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PENAEID PRAWN FISHERIES OF AUSTRALIA WITH SPECIAL REFERENCE TO NEW SOUTH WALES

by

A. A. Racek*

In Australian waters, a considerable number of commercially important penaeid prawn species are abundant in the estuarine (inside) area, and in both the inner and outer littoral areas down to the edge of the continental shelf. Here, as in other parts of the world (with the possible exception of Japan), however, the prawning activities were confined until the midforties to the estuarine area. Following the incidental discovery of prawn schools in ocean waters off New South Wales in 1947 a steadily increasing number of offshore trawlers began to operate on these new grounds. With the development of the offshore prawn fisheries, particularly in Stockton Bight near Newcastle, N.S.W., and on grounds in the Ballina-Evans Head area on the far north coast of the same State, special prawn investigations were initiated in 1951 by the Fisheries Branch, Chief Secretary's Department, in response to expressed concern about a possible depletion of the available stocks. Since May 1953, comprehensive and detailed studies were carried out by the author on the biology, ecology, and embryology of the most important commercial species in New South Wales and in adjoining Queensland waters. Their preliminary results, which helped to clear quite a number of previously encountered problems, are briefly discussed in this paper. A revision of the long neglected taxonomy of Australian Penaeinae, chiefly occurring in commercial catches, has been given elsewhere (Racek 1955).

More recently, the Western Australian State Fisheries in conjunction with the C.S.I.R.O., Division of Fisheries were exploring previously unknown offshore grounds along the whole western coastline of Australia, and observations were carried out by the Department of Harbours and Marine on prawn stocks in the vicinity of Moreton Bay, Queensland.

THE AUSTRALIAN PENAEID PRAWN FISHERIES

Development

No historical evidence is available, as to where and when commercial fishermen began with prawning activities in Australia. It seems most likely, however, that migrants from Mediterranean countries, particularly Italy and Greece, were the first to explore the estuaries in and around Sydney for the presence of these delicious crustaceans, which were known to them from their homelands. Whitelegge (1889) and Ogilby (1893) were referring to a considerable prawn production in the last two decades of the previous century. The inside prawn fisheries appear to have grown rapidly since and became the means of livelihood of a large number of fishermen in New South Wales. An incidental discovery of schools of offshore prawns in 1946 and 1947 led to the expansion of trawling activities in ocean waters off New South Wales. Large quantities of adult penaeid prawns were at first trawled in Stockton Bight, and almost simultaneously new and promising grounds were discovered off Evans Head. Since then many other payable grounds were found, and the total production of the combined offshore fisheries in New South Wales began to surpass the estuarine production considerably. At present, estuarine and offshore prawns are commercially captured in New South Wales along the whole coastline, from Tweed Heads in the north to Twofold Bay in the south.

The abundance of large penaeid prawns in Queensland waters, and particularly the success of prawning activities in offshore waters of New South Wales, led soon to the expansion of the offshore prawn fisheries into adjoining Queensland waters. Although some estuarine prawn fisheries (Brisbane River, Mary River) have been existing for a long time in Queensland, their expansion is due to extensive trawling activities in Moreton Bay. More recently, new and well-stocked grounds were discovered off Sandy Cape near Bundaberg, where large tropical species are abundant. Preliminary biological investigations, carried out in the area inside the Great Barrier Reef, indicated the presence of suitable grounds, and it is to be expected that trawling activities will soon expand to these tropical waters.

Prawn trawling in offshore waters is still in an experimental stage in Western Australia and in

* Marine Biologist, Fisheries Branch, Chief Secretary's Department, Sydney, N.S.W., Australia.

South Australia, although penaeid prawns are captured in estuarine waters of these States, as well as occasionally in Victoria.

Fishing grounds

At present, penaeid prawns are commercially captured in Australian waters on two different habitats, each possessing a stock distinct in many features from that of the other.

The inside prawn fisheries are operating in an area, comprising the lower tidal parts of rivers down to their entrance, coastal lakes and lagoons (landlocked or open), and brackish pools possessing various sea connections. These waters range from salt to slightly brackish and show enormous variations due to the influence of seasons, floods, land drainage and even wind. This environment is strongly influenced by sudden changes of salinity and temperature. Bottoms are mostly muddy with plenty of detritus, occasionally sandy with patches of weed, or with dead and living oyster shells. Depths vary from 0 to 5 fathoms.

Offshore prawn trawlers in Australia are operating at present only in a part of the inner littoral area. This extends from the surf or river entrances to a variable distance (in New South Wales between 2 and 5 miles offshore), influenced more or less by the boundary of the main ocean currents, in which prawns seem to be absent in commercial quantities. The water generally has a fairly high salinity, but less than oceanic density, particularly in perifluvial areas. During river floods this area is usually turbid with plenty of suspended matter. This environment is less influenced by sudden changes of salinity and temperature, but strongly so by wind against the current, and by ocean swell. Bottoms are mostly a mixture of mud and sand, with an occasional growth of kelp. Depths vary from 1 to 25 fathoms.

The exploration of new far offshore grounds in the outer littoral area with experimental otter trawls and baited traps is discussed in the Section on Biological Investigations. These grounds have not yet been commercially exploited.

Fishing methods, gear and vessels

In the estuaries of Australia, penaeid prawns are captured chiefly with pocketed scoop nets, hauling nets, set pocket nets, cast nets and modified otter trawl nets. In ocean waters large otter trawl nets, measuring up to 20 fathoms from wingtip to wingtip, are used solely by professional fishermen.

Hauling nets and cast nets are mainly employed in the comparatively still and shallow coastal lakes and lagoons, pocketed scoop nets and set pocket nets in inlets and channels with a considerable current during the outrunning tide, and otter trawl nets in some restricted tidal rivers.

(*a*) *Hauling net :* Hauling nets are of varying lengths, according to the locality in which they are used, and range from 5 to 75 fathoms in total length. In New South Wales the compulsory minimum mesh size for these nets (and all other types) is 1¼ in. Various methods are employed in using hauling nets. They are worked either by fishermen wading along the shore or by boats. The direction of the hauls may be parallel to the shore or at an angle to the latter. In still waters a detected school of prawns is herded by this method towards the shore or towards one end of the net, which is being lifted finally with the catch onto the shore, or into a boat. Another method of hauling is the so called ' running prawns ', used in estuaries with slight tidal currents. A motor launch is anchored at a certain distance from the shore, and a rowing boat, proceeding from this launch, pays out the full length of the net towards the shore, at an angle to the latter. At the end of the setting operation one end of the hauling net is fastened to the launch, the other to a tree or a pole on the shore. The outrunning tide drives the school of prawns against the net which leads them, due to being set at an angle, towards the shore. From time to time the fisherman in the rowing boat, moving along the corkline towards the launch, lifts up the leadline in a continuous operation and works (or ' runs ') the amassed prawns finally to the anchored launch, where the catch is hauled in.

(*b*) *Cast net :* The capture of prawns with the cast net is a quite ingenious method, although the results are limited due to the comparatively small size of the net. It is circular in outline, the hauling rope is attached to the centre, the leadline is the circumference of the net. Its use demands considerable skill. The net is skilfully folded partly over the left forearm, partly held by the right hand and the hauling line is prearranged on the ground. The net is then thrown with a swinging movement, which causes the weighted circumference to spread so that the net hits the water fully extended. After hitting the surface the leadline sinks down very fast, thus encircling all swimming animals from immediately below the net to the bottom. The use of cast nets is illegal in New South Wales, although in other States, particularly in Queensland, it is often employed by commercial and amateur fishermen in shallow coastal waters.

(*c*) *Pocketed scoop nets :* These modified scoop nets with a moderately long and narrow pocket (or bag) are employed by professional fishermen only in localities with considerable current during the outgoing tide, where other means of capture) set

pocket nets) are restricted with the view to the conservation of the local prawn fishery. The quite limited catching capacity of these nets warrants a satisfactory commercial catch only during the 'darks' (last to first quarter of the moon phase), when maturing prawns migrate to their offshore spawning grounds in dense schools.

(*d*) *Set pocket nets :* In New South Wales, set pocket nets are restricted to a few inlets and estuaries, where either other methods are impracticable, or where additional channels for the egress of sea-life exist. These nets are of various lengths and designs with one to several pockets or bags. The nets are set across channels or inlets during the outgoing tide at 'dark' nights. The outrunning prawn schools, forced by the more or less strong current against the net, are guided by the 'wings' into the pockets which are lifted and emptied from time to time by fishermen in rowboats, anchored above the pockets.

(*e*) *Otter trawl nets :* The design of the otter trawl in Australia is equivalent to that of other countries and its detailed description appears to be superfluous. It is used by professional fishermen in some restricted estuaries (small boards, 6 fathom nets) but it is the only method employed by all Australian professional fishermen in ocean waters. According to the size of the vessel and its power unit, large to very large otter boards are used, and the nets measure at the average 12 fathoms, ranging from 8 to 20 fathoms. The minimum legal mesh size in New South Wales is 1¼ in., which in offshore otter trawl nets, however, is used only in the cod-end. The average offshore nets measure 2 in. in the wings, 1½ in. in the bunt, and 1¼ in. in the cod-end. To prevent unnecessary culling of undersize prawns and fish, many offshore fishermen in New South Wales already adopted voluntarily a larger mesh size, using 1¾ in. in the bunt and 1½ in. in the cod-end. Large mesh blubber traps are employed in blubber-infested waters, although some fishermen use a more 'baggy' net and a throttling line on the cod-end, to be operated from the incoming otter boards. The average depths for offshore trawling in the inner littoral area are 12-20 fathoms, the average trawling time (net on bottom) is 30-50 minutes. The nets are operated with steel ropes on power winches.

(*f*) *Fishing vessels :* In New South Wales there are at present 2,223 territorial and 169 extraterritorial boats engaged in the fishing industry. Territorial boats are restricted in their activities from the estuaries to the 3 mile offshore limit, extraterritorial boats are operating in deeper waters beyond that limit. Many of these boats, however, are not always fully engaged in prawning but in general fishing and trapping as well. In the estuaries, the length of the boats range from 12 to 30 feet, the size of the offshore trawlers varies from 18 to 75 feet. The smaller estuarine boats are equipped with petrol engines. The majority of larger boats, and particularly the offshore trawlers are powered by diesel engines ranging from 35 to 140 b.h.p. Power winches on trawlers are operated partly by transmission from the main power unit, partly by auxiliary engines. A few large boats are equipped with electric refrigerators and cooking facilities to warrant proper handling of the catch during peak productions. Most of the trawlers and other boats, however, employ crushed ice in their holds to preserve the catch. They cook their catch ashore after returning to their port.

Catch statistics

In New South Wales the combined prawn fisheries (estuarine and offshore) rank third amongst individual fisheries by the volume of production. They are preceded only by the production of mullet (Mugilidae) and flathead (Platycephalidae). The fluctuations of catches in this State are shown in Fig. 1, showing separate values for the estuarine, offshore and total production since 1937-38. The statistical data were collected for financial years, i.e., for a period from July 1st to June 30th. The fall of the production in 1951-52 appears to be due to an extremely dry summer and autumn period, a fact which shows its consequences even a season later in the absence of young prawns in estuarine waters. The following sharp rise of catches in ocean waters, however, is not only caused by favourable climatic conditions, but is also due to the exploration of additional offshore grounds and an increased number of operating trawlers.

Seasonal variations

Under normal weather conditions, penaeid prawns in New South Wales usually enter the commercial catch in estuarine waters during the latter half of November, and are abundant until at least the first half of March. Under the same climatic conditions offshore commercial species usually commence to appear in schools around the first half of January and are taken in quantities until the end of June. As most of the Australian commercial species possess a strictly perifluvial habitat, their appearance and abundance is strongly influenced by climatic conditions and the resulting amount of land drainage. Thus their abundance in dry to very dry seasons is quite scarce, at least on the known trawling grounds. In such unfavourable seasons they may appear later in the year and disappear earlier. In wet to very wet summers when heavy rainfalls cause extensive

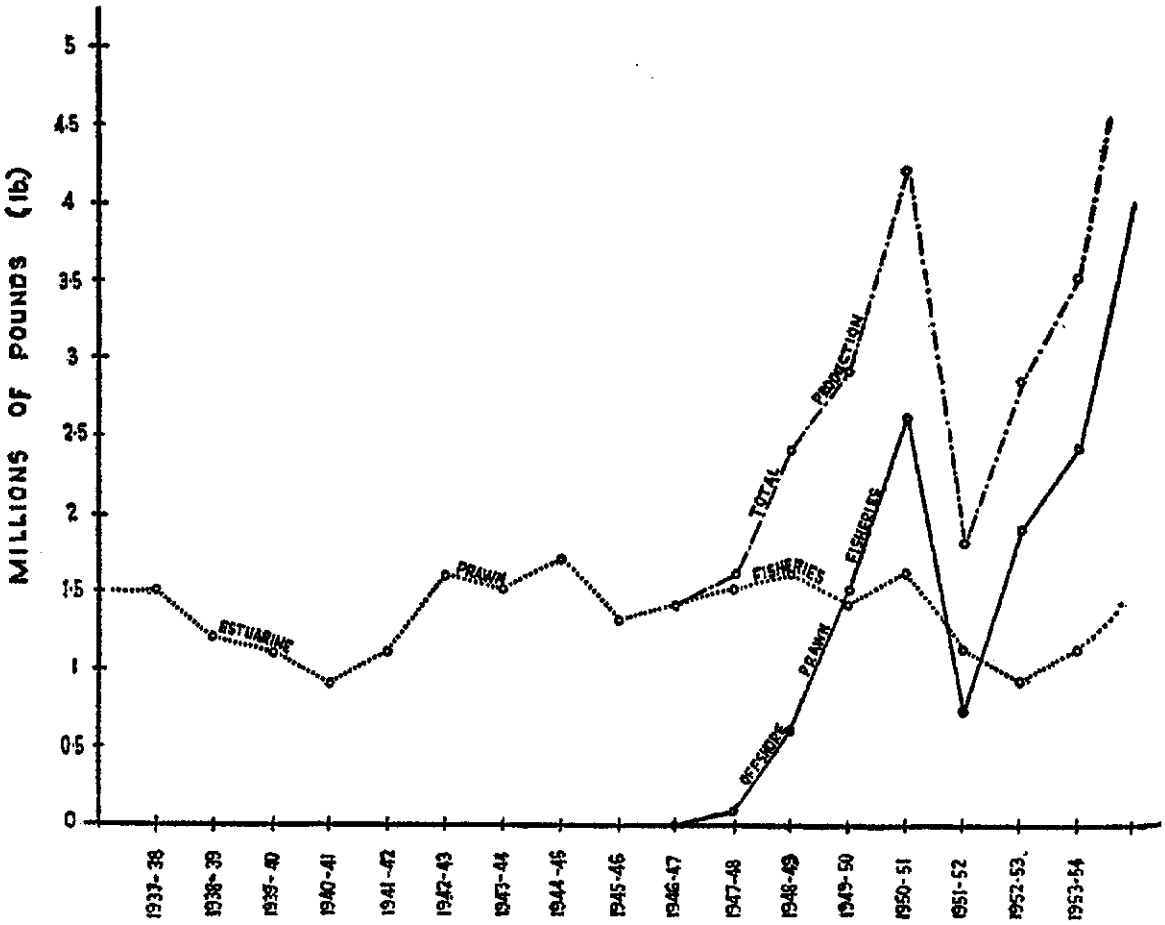
river floods, commercial species may be present in quantities on known grounds almost throughout the year. Thus the years 1954 and 1955 were extremely wet with repeated heavy river floods, and penaeid prawns were present in commercial quantities along the northern half of New South Wales even through the southern winter months. However, final statistical data for this period are not yet available.

The estuarine prawn fishery in New South Wales, producing mature stages of one strictly estuarine species (*Metapenaeus mastersii*) and adolescent or immature stages of a number of offshore species, usually commences the commercial catch ahead of the offshore fishery. Between February and June, however, the offshore fishery shows peak productions of mature or at least maturing commercial species, and stays well ahead of the inside fishery for the rest of the season.

Management and regulations

With the expansion of the prawn fisheries in Australia, particularly in New South Wales since the turn of this century, certain restrictions and regulations appeared to be necessary in view of the conservation of the available stocks. These regulations, particularly those concerning the estuarine fishery, vary considerably on different localities. Aiming to protect the available prawn stocks they are chiefly as follows :

(1) Minimum legal size of prawns.
(2) Minimum legal size of mesh.
(3) Maximum legal length of nets.
(4) Restriction of certain fishing methods (or gear).
(5) Closure during daylight in some estuaries.
(6) Total closure of certain parts of estuaries.



Fluctuations in prawn catches in New South Wales

In New South Wales the minimum legal size for green (uncooked) prawns is 3½ in. Queensland recently raised the legal size from 2½ to 3 in. Size limits were originally introduced at a time, when prawns were taken solely in estuarine waters. As smaller prawns were then believed to be immature, the introduction of a legal size limit was meant as a protective measure. However, as different penaeid species, showing enormous differences in adult body lengths, are not discriminated in the commercial catch, only some smaller species are thus being protected. The major part of offshore species before their return to their deep-sea spawning grounds is completely immature even far above the mentioned legal length.

The minimum legal size of mesh for all types of nets in New South Wales is 1¼ in. Together with limitations of the length of nets, this regulation appears to be far more important for the conservation of the prawn fisheries, as well as a means of partial elimination of undersize commercial fish from the prawn catch. It is strictly enforced by the department. As many fishermen have already changed to larger than legal mesh size with the view to better quality and larger size of the prawns, future research and tests concerning the efficiency of trawl nets may show the necessity of a slightly increased mesh size.

The use of the otter trawl in ocean waters is not restricted, apart from the limitations of the mesh size. However, trawling activities in most of New South Wales' estuaries are banned, and where they are permitted (Clarence R., Hunter R., Hawkesbury R., Port Jackson) the length of the net is limited to 6 fathoms. Set pocket nets are permitted only in such inside areas (Myall R., Wallis Lake) where more than one channel allow the free egress of life during the netting operations.

A diurnal closure in the Tuggerah Lakes, banning the commercial capture of prawns during daylight hours, became imposed following cases of food poisoning caused by improper handling of the catch during peak productions in the mid-forties.

Furthermore, parts of almost all estuaries in New South Wales are permanently closed with the view to the conservation of the fisheries generally.

Problems of the fisheries

The importance of the Australian prawn fisheries is clearly characterized by the considerable upward trend of the production in New South Wales, as well as in Queensland. Penaeid prawns are available in commercial quantities during the late summer-early autumn period generally from the 36th parallel northwards, although their abundance and the duration of their occurrence are gradually increasing towards the tropics. In offshore waters their commercial catch at present seems to be strongly influenced and limited by the necessary nearness of a local market, thus causing the extensive exploitation of some few and limited grounds, mainly along the northern half of New South Wales and southern Queensland. Although the preliminary results of the current prawn investigations do not indicate a depletion of the available stocks, such limited and intensively worked grounds could be seriously affected as far as overfishing is concerned. In view of the short life cycle of the great majority of commercial penaeids, such a possible serious reduction of the supply on limited grounds would be difficult to overcome. Furthermore, as such a possible reduction would affect consistent prawn species first, these species may become replaced by migratory (inconsistent) species, gradually displacing the former stock. An already visible decline in the offshore production of king prawns (*Penaeus plebejus*), a very consistent species, in favour of the inconsistent school prawn (*Metapenaeus macleayi*) may be an indication of the progress of such a development on some favoured grounds in New South Wales.

To prevent such possible difficulties, prawn fishermen should be encouraged to explore and exploit new grounds. Equipped with adequate refrigeration, trawlers will be able to work even on well-stocked grounds along the sparsely inhabited tropical coasts of Australia, where trawling activities are unknown due to transport difficulties. During the course of detailed prawn investigations in New South Wales a number of new, well-stocked grounds were found in this State and are being worked since. In Queensland, after the exploration of rich offshore grounds near Bundaberg, and increasing number of trawlers moved from Moreton Bay into this new area. Since commercial species have been found to be abundant on suitable grounds inside the Great Barrier Reef, trawling activities may be extending shortly also into these tropical waters.

HANDLING AND PREPARATION OF PRAWNS

In spite of the rich abundance of prawns in Australian waters and the comparatively high production in relation to the number of operating boats, an export market for these crustaceans does not yet exist. Due to a local preference for 'whole' prawns, the total catch is sent to the markets with heads on, either in raw condition (green prawns) or more frequently cooked. In view of the highly perishable nature of the prawn 'heads', particularly in the warm climate associated with this fishery, the proper and expedited handling and transportation of the catch is of utmost importance.

Handling and transportation

After emptying the cod-end on the deck of offshore trawlers, the prawns are culled and sorted and the marketable catch is then placed in cane baskets, where it is thoroughly washed with a hose. The prawns are then transferred to wooden boxes between layers of crushed ice and placed in the holds. A few large trawlers are equipped with refrigerators, the rest carry ice in the holds. After the holds are fully loaded, the trawlers usually return to their ports in the vicinity of the trawling grounds to transfer their catch to the cooking plants. During seasons with peak production, some larger trawlers along the far north coast of New South Wales cook their catch on board to ensure its reaching the markets or storage plants in good condition. Large tanks, heated with diesel oil, are equipped with wide rims of wire netting to prevent the spilling of the catch in rough seas. Their capacity for one operation varies from 50 to 150 lbs. After the catch is properly cooked (10-15 minutes) the prawns are removed from the tank, transferred to baskets or perforated metal trays and cooled down with a hose. The catch is then, after complete cooling, transferred to wooden boxes between layers of ice (or without ice on refrigerated boats), which are placed in the holds.

The majority of trawlers can absorb catches from 800 to 2,000 lb without endangering the edible quality of the prawns. Usually they stay offshore for 12-15 hours. Where a greater number of trawlers operate from the same port, radio messages are flashed to the cooking plants from the trawling grounds, reporting the individual catch per boat. The cooking plants are thus able to arrange for additional manpower and equipment, if necessary.

Most of the prawn boats operating in inside areas employ somewhat simpler methods in handling, chiefly due to the smaller size of the fishing vessels and to the limited grounds. Estuarine fishermen usually transfer their sorted catch to baskets or directly into their small holds without any icing and return to shore after being fully loaded. The catch is lifted here from the boat in baskets, washed by submerging the baskets in water, cooked in mostly improvised large tanks on the shore, cooled, salted, and packed in wooden boxes between layers of ice for transportation to the market. Such smaller craft usually return again to their fishing grounds after landing their catch, repeating such operations as often as required.

Cooking and freezing

Some larger cooking plants at the main centres of the prawning industry along the north coast of New South Wales are designed to absorb and process large quantities of prawns. In the majority they are run by fishermen's co-operatives, although some others are privately owned by fishermen. The landed catch is freed of ice, weighed, cooked with super-heated steam, cooled in running water, packed in wooden boxes, salted and finally transferred to cold storage.

A modern snap-freezing unit has been recently installed in the cooking plant of the Ballina Co-operative. The prawns are there snap-frozen in 4 lb blocks, seven of these making a carton. The blocks are kept in cold storage (or during transportation in refrigerated trucks to distant markets) at a constant temperature of 0°F. The quality of the processed prawns, when thawed after long storage, is equal to fresh cooked prawns and the flavour is completely retained.

On account of the absence of an export market, and the local preference of fresh cooked prawns, there is at present no canning industry in Australia, although various canning experiments have been carried out in this country. At some places, however, drying or 'chowing' of prawns is carried out by proprietors of Chinese restaurants.

Distribution

The marketing of prawns in New South Wales is governed by the Fisheries and Oyster Farms Act 1935-1949. All prawns for human consumption must be brought to and sold in the market. The various co-operatives transport the iced prawns by rail or road to the markets in the densely populated cities on the east coast where the demand is high. At present (March 1955) the average price for 1 lb of cooked prawns is £A-2/2 (to the fishermen), £A-3/4 (in the market), and £A-4/6 (for the public). However, the prices vary greatly with the seasons and abundance of prawns.

Interstate consignments are delivered from New South Wales to Melbourne and Brisbane chiefly in special refrigerated trucks.

BIOLOGICAL INVESTIGATIONS

The biology of Australian penaeids, although being commented on for individual species by various Australian writers (Dakin 1935, 1938, 1940, 1946; Dakin and Colefax 1940; Morris and Bennett 1951), has never been before the subject of a comprehensive study concerning all species of economic importance. The present investigations, carried out since May 1953 chiefly in areas with the highest prawn productions, were aimed at solving certain problems and phenomena connected with this fishery. Their preliminary results are here briefly discussed.

Species occurring in Commercial Catches

The species of the subfamily *Penaeinae* present in Australian waters are shown in Table 1 (abundance indicated with x):

The small size of some of these species (*P. novaeguineae*, *T. curvirostris*, and *T. anchoralis*) renders them commercially unimportant, although they may appear during the season in large schools. Some others again are too rare in Australian waters to warrant their capture in payable quantities.

The most important commercial species (in order of their importance) in New South Wales are *Metapenaeus macleayi*, *Penaeus plebejus*, *Metapenaeus mastersii*, *Metapenaeus incisipes*, *Penaeus esculentus*, and *Penaeus carinatus*.

The major species of Queensland's estuarine production are *Metapenaeus mastersii*, *Metapenaeus incisipes*, *Penaeus plebejus*, *Penaeus esculentus* and *Penaeus merguiensis*. In ocean waters of this State the production of *Penaeus merguiensis* occupies the leading place, with that of *Penaeus plebejus*, *Penaeus*

Species	N.S.W.	Qld.	W.A.	S.A.	Vic.
Penaeus carinatus Dana Giant (black) tiger prawn	x	x	x	—	—
Penaeus caeruleus Stebbing Blue tiger prawn	rare	rare	—	—	—
Penaeus semisulcatus de Haan Green tiger prawn	rare	—	rare	—	—
Penaeus esculentus Haswell Common (brown) tiger prawn	x	x	x	—	—
Penaeus merguiensis De Man Banana prawn	rare	x	x	—	—
Penaeus indicus M. Edwards Indian prawn	rare	rare	—	—	—
Penaeus latisulcatus Kishinouye Western king prawn	rare	rare	x	x	—
Penaeus plebejus Hess Eastern king prawn	x	x	—	—	x
Penaeus macculloch Schmitt Crossgrooved king prawn	rare	rare	—	—	—
Metapenaeus macleayi (Haswell) School prawn	x	rare	—	—	x
Metapenaeus endeavouri (Schmitt) Endeavour prawn	rare	x	x	—	—
Metapenaeus incisipes (Bate) Offshore greasy back prawn	x	x	?	—	—
Metapenaeus mastersii (Haswell) Inshore greasy back prawn	x	x	x	—	?
Parapeneopsis sculptilis (Heller) Rainbow prawn	—	x	?	—	—
Penaeopsis (*Metapenaeopsis*) *novae-guineae* (Haswell)	x	x	x	x	?
Trachypeneus (*Trachysalambria*) *curvirostris* (Stimpson)	x	x	x	—	—
Trachypeneus (*Trachypeneus*) *anchoralis* (Bate)	rare	x	x	—	—

Table 1. Species of Penaeinae in Australian waters

esculentus, *Penaeus carinatus*, and *Metapenaeus endeavouri* following.

Along Western Australia, *Penaeus merguiensis* and *Penaeus latisulcatus* may become species of economic importance.

The Australian distribution of *Penaeus latisulcatus* apparently ranges to South Australia, where this species seems to be the only one of commercial value.

The comparatively cold waters along Victoria appear to be inhabited by only a few east coast species of economic importance. Amongst them, *Metapenaeus macleayi* and *Penaeus plebejus* occur with certainty in payable quantities south of the N.S.W. border.

In view of a possible expansion of the Australian offshore prawn fisheries to new grounds, particularly in deeper waters of the continental shelf, the given order of commercial importance may undergo a change.

Distribution of species

As the distribution of penaeid prawns in Australian waters is strongly influenced by the seasonal system of ocean currents in the Indo-West pacific area, the ecological boundaries for the majority of Australian species are quite pronounced. The preliminary results of a survey of Australian prawns appear to allow of a more or less clear separation of the following 3 regions:

(1) *Eastern subtropical region*
Lakes Entrance (Vic.) to Cape Moreton (Qld.)

(2) *Tropical region*
Cape Moreton to Cape Inscription (W.A.)

(3) *Western subtropical region*
Cape Inscription to Kangaroo Island (S.A.)

The first region comprises the habitats of eastern subtropical species. Typical species in it are *Penaeus plebejus* and *Metapenaeus macleayi* in inner littoral waters.

The second ecological niche appears to be filled in the majority by strictly tropical commercial species, with the typical appearance of *Penaeus merguiensis*, *Penaeus esculentus*, *Penaeus carinatus*, *Metapenaeus endeavouri*, and *Parapeneopsis sculptilis*.

The third region is inhabited by western subtropical species with *Penaeus latisulcatus* as the typical form.

In eastern Australian waters there is a quite sharp boundary between the habitats of tropical and subtropical species situated at about latitude 28°S, although stray specimens of both groups may occur somewhat further south or north respectively. An equivalent north-south boundary on the western Australian coast has not yet been observed. However, according to surveyed material from Western Australia, such a dividing line seems to be situated further north, most probably due to the influence of colder currents and, consequently, mean temperatures. The north-south boundaries are particularly sharply defined for *Penaeus merguiensis*, *Metapenaeus endeavouri*, and *Parapeneopsis sculptilis* as tropical, and *Metapenaeus macleayi* as a subtropical species.

The distribution of *Penaeus plebejus*, *P. esculentus*, and *P. carinatus* appears to be less defined in eastern coastal waters. *P. plebejus* is to be found from northern Victoria to central Queensland, and *P. esculentus* as well as *P. carinatus* range to the central coast of New South Wales. On the west coast, *P. latisulcatus* occurs even in tropical waters, being absent, however, along the main eastern coastline, as *P. plebejus* does not occur in the western region.

Amongst commercial species, *Metapenaeus mastersii* appears to be the only form with a circum-Australian distribution, for it has been captured in both subtropical regions as well as in the tropics. Some not yet utilized smaller species, as *Trachypeneus curvirostris* and *Penaeopsis novae-guineae*, also have a wide distribution around Australia. *Trachypeneus anchoralis*, however, seems to be limited to tropical waters and appears to be more abundant in the west than in the east.

Habitats

The estuarine (inside) area in New South Wales is usually inhabited in summer months by maturing to mature greasy back prawns (or greentails), together with immature king prawns (*Penaeus plebejus*) and school prawns (*Metapenaeus macleayi*). The greentail (*Metapenaeus mastersii*), an inside breeding species, is usually present throughout the year, although its appearance is somewhat irregular. King prawns and school prawns are temporarily present in this area from postlarval stages in the late autumn to adolescent stages of an average body length of 3½ in. in mid-summer of the following season, when they leave the inside area on their spawning run to ocean waters. The school prawn, an early spawner, usually leaves the estuaries first, followed by the king prawn. Their spawning migrations take place usually during the outgoing tide at nights with decreasing moon phases.

The inner littoral area in New South Wales is usually stocked with maturing to mature (or at least impregnated) school prawns and with immature to maturing king prawns. The offshore greasy back prawn (*Metapenaeus incisipes*) is very often present in this area, as well as smaller specimens of the common tiger prawn (*Penaeus esculentus*) and the giant (or black) tiger prawn (*Penaeus carinatus*). With the possible exception of the king prawn,

which species is often found on sand, all other forms prefer mud bottoms, or at least a mixture of mud and sand. Consequently, prawns appear to be absent in commercial quantities on parts of the littoral areas, where the ocean currents are too strong to allow the presence of an undisturbed mud bottom. The average body length of prawns in this area is 4½ in.

Trapping and trawling experiments in deeper waters of the outer littoral area revealed the presence of quantities of king prawns, common tiger prawns, and giant tiger prawns on mud bottom. In fact, these far offshore habitats in depths ranging from 50 to 90 fathoms seem to represent the optimal habitats of both species of tiger prawns, and to a certain extent even that of the king prawns. The great majority of these prawns are females with fully mature, and often spent ovaries. Species of *Metapenaeus* are absent in these depths. The largest prawns on these grounds measure 13 in. and their average body length is 8½ in.

Migrations

Apart from the mentioned seaward spawning run of adolescent offshore prawns from the estuaries, there are many other irregular movements of prawn stocks in inside and ocean waters, chiefly due to changing climatic or food conditions. Not all commercial species are affected by such migratory movements, and consistent and inconsistent forms may be distinguished.

Consistent prawns prefer a certain habitat in a well-defined area, which may be, however, very extensive reaching from the estuaries to the outer littoral area. These species do not form pronounced age groups, except during their seasonal spawning run and are to be found, year by year, in varying abundance on the same grounds. Due to the absence of migratory schooling habits, consistent prawns are rarely caught in considerable quantities, except when leaving the estuaries. *Penaeus plebejus* and *P. esculentus* belong to this group.

Inconsistent prawn species are always on the move and show a preference to turbid waters and soft muddy grounds. They form pronounced age groups and dense schools and may occur in enormous quantities on inner littoral grounds, only to be found absent in the following season. Their abundance in perifluvial areas seems to be closely linked with the occurrence of river floods, and their presence on certain grounds is greatly influenced by the conditions of weather and sea. When the accumulation of silt, brought down by flooded rivers, ceases in ocean waters, they usually follow the current which moves this suspended matter along the coastline. Owing to their extensive schooling habits these species are often caught in great quantities. *Penaeus merguiensis* and *Metapenaeus macleayi* are typical inconsistent species in Australian waters.

The mass migration of prawns of all age groups from the estuaries to the ocean during extensive river flood is chiefly caused by the resulting rapid fall of the salinity in inside waters. On such occasions even large populations of *Metapenaeus mastersii* were found to leave the estuaries. This species usually prefers waters of low salinity and is rarely present in the inner littoral area. With the return of normal salinities in the inside area, however, these prawn stocks re-enter the estuaries during the ingoing tide in all but the adult stages.

Sex ratio, reproduction, spawning grounds

Male and female prawns do not occur in constant proportions on the fishing grounds, but may vary considerably from season to season from a slightly predominant male to an almost pure female population. Although the sex ratio varies with different commercial species, a certain mode is perceptible within the same species for certain grounds in given seasons.

The average sex ratio per cent observed in the extensive material collected for population studies in all 3 ecological areas during the period of spring 1953 till winter 1955 is shown in Table 2.

Locality and species	summer		autumn		winter		spring	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
Estuarine area								
Metapenaeus mastersii	45	55	28	72	17	83	48	52
offshore *Metapenaeus* spp.	47	53	29	71	usually	absent	54	46
Penaeus spp.	59	41	18	82	23	77	37	63
Inner littoral area								
Metapenaeus spp.	30	70	21	79	36	64	49	51
Penaeus spp.	60	40	32	68	15	85	48	52
Outer littoral area								
Penaeus spp.	4	96	3	97	1	99	no data available	

(Minimum body length of prawns in consideration : ♂♂ 3 in.; ♀♀ 3½ in.)

Table 2. Percentage sex ratio of Australian prawns

The impregnation of females takes place after their ecdysis (casting of shell), which occurs chiefly during full moon phases. In view of the peculiar reproductive habits of penaeid prawns, direct evidence as to the location of their mating and spawning grounds is almost impossible to obtain. Indirect evidence, however, can be gathered by quantitative sampling and plankton survey.

The spawning grounds of *Metapenaeus macleayi* have been indirectly located in depths ranging from 25 to 35 fathoms, those of *Penaeus plebejus* between 50 and 55 fathoms. Extensive plankton collections carried out in surface and bottom runs with descending series of nets, tied to otter trawls in action, revealed concentrations of demersal penaeid eggs in about 30 fathoms average depths. The eggs were hatched in silk cages (in ocean waters) and in experimental tanks (in the field laboratory) and the larvae reared to post-larval stages, in which their identity (*Metapenaeus macleayi*) could be established. The eggs were collected in early summer on mud by the lowest plankton net, attached just above the otter boards.

Another concentration of sub-demersal penaeid eggs has been located further offshore in late summer above mud bottom in 55 fathoms by a plankton net fishing in about 40 fathoms. Hatching experiments with these eggs failed after the second protozoea stage and the identity of the material could not be established with certainty. The larvae, however, were identical with those described and figured by Dakin (1938, 1940) as *Penaeus plebejus*, but there is a possibility that they may belong to another species of *Penaeus*, perhaps *esculentus*.

As the collected eggs were in an early stage of development (blastula stage in *Metapenaeus*, nauplius stage in *Penaeus*) conclusions can be made as to the situation of the actual spawning grounds. Generally, *Metapenaeus* spp. seem to spawn closer onshore, *Metapenaeus mastersii* even in inside waters (Morris and Bennett 1951), whereas species of *Penaeus* appear to prefer greater depths further offshore. The sub-demersal property of the eggs, belonging to the latter genus, is most probably due to a higher salinity in the open ocean.

Routine plankton catches in ocean waters often prove the presence of post-larval stages of the genera *Penaeus* and *Metapenaeus* at great distances from the shore. It is therefore probable that only a portion of the penaeid larvae and post-larvae will ever reach the estuaries, whereas the rest may spend its whole life cycle at sea. The vulnerability of inside breeding species consequently appears to be greater than that of offshore spawners.

Observations in the outer littoral area

The present investigations established the optimal habitats of a number of commercial species. *Metapenaeus mastersii* is to be found in all stages including adults in the inside area and only rarely in the inner littoral area. *Metapenaeus macleayi* and *incisipes* were found to prefer mudbanks in the shallower parts of the inner littoral area in adult life, where both species mate and spawn. *Penaeus plebejus*, although present in adolescent stages (up to 5 in.) in both the inside and inner littoral area, shows a preference in adult life for sandy bottoms in greater depths just beyond the outer border of the inner littoral area. In view of the complete absence of a prawn fishery in deeper waters, however, there was at first little evidence as to the optimal habitat of the tiger prawns (*Penaeus esculentus* and *P. carinatus*), which were only occasionally taken on the present prawning grounds.

In an effort to locate the presumable optimal habitats of these species, trapping experiments were carried out in New South Wales in far offshore waters ranging from 50 to 90 fathoms. Modified funnel-type fish traps proved to be unsatisfactory and were replaced later by improved wing-type designs. The rectangular sides of a wooden frame 3 x 2 x 2 feet were covered with ½ in. bird wire mesh. One square side of this trap represented the trap door, the other carried an upward and inward bent wing of wire mesh, so that a 2 in. slit was left open between the upper rim of the wing and the top of the trap. The traps were fitted with spikes on the bottom and were heavily weighted. Baited with horse meat or liver, they were set in various depths, usually in sets of four. The experiments were carried out from 12 to 22 miles offshore in the Ballina, Port Macquarie, and Stockton Bight areas.

Results were negative in waters with heavy ocean currents, usually between 40 and 60 fathoms on the north coast of New South Wales. Trapping experiments in 65 to 75 fathoms resulted in large individual catches, the largest being 74 prawns weighing 52 lbs. The majority of these prawns were *Penaeus carinatus*, measuring from 7 to 12 in. together with large (9 in.) *Penaeus esculentus*. King prawns of an average body length of 8½ in. were also present. Only fully mature females were taken in these experiments.

The mentioned trapping experiments were far from being a satisfactory fishing method, and the loss of gear through rough seas, whales, and destruction by ships was considerable. Since the detection of these deep sea stocks of large commercial species, trawling experiments were carried out in greater depths of the outer littoral area. Parts of the north and central coasts of New South Wales

were thus examined with the view to the possibility of a far offshore fishery. The results of these test trawling activities were quite satisfactory and fair quantities of large to very large mature prawns were taken between 50 and 82 fathoms.

A phenomenon associated with these deep sea stocks, for which an explanation has not yet been found, is the almost complete absence of males. The ovaries of all females are ripe, some of them show signs of regeneration after at least 1 spawning.

Staining and marking experiments

Various attempts have been made during the recent investigations to stain or mark live prawns in order to trace their unpredictable movements. As tagging and hole-punching methods appear to be impracticable in view of the small size of prawns, the experiments were focussed on suitable biological stains. Decisive factors in the choice of such dyes are (1) their efficiency, (2) the time of their visibility, and (3) their lethal properties. The following dyes were tested in the course of the experiments:

(1) Methylene Blue, (2) Trypan Blue, (3) Trypan Red, (4) Nile Blue Sulphate.

In the early stages of the experiments, the dyes were applied by hypodermic needle. This method, however, had to be abandoned because of high mortality. Later the technique of total immersion of prawns in dyes was tested and proved to be satisfactory. The dyes (1) to (3) were used as a 1% solution of stain in seawater. In order to ascertain the lethal properties of dyes, stained and non-stained prawns were kept together under the same tank conditions.

Trypan Red proved lethal after an immersion of more than 3 minutes. Methylene Blue showed no lethal effects, however the dye disappeared completely after 18 hours. Trypan Blue (immersion up to 2 minutes) was found to be an excellent stain, although the mortality was more than 50%. Stained prawns were kept alive for more than 2 weeks and showed a distinctive non-fading blue tint.

From all the mentioned stains, however, Nile Blue Sulphate appears to warrant the most successful results. Used originally for studies of the migrations of starfish in the United States (Loosanoff 1937), this stain is very effective and its lethal properties are quite low. In the prawn staining experiments a 0.1% solution was used. 10 grams of Nile Blue Sulphate were first dissolved in a small volume of distilled water and then diluted in seawater to make 10 litres of solution. The prawns are placed for 3-4 minutes in this dye bath, transferred for 10 minutes into a well aerated washing tank and then released. The mortality during the dyeing process is low and does not exceed 20%. The retention of the stain by the prawns is considerable and covers a long period.

The practical use of this staining method in studies of the migrations of prawn populations is simple and efficient, although the retention of the stain may be limited with the next occurrence of an ecdysis.

WORKING KEY TO AUSTRALIAN SPECIES OF PRAWNS

1. Lower edge of rostrum with teeth — 2
   Lower edge of rostrum without teeth — 10
2. Lateral (adrostral) grooves extending almost to hind margin of carapace; lower edge of rostrum with 1 tooth; telson with 3 pairs of lateral spines .. .. — 3
   Lateral (adrostral) grooves not exceeding hindmost rostral tooth; lower edge of rostrum with 3-5 teeth; telson unarmed .. .. — 5
3. An accessory (secondary) pair of adrostral grooves on the sides of the upper blade not exceeding hindmost rostral tooth; post-ocular crest with double loop .. .. — 4
   No accessory (secondary) pair of adrostral grooves; post-ocular crest with single loop .. .. *Penaeus latisulcatus* Kishinouye
4. Main adrostral grooves confluent near hind margin of carapace forming an x-shaped depression .. .. *Penaeus maccullochi* Schmitt
   Main adrostral grooves not confluent near hind margin of carapace ..... *Penaeus plebejus* Hess
5. Subhepatic ridge present; antennae tigered — 6
   Subhepatic ridge absent; antennae plain.. — 9
6. Fifth pair of walking legs without exopodites .. .. — 7
   Fifth pair of walking legs with exopodites .. .. — 8
7. Colour in life dark buff with grey to black cross bands.... *Penaeus carinatus* Dana
   Colour in life vivid blue with dark blue cross bands. . . . *Penaeus caeruleus* Stebbing
8. Postrostral carina distinctly grooved; faint tiger pattern on abdomen only; walking legs striped..... *Penaeus semisulcatus* de Haan.
   Postrostral carina not grooved; pronounced tiger pattern on carapace and

abdomen; walking legs plain....*Penaeus esculentus* Haswell.

9. Rostral crest low; dactyl of third maxillipeds of adult male about as long as propodus; colour in life pale tan speckled with blue.....*Penaeus indicus* Milne Edwards

   Rostral crest high and triangular; dactyl of third maxillipeds of adult male scarcely half as long as propodus; colour in life pale cream, speckled with brown or olive green....*Penaeus merguiensis* De Man

10. A distal fixed pair of spines on the telson (telson trifid); pterygostomian spine present on antero-inferior angle of carapace; stridulating organ present on postero-lateral margin of carapace.... *Penaeopsis* (*Metapenaeopsis*) *novaeguineae* (Haswell).

    No distal pair of fixed spines on the telson, but mobile lateral spines may be present in variable number; pterygostomian spine and stridulating organ absent 11

11. Carapace without sutures 12

    Carapace with longitudinal or transverse sutures or both 15

12. Telson without prominent spines, but with numerous minute spinules .. 13

    Telson with prominent lateral spines .. 14

13. Post-hepatic ridge very prominent throughout its length; first pair of walking legs bispinose; optimal habitat in adult life offshore; colour in life olive green to pink, walking legs with conspicuous red-cream stripes, tips of tail fan purple .....*Metapenaeus incisipes* (Bate)

    Post-hepatic ridge faint and only posteriorly developed; first pair of walking legs unispinose; optimal habitat in adult life inside waters; colour in life greenish translucent, walking legs plain, tips of tail fan rich green..*Metapenaeus mastersii* (Haswell)

14. Carapace and abdomen more or less smooth; rostrum usually with 6 teeth; anterior third of rostrum toothless, styliform, uptilted; telson armed with four pairs of lateral spines..*Metapenaeus macleayi* (Haswell)

    Carapace and abdomen covered with triangular patches of dense pubescence; rostrum straight, usually armed with 10 teeth, not styliform; telson armed with three pairs of lateral teeth..... *Metapenaeus endeavouri* (Schmitt)

15. Longitudinal sutures only present; carapace and abdomen thickly pubescent; epipodites present on third pair of walking legs; colour in life uniformly reddish 16

    Longitudinal and transverse sutures present; carapace and abdomen naked; epipodites absent from third pair of walking legs; colour in life tan with distinct tiger pattern of brown, yellow, and blue stripes .. ..
    Parapeneopsis sculptilis (Heller)

16. Epipodites present on first 2 pairs of walking legs .. ..
    Trachypeneus (*Trachysalambria*) *curvirostris* (Stimpson)

    Epipodites absent from first 2 pairs of walking legs .. ..
    Trachypeneus (*Trachypeneus*) anchoralis (Bate).

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6

SHRIMP FISHERIES OF PAKISTAN

by

M. R. Qureshi*

A. Fishing Grounds : Of the two units of Pakistan, West Pakistan is situated on the Arabian sea, and the coast extends for about 500 miles from the Indian territory on the south-east to the Gwatar Bay on the west. It is roughly divided into two sections, as follows :

(*a*) The *Sind coast* extending from Sir creek on the south-east to the Hab river on the west. It is about 200 miles long and the major part consists of the delta of the river Indus. It is a low coast except that a few barren hills are found near Karachi. The bed of the sea is mostly muddy and suitable for shrimps, which occur throughout this coast, which is a network of creeks. The main centres for shrimp fishing are Mall, Jhabb, Dabbo, Patiani, Khuddi and Korangi extending to the Karachi harbour.

In February 1955, a shrimping boat was received through the American aid programme and has struck some shrimp grounds south-east of Karachi. On one occasion 1,200 lbs. of big shrimps (*Penaeus merguiensis*) were caught in one haul lasting about two hours.

(*b*) The *Mekran coast* extends from the river Hab to the Gwatar Bay and is formed of large bays, broken at two places by backwaters. The main fishing centres are Sonmiani, inside Sonmiani Bay, Kalmat situated on Kalmat creek, Ormara, Pasni, Gwadar, Ganz and Jiwani. No exploratory work has yet been done but the data collected so far indicate that Sonmiani Bay, Kalmat creek, Pasni and Gwadar have good shrimp grounds from where a fairly large catch is dried and exported.

Rainfall on the coasts of West Pakistan is scanty averaging about 7 inches.

* Director, Central Fisheries Department, Karachi, Pakistan.