FISHING INDUSTRY RESEARCH AND DEVELOPMENT COUNCIL

FINAL REPORT TO 31.12.88 - FIRTA GRANT NO. 1985/82

GRANT RECIPIENT: Division of Fisheries
CSIRO Marine Laboratories
GPO Box 1538
Hobart, Tasmania 7001

RESEARCH STAFF: B. Wallner, Dr B.F. Phillips and L.J. Hobbs
Division of Fisheries
CSIRO Marine Laboratories
Marmion, Western Australia

THE FISHERIES BIOLOGY OF SCAMPI (*METANEPHROPS* spp.)

SUMMARY

1. There are three fisheries targeting scampi (*Metanephrops* spp).

The North West Shelf Deepwater Trawl Fishery (NWSDWTF) which is bounded by the Australian Fishing Service in the north and the 200 m isobath to the south between the meridians 114° E and 124° E. Twelve vessels are endorsed for this fishery (1989/90).

The Western Deepwater Trawl Fishery (WDWTF) between the 200 m and the outer boundary of the AFZ and from the edge of the NWSDWTF at 114° E in the north to the 115° E meridian in the south. Ten vessels are endorsed for this fishery (1989/90). The NWSDWTF targets *Metanephrops andamanicus*, *M. australiensis* and *M. boschmai* and the WDWTF *M. andamanicus* and *M. boschmai*.

The third fishery is at the boundary between Australian and Indonesian waters to the north of Darwin. Fourteen vessels from the Northern Prawn Fishery have fished this resource, targeting *M. sibogae*.

2. Annual catches of scampi in the NWSDWTF ranged from 92 to 163 t between 1985 and 1988. Effort expended for these catches ranged between 11,000 and 19,000 trawl hours. Annual catches in the WDWTF were 4.5 and 27.6 t in 1987 and 1988 for 900 and 4,000 trawl hours respectively. In 1988, 218 t of *M. sibogae* were caught for 9,000 trawl hours in the area north of Darwin.

Catches of prawns during the same fishing operations ranged from 175 to 854 t in the NWSDTF, 39 to 64 t in the WDWTF and were 104 t in the *M. sibogae* fishery.

3. Scampi species occur in different depth zones. *M. andamanicus* occurs between 340-440 m, *M. australiensis*

between 420-500 m, *M. boschmai* between 260-360 m and *M. sibogae* from 250 to at least 320 m. The distribution of all species is patchy and depends on the availability of suitable substrate. *Metanephrops* spp. probably occur in small quantities all around Australia.

4. Biological characteristics of importance are:

   a) The catches of scampi comprise up to 6 or more year classes, but do not include the 0-3 year age groups.

   b) Sex ratio in the catches is approximately 1:1.

   c) Although the animals live in burrows, berried females apparently do not hide and are vulnerable to capture.

   d) Spawning may be annual, but eggs are carried for a long period and berried females occur in the catches throughout the year, except in *M. sibogae* which may have a more defined period of spawning.

   e) Fecundity of *Metanephrops* spp. ranges between 200 and 1500 eggs per brood, depending on the size of the female.

   f) Larvae hatch in an advanced state of development and the larval life is probably in the order of a few days.

   g) No evidence of migration was obtained.

   h) No measure of natural mortality is available. However, a parasitic copepod *Nicothoe sp.* which attacks the gills was detected in high incidence in some areas. Its impact is unknown.

5. A compulsory logbook program for the NWSDWTF and WDWTF has been established. A voluntary logbook program has been established for the *M. sibogae* fishery.

   The information from the logbooks is stored in a CSIRO computer database. It will be transferred to the Australian Fishing Zone Information System (AFZIS) as soon as the necessary computing changes can be effected by the Australian Fisheries Service.

   Estimates of standing stock size for specified areas of the NWSDWTF are 78-93 t for *M. andamanicus* and 92 t for *M. australiensis*. The standing stock estimate for the *M. sibogae* fishery is 401-463 t. Estimated instantaneous total mortality rates for these same areas were *M. andamanicus* 0.04/month and *M. sibogae* 0.15/month. Total mortality rates are probably equivalent to fishing mortality rates for these species, in these specified areas.

Limited fishing in the WDWTF makes satisfactory estimates of stock size, etc., impossible at this time.

6. Conclusions

a) In the NWSDWTF, *M. andamanicus* and *M. australiensis* are fully exploited; *M. boschmai* is under exploited.

b) The *M. sibogae* fishery is too new for satisfactory estimates of exploitation rates.

c) Exploratory fishing is needed in the NWSDWTF to determine the distribution and extent of the prawn resources.

d) Exploratory fishing is needed in the WDWTF to determine the distribution and extent of both the scampi and prawn resources.

7. Management

The fisheries of the NWSDWTF, WDWTF and the *M. sibogae* fishery are all mixed fisheries with catches including, scampi, prawns, other crustaceans such as crabs and bugs, squid and finfish.

Management options which might be considered in areas where scampi abundance has declined include:

a) Closures (including total, seasonal, rotational), or other effort restrictions in specified areas.

b) Use of alternative fishing techniques, such as potting for scampi.

c) Fishing of the prawn stocks using mid-water trawls, thereby not interfering with the scampi stocks.

8. Recommendations

a) The logbook and biological catch sampling programs for both the scampi and prawns should be maintained. This program should be extended to any new areas where *Metanephrops* fisheries develop around Australia.

b) The information from the logbooks stored in the computer database should be transferred to the Australian Fishing Zone Information System (AFZIS) as a matter of urgency.

c) Alternative harvesting techniques, such as trapping for scampi and mid-water trawling for prawns, should be tested.

d) Experimental manipulations of effort in selected areas should be examined to determine the rate of recruitment of scampi to the fishing grounds.

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INTRODUCTION

Scampi, or species of clawed lobsters of the genus *Metanephrops*, occur on the continental slopes of many countries in the world, however, prior to 1985 were commercially fished only in deep water off south east Africa, *Metanephrops andamanicus* (Berry, 1969) and experimentally in the western Atlantic Ocean and Caribbean Sea, *Metanephrops binghami* (Roe, 1966).

The presence of scampi on the north west slope of Australia was first reported by the survey steamer Investigator in 1891 (Alcock, 1894), but it was not until 1985 that a commercial fishery based on three species of scampi (*Metanephrops andamanicus*, *M. australiensis* and *M. boschmai*) was developed.

The scant scientific knowledge of these species used to establish initial management plans for the fishery prompted the initiation of a CSIRO research program. This three year research program, which commenced in January 1986, aimed to collect fundamental information on the fisheries biology of these animals in order that a rational long term management strategy for the fishery could be designed.

OBJECTIVES

1) To obtain information on the size, fishing and natural mortality, growth, reproduction and migration of the three scampi species - *M. australiensis*, *M. andamanicus* and *M. boschmai* - from the existing NW slope fisheries.

2) To document the fishing withdrawals from the grounds and the fishing effort by type and quantity.

This report summarises the information collected on scampi biology and discusses the fishery for these species and the suite of deepwater prawn species which now dominate the fishery catches (Wallner and Phillips, 1988).

THE FISHERY

(i) Location and History

Promising catches of scampi and deep water prawns at depths between 300 and 500 metres were made on the north-west continental slope of Australia in 1982 by the RV "Soela" (Anon., 1983). Following trial fishing by the FV Fisheries Pty Ltd vessel "Courageous" in 1983 (Carter *et al.*, 1983) and the discovery of additional scampi grounds in 1984 by Soela (Davis and Ward, 1984), the Australian Fisheries Service (AFS) released a development plan for the fishery in March 1985.

Eight trawlers began operating in a specified Development Area which encompassed the known concentrations of scampi. With exploratory activity by these vessels significant scampi catches were also made outside the boundary of the Development Area and on this basis small expansions of the boundary and increases in the number of endorsements for the fishery were made annually in 1986 and 1987.

Currently, this fishery is known as the North West Shelf Deepwater Trawl Fishery (NWSDWTF) and is bounded by the 800 metre isobath to the north and the 200 metre isobath to the south between the meridians of longitude 114°E and 124°E (Figure 1). Twelve vessels have endorsement to fish in this fishery (1989/90).

In May 1987, the AFS gazetted the Western Deepwater Trawl Fishery (WDWTF), (Figure 2), following recordings of good catches of *Metanephrops andamanicus* and other deepwater crustaceans at about 27°S. Initially, all 98 applicants were endorsed for this new fishery for a one year period, however most of these vessels did not satisfy the selection criteria for continued endorsement in the fishery, thus 20 vessels had access to this fishery in 1988/89 and 10 in 1989/90.

During August 1987, exploration by the FV Fisheries Pty Ltd trawler "Kingfisher", on the boundary of Australian and Indonesian waters to the north of Darwin (Figure 3), produced commercial catches of another scampi species *Metanephrops sibogae*, previously not reported from Australian waters. Since this time 14 NWSDWTF or WDWTF trawlers have fished this resource.

(ii) Vessels and Harvesting Methods:

With the exception of the two dedicated Deep Sea Fisheries Ltd trawlers the vessels in the NWSDWT Fishery are prawn trawlers also endorsed for the Northern Prawn Fishery and thus fish the scampi grounds seasonally during closures or during periods of low catch rate in the Gulf of Carpentaria.

All vessels are 'Otter' trawlers of steel construction between 23 and 30 metres LOA, powered by engines producing between 360 and 800 BHP. These vessels are generally manned by a skipper, engineer, mate and 3 or 4 deck hands. Sufficient fuel and water is carried for fishing trips of one month duration. Catch is always packaged and frozen at sea and held in refrigerated holds of 20-50 tonne capacity. These 'prawn' trawlers have been modified for operation in water depths to 1000 metres. Modifications include large-capacity hydraulic winches, and catch handling equipment capable of processing large volumes of fragile product.

Fishing gear is usually twin nets towed over the stern from a single or double warp and spread by two steel boards, a central skid connects the two nets. Net design is frequently based upon prawn net specifications such as the 'Florida Flyer' with extended wing panels and are between 28 and 40 fathoms total headline length depending upon the size of the vessel. Mesh size is commonly 3 inch with 1.75-2 inch cod-end when targeting scampi, but 2 inch mesh is used when targeting the smaller deepwater penaeid species.

Trawling for scampi is conducted continuously over the 24 hour period. Trawl 'shots' are made parallel to the bathymetric contours over soft, muddy bottom. Shot durations vary between 3 and 6 hours. During target fishing for the deepwater penaeid *Aristaeomorpha foliacea* it is normal to reduce shot duration to 1.5-3 hours and to trawl only during daylight hours. After completion of a trawl the cod-end is winched aboard and the contents spilled into a hopper filled with refrigerated seawater to which has been added a quantity of an antioxidant such as sodium metabisulphate. Catch is then sorted from a conveyor belt, separated by species and size. Product is then thoroughly washed to remove any mud or eggs adhering to the pleopods of scampi and packaged in waxed cardboard cartons before snap freezing in a fan-forced blast freezer.

METHODS

(i) Recording of Commercial Catch and Effort

All vessels in the NWSDWT and WDWT Fisheries are required to complete and return a daily logbook record of their fishing activity and catches. These records provide a shot by shot breakdown of all fishing activity; giving position, time of day, trawl duration, depth, fishing gear used, and catch retained.

Catch records are converted into kilograms and verified against actual landed product records provided by the participating fishing companies.

This information is stored in a CSIRO computer database and will be transferred to the Australian Fishing Zone Information System (AFZIS) as soon as the necessary computing changes can be effected by the Australian Fisheries Service.

Analysis of these records provided information on the composition of the catch and rates of catch by species, time, area and depth. For all comparison of catch rates, actual effort has been standardised according to the total length of net towed, by scaling to a common 40 fathom total headline length.

The *M. sibogae* area is within the boundaries and under management jurisdiction of the Northern Prawn Fishery (NPF), although to date, only NPF vessels who also hold NWSDWT or WDWT fishery endorsements have been equipped to fish the resource. All vessels fishing this resource have been asked to voluntarily complete a deepwater crustacean logbook, in addition to their northern prawn logbook.

Apart from the requirement that participating vessels must hold a Commonwealth Fishing Boat Licence and the appropriate endorsement for the deepwater trawl fishery there are no restrictions on vessels in any of these fisheries. No closure periods or areas apply to these fisheries. Similarly, the type or size of trawl gear, or the catch that can be taken are unrestricted.

(ii) Collection of Biological Data

Twelve trips to sea aboard commercial trawlers were made between February 1986 and December 1988. Although these trips were scheduled at bimonthly intervals it was not always possible to maintain the schedule due to lack of available vessels, especially during periods such as the April-May 'Banana Prawn' season in the Gulf of Carpentaria. Similarly, no control could be exercised over the sample location as the host vessel was at all times under the direction of the skipper who aimed to maximise catch rates. Therefore, this *ad hoc* sampling produced 'snap shots' of different populations at different times and could not provide a continuous time series of data for any single population.

The most abundant species of scampi was sampled from the commercial haul aboard the vessel. The sample was counted and weighed, then the individuals sexed, measured, and assessed for spawning condition, recent moulting and presence of parasites.

The measure of length adopted for this study was carapace length as defined by Berry (1969). Vernier calipers were used to measure, to the nearest millimetre, the carapace from the base of the major supra-orbital spines to the posterior margin of the carapace. These measurements were used to construct length frequency distributions for the populations and subjected to cohort dissection techniques for the estimation of rates of growth and natural mortality. The maximum likelihood method (MacDonald and Pitcher, 1979) was used to estimate the age group parameters using the personal computer software 'MIX' (version 2.3). This interactive computer program enabled rapid determination of the parameters that could be estimated from a set of data. The best fit sometimes involved a trade-off between statistical precision and biological plausibility.

In order to try to time reproductive periodicity and estimate population fecundity, females were examined by eye for the presence of a developed ovary and or eggs according to the following criteria, (modified from Berry, 1969):

Developed ovary - ovary bright blue, occupying whole of the thoracic cavity dorsally, with posterior lobes extending into the first abdominal segment (equivalent to Berry's stage 3-4 ovary).

Egg stage I - recently spawned eggs, small spherical regular sized eggs with even bright blue coloration.

Egg stage II - paler blue coloration than stage I, with developing embryo just visible as a pale patch of tissue at the pole of the egg.

Egg stage III - coloration variable, pink appendages of the embryo visible but some residual blue yolk remaining.

Egg stage IV - eggs ready to hatch, large, slightly ovoid, embryo within has visible eye spots, coloration pink red with no residual blue yolk remaining.

4. RESULTS

(i) Fishery Production

(a) NWSDWT FISHERY:

The past three year development phase of this fishery has displayed rapid expansions in the commercial catches and effort expended, (refer to TABLE I). Catch increased from 350 annual tonnes in 1985-86 to 962 annual tonnes in the most recent year, an increase of 175%. This was produced by a smaller 71% increase in effort from 10,800 trawl hours to 18,500 trawl hours. However, the relative importance of the scampi component of the catch has declined. In 1985-86 scampi composed 47% of the total catch and a significantly greater proportion of the fishery value, this declined progressively to only 10% of the total catch in 1987-88.

Conversely, the proportional prawn component of the catch has increased from 54% of the catch in 1985-86 (175 tonnes) to 89% in 1987-88 (854 tonnes). Of this catch four deepwater penaeid species are of commercial importance accounting for 67% of the catch: *Aristaeomorpha foliacea* (red prawn), *Haliporoides sibogae* (pink prawn, or royal red prawn in NSW), *Aristeus virilis* (pink striped prawn) and *Plesiopenaeus edwardsianus* (giant scarlet prawn). The red prawn, *Aristaeomorpha foliacea*, is the single most important species at present comprising 49% of the prawn catch and 43% of the total fishery catch. Two carid species, *Heterocarpus woodmasoni* (red carid shrimp) and *Heterocarpus sibogae* (white carid shrimp), make up the balance of the commercial prawn catch. The white carid (*H. sibogae*) is the second most dominant prawn species by weight but has very low value as the recovery from commercial peeling is only 20% and no reliable market exists for whole product.

By-catch include squid (mainly *Nototodarus hawaiiensis*), fish and other crustaceans such as bugs *Ibacus* spp. and the spear lobster *Linuparus trigonis*. Although the total of these comprises only between 2% and 7% of the catch, much of the material brought up in the trawl is discarded, hence both the potential catch and the effect of trawling are underestimated.

These figures are further reflected in the changes in catch rate or catch-per-unit-effort (CPUE) over the three years. Overall, the average CPUE for total catch has increased from 32 kg/h in 1985-86 to 52 kg/h in 1987-88.

In order to more accurately compare catch rates for scampi and prawn components a weighting factor for each fishing vessel was used. Catch rates for prawns and scampi were weighted according to the proportion of each in the total annual catch for each vessel so as to reflect the vessel's target preference or relative catch efficiency for each component of the catch. For example, during 1985-86, KFV Fisheries Pty Ltd trawlers concentrated almost exclusively upon scampi and discarded most of the prawns caught, while A. Raptis and Sons trawlers targeted 'red prawns' and consequently showed very low catch rates of scampi species. The weighting applied in this case weights 'KFV' vessels high and 'Raptis' vessels low in calculating total scampi CPUE, and *vice versa* in calculating prawn CPUE. Assuming that relative proportions of scampi:prawn catch in a year reflect target preference, total annual scampi and prawn CPUE can be expressed by the following equations:

$$CPUE\ (scampi) = \Sigma\ SC\ (V1\quad Vn)/E(V1\quad Vn)\ *\ SW(V1\quad Vn)/\Sigma\ SW\ (V1\ Vn)$$

$$CPUE\ (prawn) = \Sigma\ PC\ (V1\quad Vn)/E(V1\quad Vn)\ *\ PW(V1\quad Vn)/\Sigma\ PW(V1\ Vn)$$

where:
SC = total annual scampi catch per vessel
PC = total annual prawn catch per vessel
E = annual effort per vessel
V = a specified vessel
N = maximum number of vessels in the fishing fleet
SW = scampi weighing factor = Σ SC(V1 Vn)/Σ total catch(V1 Vn)
PW = prawn weighing factor = Σ PC(V1 Vn)/Σ total catch(V1 Vn)

Catch rates calculated in this way indicate scampi CPUE has declined from 13.7 kg/h to 9.1 kg/h and the prawn CPUE increased, accounting for the increase in total rate of catch. In 1987-88 the prawn CPUE is lower than for the previous year, due mostly to a significantly lower catch rate for the 'red prawn'. This may be attributed to lower overall efficiency of the larger number of vessels targeting this resource or may reflect a lower abundance of this species in the latter year.

(b) WDWT FISHERY:

The formation of the WDWT Fishery in 1987 was based upon the catches made during 84 boat days of exploratory fishing by vessels endorsed for the NWSDWTF during the preceeding year. These are detailed in TABLE 2.

With the application of 4,000 trawl hours of endorsed effort during 1987-88 a catch of 116 tonnes was obtained. This catch was composed of 24% scampi, 55% prawns and 22% other species. Scampi were predominantly *M. andamanicus* with a minor contribution by *M. boschmai* (*M. australiensis* has not been recorded to date), and the prawns were the penaeid 'royal-red prawn' *Haliporoides sibogae* and the ubiquitous 'white carid prawn' *Heterocarpus sibogae*. In addition to squid other by-catch of note were a species of scyllarid lobster or 'bug' *Ibacus altricrenatus*, and a large crab *Geryon* sp., dubbed the 'snow crab' for marketing purposes. It appears that the commercial crustacean fauna is less diverse than for the NWSDWTF.

Average catch rates obtained during 1986-87 declined the following year probably due to the lower average efficiency of the new operators, many of which had little or no experience in deep-water operations.

(c) *METANEPHROPS SIBOGAE* FISHERY:

Due to the recent discovery of this scampi resource only a single year of fishing has been recorded (see TABLE 3).

Over 9,000 trawl hours were applied to this small area to produce a total catch of 326 tonnes, of which 218 tonnes was the scampi species *Metanephrops sibogae*. Of the other 108 tonnes, 96% were prawns, predominantly *Penaeopsis eduardoi* and a mixture of carid species.

The scampi catch and average scampi CPUE of 19.2 kg/h was greater than for any year in the NWSDWT or WDWT Fisheries. It, therefore, constitutes an important scampi resource for Australia, that should be considered when developing management options for all scampi stocks.

Prawns and other species were apparently less abundant than in the other scampi fisheries and the species composition also differs. For example, the prawns *Plesionika sindoi* and *Penaeopsis eduardoi*, while present in other fishing areas, are caught in sufficient quantity to assume commercial importance in this area.

(ii) Distribution and abundance

(a) SPATIAL DISTRIBUTION AND ABUNDANCE:

Spatial distribution

Standardised commercial trawl CPUE may be used as a measure of relative abundance for scampi. Plotting this information on a map reveals the geographical distribution of these species, (Figures 4,5,6 and 7). All the species are distributed in a band along the upper continental slope between depths of 260m - 500m.

M. andamanicus is a by-product of deepwater prawn trawling off the east coast of the African continent and the west coast of the Indian continent and displays the most widespread distribution in Australian waters, extending from the boundary of the AFZ at 13°S in the north west around the Western Australian coastline into the Great Australian Bight as far as Kangaroo Is. off South Australia.

The distribution range for *M. boschmai* extends from the same northerly point as *M. andamanicus* to at least 29°S along the W.A. coast. *M. australiensis* exhibits the most restricted distribution, being found only between latitudes 15°S and 20°S. Each species has areas of concentration thought to be determined by sediment preference according to the burrowing ability of each species, as suggested by Carter *et al.* (1983). High abundances occur around the Rowley Shoals and Scott Reef suggest that these isolated oceanic atolls may contribute to higher productivity in the surrounding benthic communities.

Density

In areas of preferred substrate commercial scampi trawling for varying durations produce fairly constant catch rates. This may indicate that scampi tend toward an even distribution on the bottom rather than a highly aggregated pattern of distribution which is commonly observed for some deepwater prawn species such as *Aristaeomorpha foliacea* and *Heterocarpus woodmasoni*. These prawns exibit marked fluctuation in catch rate.

Based on the swept area of a trawl and 100% catchability a catch rate of 25 kg/h represents a mean density of only $0.00125/m^2$, or 1 animal per $800m^2$. If a catchability of 20% is assumed then density is $0.00625/m^2$.

Depth distribution

All species of scampi have strong depth preferences. A plot of commercial CPUE (as a measure of abundance) for each species within 20 m depth intervals across the continental slope (Figure 8) shows a consistent pattern. Scampi occur from about 260 m to about 500 m on the continental slope. *M. boschmai* dominates from 260 m to 360 m with 300 m to 320 m the most preferred depth. *M. andamanicus* occurs from 340 m to 440 m with 380 m - 400 m the preferred depth contour. *M. australiensis* is the dominant species in the deepest areas between 420 m and 500 m, with peak abundance occurring between 440 m and 460 m depth.

Stock size

TABLE 4, below, shows estimated minimum stock sizes for small substock areas of *M. andamanicus* and *M. australiensis* and total stock size for *M. sibogae*. Two methods were used; firstly, the swept area method where initial maximum catch rates are applied to the total area; and secondly, a regression method (Leslie and Davis, 1939; De Lury, 1947) where a plot of declining CPUE against cumulative catch is extrapolated to the x-axis point of zero CPUE. Potentially large sources of error exist in both these methods, therefore the estimates are not robust.

In using the swept area method, 100% catchability is assumed, this is almost certainly not so for these burrowing species, thus under-estimation occurs. Also, the maximum catch rate is applied to the total area, although in reality the total area contains patches of lower density as well. This source of error tends to check the former. Error arises with the depletion method as catchability may change with density, and because commercial fishing usually stops at the point of unprofitability well above a zero catch rate, thus considerable extrapolation is often required.

(b) TEMPORAL DISTRIBUTION AND ABUNDANCE

Seasonal patterns

Figure 9, shows the trends in abundance for three species of scampi. For each species the average fleet CPUE was calculated for a specific small fishing ground. The areas examined were defined as follows:

M. andamanicus ground:- between latitudes 17.40°S - 18.40°S
- between depths 360 m - 420 m

M. australiensis ground:- between latitudes 16.10°S - 17.10°S
- between depths 420 m - 480 m

M.sibogae ground:- between longitudes 128.00°E - 132.00°E
- between depths 240 m - 320 m

The *M. andamanicus* and *M. australiensis* curves show no clear pattern of fluctuation with season. Oscillations are probably due to varying efficiencies of different operators rather than changes in the real abundance of scampi. However, it is noteworthy that in June/July during 1986 and 1987 catch rates showed significant increases. It is likely that this is a real phenomenon resulting from a 2-3 month period of little or no fishing during April to June when most trawlers return to the Gulf of Carpentaria for the 'banana prawn' season. Real abundance may rise during this period due to recruitment or apparent abundance may rise due to increased catchability as animals, exposed to less trawl disturbance emerge from burrows for greater periods.

Despite fluctuations in the CPUE, the curves for both species and in particular *M. andamanicus* trend downwards. The mean catch rate for *M. andamanicus* for the first 7 month period of logbook records June to December 1985 was 19.3 $\pm$ 4.5 kg per hour, this declined to 5.8 $\pm$ 2.2 kg per hour for the period September 1987 to March 1988. This trend is more pronounced when it is remembered that sporadic unrecorded fishing occurred from August 1983 when fishing trials by the KFV 'Courageous' produced a catch rate of 35.5 kg/h using small prawn nets (Carter *et al*, 1983), or a standardised catch rate of 50.7 kg/h.

The *M. sibogae* curve shows the first 8 months' CPUE after the discovery of this area in August 1987. This short period is insufficient to determine any seasonal trends. However abundance is also seen to decline rapidly under fishing pressure. The initial data point is low as this represents the exploratory phase when vessels determined the optimum areas and depth range of this new species.

Daily Patterns

Ward and Davis (1987) examined the diel periodicity of catch rates for scampi. *M. australiensis* was found to exhibit higher catch rates at dusk and dawn, similar to the pattern decribed for *Nephrops norvegicus* (Chapman and Howard, 1979), while *M. andamanicus* showed no diel periodicity. Although a full analysis of the data has not yet been completed, commercial logbook data show no apparent diel fluctuation in catch rate for any scampi species. Consequently, vessels target scampi trawl continuously.

In contrast, catch rates for the penaeid species *Aristaeomorpha foliacea, Aristeus virilis and Penaeopsis eduardoi* and carid species *Heterocarpus woodmasoni* and *H. sibogae* show a very clear nocturnal decline in catch rate. This is attributed to these species undertaking a nocturnal vertical migration up into the water column. Thus, vessels targeting deepwater prawns, particularly *A. foliacea*, trawl only during daylight hours.

(iii) Population Structure

(a) SIZE COMPOSITION:

Size frequency distributions of different scampi species always assume a species specific shape. Samples of each are presented in Figures 10,11,12 and 13. They are obviously polymodal and it is assumed this polymodality is the result of annual recruitments forming age (size) cohorts.

The figures indicate the 50% selection size for *Nephrops norvegicus* for a 70 mm cod-end trawl (Main and Sangster, 1984). The trawl nets used in the NWSDWTF use mesh of 51-90 mm in the wing panels and 45-51 mm cod-ends, thus the mesh selection size for Australian scampi species could be smaller than indicated. It is clear that small size classes that are above the mesh selection size are not well represented in the samples. This is attributed to reduced catchability of young animals, possibly due to greater proportions of time spent in burrows. Therefore, although small scampi may abound on the fishing grounds they do not recruit fully to the fishery until about 3+ years, coincident with reproductive maturity.

(b) SEX RATIO:

For *M. australiensis* and *M. boschmai* males and females were almost always equally represented in the catch. Samples of *M. andamanicus*, however, frequently had significantly greater numbers of females than males. This usually occured during periods when proportions of females carrying berry was high.

It is hypothesised that berried female *M. andamanicus*, a deeper burrowing animal, emerge from the burrow for longer periods to oxygenate the brood and therefore suffer a higher catchability. Berried females sometimes accounted for up to 72% of the total *M. andamanicus* catch.

(iv) Species Biology

(a) HABITAT AND BEHAVIOUR:

Metanephrops spp. are probably similar to *Nephrops norvegicus* in the fact that they expend considerable energy in building burrows (Rice and Chapman 1971) and display aggressive home ranging behaviour (Farmer 1975). Consequently, scampi habitat is closely correlated with sediment type and grain size. McLoughlin *et al.* (1988) found that areas of calcareous muddy sands supported the highest concentrations of *Metanephrops* spp. around the Scott Reef-Rowley Shoals area.

Based upon observations of the frequency of epizooic barnacles on the carapace, the degree of spination of the exosketeton and sediment adhering to captured animals Carter *et al.* (1983) suggested that *M. australiensis* preferred comparatively firmer substrate, may not build extensive burrows and may be active outside the burrow for considerable periods of time, while *M. andamanicus* and *M. boschmai* made deeper burrows in softer sediment. Observations during this study support this hypothesis.

(b) REPRODUCTION:

Reproductive Cycle

Mating and reproduction in *Metanephrops* spp. are probably similar to that described for *Nephrops norvegicus* (Farmer, 1975) and *M. andamanicus* (Berry, 1969). In *Nephrops*, copulation occurs between a male and a recently moulted female. The male transfers sperm from the opening of the vas deferens on the coxa of the fifth periopods via the highly modified first abdominal appendages. These appendages form a pair of grooved, pointed stylets or penes which are inserted into the female goniopores on the coxa of the third pereiopods. Fertilization is probably internal, occurring during spawning of the ova. Fertilized eggs are adherred to the pleopods where they are incubated for many months. The embryo is lecithotrophic, nourished from the large yolky egg which is characteristically bright blue when first spawned. The egg gradually changes to pink then red as the embryo becomes pigmented and the yolk is absorbed. The larvae hatches in an advanced stage of development and undergoes a few rapid moults before adopting a benthic habit as a juvenile (Uchida and Dotsu, 1973, Wear, 1976).

Reproductively mature metanephropids probably moult and spawn annually (Berry, 1969), however, only coarse estimates of the timing of these events can be drawn from this study due to the inability to regularly sample a population at one location. It is thought that latitudinal variation in the timing of spawning events confounded a clear pattern.

For *M. andamanicus* and *M. australiensis* the proportion of female animals in samples carrying eggs (berry) was lowest in June and July (21-35%), although the incidence of developed ovaries was high. Proportions of berried females was highest during the period from October to January (50-94%). The data indicate that these two species spawn during spring and summer months, incubating the eggs attached to the pleopods for possibly 6-7 months before the eggs hatch during the autumn - winter period. This cycle is similar to that reported for *M. andamanicus* in South African waters (Berry, 1969). Berry also found that peak moulting and subsequent mating occurred during May to July. However, in this study the numbers of recently moulted (soft) animals in commercial catches was always small and variable and it is believed that animals in soft condition were less susceptible to capture. Therefore this finding cannot be confirmed.

Insufficient sampling of *M. boschmai* was conducted to estimate the timing of reproductive events for this species.

Time of spawning appears to differ for *M. sibogae* compared to the two NW slope species discussed. Sampling of the recently discovered population during early October 1987 revealed that the majority of females were ovigerous but only 0.2% carried berry. By the end of January 1988 a comparatively synchronous spawning had occurred, with 80.2% of females in berry.

CROSS SHELF PROFILE OF BOTTOM WATER TEMPERATURES (°C)

STATION NO	8	9	10	11	12	13
DEPTH (M)	40	70	100	110	400	1082
WINTER TEMP	21.36	21.82	23.09	23.57	9.37	4.68
SUMMER TEMP	27.74	25.03	23.17	23.21	9.59	4.57

NOTE: Winter temperature from Soela cruise AS04 - August 1982
: Summer temperature from Soela cruise AS01 - February 1983

The cross shelf transect is just south of the Rowley Shoals.

Higher ambient water temperatures resulting from the shallower depth and equatorial latitude (inferred from hydrographic data for the NW Shelf collected by the RV Soela - see table) may contribute to the delay in spawning for this species and could significantly reduce the incubation period.

Size at Sexual Maturity

Sexual maturity for females was taken as the size at which spawning and egg incubation occurs. TABLE 5 details the minimum sizes at which berried females were found and the size at which 50% of berried females occurred for aggregated samples of each species.

Differences between the two measures reflect the capacity of occasional small individuals to successfully spawn as opposed to the general trend for the population.

Apparent variation in the size of first sexual maturity was observed for *M. andamanicus* with respect to latitude. Samples taken from 26-27°S tended to have a slightly larger size at which 50% were berried than samples taken from 17-18°S. However, insufficient samples were taken at the more southerly latitude to statistically verify this observation.

Fecundity

Metanephropids have lower fecundity than *Nephrops norvegicus*. Female *Nephrops* sp. produces between 800 and 5000 eggs (Farmer, 1975), while Figure 14 indicates that the number of newly spawned (Stage I) eggs for the most fecund Australian scampi species (*M. australiensis*) is between 400 and 1500. The effective fecundity is more than 50% lower as shown by the Stage IV curve in Figure 14, due to egg loss during the incubation period. Despite careful selection of females for egg counts, some of this egg loss could be attributed to capture and handling. Chapman and Ballantyne (1980) suggest trawling causes an 11-22% loss of eggs from *Nephrops norvegicus* compared to trapped animals. However, during the long incubation period natural attrition is probably responsible for the majority of egg loss. For *Nephrops* egg loss as high as 10% per month or 75% total has been recorded (Figueiredo *et al.*, 1983).

Given the high rates of egg loss that seem to be a feature of this genus, calculation of population fecundities should be based upon animals in the terminal stage of egg incubation or effective fecundity.

Figures 15 and 16 indicate similar patterns for *M. andamanicus* and *M. boschmai* respectively, although the fecundities are lower in keeping with their smaller size and r^2 values indicate more variable data about the regression lines.

(c) <u>GROWTH</u>:

Preliminary analysis of length frequency data indicates that length frequency histograms for *M. australiensis, M. andamanicus* and *M. boschmai* may be sucessfully separated into 6, 5 and 3 component cohorts respectively. Assuming that the polymodal structure of all scampi length frequency histograms reflects annual cohorts then it is likely that *M. boschmai* become fully recruited or available to the fishery from about age 3 years and *M. andamanicus* and *M. australiensis* from about age 4. These ages are also the approximate ages of animals which reach sexual maturity or spawning size.

This data is being further analysed for modal progressions in time to confirm rates of growth and will be the subject of a separate report.

(d) <u>MORTALITY</u>:

In measuring the mortality in a fished population, two components of the total mortality (Z) must be considered, natural mortality (M) and fishing mortality (F).

<u>Fishing Mortality</u>

If we assume over time that a population is in equilibrium with recruitment to the population balanced by natural mortality and no net migration, then changes in the abundance of the population are due to fishing mortality.

Changes in the natural log of the abundance for *M. andamanicus* in the area first trawled by a commercial vessel in 1983 (Carter *et al.* 1983) are plotted on Figure 16. The area considered, between 17.40°S and 18.40°S and 360 to 420 metres depth has been consistently fished and it is believed that CPUE standardised for net size represents a reliable index of abundance. Z is derived from Gulland's (1969) equation;

$Nt=Noe^{-zt}$; and is represented on Figure 17 by the slope of the regression.

Therefore: $F=Z=0.0013 \pm 0.0001\ day^{-1}$
$=0.04 \pm 0.003\ month^{-1}$, for the period of the fishery.

Simply, this approximates to the fishing activities of the current fishing fleet reducing the population by about 5% per month between September, 1983 and April 1988.

A similar approach was unsuccessful for *M. australiensis* in the area bounded by latitudes 16.10°S and 17.10°S, between depths of 420 and 480 metres as this area was less consistently fished.

After the discovery of the *M. sibogae* grounds in August 1987, this population was fished until the commencement of the 'Banana prawn' season in the Gulf of Carpentaria. The results of this analysis are shown in Figure 18.

$$F=Z=0.005 \pm 0.0004 \ \text{day}^{-1}$$
$$=0.15 \pm 0.012 \ \text{month}^{-1}$$

This instantaneous mortality rate approximates to a reduction in population abundance, due to fishing, at a rate of about 15% per month.

Natural Mortality

No reliable estimates for natural mortality could be made during this study.

Attempts to estimate natural mortality from declining frequencies on the right hand tail of the length frequency distribution gave unrealistically high estimates. This is due to merging of cohorts in these slow growing age classes. A result using this method would have reflected the M of a senescent portion of the population and may not have been generally applicable to the whole stock.

It is suspected that M may vary widely between areas and different species due to the presence or absence of the parasitic copepod *Nicothoe* spp. (Kabata, 1967). This parasite attaches to the gills of the scampi eventually causing extensive gill damage and disfiguring the carapace. It was found only in *M. andamanicus* and *M. boschmai*, while *M. australiensis* appeared to be free of it. Frequency of infection was higher in smaller animals indicating the possibility of increased mortality of infected hosts. On the principal *M. andamanicus* fishing ground south of the Rowley Shoals, up to 57% of the catch was infected, while no incidence of infection was recorded for the same species caught between 25°S and 27°S.

(e) MIGRATION:

No evidence of migration was found during this study.

Experimental tagging of *Nephrops norvegicus* revealed localised movements generally less than 5 miles (Farmer, 1975) and it is likely given the energetic investment in burrow building, that scampi do not undertake extensive migrations, rather, localised movements within their home range for the purposes of feeding, reproduction and defence. Commercial catch and effort statistics support this view. Concentrations of scampi or areas producing high CPUE did not shift, unlike aggregations of the prawn species *Aristaeomorpha foliacea* and *Heterocarpus woodmasoni* which vary in position and can rapidly disperse under fishing pressure.

5. DISCUSSION

(i) Stock Size Estimates and Exploitation:

In these scampi fisheries a significant proportion of the total standing stock biomass is distributed at low densities. The main fishing activity is directed toward a number of discrete small areas that support higher densities. It is the stock in these small areas that are subjected to fishing mortality and the sum of these small productive areas should be considered to be the "effective" stock size for the purposes of managing these fisheries.

In most new fisheries, abundance measured as CPUE, falls quickly as surplus standing stock is removed. The fishery then stabilises at a lower level partly due to a density dependent enhancement of recruitment above the amount removed from the population by mortality, permitting further removals from the stock by fishing. It is not possible to tell at this time if CPUE will stabilise in the areas that have been fished. However, in some areas, such as the *M. andamanicus* area examined for CPUE, the catches are now below what is currently viable to support the vessels by exclusively fishing for scampi.

NWSDWTF

Davis and Ward (1984) estimated standing stock sizes for three species based on catch rates obtained for a given swept area and extrapolating to the estimated total area inhabited by each species. These were:

M. andamanicus - 880 tonnes
M. australiensis - 300 tonnes
M. boschmai - 660 tonnes

Commercial fishing since that time indicates that the areas inhabited by profitable densities of *M. andamanicus* and *M. australiensis* were probably overestimated, consequently stock size estimates made in this study apply only to small sections of the fishery. Insufficient commercial trawling for *M. boschmai* has taken place to date to estimate stock size.

The NWSDWTF fishery for scampi is probably fully exploited, with the exception of the *M. boschmai* stocks which have received little commercial attention due to the difficulties involved in marketing the smaller grade product. The following points support this view:-

- All the trawlers, with the exception of two vessels, are endorsed for other fisheries and fish the NWSDWTF during seasonal closure in other fisheries. Therefore there is considerable latent effort capacity in the existing fleet.

- It has been demonstrated that the current fleet can rapidly reduce the CPUE with only seasonal application of effort.

- Although scampi are widespread (particularly *M. andamanicus*) beyond the small productive areas used above in stock size estimates. Much of the additional areas apparently support low densities.

- The depth contours favoured by scampi have been thoroughly explored in the NWSDWTF and there is little chance that additional major concentrations of scampi will be found in future in this fishery.

However, the NWSDWTF is a mixed fisheries with the greatest catch and value now taken as prawns, particularly the 'red' prawn *Aristaeomorpha foliacea* (Wallner and Phillips, 1988). Catch rates of vessels fishing aggregations of *A. foliacea* and *Heterocarpus woodmasoni* may be very high tending to indicate a large standing stock. However, the size and number of these aggregations is still unknown.

The current fleet has undertaken only limited exploration into deeper waters below 800 m concentrating instead on known resources. Thus, there is some merit in the argument to increase the effort levels in these fisheries to obtain information about the extent of these crustacean resources. This effort would only be effective in achieving this aim if it were widely distributed and closely controlled. As this may require fishing unprofitable areas, fishing companies would possibly require financial assistance as suggested by Jernakoff (1988).

RECOMMENDED FUTURE RESEARCH

Limitations imposed by the scope, duration and sampling operations during this study have resulted in some gaps in the baseline knowledge of the scampi fishery. The following points indicate areas where further research would be beneficial in determining long term management strategies for the exploitation of *Metanephrops* species.

- To refine estimates of the timing and duration of spawning events. Especially to determine variation between populations for each species.

- Estimate natural mortalities, to permit yield modelling for each population.

- Estimate the catchability (q) or vulnerability of each species to trawl fishing, and determine if q varies with sex and season.

- Determine post-larvae and juvenile habitats, and assess if trawling impacts upon these pre-recruits.
- Determine the rates of recovery of heavily fished areas under different levels of fishing effort.
- Determine commercial viability of alternative fishing methods for scampi and selected deepwater prawns.

WDWTF

This fishery has has only just started and the extent of resources is largely undetermined.

M. sibogae Fishery

This fishery produced 211 t with the effort of a small number of vessels applied over a 7 month period. Preliminary standing stock size estimates on greater than 400 t, therefore, this fishery represents a significant scampi resource.

Under present management arrangements this fishery is open to any Northern Prawn Fishery (NPF) vessel. Serious consideration should be given to preventing any rapid escalation of fishing effort into this new scampi fishery from the NPF fleet as this would make continued accurate collection of catch and effort data difficult and may be detrimental to the stock.

(ii) Effects of Trawling

Demersal trawling is relatively destructive and in these deep, infrequently disturbed waters may have deleterious effects which could reduce the productivity of the fishery.

Trawling tends to reduce the topographic and structural complexity on the bottom, which has been shown to have altered fish assemblages in shelf waters. Observations made during the period of this study indicate some faunal change. For example, initially common large siliceous sponge fauna have virtually been eliminated from some heavily trawled areas. The long term effects of this type of change are not yet known.

The balance of food chains can be changed with continuous trawling. In deep water nutrients and food availability tend to be limiting to productivity. Examination of scampi gut contents indicated a diet consisting almost entirely of fish and crustaceans. Many of the fragments found (eg. otoliths and vertebra) indicated a food species larger than the scampi.

Therefore it is probable that scampi are opportunistic scavengers/predators, rapidly switching from a predatory mode in undisturbed circumstances to scavenger, utilising the large quantities of trawl trash discarded from the fishing vessels on a fished ground.

The reproductive strategy of scampi involves a very brief pelagic larval phase. Therefore, it is probable that settled larvae and juveniles up to several years old co-inhabit the same grounds as adult stocks. Although these animals are not caught directly by trawling activities it is possible that destruction of burrows etc. may result in a significant unseen mortality of pre-recruit age classes.

(iii) Harvesting and Management Strategies

It is apparent in areas where scampi abundance has declined due to fishing that some management intervention may be desirable, with the aim of recovery of the stocks. A problem arises in that many of these areas also support profitable prawn catches. Therefore, is it possible to foster the harvesting of these prawn species while protecting scampi through gear restrictions, depth based closures or changes in trawl methods.

- Trawl gear could be compulsorily restricted to fish lightly on the bottom, for example, removal of tickler chains and lengthening of drop chains. While this may reduce scampi catch but maintain prawn catch it would be difficult to enforce and may still produce substantial trawl related scampi mortality.

- The 'red' prawn *A. foliacea* and *M. andamanicus* are caught in the same geographical area. However aggregations of *A. foliacea* tend to occur in depths of 420-460 m, slightly deeper than the peak abundance of *M. andamanicus*. Effort could be restricted in depths less than 420 m, however the spatial separation of depth contours on the slope is small so this measure would be difficult to enforce. Also it may prevent catches of other prawn species such as *H. woodmasoni* which may aggregate between depths of 300-500 m.

- Seasonal Closures: Usually seasonal closures are enforced to permit spawning to be maximised. Female scampi are reproductively active throughout the year either carring berry or maturing ovaries. Thus, an appropriate seasonal closure is not obvious. At present a defacto seasonal closure exists anyway as the majority of the endorsed vessels do not fish these deep-water fisheries during the Gulf of Carpentaria prawn season.

- Rotational Closures: It is possible that yield could be maximised when scampi grounds are fished intensively for short periods, reducing the population to a predetermined level, then closed to enable recovery. An experimental closure of a fished area is required to enable estimation of the recovery period required. However, the recovery period could be in the order of years, given the biological features of scampi. These being; duration of several years before animals grow to recruitment size, vulnerability of the spawning stock, low fecundity and non-dispersive larvae.

This approach requires that sufficient grounds exist or are found to employ the fishing fleet on a rotational basis, knowledge of the rate of recovery of a fished ground and that the value of any prawn catch foregone during the closure is less than the expected return from scampi catches.

- Trapping: Demersal trawling with small mesh nets tends to be non-selective, destructive and expensive. Successful trap or creel fisheries for *Nephrops norvegicus* prompted the suggestion that metanephropid scampi could also be trapped.

CSIRO constructed some Scottish *Nephrops* creels and conducted gear trials in August 1987. The W.A. Fisheries Department research vessel RV 'Flinders' was used to deploy pots in 400 m deep waters west of Rottnest Is. This exercise indicated that long-lined sets of 20-40 pots could be successfully operated in deep water.

No scampi were caught during the trials as the vessel was not equipped for trawling at these depths, nor capable of offshore position fixing, thus unable to locate known concentrations of scampi to set traps upon. The traps appeared to fish effectively due to the catches of giant isopods, galatheids *Munida* sp. and quantities of a small, as yet unidentified, pandalid shrimp. The maximum catch rate of this shrimp was 1.0 kg/trap lift with a best average catch rate for 10 traps of 0.5 kg/trap lift. The commercial size grade of this species would have been classed as very small at 90 animals/kg.

During 1988, a fisherman used similar traps in deep water north west of the Abrolhos Islands, and reported catching a few small scampi, probably *M. boschmai* (S. Peters, pers. comm).

If estimates of density based upon trawl catches are indicative of true densities, a successful trap fishery for scampi would require very large numbers of traps and the ability for a baited trap to attract scampi over a relatively large distance. However, the advantages of trapping in producing better quality product with less benthic disturbance warrant further investigation of this fishing method.

- Mid-Water Trawling: If vertically migrating prawn species such as *A. foliacea* and *H. woodmasoni* remain aggregated and do not diperse widely in the water column then mid-water trawling at night for these species would achieve the aim. However, considerable research is required to determine the vertical movements of these prawns before a change in fishing practice could effectively target them.

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LIST OF FIGURES

FIRTA 85/52

STATEMENT OF EXPENDITURE 1.7.88 - 30.9.88A
DF24JAGAA/NAA

	PROVISION	EXPENDITURE	BALANCE
SALARIES	24327	24327	NIL
TRAVEL	1372	1372	NIL
OPERATING	1300	1300	NIL
TOTAL	26999	26999	NIL

STATEMENT OF EXPENDITURE 1.10.88 - 31.12.88
DF24JAGAA/QZ

	PROVISION	EXPENDITURE	BALANCE
SALARIES	33055	33054	1
TRAVEL	2284	2284	NIL
OPERATING	2890	2890	NIL
TOTAL	38229	38228	1

TABLE 1: Annual catch and effort statistics for the NWSDWT Fishery.

STATISTIC	1985-1986	1986-1987	1987-1988	1988-1989 (Estimate)
TOTAL CATCH (tonnes[1])	348.6	553.2	959.9	583.8
SCAMPI CATCH				
Total	161.9	121.0	92.0	144.2
% catch as tails	4.9	7.2	11.6	15.2
PRAWN CATCH				
Total	174.2	394.3	853.7	434.4
Penaeid Species	90.7	287.0	575.5	282.2
Aristaeomorpha foliacea	49.7	199.5	418.7	203.6
Haliporoides sibogae	27.1	60.8	59.7	48.1
Aristeus virilis	12.6	24.1	92.8	29.4
Plesiopenaeus edwardsianus	1.7	2.6	4.4	1.1
Carid Species	50.9	95.2	220.9	150.1
Heterocarpus sibogae	22.5	55.3	135.5	42.2
Heterocarpus woodmasoni	28.4	40.0	85.4	109.9
BY-CATCH				
Total	12.5	37.8	15.2	5.3
Squid	9.2	34.2	13.9	5.1
Fish	2.3	2.4	0.6	0.02
Spear lobster (Linuparis sp.)	1.1	0.2	0.2	0.1
EFFORT (1000's trawl hours)	10.8	13.0	18.5	16.35
number of boat days fished	726	1037	1491	1308
CATCH PER UNIT EFFORT (kg/h)				
Total Product[2]	32.4	42.6	52.2	35.72
Scampi[3]	13.7	11.2	9.1	9.36
Prawns[4]	25.2	41.4	35.8	29.13

NOTE 1 - all catch in metric tonnes
2 - average CPUE rate for fleet
3 - average CPUE weighted by proportional scampi catch per vessel
4 - average CPUE weighted by proportional prawn catch per vessel

TABLE 2: Annual catch and effort statistics for the WDWT Fishery.

STATISTIC	1986-1987	1987-1988	1988-1989 (Estimate)
TOTAL CATCH (tonnes[1])	46.1	116.3	4.3
SCAMPI CATCH			
Total	4.5	27.6	0.7
% catch as tails	4.7	4.3	11.3
PRAWN CATCH			
Total	38.6	63.6	1.5
Penaeid Species			
Haliporoides sibogae	25.6	53.0	1.4
Aristeus virilis	0	0	0
Carid Species			
Heterocarpus sibogae	11.4	2.1	0.1
Heterocarpus woodmasoni	0	0.1	0.1
BY-CATCH			
Total	3.0	25.1	2.2
Squid	1.1	10.8	0.3
Fish	0.6	2.1	1.1
Bugs (*Ibacus* sp.)	1.3	7.0	0.8
Crabs (*Geryon* sp.)	0.7	5.3	0
EFFORT (1000's trawl hours)	0.9	4.0	0.5
number of boat days fished	84	390	74
CATCH PER UNIT EFFORT (kg/h)			
Total Product[2]	52.2	28.9	9.1
Scampi[3]	8.4	6.6	4.1
Prawns[4]	51.7	15.2	11.4

NOTE 1 - all catch in metric tonnes
2 - average CPUE rate for fleet
3 - average CPUE weighted by proportional scampi catch per vessel
4 - average CPUE weighted by proportional prawn catch per vessel

TABLE 3: Annual catch and effort statistics for the deepwater *Metanephrops sibogae* grounds in the Arafura/Timor sea.

STATISTIC	1987-1988
TOTAL CATCH (tonnes[1])	326.1
SCAMPI CATCH	218.4
% catch as tails	8.7
PRAWN CATCH	103.5
Penaeid Species	16.7
Penaeopsis eduardoi	15.7
Carid Species	44.4
Plesionika sindoi	1.5
Heterocarpus sibogae	20.9
Heterocarpus woodmasoni	21.9
BY-CATCH	4.2
Squid	0.8
Fish	0.7
Speak lobster (Linuparis sp.)	1.3
Bugs (Ibacus sp.)	1.1
EFFORT (1000's trawl hours)	9.2
Number of boat days fished	548
CATCH PER UNIT EFFORT (kg/h)	
Total Product[2]	35.6
Scampi[3]	19.2
Prawns[4]	10.3

NOTE:
1 - all catch in metric tonnes
2 - average CPUE rate for fleet
3 - average CPUE weighted by proportional scampi catch per vessel
4 - average CPUE weighted by proportional prawn catch per vessel

TABLE 4: Standing stock size estimates and tonnages actually removed for three scampi areas.

	M. andamanicus	*M. australiensis*	*M. sibogae*
Geographical Area	17.40°-18.40°S	16.10°-17.10°S	128.0°-132.0°E
Depth Range	360m-420m	420m-480m	240m-310
Swept Area Estimate	78t	92t	463t
Depletion Estimate	93t	-	401t
Total Catch to Date	84t	87t	211t

TABLE 5: Size of berried females.

	M. australiensis	*M. andamanicus*	*M. boschmai*
No. of females in sample (n)	5213	7523	1874
No. of berried females in sample	2774	3675	878
Size of smallest berried female (mm CL)	36	33	31
Size at which 50% berried (mm CL)	54	51	42

FIG 1. NORTH WEST SHELF DEEP WATER TRAWL FISHERY

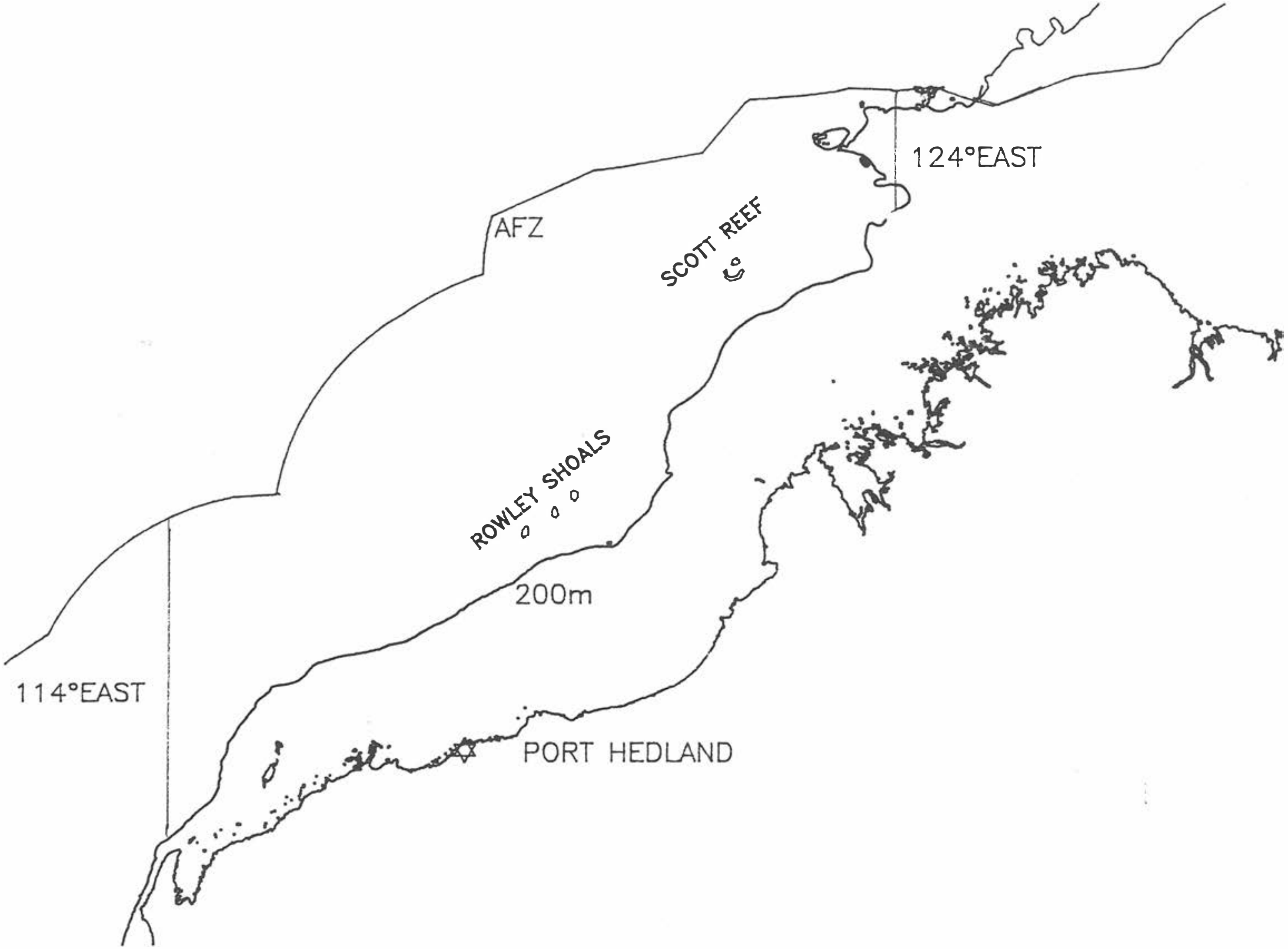


FIG 2. WESTERN
DEEP WATER TRAWL FISHERY

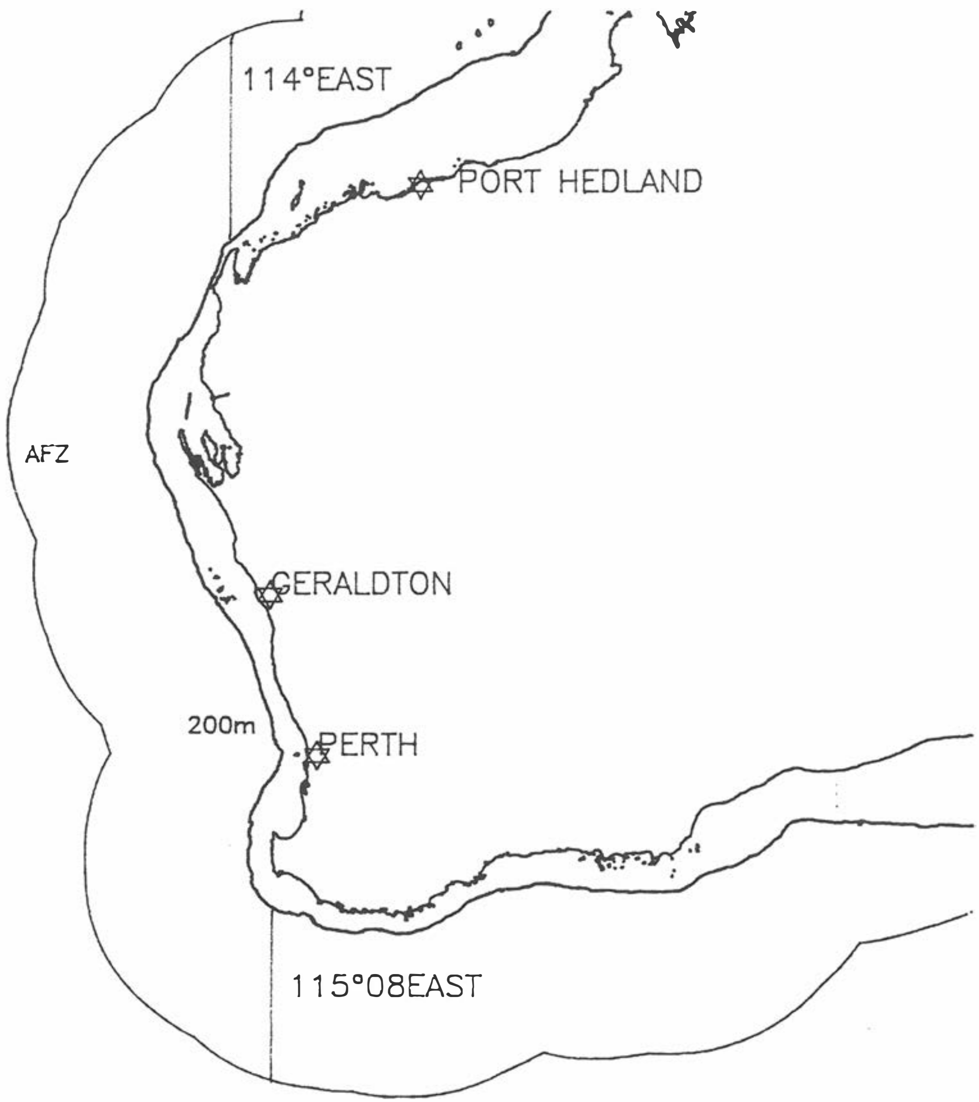


FIG 3. METANEPHROPS SIBOGAE FISHERY

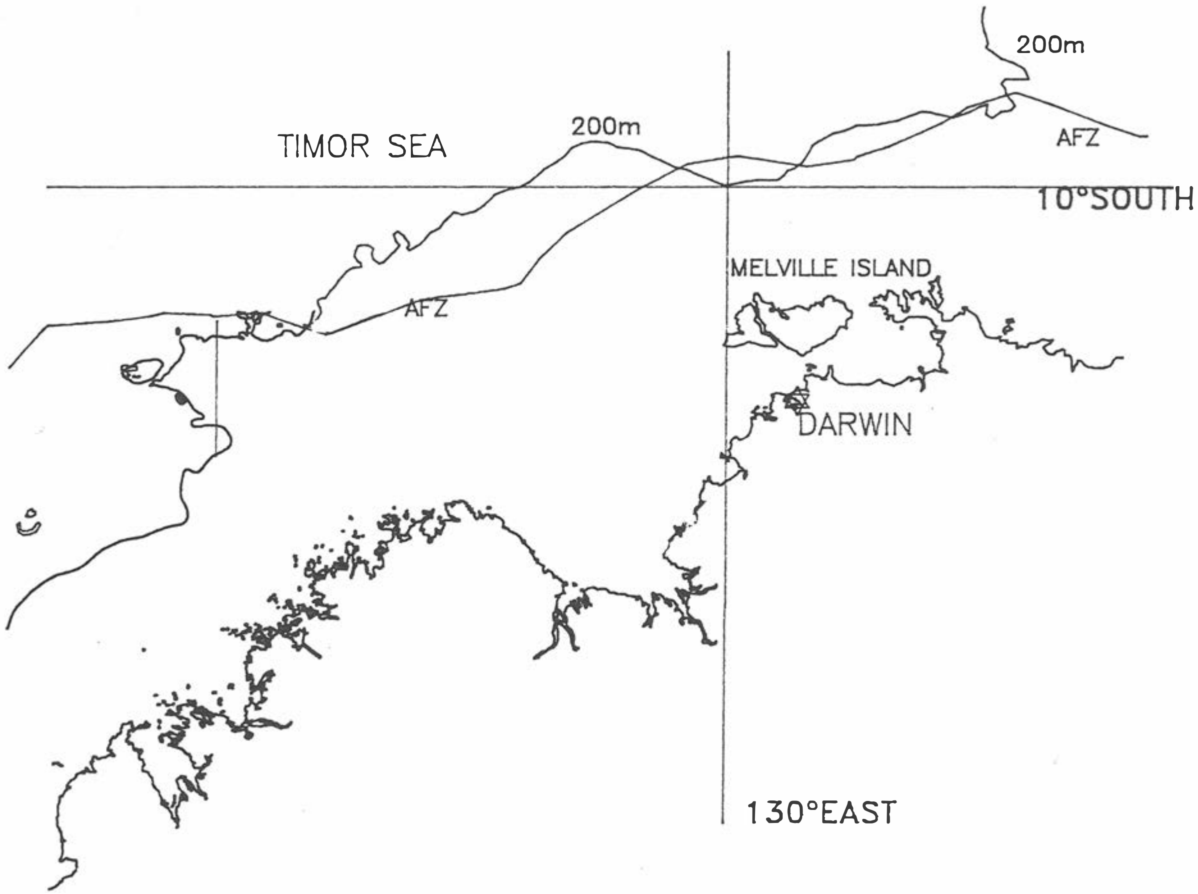


FIG 4. DISTRIBUTION OF METANEPHROPS AUSTRALIENSIS

MAXIMUM CATCH RATE PER SHOT 1985-1988

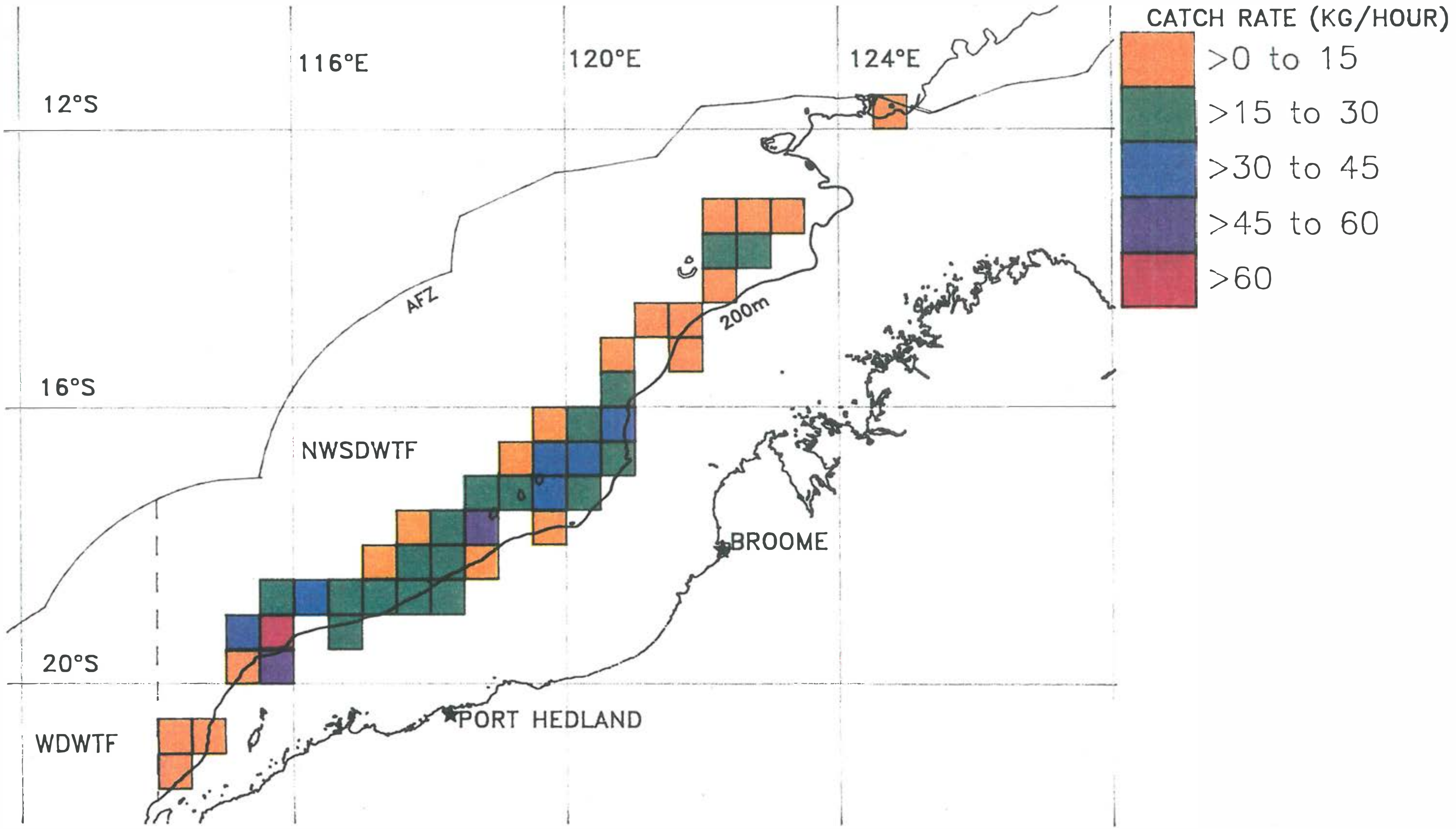


FIG 5. DISTRIBUTION OF METANEPHROPS ANDAMANICUS

MAXIMUM CATCH RATE PER SHOT 1985-1988

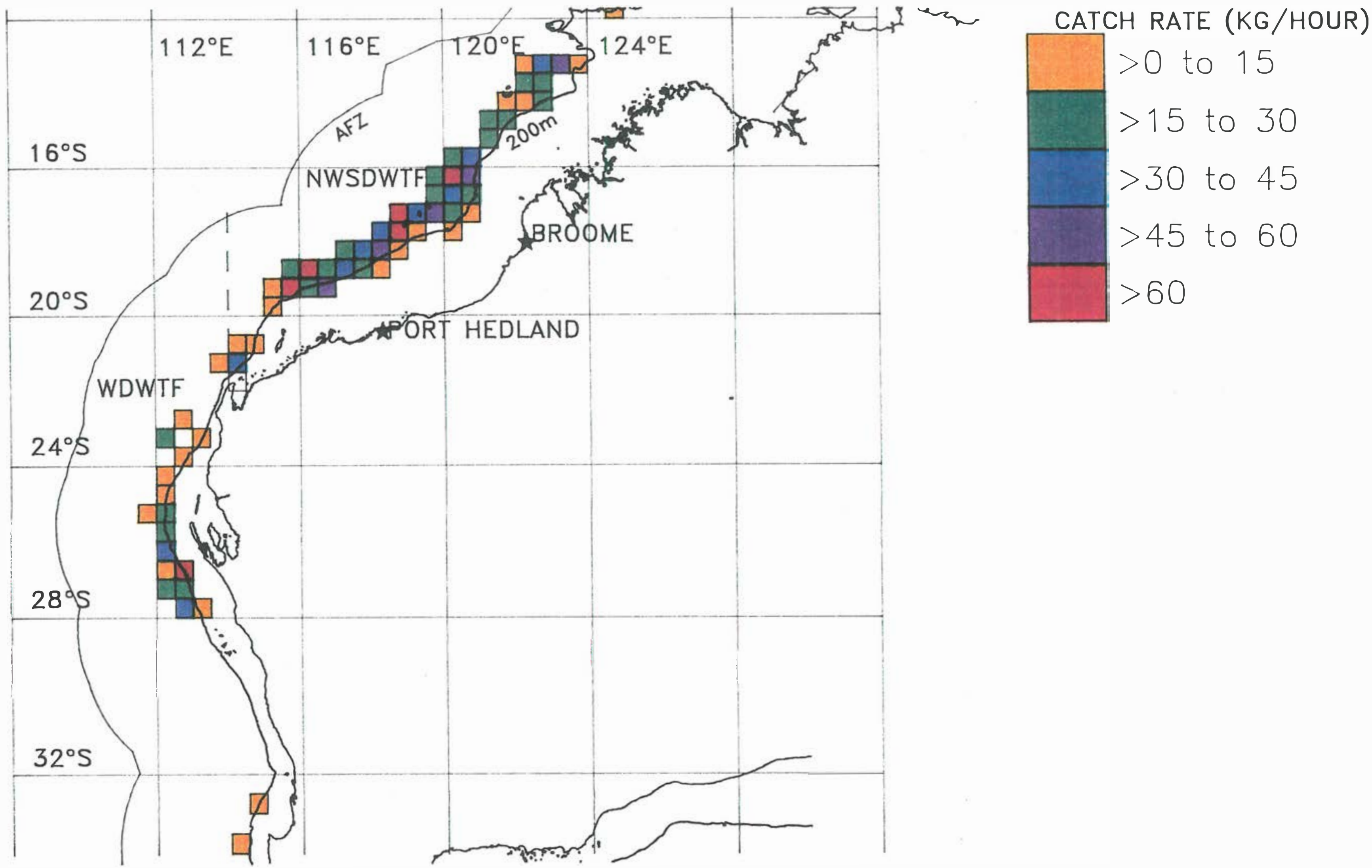


FIG 6. DISTRIBUTION OF METANEPHROPS BOSCHMAI

MAXIMUM CATCH RATE PER SHOT 1985-1988

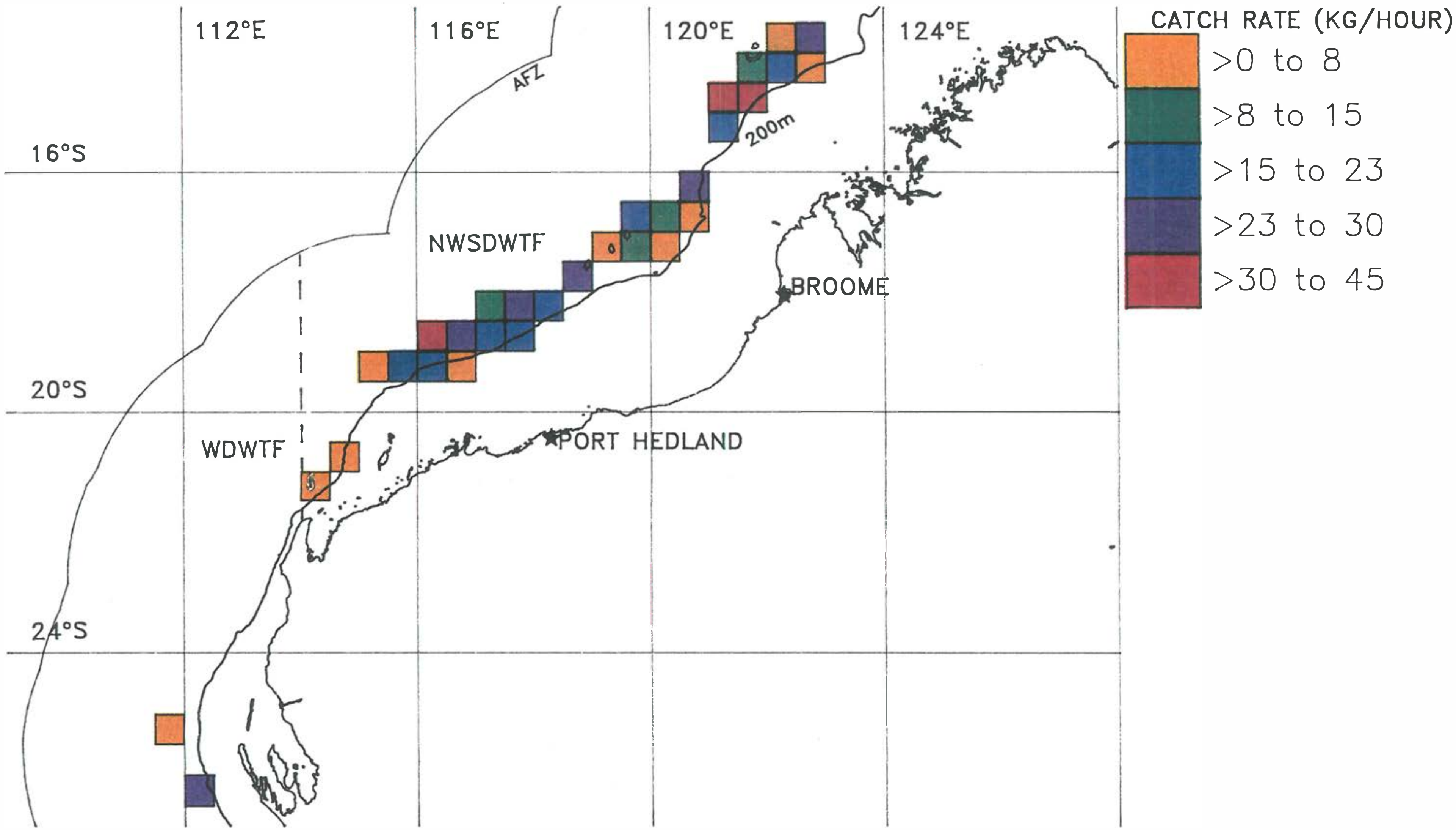


FIG 7. DISTRIBUTION OF METANEPHROPS SIBOGAE

MAXIMUM CATCH RATE PER SHOT 1985-1988

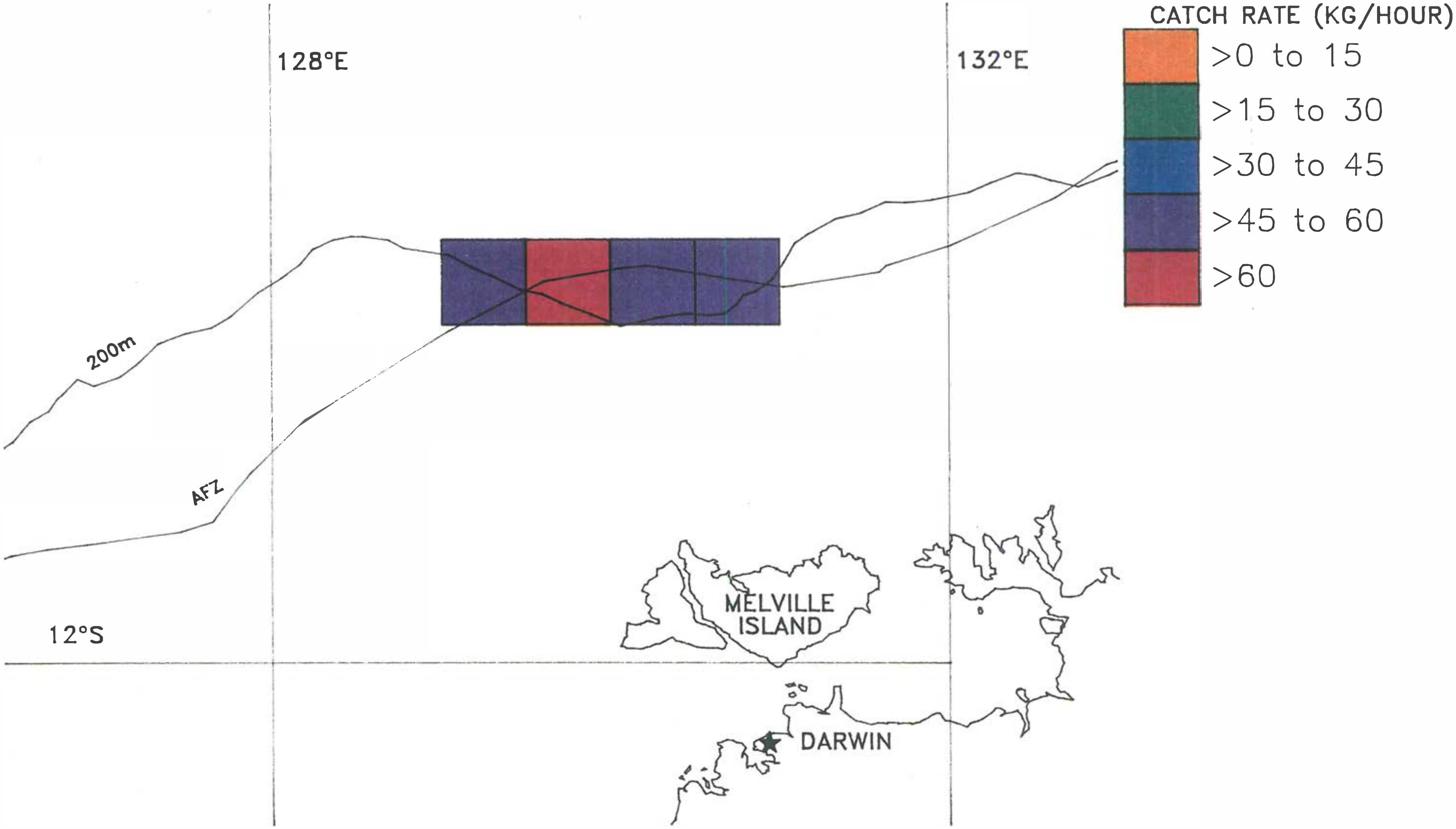


FIGURE 8. Depth distribution of Metanephrops species

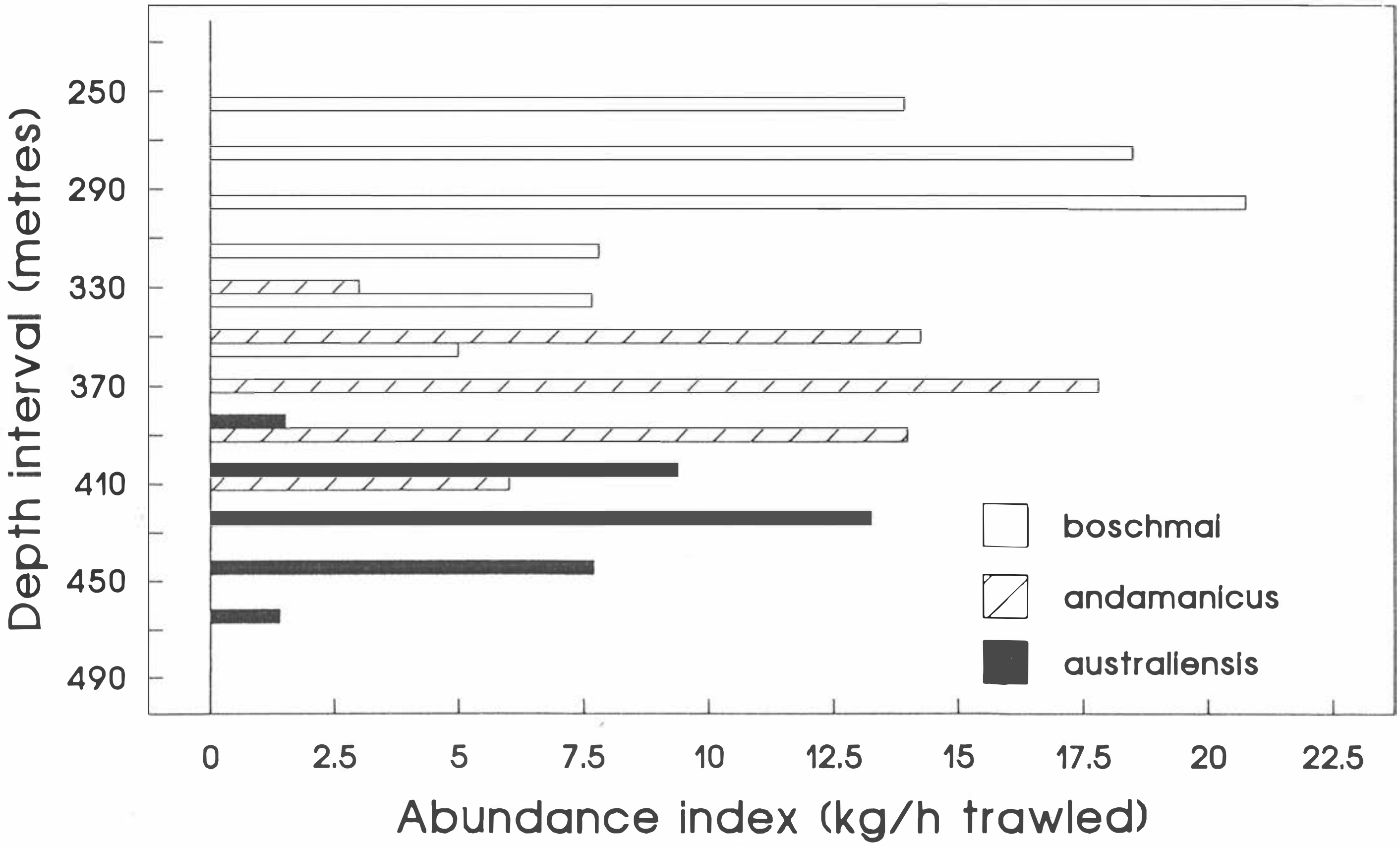


FIGURE 9. Abundance trends for Metanephrops species

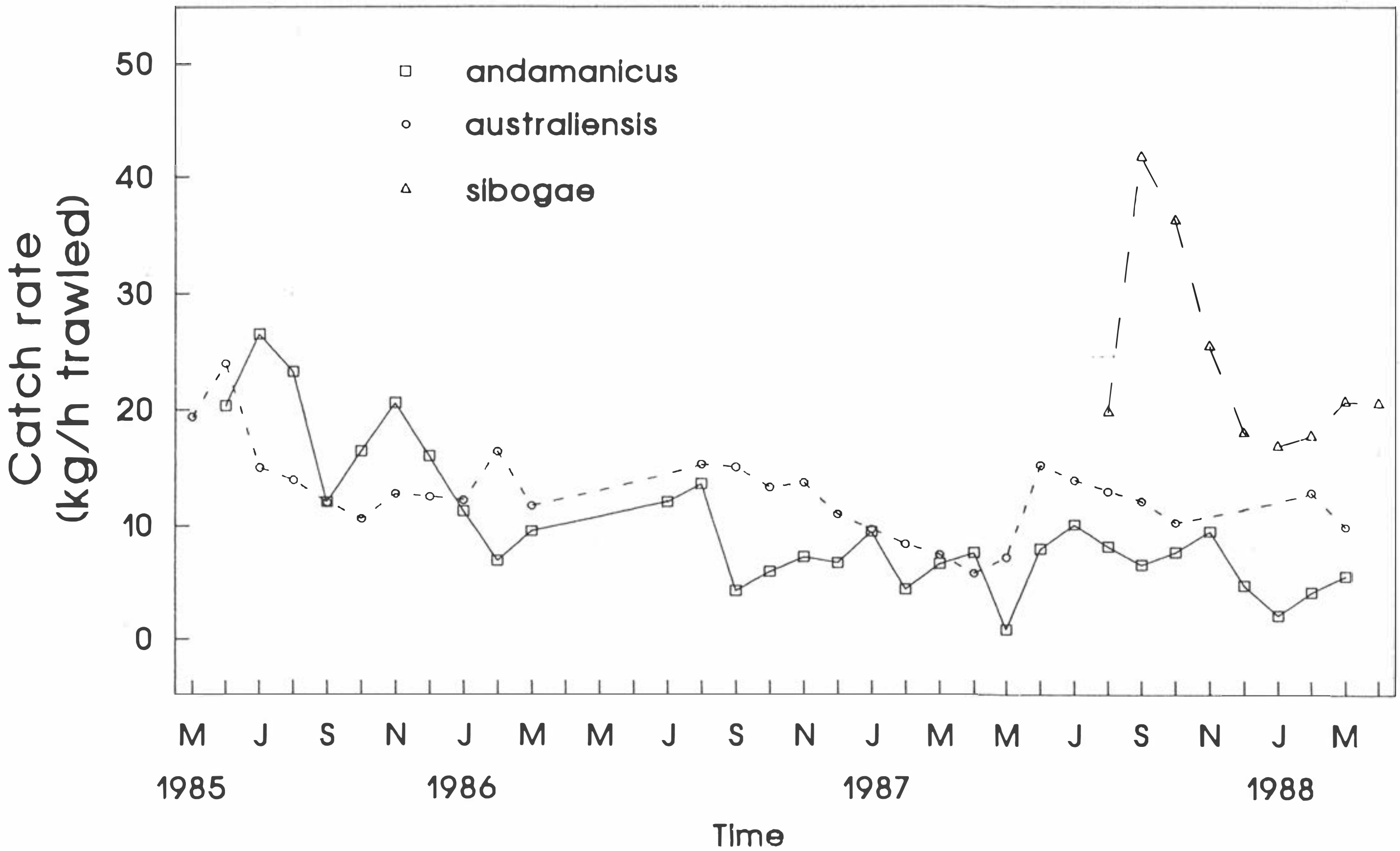


FIGURE 10. Size frequency distribution

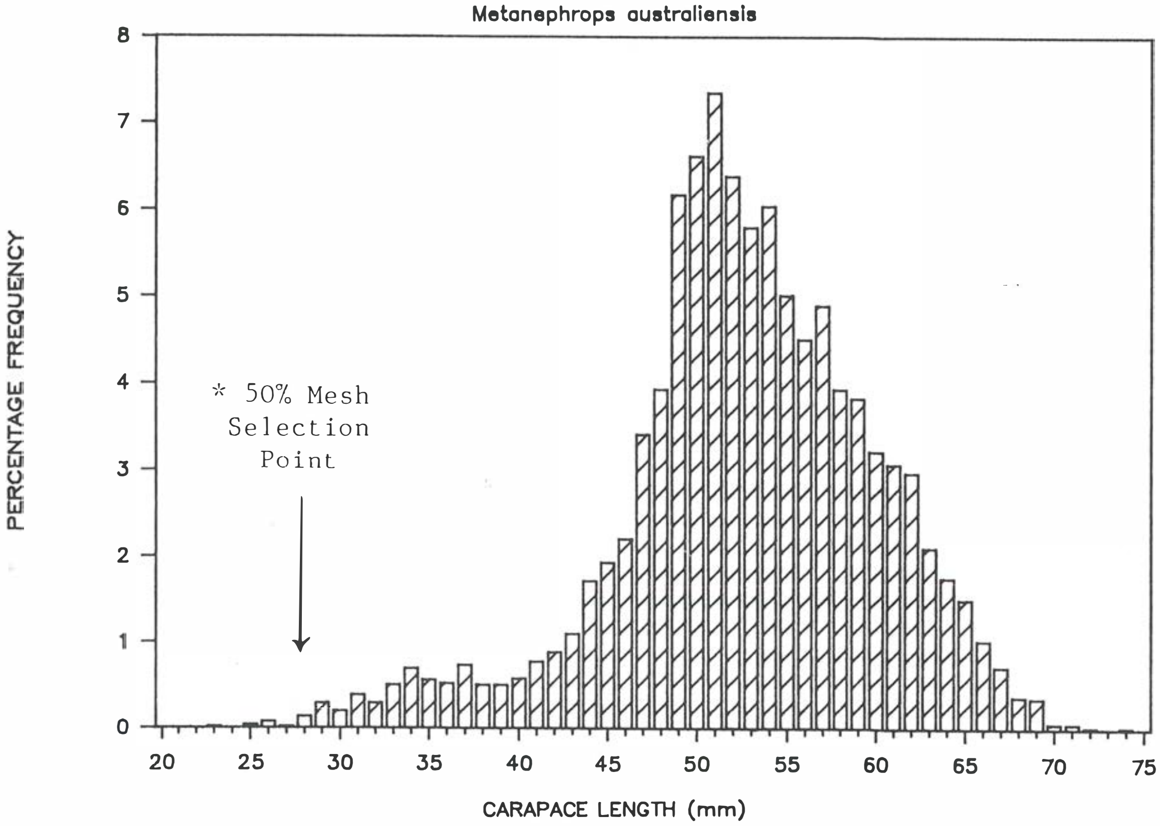
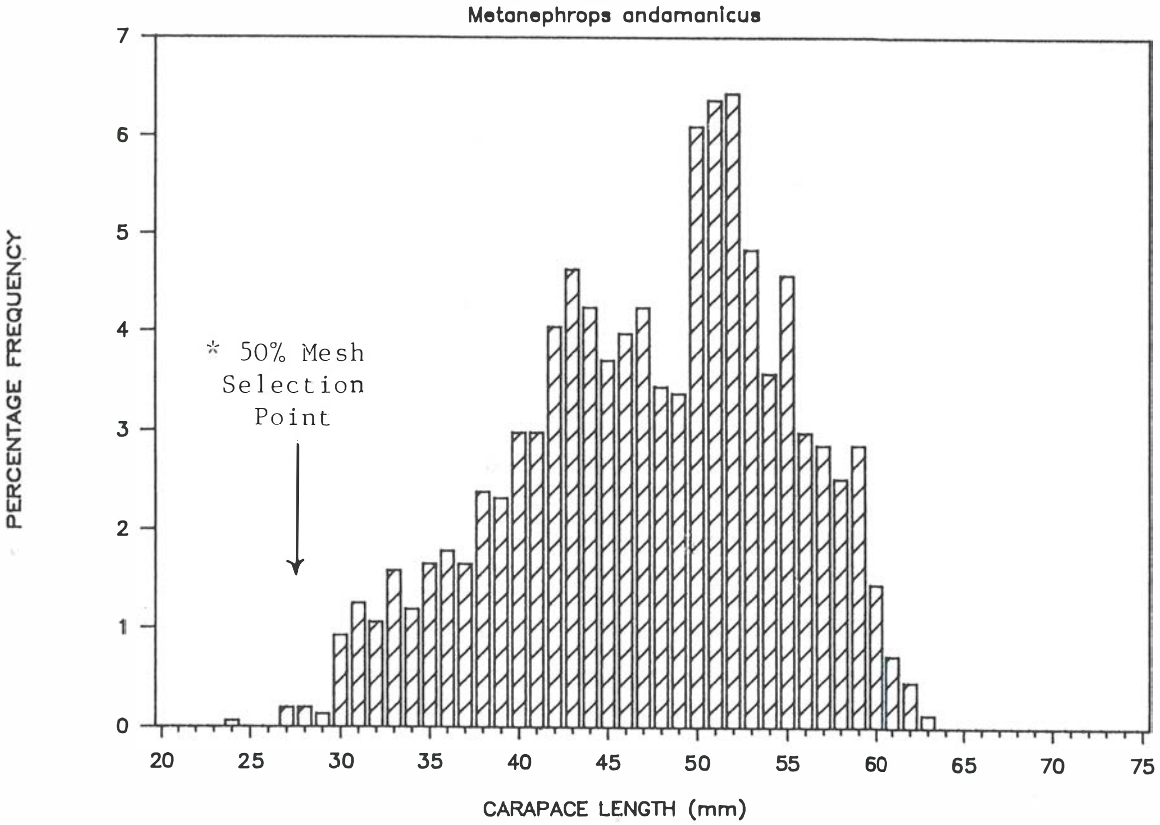


FIGURE 11. Size frequency distribution



* See Text

FIGURE 12. Size frequency distribution

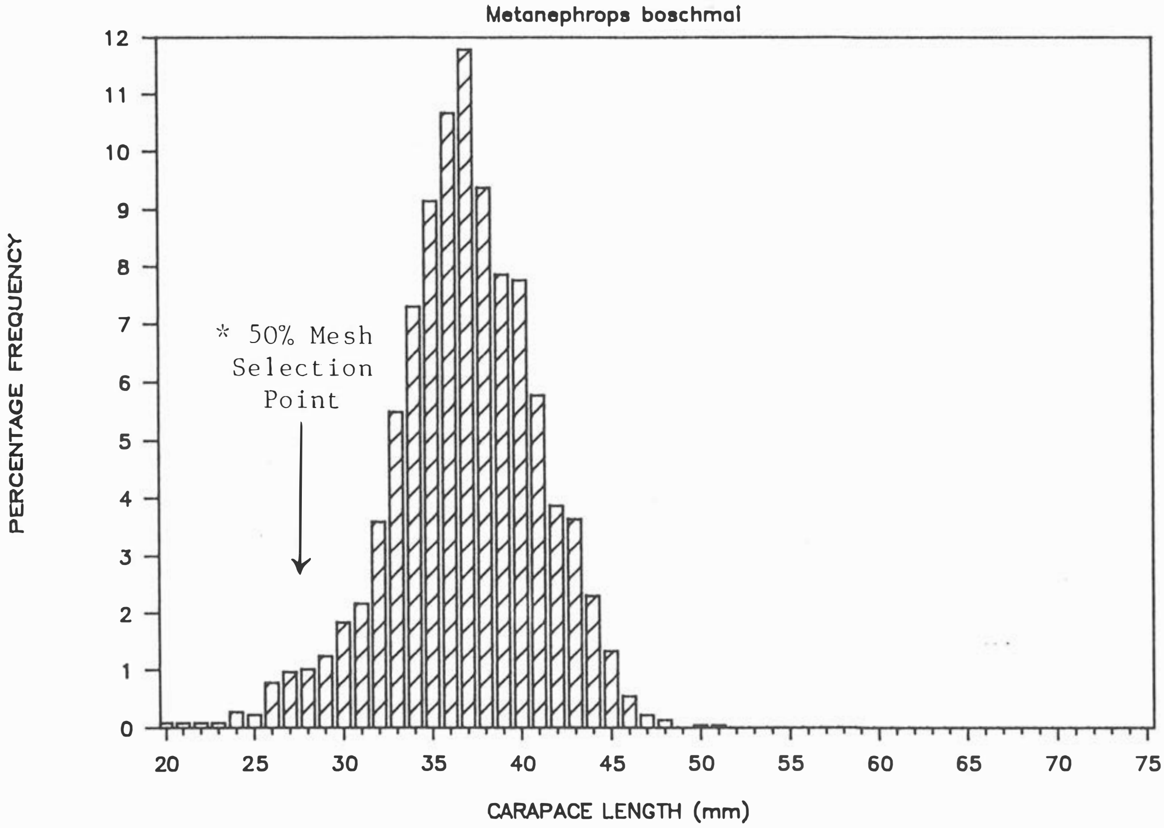
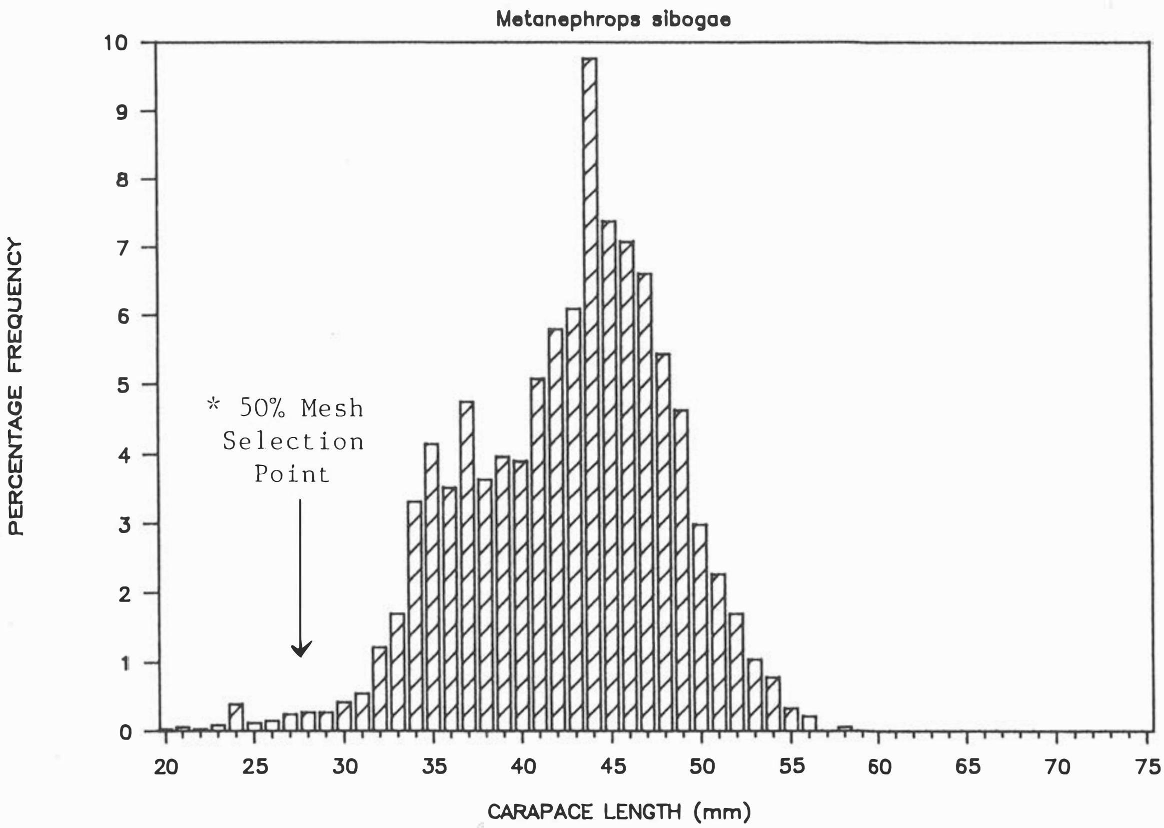


FIGURE 13. Size frequency distribution



* See Text

FIGURE 14. Fecundity per size

Metanephrops australiensis

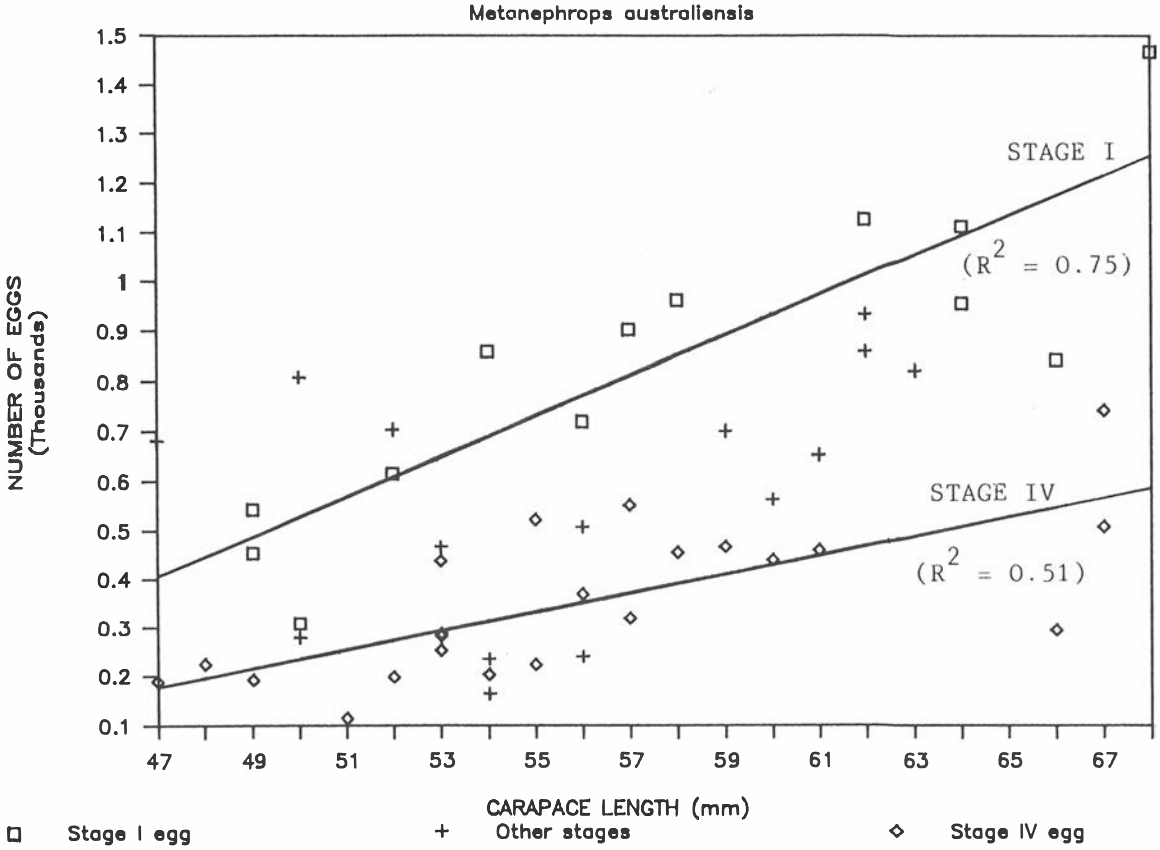


FIGURE 15. Fecundity per size

Metanephrops andamanicus

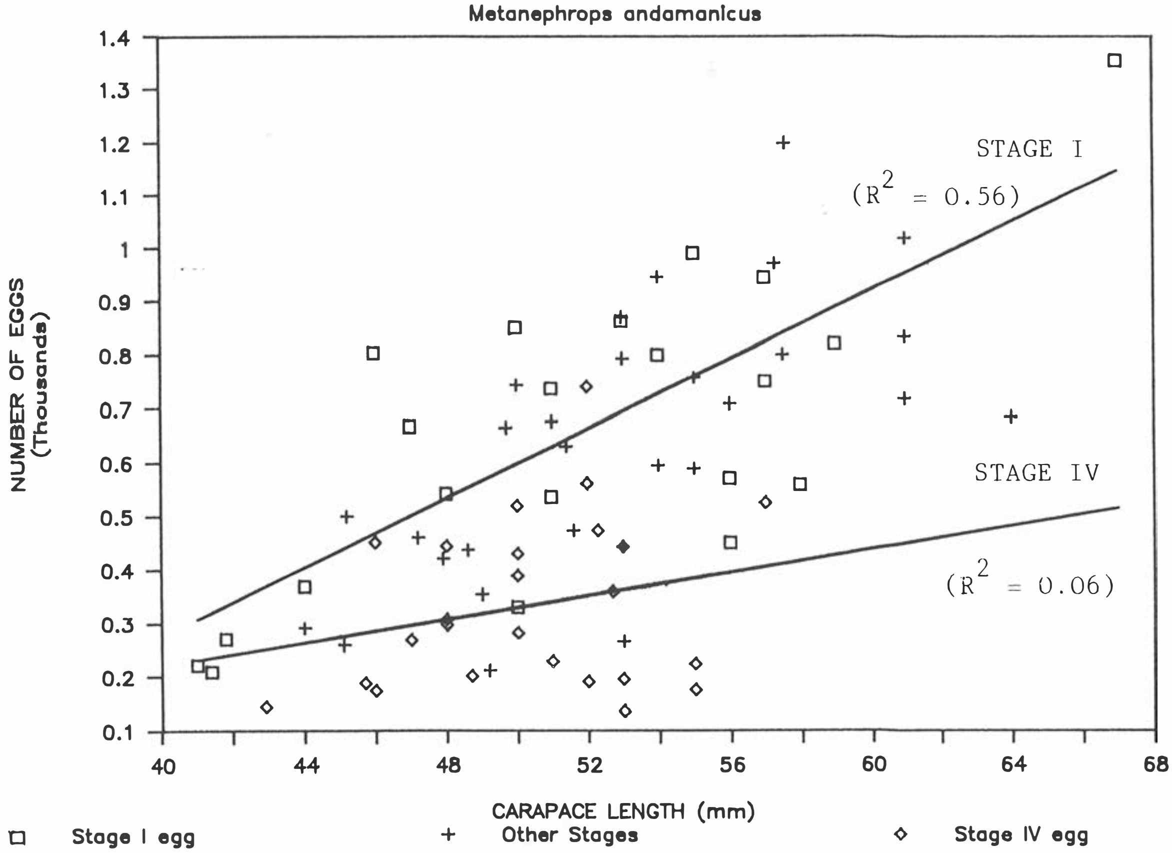


FIGURE 16. Fecundity per size

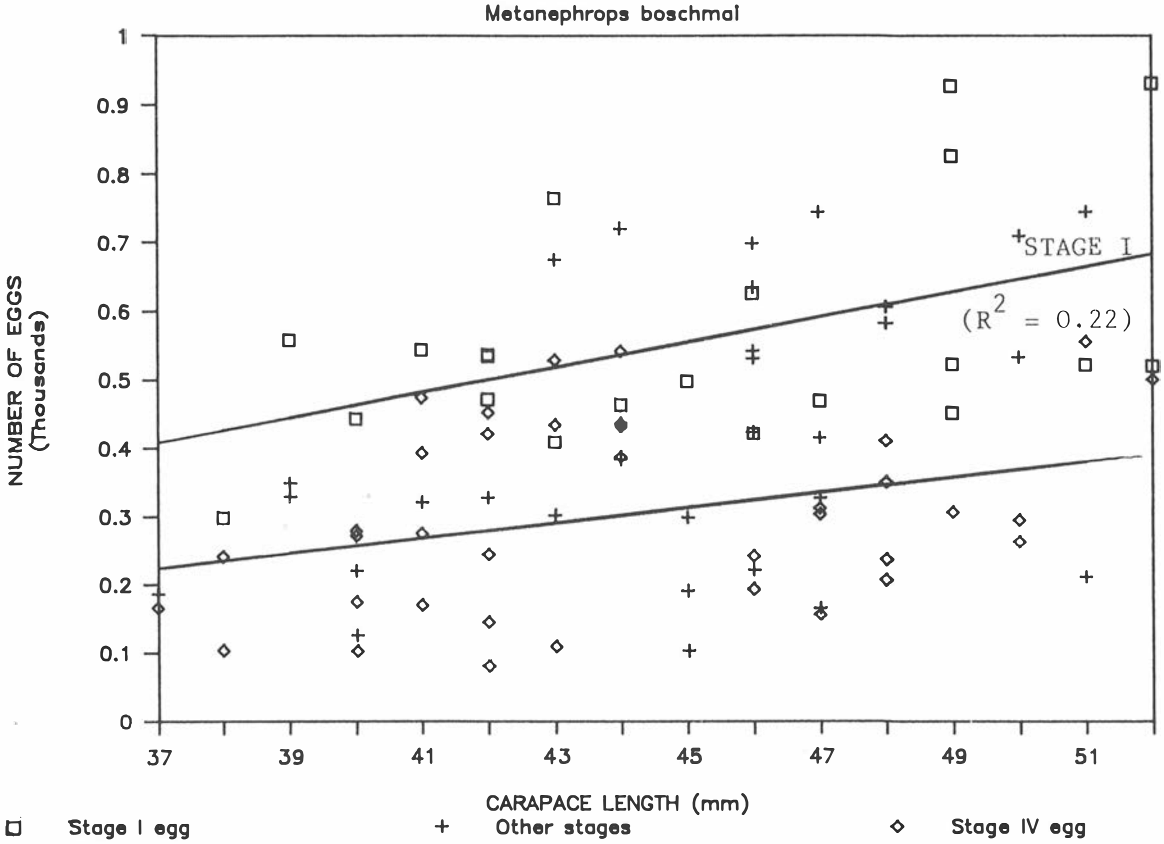


FIGURE 17. Total mortality rate

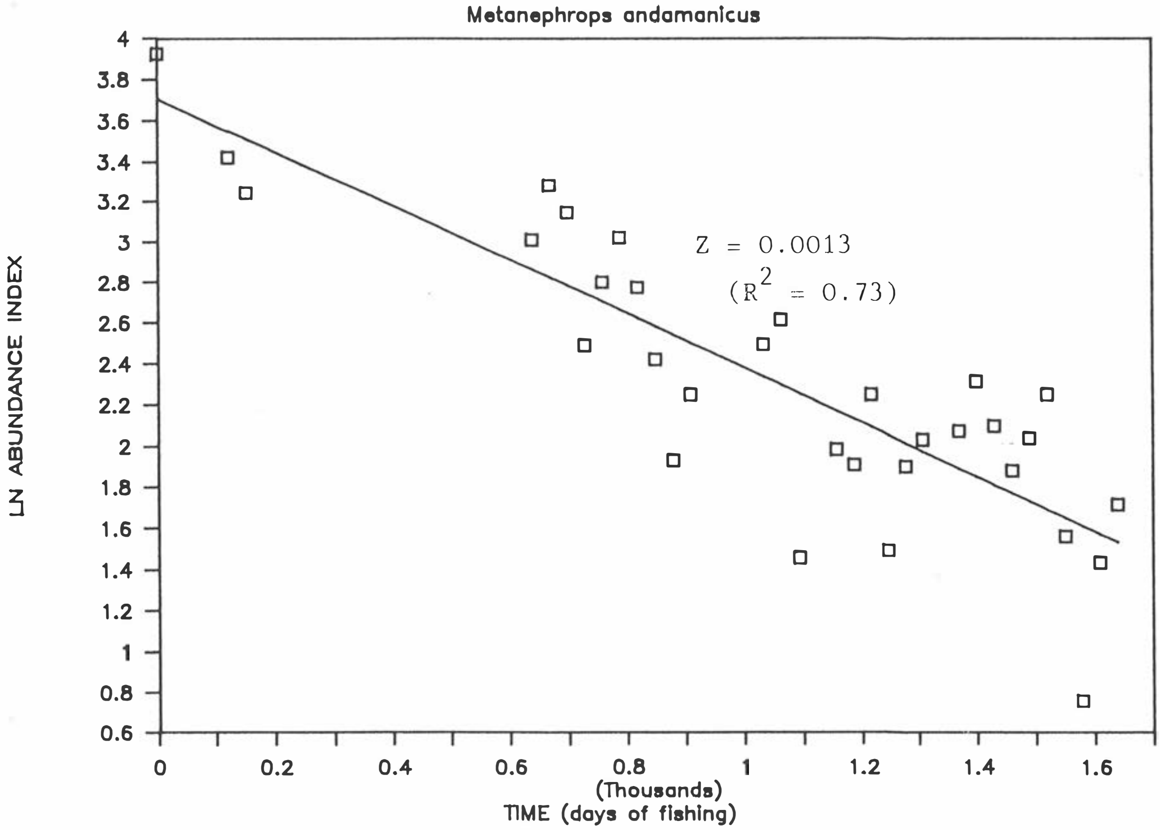


FIGURE 18. Total mortality rate