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## INTRODUCTION

Approximately 1000 trawlers, ranging in length between 7 and 20 m, are licenced to fish on the Australian continental shelf between 10°S and 28°S. The shelf area is unusual in that while one side (to the west) is bordered by the coast, the eastern boundary is parallel and close to the Great Barrier Reef. The body of water between the coast and the Great Barrier Reef is refered to as the Great Barrier Reef Lagoon. Trawl fisheries on much of Queensland's continental shelf are as much near-reef fisheries as coastal in their distribution. Landings from these trawl fisheries are dominated by penaeid prawns (Crustacea, F. Penaeideae) , slipper lobsters (Crustacea, F. Scyllaridae) and saucer scallops (Mollusca, F. Pectinidae).

Penaeid prawns are the most valuable source of income to fishermen. Approximately 11500 tonnes, valued at about $A 130 m were processed in the 1986/7 financial year (Anon 1987). The bulk of these came from 6 species of Penaeus spp. and 4 species of Metapenaeus spp. Nine of the 10 species have been regarded as having conventional lifecycles (sensu Garcia and Le Reste 1985) in that juveniles have been located in estuarine areas or shallow coastal flats. (Young 1978, Staples et al. 1985, Coles et al. 1987) The adults are found in deeper, offshore waters where they spawn, and are fished. There is some evidence that not all of these species are exclusively estuarine-dependant. Coles et al. (1987) reported the occurence of a number of these species in coral reef lagoon environments, particularly on seagrass beds (Table 1). The juveniles of one species, Penaeus longistylus, occur only in coral reef lagoons through much of its Queensland distribution (Dredge, unpub).

Table 1. Queensland's commercially harvested penaeid prawn species, and known habitats for juveniles of these species. Figures in brackets refer to source.

| | Recorded juvenile habitat | |
|---|---|---|
| | estuarine | reef-top |
| Penaeus merguiensis | Yes (1) | No |
| P. plebejus | Yes (2) | No |
| P. latisulcatus | Yes (3) | Yes (3) |
| P. longistylus | Yes (3) | Yes (3) |
| P. esculentus | Yes (1,2,3) | Yes (3) |
| P. semisulcatus | Yes (2,3) | Yes (3) |
| Metapenaeus bennettae | Yes (2) | No |
| M. macleayi | Yes (2) | No |
| M. endeavouri | Yes (1,2,3) | Yes (3) |
| M. ensis | Yes (1,3) | No |

Source references are (1)-Staples et al.(1985), (2)-Young (1978), (3)-Coles et al.(1987).

Landings from the saucer scallop (Amusium balloti) fishery have averaged about 600 tonnes (adductor weight) per year over the past 5 years. Annual value of landings is currently about $A8 m. A smaller coastal species, A. pleuronectes is abundant but rarely fished commercially. A. balloti is normally fished in open water and near-reef grounds of the Great Barrier Reef Lagoon. Likewise, the most valuable of the two species of slipper lobsters, Thenus sp., is most abundant in open water and near-reef areas. Annual landings of slipper lobsters in 1986 were about 1000 tonnes (Anon 1987), with a value of about $A6 m.

The geographic distribution of major Queensland east coast trawl grounds are shown in Fig. 1 a,b,c. Two species, A. balloti and P. longistylus which are fished in open water and near-reef grounds of the

Great Barrier Reef Lagoon may have some potential as fisheries resources in SPC waters. In this paper, I will summarize what is known of their biology and habitat requirements. I will also comment on what is known of relationships between the faunas of coral reefs and those on trawl grounds.

## BIOLOGY OF AMUSIUM BALLOTI

### Distribution

Amusium balloti has been recorded in waters off Western Australia, the tropical and sub-tropical Queensland coast, and from New Caledonia. Sympatric species have been recorded from an extensive area throughout the Indo-Pacific (Habe 1964). In waters off Western Australia and Queensland, the species occurs between about 18°S and 30°S, and is typically fished in depths of 25-55 m. The main Queensland fishing grounds lie between 22°S and 26°S. The trawl grounds in this area cover some 16000 $km^2$ and scallops have been taken from most areas in the grounds in the past 5 years. But fishing effort has been more intense in areas adjacent to reefs, islands, deep gutters and coastal headlands (Fig. 2 a,b). These features may generate tidal eddies which act as larval traps (Wolanski et al. 1984). The species is also taken irregularly between 18°S and 21°S, typically as bycatch from prawn fisheries. The species has been recorded as occuring on graded mud-sand substrate (mean grain size $125\mu$), but was most abundant in areas where the substrate consisted of sand and fine shell grit with a mean particle size ranging between $200\mu$ and $500\mu$ (Campbell, unpub). On the Queensland east coast, it occurs in waters with an annual temperature range of 18-30°C (Dredge 1981).

### Reproduction, Growth and Movement

The reproductive cycle of A. balloti has been described by Dredge (1981). The species is gonochoristic. Gametogenisis commenced in February and spawning took place over a five month period between May and September.

All scallops with a shell height greater than 90 mm appeared to spawn. Female scallops carried $5*10^5 - 2*10^6$ mature oocytes and appeared to have the capacity to spawn more than once in a breeding season. Spawning could be readily induced by minor thermal shock. In laboratory environments, the larval duration was 18-22 days (Rose and Campbell in press), and settlement of young scallops occurred without a byssal phase being apparent. Growth was rapid. Williams and Dredge (1981) gave estimates for the von Bertalanffy parameters $L_\infty$ and K of 102-108 mm and .051-.059 week$^{-1}$. These figures, when applied to a growth model, indicate that A. balloti attains a size of 85-90 mm at 6 to 9 months of age, and therefore spawns at the end of its first year of life. Their maximum longevity is 3-4 years (Heald and Caputi 1981).

Tagging studies conducted on A. balloti in a number of areas suggest that the animals are effectively sedentary. Whilst a small proportion of animals recorded movements of up to 20 km during periods at liberty of up to fifteen months, movement was essentially random and represented slow dispersal rather than migration.

Stock dynamics

The natural mortality rate of tagged adult A. balloti was estimated to be 2 - 2.5 % weekly (M =.020-.025 week$^{-1}$). A yield per recruit model incorporating this rate over a wide range of fishing mortalities indicated that optimum yield would be obtained if scallops were first harvested at an age of 28-36 weeks, or at a size of 82-90 mm (Dredge 1985). Stock-recruitment relationships of the species have not been described. Dredge (in press) expressed some concern that the decline in catch rates observed between 1976 and 1986 may reflect a very efficient trawl fishery reducing density to the point that spawning success and recruitment may be adversely effected.

## BIOLOGY OF REDSPOT KING PRAWNS

Field studies on the biology of P. longistylus have been completed only in the last 12 months. There is, at this time, little published other than a summary of distribution and a length-weight relationship for the species in its Western Australian distribution (Penn 1980).

### Distribution

Penaeus longistylus is known from waters of the South China Sea, the Indonesian archipelago, off Western Australia (Grey et al 1983), but is only fished commercially in the Torres Straits and off the central Queensland coast, where the species has been recorded between 10°S and 24°S. Juvenile P. longistylus are found only on coral reef lagoons in the vicinity of the major Queensland fishing grounds (18°S-21°S), typically on coarse sand substrates in depths of 1-3 m. Adults occur both in the inter-reef channels of the Great Barrier Reef, and west of the Great Barrier Reef in the Great Barrier Reef Lagoon, in the depth range 35-55 m. They are rarely found more than 30 km from coral reef systems, typically in areas of coarse coral sand/ shell grit substrate.

### Reproduction, Growth and Movement

A study on the reproduction of P. longistylus has been documented by Courtney and Dredge (m/s). A fecundity index incorporating female population numbers, proportion of ripe females, and size of females in the population was developed. The index was calculated monthly for a two year period, and showed that P. longistylus had an extended spawning period between May and October. The biannual spawning peaks observed in many species of Penaeidea were not apparent.

The larval form, duration and transport mechanisms are undescribed. Larvae are transported to reef-tops and settle as post-larvae on shallow sandy areas ofcral reef crests. Juvenile P. longistylus have been found in lagoons between September and May, suggesting that the recruitment process is extended. They emigrate from reef tops at a size of 15-20 mm (carapace length, C.L.). The timing of emigration has not been studied. Tagged P. longistylus larger than 25 mm C.L. released in typical near-reef areas were effectively sedentary. Fewer than 10% of tagged prawns which were recovered had undertaken recognisable movement from their release point, and those that did moved did so in an apparently random manner.

Growth of tagged P. longistylus larger than 25 mm C.L. has been modelled using a von Bertalanffy model. Estimates for the parameters K and $L_\infty$ of .022-.039 ($week^{-1}$) and 42-54 mm C.L. respectively (Dredge m/s) are a little less than those published for conspecific species (Lucas 1973, Penn 1975).

Stock dynamics

The stock dynamics of P. longistylus are not well understood. An initial estimate of adult natural mortality (Dredge m/s) was imprecise, and any estimate of total mortality made using fisheries data will be confounded because of the bi-specific nature of the fishery. Catch rate data (Table 2) are stable, which is at least indicative that recruitment is remaining reasonably steady under increasing fishing pressure.

TRAWL FISHERIES FOR SAUCER SCALLOP AND RED SPOT KING PRAWNS

Trawl fisheries in Queensland are characterised by vessels which have access to a wide range of stocks, and which move freely from one target stock to another. Many of the trawlers which fish for scallops in the area between 22°S and 26°S also work in the redspot king prawn grounds between 18°S and 21°S. These boats are typically in the size range 15-20 m, are powered by 150-300 kw diesel engines and have the capacity to tow three 15-30 m headrope length trawl nets.

Scallops

The fishery for A. balloti has been conducted throughout the year, but effort directed at the stock has been influenced by seasonal availability and price of alternative targets, particularly the various stocks of penaeid prawns. Saucer scallops have normally been fished 24 hours a day, although recent management decisions have changed this practice. Boats working for scallops will locate a bed of scallop and work constantly for periods of up to a fortnight or until refrigerated holds are filled. When the fishery was developing (in the period 1960 to 1980) and new grounds were being opened up, catches comprised of mixed age classes. The fishery has now developed to the stage where the bulk of the catch appears to be from a single age class each year, and most areas with depth and substrate characteristics suited for scallop settlement are searched comprehensively. In real terms, density of scallops in beds being fished has declined from a maximum of about one animal $m^{-1}$ in 1978 to an averaged fished density of about one animal 150-200 $m^{-1}$ in 1987. Catch rates have declined from an average of about 38 kg adductor meat per boat hour trawled in 1978 to about 6.0 kg per boat hour in 1986 (Dredge in press).

Red spot king prawns

Penaeus longistylus is a minor component of total penaeid prawn landings in the Torres Strait prawn fishery (Channels et al. 1988), but comprises more than 70 % of landings from the cental Queensland (18°S-21°S) king prawn fishery. The remaining 20-30 % of landings from this fishery are blue legged kings, (P. latisulcatus). The fishery is seasonal, with more than 70 % of the catch being taken betwen May and September. The main fishing grounds extend over a 20- 30 km wide strip to the west of the Great Barrier Reef (Fig 3). There is little geographic overlap between the king prawn fishery and a coastal fishery for tiger and endeavour prawns (P. esculentus, P. semisulcatus, M. endeavouri, M. ensis) which exists in the same latitudes.

Landings from the fishery have increased rapidly in the last 5 years, but average annual catch rates have remained stable (Table 2). The increase in landings is obviously due to increased effort. More than 300 trawlers have participated in the central Queensland prawn fishery in the past two years. There is some evidence that the fishery for P. longistylus may be developing both to the north and south of existing grounds. Extensive near-reef areas between 22°S and 23°S have been fished for P. longistylus in the past 6 months, and the species is also being increasingly sought in waters north of 16°S.

Table 2. Estimates of total landings and average catch rates from the central Queensland king prawn fishery.

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
| Catch (tonnes) | 200 | 750 | 650 | 650 | 650 | 1800 | 2000 |
| Catch rate (kg/boat/hour) | - | - | - | - | 9.8 | 11.0 | 10.6 |

BYCATCH

There are few detailed studies of bycatch taken in Queensland's trawl fisheries. Maclain (1973) documented bycatch in the Moreton Bay (southern Queensland) fishery and Cannon et al. (1987) reported on trawl catch species composition and broad scale community structure along the Queensland coast, using data obtained in a series of unrepeated surveys. They found evidence of clines between recognisable inshore and offshore (near-reef) faunal communities over an extended area off the Queensland coast.

Results from a 12 month long, intensive monthly survey of trawl bycatch from coastal, near-reef and inter-reef trawl grounds between 18°S and 19°30S are given by Jones and Derbyshire (in press) and Watson and Goeden (m/s). The authors identified 477 taxa in the programme, and were able to describe 3 distinct site-assemblages (coastal, near-shore and inter-reef) on the basis of faunal composition. Seasonal changes in the fauna did not affect groupings of sites.

Trawl catches were dominated by the Osteichthyes (bony fish) (55 % of all taxa identified, 74 % of trawl biomass) and Crustacea (19 % of taxa, 20 % of biomass).The trawl fauna as a whole was very different to that of coral reefs as a whole. A comparison of the species present in trawl grounds and on reef environments is only possible for Osteichthyes.

Eighty two families are represented in the 267 species of Osteicthyes collected by trawl. The 10 richest families, in terms of numbers of species identified, are shown in Table 3. Species which were common to this study and Russell's (1983) checklist of fish from the Capricorn-Bunker Group are also enumerated. Russell's checklist is heavily biased towards species occurring in the reef environment and generally identifies those species which were taken in trawl samples from non-reef areas (Russell, pers com). Fewer than 5% of species were common to the inter-reef/ near shore/ coastal trawl grounds between 18°S and 21°S and the reef environment of the Capricorn-Bunker group between 22°30'S and 24°S. Of the 10 most species-diverse families from the reefal environment of the Capricorn-Bunker Group, two (Apongonidae and Serranidae) appear in the most specious families from trawl samples. Their rank in order of species abundance from trawl samples was 1 and 9, respectively, and 5 and 6 from Russell's (1983) survey of reef fishes.

Table 3. Number of species in 10 most specious-rich families from trawl grounds between 18 S-21 S, numbers of species from these families occurring in Russell's (1983) checklist, and number of species common to both.

| Family | Number of species(trawl) 18°-21° | Number of species-Russell | Number of common species | Common species taken by trawl (Russell) |
|---|---|---|---|---|
| Apogonidae | 17 | 33 | 2 | 0 |
| Scorpaenidae | 16 | 21 | 2 | 1 |
| Carangidae | 16 | 21 | 4 | 1 |
| Platycephalidae | 14 | 4 | 1 | 0 |
| Tetradontidae | 12 | 11 | 2 | 0 |
| Nemipteridae | 11 | 9 | 3 | 2 |
| Monocanthidae | 8 | 13 | 3 | 3 |
| Leiognathidae | 8 | 0 | 0 | 0 |
| Serranidae | 8 | 32 | 3 | 0 |
| Synodontidae | 8 | 8 | 1 | 0 |
| Total | 118 | 152 | 21 | 7 |

(Adapted from Jones and Derbyshire in press)

## DISCUSSION

Coastal and continental shelf trawl fisheries are an important component of the Queensland economy. Some species of the range taken in these fisheries can be considered as being animals adapted to a near-reef or tropical continental shelf environment. These species, which include P.longistulus and A. balloti do not require estuarine or coastal environments for the successful completion of their lifecycle, and occur in sufficient density to support trawl fisheries in relatively small areas.

Some aspects of the biology of these two species show similarities. They are most abundant in areas of coarse sand/ shellgrit substrate with high carbonate content. Both are fast growing and recruit into their respective fisheries prior to attaining sexual maturity. And even though A. balloti has a maximum longevity of 3-4 years the fishery is based on a single year class, as could be expected for P. longistylus. Both species are sedentary as adults. While this is the norm for scallops, most penaeids undergo some form of migration as adolesents or adults. The apparent specialization by P. longistylus to a specialized lifecycle adapted to the coral reef environment appears to have resulted in the species losing the requirement to undertake migration associated with reproductive behaviour.

There is little doubt that trawl fisheries can have some restructuring influence on the faunal communities in trawl grounds. Poiner and Harris (1986) have compared the faunal communities from an area in the Gulf of Carpentaria before the commencement of a trawling industry with that in the same area after some years of trawling. They were able to detect changes despite having relatively uncontrolled data sets to work with. Data contained in Watson and Goeden (m/s) show that there are clearly defined faunal associations on trawl grounds which can be linked to depth, distance from shore, proximity to reefs or substrate composition. These faunal associations are comprised of species which are characteristic of the mud-silt-sand substates of trawl grounds, and few species occur both in this environment and on true coral reef areas. Disturbance to trawl ground fauna may be apparent if there are large sessile organisms (including sponges and deep water corals) which act as patch reefs in developing trawl grounds.

The development of near-reef trawl fisheries has been an important phase in the evolution of Queensland's fisheries. Valuable resources have been located and exploited in areas which have not previously been considered to have the capacity to support trawl fisheries. But bodies including the Great Barrier Reef Marine Park Authority, have expressed concern over the effects of near-reef trawling. Research programmes aimed at resolving this concern are being developed at this time.

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Figure captions

Figure 1 a. Location of Queensland's east coast trawl fisheries. Eastern king prawn (Penaeus plebejus- ) and banana prawn (Penaeus merguiensis- ).

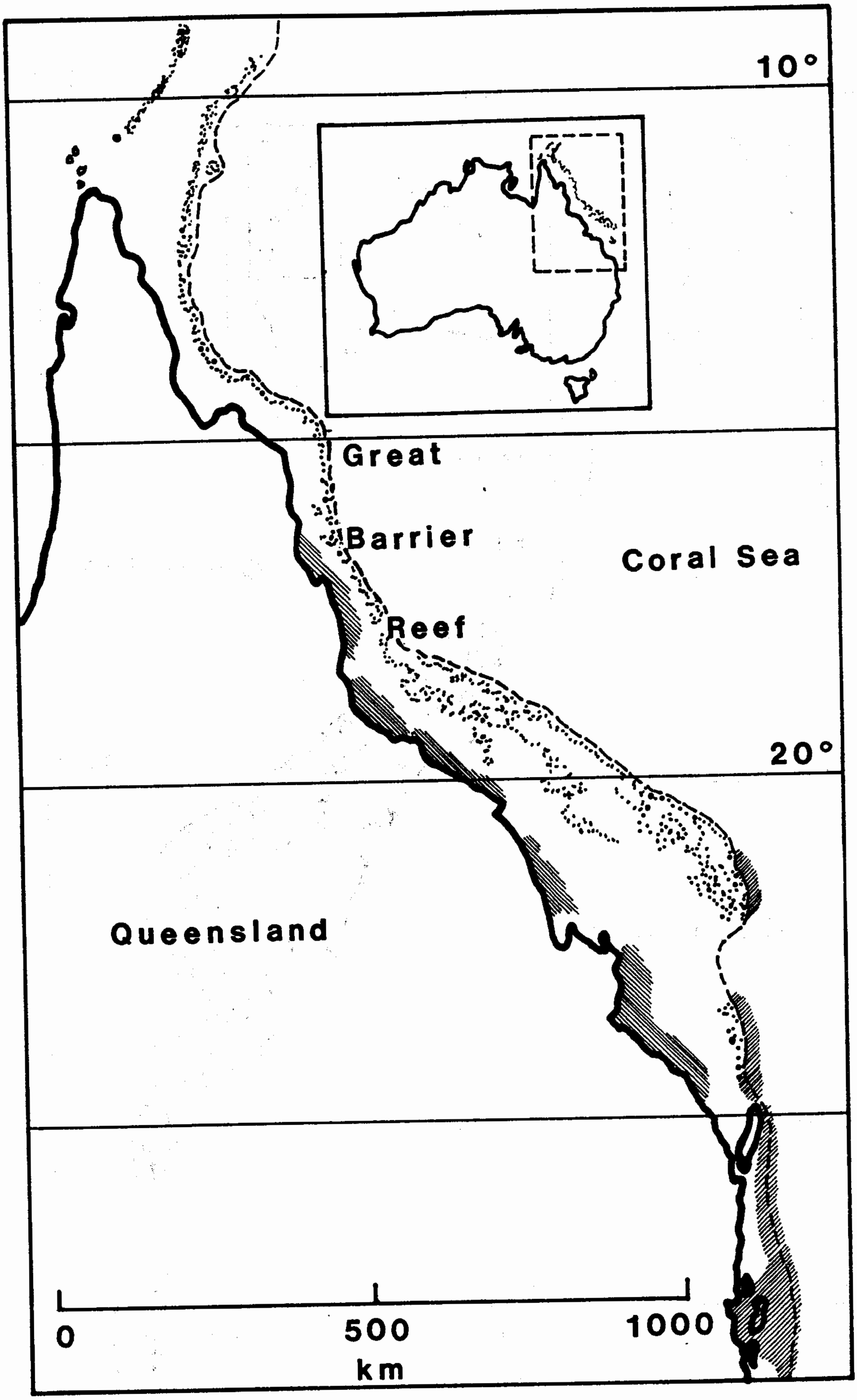
Figure 1 b. Location of Queensland's east coast trawl fisheries. Tiger and endeavour prawns (Penaeus esculentus, P. semisulcatus, Metapenaeus endeavouri, M. ensis- ) and saucer scallops (Amusium balloti- ).

Figure 1 c. Location of Queensland's east coast trawl fisheries. Central coast king prawns (Penaeus longistylus, P. latisulcatus- ) and "bay" prawns (Metapenaeus bennettae, M. endeavouri, M. maclaeyi- ).

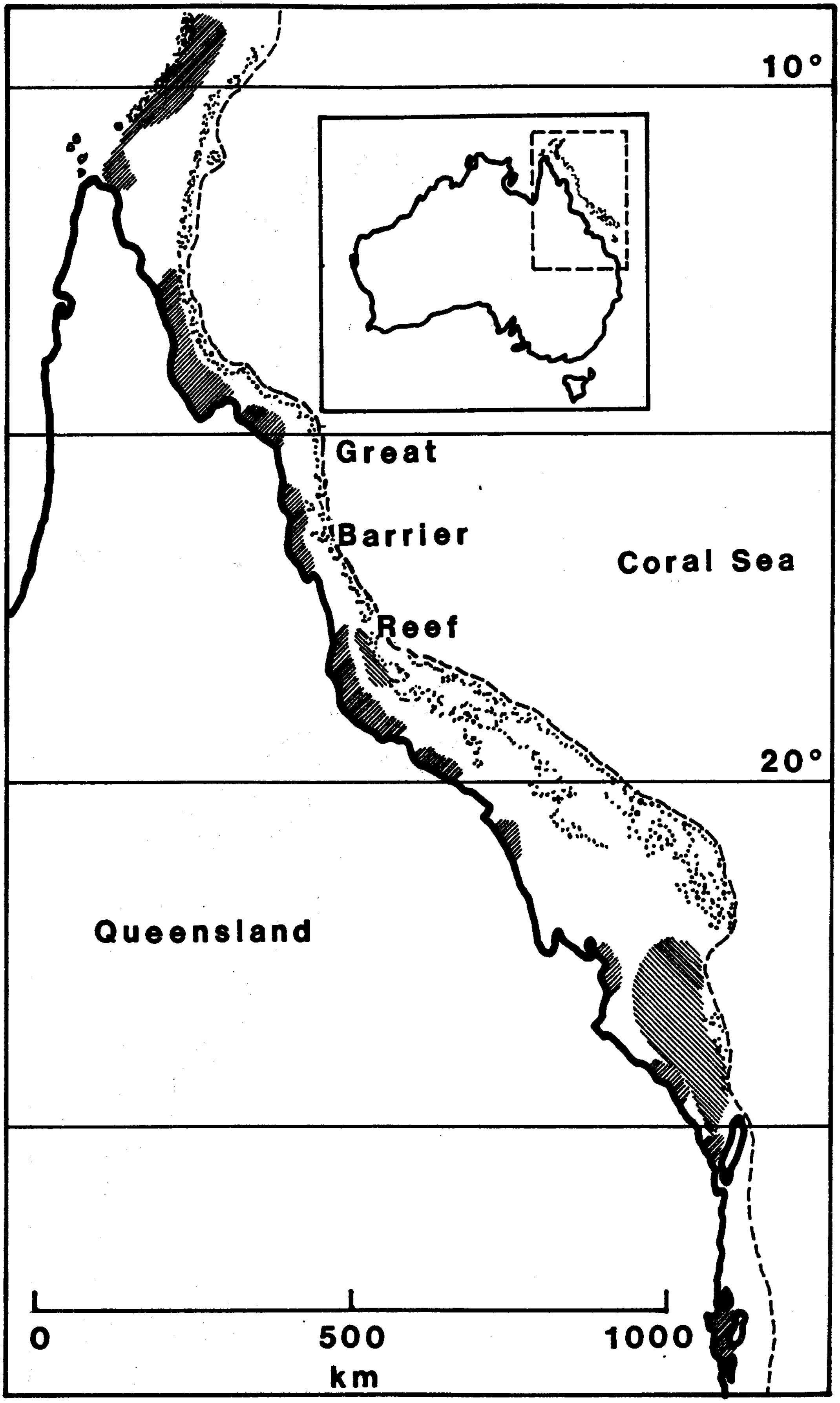
Figure 2 a. Spatial distribution of the 1987 saucer scallop (Amusium balloti) catch between 21°S and 24°S, in 6′ * 6′ grids.

Figure 2b . Spatial distribution of the 1987 saucer scallop (Amusium balloti) catch between 24°S and 27°S, in 6′ * 6′ grids .

Figure 3. Spatial distribution of the 1987 central Queensland king prawn catch (Penaeus longistylus, P. latisulcatus) in 6′ * 6′ grids.



10°
Great
Barrier
Reef
Coral Sea
20°
Queensland
0
500
1000
km



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Coral Sea
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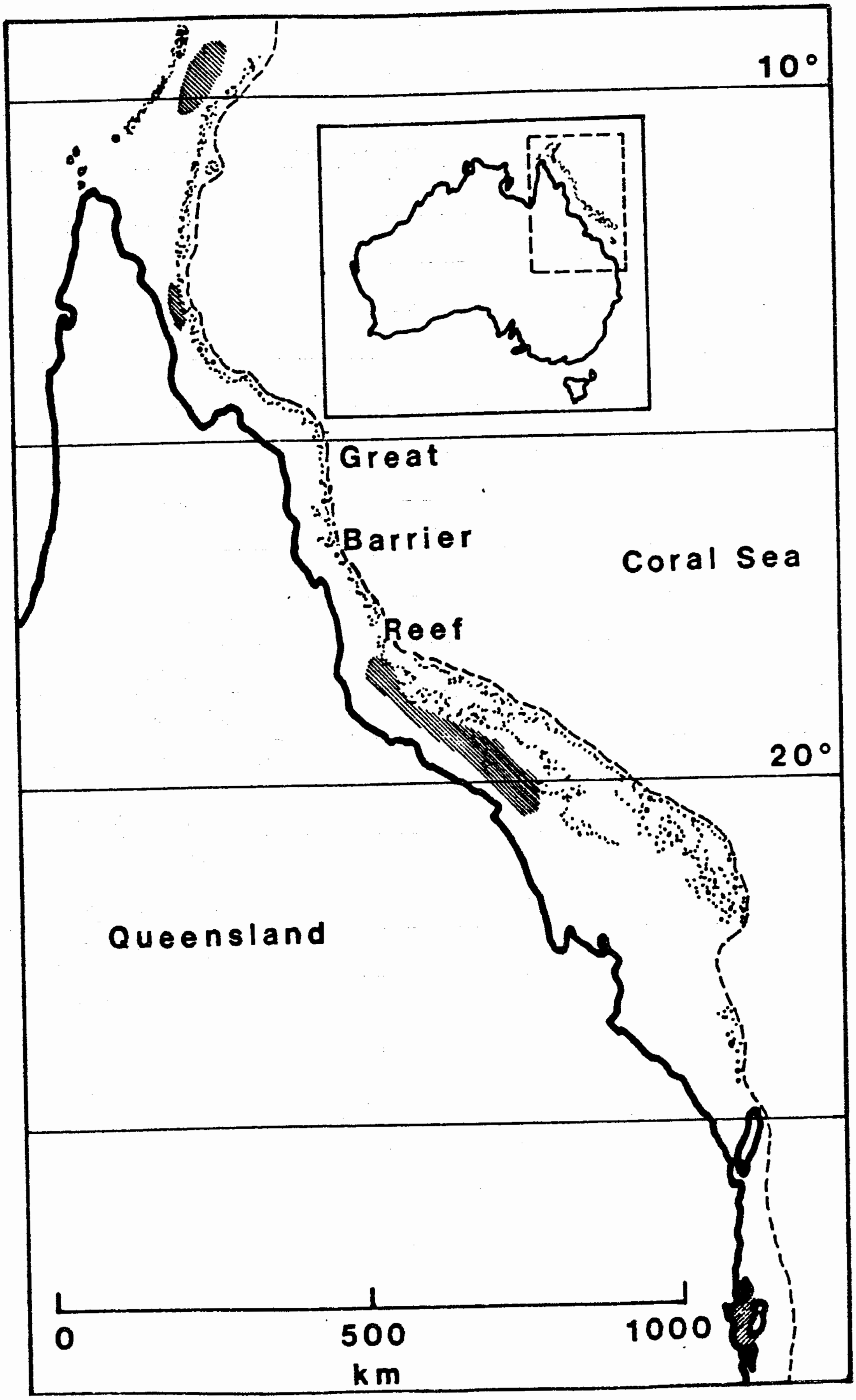

10°
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Coral Sea
Queensland
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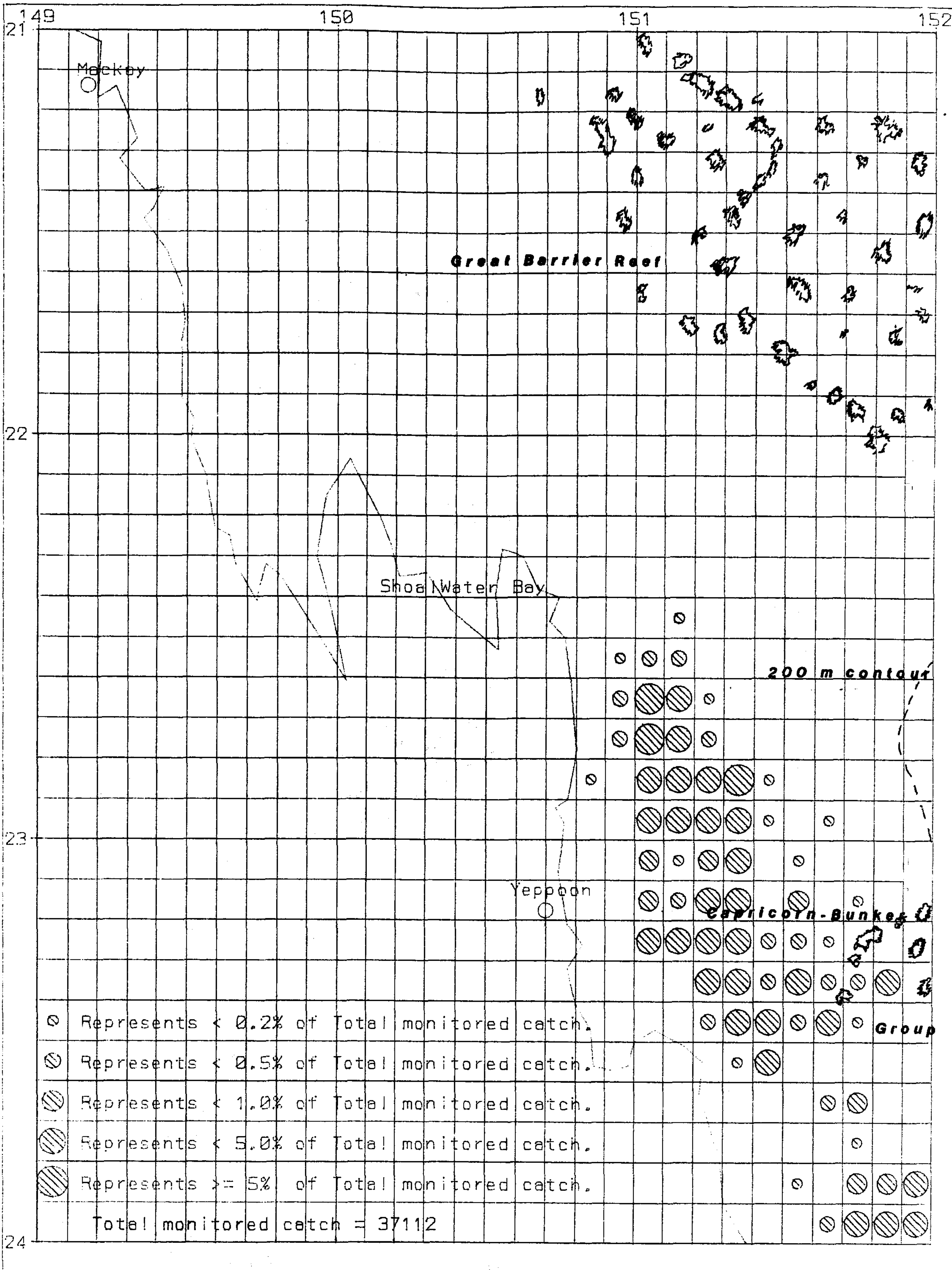
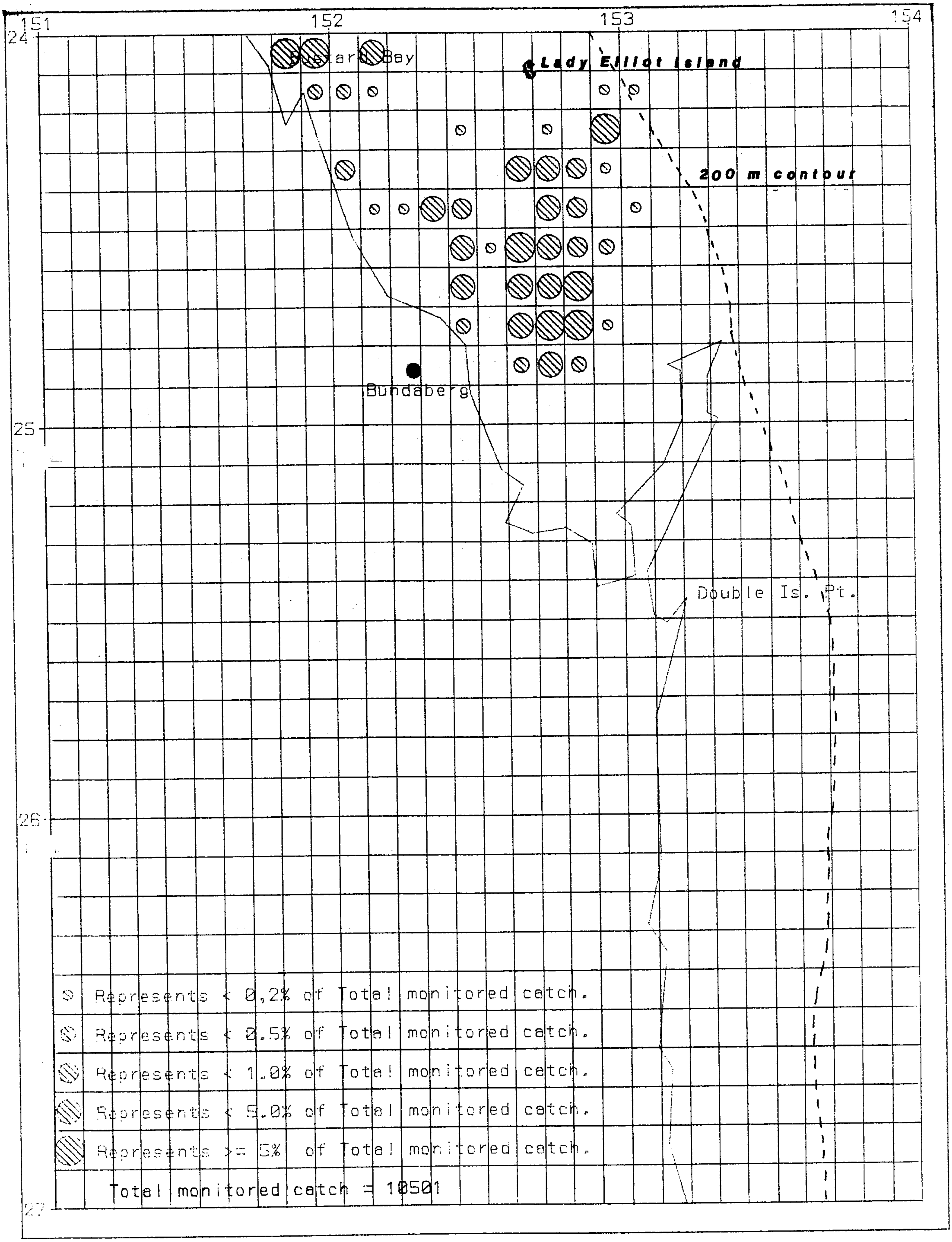
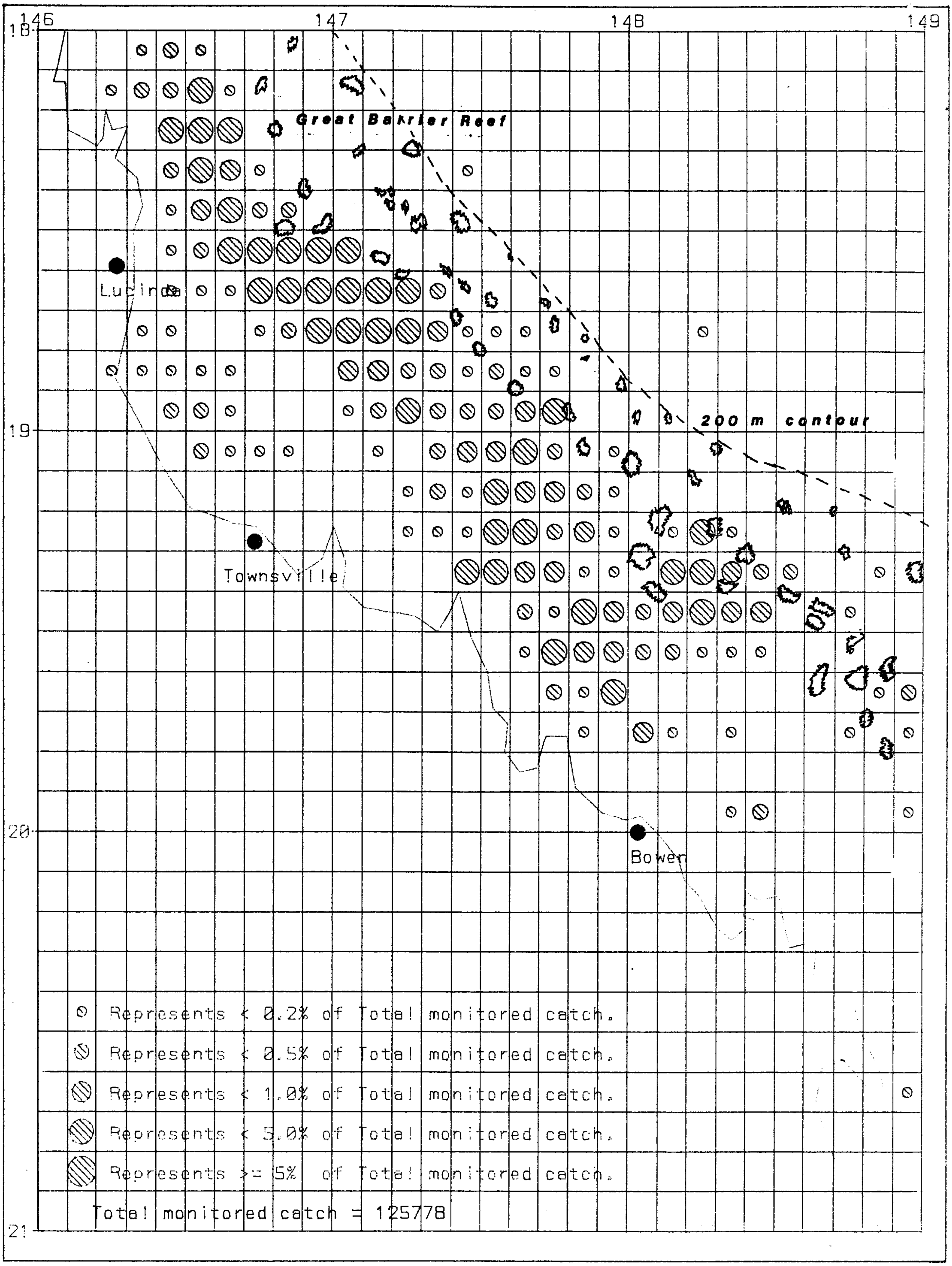


149
150
151
152
21
22
23
24
Mackay
Great Barrier Reef
Shoal Water Bay
200 m contour
Yeppoon
Capricorn-Bunker Group
Represents < 0.2% of Total monitored catch.
Represents < 0.5% of Total monitored catch.
Represents < 1.0% of Total monitored catch.
Represents < 5.0% of Total monitored catch.
Represents >= 5% of Total monitored catch.
Total monitored catch = 37112


151
152
153
154
24
25
26
27
Bustard Bay
Lady Elliot Island
200 m contour
Bundaberg
Double Is. Pt.
Represents < 0,2% of Total monitored catch.
Represents < 0.5% of Total monitored catch.
Represents < 1.0% of Total monitored catch.
Represents < 5.0% of Total monitored catch.
Represents >= 5% of Total monitored catch.
Total monitored catch = 10501



146
147
148
149
18
19
20
21
Great Barrier Reef
200 m contour
Lucinda
Townsville
Bowen
Represents < 0.2% of Total monitored catch.
Represents < 0.5% of Total monitored catch.
Represents < 1.0% of Total monitored catch.
Represents < 5.0% of Total monitored catch.
Represents >= 5% of Total monitored catch.
Total monitored catch = 125778