* in Japanese waters and was satisfied it moved in the same way. He suggested Buxton's specimens had been tumbled about in the net while being collected.

The Low Isles species, *P. pacifica*?, appeared to behave as described by Tokunaga; it has been taken also at Sherrard and Green Islands. A larger and distinctive species has been collected in a night plankton haul at Heron Island, but nothing is known of its habits. *P. cottoni*, described from the coast of Reevesby Island in Spencer Gulf, South Australia, is likewise known only from males; it has been taken also at Gunamatta Bay, New South Wales, and (probably this species) at Alexandra Headland, Queensland.

Pontomyia and *Clunio* adults seem to appear in cycles related to moon phases or associated tides, but careful regular observations at one locality are needed to clarify this. Daytime collections of *P. pacifica*? at Green Island and Low Isles appeared related to full moon, and at Sherrard Island to new moon; no observations were made at nocturnal low tides.

Trichoptera

One marine caddis fly, *Philanisus plebeius* (Philanisidae), occurs on rocky headlands and open coasts of southern Australia and New Zealand. It breeds in rock pools close to low tide mark. The larvae make a slightly curved tubular case, which may be covered with fragments of coralline algae. The adults, which have a wing-span of about 1·7 centimetres, generally remain in the shelter of projecting rocks close to water-level. The long ovipositor of the female is probably used to insert the eggs into crevices.

Enough has been said to indicate that the recorded distribution of the insects of the seas around Australia is very much the distribution of a few collectors. A great deal is yet to be discovered about these insects' biology, and they present a challenging and fruitful field of endeavour for naturalists.

BOOK REVIEW

AUSTRALIAN GROUND ORCHIDS, by Densey Clyde, a Periwinkle Book, published by Lansdowne Press; 1970; 112 pages; price, $1.50.

It was a pleasure to read this book for this review. Even though another book on native orchids appeared in what I had thought was a saturated market, there was no comparison in my mind between Mrs Clyne's excellent work and a couple of far more expensive and recent publications of a similar nature. Both the black and white and colour plates in the book are clear and well reproduced. Many of the salient features of the species shown are readily discernible from the excellent close-ups. The line drawings used to illustrate some of the variations to be found in many orchid genera are well-done, accurate, and informative. The chapter entitled "How to Photograph Orchids" should be of use to the native-plant lover but very amateur photographer (like the reviewer). The text throughout the book is the most informative on this subject that I have read in a book of this level. Obviously the author is as competent at prose as she is at photography. I found the style very refreshing, a manifestation of the very keen interest shown in the subject by the author. This book doesn't attempt to give advice on growing these plants, but it does present an introduction to part of Australia's diverse flora. I understand that a companion volume on the epiphytic orchids is to follow.—*D. Blaxell, Royal Botanic Gardens and National Herbarium, Sydney.*

AUSTRALIAN SHIPWORMS

By RUTH D. TURNER
Museum of Comparative Zoology, Harvard University, U.S.A.

THE numerous common names given to a family of highly specialized, wood-boring, bivalve molluscs (Teredinidae) reflect their impact on maritime people throughout the world. The English, for example, call them *pileworms*, *shipworms*, or *augerworms;* the French, *tarets;* the Dutch, *zeeworms*, and the Spanish, *bromas*. The Fijians call them *obe*, the northern Australian Aborigines *cobra*, and the southern Aborigines *warragárá*.

Teredinids are burrowing, worm-like animals: in short, bivalves whose bodies are elongated posteriorly so that their shells cover only a small part of the anterior end (plate 1). The shell is sculptured with file-like ridges which, when scraped against the anterior end of the burrow, rasp off particles of wood. These particles are carried, by cilia, to the mouth and are used as food. The siphons normally protrude through the minute opening of the burrow; the incurrent siphon takes in water for feeding and respiration, the excurrent one discharges waste and reproductive products. Under adverse conditions, shipworms withdraw the siphons and plug the burrow aperture with the calcareous pallets, and in this way they can exist for about 6 weeks. Species of teredinids vary greatly in size; some do not reach 6 inches in length, but others exceed 6 feet. Because they grow undetected inside timber they are often referred to as "termites of the sea".

Shipworms are considered pests because accounts of early voyages are replete with stories of riddled ships and of desperate sailors manning the pumps to keep them afloat. Even Captain Cook feared shipworms, and did not trust the then new procedure of copper sheathing. Instead, he preferred the old reliable "double-hull" method of protection, with the space between the outer wood sheathing and the true hull filled with animal hair and tar. This choice was fortunate, for it helped protect his ship from quite a different destructive element when it struck a reef off the Endeavour River, Queensland. Today most trans-oceanic vessels are made of steel, and borers are no longer a threat. Smaller wooden fishing vessels, yachts, and even rowboats,

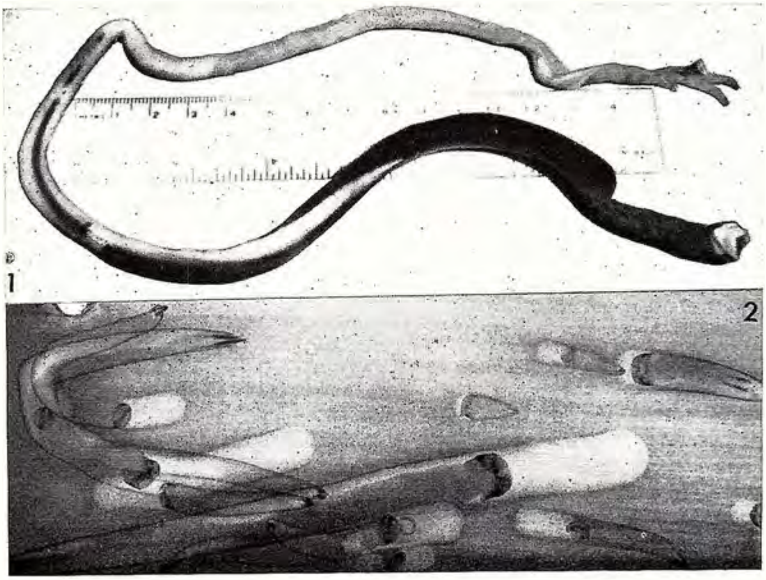


Plate 1, fig. 1: *Dicyathifer manni* (Wright) removed from wood collected near Port Moresby, New Guinea, showing the long worm-like animal, the small shell at the anterior end, and the two siphons and pallet at the posterior end. The large white patch is ripe gonads. Fig. 2: An X-ray picture of a test panel, showing young *Bankia australis* (Calman) in the wood. Note the dark pallets plugging the entrance to the burrows. [Photos: Author.]

however, are susceptible, and their owners are well aware of the costs of protection and repair. People also react negatively to pileworms because they hear of the sudden collapse of wharves or other waterfront structures resulting in loss of money, property, and occasionally life.

Shipworms our friends as well as foes

All this is true, but it is only part of the story. As with so much of life, the good goes quietly on, unnoticed and unacclaimed. Such is the case with the teredinids, for they play an important role in nature. Only when man began using wood in the sea did they become pests. Teredinids arose in the Cretaceous, and since then have been most important in the recycling of wood in the sea. Few of the many papers on food cycles in the sea discuss terrestrial detritus, particularly woody plants. However, there is increasing evidence of the connection between the richness of animal life in the sea and the presence of terrestrial plant material, including huge tree trunks. Bottom-living animals do not have digestive enzymes that allow them to feed directly on plant material, but bacteria can digest cellulose and these then become the first link in a secondary food chain. The importance of teredinids in this process is threefold: (1) Their activity exposes more wood surface and thus increases the number of bacteria on which other organisms can feed. (2) They hasten the break-up of wood spewed by rivers into the sea and so prevent the clogging of estuaries. (3) Their faecal pellets as well as their bodies are a source of nutrient for flatworms, annelids, predatory snails, and other invertebrates.

On two occasions, in Puerto Rico and New Guinea, I observed a muricid and a thaid, respectively, feeding on teredinids. When these large snails were picked from submerged logs, their proboscides extended far down into the tubes of their prey.

One does not usually think of vertebrates feeding on teredinids, but fish vigorously attack exposed "worms". Seagulls immediately move in for a feast from broken infested wood left on the beach. Though I can not find a reference in the literature, it may be that some mammals living in mangrove areas break roots to get at the juicy morsels; certainly man has learned the trick.

Teredines "good tucker"

While collecting at Tree Point, north of Darwin, Australia, we found that the Aborigines knew about teredines, and they quickly collected a bucket of large specimens for us. Cobra are considered "good tucker" by the natives, and they could not understand why we popped the "worms" into preservative instead of into our mouths. It is not surprising that cobra are eaten in this part of the world, for they are abundant in the extensive mangrove forests and commonly are more than 3 feet long. This experience recalled the story of a hungry young explorer lost in the bush on the Queensland coast in 1836. He was "driven by hunger to eat a species of *Teredo* or Auger worm, called by the blacks cobra, which he found very palatable" (J. Backhouse, 1845). Another example of the use of teredines by the Aborigines comes from N. Taylor (1866) in his report of the exploration of southeastern Gippsland, in which he relates "an instance of acclimatization by the natives" as follows:

> Genoa Jack, an aboriginal, says that formerly there were no Warragárá (a species of Teredo, living in rotten logs lying in the half-saltwater of the Genoa and tributaries) in the Snowy River, till the Dora or Snowy River blacks, who used to come periodically to the Genoa, discovered it, cut up the logs into billets, and carried them along the coast to the Snowy River, where they split them and planted them upright in the mud. He says they are plentiful there now. They eat them raw as they pull them out, some are over a foot long.

Rich teredinid fauna in Australia

To the biologist the teredinid fauna of Australia-New Guinea is the richest and most interesting in the world, but to boat owners, harbour engineers, and wood preservers it presents many problems. The unexpected failure of wharves in Bowen, Queensland, and Port Huon, Tasmania, resulted in a survey of the marine wood borers of Australia-New Guinea by the Forest Products Division of the Commonwealth Scientific and Industrial Research Organization, in which I was asked to participate. Many State organizations co-operated with the CSIRO in this survey, and they offered Miss Jeannette Marshall, my assistant, Mr John Beesley, of the CSIRO, and me every assistance in the field. Miss Marshall is a graduate student in the School of Zoology, University of New South Wales. Her research is on the biology of Teredinidae, and she would be grateful for material and data on borer attacks. Before the fieldwork began Mr Beesley set up thirty-eight test stations around Australia, nine in Papua, and sixteen on offshore islands. In addition, test panels put out by other organizations gave us a total of sixty-seven test sites. In the course of the survey we made 111 field stations. From these sources and museum collections we obtained forty species of teredinids (two new) belonging to eleven genera. Of the sixty-six species recognized for the world (R. D. Turner, 1966) thirty-eight are found in Australia-New Guinea and only three (*Kuphus*, *Psiloteredo*, and

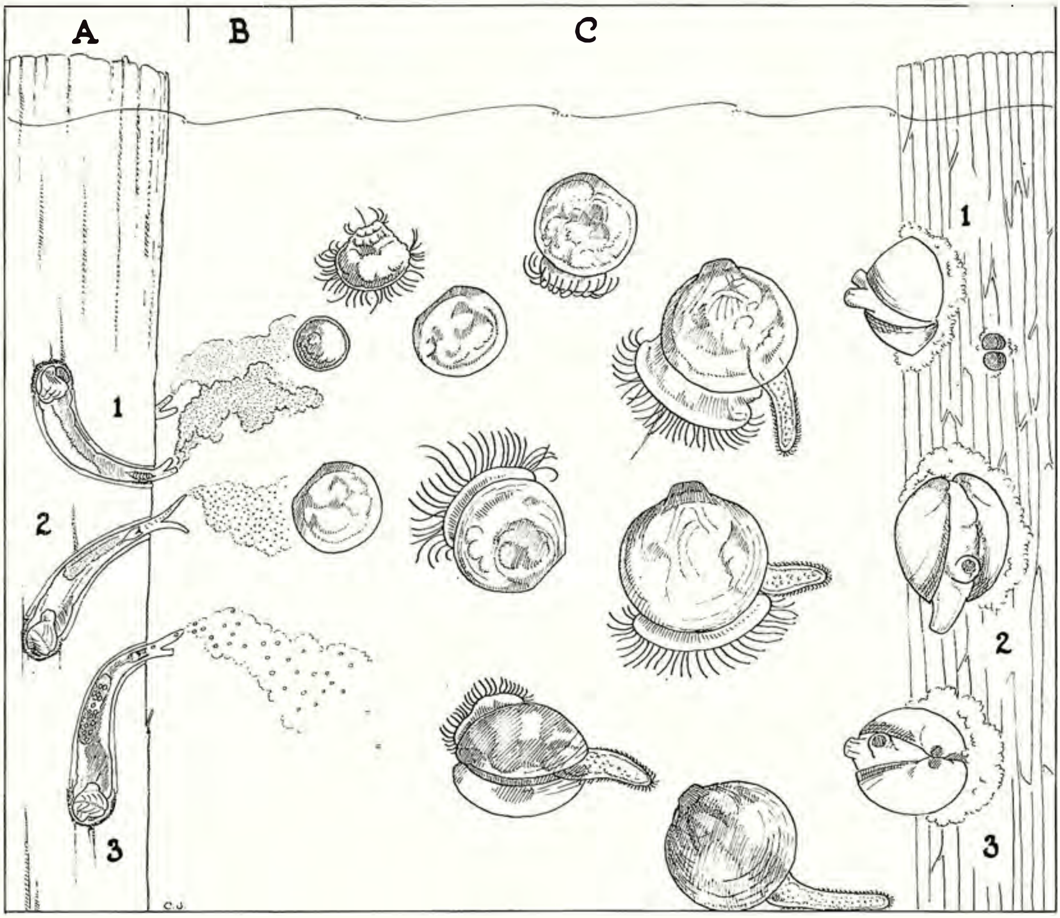


Plate 2. Semidiagrammatic representation of the three types of life-histories in the Teredinidae. The adults in the wood (column A) extend their siphons into the water and release reproductive products (column B). The developing free-swimming larvae (column C) may remain in the plankton for from a few days to six weeks. The three types of life-histories are illustrated horizontally. Fig. 1–1 is of *Bankia australis* (Calman), an oviparous species in which the eggs and sperm (left, top) are released, and fertilization takes place in the sea. The trochophore, straight-hinge and pediveliger stages are spent in the plankton and after three to four weeks the young borer penetrates the wood (top, right). Fig. 2–2 is of *Teredo navalis* Linnaeus, a short-term larviparous species in which the young are released in the straight hinge stage (left, middle), develop in the plankton to the pediveliger, and then penetrate the wood (right, middle). Fig. 3–3 is of *Lyrodus pedicellatus* (Quatrefages), a long-term larviparous species which releases the young in the pediveliger stage (left, bottom), and within a few hours to days the larva is ready to penetrate the wood (right, bottom). Column A—$\frac{1}{4}$X; column B—about natural size; column C—25X. [Diagram by C. Jones.]

Neoteredo) of the fourteen known genera are missing. It is little wonder that wood borers are a problem in Australia, particularly as so much of the coast is lined with mangrove or other forests. These forests are the natural breeding grounds of teredines but, as mentioned earlier, borers are beneficial in such areas. One hesitates to mention mangrove forests as the habitat of wood borers for fear that every harbour engineer and wharf owner will cut the mangrove for miles around. This rash act would be tragic, for mangrove forests are beautiful and biologically rich areas, and the living tree roots maintain the shore line by preventing sediment transport.

Our purpose in collecting in natural areas as well as from wharves and test panels was to ascertain whether the same species occurred in all situations, and, if possible, the source of infestation of a new wharf. Tabulations of our results are incomplete, but we have noticed that, of the two largest tropical species, *Dicyathifer manni* (Wright) and *Bactronophorus thoracites* (Gould), the first was taken at thirty-six field stations and only twice in test panels, and the latter at twenty-three field stations but never in test panels. There were only eight records of *Nausitora* in test panels, though species in this genus were taken at twenty-five field stations. These results agree with collections made by Smith in Queensland and Howlett in Western Australia a decade ago. Occasionally these species are present in wharves, and their absence from test panels is difficult to explain. We know that many of the panels were in the water during the breeding season of these species, at sites easily within reach of the free-swimming larvae. It is possible that sawn wood is not a favourable substrate for these typically mangrove species, and that only an occasional animal successfully penetrates piling, or that test panels are not in the water long enough for the succession of events necessary for the settling of the larvae. It is also possible that the types of bacteria or fungi found on mangrove differ from those on wharves, for we know some bacteria attract larvae while others repel them. Further research on the requirements and behaviour of the larvae at the time of settlement is needed before we can answer this question.

The four species most commonly found both at field stations and in test panels are *Teredo furcifera* von Martens, *Teredo navalis* Linnaeus, *Lyrodus pedicellatus* (Quatrefages), and *Bankia australis* (Calman). The first three are larviparous species, world-wide in distribution within their range of temperature and salinity tolerance. The fourth is oviparous and confined to Australia and New Zealand, except for the population at Rabaul, New Britain, where it was probably introduced during the Second World War, and survives. A knowledge of the life-history of these species can explain the distribution patterns.

Life-histories of teredinids

Once teredinid larvae have penetrated the wood and metamorphosed to the adult form, they are "prisoners", no longer capable of moving from one log to another as are the crustacean borers, *Limnoria* and *Sphaeroma*. Consequently, if the timber disintegrates the cobra perish. Teredines may be divided into three groups on the basis of larval development and length of planktonic life. So far as we know, species in all genera except *Teredo* and *Lyrodus* are oviparous, i.e., fertilization of the egg, and development to the pediveliger stage, take place in the sea (plate 2, fig. 1). Larvae in this group may spend from 4 to 10 weeks in the plankton. A few species of *Teredo* and *Lyrodus* (e.g., *T. navalis* and *L. massa*) brood the young in the gills until they have developed a straight-hinged shell and a velum. These are called short-term larviparous species; the young spend from 2 to 4 weeks in the plankton, where they feed and develop into pediveligers (plate 2, fig. 2). Most *Teredo* and *Lyrodus* brood the young to the pediveliger stage, and are referred to as long-term larviparous species. The young in this group can both swim and crawl when released, and spend only a few hours or days in the plankton (plate 2, fig. 3).

The distance that larvae are dispersed by currents is proportional to the time spent in the plankton; therefore, one would expect oviparous species to be the most widely distributed. Experiments and collecting show that this is not the case. Except for a few circumtropical *Bankia*, oviparous marine species are confined to large ocean basins. Probable reasons for this distribution are the lack of wood

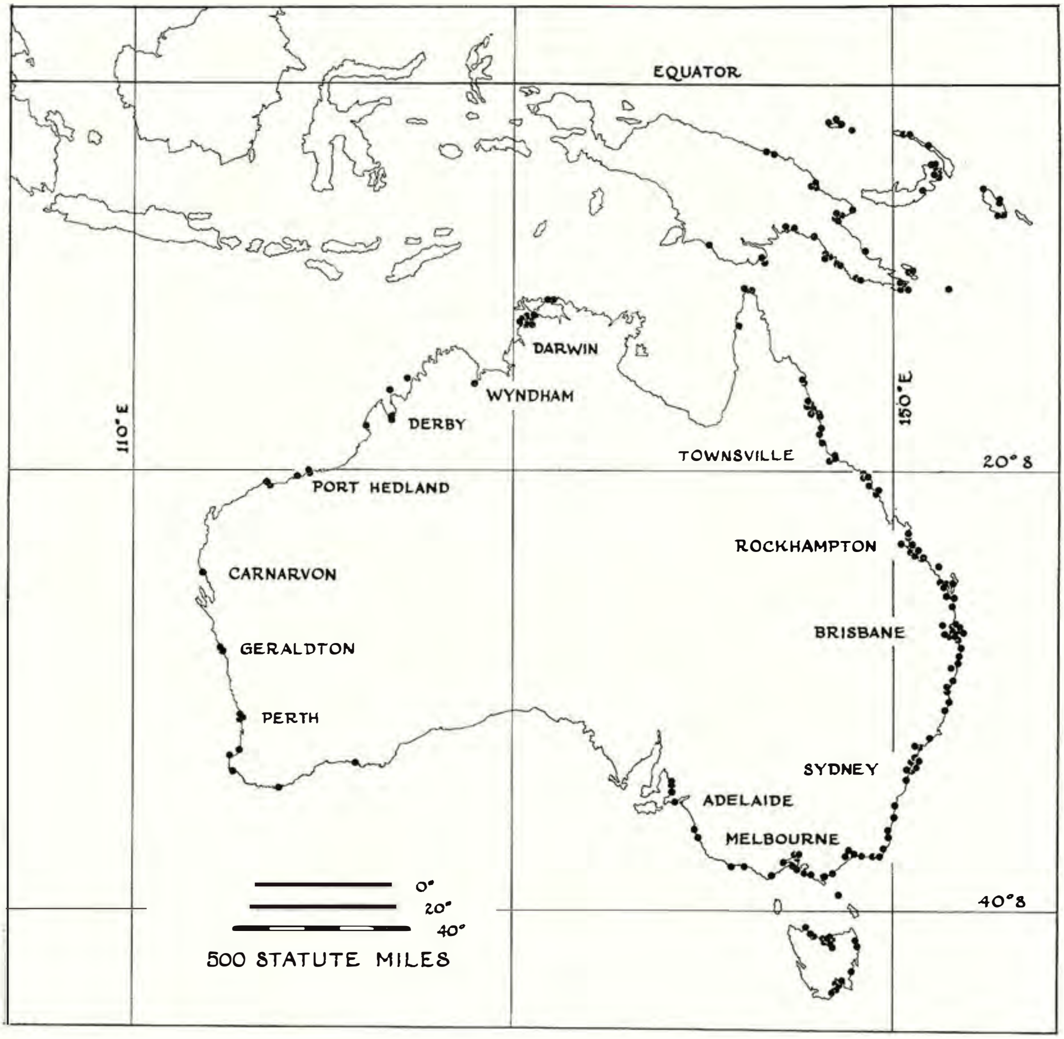


Plate 3. Localities from which molluscan wood-borers were obtained. [Map by C. Jones.]

available to settling larvae spawned in mid-ocean, and the shortness of the adult life-span relative to the time required for a sailing vessel or floating wood to travel from one ocean basin to another.

Oviparous brackish-water species are limited by their salinity requirements, particularly as larvae, and normally occur in adjacent estuaries or rivers. It is unlikely that infected wood discharged by one river could enter and float up another, so introductions to a new system are probably effected by man. The Aboriginal transplant mentioned earlier helps to explain the distribution of *Nausitora dunlopei* in the south of Australia.

Larviparous marine species are or may become world-wide in distribution within the limits of their salinity and temperature tolerances. The probable reason is that the larvae are carried in an envelope of quiet water created by the fouling organisms on the hull, and, when they are ready to settle, the "parent" wood is available. During the slow voyages of sailing-ship days it was probably the second or third generation that produced the larvae infecting new wood in a foreign port.

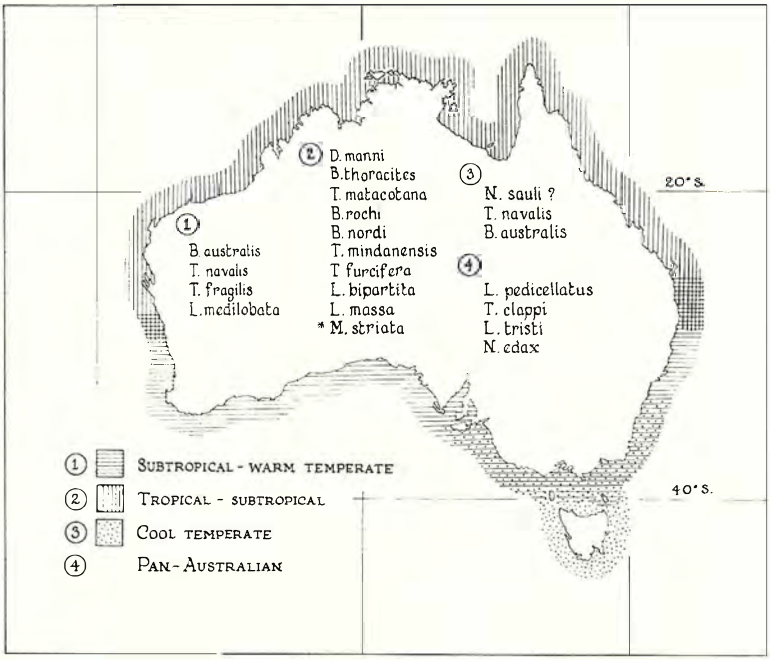


Plate 4. General distribution patterns of some Australian molluscan wood-borers. All are Teredinidae except *Martesia striata* (Linnaeus), marked with an asterisk, which is in the family Pholadidae. A question mark follows *Nausitora sauli* because it is not certain that this name can be applied to this species. Full names and remarks concerning different species can be obtained by checking the author's book mentioned in the "further reading" list at the end of this article. [Diagram by C. Jones.]

Larviparous brackish and freshwater species are very restricted. Australia has one of the few species in this group, *Teredo poculifer* Iredale, taken only from the Brisbane River system; Marys River, Maryborough; Burnett River, Bundaberg, and Barnes Creek, Mackay.

Adult teredinids, by closing their burrows, can withstand wide ranges in salinity and even desiccation for periods of about a month. Their larvae, however, are far more sensitive. As a result, populations of brackish-water species, such as *N. dunlopei* and *T. poculifer*, shift up and down a river with changing salinities, while species requiring higher salinities move in and out the mouths of rivers and estuaries. A species may be introduced into an area and survive for a generation or two, or a local marginal population may suddenly build up only to be reduced or wiped out if conditions change. Sudden rain may kill the larvae in the plankton or a prolonged drought may promote their survival and settlement. Unexpected heavy attacks of borers such as those mentioned for Hobart and Bowen or the sudden disappearance of a species can often be explained on the basis of such population explosions and crashes.

The breeding season of *N. dunlopei* is controlled mainly by temperature in the southern end of its range and by reduction of salinity in the north. Marine species with broad latitudinal ranges have longer breeding periods towards the tropics. Fluctuations in temperature affect the success of a breeding season of a species, especially at the limits of its range, resulting in expansion or contraction of the range. In summary, there is no simple way to predict an attack in an area without knowing the species involved and the changing ecologic conditions. An estimate of "spat-fall", however, can often be obtained by periodic sampling of the plankton. Sound prediction requires constant monitoring of the area in question.

The map (plate 3) shows the extent of, as well as the gaps in, our collections. It is obvious that more fieldwork is needed before detailed ranges can be given for the various species. Nine species are known from only two or three localities each, and little can be said about their ranges; four are common to north Queensland and New Guinea; ten are known only from New Guinea and islands to the north; and four, all of wide distribution in the Indo-Pacific, are found all around Australia. The ranges of fifteen commonly collected species indicate the presence of three faunal provinces for the teredines. The provinces and representative species in each are shown on the map (plate 4). The tropical-subtropical province equals the combined Damperian and Solanderian Provinces of Bennett and Pope (1953), the warm temperate subtropical province equals the combined Flindersian-Peronian Provinces, and the cool temperate equals the Maugean. Since wood is the common substrate for all teredinids they do not reflect the divisions of the larger temperature controlled provinces, which are largely based on substrate differences. There is a considerable overlapping of the provinces, and this may be explained by the fact that many species can extend their ranges into colder latitudes by living in inlets where waters are warmed on the shallow flats during the summer.

Control of teredines

There are numerous ways of protecting wharves against borers, the most commonly used being impregnation of the piling with copperchromearsenic or creosote. Boats are best protected by keeping the paint, fibreglass, or other coating intact. Any of a variety of good marine paints on the market, if properly applied and kept in good condition, will afford protection. The latest information on various preservatives and paints can be obtained by consulting the reports of the Standards Association of Australia.

One of the most important and least practised methods of protection is "good housekeeping". Old untreated wood, the butt ends of old piling, remnants of collapsed or dismantled wharves, and other trash wood lying around a port are ideal breeding sites for pileworms.

Though man has been attempting to control marine boring and fouling organisms for hundreds of years, he has had relatively little success. The reason may be that more emphasis has been placed on testing materials rather than studying the organisms involved. In contrast, the medical profession has had remarkable success in virtually eliminating many diseases by studying the life-history of the pathogenes and disease carriers, and, finding a "weak link", has effected control. We know from exposure tests that some methods of treating wood are better than others, but we do not know why. In recent years there has been an increased interest in studying the life-histories of the animals doing the damage to ascertain the factors controlling the settlement of the larvae. It is quite possible that the ultimate control will be effected by preventing the attachment of certain bacteria to the wood surface. Co-operative research by biochemists, bacteriologists, mycologists, and invertebrate zoologists, as well as wood specialists and preservation experts, is essential to accomplish these ends.

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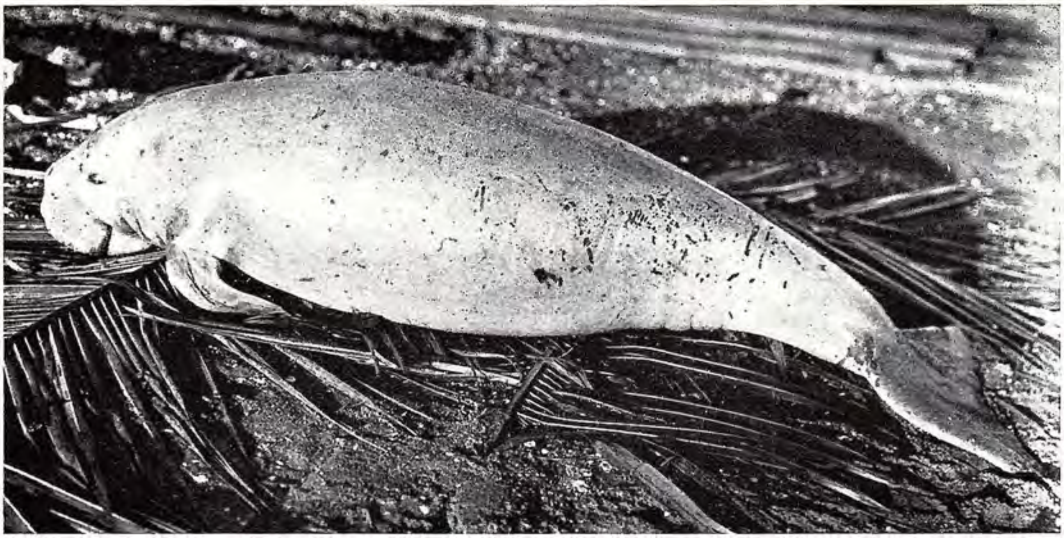


The dugong, once plentiful around the northern coasts of Australia, is now rare. [Photo: Frank Hurley.]

The Decline of the Dugong

By KATE BERTRAM,
President of Lucy Cavendish College, Cambridge,
and COLIN BERTRAM,
Senior Tutor of St John's College, Cambridge

SADLY, dugongs are not what they used to be. In the past, vast numbers of them lived round the coasts of Australia northwards from Brisbane to Perth. They browsed in large herds on the masses of Dugong Grass which grow in the inshore regions of these coasts. Their bodies supplied meat and oil for local use, and, in the past century, great quantities of oil for commercial enterprises.

Now, they have become very rare, and we were surprised, during our period of study in Queensland and the Northern Territory in 1965, how many people had never even heard of their existence in Australia. Gone are the huge herds off Brisbane, one such having been reported to extend 3 miles in length and 1 mile in width and to contain many thousands of individuals. Gone is a valuable supply of meat, easily obtained and much prized for flavour. Gone too, is a big supply of oil, which was sold for purposes including cooking, medicine, and varnishing canoes.

The meat now has less charm, for, with scarcity, the animals are harder to catch and only some of the older Aboriginal men are said to have sufficient patience to go out quietly on moonlight nights in canoes with muffled paddles to harpoon their victims as they come to the surface to breathe. For, though much has changed, dugongs still remain large aquatic mammals which need to breathe air, and for this purpose they have to put the tips of their snouts out of the water, so revealing their presence to the watchful hunter. A breath is taken quickly and softly and the animal then sinks silently again and disappears, to reappear at some other spot. The skill of the hunter depends on his ability not to frighten the animal and to forecast what its movements are likely to be.

Dugong oil has also lost much of its appeal, for recently it has been found that shark oil has an equally good vitamin content and can be more cheaply produced. Dugong oil was still in use for medicinal purposes in the Government hospital on Thursday Island, Queensland, in 1965, but has since been discontinued. Perhaps the oil itself has lost some of its power, for it was reported to be so penetrating that it could force its way out of even a glass container, but we have successfully kept some in a bottle for 5 years.

Dugongs belong to the order Sirenia and are perhaps closest to elephants among mammals. By tradition, the sirens had lovely voices, but it seems doubtful whether dugongs now make any significant sounds. It is also doubtful whether they have sufficient aesthetic charm to warrant their being thought to be the origin of the mermaid myth. Certain it is that they have pectoral breasts, but these are small and almost hidden in the armpits and so are rarely visible. Further, suckling normally takes place in a horizontal position, below water. Dugongs' hair, far from being streaming masses, is restricted to bristles round the mouth and single hairs about a quarter of an inch in length, scattered at about 1-inch to 2-inch intervals over the whole body. The tail is forked and the flippers are smooth, unlike its Atlantic relatives, the manatees, which have rounded tails and traces of finger-nails on the tips of the flippers. The skin is thick and tough, and is believed to have been used as a covering for the Ark of the Covenant during its travel in Sinai. From the Red Sea to the Solomon Islands, dugongs still just survive in very small numbers throughout the warm Indo-Pacific region.

Though much is known of the anatomy and habits of dugongs, the time-scale in their life-history is as yet undiscovered. It is known that the animals are long-lived, that they breed slowly, normally have only a single calf, and usually reach lengths of up to 9 or 10 feet, though occasional much larger specimens are said to have been seen. No actual data, however, exists about life-span, age of maturity, or period of gestation or suckling. However, it is hoped that a study now proceeding at Cambridge University on our skull collections will yield some picture of the ages of the animals and their rate of growth.

But it is their feeding habits which make dugongs of particular interest. Unlike the other large marine animals, with the exception of the Green Turtle, they are entirely herbivorous. With their highly muscular upper lips they tear off sea grasses and other higher marine plants, which they then grind up with their molars. These teeth are peculiar in that, instead of being replaced vertically, they are constantly moving forward along the jaw to drop out at the front. They are six in number in the embryo and become reduced to two in the adult. There are also two pairs of incisors, the first of which fall out while the second erupt in the male. The function of these tusks is unknown.

The feeding habits are not only interesting but could also restore to dugongs some of their economic importance. Being herbivores, they are able to consume a vast volume of marine vegetation and convert it into meat suitable for human consumption. There is believed to be still a sufficient residual stock of these animals round the north of Australia which, with proper conservation, could rebuild themselves and add locally to the supply of protein needed by man in a world hungry for meat.

MEET OUR CONTRIBUTORS . . .

COLIN and KATE BERTRAM, a husband and wife team, are, respectively, Senior Tutor of St John's College, Cambridge, and President of Lucy Cavendish College, Cambridge. Each is an M.A. and Ph.D of Cambridge. Dr Colin Bertram was Biologist to the British Graham Land Expedition of 1934--37, and has been Chief Fisheries Officer to the Palestine Government and Director of the Scott Polar Research Institute in Cambridge. Dr Kate Bertram's activities have included Biologist in the Colonial Office Nutrition Survey in Nyasaland and Advisor on Freshwater Fisheries to the Palestine Government.

ROGER GRACE is a student at the University of Auckland, New Zealand, where he gained his Master of Science in Marine Zoology in 1968. He is at present completing a thesis on marine benthic ecology, involving a considerable amount of diving, for a Doctorate of Philosophy in Zoology. He has been diving since 1959, and is a member of the technical sub-committee of the New Zealand Underwater Association. He has a keen interest in underwater photography, particularly close-ups, from a marine biological point of view.

B. V. HAMON, a physical oceanographer, is a Senior Principal Research Scientist with the CSIRO Division of Fisheries and Oceanography. After taking B.Sc. and B.E. degrees at the University of Sydney he worked for a number of years with the CSIRO National Standards Laboratory. He took up his present position in 1957, and for the last 15 years he has made a special study of the East Australian Current.

ELIZABETH N. MARKS, M.Sc. (Queensland), Ph.D. (Cambridge), is Senior Research Officer of the National Mosquito Control Committee, working in the Department of Entomology, University of Queensland. Her research on the taxonomy and biology of mosquitoes is supported by a grant from the Queensland Department of Health, and she has taken part in fieldwork in many remote parts of Queensland, Torres Strait, and New Guinea. Dr Marks has a wide general interest in natural history and has twice been president of the Queensland Naturalists' Club, as well as editor of its journal. She has served on the executive of the Australian Conservation Foundation, and is currently convenor of the Conservation Committee of the Australian Entomological Society.

HANK NEWMAN was born in Cape Town, South Africa, in 1920, was active in angling organizations there for many years, and was an executive member of the South African Anglers' Union. In 1956 he held the International Game Fish Association's world record for Blackfin Tuna and, the following year, represented South Africa in the International Game Fishing competition in Mozambique. Mr Newman came to Australia in 1962, has been president-chairman of the Amateur Fishermen's Association of New South Wales since 1966, and is a member of the Amateur Fishermen's Advisory Council of N.S.W. He captained Australian teams in the New Zealand International Game Fishing Contests in 1964, 1966, 1968, and 1970. He is a member of the New Zealand Big Game Fishing Council.

PETER C. POWNALL has been editor of *Australian Fisheries* (previously called *Australian Fisheries Newsletter*) for the past 8 years. This monthly journal is published by the Fisheries Division of the Commonwealth Department of Primary Industry in Canberra. Born and educated in New Zealand, Mr Pownall has had more than 20 years' experience as a journalist and writer in New Zealand, the United States, and Australia.

VINCENT SERVENTY, after working for many years in Western Australia, moved to New South Wales in 1965. Now a freelance author, lecturer, film producer, and conservationist, he is president of the Wild Life Preservation Society of Australia and editor of the magazine *Wildlife in Australia*. He is also chairman of the Nature Conservation Council of N.S.W. His books include: *A Continent in Danger*, *Australian Wildlife Conservation*, *Australia's National Parks*, *Southern Walkabout*, *Nature Walkabout*, and *Dryandra*.

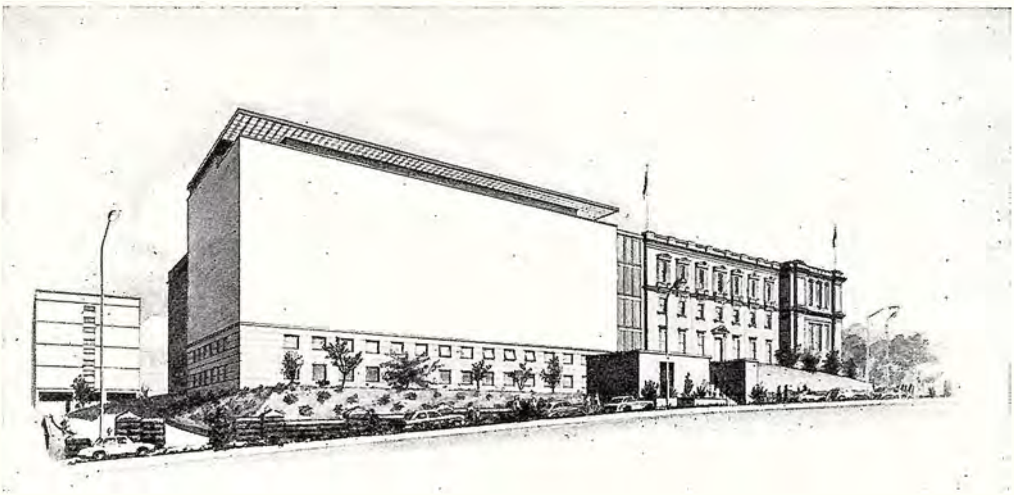
RONALD V. SOUTHCOTT holds doctorates in both medicine and science. A Fellow of the Australian College of Medical Administrators, he is Deputy Director, Medical Services, Repatriation Department, South Australia. A lifelong interest in museums and natural history has led to him becoming Honorary Zoologist, South Australian Museum, and he is also a member of the South Australian Museum Board. As an Army doctor, he was puzzled by a curious set of symptoms in soldiers swimming in the seas near Cairns—a distinct illness due to an unseen jellyfish christened the "Irukandji". This led to a continuing study of jellyfish and other marine creatures, and resulted in the describing of the lethal box-jelly *Chironex fleckeri*, as well as the Irukandji box-jelly, *Carukia barnesi*.

REG. C. SPRIGG is a graduate of Adelaide University, where he majored in geology (M.Sc.) and zoology (B.Sc.). As Assistant Government Geologist in South Australia, he was responsible for setting up the State's regional geological mapping programme and the Radium Hill Uranium Project. In 1954 he formed Geosurveys of Australia Pty Ltd as a geological and geophysical consulting and contracting organization in mining and petroleum exploration. Mr Sprigg is a foundation member of the Geological Society of Australia and a former president of the Australian Marine Sciences Association. He is a keen deep-sea scuba diver.

DAVID J. TRANTER, M.Sc. (Queensland), is a planktologist whose main field of research is the biology of plankton ecosystems. He is a Principal Research Scientist with the CSIRO Division of Fisheries and Oceanography, and worked for a number of years at Thursday Island, Queensland, on pearl oyster biology. From 1967 to 1969 he was UNESCO Curator of the Indian Ocean Biological Centre at Cochin, India.

RUTH D. TURNER is at the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, U.S.A., as Research Fellow in Malacology, Alexander Agassiz Fellow in Zoology and Oceanography, and Lecturer in Biology. She has published in the fields of land, freshwater, and marine molluscs, but specializes in boring and fouling bivalves. During 1970–71 she visited Australia as a Research Fellow with the CSIRO's Division of Wood Preservation to make a survey of Australian wood-borers or shipworms.

JOHN A. W. WHITE, Supervising Petroleum Technologist with the Bureau of Mineral Resources, Canberra, was born at Great Warley, Essex, England. After graduating at Imperial College, London, with a special Degree in Oil Technology, he joined the French oil-well service company of Schlumberger, and worked with that company in a dozen different countries for 13 years before joining the Bureau. His work covers petroleum exploration throughout Australia and Papua-New Guinea, both onshore and offshore.



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