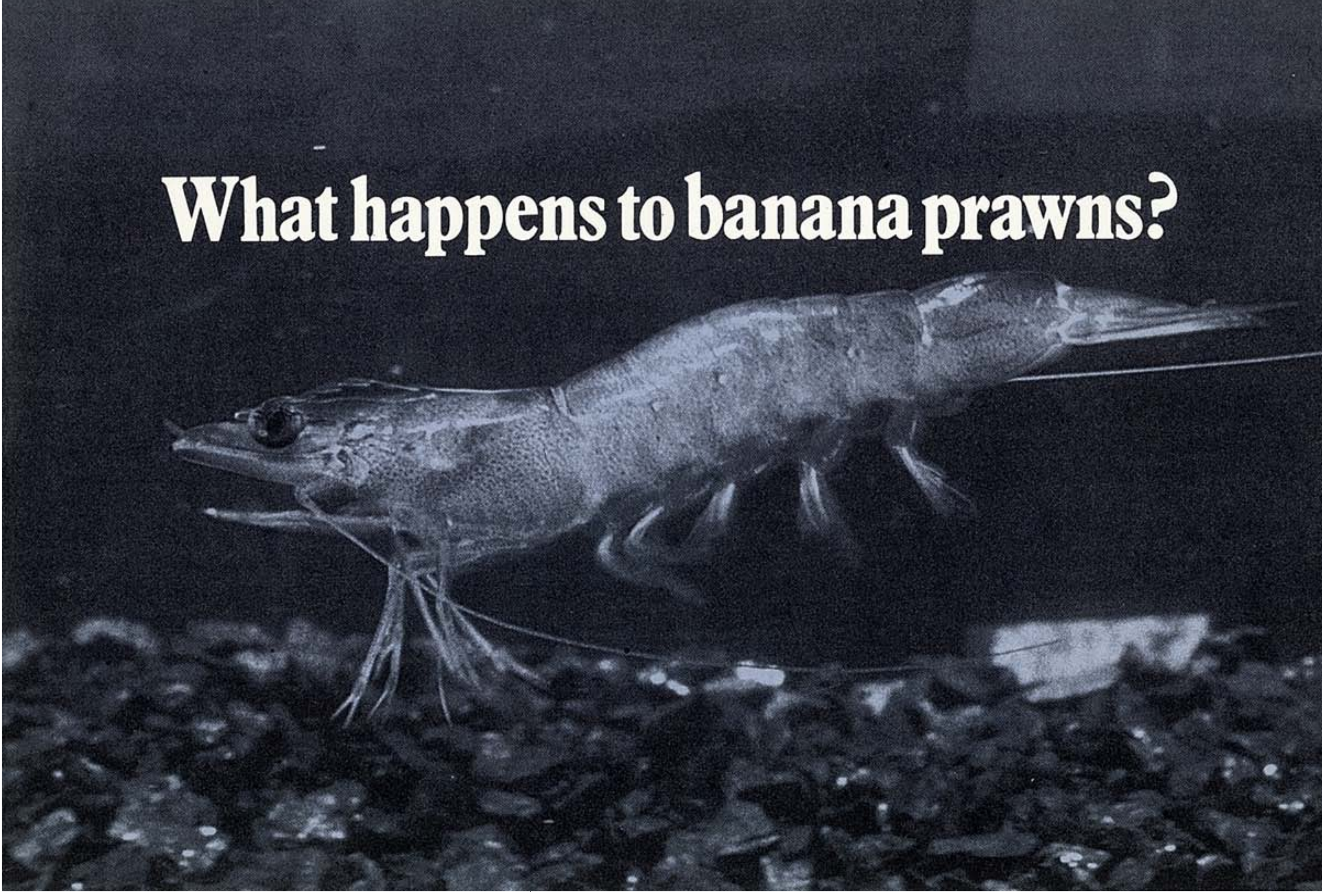
What happens to banana prawns?



The banana-prawn fishery in the Gulf of Carpentaria, which started in the late 1960s, nets up to $20 million a year in export revenue. Over the years, annual landings have fluctuated widely, prompting concern about a possible collapse of the fishery.

Studies by the CSIRO Divisions of Fisheries Research and Oceanography are uncovering the details of the prawn's complicated life history, in an attempt to supply the information necessary for a management plan aimed at ensuring that the prawns are not overfished.

Commercial prawn-fishing in the Gulf followed intensive ecological investigations from 1963 to 1965 by a team from CSIRO, the Queensland Department of Harbours and Marine, and the Commonwealth Department of Primary Industry. This study not only showed the presence of plenty of prawns, it also recorded information on their numbers and habits before fishing began — information that subsequent investigators have found valuable for comparison.

Adult banana prawns congregate in dense schools. These often occur in places where mud from the bed of the Gulf has been stirred up, making the water look from the air as though it is seething. Fishermen call the phenomenon a 'boil', and some say that the huge numbers of prawns raise this mud; but prawns and muddy water do not always go together.

Boils produce spectacular catches, and fishing soon developed into a 'search and destroy' or 'seagull' operation, with skippers spending much of their time looking for echoes from schools on echo sounders and using radar to follow other boats' movements to see whether anybody had found a boil. Some have used spotter planes as well.

As trawlermen's expertise increased, so the fishing season shortened. In the late 1960s prawns abounded in the south-east of the Gulf from March until October or November, with good commercial catches throughout that period. But now the action is over within 5 weeks.

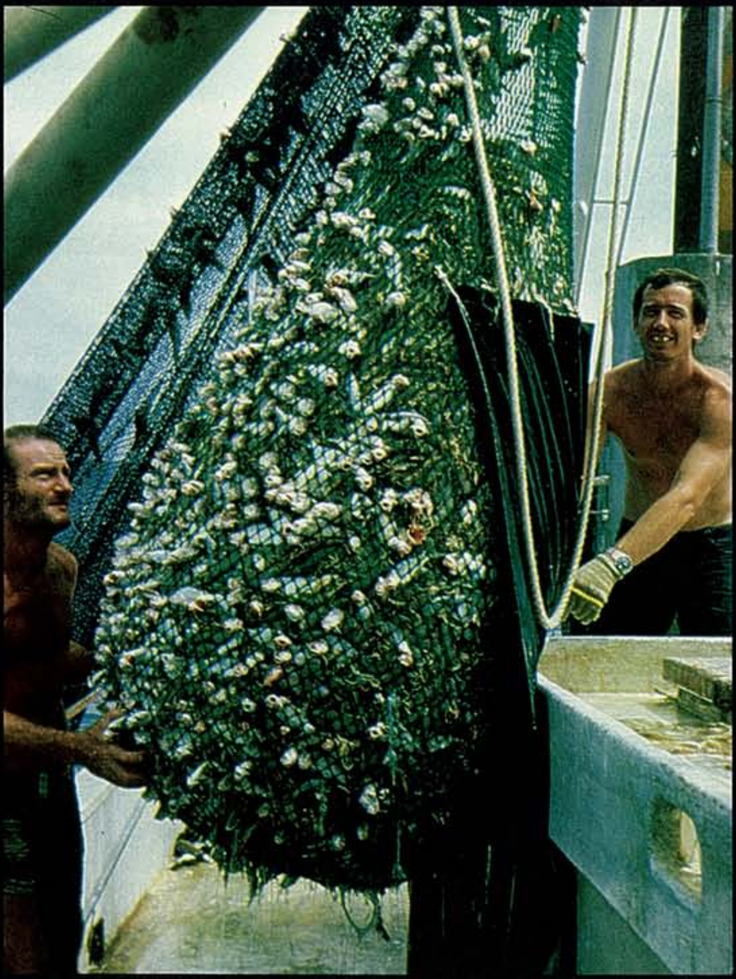
Mr Ian Somers of the Division of Fisheries Research has shown that the fishing effort has remained more or less constant since the initial rapid increase in the late 1960s and early 1970s. Despite this, catches have continued to fluctuate markedly from year to year. Of the Gulf's 10 most recent seasons, the best (1974) brought 9700 tonnes, and the leanest (1978) only 1670 tonnes.

The CSIRO northern prawn research project began in 1969 after a poor harvest. To begin with, scientists set out to estimate the stock — that is, the number of banana prawns available for fishing — and to predict the catch for the following season, but they quickly realized that they needed a thorough understanding of the animal's biology, particularly if they wanted to make predictions.

A new project involving biologists from the Division of Fisheries Research marine laboratory at Cleveland, near Brisbane, began in 1975. This was an investigation of all aspects of the prawn's life, placing a high priority on explaining the ups and downs in annual catches. Above all, the scientists wanted to find out how far environmental fluctuations could explain the good and bad seasons — and whether Gulf banana prawns were being fished out of existence.

Catches fluctuate markedly from year to year.

Prawn trawlers at Karumba.



Banana prawns in the net.

At sea, looking for prawn larvae with plankton nets.

Setting nets for sampling 'post-larvae', which surge into the rivers on flood tides.

The annual rainfall correlates well with the catch of prawns.

Life of a prawn

The banana prawn occurs from India to New Caledonia and, in Australian waters, south to latitude 29°. Scientifically, it is known as *Penaeus merguiensis*.

Some species in this Penaeidae family spend their whole lives at sea, and a few live entirely within estuaries; but the species reaching the biggest biomass, and therefore the ones most likely to attract fishermen, are those that migrate between the two habitats. The banana prawn shows this behaviour.

Adults live and spawn offshore; their offspring enter rivers, where they spend their juvenile lives; then, as 'adolescents', they return to the open sea. The maximum life span of a banana prawn is about 1 year. Dr David Moriarty and Ms Margaret Barclay, of the Division of Fisheries Research, have found that the prawns eat protozoans, small molluscs, crustaceans, and polychaete worms.

The prawns reproduce prolifically, each female shedding from 100 000 to 450 000 eggs. Mr Peter Crocos of the Division has shown that spawning occurs almost the year round in the south-east of the Gulf, but the main periods fall in spring and autumn. After hatching, the larvae moult their way through a series of stages, the earliest of which are microscopic.

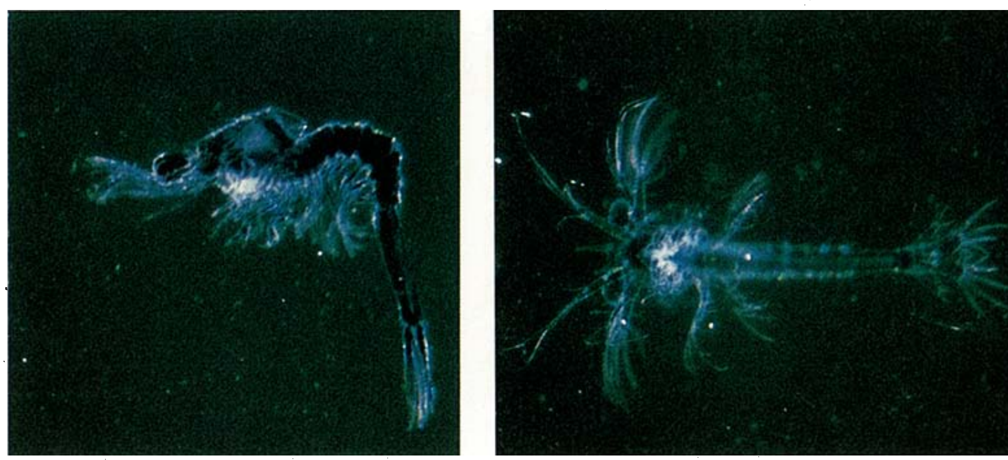
After 2–3 weeks they reach a post-larval stage. As part of an investigation into the prawn's biology, extending over several seasons, Dr Derek Staples of the Division used plankton nets with 1-mm mesh to sample the post-larvae entering the Norman River, which flows into the south-eastern corner of the Gulf at Karumba. He found that post-larvae surged into the river on flood tides from November to May, with the largest immigration in November, just before the wet season.

When the rains fell, the river swelled so much that few tides carried water (and post-larvae) into the estuary, and Dr Staples recorded small groups of incoming post-larvae for only short periods in January and March.

Once in the estuary, young prawns settle on the mud in shallow water among the mangroves lining the river banks. Juveniles, as they are now called, may be found in the Norman River in any month of the year, but during Dr Staples' study they reached their largest numbers in early December, following the main influx of post-larvae. Some juveniles settled as far as 85 km upriver, in near-fresh water, and many made their home between 48 and 72 km upstream, where the river's salinity fell in the range 1–2% (about half that of sea water).

As each tide carries sea water some 30 km up the river, most post-larvae probably spend several days travelling from the estuary mouth to their nursery areas.

Sampling the juveniles with a beam trawl of 2-mm mesh, Dr Staples found that the population rapidly declined from its December peak, thereafter showing only minor gains as relatively small parties of post-larvae entered the river during the wet season. On average, juveniles from the main batch (the November immigrants) spend 6–8 weeks among the mangroves, growing rapidly before setting off on the return journey downstream. One batch that came into the river in late January stayed less than a week.



Banana-prawn post-larva and larva.

At the other extreme, prawns that settle after the wet season generally overwinter in the river. Only a few of these survive to head out to sea the following spring, after 9 months in the nursery area.

Back at sea, the prawns begin maturing. At first they remain in shallows near the mouth of the estuary, but as summer progresses they move farther offshore, to reach sexual maturity in the deeper waters of the Gulf. Here the numbers of adolescents and adults gradually increase from December to April, when the trawlers arrive.

The role of the rain

True, the number of post-larvae reaching estuaries varies greatly from year to year, but the number of prawns leaving the rivers and joining the commercial fishing grounds fluctuates even more dramatically, causing the good and bad trawling seasons. So the question is: why do so many more prawns leave the estuaries in some years than in others?

The answer may be put in one word: rainfall. Ecologically, the emigration behaviour of juvenile prawns involves a number of factors, but scientists can confidently state that the amount and timing of rain in the catchment areas of the rivers feeding the south-eastern region of the Gulf largely determine how many young prawns will leave the estuaries for the fishing grounds.

From the commercial fisherman's point of view, interest centres on the post-larvae that enter the rivers in spring and become the juveniles that congregate in the nursery areas in early summer. If the trawlers are to enjoy a good season, something must 'flush' these prawns out of the rivers.

Juveniles swim close to the surface on their seaward journey, and can be sampled using fixed nets moored near the river mouth. Dr Staples observed waves of emigration within a period of several weeks following heavy rain. During spells of lower rainfall, only the largest prawns left the river, but after a good rain prawns of all sizes emigrated, scotching an earlier theory that juveniles stayed in the nursery until they reached a certain size.

If you plot on the same graph the annual rainfall and the banana-prawn catch for the Karumba region over the last 10 years, you produce two strikingly similar patterns. In fact, Mr David Vance of the Division of Fisheries Research, Dr Staples, and Mr John Kerr of the Division of Mathematics and Statistics have shown that differences in rainfall account for 71% of the variation in prawn catches. Virtually all the year's rain falls during the 'wet' (December to March) — just when the prawns that form the potential catch for the following fishing season are ready for their seaward journey. The same story applies to other parts of the southern Gulf.

In northern regions of the Gulf, rainfall does not correlate as well with the annual catch, but on average the prawns caught in the southern region make up more than half the Gulf harvest. In general, therefore, the annual rainfall over the whole area correlates well with its total catch of prawns.

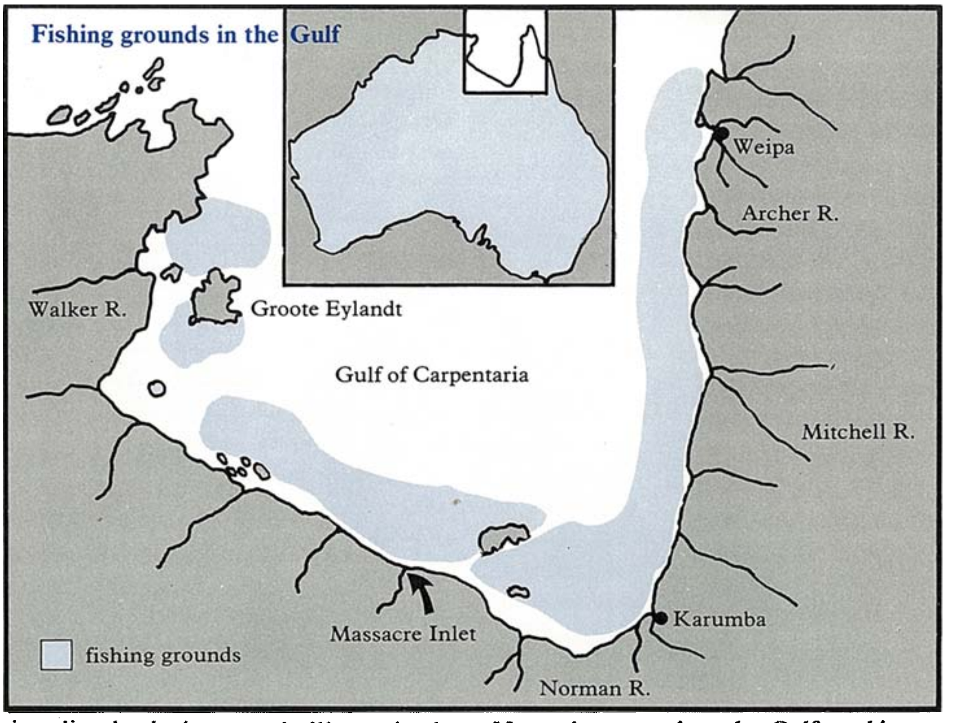
In the south-eastern region of the Gulf, the average 'wet' brings about 950 mm of rain. An exceptional year may see twice that amount: in 1974 more than 1600 mm fell, and the banana-prawn catch hit a peak at 3854 tonnes. In 1978, by contrast, rainfall reached only half the average and the Karumba region experienced one of its poorest seasons, with a catch of only 364 tonnes.

But why do juvenile banana prawns respond to rain in this way? Dr Bill Dall of the Division of Fisheries Research has shown that, as prawns grow older, they become less tolerant of low salinity, and find it harder to regulate the composition of their body fluids in fresh or near-fresh water.

Yet the young prawns do not simply leave the river as its saltiness declines. Dr Staples found that salinity near the mouth of the Norman River fell rapidly in December as fresh water from earlier rains over the catchment area accumulated in the estuary. But few prawns emigrated until the next heavy rain fell.

Perhaps the immediate physiological stimulus to the prawns, the unknown factor that gives them their final 'shove' into the ocean, may be chemical. Dr Staples recorded large fluctuations in the concentrations of various nutrients, including dissolved nitrate and silicate, in the estuary water — silicate reaching its peak and nitrate its lowest level in the wet season. Detailed laboratory experiments would be needed to determine whether one of these or some other chemical or physical influence stimulates the prawns to make their move.

In a search for further clues — and as part of a project to develop techniques for predicting the catch before a season starts — Mr Vance, Dr Staples, and Mr Kerr have analysed, for six different regions of the Gulf, the relations between catches in recent years on the one hand, and, on the other hand, not only rainfall but also the flow rate down rivers, air temperature, wind speed and direction, the number of spawning adult prawns, and the number of juveniles.



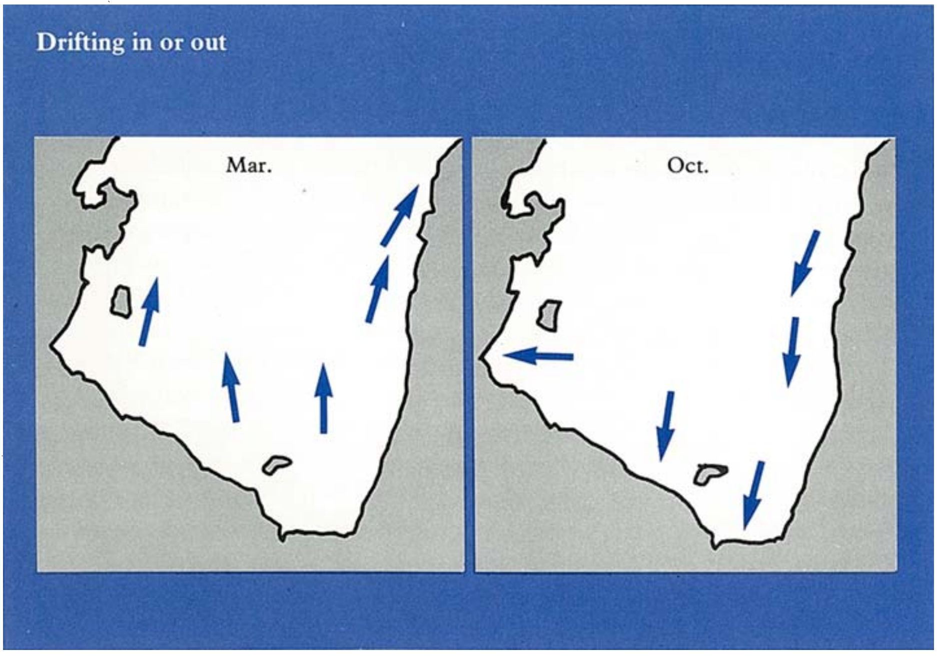
Many rivers run into the Gulf, making much of the coastal waters area good for prawn-fishing.

Some idiosyncracies

They found that prawns in the north of the Gulf responded quite differently from those around Karumba. In the Weipa region more summer rain even meant a poorer season! In general, wind and temperature had the greatest influence on northern prawn catches, but the mechanisms by which these various environmental factors operate and interact have still to be sorted out.

Banana prawns in different parts of the Gulf show other idiosyncracies that help explain why the effects of rainfall on juvenile prawns differ in the different areas. From 1970 to 1973, Mr Stan Hynd of the former Division of Fisheries and Oceanography sampled juvenile prawns in 20 major rivers around the Gulf, from Groote Eylandt to north of Weipa. On the basis of his results, Dr Staples found that the Gulf could conveniently be divided into four areas, each with its individual seasonal pattern of prawn movements in and out of the rivers.

Near Weipa the largest numbers of young prawns are to be found from February to June, but further south, from the Archer River to the Mitchell, post-larvae and juveniles turn up in all months. Move south again, to Karumba, and you find



Larval drift, as predicted by the computer model. The prawns have two breeding seasons, but the products of only one of them find, havens in the rivers flowing into the Gulf.

prawns in the rivers from October to June, but along the west of the Gulf, from Massacre Inlet to the Walker River, juvenile prawns appear intermittently the year round.

How could scientists account for this bewildering variety? Knowing that prawns spawn twice a year, and combining his own observations with figures for adult numbers calculated from catch statistics by Mr Somers, Dr Staples deduced that some batches of larvae have much greater success than others in reaching the rivers essential for their further development.

This would explain, for example, why the young spawned in spring near Karumba grow into an adult generation worth harvesting the following autumn, but the young produced in autumn do not subsequently form a commercial crop, although more females spawn in February and March than in spring in this part of the Gulf. Mr Crocos and Mr Kerr have shown that the converse applies to Weipa prawns: there, most eggs are shed in spring, but the autumn brood has much greater success in getting to estuaries.

Larvae carried away

And what prevents some larvae from reaching rivers? Quite simply, currents carry them the wrong way — but the proof of this involved a major exercise in tide measurements and computer modelling, coupled with research into the behaviour of young prawns.

To find out how currents circulate within the Gulf, Dr John Church and Mr Andrew Forbes, of the Division of Oceanography, developed a computer model, using available records of tide heights at 10 stations around the Gulf and of wind speed and direction, and making their own observations of tidal currents in the south-eastern corner. The scientists also obtained useful information by releasing four drifting buoys, which were tracked by the NIMBUS-VI meteorological satellite (the use of such buoys to map currents was described in *Ecos* 18).

This first model was two-dimensional, showing the average water movements without discriminating between flows at different depths. Was this a significant drawback?

By sampling larvae at different times of day and night and at various depths in the Gulf, Dr Peter Rothlisberg of the Division of Fisheries Research built up a picture of their vertical migrations. Just after hatching, the larvae are to be found only in the bottom one-third of the water. Older larvae move up and down within the bottom two-thirds, and the post-larvae travel throughout the depth of the water. Dr Rothlisberg showed that the larvae are responding to light; they spend the daylight hours relatively deep in the water, and swim closer to the surface when it gets dark.

These findings pointed to the need for an improved computer model taking into account different current speeds and direction at the surface and near the sea bed. Dr Church and Mr Forbes constructed such a three-dimensional model, and then put newly hatched larvae into it — or, more precisely, instructed a computer to calculate where currents would carry larvae that had just hatched in five spawning locations.

Using information from studies Dr Rothlisberg had made of the rates at which larvae grow, the researchers assumed that the autumn larvae moulted each day, becoming post-larvae — and beginning to rise and descend throughout the depth of the water — on the seventh day after hatching. In spring, development proceeds more slowly in the cooler water, and larvae were estimated to spend twice as long passing through each stage.

The computer worked its way through the calculations, each 'night' lifting the larvae into the higher water levels appropriate for their stage of development, and each 'day' returning them to near the bottom, all the while calculating how far the horizontal currents at each level carried the young prawns away from their offshore spawning grounds. The results of the exercise proved striking and illuminating.

Larvae lie at the mercy of winds and currents.

The simulated larvae drifted up to 165 km during their brief planktonic life. In spring, the currents in the south-eastern corner of the Gulf conveyed young prawns southwards the 130 km or so to the mouths of the Norman and nearby rivers containing their nursery areas.

In autumn, even larger numbers of female banana prawns occur in the same spawning ground in the south-east of the Gulf. Where do the currents carry their young? Almost due north, replies the computer, well away from the Norman or any other southern river. Unable to reach a nursery area, these larvae form a doomed generation.

North of Weipa, things turn out differently. Here, the autumn brood travels north to the local nursery rivers, but larvae that hatch in spring drift south-west into the open Gulf.

The modelling exercise has clearly shown why each year brings only one new generation of adults, even though the prawns have two breeding seasons. The products of one breeding season drift out to sea.

We think of most animals as finely adapted to their environments; how can scientists account for the banana prawn wasting so much reproductive effort creating larvae destined to drift in the wrong direction? The scientists think the prawn has simply not had enough time to make the necessary evolutionary adjustments.

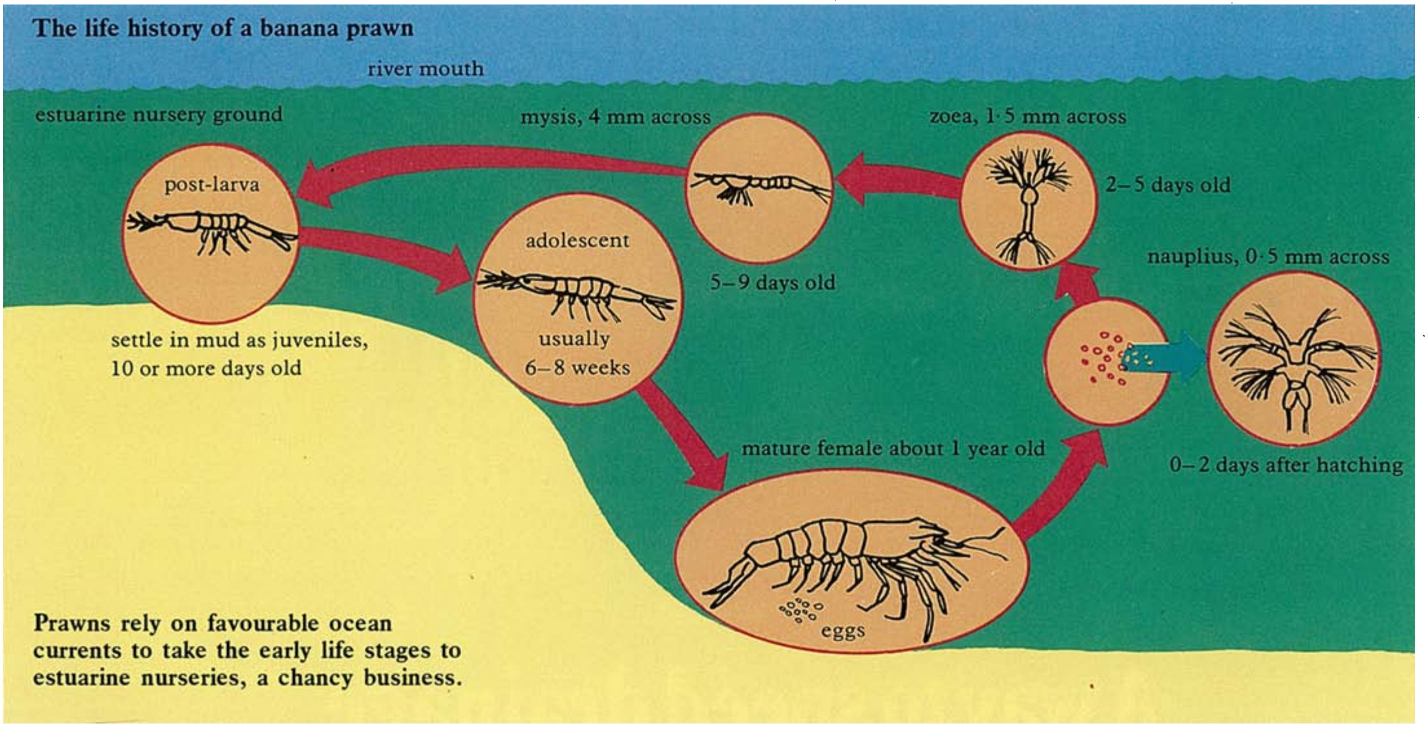
Genetic clues indicate that the penaeid prawns have been in the Gulf between 1 and 6 million years. Dr Jim Redfield and Mr John Salini, of the Division of Fisheries Research, and Dr Denis Hedgecock and Mr Keith Nelson, of the Bodega Marine Laboratory, California, have found remarkably low levels of genetic variation among banana prawns and several other crustacean species in the Gulf, which suggests that these animals are evolving only slowly.

The Gulf itself, on the other hand, has changed relatively rapidly. It has not been flooded continuously over the last 10 million years, and it attained its present size and shape a mere 7000 years ago. It should hardly be surprising if the local prawns have not yet adjusted their reproduction precisely to the Gulf tides. Their larval dispersal strategy may even be an adaptation to a swiftly altering environ-

Rivers — home to juvenile prawns.

Larvae drifted up to 165 km during their brief planktonic life.

In the wet season.



ment: whatever the configuration of coastline and river mouths, some larvae should find a suitable place to grow into the next generation.

The modelling study also helps explain an observation made some years ago: that — of all the penaeid prawns — the species with mixed life cycles (part estuarine, part marine) experience the greatest fluctuations in numbers. Their larvae lie at the mercy of winds and currents, so reaching the sanctuary of a river is a 'hit and miss' affair, liable to the disruption by adverse weather.

Add to this the dependence of juvenile banana prawns on good rains for the start of their return journey out of the rivers, and you can see how year-to-year fluctuations in the weather must cause enormous variations in the number of prawns available to fishermen.

Fishery at risk?

Banana-prawn fishermen have been worried by the great variations in their catch from year to year — particularly when several poor seasons succeed one another. The prawn's hazardous life cycle makes fluctuations inevitable, but does it fully account for those observed? In addition to its ups and downs, is the fishery declining through over-exploitation?

The CSIRO scientists have calculated that varying rainfall can account for the different catches over recent years. The fishery shows no sign of underlying decline.

But the researchers do sound a warning. So many (about 80%) of the available stock are caught each year that the number of spawning prawns left each spring could be reduced enough to start affecting the number of larvae settling in the estuaries.

As Dr Staples puts it, 'in the extreme case, no spawners must mean no larvae'. He points out that, since each prawn lives only 1 year, further reductions in the breeding population could lead to 'the rapid collapse of the fishery with virtually no warning'.

Ominously, collapses of fisheries based on populations with similar biology have been all too frequent; examples include those based on the Californian sardine, the Atlantic herring, the Peru anchovy, and the American white prawn, a relative of the banana prawn.

Understandably, the CSIRO team puts a high priority on discovering the unknowns in the banana prawn's life history, and on developing mathematical models for predicting and managing stocks of the species before it is too late.

John Seymour

More about the topic

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