Designing, implementing and assessing an integrated monitoring program for the NPF

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CHAPTER 2 SUMMARY AND INTRODUCTION

2002/101	**Designing, implementing and assessing an integrated monitoring program for the NPF**

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2.1 Outcomes

The major outcome of this project is a long term monitoring program on target and byproduct species in the NPF that will provide an independent index of abundance for assessments and management. The potential reduction in uncertainty will greatly benefit managers and the industry.

2.2 Project objectives

a. To determine the final design and analyses for two surveys in the Gulf of Carpentaria

b. To undertake a survey in September 2002 to determine whether there has been a spatial contraction of the tiger prawn resource

c. To undertake a survey in January/February 2003 that will provide a recruitment index of the main commercial prawn species in the Gulf of Carpentaria

d. To determine the appropriate scale and frequency of future surveys

e. To spatially map the distribution of the main prawn species in the Gulf of Carpentaria

In addition, we also investigated the use of the survey mentioned in (b) as a Spawning Index. Since byproduct and environmental variables were also collected, we provide results for these in the report as well.

2.3 Non-technical Summary

Two surveys were undertaken during the 2002/3 financial year.

2.3.1 Recruitment-Index Survey

The Recruitment Index survey in January 2003 was even more successful than the August 2002 survey as the experience gained in the first survey led to an improved survey design. A stratified random design was utilized with the strata within a region being defined by water depth and alongshore distance. The slightly non-random nature of the site allocation process was part of the design plan, rather than undertaken in an *ad hoc* way when the survey was underway. The new design and good weather meant that in most areas more sites than expected were sampled.

Initially, a survey design similar to that used for planning optimal Marine Protected Regions was attempted, but (a) the optimisation of distance travelled and (b) including all the strata, meant that spatial coverage was seriously compromised. An alternate plan was implemented whereby two sets of random sites were drawn up and the primary set was used except where a primary site was untrawlable or where the calculated distance to the next site extended beyond a night's fishing in which case a secondary replacement site was used.

This was a very large survey and was undertaken with great success given the survey length, number of people involved and sites that had to be sampled. A regional Recruitment Index can be produced for the common banana prawn (*Penaeus merguiensis*), brown and grooved tiger prawns (*P. esculentus* and *P. semisulcatus* respectively) and the endeavour prawn, *M. endeavouri*. CV's ranged from about 8 to 50% and will be improved when the specific size range needed for the Index is used rather than the whole catch. It should be noted that the survey was not designed to provide precise within-region indices.

Generally, past survey data had shown a very clear relationship between mean catch rates and variance (Dichmont *et al*. 2002) and this relationship was used in the survey design to stratify a region and allocate the number of sites within a stratum. Based on the two surveys undertaken here, we can confirm that the relationship exists.

Many aspects of the survey have anecdotally reflected the relative distribution between the regions of species (even though the survey needs to be repeated before these are fully substantiated). We obtained very poor banana prawn catches and the subsequent banana season has seemed to have been characterised by poor or late recruitment.

2.3.2 Spawning-Index Survey

A Spawning-Index survey was completed in August 2002 in order to produce an index of abundance for much of the old and new fishing grounds in Mornington, Vanderlins and Groote Eylandt. The survey was designed to be carried out after the winter months when tiger prawns are more catchable, but before substantial catches have been taken by the fishing fleet, so that both tiger prawn species are in large enough numbers to survey.

For the August survey, a stratified random design was implemented in which the strata within a region were based on depth and fishing effort. The stratification resulted in a regional Spawner Index Coefficient of Variation (CV) of about 20% which is good given the large area that was covered with the resources available. We have therefore found that a useful relative index of spawning abundance can be produced. The survey, on the other hand, is not intended to provide precise within-region indices.

Even though the CV's are fairly good, the survey did not execute the design exactly as planned as some of the sites were too far apart and redesign was necessary during the survey. The number of sites trawled per night in past surveys was not achieved during this survey because of the random nature of the design and the large area to be covered. Most of the strata were therefore not sampled to the intensity that was planned and CV's will therefore only improve in the future based on this knowledge.

The results of this survey were also used to evaluate the new spatial fishing power model (not part of this project). They have been shown to be extremely useful in comparing logbook data of a year, with biomass changes close to the time of fishing, irrespective of the spatial extent of the fishery in the year. From this result, it is clear that the Spawning Index, if repeated to become a yearly series, can:

- be used as an relative index of abundance in the fishing power or stock assessment models,
- keep track of the spatial extent of the resource rather than the fishery (as logbook data would only produce), and
- provide for a good spatial distribution map for tiger and endeavour prawns.

2.4 Recommendations and Conclusions

1. It is recommended that future surveys be undertaken at a similar moon phase and calendar month where possible.
2. The spatial extent of the fishery in South Groote should be investigated so that sites can be re-allocated to the inshore region where brown tiger prawn indices were not very precise.
3. There were important changes in species composition, distribution and abundance between the regions. No region is therefore representative of another region. Since a survey index needs to be applicable to regions where most of the catch is obtained, it is recommended that the present spatial coverage (especially for the Recruitment Index survey) be maintained.
4. The Recruitment Index needs to be undertaken annually. Its value seriously declines if there is a break in the series or a major change in the timing of the survey. At this stage, the calculated stock and recruitment relationship in the tiger prawn stock assessment is based on estimated recruitment and calculated stock sizes. Ideally both should be obtained from independent sources, but in most cases in the world, robust relationships are produced by independently surveying the Recruitment Index as little commercial logbook data from past decades can be applied to this parameter.
5. The Spawning Index has been used to evaluate the new fishing power model (not part of this project), although this work is still highly preliminary and needs much further work. It is unclear at this stage whether the survey needs to be undertaken annually, but again the spatial coverage of the survey should not be decreased.
6. Since the mid-season closure is so long, little fishery dependent data is available on brown tiger prawns and it would be of value to consider annually repeating the

Spawning Index survey until recovery of the resource can be demonstrated independent of the assessment.

7. For both surveys, the relative regions of importance will depend on the objectives and the species being targeted.

8. The indices produced by these surveys should be compared with relevant studies undertaken in the 1980 and 1990's.

2.5 Background

For more than a decade the Northern Prawn Fishery assessments have indicated that the tiger prawn resource is overexploited. A review of the tiger prawn assessment in 2001 supported this conclusion and has also drawn attention to the high level of uncertainty in the assessment. For this reason, Dr Deriso[1] strongly recommended that the logbook data be augmented by fishery-independent survey data and that the survey should be designed both to provide an independent index of abundance for each tiger prawn species and to quantify fishing power changes.

The clear message of the review was that a survey program is an essential investment for this fishery, but since it is clearly going to be expensive there is a need to achieve as much return as possible from it.

A well-designed independent survey may also be able to perform other urgently needed tasks in the fishery without compromising its primary function. Examples are bycatch monitoring, as required by the Bycatch Action Plan and byproduct monitoring.

In response to this review, an initial industry-funded (Dichmont *et al.* 2002) consultancy was established to investigate and design an integrated monitoring program for the NPF. The initial design results were presented to a well-attended industry meeting in Cairns in February 2002. Suggestions from industry were incorporated into the project and a final report included a modular design and costing structure, which was presented to a special NORMAC meeting in March 2002. This meeting agreed to all components of the proposed program except the work in Joseph Bonaparte Gulf, which was seen as premature. As a result of this decision, a one year pilot test of the desk top design would be undertaken incorporating two trawl surveys in 2002/03. The first, aimed at estimating a spawning index that could also be used in future fishing power studies, was undertaken in 3 regions of the Gulf of Carpentaria (GOC) in August 2002. The second survey aimed to produce an index of recruitment and was undertaken throughout most of the fishing regions of the Gulf of Carpentaria in January/February 2003. The final funding mix, based on an assumption of a 50:50 ratio of monitoring to research, was 50% industry funded and the remainder equally funded by AFMA Research Fund, FRDC and CSIRO.

This project is integrated with two other on-going projects: FRDC 2002/014 "Developing a new method of evaluating catch rates of spatially mobile and aggregating prawn resources" (Principal Investigator - Cathy Dichmont); and, FRDC 2002/035 - Design, trial and implementation of an integrated long-term bycatch monitoring program in the NPF (Principal

[1] Dr Deriso from Scripps Institution of Oceanography reviewed the NPF tiger prawn assessment in 2001

Investigator - Neil Loneragan). Bycatch has therefore been collected by this study but processed by the latter FRDC project. The results of this survey have also been directly used by two other projects: ARF "A new approach to fishing power and its application in the NPF" (Principal Investigator - Cathy Dichmont) and AFMA R01/1149: Species Distribution and Catch Allocation: Data and Methods for the NPF (Principal Investigator – Bill Venables).

Dichmont *et al*. 2002 found that future tiger prawn assessments would benefit greatly from a fishery-independent recruitment index, which would be derived from a survey undertaken at the start of the calendar year during the seasonal closure. This is because peak tiger prawn recruitment is between December and February. Studies have also shown that the best time to survey common banana prawns is in January when they are less aggregated and therefore easier to survey with good precision. This January survey would therefore provide data for tiger, endeavour and banana prawns at a time when no commercial catch data is available. However, the spatial contraction of the prawn fishery, which has been highlighted by Die *et al* (2001) and Dichmont *et al*. (2002), changes in fishing power and a spawning stock index cannot be investigated through a January survey alone, when the prawns are not being fished commercially. A further survey has therefore been designed at the start of the second fishing season (August/September) with the main aim of developing a fishery-independent index of biomass that will help managers, researchers and industry interpret trends in tiger prawn catches in the fishery, monitor the spatial extent of the resource rather than the fishery and also provide an index of spawning stock. Given the advantages of a research platform covering large areas not usually fished by the industry, allied information such as bycatch is of interest and benefit. This project aimed to undertake these two surveys, and develop the basic analyses necessary to test the design. Furthermore, it will be used to design the scale of successive surveys (both temporally and spatially).

2.6 Need

An international review of the NPF tiger prawn assessment agreed with the conclusions of the 2001 assessment that tiger prawn levels are critically low, especially for brown tiger prawns. It highlighted the critical need for an independent monitoring program given the confounding and complexities of the catch rate data used as the sole index of abundance in the NPF assessments. The survey data used to determine the initial design for this project (see Background) is more than a decade old and does not cover the full study area. Therefore the initial surveys will be largely exploratory in nature and very much a trial to see if the proposed design is effective. Also, the survey design includes integrated components such as the assessment of long-term changes in fishing power and the contraction of the fishery over time that have not been undertaken in prawn survey designs (both nationally and internationally) before. These aspects highlight that this project has a large research component, which has as a major output, not just the survey results itself, but recommendations for a final design, analyses and scale of future survey requirements. Half the project is therefore seen as research. For this reason, CSIRO is supporting the project to the scale of about $100,000. A similar amount is being applied for from FRDC's MOU funds using the matching $100,000 from industry i.e. a total of about $200,000. The remainder of the project, some $270,000 will be underwritten by the industry as agreed in NORMAC, March 2002 with a possible $100,000 initial seed contribution by AFMA. The industry and NORMAC have also in principal supported the long-term need for regular industry-funded monitoring surveys based on the output of this project. There is a need to provide an updated design for the NPF that would work in the long-term to provide indices of abundance to key species and enhance a difficult-to-use commercial catch rate series. Furthermore, this design needs to address target, byproduct, bycatch and possibly some effects-of-trawling issues to make the best use of the surveys, as they will be a large expense to the industry.

2.7 Benefits and adoption

This project had several benefits to managers, scientists and to industry participants in the fishery:

- the survey design was shown to be extremely effective after a few modifications were made during the project. This project therefore finalises the target species design process.
- managers have reduced their risk of relying on stock assessment alone to monitor the recovery of brown tiger prawns. The August survey benefits all by providing the only data source during an extremely long mid-season closure in part designed to substantially reduce effort on brown tiger prawns.
- managers and industry will benefit in future years as the survey also monitors byproduct and seasnake species.
- industry obtained distribution maps of prawn catches immediately after the Recruitment and Spawning surveys. These gave good relative distribution information as to where best to place their commercial efforts.

The adoption of the project results can be demonstrated by the use of the design in a new on-going monitoring project and by regular discussions at NPFAG meetings of survey results. Also, the use of new technologies such as a system that links an electronic measuring device directly to a computer database (the program for which was written within this project) has been beneficial and cost-effective.

In the medium to long term, managers, scientists and industry benefit from a long term monitoring program in which the design has been rigorously tested. The new monitoring project will use the design from this project, undertake another cycle of surveys and modify the stock assessment so that it can incorporate the resultant survey time series.

2.8 Further development

Although the main survey design is complete in terms of sample size and position, there is a need to:

- finalise the timing and frequency of the surveys,
- absorb the results into the stock assessment, and
- further analyse the benefits of this survey for byproduct monitoring.

2.9 Planned outcomes

The planned outcome was to produce an integrated monitoring survey design, defining the scale, frequency, objectives and cost of the surveys and to test the survey design. This outcome has been met as evidenced by the funding of a subsequent on-going monitoring project that absorbed all our outputs.

2.10 Intellectual property

The important information from this project is:

- two complete survey designs for Recruitment and Spawning indices
- the actual results for these surveys – distribution and densities of prawns and byproduct
- the trawl positional data - trawl tracks and points.

2.11 Acknowledgements

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2.12 Project Staff in Alphabetical Order on Surname

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2.13 References

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Dichmont, C.M., Burridge, C., Deng, A., Jones, P., Taranto, T., Toscas, P., Vance, D. and Venables, W. 2002. Designing an integrated monitoring program for the NPF optimising costs and benefits. MIRF R01/1144.

CHAPTER 3 SAMPLING GEAR AND DATA COLLECTED

A major issue for long-term research surveys is to use sampling gear such that the fishing power of the survey vessel can be maintained as constant as possible over many years. This standardisation is fairly important for a recruitment survey but is essential for any survey where changes in the fishing power of the fishing fleet are being estimated. We used only NPF-based commercial vessels that were chartered using a public tender process. In all cases, A. Raptis and sons won the charter and, although we used several different vessels, they were all sister ships that were built at the same time using the same design e.g. length, draft etc.

3.1 Trawl gear description

For each survey, two vessels were chartered and, as much as possible, worked in similar areas at the same time. Each vessel used two 12-fathom tiger prawn nets manufactured for CSIRO by GNM Chandlery. Net and rigging specifications were as follows:

- 400d/30ply 2” stretched mesh net.
- Codend of 400d/4x16ply black braided 1⅞” stretched mesh net, 150 mr (meshes round) x 120 md (meshes deep).
- Fitted with 8mm S/S drop chains and 13mm regular link S/S ground chain.
- Headrope of 8mm S/S wire wrapped in 6mm PE rope.
- Footrope of 10mm S/S wire wrapped in 8mm PE rope.
- Fitted with 150 mr x 75 md skirt.
- An upward-excluding Turtle Excluding Device (TED) was fitted to each net but no Bycatch Reduction Devices (BRD) were fitted.

The nets were attached to Number 9 Bison Boards provided by the survey vessels.

3.2 Abiotic data collected

For each trawl, start and finish times and locations were recorded and the GPS plotter track of the vessel during each trawl was recorded. Trawling was commenced each night at about 30 minutes after sunset and the last trawl of the night was completed at least 30 minutes before sunrise. Each trawl was about 30 minutes in length, unless trawling was interrupted due to rough bottom or gear problems. Other details relating to weather, tides, moon and problems with gear were also recorded (see Chapter 15 for examples of field data sheets). We attempted to maintain vessel trawl speed at about 3.2 knots although this was not always possible in strong tidal currents.

Salinity/Temperature: A small Diver datalogger was attached to one trawl net on one vessel during each survey. The logger recorded conductivity (later converted to salinity), temperature and water depth at 1-minute intervals throughout each night and the data was downloaded to a computer at the end of each night's work.

3.3 Biological data collected

In most cases, all commercial species of prawns, bugs and scallops were identified to species and total weights and numbers were recorded for each net. All squid and cuttlefish were frozen and later transported to CSIRO, Cleveland for identification and further processing. Up to 100 individuals of each species of prawn and smaller numbers of bugs and scallops were measured to provide information on population structure. For the prawns, the spawning stage, moult stage and presence of any parasites was also recorded. When substantially more than 100 individuals of any prawn species were present in the catch, only a randomly selected subsample was measured, but the numbers and weights of subsample and total catch were recorded to allow us to relate the subsample details to the total catch. In both surveys, an extra CSIRO staff member from the FRDC-funded "Bycatch monitoring" project was on board each vessel. Data on bycatch species and weights were collected from each trawl and in many cases, samples of bycatch were frozen and shipped to CSIRO, Cleveland for further analysis. The results of this research will be reported in detail in a separate report of the Bycatch project.

CHAPTER 4 ANALYSES

4.1 Background

A major component of the design and initial analyses of this survey is reported in Dichmont *et. al.* (2002).

4.2 Definition of adults and sub-adults

We classified prawns into two age groups: "sub-adults", and "adults". For the recruitment survey in January, "sub-adults" are of primary interest while for the spawning survey in August, "adults" are of more interest.

We used carapace length as a surrogate for age, and applied the following thresholds in allocating individual prawns to one of the age groups. For *P. semisulcatus*, female prawns with a carapace length of more than 38 mm were labelled as adults and male prawns with a carapace length of more than 33 mm were labelled as adults. Smaller prawns were labelled as sub-adults. In both surveys, we caught few prawns smaller than 20 mm.

For the other species of commercial interest (*P. esculentus, P. latisulcatus, P. longistylus, P. merguiensis, M. endeavouri and M. ensis*), female prawns with a carapace length of more than 33 mm and male prawns with a carapace length of more than 30 mm were labelled as adults.

4.3 The sampling frame

For each survey, three sets of information are needed when constructing the index for each prawn species for each region[2]. The three data sources are:

- The sampling frame – this is the full set of 2 nm cells from which sample sites are selected, each cell being uniquely defined by a 15-character grid reference representing the latitude and longitude at its centre (e.g. S17d15mE140d07m.) Each cell is also assigned a region and a stratum label. For the August survey, the strata within each region are defined by fishing effort and water depth. For the January survey, the strata are defined by sub-region and water depth. The sampling frame is also used to evaluate the total area of each stratum, and from this is derived the weight given to each stratum when calculating each regional index.

- Design information – this is the suite of stratification variables for the sites that were sampled (survey, region, depth stratum, effort stratum for the August survey, sub-region for the January survey).

[2] Additional offshore sites sampled in January 2003 for a bycatch monitoring project were not included in the calculation of the recruitment index.

- Number of prawns by species – this is the number of adult and sub-adult prawns of each species in each trawl, standardized by trawl duration and adjusted where one net failed. Carapace length was often measured on only a subset of a particular species in a given net in a given trawl. These animals were partitioned into two age groups ("sub-adult" and "adult"). Then the sub-adult and adult counts were multiplied by the ratio of the total number in that net to the number in the sub-sample. For example, if half the *P. esculentus* prawns in the port net were measured then the sub-adult and adult counts in that net were doubled. The adjusted counts from the two nets for that species were then added together. If one net had failed (e.g. torn net, catch substantially lower in one net than the other), the count from the remaining net was doubled. Finally, the adjusted total count for the shot was converted to an hourly catch rate by dividing by the effective duration of the trawl in hours. The effective duration was calculated by subtracting 'down-time' from the total duration of the shot due to nets being lifted clear of untrawlable seabed.

4.4 Calculating the indices of abundance

The estimated index for each region ($\hat{\mu}_R$) consists of a weighted sum of the sample mean count per hour in each stratum ($\bar{y}_{R,i}$), where each stratum weight ($w_{R,i}$) is the proportion of the region represented by that stratum. The sum of stratum weights within a region is 1.

$$\hat{\mu}_R = \sum_{i=1}^{N_R} w_{R,i} \bar{y}_{R,i} \tag{1}$$

The variance of the index consists of a weighted sum of the stratum sample variances. In this calculation, the stratum weights used for the index are squared and hence no longer sum to 1. No finite population correction was applied as each trawl sweeps a very small fraction of the cell it samples.

$$V(\hat{\mu}_R) = \sum_{i=1}^{N_R} w_{R,i}^2 V(y_{R,i}) \tag{2}$$

The square root of this variance gives the standard error of the estimated index for that region. The coefficient of variation is the ratio of the standard error to the estimated index, multiplied by 100.

4.5 References

Dichmont, C.M., Burridge, C., Deng, A., Jones, P., Taranto, T., Toscas, P., Vance, D. and Venables, W. 2002. Designing an integrated monitoring program for the NPF optimising costs and benefits. MIRF R01/1144.

CHAPTER 5 RECRUITMENT INDEX

5.1 Introduction

The objectives of the Recruitment Index survey were to provide:

a. a final design for future surveys, scoping the spatial scale and temporal regularity of the survey, including the cost of these subsequent surveys.

b. an index of recruitment with coefficients of variation (CV) for tiger, banana and endeavour prawns.

c. a catch rate distribution map made available to industry on the AFMA web site.

d. advice as to the utility of the survey for byproduct biology and abundance.

5.2 Survey design

In this section we discuss the following aspects of survey design:

- The timing of the surveys within a year depending on survey objectives,
- The spatial extent of the survey given the resources available, and
- Stratification and site selection.

These points have been extensively discussed in Dichmont *et al*. (2002) but confirmation of these issues is needed in light of our practical experience.

5.2.1 Timing of the survey

The motivation for the timing of the Recruitment Index survey in January is:

- Banana prawns are less aggregated in January (Crocos, Wang and Vance *pers. comm.*) and therefore can be adequately surveyed with relatively low fishing effort (the main risk here is that our information on the aggregation behaviour comes from surveys in the Weipa region only, and we have assumed the behaviour is similar in all regions),
- Tiger prawn recruitment peaks between December and February (Somers *et. al* 1987). If banana prawns are not being surveyed, then February would probably be slightly better for tiger prawns.

- Due to the offshore movement of prawns as they mature, it is likely that the resource is more contracted in January than later in the year, and therefore easier to sample.

A cost-effective approach to obtaining a Recruitment Index for both banana and tiger prawns is to conduct the survey in January.

A risk for undertaking the survey so early in the year is that sampling in January may miss the smaller recruitment that occurs to the fishery later in the year or miss the peak of recruitment in years in which recruitment is delayed. However, we attempted to minimize this risk by sampling a large range of depths, from relatively shallow to the deeper edge of the fishery.

In order to sample mostly during the new moon, the survey was undertaken between 25 January and 15 February 2003 using two vessels. It is well known by industry and scientists that the moon phase affects catchability and so it is **recommended that future surveys be undertaken at a similar moon phase and calendar month.**

From the results shown in Section 5.2.3, there is some indication that different regions may have different recruitment as the relative abundance between shallow and deep strata is not consistent across regions. However, we generally trawled depth ranges from about 8 to 45m, which is likely to sample most of the prawn distribution. Furthermore, the mean-variance relationship for banana prawns is similar to that of tiger prawns, but with a shallower slope than for the Spawning survey. This suggests that the banana prawns have yet to school (one of our major reasons for undertaking the survey so early in the year). Indications are that the timing is correct, but more surveys are needed to confirm this.

5.2.2 Extent of the survey

The spatial extent of the survey recommended in Dichmont *et al.* (2002) was based on past logbook and survey data. In January, the prawns are distributed either on the fishing grounds or inshore towards the mangroves and seagrass beds. Final survey regions selected for possible sampling are given in Figure 1. The spatial extent of this survey was decreased slightly from that proposed in Dichmont *et al.* (2002). In particular, a section in the south-eastern Vanderlins region was omitted as the available funding could not cover the recommended area with good precision. The initial design was based on being able to sample an average of 10 sites per night whereas the survey undertaken prior to this one in August 2002 showed that this figure was probably difficult to attain consistently. Further changes in other regions e.g. Mornington were due to having to remove large areas of untrawlable ground from the survey design, based on advice from industry and the experience of the August 2002 survey.

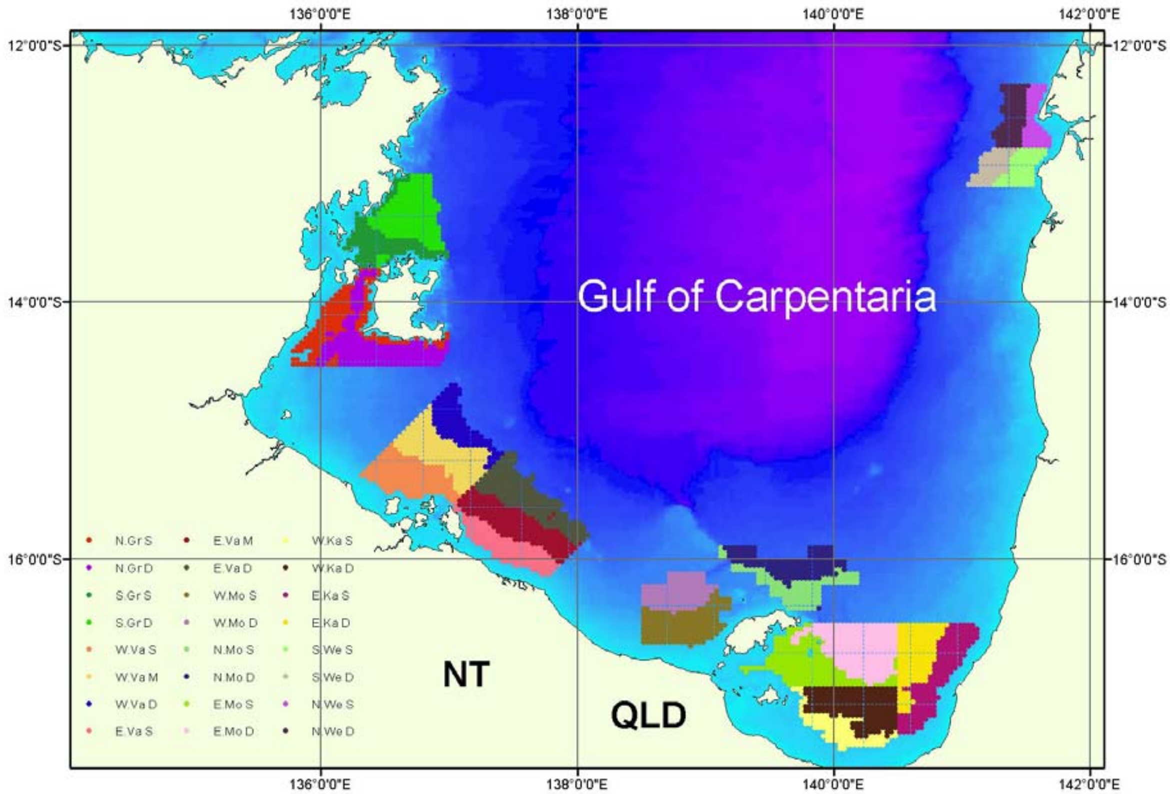


Figure 1: Location of potential survey sites showing the extent of the January/February 2003 Recruitment Index survey. Colour coding show the different strata within a region. The last letter in each legend item refers to the depth stratum: s shallow, m medium, d deep

5.2.3 Stratification and site selection

A critical problem for this survey was to sample enough sites to produce useful indices of abundance. This is because a relative index of abundance needs to be able to differentiate between random noise and real changes in abundance over a realistic time scale. This high precision can be gained by obtaining a large number of sample sites and/or by stratification. The former is often limited by financial constraints and therefore stratification is an essential aspect of survey design.

The number of sites chosen for the survey was based on a mean-variance relationship observed in past surveys – some from over 20 years ago. The relationship between the mean μ_i for the *i*'th stratum and its standard deviation σ_i, was well described by:

$$\sigma_i = e^{\alpha} \mu_i^{\beta} \tag{1}$$

This form is still valid (Figure 2 to Figure 4, and Table 1) though the slope now appears to be steeper for most species. This relationship means that as the abundance between years or areas increases so would the variance (i.e. lower precision). Until we have enough survey data to roughly predict the expected yearly mean and allocate the number of samples accordingly, there is nothing we are able to do about this, other than maintain some form of conservatism in the number of sites. The relationship is similar across regions, so the regional data were combined.

Table 1: Parameters for relationship between mean and standard deviation per stratum for two age groups of five commercially important species, based on number of prawns caught per hour in the January 2003 survey.

Species	Age group	Intercept (α)	S.E. of α	Slope (β)	S.E. of β
Banana prawns					
P. merguiensis	Sub-adult	**0.135**	0.078	**1.088**	0.032
	Adult	**0.119**	0.069	**1.075**	0.038
Endeavour prawns					
M. endeavouri	Sub-adult	**0.390**	0.140	**0.845**	0.036
	Adult	**0.225**	0.094	**0.874**	0.034
M. ensis	Sub-adult	**0.118**	0.075	**1.069**	0.055
	Adult	**0.128**	0.089	**1.010**	0.059
Tiger prawns					
P. esculentus	Sub-adult	**–0.198**	0.208	**1.087**	0.057
	Adult	**0.295**	0.140	**0.926**	0.038
P. semisulcatus	Sub-adult	**0.252**	0.094	**0.955**	0.022
	Adult	**0.274**	0.107	**0.891**	0.036

The relationship is similar for the two tiger species, for both age classes (Figure 2), though the slope is slightly shallower for *P. semisulcatus* (0.955, 0.891; Table 1) than for *P. esculentus* (1.087, 0.926). Over the five regions (a total of 22 strata), both tiger species covered a similar, wide range in mean catch rates. The relationships for the two endeavour species appear to differ to some extent (Figure 3) but as the range of catch rates for *M. ensis* is appreciably narrower than for the other species, the difference in relationships may in fact be negligible. The slope and intercept of *M. ensis* (1.069, 1.010) is very similar to those of the tiger species and *P. merguiensis* (1.088, 1.075; Table 1). On the other hand, the slope for *M. endeavouri* (0.845, 0.874) is shallower than for the other four species, and is the most similar to slopes obtained from historical data reported in Dichmont *et al*. (2002). The mean-variance relationship is practically identical for both *P. merguiensis* age classes with a slope that is very close to 1 (Figure 4). A slope of more than 0.5 indicates that animals tend to be clustered rather than distributed randomly, and the steeper the slope is, the more patchily the animals are distributed. In this respect, it is noteworthy that the mean-variance relationship for the banana prawns is so similar to three other species that are not known to school. This suggests that the survey was well-timed with respect to avoiding banana prawn schooling behaviour.

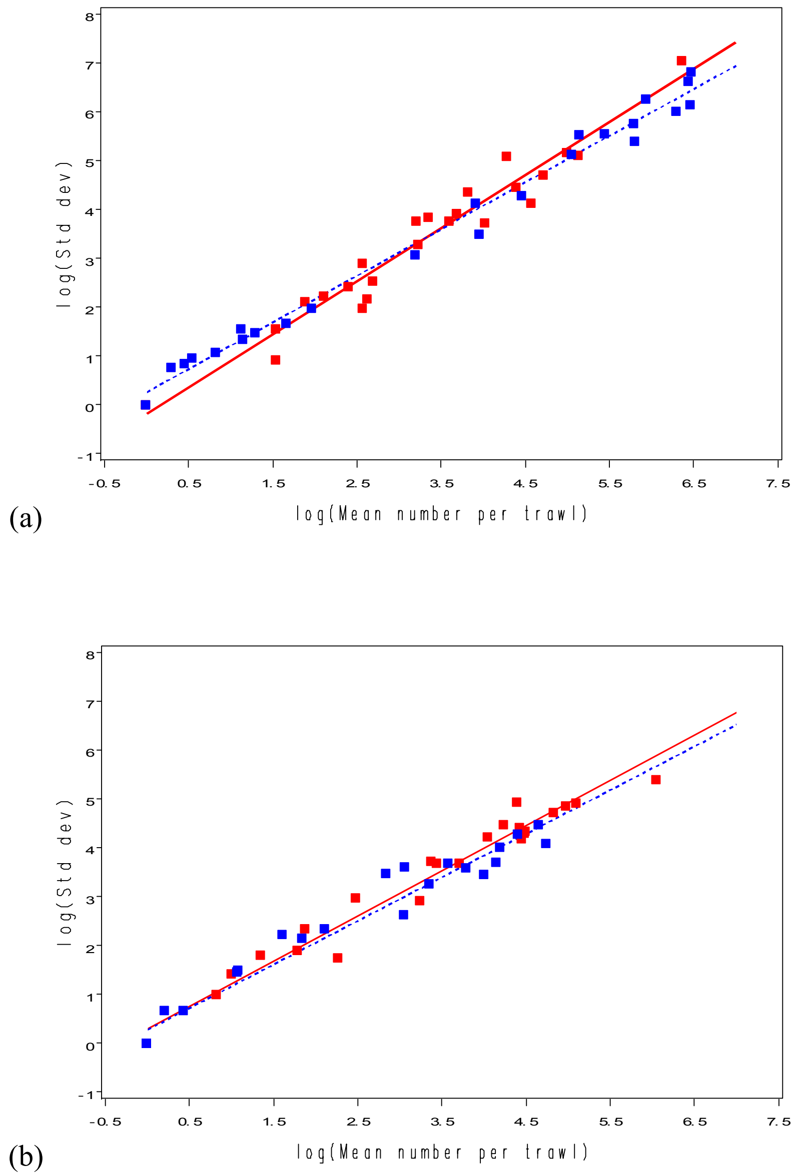
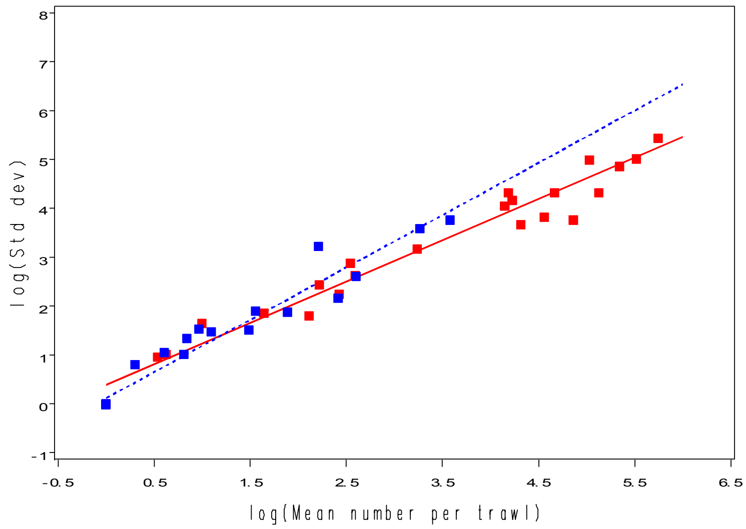
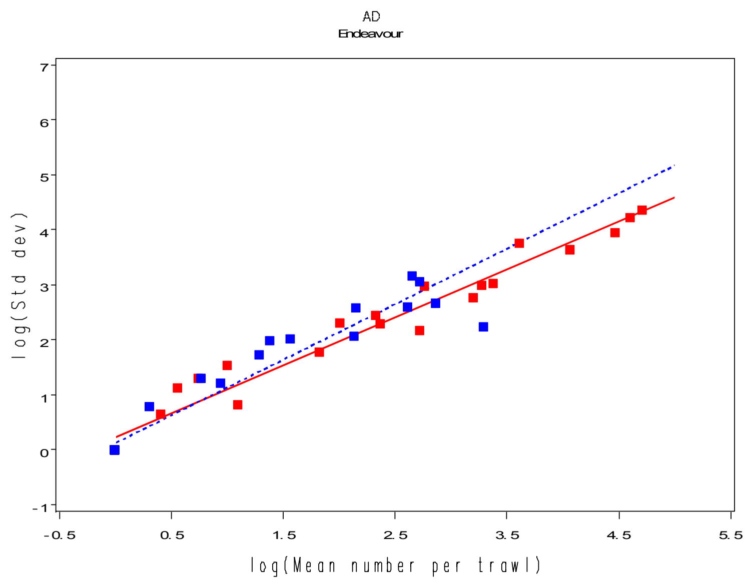


Figure 2: Relationship for *Penaeus esculentus* (red) and *Penaeus semisulcatus* (blue) between sample mean and sample standard deviation for number of (a) sub-adult and (b) adult prawns caught per hour in January 2003 survey. The mean and standard deviation have been log$_e$-transformed

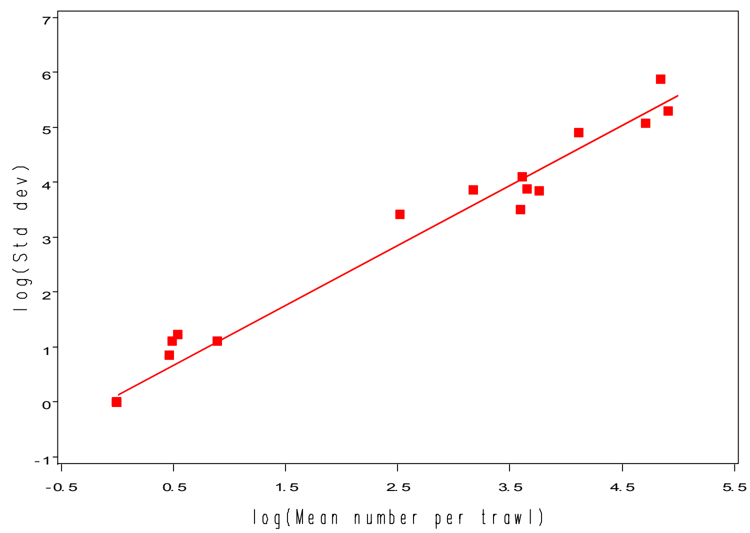


(a)



(b)

Figure 3: Relationship for *Metapenaeus endeavouri* (red) and *Metapenaeus ensis* (blue) between sample mean and sample standard deviation for number of (a) sub-adult and (b) adult prawns caught per hour in January 2003 survey. The mean and standard deviation have been $\log_e$-transformed.



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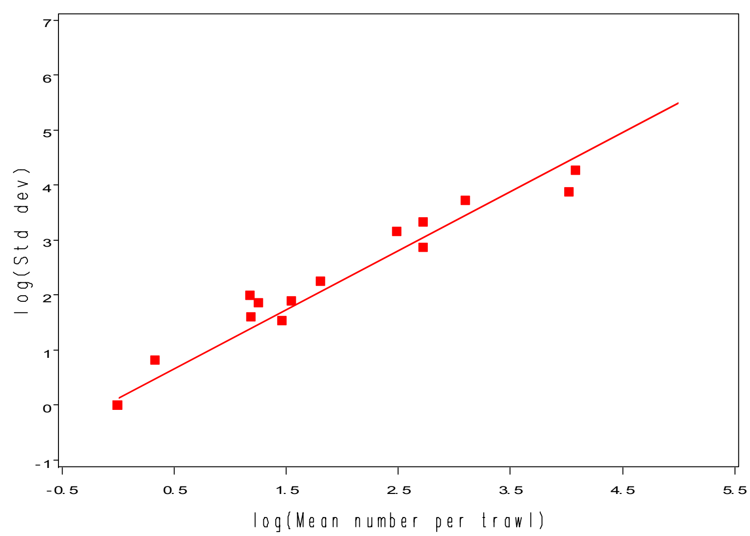


(b)

Figure 4: ***Relationship for*** *Penaeus merguiensis* ***between sample mean and sample standard deviation for number of (a) sub-adult and (b) adult prawns caught per hour in January 2003 survey. The mean and standard deviation have been log$_e$-transformed.***

Past studies have shown that brown tiger prawns tend to be found in higher abundance inshore than offshore for most of the year (Somers et al. 1987). Grooved tiger prawns have been found to be more mobile and even at this time of year have been found in higher abundance offshore than inshore in North Groote and Weipa. For both tiger species, there was substantial alongshore difference in density and species composition within each region.

Based on this information, the primary mechanism for stratification was alongshore distance and the secondary was offshore distance divided into roughly shallow and deep regions.

Table 2 gives the stratification details. The depth strata are not consistent from one region to the next, due to the large variation in the offshore distance for a specific depth range governed by the different bottom topography. The partitions were chosen so that the strata for a given region would be reasonably similar in spatial extent, but with boundaries wherever possible on an 8m depth contour. Figure 1 displays the sampling frame – all the 2 n.mile locations from which sites could have been chosen.

A fully stratified random survey was attempted in August 2002. The number of sites per night obtained was well below reasonable levels and an adapted approach was designed for the January survey. At first, an attempt at a computerised design method based on the development of Marine Protected Area Systems using simulated annealing was attempted. However, the optimisation of distance travelled and sampling over the regions resulted in aberrations that seriously compromised coverage. As a concession, sites were chosen from two sets of random site allocations (for example, at Groote, Figure 5). Each set consisted of randomly chosen sites with the designed number of sites per stratum. Wherever possible, primary sites were used. Secondary sites were used only when the distance between primary sites was too great. In these cases, nearby secondary sites were allocated instead of primary sites so that a reasonable number of sites could be trawled each night. This slightly non-random design often occurs in an *ad hoc* way in the field. Since the number of secondary sites used is low, we feel that the randomness assumed in the analyses is still warranted.

All strata within a given region were intended to be sampled with the same intensity, for two reasons. First of all, the multi-species nature of this survey together with the lack of historical data (for example on the Vanderlins) meant that it was not possible to optimise the allocation of samples in proportion to the anticipated relative means (and hence variances). Secondly, it resulted in a more-or-less uniform distribution of sites over each region that would facilitate the application of spatial statistics (and hence mapping of predicted means with appropriate prediction errors) at a later date.

From a practical point of view, when conditions were good and an extra night's sampling was available, this resulted in some strata receiving considerably more effort than others (for example, the northern part of Groote compared with the southern part).

NPF survey sites in Groote
(Primary sites and Secondary sites)

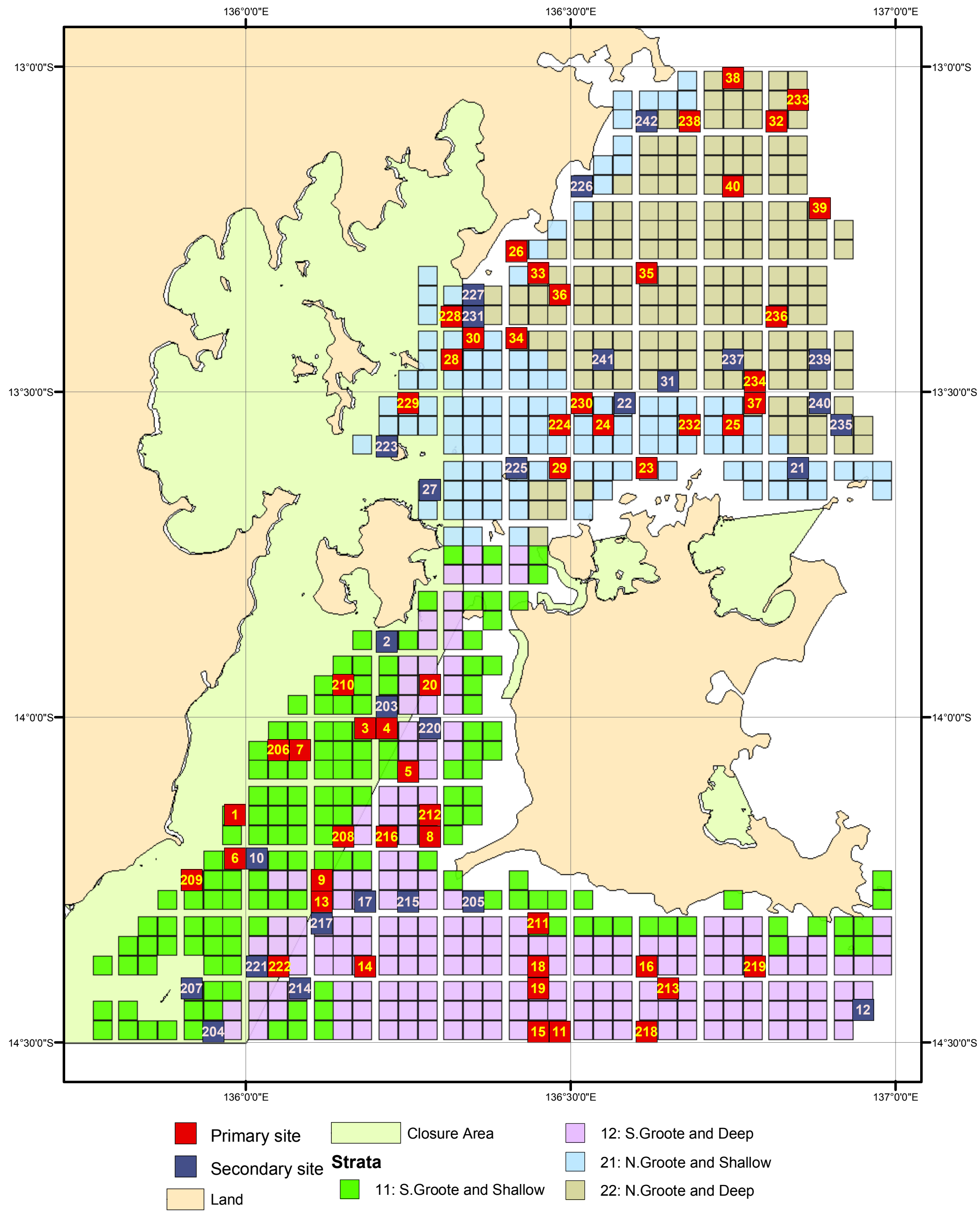


Figure 5: Primary (red) and secondary (blue) sites for the Groote region also showing the North shallow (light blue), North deep (brown, South shallow (green) and south deep (pink)

Table 2: Sampling design by region in terms of area (nm^2) and number of sites planned and completed

Region	Location	Depth stratum	Stratum area (nm^2)	Number of sites for selection	Number of sites planned to trawl	Number of sites completed
Groote	North	Shallow (8-25m)	532	133	10	22
		Deep (25-40m)	760	190	10	19
	South	Shallow (8-20m)	656	164	10	11
		Deep (20-40m)	828	207	10	16
Vanderlins	West	Shallow (8-25m)	676	169	8	11
		Medium (25-35m)	744	186	8	8
		Deep (35-40m)	464	116	8	11
	East	Shallow (8-20m)	528	132	8	11
		Medium (20-30m)	696	174	8	9
		Deep (30-40m)	760	190	8	11
Mornington	West	Shallow (8-25m)	668	167	9	10
		Deep (25-33m)	484	121	9	8
	North	Shallow (14-35m)	484	121	9	10
		Deep (35-44m)	556	139	9	20
	East	Shallow (8-20m)	800	200	9	16
		Deep (20-36m)	904	226	9	9
Karumba	West	Shallow (8-15m)	408	102	9	11
		Deep (15-24m)	748	187	9	9
	East	Shallow (8-12m)	696	174	9	10
		Deep (12-20m)	588	147	9	12
Weipa	South	Shallow (8-30m)	276	69	6	8
		Deep (30-40m)	240	60	6	6
	North	Shallow (8-25m)	260	65	6	7
		Deep (25-40m)	352	88	6	10

5.3 Recruitment Index

5.3.1 Precision of index

The catch rates presented for each species are the number of prawns caught per hour, in two age classes (sub-adults and adults; definitions given in Chapter 4). For a number of trawls, the catch from one net was discarded from analysis because of gear problems or the presence of, for example, substantial numbers of jellyfish that suggest the catch would not be representative. Five trawls were discarded as the trawling had been cut short due to difficult bottom type. An index was calculated for each region, age class and species, using the methods described in Chapter 4.

Catch rates for sub-adult *P. semisulcatus* (grooved tigers) (Table 3) were highest in the Vanderlins (311.0 h^{-1}) and Weipa (329.6 h^{-1}) with slightly less caught in Groote (270.8 h^{-1}) and negligible quantities caught in the South East Gulf. Sub-adult *P. esculentus* (brown tigers) were most abundant in Groote (176.2 h^{-1}) and much less abundant around Mornington (71.7 h^{-1}) and the Vanderlins (60.6 h^{-1}). Abundance in Karumba and Weipa was low. *M. endeavouri* (blue endeavours) abundance was highest in Groote (178.4 h^{-1}) followed closely by the Vanderlins (142.3 h^{-1}). Small quantities were caught in Mornington and Weipa and essentially none in Karumba. *M. ensis* (red endeavours) were much less abundant everywhere than the other commercial species, the highest regional catch rate (at Weipa) being only 18.7 h^{-1}. Regional catch rates of sub-adult *P. merguiensis* (banana prawns) were lower than for the tigers with rates of 28.2 to 37.5 h^{-1} for the four southern and eastern regions and negligible quantities in Groote. This corresponds well with the anticipated regional profile for this species.

From a species point of view, relative precision varied from good to excellent for *M. endeavouri* and *P. semisulcatus* (coefficient of variation of 20% or less in all regions with a catch rate of more than 100 h^{-1}). It was mostly good for *P. esculentus* with the notable exception of Groote where the C.V. was 47.4%. This poor C.V. was due to some very high catches in the shallow waters off South Groote, but relatively few samples in that stratum compared with the other three strata. For *P. merguiensis* the precision was generally poor (C.V. of more than 30% except for Karumba) due primarily to low catch rates.

From a regional point of view, the Vanderlins was best with three out of four important species having a C.V. of less than 17%, banana prawns being the exception. For other regions species with catch rates of more than 30 h^{-1} had good precision except for *P. esculentus* at Groote. While there is scope for improvement in precision, the design of this survey has been largely effective.

In general, the regional characteristics of adult prawns were similar to those of sub-adults (Table 4), except that catch rates were about one-third those of the sub-adults. A notable exception to this pattern was *P. esculentus* in the Vanderlins, where three times as many adults (168.1 h^{-1}) were caught as sub-adults (60.6 h^{-1}). Relative precision was similar to that found for sub-adult prawns.

Table 3: Mean number of sub-adult prawns caught per hour per region for the January 2003 survey, for five commercial species, with standard error (S.E.) and coefficient of variation (C.V.).

Species	Statistic	Region				
		Groote	Karumba	Mornington	Vanderlins	Weipa
Banana prawns						
P. merguiensis	Mean	**0.6**	**37.5**	**28.2**	**27.8**	**34.4**
	S.E.	0.2	7.8	8.9	16.2	17.5
	C.V.	36.7	20.8	31.6	58.2	51.0
Endeavour prawns						
M. endeavouri	Mean	**178.4**	**0.7**	**30.3**	**142.3**	**8.1**
	S.E.	19.7	0.3	4.0	11.5	1.7
	C.V.	11.1	40.9	13.3	8.1	21.2
M. ensis	Mean	**1.7**	**0.0**	**0.0**	**5.3**	**18.7**
	S.E.	0.3	0.0	0.0	1.6	4.9
	C.V.	18.1	–	–	29.7	26.3
Tiger prawns						
P. esculentus	Mean	**176.2**	**21.7**	**71.7**	**60.6**	**5.0**
	S.E.	83.4	6.0	14.8	9.5	1.1
	C.V.	47.4	27.6	20.7	15.7	23.0
P. semisulcatus	Mean	**270.8**	**0.6**	**3.0**	**311.0**	**329.6**
	S.E.	49.6	0.2	0.5	51.4	65.4
	C.V.	18.3	37.8	16.9	16.5	19.9

Table 4: Mean number of adult prawns caught per hour per region for the January 2003 survey, for five commercial species, with standard error (S.E.) and coefficient of variation (C.V.).

Species	Statistic	Region				
		Groote	Karumba	Mornington	Vanderlins	Weipa
Banana prawns						
P. merguiensis	Mean	**0.4**	**19.3**	**15.0**	**5.4**	**1.9**
	S.E.	0.2	3.9	4.1	2.2	0.9
	C.V.	37.2	20.1	27.2	40.7	50.5
Endeavour prawns						
M. endeavouri	Mean	**54.0**	**0.0**	**5.8**	**48.1**	**2.2**
	S.E.	6.6	0.0	1.1	4.8	0.5
	C.V.	12.3	–	19.1	10.0	23.8
M. ensis	Mean	**6.0**	**0.0**	**0.2**	**11.6**	**5.2**
	S.E.	1.7	0.0	< 0.1	1.2	2.0
	C.V.	28.1	–	33.6	10.3	37.5
Tiger prawns						
P. esculentus	Mean	**60.3**	**1.1**	**48.0**	**168.1**	**5.2**
	S.E.	8.6	0.4	7.9	19.1	1.1
	C.V.	14.2	37.5	16.4	11.4	21.3
P. semisulcatus	Mean	**49.2**	**0.0**	**5.1**	**60.7**	**24.3**
	S.E.	6.2	0.0	0.9	7.0	4.9
	C.V.	12.7	–	17.8	11.6	20.1

5.3.2 Results by stratum

The results for the individual sites are presented in Chapter 13 and show where the highest catches occurred. They also show whether a stratum has a high mean catch due to a few productive sites or consistently high catch rates over most sites in that stratum. Often, if it is the former, then the precision for that stratum will be lower (larger standard error) than for similar means in other strata. As an example, the large standard error (number per hour) of brown tiger prawns (Figure 6) in the south Groote stratum is largely due to one or two large catches in the very shallow water (Chapter 11). However, the index of abundance by stratum for the other areas is very good.

5.3.2.a Brown tiger prawns

In Groote and the Vanderlins, higher numbers of sub-adult brown tiger prawns were found inshore in the shallower strata in January, consistent with historical survey data for North Groote (Somers et al. 1987). Around Mornington, the catch rates were slightly higher in deeper waters but it should be noted that the deep strata around Mornington are a similar depth to the shallow strata in the western regions. As expected, catch rates were very low in all the Weipa strata. Adult brown tiger prawns showed similar overall patterns but with surprisingly high catches compared with sub-adults in the medium and deep strata of the Vanderlins.

5.3.2.b Grooved tiger prawns

Most of the sub-adult grooved tiger prawns (Figure 7) were found in Vanderlins, Weipa and North Groote. Again, unlike the Spawning survey, there is no consistency between regions as to which depths had the highest catch rates of sub-adult grooved tiger prawns. For example, in Vanderlins, the highest catch rates were in the shallow stratum, for North Weipa both the deep and shallow strata and for North Groote the deep stratum. This may reflect that depth is not a necessarily a good surrogate for distance from the nursery grounds, but the good overall precision means that it is still a good means of stratification.

The precision of the East Vanderlins shallow site for grooved tiger prawns is lower than expected and future surveys should investigate whether further survey effort needs to be placed in this region. Even so, given the size and complexity of the region, tiger prawn precision by stratum is generally good. Catch rates of adult grooved tiger prawns showed the same general trend among regions as the sub-adults, but were higher in the deeper strata of the Vanderlins, as would be expected.

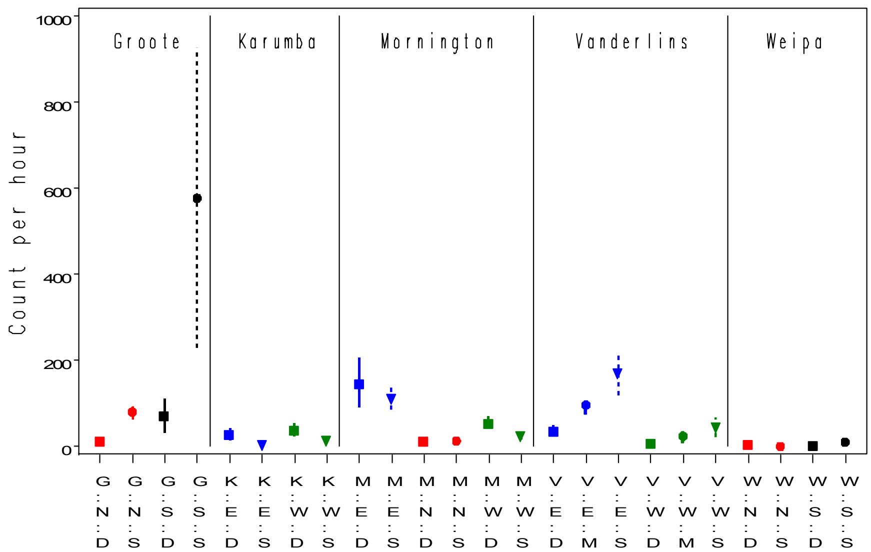
5.3.2.c Endeavour prawns

M. endeavouri sub-adult prawn catch rates (Figure 8) in North and South Groote are similar in the deep and shallow strata. On the other hand, in Vanderlins, the best endeavour catch rates occurred in the shallow stratum. Most of the endeavour prawns were found in Groote and Vanderlins (Table 3 and Table 4). The precision by stratum for each area is very good, which means that little or no change in the survey effort distribution is needed at this stage for a good Recruitment Index of endeavour prawns. Adult *M. endeavouri* were more numerous in the shallower strata in the Vanderlins.

Figure 9 shows the mean catch rates for the red endeavour prawn (*M. ensis*). The catch rates in all strata and areas were extremely low. It is unclear if this is a different phenomenon to past surveys in the 1980’s and 1990’s and this should be investigated. We obtained the highest catch rates in the Vanderlins and Weipa and, similar to the tiger and other endeavour prawn results, there is no consistency in the pattern with depth strata when comparing between regions.

5.3.2.d Banana prawns

The standard error for sub-adult *P. merguiensis* is quite large for the three strata with the highest catch rates. These are the shallow strata in east Mornington, east Vanderlins and North Weipa (Figure 10). The other strata were surveyed quite well, although the abundances were quite low. These indices show that the banana prawns in many of the strata were not schooled up, which allowed us to produce an index with good precision.



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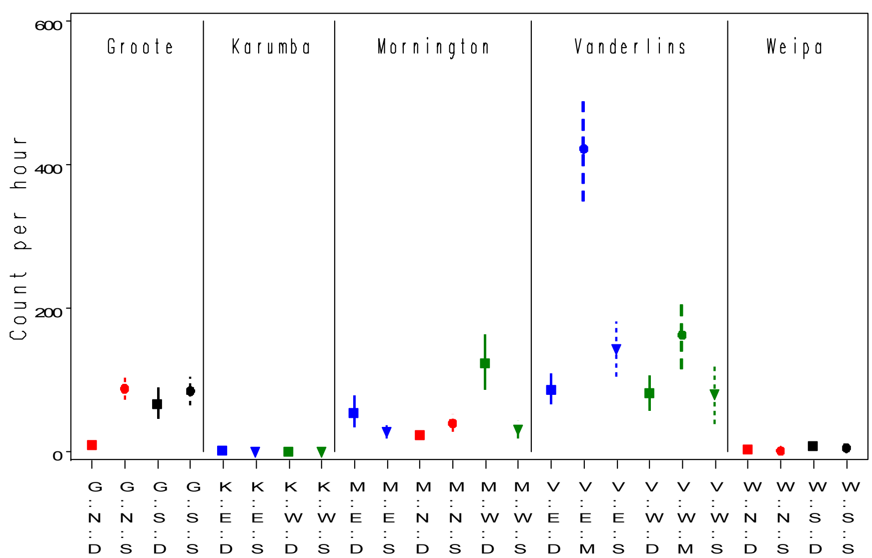
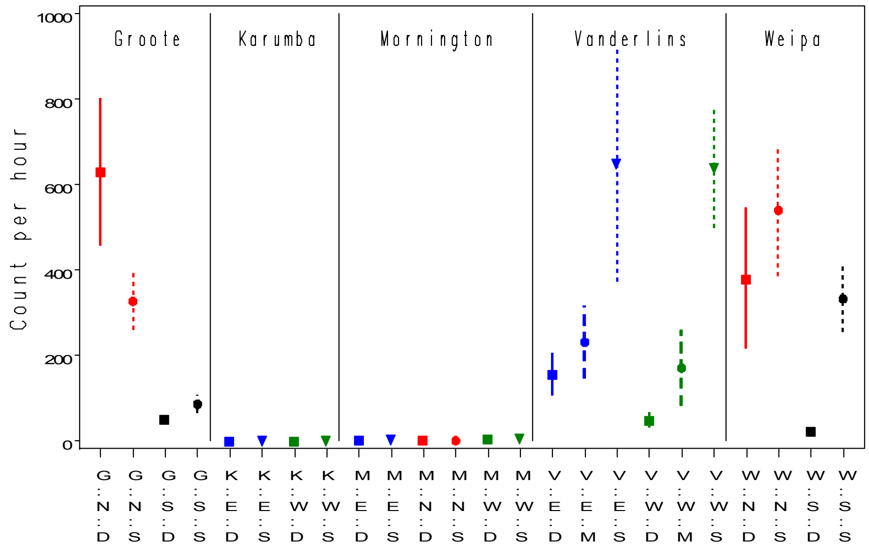


(b)

Figure 6: Mean (with standard errors) numbers per hour in the January 2003 survey for *Penaeus esculentus* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, K=Karumba, M=Mornington, V=Vanderlins, W=Weipa}, sub-region {N (red)=north, S (black)=south, E (blue)=east, W (green)=west} and depth stratum {D (solid square)=deep, S (solid circle)=shallow}.



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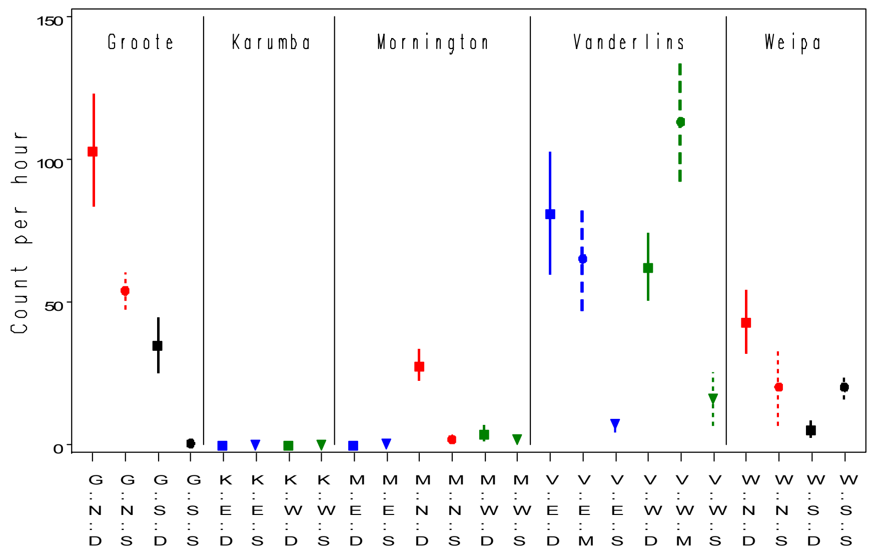
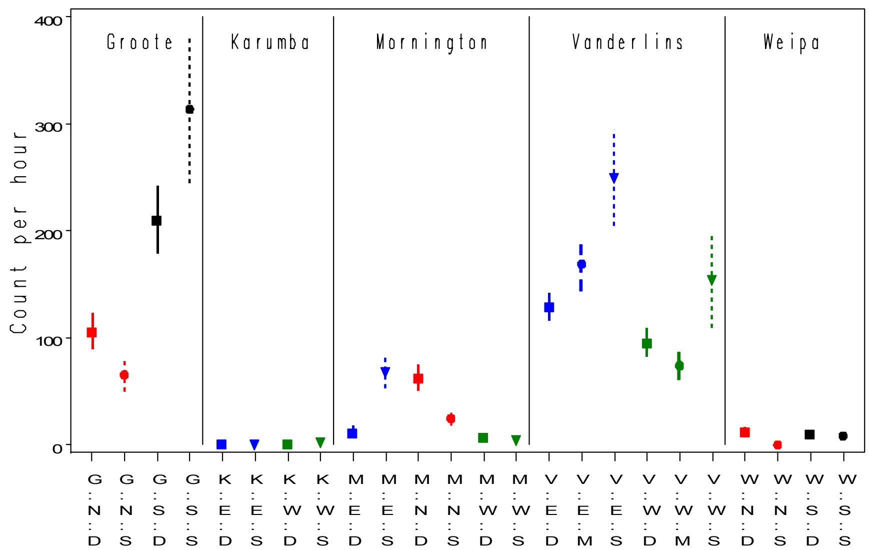
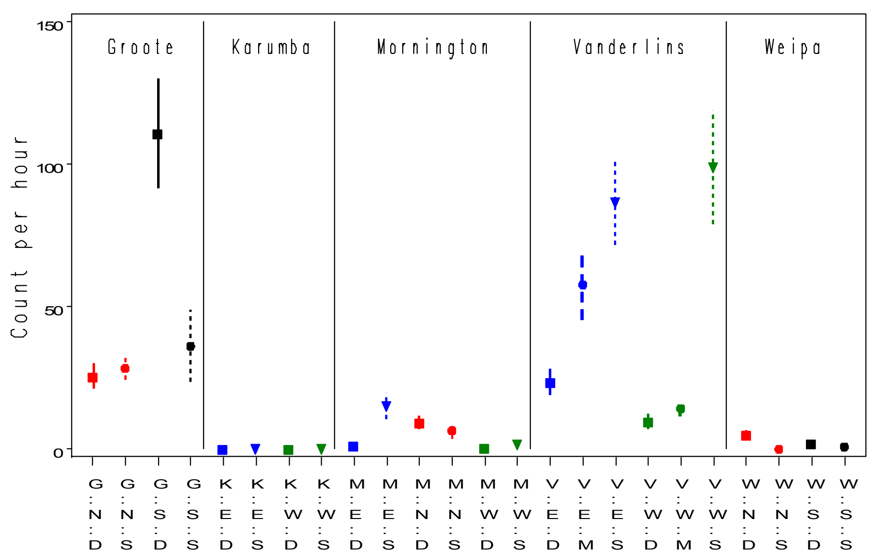


(b)

Figure 7: Mean (with standard errors) numbers per hour in the January 2003 survey for *Penaeus semisulcatus* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, K=Karumba, M=Mornington, V=Vanderlins, W=Weipa}, sub-region {N (red)=north, S (black)=south, E (blue)=east, W (green)=west} and depth stratum {D (solid square)=deep, S (solid circle)=shallow}.



(a)



(b)

Figure 8: Mean (with standard errors) count per hour in the January 2003 survey for *Metapenaeus endeavouri* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, K=Karumba, M=Mornington, V=Vanderlins, W=Weipa}, sub-region {N (red)=north, S (black)=south, E (blue)=east, W (green)=west} and depth stratum {D (solid square)=deep, S (solid circle)=shallow}. Note the different y-axis scale compared to previous figures.

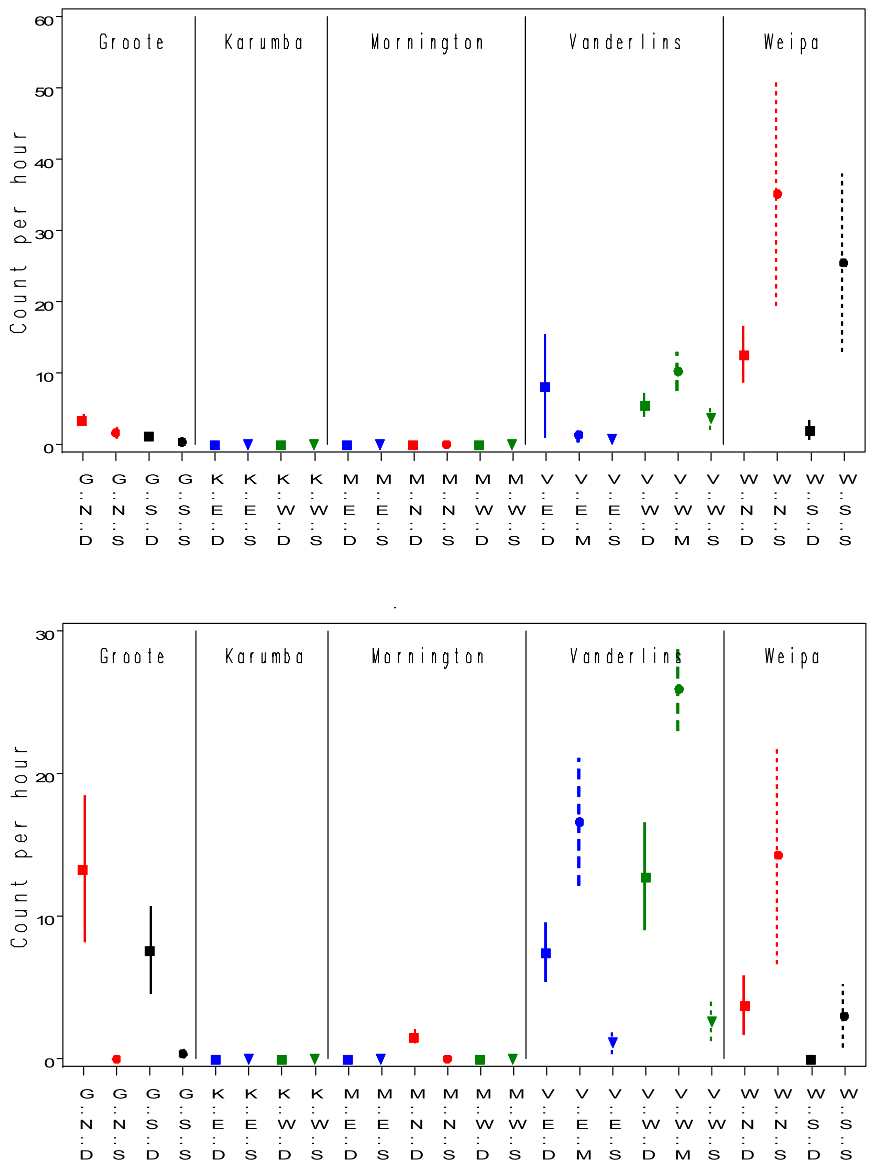
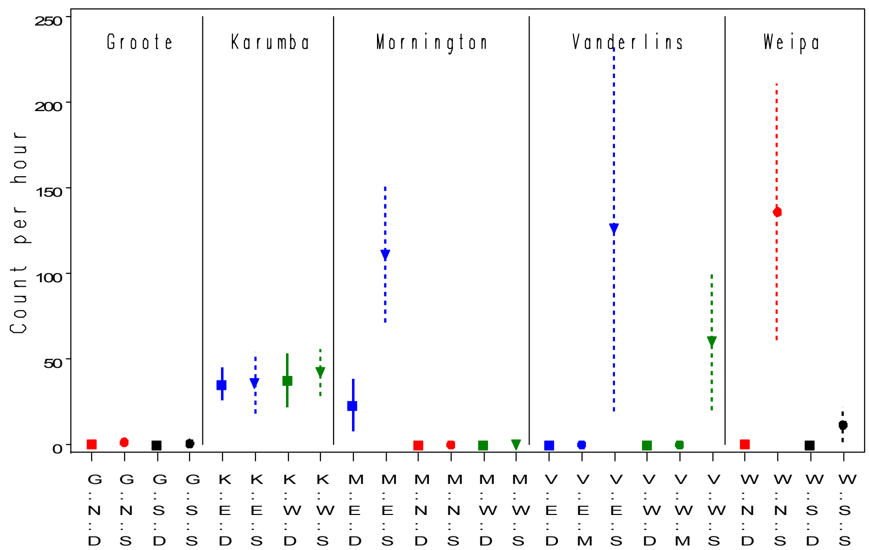
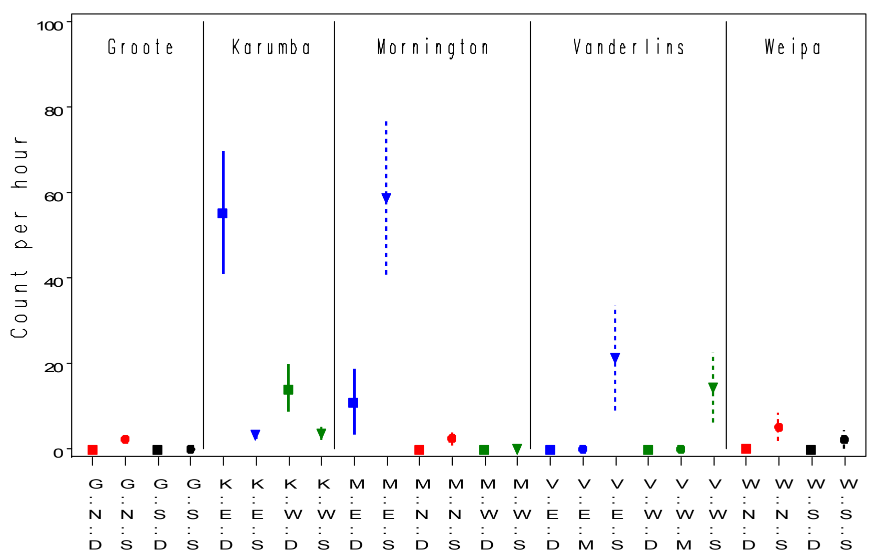


Figure 9: Mean (with standard errors) count per hour in the January 2003 survey for *Metapenaeus ensis* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, K=Karumba, M=Mornington, V=Vanderlins, W=Weipa}, sub-region {N (red)=north, S (black)=south, E (blue)=east, W (green)=west} and depth stratum {D (solid square)=deep, S (solid circle)=shallow}.



(a)



(b)

Figure 10: Mean (with standard errors) count per hour in the January 2003 survey for *Penaeus merguiensis* **in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region** ***{G=Groote, K=Karumba, M=Mornington, V=Vanderlins, W=Weipa}, sub-region {N (red)=north, S (black)=south, E (blue)=east, W (green)=west} and depth stratum {D (solid square)=deep, S (solid circle)=shallow}.***

5.4 Temperature and Salinity

Temperatures recorded just above the seabed during trawls in January were not significantly different between shallow and deep sites in the same region. However, temperatures in the south-eastern corner of the Gulf of Carpentaria were lower (28.1-28.6°C) than temperatures around Groote (30.0-30.3°C). Salinities at the seabed in the south-eastern corner were also slightly higher (33.9-34.3) than those to the west of Mornington (32.1-33.0). This was probably due to the relatively low levels of rainfall in the eastern Gulf early in the wet season.

Table 5: Mean bottom temperature (°C) and salinity (+standard errors) for shallow and deep sites during the survey in January 2003. Data was not available for some areas due to technical problems with one of the loggers.

Region	Temperature		Salinity	
	Shallow	Deep	Shallow	Deep
North Groote	30.3 (0.07)	30.0 (0.05)	33.0 (0.07)	33.5 (0.03)
South Groote	30.0 (0.15)	29.8 (0.10)	32.7 (0.10)	33.1 (0.12)
West Vanderlins	28.6 (0.11)	29.0 (0.14)	32.1 (0.15)	33.0 (0.01)
East Vanderlins	27.8 (0.05)		32.7 (0.03)	
West Mornington	29.5 (0.17)		32.9 (0.11)	
North Mornington	28.3 (0.07)	28.3 (0.06)	33.2 (0.05)	33.1 (0.04)
East Mornington	28.6 (0.07)	28.3 (0.04)	33.9 (0.06)	33.4 (0.08)
West Karumba	28.1 (0.05)	28.0 (0.07)	34.3 (0.06)	33.9 (0.08)
East Karumba	28.2 (0.07)	28.3 (0.04)	34.1 (0.14)	33.5 (0.07)

5.5 Discussion

The Recruitment Survey conducted in January 2003 is the first survey ever to provide a simultaneous Gulf-wide fishery-independent assessment of stocks of all commercial prawn species. This has filled regional gaps for which no previous survey data was available (Vanderlins and Mornington). It has also enabled the regional distribution of individual species to be assessed more comprehensively than before, and highlighted substantial differences between sub-regions for some species (catch rates of grooved tiger prawns were much higher in north Groote than south Groote, for example, while the reverse was true for brown tiger prawns). The relationship between abundance of sub-adult prawns and water depth was not consistent across regions which may either indicate that distance from shore is a more important driver or that the peak in recruitment happens at different times in different regions.

5.6 Conclusions

1 The results are consistent with past information, namely:

1.1. The species composition between regions and within regions (e.g. North and South Groote) can change quite substantially,

1.2. The relative density of the different species also changes markedly between regions and strata,

1.3. The variation increases with the mean and this relationship is consistent over regions,

1.4. The mean-variance relationship for all species except blue endeavours is very similar.

2 However, for most species there is no consistent depth preference across regions for sub-adults at this time of year. This result is different to the Spawning Index survey (Chapter 6). We can therefore conclude that the recruitment timing is different between regions but also distance from the nursery grounds may be a better stratification variable than depth.

3 We generally produced precise indices of abundance. The few exceptions such as sub-adult brown tiger prawns at South Groote will need re-evaluation.

4 The general design is therefore supported.

5 Anecdotally (we need further survey data to confirm this), the low densities recorded for banana prawns relate well with the observation that the fishing industry have had a subsequently poor banana season in the Gulf of Carpentaria.

6 Based on points 1 and 2 above, no single area seems to represent another. This means that surveys of all areas need to be continued so that a Recruitment Index can be obtained for the two tiger, the endeavour and the banana prawn species.

5.7 References

Dichmont, C.M., Burridge, C., Deng, A., Jones, P., Taranto, T., Toscas, P., Vance, D. and Venables, W. 2002. Designing an integrated monitoring program for the NPF optimising costs and benefits. MIRF R01/1144.

Somers, I.F., Crocos, P.J. and Hill, B.J. 1987. Distribution and abundance of the tiger prawns *Penaeus esculentus* and *P. semisulcatus* in the north-western Gulf of Carpentaria, Australia. Aust. J. Mar. Freshw. Res. 38: 63-78.

CHAPTER 6 SPAWNING SURVEY

6.1 Introduction

The objectives of this survey were to provide:

a. an index of spawning abundance with coefficient of variation (CV) for tiger and endeavour prawns,

b. a distribution of abundance over the old and present fishing grounds at a time of the year more relevant to fishing,

c. details of the prawn abundance in areas previously fished and not presently fished, and

d. data on the distribution, abundance and size composition of the main byproduct species.

Since the August 2002 survey occurred before the larger January 2003 recruitment survey, the Spawning Index survey results also provided:

- an updated survey design for the January survey,
- input to analyses undertaken in the tiger prawn stock assessment analysing the reason for the contraction of the fishery, and
- a catch rate distribution map made available to industry on the AFMA web site.

6.2 Survey design with emphasis on actual versus predicted

The timing of the survey and spatial extent of the survey was discussed extensively in Dichmont *et al.* (2002) and the issues are summarised below. The Spawning survey would provide a relative index of spawning abundance of tiger prawns and address the issue of the spatial contraction of the fishery. It has also been shown that this survey is useful as input to the spatial model developed by the fishing power project[3].

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[3] A new approach to fishing power and its application in the NPF. ARF and FRRF fund.

6.2.1 Extent and timing of the survey

In Dichmont *et al.* (2002), detailed analyses had been carried out of the distribution of tiger prawn fishing effort in the first six weeks of the second season, with a view to defining suitable regions for the August survey and the extent of each region. Because most of the commercial effort in the Gulf of Carpentaria at this time is focused around three areas, Groote, the Vanderlins and Mornington Island, only these areas were surveyed (Figure 12). These areas were also shown to have effort contraction between the early 1980's and present.

The catchability of tiger prawns decreases markedly during the cooler winter months. This is especially true for grooved tiger prawns (*P. semisulcatus*) that migrate offshore beyond the fishing grounds. Because of this difference in availability between grooved and brown tiger prawns, brown tiger prawns (*P. esculentus*) tend to get fished earlier in the season than grooved tiger prawns (Figure 11) and, in recent years, their numbers decline dramatically by September. The survey therefore has to optimise its timing between fishing too early (at times when catchability is low) and too late (when few brown tiger prawns remain). To minimise costs, a survey in August was undertaken, just prior to the start of the second season.

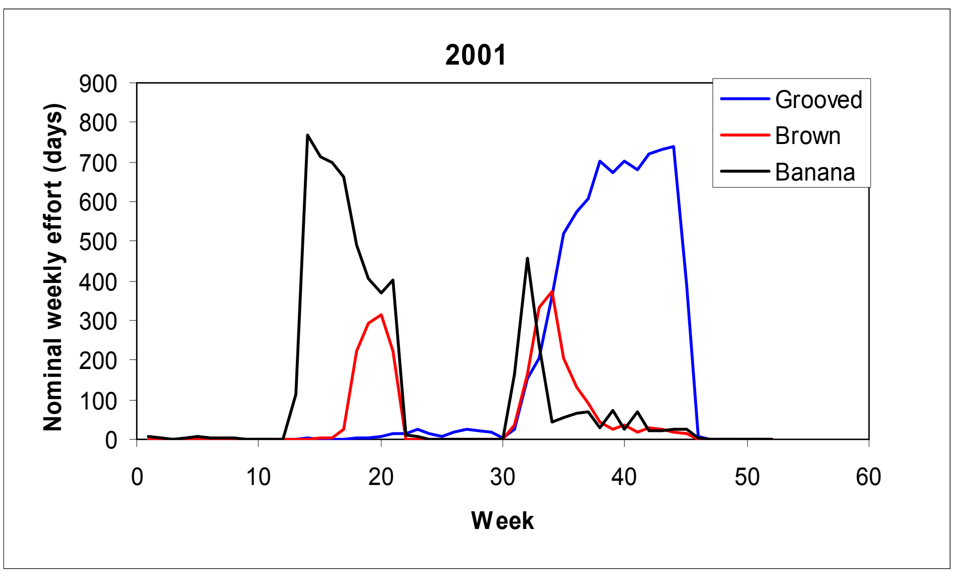


Figure 11: Weekly effort pattern targeted at banana prawns, and grooved and brown tiger prawns for the year 2001.

6.2.2 Stratification and site selection

The survey design proposed in Dichmont *et al.* (2002) was used with very few changes in design. The overall area was based on 6nm grid scale logbook data for 1980-2000 for the 6-week period August to mid-September. This means that, within limits, a region that was fished at some stage would be included within the survey.

The first stratification criterion was based on depth. Two depth strata were used at the 30m depth contour for each region (i.e. > 30m, < 30m). Within each depth stratum, a second criterion, fishing effort, was applied (we assume that, generally, the fishery tends to fish in higher density areas). Vessel Monitoring System data at 2nm scale for the year 2000 was used to divide the area into low, medium and high effort grids. An additional stratum within the shallow area is needed as some previously fished areas fall within permanent closures. These resultant strata are shown in Figure 12 and Table 6 shows the number of sites planned and successfully sampled.

Since the survey is a stratified random survey, the intention was that only the primary sampling sites should be used, and secondary sites should be used when a primary site falls within untrawlable ground (Figure 13). The *in situ* reality was that the number of sites was too many for a nights trawling, given the large distances to be travelled between sites, and the survey fell behind. Survey redesign after the first few nights was required, and some secondary sites were used in advance if the travel distance to the next primary site was too far. This did not happen often enough for the randomness of the survey to be compromised. Even so, the survey fell short of the planned number of sites per stratum in several regions (Table 6).

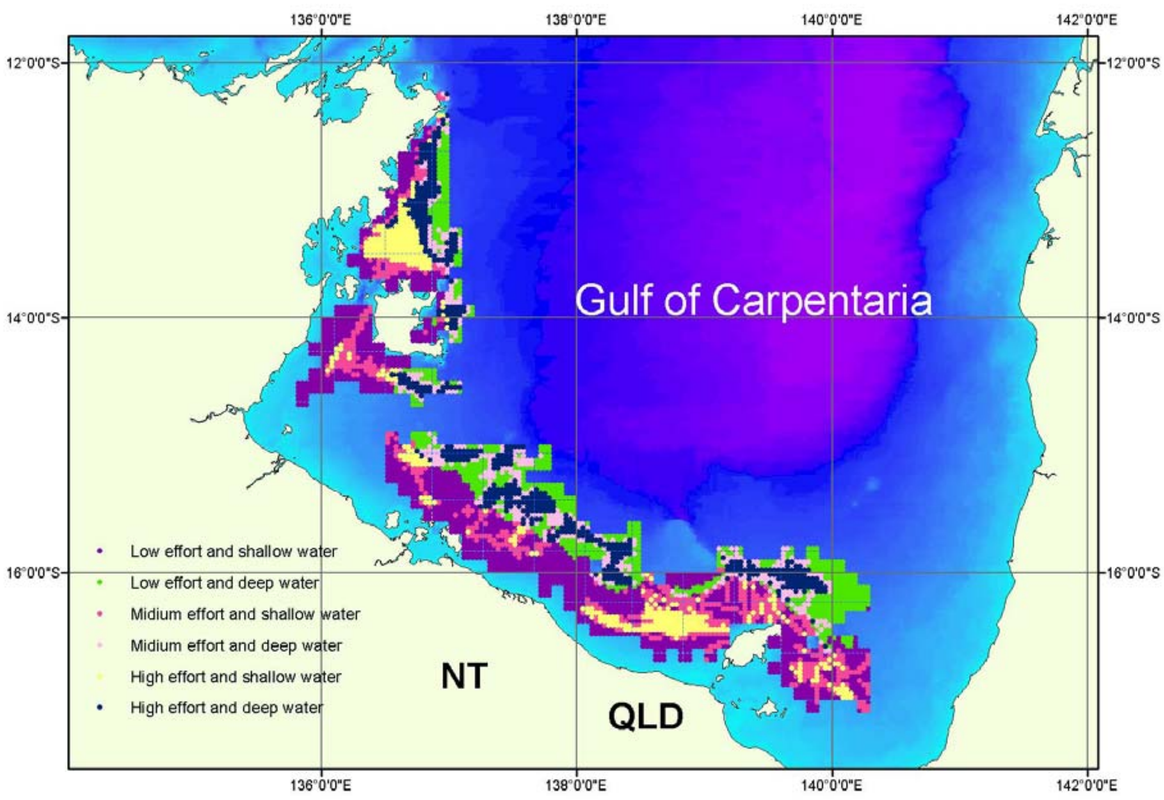


Figure 12: Spatial coverage of the survey showing all possible site locations. Colour coding shows the strata within a region.

Table 6: Sampling design by region; number of sites planned versus number completed.

Region	Effort stratum (VMS units)	Depth stratum	Stratum area (nm^2)	Number of sites for selection	Number of sites planned to trawl	Number of sites trawled successfully
Groote	Low (0–192)	Shallow (5–30m)	1756	439	12	11
		Deep (> 30 m)	548	137	6	6
	Medium (193–828)	Shallow (5–30m)	544	136	9	5
		Deep (> 30 m)	384	96	6	6
	High (> 828)	Shallow (5–30m)	644	161	12	12
		Deep (> 30 m)	744	186	15	16
Vanderlins	Low (0–167)	Shallow (5–30m)	1604	401	15	13
		Deep (> 30 m)	916	229	6	5
	Medium (167–634)	Shallow (5–30m)	1080	270	6	10
		Deep (> 30 m)	424	106	9	7
	High (> 634)	Shallow (5–30m)	612	153	6	13
		Deep (> 30 m)	368	92	18	9
Mornington	Low (0–16)	Shallow (5–30m)	2336	584	15	10
		Deep (> 30 m)	1080	270	6	5
	Medium (17–133)	Shallow (5–30m)	472	118	6	7
		Deep (> 30 m)	664	166	9	9
	High (> 133)	Shallow (5–30m)	268	67	6	4
		Deep (> 30 m)	868	217	18	21

NPF survey sampling sites (2nm grid) in Groote

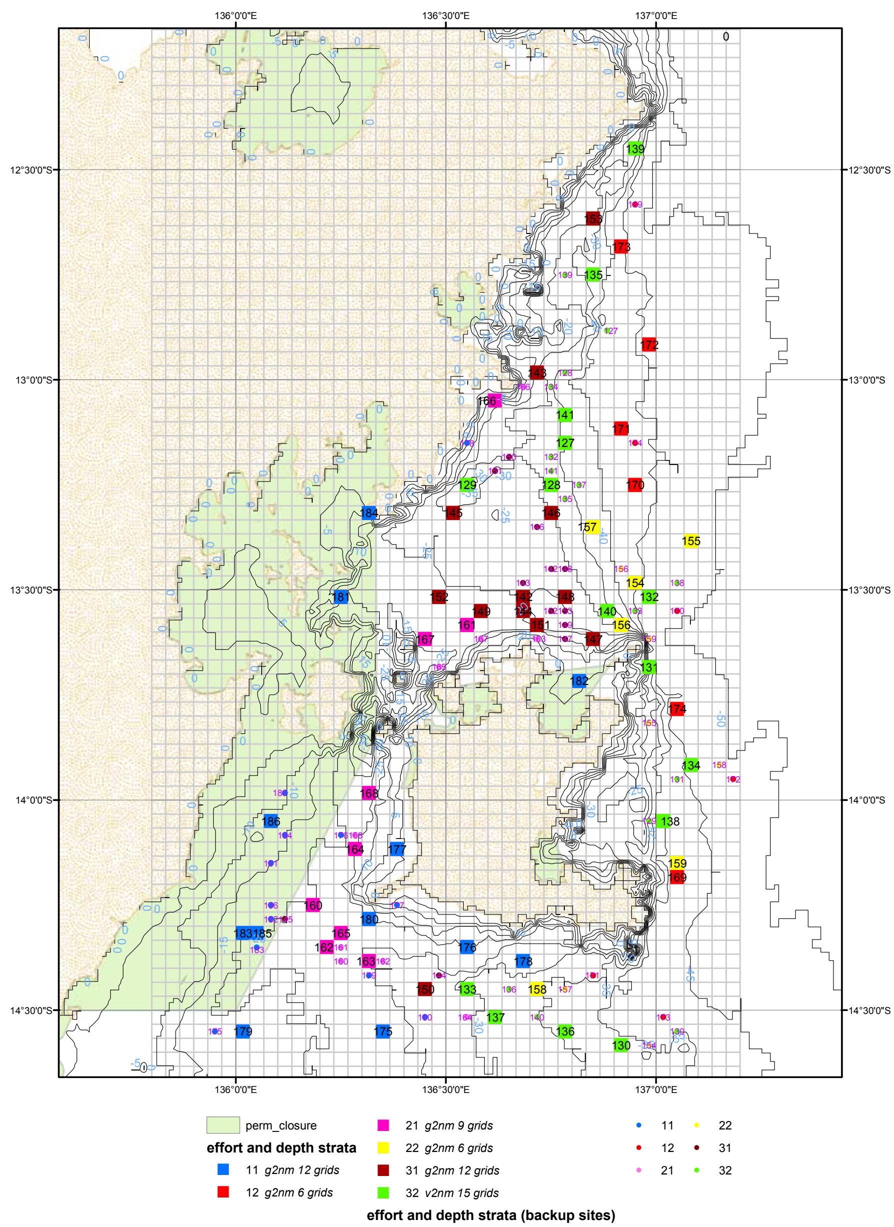


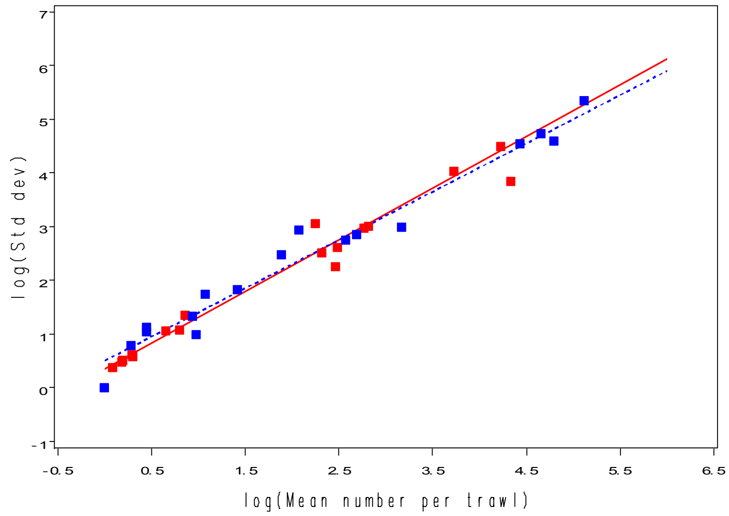
Figure 13: Location of 2-nm sampling grids for Groote Eylandt. The primary sampling grids are completely colour-filled according to their depth and effort stratum. Secondary (backup) sampling grids are denoted by a coloured dot within the grid.

Table 7: ***Parameters for relationship between mean and standard deviation per stratum for two age groups of five commercially important species, based on number of prawns caught per hour in the August 2002 survey***

Species	Age group	Intercept (α)	S.E. of α	Slope (β)	S.E. of β
Banana prawns					
P. merguiensis	Sub-adult	**0.097**	0.056	**1.323**	0.093
	Adult	**0.052**	0.097	**1.251**	0.047
Endeavour prawns					
M. endeavouri	Sub-adult	**0.420**	0.465	**0.860**	0.150
	Adult	**0.196**	0.502	**0.950**	0.113
M. ensis	Sub-adult	**0.111**	0.064	**1.487**	0.131
	Adult	**0.118**	0.063	**1.068**	0.038
Tiger prawns					
P. esculentus	Sub-adult	**0.344**	0.088	**0.962**	0.039
	Adult	**0.561**	0.210	**0.884**	0.049
P. semisulcatus	Sub-adult	**0.501**	0.116	**0.900**	0.041
	Adult	**0.771**	0.130	**0.833**	0.035

The number of sites chosen for the survey was based on a measured mean-variance relationship obtained in past surveys – some from over 20 years ago. This survey has shown that this relationship is still valid (Figure 14, Figure 15, Figure 16 and Table 7). This relationship means that as the abundance between years or areas increases so would the variance (i.e. lower precision). Until we have enough survey data to roughly predict the expected yearly mean and allocate the number of samples accordingly, we can only maintain some form of conservatism in the number of sites. The analyses were initially carried out for each region separately, but results were very similar for each region so they have been combined.

The relationship is almost identical for the two tiger species, for both age classes (Figure 14), in both cases slightly steeper for sub-adults (Table 7) suggesting these are perhaps slightly more aggregated. Over the five regions (a total of 22 strata), both tiger species covered a similar, wide range in mean catch rates. The relationships for the two endeavour species appear to differ to some extent (Figure 15), as seen in the Recruitment survey. Again, the range of catch rates for *M. ensis* is appreciably narrower than for the other species, so the difference in relationships may in fact be negligible. The steeper the slope, the more patchily the animals are distributed. In this respect, it is not surprising that the mean-variance relationship for the banana prawn, *P. merguiensis*, is steeper than for the three other species that are not known to school.



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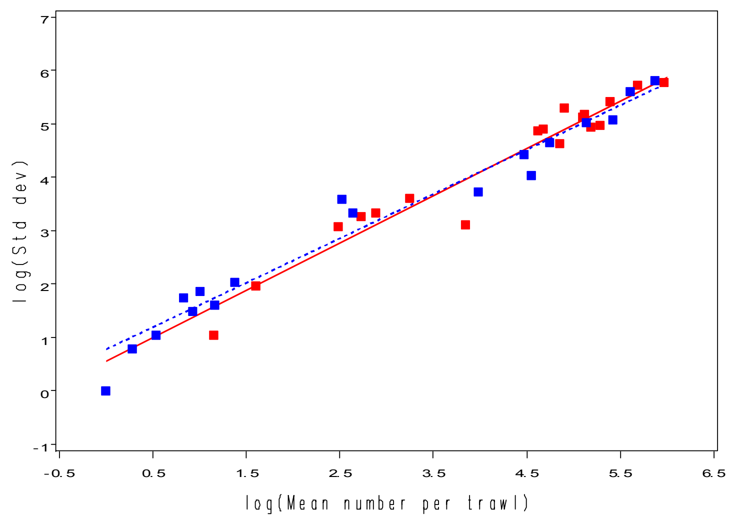
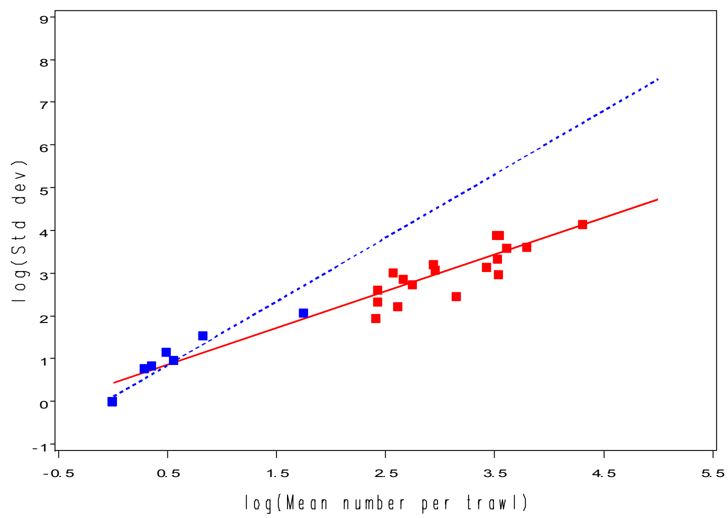


(b)

Figure 14: Relationship for *Penaeus esculentus* (red) and *Penaeus semisulcatus* (blue) between sample mean and sample standard deviation for number of (a) sub-adult and (b) adult prawns caught per hour in August 2002 survey. The mean and standard deviation have been log$_e$-transformed.



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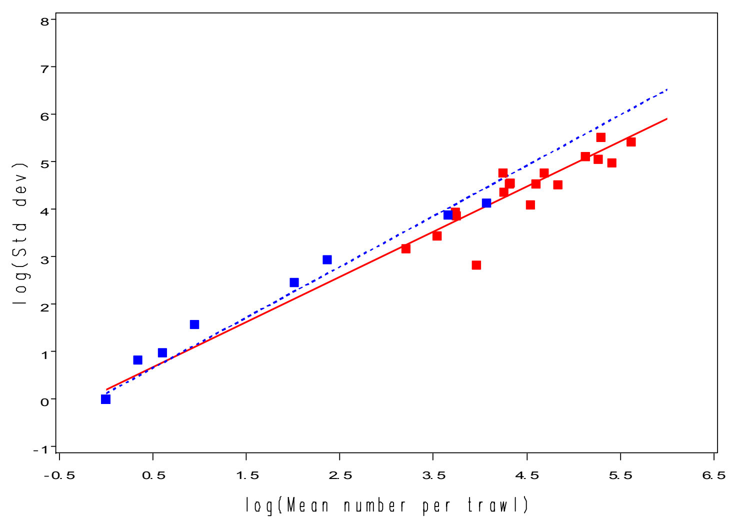
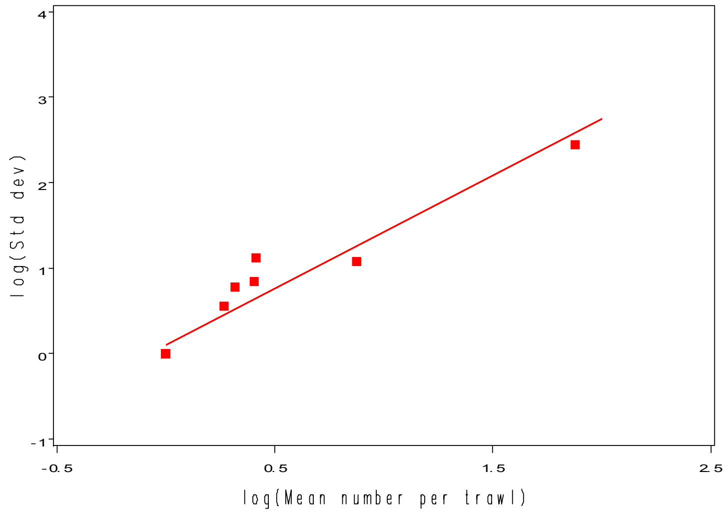


(b)

Figure 15: Relationship for *Metapenaeus endeavouri* (red) and *Metapenaeus ensis* (blue) between sample mean and sample standard deviation for number of (a) sub-adult and (b) adult prawns caught per hour in August 2002 survey. The mean and standard deviation have been log$_e$-transformed.



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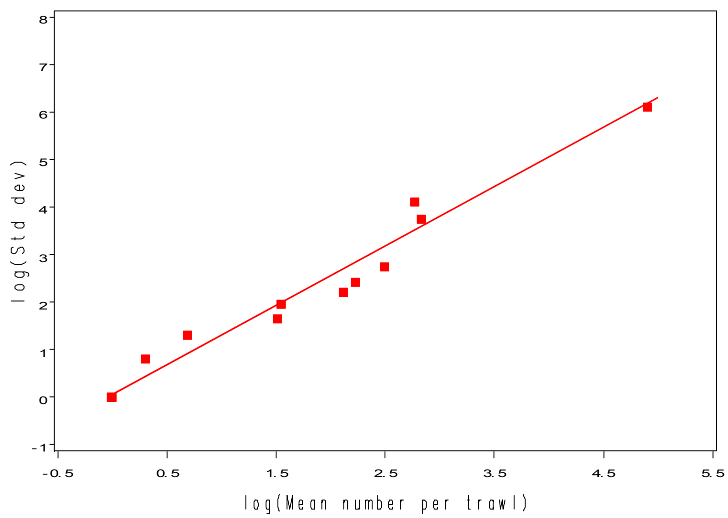


(b)

Figure 16: Relationship for *Penaeus merguiensis* between sample mean and sample standard deviation for number of (a) sub-adult and (b) adult prawns caught per hour in August 2002 survey. The mean and standard deviation have been $\log_e$-transformed.

6.3 Spawning Index

6.3.1 Precision of index

The catch rates presented in this chapter for each species are the number of prawns caught per hour, in two age classes (sub-adults and adults; definitions given in Chapter 4). For each region, age class and species an index was calculated in the manner described in Chapter 4.

Catch rates for adult *P. semisulcatus* (grooved tigers) (Table 8) were highest at Groote (131.5 h^{-1}) with negligible quantities caught in the South East Gulf. Adult *P. esculentus* (brown tigers) were more or less equally abundant in all three regions (121.8–146.0 h^{-1}), as were *M. endeavouri* (blue endeavours) (95.4–120.1 h^{-1}). Catch rates for *M. ensis* (red endeavours) were negligible everywhere except at Groote where 14.1 h^{-1} was caught. Adult *P. merguiensis* (banana prawns) were most abundant at Mornington (44.5 h^{-1}) but this is low compared with the other commercial species.

The coefficient of variation (CV) for the two tiger prawn species and blue endeavours ranged from 14.8% to 27.4% for this survey, which is very good. However, we should consider incorporating a few extra sites to reduce CV's even further.

Catch rates for sub-adult prawns were highest at Groote for grooved and brown tiger prawns and the blue endeavours (64.8 h^{-1}, 41. 0 h^{-1}, 30.8 h^{-1} respectively; (Table 9). Very few sub-adult bananas were caught in any region.

The mean-variance relationship obtained in this survey (Figure 14 to Figure 16) confirms, in principle, the expectations of the preliminary design (Dichmont *et al.* 2002). This means that the decision to stratify by effort and depth (and allocate more effort to the areas of expected higher catch) has resulted in better CV's than if we had undertaken an unstratified survey.

In terms of within-region information, indices for each depth show enough contrast in density to provide fairly good comparisons even though the CV's for strata with high means are fairly high. On the other hand, many of the indices for the different effort strata are probably not statistically significant and further sampling design may be needed (Figure 14 to 18).

Table 8: Mean number of adult prawns caught per hour per region for the August 2002 survey, for five commercial species, with standard error (S.E.) and coefficient of variation (C.V.)

Species	Statistic	Region		
		Groote	Mornington	Vanderlins
Banana prawns				
P. merguiensis	Mean	**5.0**	**44.5**	**7.1**
	S.E.	2.5	39.5	5.3
	C.V.	50.8	88.8	75.3
Endeavour prawns				
M. endeavouri	Mean	**120.1**	**95.4**	**119.6**
	S.E.	18.0	17.5	32.7
	C.V.	15.0	18.4	27.4
M. ensis	Mean	**14.1**	**< 0.1**	**1.1**
	S.E.	3.6	< 0.1	0.4
	C.V.	25.5	100.0	32.7
Tiger prawns				
P. esculentus	Mean	**127.7**	**121.8**	**146.0**
	S.E.	24.0	18.5	35.9
	C.V.	18.8	15.2	24.6
P. semisulcatus	Mean	**131.5**	**6.0**	**50.5**
	S.E.	19.4	1.5	8.4
	C.V.	14.8	24.4	16.6

Table 9: Mean number of sub-adult prawns caught per hour per region for the August 2002 survey, for five commercial species, with standard error (S.E.) and coefficient of variation (C.V.).

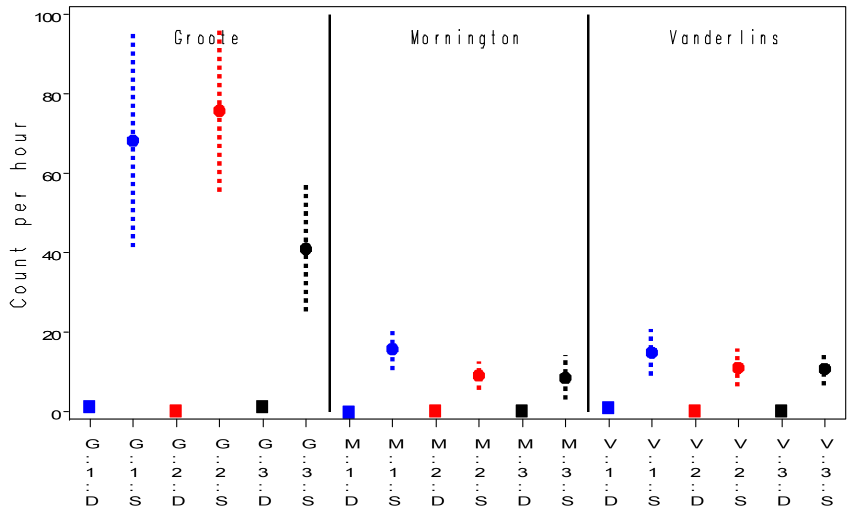
Species	Statistic	Region		
		Groote	Mornington	Vanderlins
Banana prawns				
P. merguiensis	Mean	**< 0.1**	**2.1**	**0.2**
	S.E.	< 0.1	1.0	0.2
	C.V.	100.0	44.7	81.5
Endeavour prawns				
M. endeavouri	Mean	**30.8**	**23.1**	**24.0**
	S.E.	6.5	3.9	6.3
	C.V.	21.1	16.8	26.3
M. ensis	Mean	**0.7**	**0.4**	**< 0.2**
	S.E.	0.3	0.3	< 0.1
	C.V.	46.7	78.0	60.0
Tiger prawns				
P. esculentus	Mean	**41.0**	**8.1**	**7.8**
	S.E.	10.7	2.0	2.5
	C.V.	26.2	24.8	31.5
P. semisulcatus	Mean	**64.8**	**0.6**	**10.4**
	S.E.	11.2	< 0.3	2.9
	C.V.	17.3	41.9	27.6

6.3.2 Results by stratum and region

The mean results for each stratum are presented in Figures 17 to 21. These show where the highest catches occurred. They also show whether a stratum has a high mean catch due to a few productive sites (large standard error bars) or consistently high catch rates over most sites in that stratum (small standard error bars).

Both adult and sub-adult brown tiger prawns were found in the shallower strata for all three regions. For adult prawns, the highest effort stratum in each region had the highest catch rates though the difference among effort strata was small in the Mornington region (Figure 17). In sharp contrast to the brown tiger prawns, both adult and sub-adult grooved tiger prawns (Figure 18) were found in the deeper strata for all regions. In the Groote region especially, higher catch rates were observed in the highest-effort strata.

M. endeavouri prawns (Figure 19) had higher catch rates in shallower waters of the Groote and Vanderlins regions, but the reverse in the Mornington region, for both adult and sub-adult prawns. *M. ensis* (Figure 20) catch rates were negligible everywhere except in the deeper waters off Groote. Except for one big catch in the shallow, low effort stratum off Mornington, very few *P. merguiensis* were caught.



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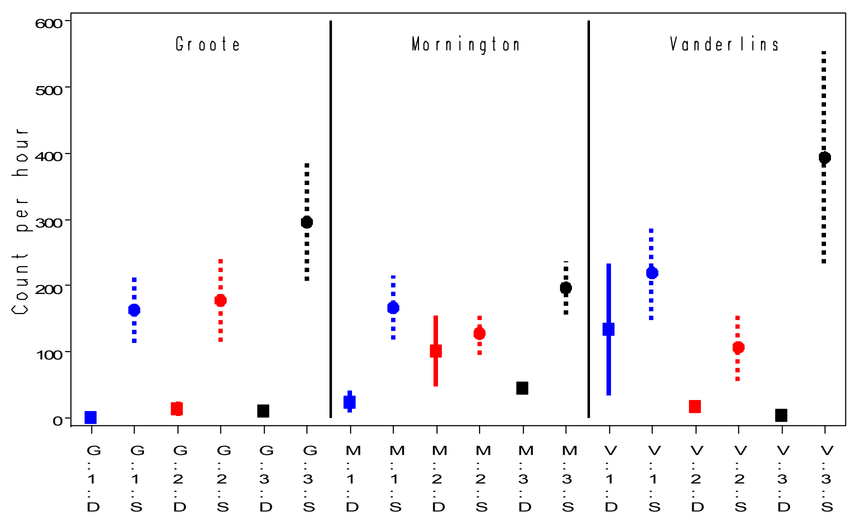
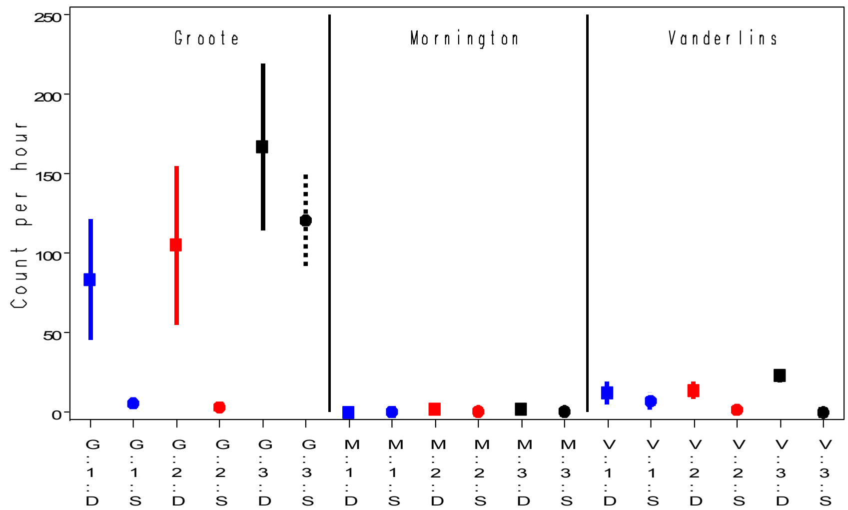


(b)

Figure 17: Mean (with standard errors) count per hour in the August 2002 survey for *Penaeus esculentus* **in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, M=Mornington, V=Vanderlins}, effort stratum {1 (blue)=light, 2 (red)=medium, 3 (black)=heavy} and depth stratum {D (solid line)=deep, S (dashed line)=shallow}.**



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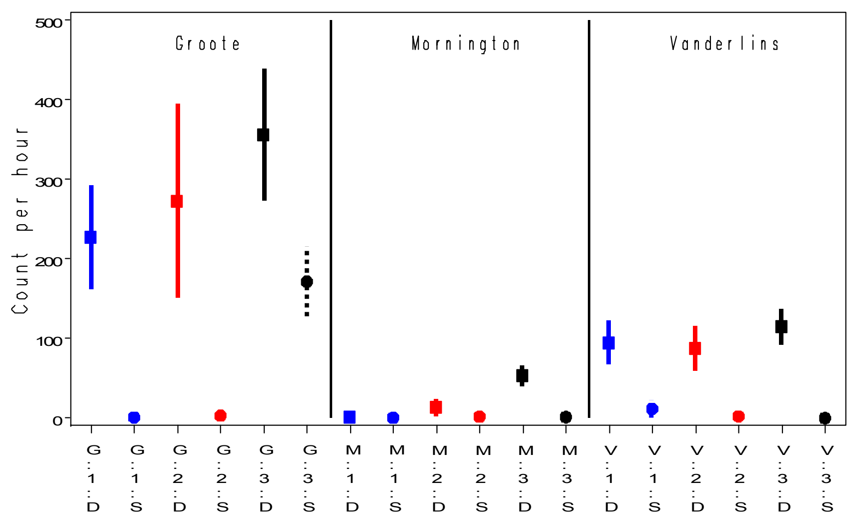


(b)

Figure 18: Mean (with standard errors) count per hour in the August 2002 survey for *Penaeus semisulcatus* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, M=Mornington, V=Vanderlins}, effort stratum {1 (blue)=light, 2 (red)=medium, 3 (black)=heavy} and depth stratum {D (solid line)=deep, S (dashed line)=shallow.

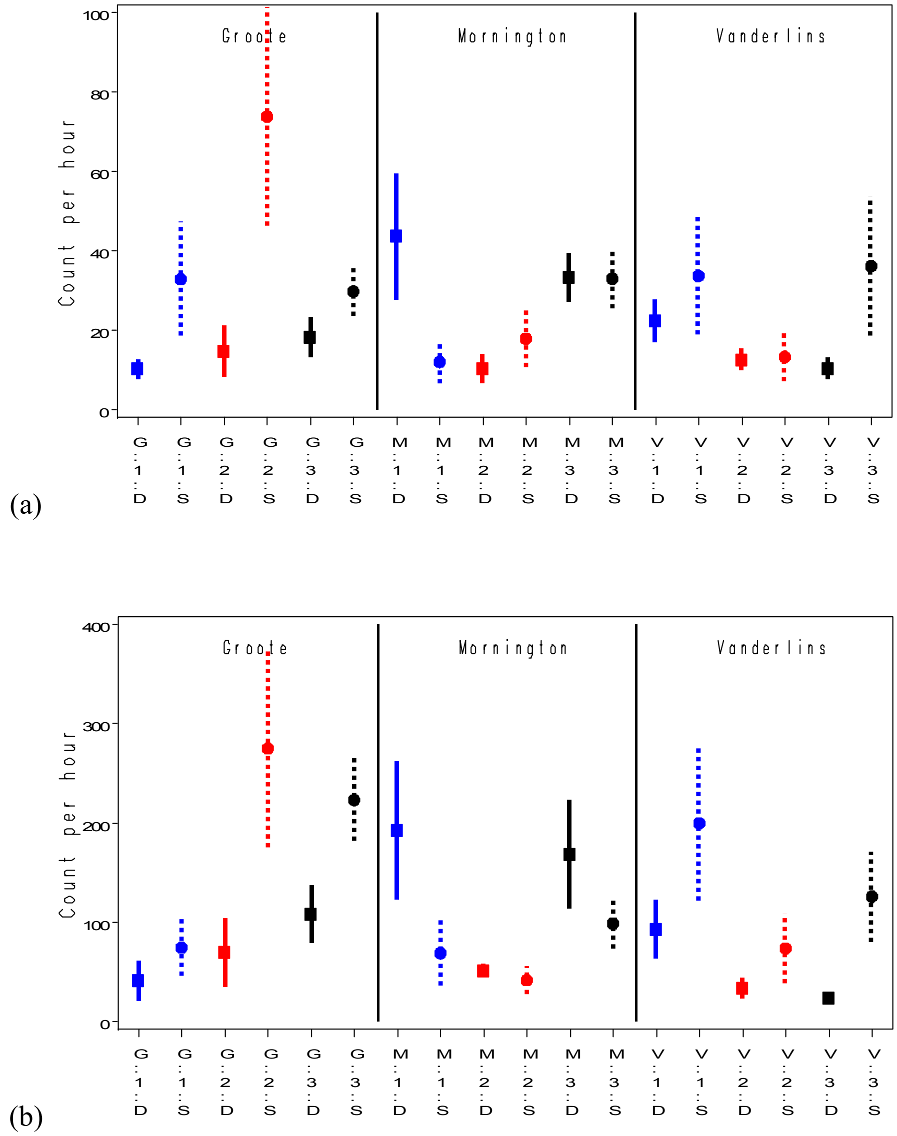


Figure 19: Mean (with standard errors) count per hour in the August 2002 survey for *Metapenaeus endeavouri* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, M=Mornington, V=Vanderlins}, effort stratum {1 (blue)=light, 2 (red)=medium, 3 (black)=heavy} and depth stratum {D (solid line)=deep, S (dashed line)=shallow.

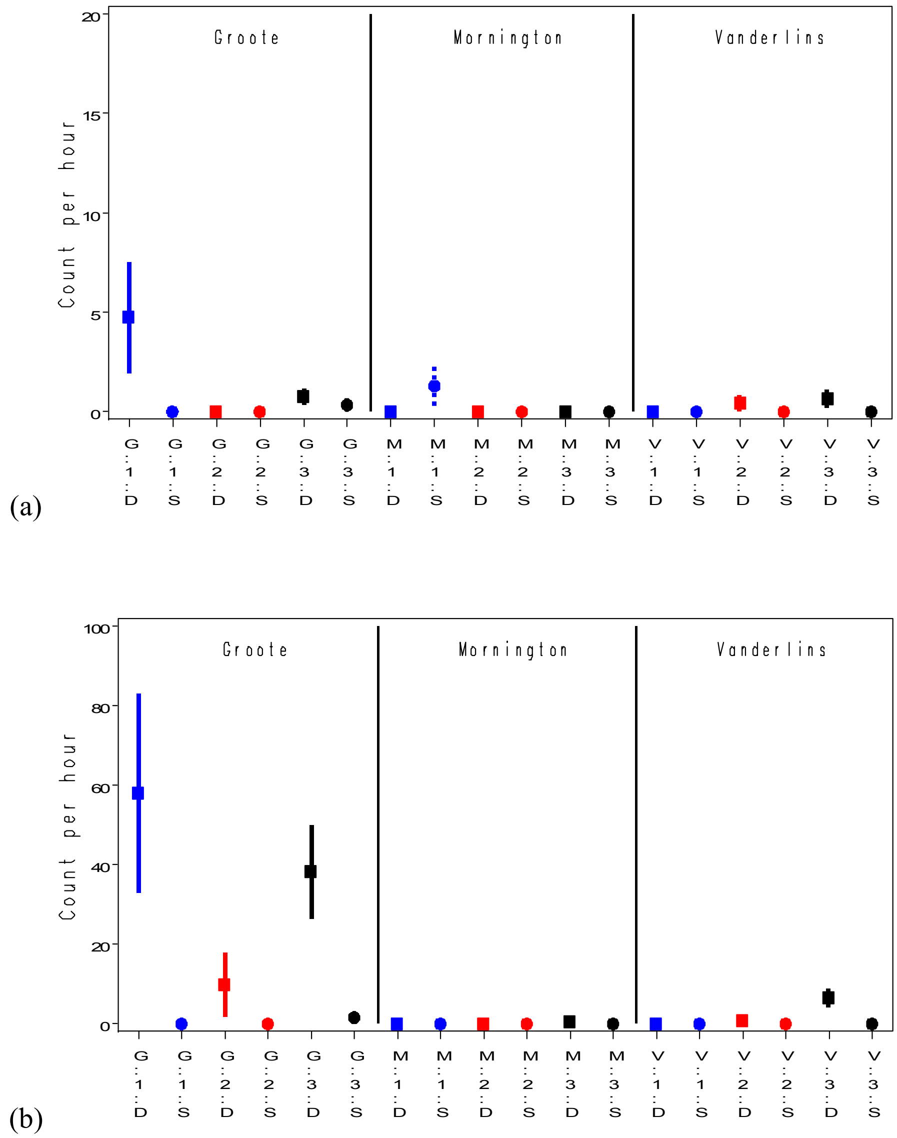
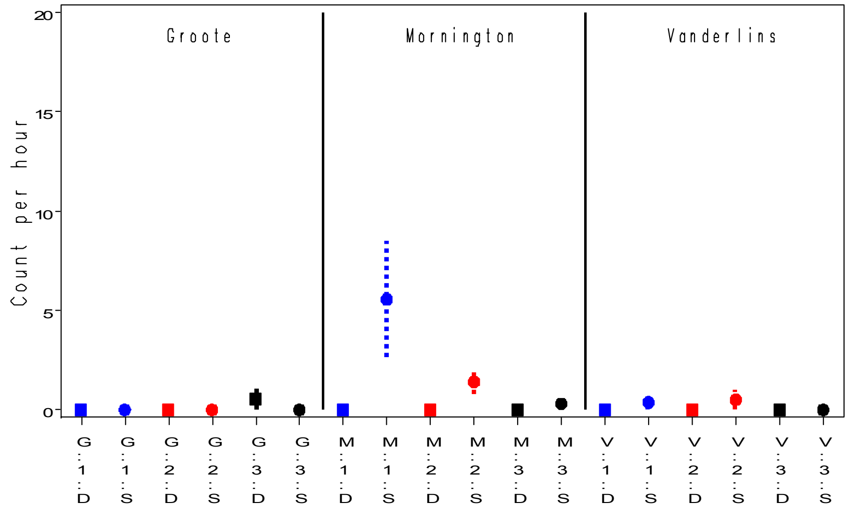


Figure 20: Mean (with standard errors) count per hour in the August 2002 survey for *Metapenaeus ensis* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, M=Mornington, V=Vanderlins}, effort stratum {1 (blue)=light, 2 (red)=medium, 3 (black)=heavy} and depth stratum {D (solid line)=deep, S (dashed line)=shallow.



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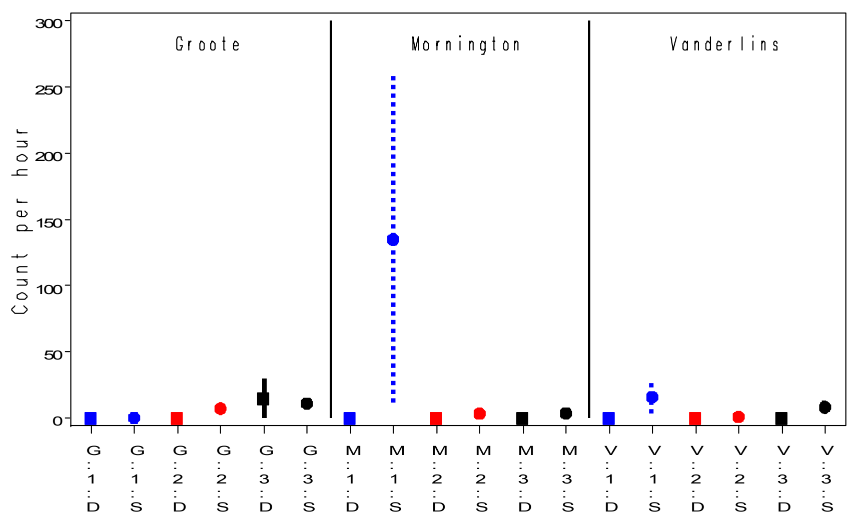

(b)

Figure 21: Mean (with standard errors) count per hour in the August 2002 survey for *Penaeus merguiensis* in each stratum in each of the five study regions for (a) sub-adult and (b) adult prawns. Label on horizontal axis indicates region {G=Groote, M=Mornington, V=Vanderlins}, effort stratum {1 (blue)=light, 2 (red)=medium, 3 (black)=heavy} and depth stratum {D (solid line)=deep, S (dashed line)=shallow.

6.4 Temperature and Salinity

Temperatures recorded just above the seabed during trawls in August were not significantly different between shallow and deep sites in the same region. Temperatures around Groote (23.0-24.0) were slightly higher than elsewhere (21.3-22.8). There was little variation in salinity among survey regions. Water temperatures in August were substantially lower than temperatures recorded during the January 2003 survey (28.1-30.3°C).

Table 10: Mean bottom temperature (°C) and salinity (+standard errors) for shallow and deep sites during the survey in August 2002. Data was not available for some areas due to technical problems with one of the loggers

Region	Temperature		Salinity	
	Shallow	Deep	Shallow	Deep
North Groote	23.7 (0.08)	24.0 (0.05)	33.4 (0.06)	33.2 (0.04)
South Groote	23.0 (0.04)		33.7 (0.03)	
West Vanderlins	22.3 (0.07)		33.2 (0.14)	
East Vanderlins	22.3 (0.05)	22.8 (0.08)	33.4 (0.07)	33.4 (0.02)
West Mornington	22.2 (0.12)		33.3 (0.05)	
North Mornington		22.7 (0.06)		33.1 (0.03)
East Mornington	21.3 (0.09)		33.3 (0.13)	

6.5 Discussion

It is difficult to assess, based on one survey, how successful this first survey has been in providing an accurate index of the abundance of spawners in the Gulf of Carpentaria fishery. However, there are several indications that the survey has been successful and that, with some modifications, it will be useful in providing an assessment of the annual variation in abundance of prawns in the fishery and of long-term trends.

- The level of variation in catch rates found within each region in the survey was mostly within the limits expected from analyses of past survey data. Some of the comparisons between strata within regions are probably not statistically significant. However, it is likely that useful comparisons will be able to be made between years in the future for those species and regions that are regarded as being very important for the fishery; e.g. brown tigers at Mornington, grooved tigers at Groote.

- The pattern of catches for tiger prawns agrees well with the regional pattern of commercial catches seen in the fishery in recent years – adult grooved tiger prawns were most abundant north of Groote. Adult brown tiger prawns were caught in similar numbers across the three regions, whereas historically these would have been highest around Mornington.

- The combined tiger prawn catch was highest at Groote, particularly north of Groote, and this pattern was also reflected in the catch rates in the commercial fishing season that began just after the completion of this survey. This gives us some confidence that the trends in catches seen in the survey reflected real patterns of abundance on the fishing grounds.

This survey represents the first time that a substantial prawn research survey has been carried out in the Vanderlins region and, despite the lack of previous survey data, the Coefficients of Variation were mostly in line with C.V.s for the other regions.

It is clear that the mix of species and the pattern of catch rates was quite different for each region and therefore further surveys in August need to continue sampling these three regions to provide an accurate estimate of the spawning abundance in the Gulf of Carpentaria.

6.6 Conclusion

1. The survey further supports the recruitment index conclusions.

2. Brown tiger prawns are more numerous inshore than offshore and vice versa for grooved tiger prawns.

3. The distribution patterns of *M. endeavouri* were similar to brown tiger prawns and *M. ensis* were similar to grooved tigers (although the *M. ensis* densities were very low).

4. The mean-variance relationships obtained were, in general, similar to those derived from past surveys. The slopes for tiger prawns were lower than that obtained in the January recruitment index survey. For banana prawns, the slope was higher.

5. The stratification by depth and effort was successful in producing quite good Coefficients of Variation (CVs) for the two species of tigers ranging from 14.8–24.6% for adult prawns.

6. We were able to produce good indices of abundance at regional level, despite having to re-allocate trawl sites during the survey in order to maintain the sampling rate.

7. Preliminary work using these results in another study (the fishing power project) has shown that this survey (as part of an ongoing series) will be useful for evaluating both the fishing power series over time, and spatial changes of the fishery relative to the resource.

8. As a result of the good precision obtained, the survey will be very useful as an index of Spawning abundance as part of an ongoing series.

6.7 References

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CHAPTER 7 PRAWN SIZE COMPOSITION, MATURITY, PARASITES

7.1 Introduction

It is important when analyzing the prawn catch data from these surveys and, ultimately, in using the results to comment on the status of stocks, to have an understanding of the size and reproductive status of the prawns caught during the surveys. For the January recruitment survey, we need to know that our survey has adequately sampled the smaller, new recruits to the fishery, whereas for the August spawning survey, we need to adequately sample the prawns that are contributing to the fishery and to the spawning stock at that time of year.

7.2 Methods

For most trawls, we measured all individuals of the commercial prawn species that we caught. In some trawls where the prawn catch was large, not all prawns were measured. In these cases a subsample of around 100 prawns was measured and this was taken as being representative of the size composition of the whole catch for that sample. The carapace length (CL) (head length) was measured using vernier calipers to the nearest 0.1 mm.

In order to calculate the size-frequency, we aggregated the measurements into 1-mm size categories and pooled all measurements for each species, region and depth stratum.

7.3 Results and Discussion

7.3.1 Size composition

A large number of prawns were measured in the two surveys. In August 2002, over 20,200 prawns and in January 2003, over 45,600 prawns were measured.

The size range of prawns measured in both surveys was large (Table 11). For example, in January, the smallest *Penaeus esculentus* measured was 15.8 mm Carapace Length (CL) and the largest was 57.0 mm CL. For all species except *Penaeus longistylus* the mean size of all prawns measured was smaller in January than in August. Similarly, the smallest prawn measured for all species was caught in January. This is as one would expect given the life cycle of prawns in the NPF (Rothlisberg et al. 1985, Somers et al. 1987).

Table 11: The number measured and the mean, minimum and maximum sizes of all commercial prawn species measured during the two surveys in August 2002 and January 2003.

	August 2002				January 2003			
Species	Number measured	Mean	Min	Max	Number measured	Mean	Min	Max
Penaeus esculentus	6054	37.3	18.2	56.8	10536	32.1	15.8	57.0
Penaeus semisulcatus	5129	38.3	18.8	58.8	13940	31.1	15.9	61.2
Metapenaeus endeavouri	6551	33.8	15.5	49.6	14092	27.7	11.5	49.6
Metapenaeus ensis	443	37.3	17.5	54.2	1077	31.7	13.3	51.0
Penaeus merguiensis	464	36.2	24.8	48.8	3077	30.7	19.3	49.9
Penaeus latisulcatus	1592	36.5	20.7	57.2	2501	34.1	17.1	58.6
Penaeus longistylus	52	34.7	23.0	53.1	452	37.9	18.7	58.5
Penaeus monodon	1	53.0	53.0	53.0	19	44.0	31.4	57.0

The size composition of prawns caught for each species is slightly different for each region but the predominant patterns can be clearly seen at North Groote Eylandt. In August 2002, the *Penaeus semisulcatus* population was dominated by large males and females with shallow (< 30 m) and deep (> 30 m) site patterns being quite similar (Figure 22a and b). In January 2003, the majority of prawns in the population were much smaller; derived from spawning occurring in the last half of the previous year (Figure 22c and d). The remnant of prawns that were in the population sampled during the previous August can still be seen as small peaks of larger prawns (highlighted by arrows on Figure 22).

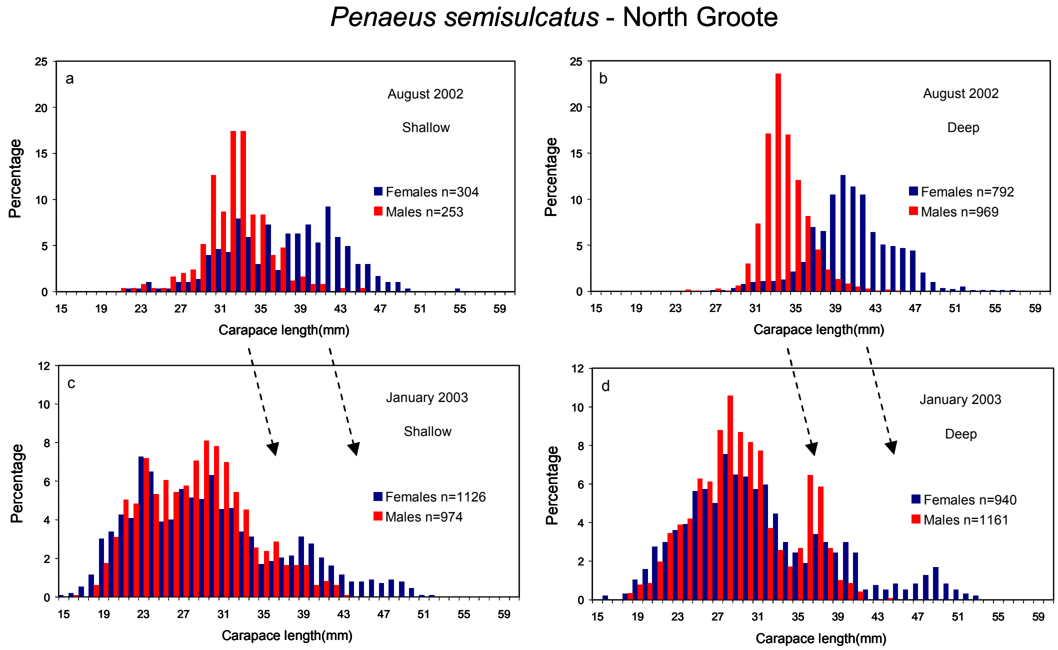

Figure 22: Percentage length frequency distribution of *Penaeus semisulcatus* at shallow and deep sites at North Groote in August 2002 and January 2003. Note the different scales for August and January.

The pattern for *Penaeus esculentus* was similar although there were fewer very small recruits in January (Figure 23). The very erratic size composition seen at the deep sites reflects the overall lower abundance of *Penaeus esculentus* in offshore waters at Groote.

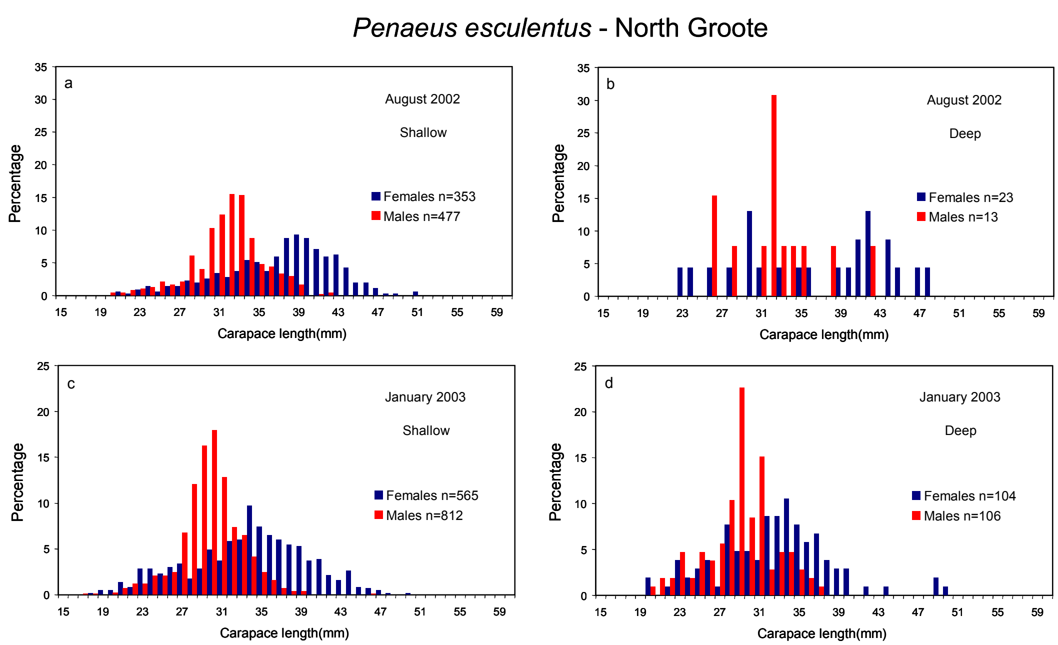

Figure 23: Percentage length frequency distribution of *Penaeus esculentus* at shallow and deep sites at North Groote in August 2002 and January 2003. Note the different scales for August and January.

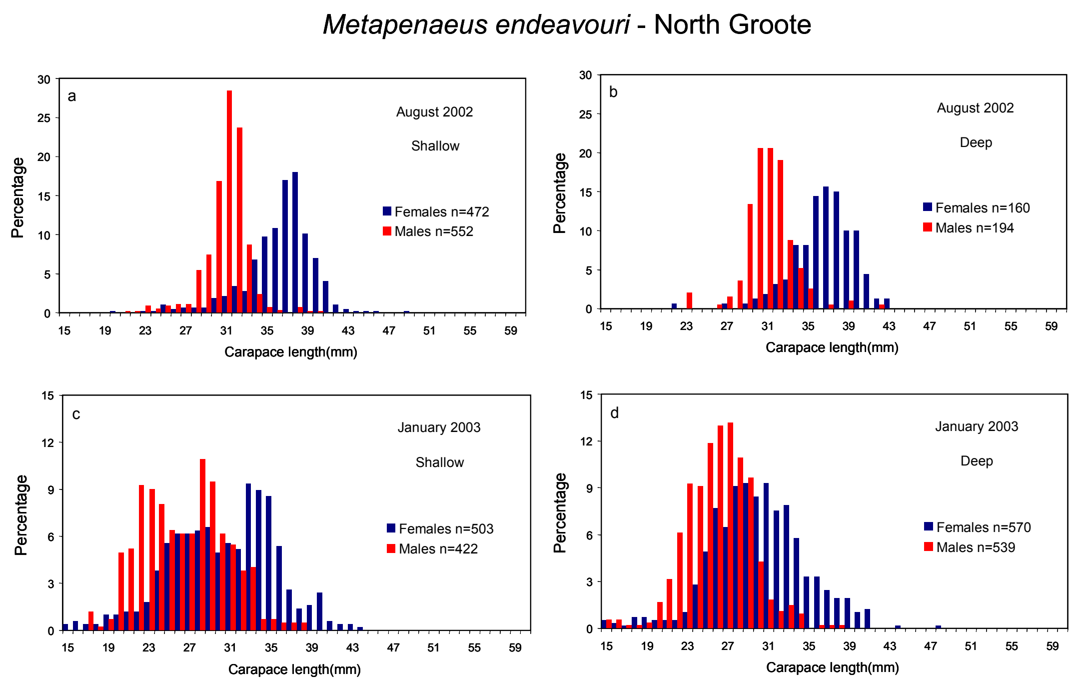

Figure 24: Percentage length frequency distribution of *Metapenaeus endeavouri* at shallow and deep sites at North Groote in August 2002 and January 2003. Note the different scales for August and January.

Penaeus esculentus

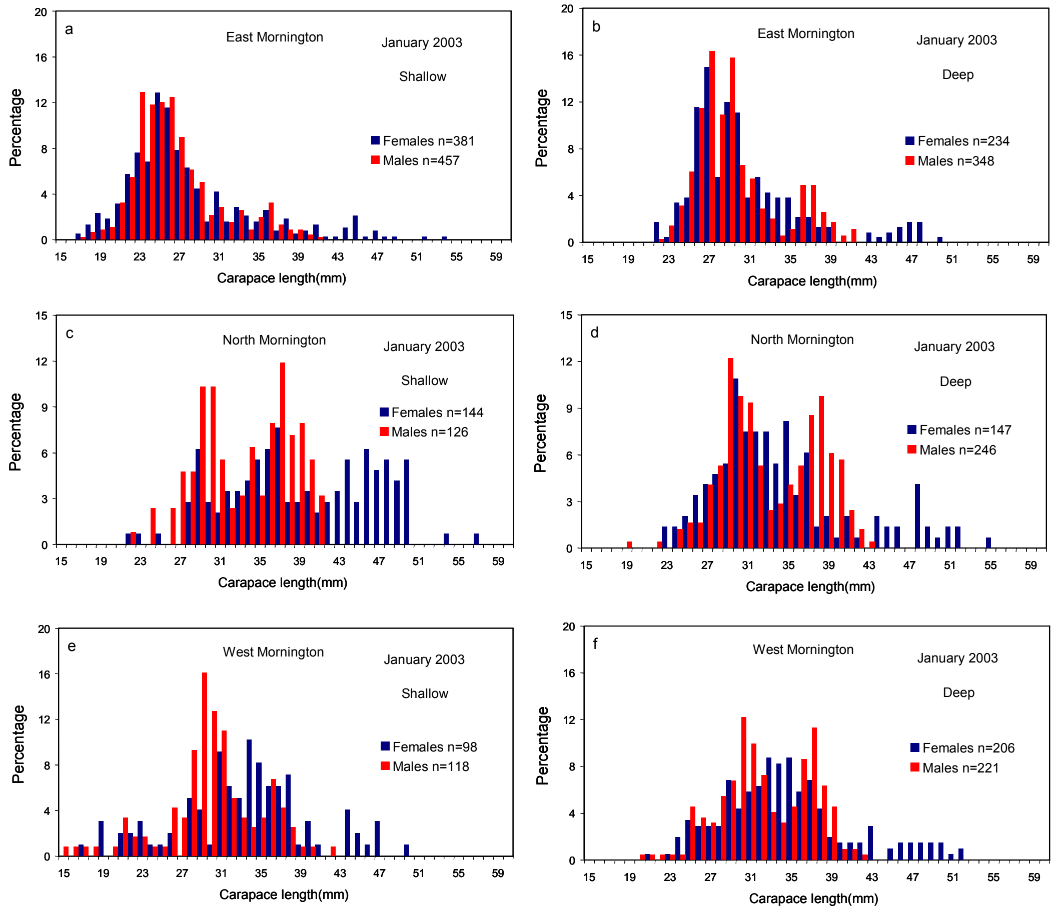

Figure 25: Percentage length frequency distribution of *Penaeus esculentus* over all shallow and deep sites at East, North and West Mornington Island in January 2003. Note the different scales for each region.

The size composition of prawns in the *Penaeus esculentus* populations around Mornington Island were of some interest (Figure 25). There were some new recruits and some larger prawns from the previous year in all areas, however the highest proportion of smaller recruits was at the shallow sites East of Mornington. The North Mornington sites had the smallest proportion of new recruits and also had a high proportion of large prawns from the previous year’s stock.

Penaeus merguiensis

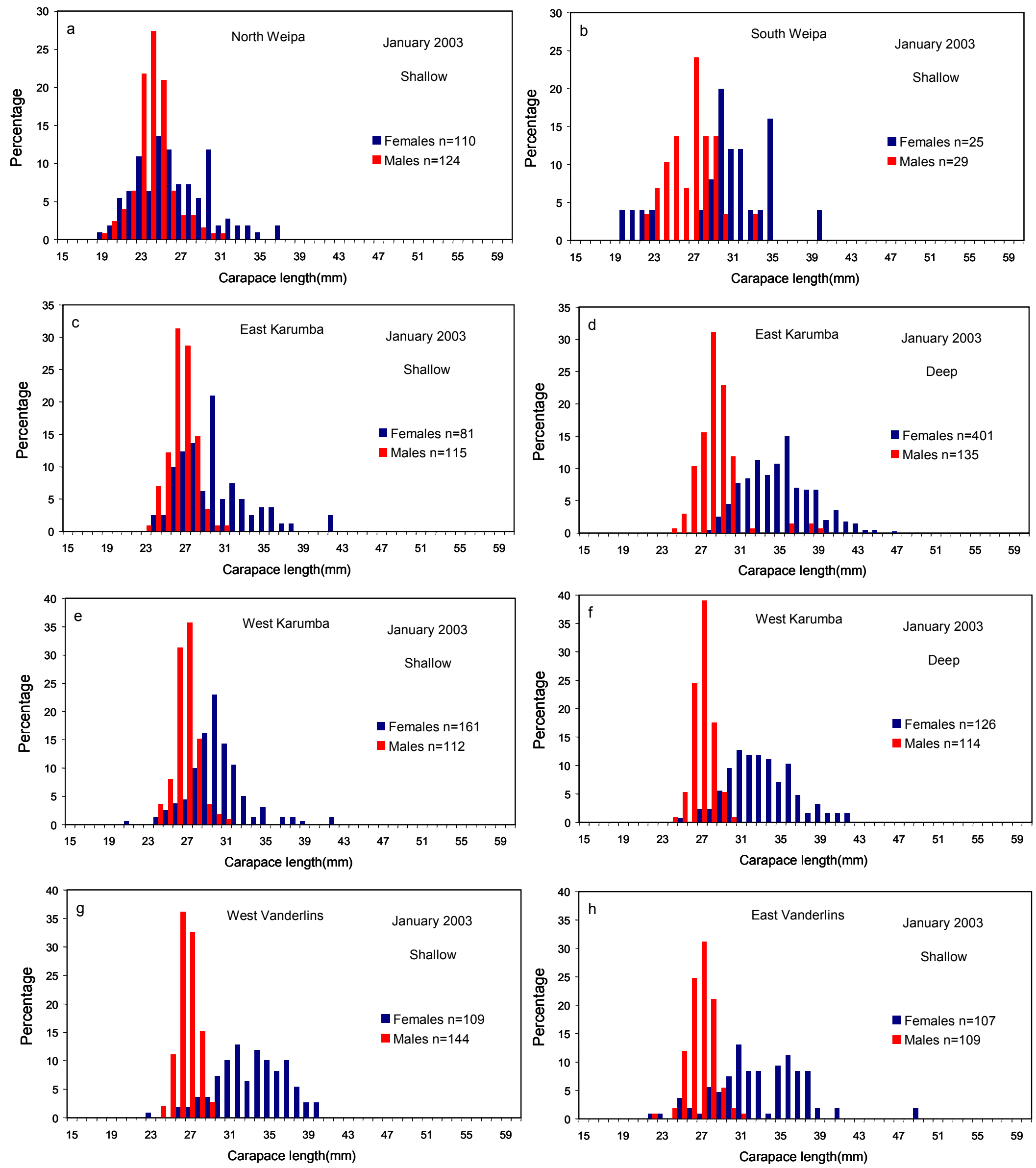

Figure 26: Percentage length frequency distribution of *Penaeus merguiensis* over some shallow and deep sites at North and South Weipa (shallow), East and West Karumba (shallow and deep), and East and West Vanderlins (shallow) in January 2003. Note the different scales for each region.

Very few *Penaeus merguiensis* were caught in August but the size composition of catches in several regions in January 2003 showed the presence of small recruits in the populations (Figure 26). The highest proportion of small recruits was seen at Weipa, while recruits at the Karumba and Vanderlins sites were larger. At Karumba, the recruits caught at the deep sites were larger than at the shallow sites.

7.3.2 Prawn maturity

A large proportion of the females measured in August 2002 had visible ovaries (ripe) indicating that they were in reproductive condition (Table 12). When more than 50 females of *Penaeus esculentus* were caught in a region, from 62.3 to 91.2% of the females had visible ovaries. The lowest proportion of ripe females was for *Penaeus semisulcatus* in shallow water at South Groote where only 21.1% of the females were ripe.

Table 12: The percentage of females measured with visible ovaries at each group of sites in August 2002. Percentages were only included if at least 50 females were measured

	Penaeus esculentus		*Penaeus semisulcatus*		*Metapenaeus endeavouri*	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
North Groote	62.3		48.4	68.1	74.4	61.9
South Groote	70.8		21.1	51.7	75.1	57.9
West Vanderlins	67.3			56.1	79.1	41.7
Vanderlins				67.1		55.8
East Vanderlins	86.6			75.4	74.7	51.8
West Mornington	78.9				61.8	
North Mornington		91.2		79.8		70.7
East Mornington	79.1				53.6	

In January 2003, the proportion of ripe females was generally less for most species, but particularly for *Penaeus semisulcatus*; in shallow water at South Groote and at the Vanderlins, less than 10% of the females were ripe (Table 13). The lower proportion of ripe females in the population is consistent with the higher numbers of young recruits in the populations in January compared to August. The differences in the proportions of spawners between *Penaeus esculentus* and *Penaeus semisulcatus* are also consistent with the results of the CSIRO study at Groote Eylandt in 1983 to 1985, where *Penaeus esculentus* was shown to mature at a smaller size and have a less seasonal pattern of spawning (Crocos 1987).

Table 13: The percentage of females measured with visible ovaries at each group of sites in January 2003. Percentages were only included if at least 50 females were measured

	Penaeus esculentus		*Penaeus semisulcatus*		*Metapenaeus endeavouri*		*Penaeus merguiensis*	
	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
North Groote	46.7	41.3	13.1	18.5	43.7	45.4		
South Groote	24.4	45.7	2.8	26.6	35.5	60.3		
West Vanderlins	51.4	58.9	2.6	36.6	63.5	18.3	47.7	
East Vanderlins	35.0	25.6	1.5	21.5	45.9	22.0	30.8	
West Mornington	45.9	51.0						
North Mornington	68.8	21.8		68.0	58.8	34.5		
East Mornington	14.2	20.9			65.2		48.4	
West Karumba							19.3	49.2
East Karumba							14.8	47.9
North Weipa			2.2	10.5			33.6	

7.3.3 Parasites

Bobyrid parasites can potentially have some impact on prawn populations as they make the prawns that they infest sterile (Table 14) (Somers & Kirkwood 1991). In these surveys, only three prawn species were found with bobyrid parasites (*Penaeus semisulcatus, P. merguiensis,* and *Metapenaeus ensis*). The percentages of prawns with parasites was mostly quite low although around 21% of the *Penaeus semisulcatus* recruits in shallow water at North Groote in January were infested. No prawns with parasites were found in the Mornington Island area.

Table 14: The percentage of prawns measured with bobyrid parasites at the shallow and deep sites in August 2002 and January 2003

	Penaeus semisulcatus		*Metapenaeus ensis*		*Penaeus merguiensis*	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
August 2002						
North Groote	10.2	2.2		0.3		
South Groote	3.1	0.3				
West Vanderlins						
East Vanderlins						
West Mornington						
North Mornington						
East Mornington						
January 2003						
North Groote	21.4	7.6				
South Groote	2.1			1.4		
West Vanderlins						
East Vanderlins		0.1	12.5			
West Mornington						
North Mornington						
East Mornington						
West Karumba					0.7	0.4
East Karumba					1.5	0.2
North Weipa	1.3	0.4				
South Weipa	1.1					

7.4 Conclusions

1. The January survey has clearly been successful in sampling smaller prawns recruiting to the fishery.
2. The August survey has also been successful in sampling mature and spawning prawns in the fishery.
3. Although January is a time of recruitment of new prawns to the fishing grounds, there are still some older prawns present in the populations.
4. A long term series of the two surveys would provide a good link between stock and subsequent recruitment.

7.5 References

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Somers, I.F., Crocos, P.J. and Hill, B.J. 1987. Distribution and abundance of the tiger prawns *Penaeus esculentus* and *P. semisulcatus* in the north-western Gulf of Carpentaria, Australia. Aust. J. Mar. Freshw. Res. 38: 63-78.

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CHAPTER 8 SURVEY DESIGN IN TERMS OF LOST TIME

8.1 Introduction

One of the key questions with regard to the design of a survey is how the results would be affected by lost time due to bad weather or vessel breakdown. In both the August 2002 (Spawning) and January 2003 (Recruitment) surveys, two vessels were used – though the Spawning survey would normally be carried out by a single vessel. In this chapter we have used data from these two surveys to examine the issue of lost time.

Due to the large spatial extent of most regions and the limited time available, the sampling itinerary has already been optimised to maximise the number of trawls per night. Sampling in a region may be interrupted halfway through, and it would be difficult to re-schedule the sampling 'on the fly' to reduce the sampling density evenly over the remaining area. Therefore, we have taken the approach that when a particular night is lost due to bad weather or gear breakdown, this results in the loss of the entire night's intended sample sites from the survey.

If two vessels are working in the same region on a given night, bad weather can mean two vessel-nights are lost from that region, which often represents one-third of the sampling effort. If vessels are working in separate regions, only one vessel-night might be lost. Gear breakdown may also cost only one vessel-night.

8.2 Methods

We used the actual sampling sequence for the August 2002 and January 2003 surveys to provide a set of pre-determined survey sites, the night on which they would be sampled and the allocation between two vessels. For each region, we then deleted in turn the data collected on each night in that region and constructed all the species by age class indices with the partially-sampled data. This usually reduces the sample size in one or more strata either to zero, or too few to construct a mean and a variance. To handle this problem, such strata were combined with suitable 'neighbouring' strata so that the region was partitioned into fewer strata that covered larger areas. The sampling frame was adjusted accordingly.

When dealing with under-sampled strata in the Spawning survey, preference was given to amalgamating with another stratum at the same depth since the mean count per hour differed more between depths than between effort levels. For example, if there were less than four samples in the medium effort, shallow stratum in Groote, this stratum would either be pooled with the low effort or the high effort stratum in shallow waters, the aim being to pool those strata with smaller sample sizes. If pooling across two effort levels did not give enough samples, the stratum was pooled with one with the same effort but different depth.

For the Recruitment survey, preference was given to pooling strata in the same sub-region except for the Vanderlins region where differences among the three depths were more pronounced than differences among the sub-regions.

8.3 Results and Discussion

Figure 27 to Figure 31 show the degree of bias for adults and sub-adults of each species in each region, for four commercial species. In these figures, each data point is the index calculated from data with either a lost region-night (blue) or a lost vessel-night (red). In some regions, a region was surveyed by only one vessel so there is effectively only one set of points on the plot. We also show the abundance index that no bias (100%) corresponds to, which is of course the index with all the sites.

In a few cases, the loss of a night has little effect e.g. sub-adult *P. esculentus* in the August survey of the Groote region (Figure 27). However, by far the most common result is serious bias. Most species are affected in each region. The bias observed can be both positive and negative depending on the relative densities of the area removed i.e. it tends to depress the index if the area contained many prawns and *vice versa*. Surprisingly, the affect of losing two vessel nights due to bad weather, at times, is not much different than losing a single vessel night. This may be because the vessels survey some of the regions within close proximity of each other.

It is clear that the continuity of the survey can be seriously compromised when at least a single vessel night is lost. The reason for this serious bias is that a vessel tends to cover a stratum or a large part thereof in a night's fishing. The loss of a night compromises the spatial integrity of the survey. It is therefore recommended that bad weather or vessel loss be recovered by adding to the survey and sampling the lost region.

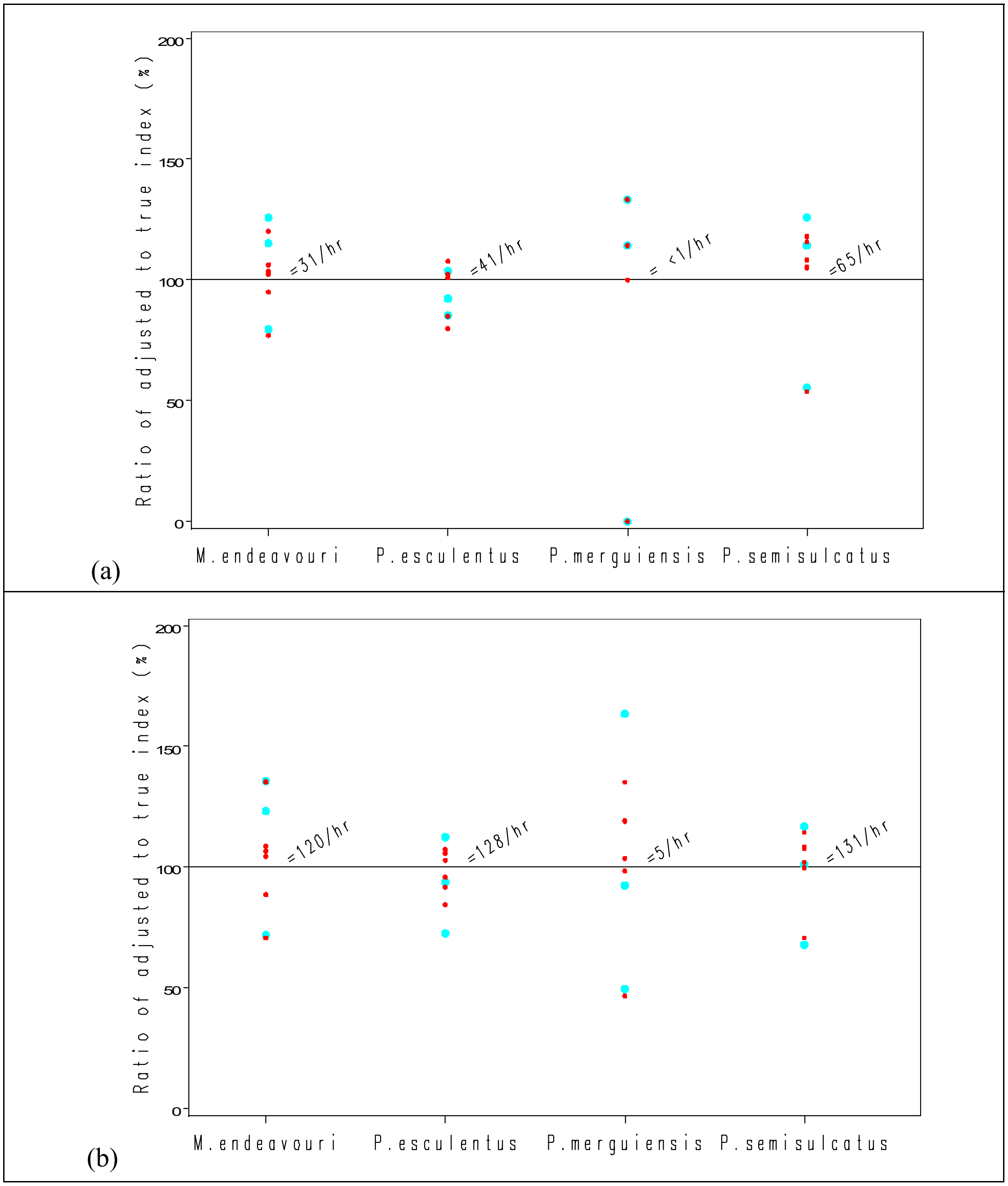


Figure 27: The effect of deleted survey nights on the August 2002 survey index for (a) sub-adult and (b) adult prawns of four commercial species, in the Groote region. Each data point is the ratio of the index calculated using the incomplete data to the index calculated from the full data for that region. Blue dots indicate a deleted night for the region (two vessels); and red dots indicate a deleted vessel night for the region. The 100% line represents the index calculated for the complete data for each species for that region. The numbers in black (e.g. = 120/hr) represent the actual number of prawns per hour caught using all data for the species.

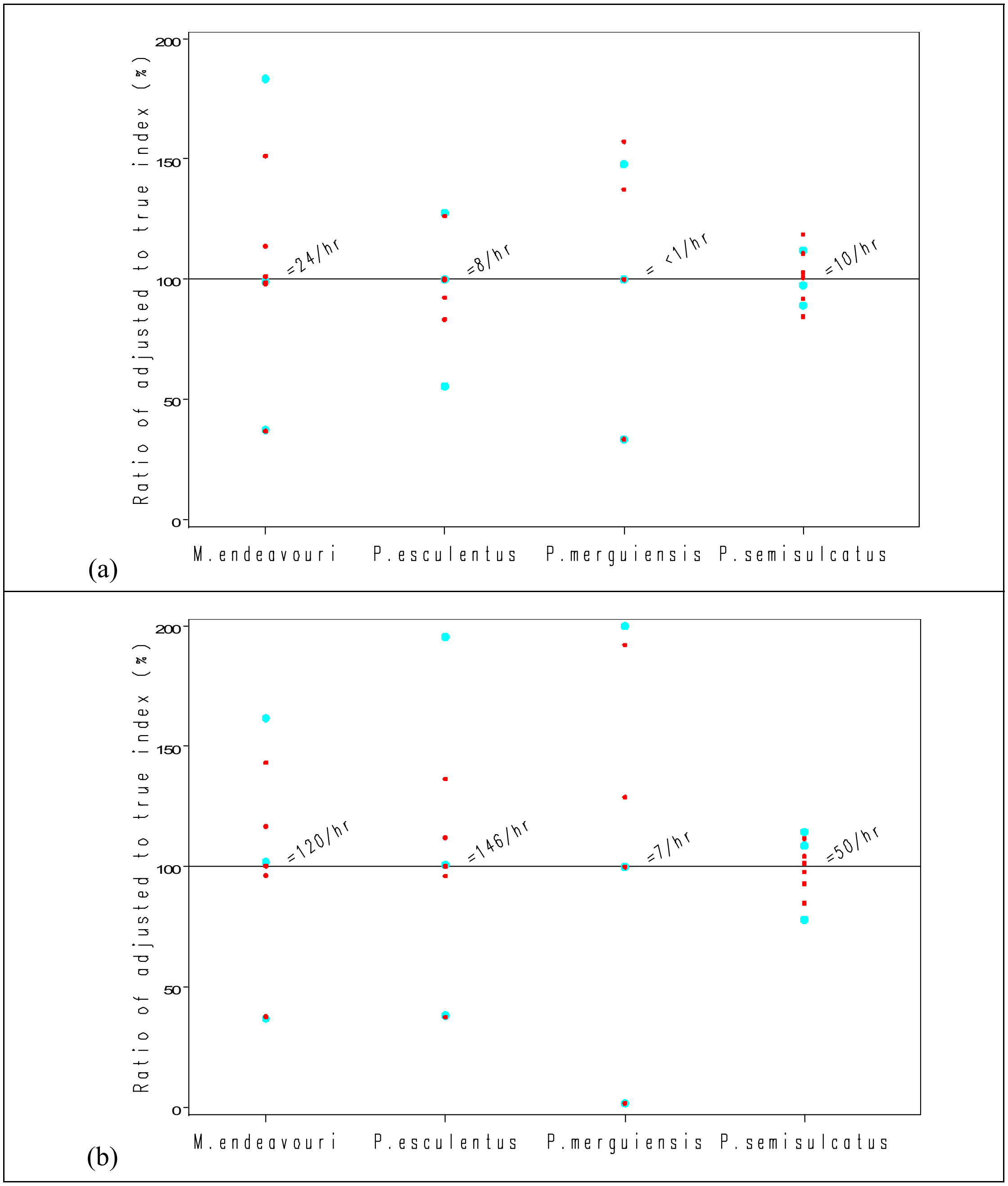


Figure 28: The effect of deleted survey nights on the August 2002 survey index for (a) sub-adult and (b) adult prawns of four commercial species, in the Vanderlins region. Each data point is the ratio of the index calculated using the incomplete data to the index calculated from the full data for that region. Blue dots indicate a deleted night for the region (two vessels); and red dots indicate a deleted vessel night for the region. The 100% line represents the index calculated for the complete data for each species for that region. The numbers in black (e.g. = 120/hr) represent the actual number of prawns per hour caught using all data for the species.

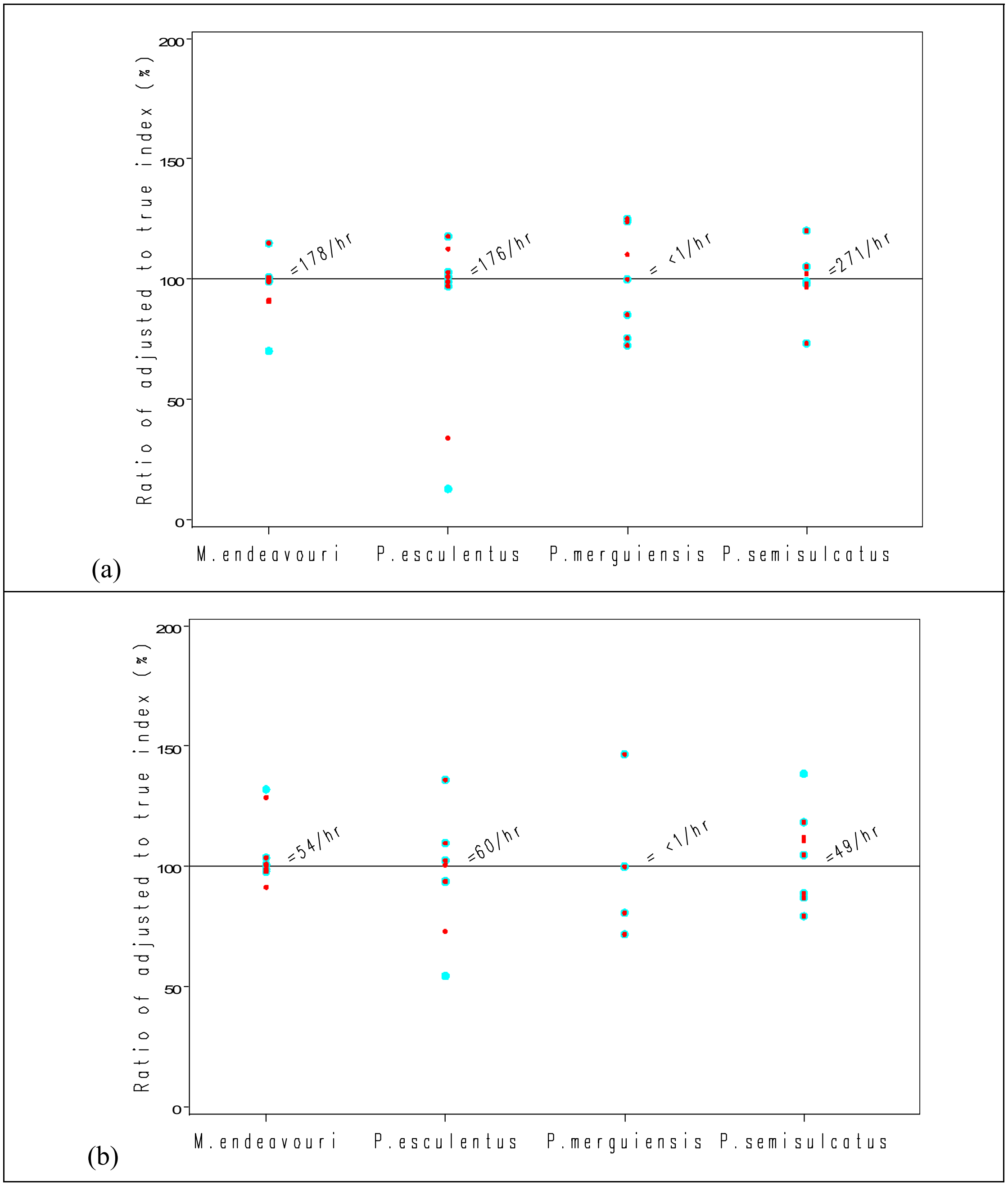


Figure 29: The effect of deleted survey nights on the January 2003 survey index for (a) sub-adult and (b) adult prawns of four commercial species, in the Groote region. Each data point is the ratio of the index calculated using the incomplete data to the index calculated from the full data for that region. Blue dots indicate a deleted night for the region (two vessels); and red dots indicate a deleted vessel night for the region. The 100% line represents the index calculated for the complete data for each species for that region. The numbers in black (e.g. = 54/hr) represent the actual number of prawns per hour caught using all data for the species.

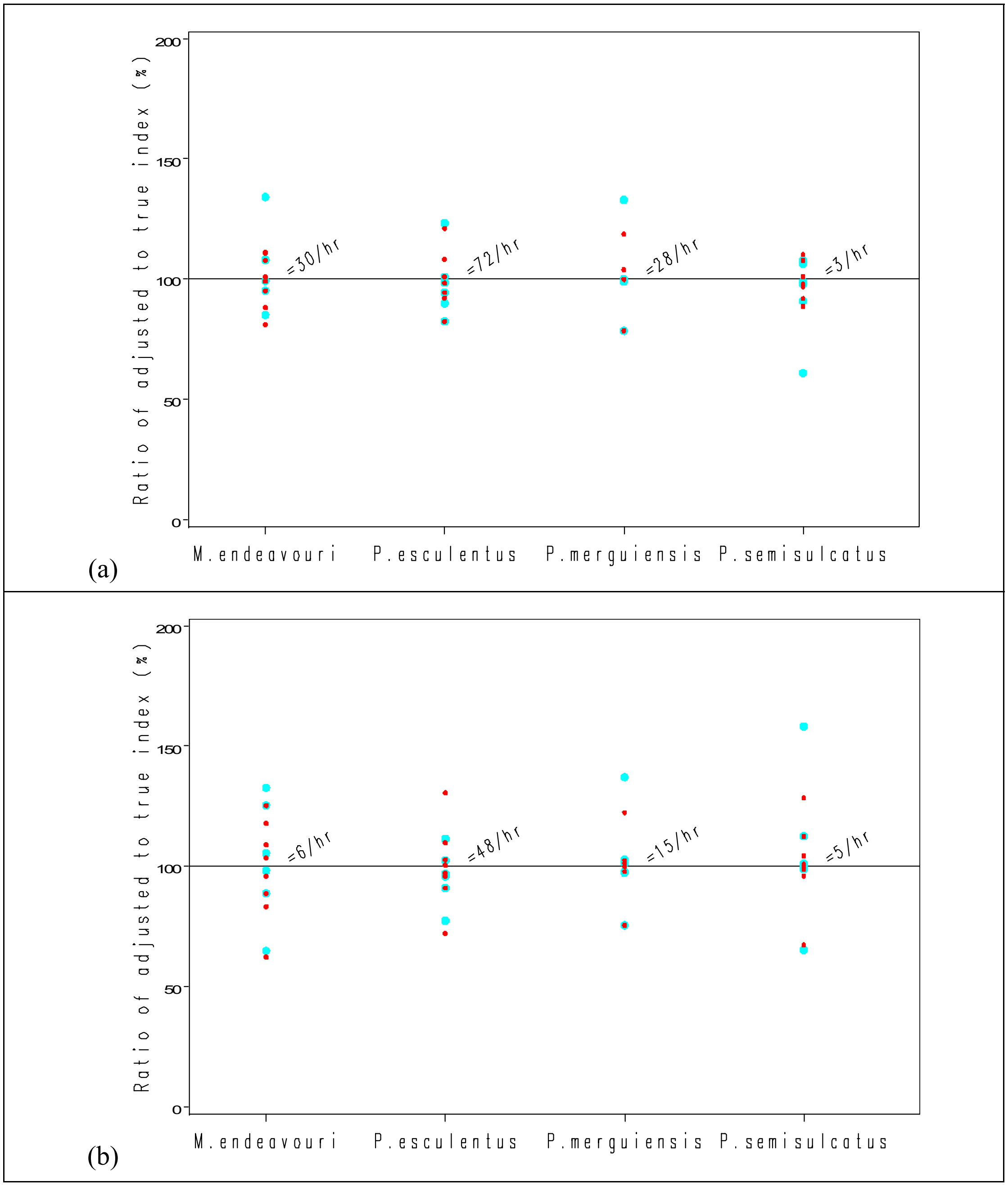


Figure 30: The effect of deleted survey nights on the January 2003 survey index for (a) sub-adult and (b) adult prawns of four commercial species, in the Mornington region. Each data point is the ratio of the index calculated using the incomplete data to the index calculated from the full data for that region. Blue dots indicate a deleted night for the region (two vessels); and red dots indicate a deleted vessel night for the region. The 100% line represents the index calculated for the complete data for each species for that region. The numbers in black (e.g. = 6/hr represent the actual number of prawns per hour caught using all data for the species.

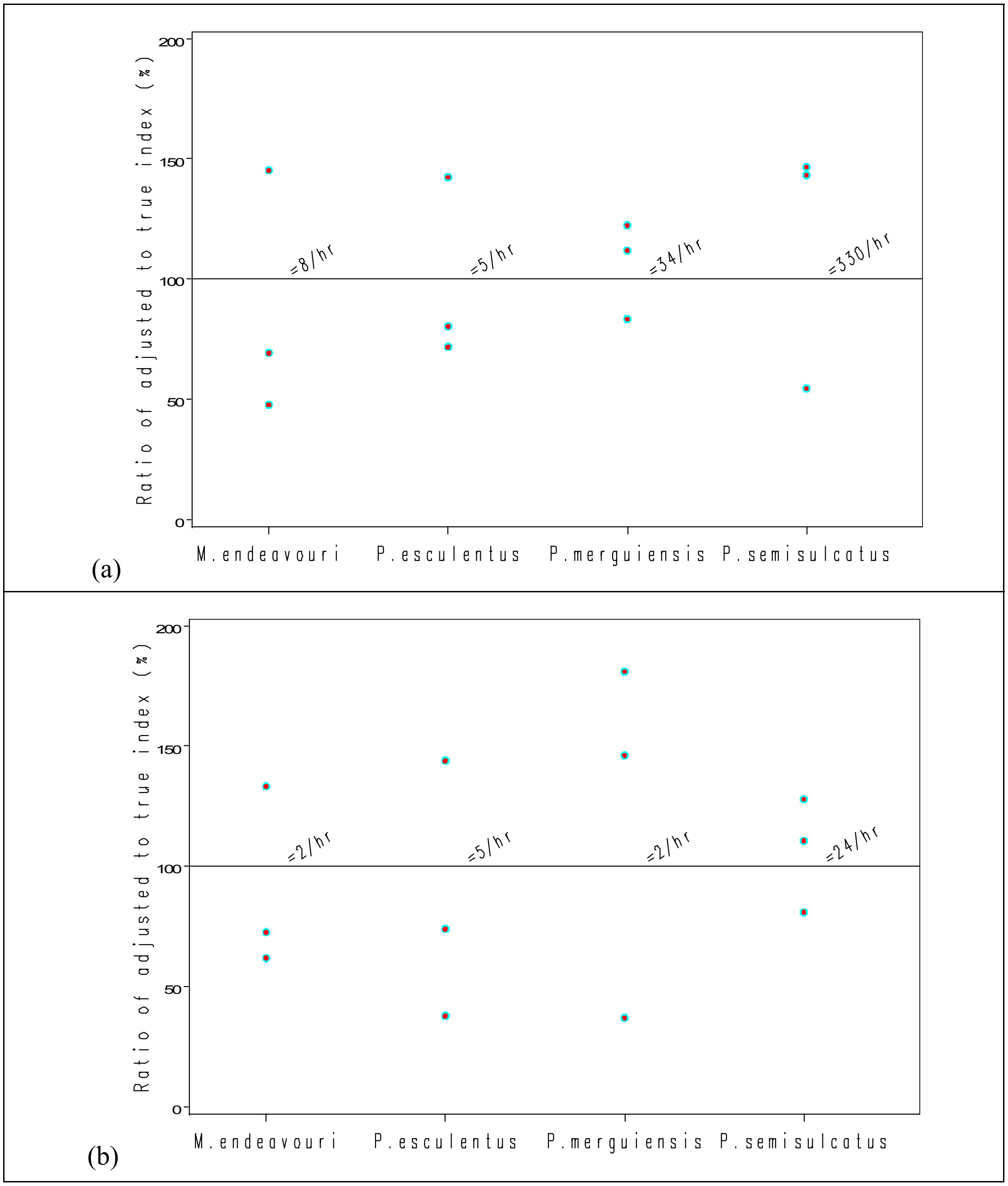


Figure 31: The effect of deleted survey nights on the January 2003 survey index for (a) sub-adult and (b) adult prawns of four commercial species, in the Weipa region. Each data point is the ratio of the index calculated using the incomplete data to the index calculated from the full data for that region. Blue dots indicate a deleted night for the region (one vessel); and red dots indicate a deleted vessel night for the region. The 100% line represents the index calculated for the complete data for each species for that region. The numbers in black (e.g. = 2/hr represent the actual number of prawns per hour caught using all data for the species Effect of deleted survey nights on the January 2003 survey index for (a) sub-adult and (b) adult prawns of four commercial species, in the Weipa region. Each data point is a night (blue) or vessel (red) lost.

CHAPTER 9 BYPRODUCT SPECIES

9.1 Introduction

The Spawning Index survey in August 2002 and the Recruitment Index survey in January/February 2003 are the most widespread scientific surveys on prawn distribution that have been carried out in the NPF. Although the surveys were designed mainly for obtaining reliable indices for prawn species, byproduct species caught during the surveys were also recorded to investigate the utility of the surveys with regard to byproduct species. The modern policy, to manage fisheries on an ecosystem basis, and the Strategic Assessment Provisions of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC act) also require data collection of all key species related to prawn fishing. Given the advantages of a fishery platform covering large areas, both on the fishing grounds and also inshore, the data on byproduct species collected during these surveys may provide valuable information and knowledge about the spatial distribution and catch rates of byproduct species.

A total of 7 byproduct species and/or species groups were recorded during these two surveys, including 2 species of scallop, *Annachlamys flabellata* and *Amusium pleuronectes*, 3 species of bugs, *Thenus indicus*, *Thenus orientalis*, and *Thenus* sp, 1 family of cuttlefish, *Sepiidae* and 1 family of squid, *Loliginidae*. A few species of byproduct fish were caught during the surveys but the numbers were very low and were excluded from the analysis of spatial distribution and catch rates.

9.2 Processing of the survey data

To describe the spatial distribution and abundance of a species, catch rate in number/hr or catch rate in weight/hr is the index most often used in fisheries. Although the survey staff attempted to record as much information for byproduct species as possible, it was not possible to have all catches of byproduct species counted, measured in length and weighed separately for each net at each site. When a large volume of byproduct species was caught in one shot, total weight was measured and a sub-sample was taken for counting. Sometimes only the catch from one net was processed fully. On other occasions, only total catch weight was recorded or only total numbers of catch for each species were counted. For those sampling sites and trawl nets that did not have data to calculate their total catch rates in number or weight, imputation was carried out as follows:

1. When a sub-sample of a species was taken, the total number of individuals for that species was calculated from the mean individual weight of the sample, the total catch weight and the number of individuals in the sub-sample, or vice versa.
2. When data for a species was recorded from only one net, the total number or total weight of the other net was calculated based on the assumption that the two nets at the same site had the same mean individual weight for the species.

3. When only total weight of catch of a byproduct species was recorded for a site, the total number of individuals for that species was imputed by using the average individual weight of the species in the same region, or vice versa.
4. All catch rates were standardized to a one hour trawl of a single net at about 3.2 knots.

The spatial distribution of catch rates were depicted at the locations of sites on a map. Those sites with zero catch were not shown for clearer visual effects. Catch rates were divided into 5 grades, each grade consisting of about 20% of the non-zero catch sites to avoid visual distortion. The catch rates shown on the maps were average catches of the two nets towed at each site and standardized to one hour trawl at about 3.2 knots. The same system applies to plots depicting the distribution of mean individual weights.

For some abundant byproduct species, we also produced a table of detailed statistics. We post-stratified the survey areas into 5 strata by depth (<15m, 15-25m, 25-35m, 35-45m and >45m). The stratification used in the survey was designed particularly to sample the prawn species and therefore may not be an ideal design for the byproduct species. The catch rates were first averaged over the two nets at each site (the sampling unit in the survey). Mean catch rates and standard errors in each stratum of the survey areas were calculated. As byproduct species were not the target species of the survey, many sampling sites caught nothing. Sites with zero catches were not included in the statistics of catch rates, but percentages of sites with zero catches were presented in the statistics table, which gives information about the patchiness of the distribution of a species.

The length frequency distributions presented in this chapter are simply pooled. No standardization was possible because length frequency data were not collected from all the sites. When the collection of length frequency data is significantly unbalanced in spatial distribution (e.g. only from areas of abundant juveniles) the measured length distribution will not represent the total population. This distortion may lead to biased conclusions regarding recruitment, individual growth and age composition. Consequently, caution should be exercised when interpreting the length distribution graphs in this chapter.

9.3 Results - Scallops

Two scallop species were recorded during these two surveys: *Amusium pleuronectes* and *Annachlamys flabellata*. In general, the survey data shows that *A. pleuronectes* has a wider distribution and higher catch rates than *A. flabellata.*

9.3.1 Mud scallop

The mud scallop (*A. pleuronectes*) has not been subject to extensive study, but its general life cycle is assumed to be the same as the saucer scallop (Dredge and Williams 2002). Saucer scallops are winter-spring spawners that have a short (2-3 week) pelagic larval phase. The scallops settle on the ocean floor, perhaps undergoing a transitional byssal phase. They appear to be effectively sedentary from this time on and settle in aggregations or beds. They spawn in their first winter of life, at an age of 9-12 months, and thereafter each winter.

9.3.1.a Spatial distribution

A. pleuronectes was widely distributed in the survey area (Figure 32). In August 2002, Mornington, particularly west Mornington, had the highest catch rates, with most sites having >349 scallops per standard net trawl (1 hour trawl per net). In contrast, the adjacent area, Karumba, had the lowest density, all sites having <28 scallops per standard net trawl.

In the survey in January 2003 a similar spatial distribution was seen. Mornington and Weipa had the highest densities with many sites having densities of more than 300 scallops per standard net trawl. Karumba had the lowest densities with all sites having <26 scallops per standard net trawl. Groote seemed to have a smaller spatial distribution compared with the August 2002 survey, with a gradient of higher densities towards the coast. This was particularly noticeable in the north of the Groote area. This change between August and January/February surveys may well indicate the arrival of new recruits.

Catch records of mud scallop obtained from the offshore surveys carried out in January/February 2003 by the Bycatch Monitoring Project were also included (Figure 33). The bycatch sampling sites in offshore areas were positioned in lines along a contour and can be clearly distinguished from prawn survey sites. In general, offshore areas had lower scallop densities than inshore areas. However, this decreasing trend towards offshore is not as apparent in Mornington.

In August 2002, the smaller mud scallops were generally found closer to shore and large ones were more likely to be found further offshore (Figure 34). However, this spatial pattern is not clear in the North of Groote and western Vanderlins. The January/February 2003 survey showed a spatial distribution similar to August 2002 (Figure 35). Only Karumba contrasts with other areas in that large scallops were caught in most of its sites. The average individual weights in offshore areas are clearly higher than those in inshore areas. It should be noted that the size grades used in these two graphs are not the same.

9.3.1.b Catch rates

The surveys carried out in August 2002 and January/February 2003 were designed to obtain reliable abundance indices for key prawn species. Byproduct species were not the target species of the surveys. As a result, many sites had zero catches. The spatial distributions in Figure 32 to Figure 35 show only the sites that have non-zero catches. In August 2002, scallops were caught at 94% of the sites, but this figure dropped to 80% in January 2003 (Table 15). Please note that these two surveys are different in spatial coverage; in January, sites at Weipa, and extra sites at Karumba were sampled.

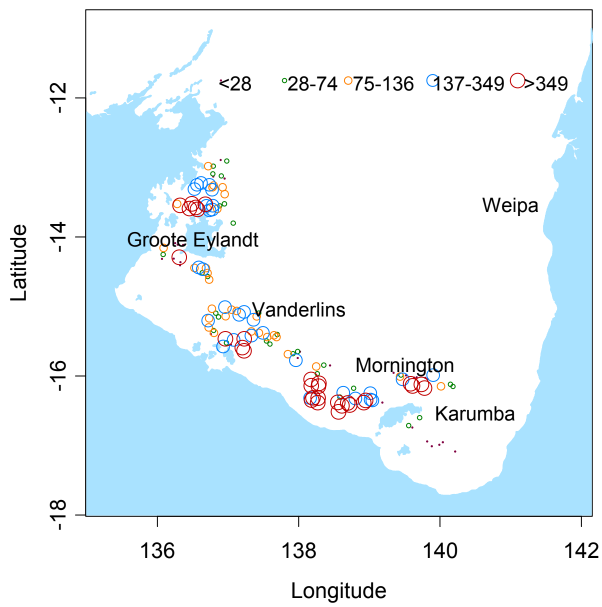


Figure 32: Spatial distribution of mud scallops (*Amusium pleuronectes*) (no/hr) in August 2002

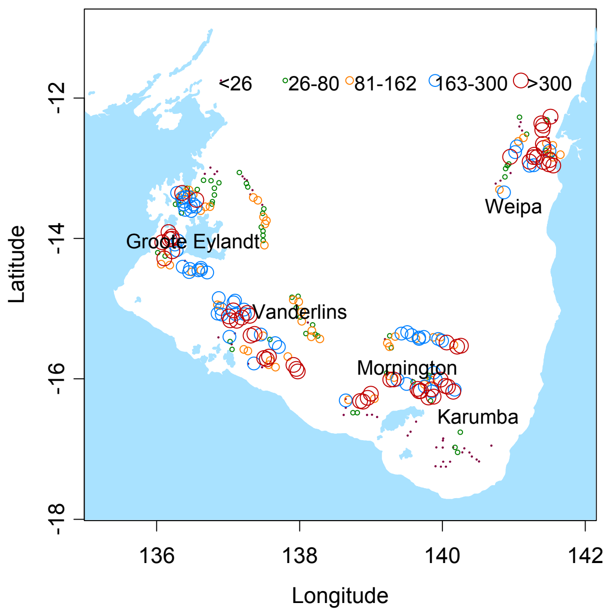


Figure 33: Spatial distribution of mud scallops (*Amusium pleuronectes*) (no/hr) in January/February 2003

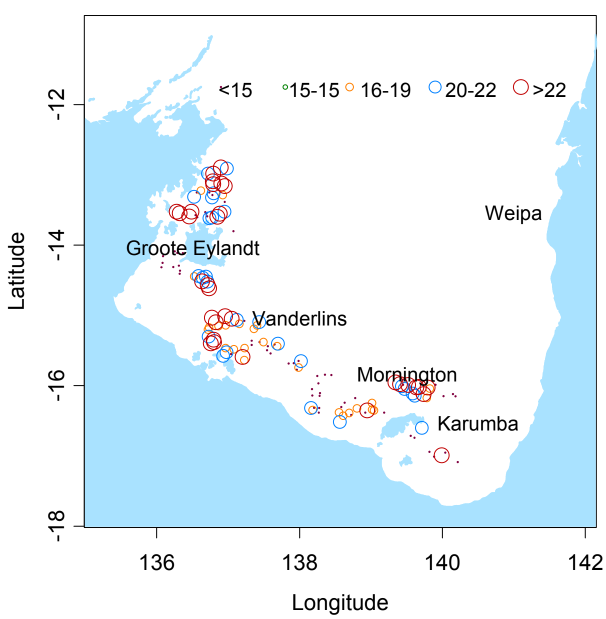


Figure 34: Distribution of average individual weight (g) of mud scallops (*Amusium pleuronectes*) in the survey of August 2002

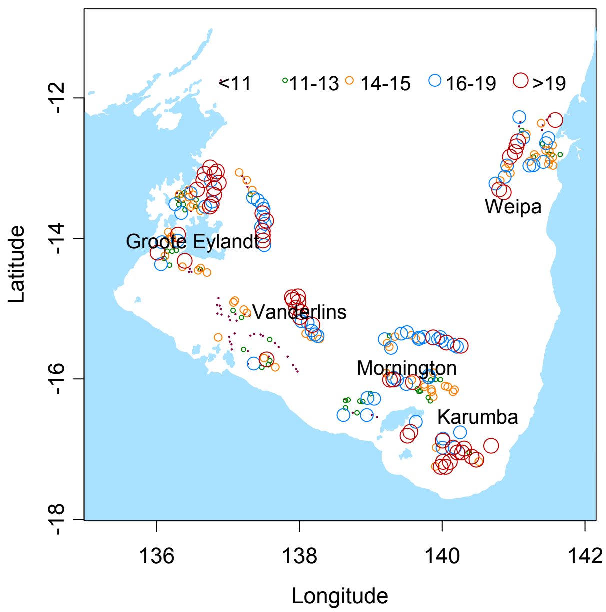


Figure 35: Distribution of average individual weight (g) of mud scallops (*Amusium pleuronectes*) in the survey of January/February 2003

Table 15: Mean catch rates (no/hr; standard errors in brackets) of *Amusium pleuronectes* in each depth stratum of the different regions for the surveys of August 2002 and January/February 2003

Survey	Area	Depth					No. Sites Sampled	% of zero catch sites
		<15m	15-25m	25-35m	35-45m	>45m		
August	Groote	2.00	239.16	151.04	58.04	50.32	56	4
2002			(51.41)	(22.77)	(15.14)			
	Vanderlins	94.51	471.94	201.19	86.19		57	0
		(30.48)	(107.12)	(51.33)	(14.99)			
	Mornington	13.44	524.21	210.00	117.24		56	14
		(5.15)	(152.53)	(67.62)	(45.39)			
	Mean	25.04	398.60	181.95	87.36	50.32	169	6
		(10.05)	(62.32)	(25.44)	(15.63)			
Jan/Feb	Groote	72.71	187.66	99.71	18.74	49.86	90	3
2003		(64.71)	(30.79)	(21.86)	(6.29)	(8.13)		
	Vanderlins	4.00	77.54	813.95	266.69	68.27	77	69
			(21.58)	(164.15)	(54.76)	(9.65)		
	Mornington	7.24	26.05	381.65	158.24	212.45	95	16
		(2.77)	(10.35)	(57.09)	(37.58)	(30.42)		
	Karumba	3.69	12.71				45	27
		(0.90)	(5.94)					
	Weipa	74.00	199.60	649.22	1387.7	90.25	50	4
		(33.29)	(79.57)	(208.84)	(355.4)	(21.95)		
	Mean	21.34	139.05	475.99	417.68	107.99	357	20
		(8.89)	(20.48)	(63.84)	(110.74)	(12.64)		

Some general patterns can be seen from these two surveys (Figure 36), although they may not be conclusive:

1. In general, January/February has a higher density than August.
2. Density distribution over depth has a single mode, i.e. both coastal and offshore areas have lower densities than the mid-depth areas.
3. The depth of the highest density is deeper in January/February than in August.

The mean weight of individual scallops shows much smaller variation, particularly among areas (Table 16). An increasing trend in mean weight can be seen towards offshore sites in the August 2002 survey (Figure 37). In contrast, the January/February survey in 2003 shows the smallest scallops in the middle, but larger ones in both coastal and far offshore areas (Figure 37).

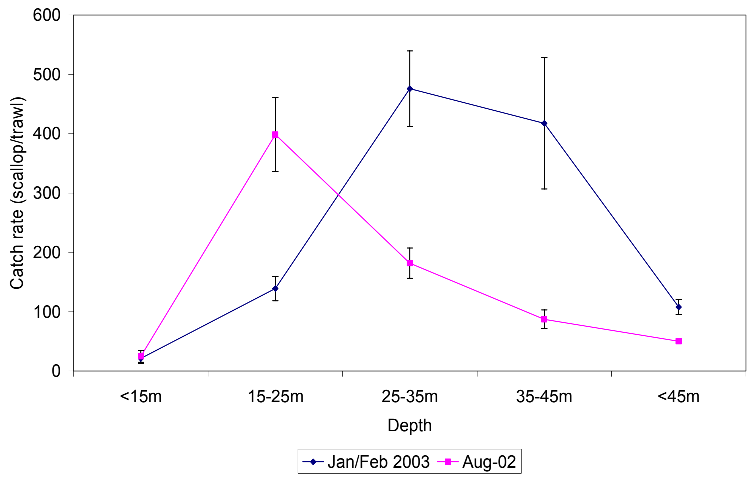


Figure 36: Mean catch rates (no/hr) of mud scallops (*Amusium pleuronectes*) in different depths (the bars indicate 1 standard error).

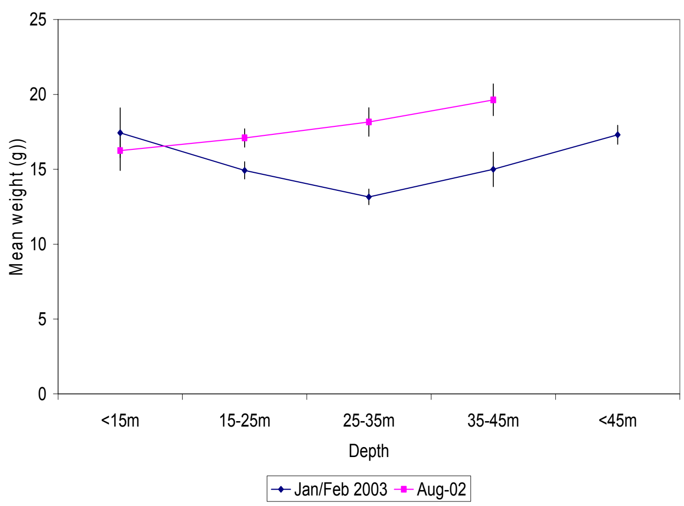


Figure 37: Mean weight (g) of mud scallops (*Amusium pleuronectes*) in different depths (the bars indicate 1 standard error).

9.3.1.c Length Distribution

The length distribution of mud scallops caught in August 2002 ranged from 20mm to 80mm with a mode around 60mm (Figure 38). The distribution is positively skewed, which may indicate a mode around 40mm for a second cohort. This possibility is supported by the length distribution obtained in January 2003 (Figure 39), which is a unimodal distribution; presumably, the new generation of scallops in January are not large enough to be caught by our survey nets. If scallops spawn in winter/spring in the Gulf of Carpentaria, by August the youngest cohort should be about 1 year old. In January, this cohort average size should be about 40mm. In comparison with saucer scallops (*A. japonicum balloti*), which can reach 90mm in 6-15 months (Dredge and Williams 2002), it may be that the mud scallop in the Gulf of Carpentaria has a slower growth rate and also a smaller maximum size.

Table 16: Mean weight (g) (standard errors in brackets) of *Amusium pleuronectes* in each depth stratum of the different regions for the surveys of August 2002 and January/February 2003

Survey	Area	Depth <15m	 15-25m	 25-35m	 35-45m	 >45m	No. Sites Sampled	% of zero catch sites
August 2002	Groote	14.54	16.89 (1.29)	20.57 (1.43)	23.81 (2.96)	8.54	56	4
	Vanderlins	17.72 (2.73)	17.33 (0.91)	15.44 (1.65)	21.62 (1.00)		57	0
	Mornington	16.21 (1.67)	17.14 (0.76)	16.93 (1.17)	16.00 (1.28)		56	14
	Mean	16.25 (1.32)	17.10 (0.61)	18.16 (0.95)	19.64 (1.06)	8.53	169	6
Jan/Feb 2003	Groote	14.54 (1.32)	16.89 (0.67)	20.57 (1.64)	23.81 (5.09)	8.54 (1.05)	90	3
	Vanderlins	10.00 (0.90)	12.87 (0.70)	9.98 (0.74)	10.56 (1.30)	20.30	77	69
	Mornington	20.97 (4.09)	16.23 (1.41)	12.79 (0.31)	16.32 (0.81)	16.29 (0.60)	95	16
	Karumba	18.23 (0.89)	24.33 (4.40)				45	27
	Weipa	14.67 (7.79)	14.13 (0.98)	14.19 (1.13)	12.32 (0.74)	17.67 (1.76)	50	4
	Mean	17.44 (1.66)	14.93 (0.57)	13.16 (0.52)	15.00 (1.15)	17.31 (0.63)	357	20

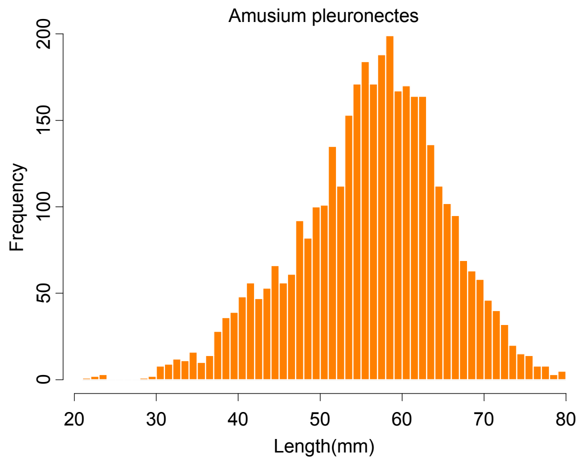


Figure 38: Length distribution of the mud scallops (*Amusium pleuronectes*) caught in August 2002 survey

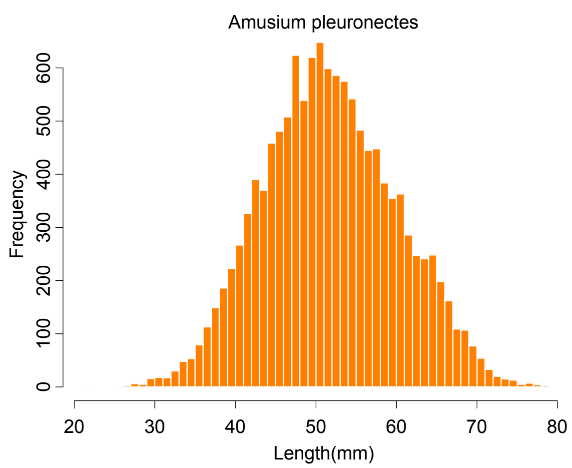


Figure 39: Length distribution of the mud scallops (*Amusium pleuronectes*) caught in January/February 2003 survey

9.3.1.d *Annachlamys flabellata*

A. flabellata were recorded in both the surveys. Their distribution is sparse in the Gulf of Carpentaria. *A. flabellata* were caught at only a few sites in August 2002, and the highest catch rate was 4 per standard net trawl. Mornington had the highest density (Figure 40). More *A. flabellata* were caught in the January/February survey in 2003 (Figure 41). The maximum catch rate was 74 per standard net trawl. However, the increase in density and spatial expansion was only seen in Mornington. Groote and Vanderlins did not show much change in either density or spatial distribution (Figure 41). Weipa was only surveyed in January/February 2003. Although no comparison is possible to investigate seasonal changes, Weipa seems to be a region of very few *A. flabellata* (Figure 41).

The mean individual weight of *A. flabellata* in August 2002 was quite consistent throughout the entire survey area, all above 13g (Figure 42). In January/February 2003, the mean weight became more variable, ranging from 5-20g (Figure 43). The increase in density, the spatial expansion and the decrease in size seen in January/February 2003 might indicate new recruitment.

The length data of *A. flabellata* collected in August 2002 ranged from 35mm to 65mm, but they are not sufficient to represent a full distribution in length (Figure 42). The data from January/February 2003 shows a smooth length frequency distribution with two modes (Figure 43), one at ~40mm and the other at ~55mm. The 55mm mode seems consistent with the mode seen in the August survey, although not well defined (Figure 42), and the 40mm mode represents new recruits. The conclusion that the January/February data includes new recruits is supported by the large difference in catch rates between August and January/February surveys (Figure 40 and Figure 41). In general, *A. flabellata* (Figure 42) are smaller than *A. pleuronectes* (Figure 43).

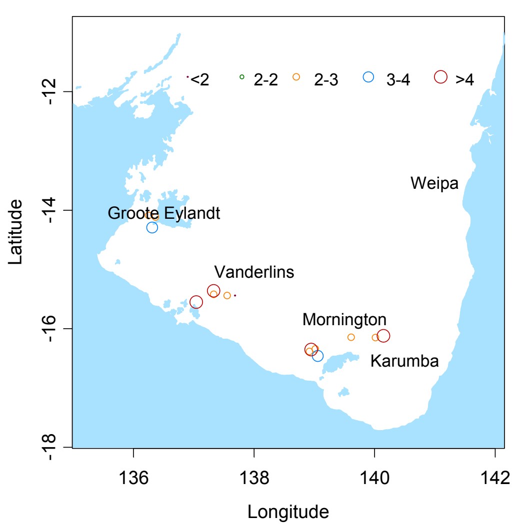


Figure 40: Spatial distribution of scallops *Annachlamys flabellata* (no/hr) in the survey of August 2002

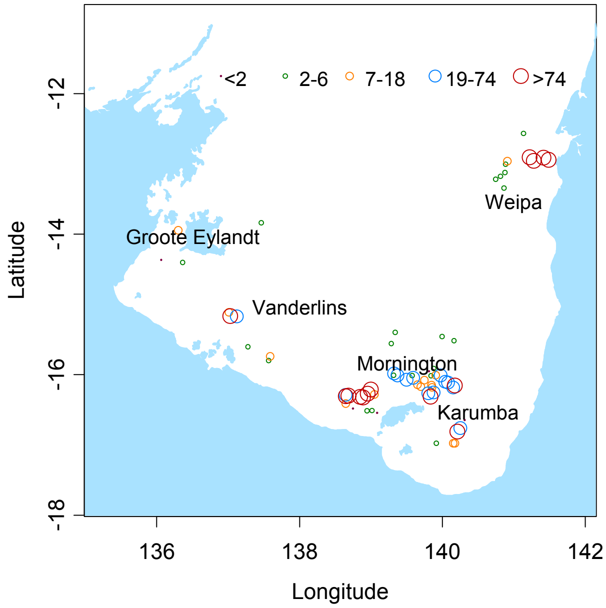


Figure 41: Spatial distribution of scallops *Annachlamys flabellate* (no/hr) in the survey of January 2003

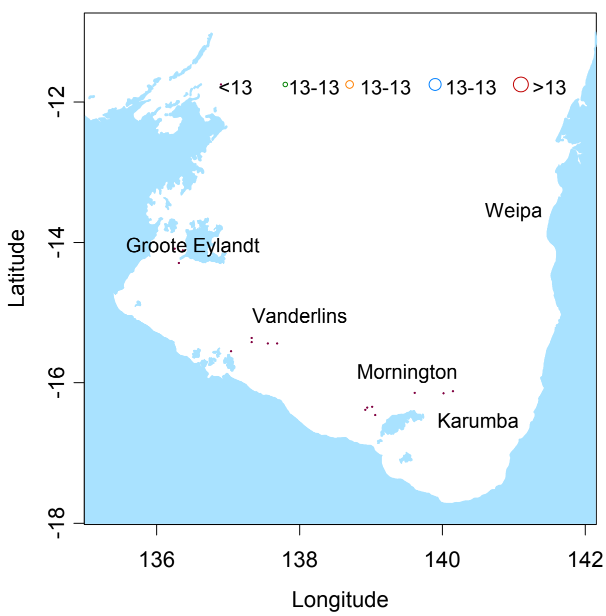


Figure 42: Distribution of average individual weight (g) of scallops *Annachlamys flabellata* in the survey of August 2002

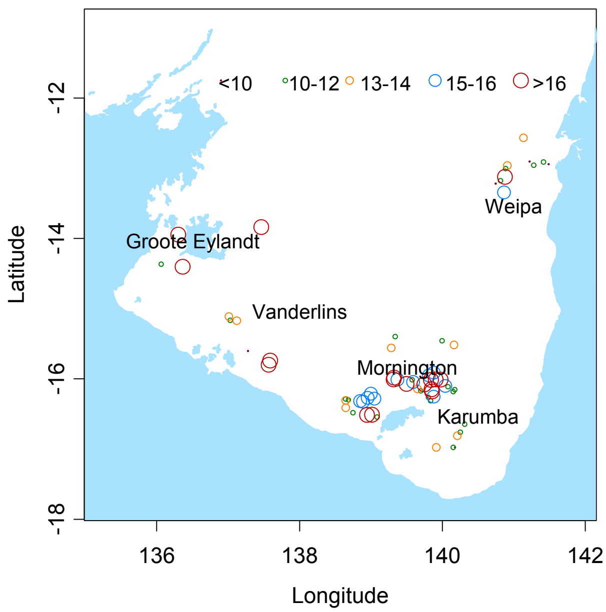


Figure 43: Distribution of average individual weight (g) of scallops *Annachlamys flabellata* in the survey of January/February 20023

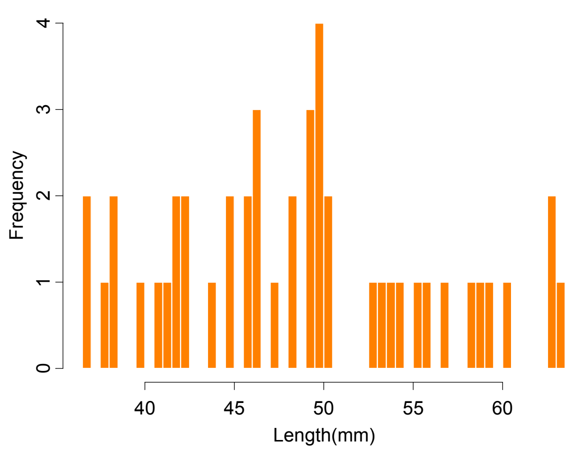


Figure 44: Length distribution of the scallops *Annachlamys flabellata* caught in August 2002

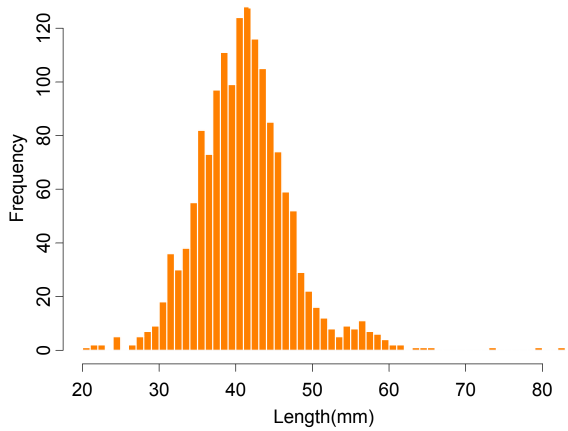


Figure 45: Length distribution of the scallops *Annachlamys flabellata* caught in January/February 2003 survey

9.4 Results - Bugs

Among the three bug species that were recorded in the two surveys, mud bugs (*Thenus indicus*) and reef bugs (*Thenus orientalis*) were the most abundant. *Thenus* spp. had only a few records and is not presented here in detail.

9.4.1 Mud bugs

Mud bugs typically occur in waters shallower than 25m north of 23^0S, where substrates tend to be muddy (Courtney and Williams, 2002). On the Queensland east coast, about 90t of mud bugs are landed each year, on average, as byproduct of tiger and endeavor prawn harvests (Courtney and Williams, 2002).

9.4.1.a Spatial distribution

Mud bugs were widely distributed in the survey area. Their maximum catch rate was more than 57 individuals per standard net trawl in the August 2002 survey (Figure 46). No clear spatial pattern can be recognized, except that Mornington seems to have a higher density than other areas.

The catch rates in January 2003 were lower in general than those in August 2002 (Figure 47). However, mud bugs were caught at more sites in August than in January/February, suggesting that their spatial distribution was less patchy in August. The densities in the coastal waters of Mornington and Karumba were much higher than the rest. All the offshore sites sampled in Groote, Vanderlins, Mornington and Weipa had very low densities.

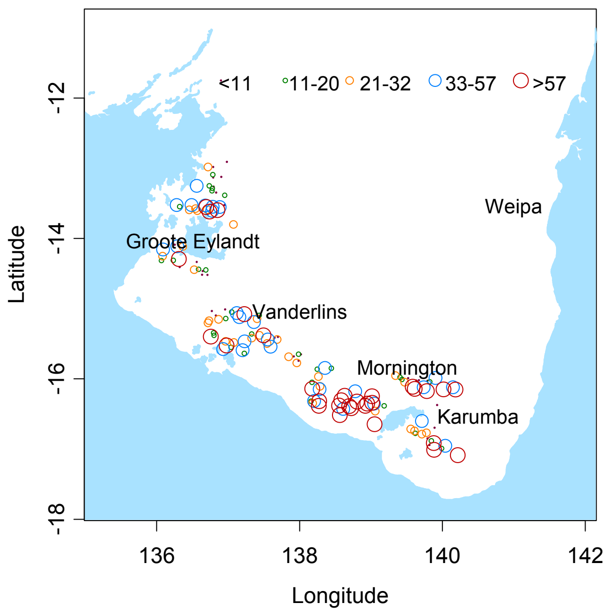


Figure 46: Spatial distribution of mud bugs (*Thenus indicus*) (no/hr) in the survey of August 2002

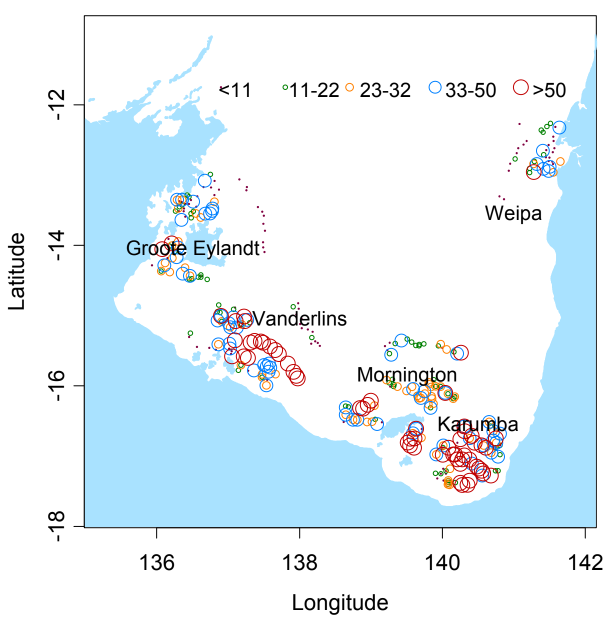


Figure 47: Spatial distribution of mud bugs (*Thenus indicus*) (no/hr) in the survey of January 2003

The spatial distribution of individual weights from the August 2002 survey shows larger mud bugs in northern areas such as north of Groote and north-west of Vanderlins (Figure 48) and smaller mud bugs south-east of Vanderlins, Mornington and Karumba. The maximum individual weight recorded was more than 104g in August 2002.

The size distribution derived from the survey in January 2003 has a similar trend (Figure 49). South of Groote, Vanderlins, Mornington, and Karumba have smaller mud bugs in coastal waters, but larger bugs in offshore areas. However, larger bugs dominate in Weipa and Northern Groote.

9.4.1.b Catch rates

The average catch rates of mud bugs in the different strata ranged from 19-43 bugs per standard net trawl in August 2002 (Table 17). Overall 94% of the sampled sites caught mud bugs. A decreasing trend towards offshore in density is evident (Figure 50).

The average catch rates of mud bugs in January 2003 were very similar to those in August 2002, only slightly higher (Table 17). The percentage of zero catches remained at a similar level of 9%. The offshore decreasing trend was still seen, but the gradient became gentler within the depth of 45m (Figure 50).

Mud bugs are widely distributed in the Gulf of Carpentaria (Figure 46 and Figure 47). They can be caught in depths of up to 50m, which is in contrast to the results reported in Courtney and Williams (2002) that mud bugs occur in waters shallower than 25m in the east coast of Queensland.

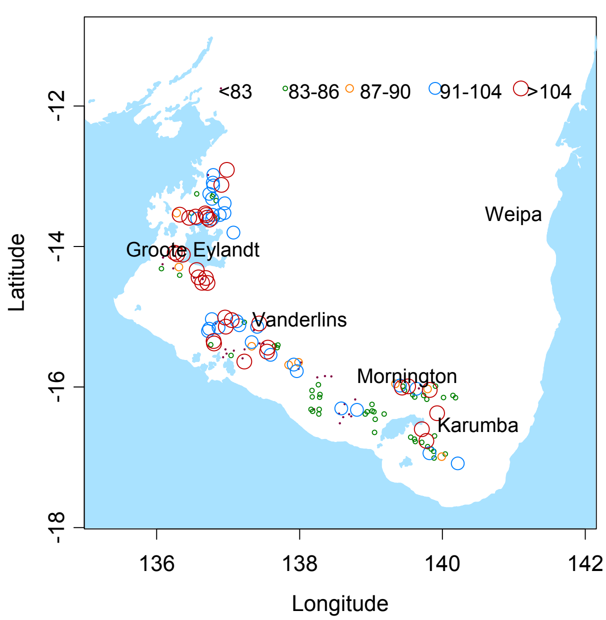


Figure 48: Distribution of average individual weight (g) of the mud bugs (*T. indicus*) caught in the survey of August 2002

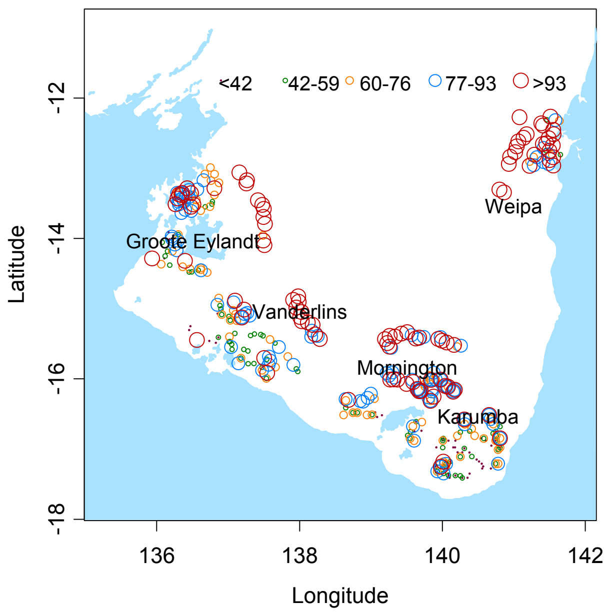


Figure 49: Distribution of average individual weight (g) of mud bugs (*T. indicus*) caught in the survey of January/February 20023

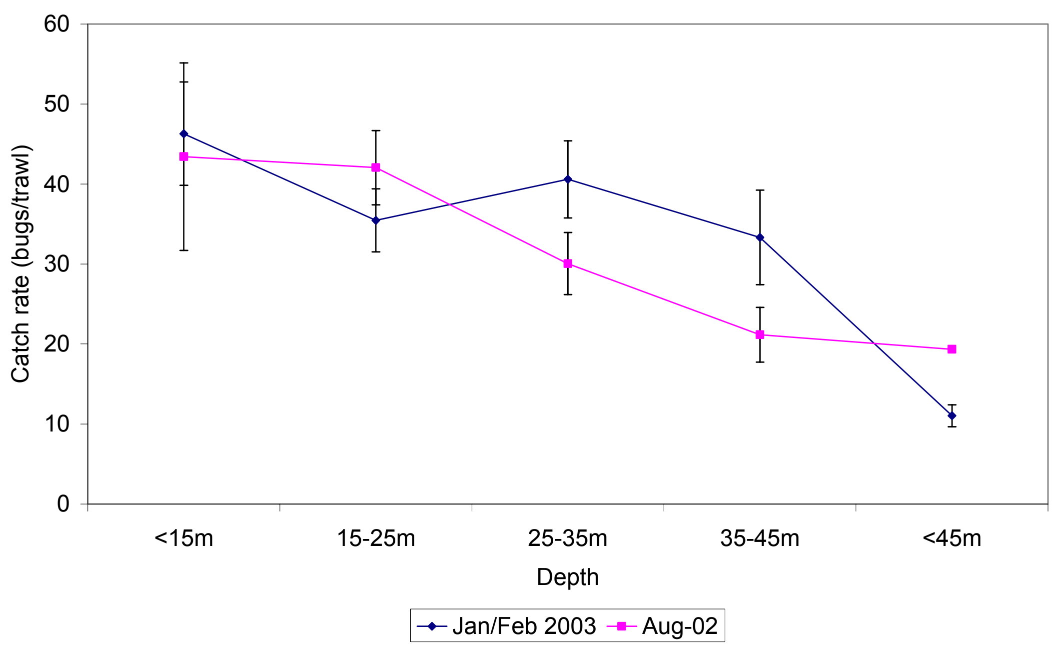


Figure 50: Mean catch rates of mud bugs (*Thenus indicus*) in different depths (the bars indicate 1 standard error).

Table 17: Mean catch rates (no/hr; standard errors in brackets) of *Thenus indicus* in each depth stratum of the different regions for the surveys of August 2002 and January/February 2003

Survey	Area	Depth					No. Sites Sampled	% of zero catch sites
		<15m	15-25m	25-35m	35-45m	>50m		
August 2002	Groote	30.00	34.90 (5.51)	14.59 (3.49)	8.03 (3.46)	19.35	56	14
	Vanderlins	54.28 (22.28)	40.08 (10.75)	26.47 (4.15)	25.32 (4.73)		57	4
	Mornington	42.84 (14.07)	52.47 (8.28)	63.13 (8.71)	21.44 (6.83)		56	0
	Mean	43.42 (11.72)	42.05 (4.64)	30.05 (3.89)	21.15 (3.42)	19.35	169	6
Jan/Feb 2003	Groote	14.31 (9.45)	21.33 (1.96)	19.46 (3.54)	3.38 (0.69)	6.55 (0.77)	90	14
	Vanderlins	15.13 (5.74)	28.16 (5.48)	62.65 (13.29)	68.15 (12.07)	7.80 (0.89)	77	14
	Mornington	65.25 (11.86)	61.80 (13.00)	42.24 (6.72)	21.64 (2.17)	19.00 (2.95)	95	0
	Karumba	51.99 (9.70)	77.10 (18.33)				45	0
	Weipa	16.40 (5.31)	16.60 (4.21)	25.91 (5.91)	13.67 (1.58)	5.50 (2.12)	50	14
	Mean	46.29 (6.46)	35.45 (3.94)	40.58 (4.81)	33.33 (5.92)	11.03 (1.36)	357	9

The mean weight of mud bugs in different strata ranged from 88-104g in August 2002, and this range increased to 52-116g in January/February 2003 (Table 18). The size of mud bugs varied very little with depth in August; however, an offshore increase in size was evident in January 2003 (Figure 51). This may imply that recruitment starts in shallow waters.

Table 18: Mean weight (g) (standard errors in brackets) of *Thenus indicus* in each depth stratum of the different regions for the surveys of August 2002 and January/February 2003

Survey	Area	Depth					No. Sites Sampled	% of zero catch sites
		<15m	15-25m	25-35m	35-45m	>50m		
August 2002	Groote	98.33	98.38 (5.19)	98.92 (5.70)	117.03 (15.26)	100.80	56	14
	Vanderlins	71.98 (1.67)	89.74 (3.31)	91.82 (3.52)	90.55 (5.98)		57	4
	Mornington	89.57 (2.52)	84.28 (2.34)	85.76 (5.13)	118.02 (25.22)		56	0
	Mean	88.01 (2.58)	91.35 (2.45)	93.12 (2.83)	104.12 (9.28)	100.80	169	6
Jan/Feb 2003	Groote	42.31 (20.20)	79.76 (3.86)	74.16 (5.91)	56.67 (24.88)	120.52 (5.79)	90	14
	Vanderlins	60.67 (14.06)	59.76 (7.51)	63.61 (3.74)	66.90 (7.73)	109.66 (6.58)	77	14
	Mornington	44.35 (4.02)	53.25 (4.47)	80.16 (2.31)	96.91 (4.51)	98.56 (2.81)	95	0
	Karumba	48.80 (4.23)	42.09 (6.15)				45	0
	Weipa	87.80 (25.52)	97.39 (8.05)	88.52 (5.86)	89.71 (15.43)	151.82 (24.84)	50	14
	Mean	51.91 (3.79)	69.40 (2.91)	75.83 (2.18)	81.93 (5.30)	116.19 (5.85)	357	9

9.4.1.c Length distribution

The length frequency distribution of mud bugs from the August 2002 survey exhibits only one mode at around 55mm (Figure 52). Very few are smaller than 40mm. Mud bugs caught in January/February 2003 clearly show two modes: one around 30mm and one around 55mm, representing two cohorts (Figure 53). From this distribution, mud bugs seem unlikely to survive more than 3 years old. However, potential bias is likely, due to the way all the length distribution data are pooled without considering their locations and net selectivity.

9.4.2 Reef bugs

Reef bugs (*Thenus* orientalis) occur in water depths of 25-60m, in areas with sandy substrates, and are rarely found south of 26^{0}S on Australia's east coast (Courtney and Williams, 2002). Spawning activity for reef bugs occurs throughout the year, but peaks in the spring and early summer months. Females carry a relatively small number of eggs (thousands to tens of thousands) on the pleopods (swimming legs) before spawning. The eggs hatch and undergo a series of complex larval metamorphoses of less than a month, before settling out as juveniles. Growth of juveniles appears to be fairly rapid, reaching 60mm carapace width and recruiting into the Queensland fishery at 1-2 years of age. The annual mortality rate is estimated to be about 75% and longevity appears to be approximately 5-6 years (Courtney and Williams, 2002). On the Queensland east coast, about 340t of reef bugs are landed each year as byproduct of prawn fishing (Courtney and Williams, 2002).

9.4.2.a Spatial distribution

Reef bugs in the Gulf of Carpentaria are much less abundant than mud bugs. Reef bugs were caught at only a few sites in August 2002, mainly in Vanderlins and Mornington (Figure 54). Some catch rates were >10 bugs per standard net trawl. Although the abundance increased in January 2003, most catches were still quite low, below 14 bugs per standard net trawl (Figure 55). The abundance was highest at Weipa and Vanderlins.

Distributions of average individual weight of reef bugs are presented in Figure 56 and Figure 57. Maximum weight recorded was >120g in August 2002 and >132g in January/February 2003. In general, reef bugs are larger than mud bugs (Figure 48 and Figure 49). A decreasing trend in size towards offshore was also seen in reef bugs, particularly in January/February.

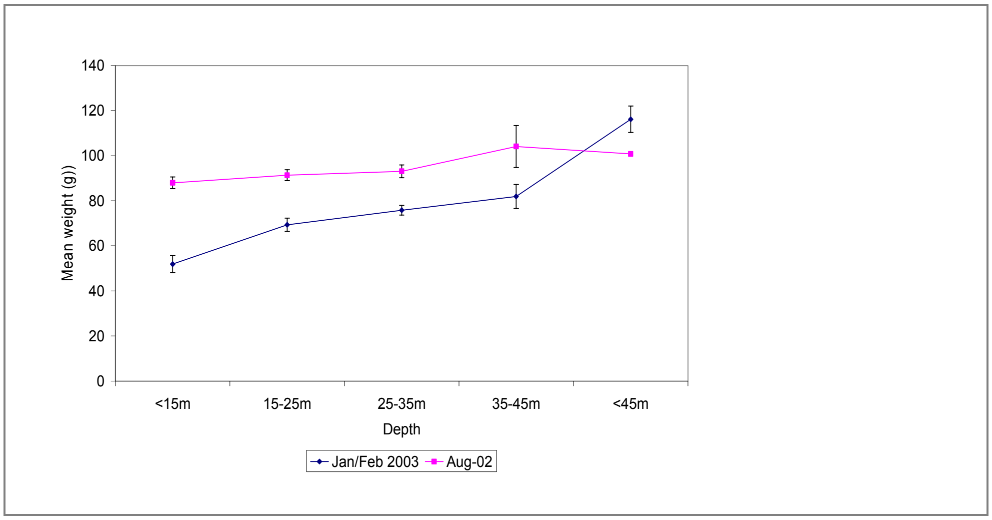


Figure 51: Mean weight (g) of mud bugs (*Thenus indicus*) in different depths (the bars indicate 1 standard error).

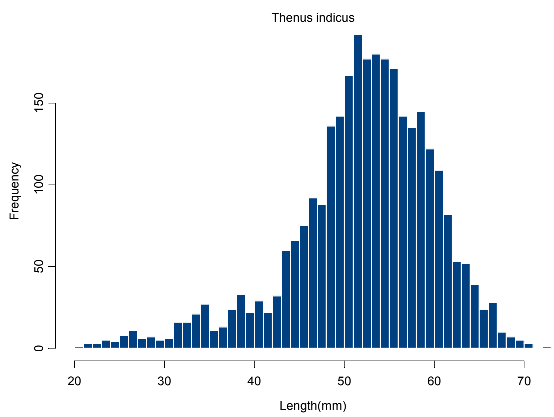


Figure 52: Length frequency distribution of mud bugs (*Thenus indicus*) in August 2002

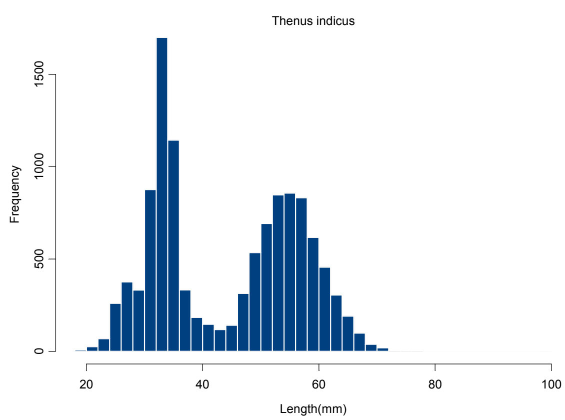


Figure 53: Length frequency distribution of mud bugs (*Thenus indicus*) in January 2003

9.4.2.b Length Distribution

Size of reef bugs ranged from 35mm to 90mm in August 2002, and a single mode appeared around 60mm (Figure 58). Length frequency distribution of the reef bugs caught in January/February 2003 exhibited two modes. One appeared around 30mm and the other located at about 60mm (Figure 59). The lifespan of reef bugs seems unlikely to exceed 4 years as seen from the length distribution. However, this conclusion needs to be investigated further, as the reef bugs in Queensland east coast are believed to have a maximum longevity of 5-6 years (Courtney and Williams 2002).

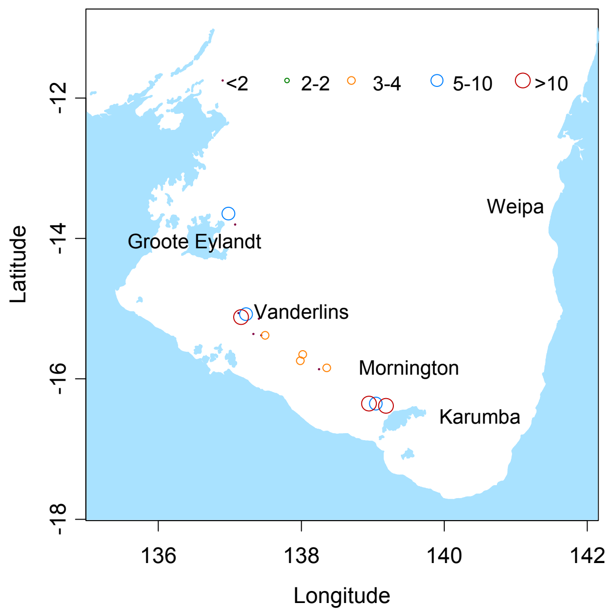


Figure 54: Spatial distribution of reef bugs (*Thenus orientalis*) (no/hr) in August 2002

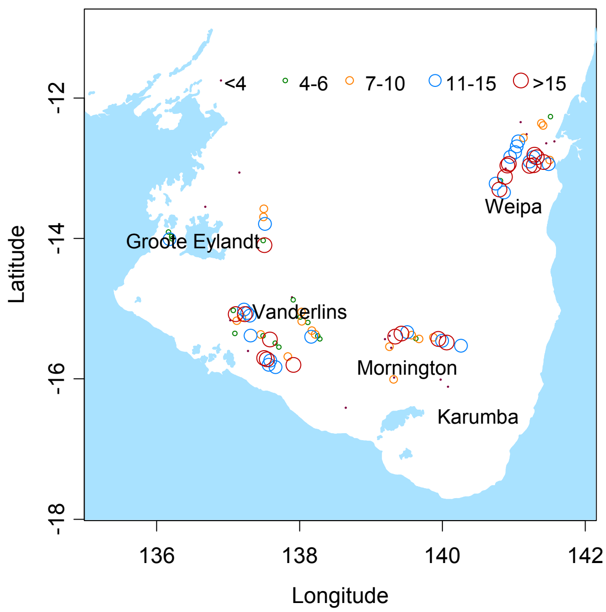


Figure 55: Spatial distribution of reef bugs (*Thenus orientalis*) (no/hr) in January 2003

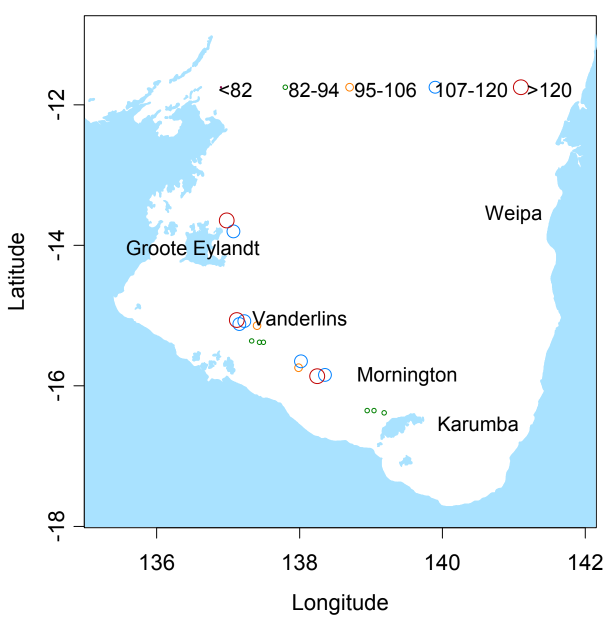


Figure 56: Distribution of average individual weight (g) of the reef bugs (*Thenus orientalis*) caught in the survey of August 2002

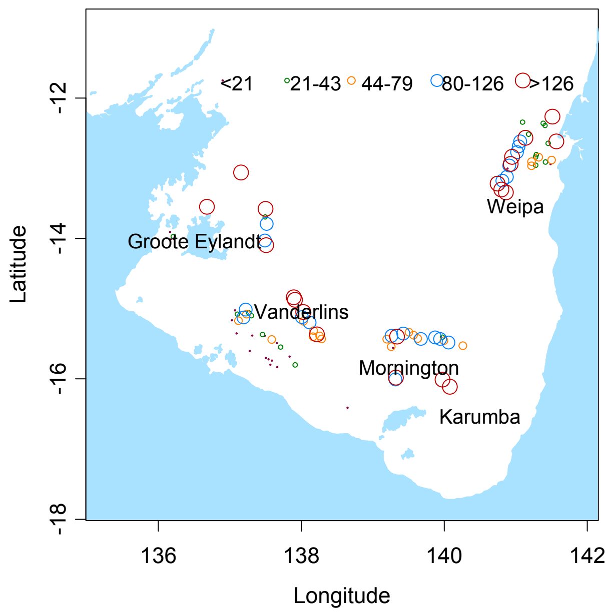


Figure 57: Distribution of average individual weight (g) of the reef bugs (*Thenus orientalis*) caught in the survey of January 2002

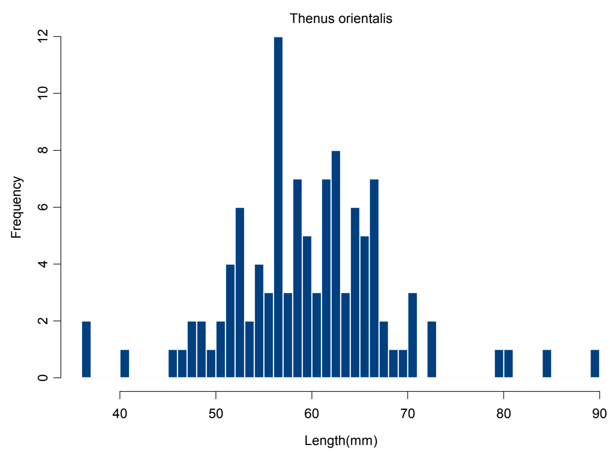


Figure 58: Length frequency distribution of reef bugs (*Thenus orientalis*) in August 2002

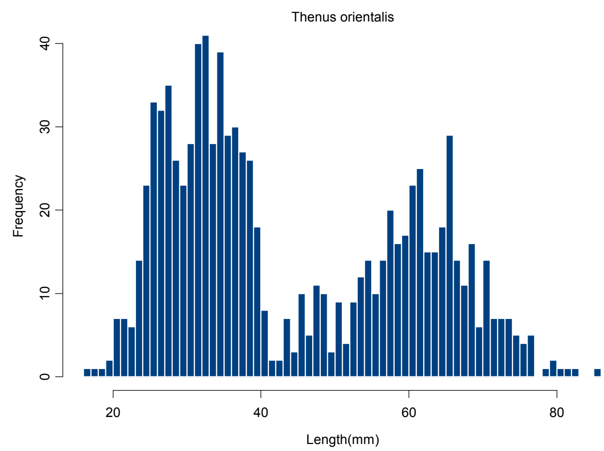


Figure 59: Length frequency distribution of reef bugs (*Thenus orientalis*) in January 2003

9.5 Results - Cuttlefish

The family *Sepiidae* includes numerous species (more than 100) that live in tropical, subtropical and temperate waters in all oceans and seas except the coasts of the Americas (Adam and Rees, 1966). The *sepiids* are benthic or benthopelagic, and are incidentally caught in prawn fishing. Our surveys did not record them by species, rather as a family undifferentiated.

9.5.1 Spatial Distribution

Sepiidae were frequently caught during the two prawn surveys. The maximum catch rate was more than 24 cuttlefish per standard net tow (Figure 60) in August 2002. No clear distributional pattern appeared although higher catch rates were seen in deep waters, particularly in the Mornington area. Catch rates in January 2003 remained similar to the level seen in August 2002 (Figure 61). However, it became clearer that deep waters, particularly in the offshore sites sampled by the Bycatch Project, had higher densities than sites in shallow waters.

The individual weight ranges of *Sepiidae* caught during the two surveys were very similar, with a maximum of more than 86g (Figure 62 and Figure 63). No clear spatial pattern could be recognized. However, a data deficiency occurred in the analysis of mean weights. Although we separated the weights into 5 grades, only two grades appeared in Figure 62 and Figure 63. This is not a technical deficiency of the program, but because the data consist of a few major grades of individual weights. Our strategy to allocate about 20% of records to each class was not able to break down a single major grade of more than 20% of the total records. This deficiency was mainly caused by the imputation for the missing individual weights through very few measurements made in the field.

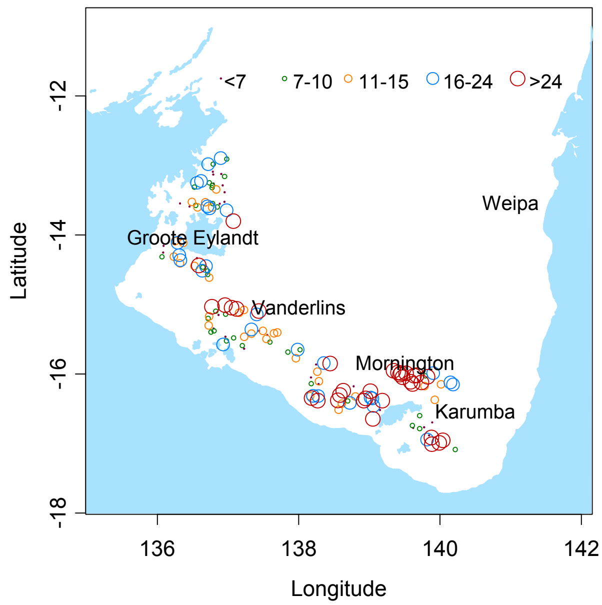


Figure 60: Spatial distribution of cuttlefish (*Sepiidae*) (no/hr) in the survey of August 2002

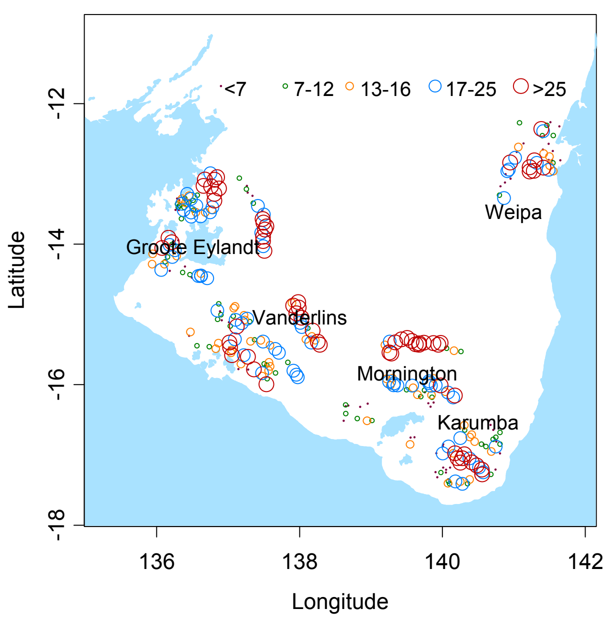


Figure 61: Spatial distribution of cuttlefish (*Sepiidae*) (no/hr) in the survey of January 2003

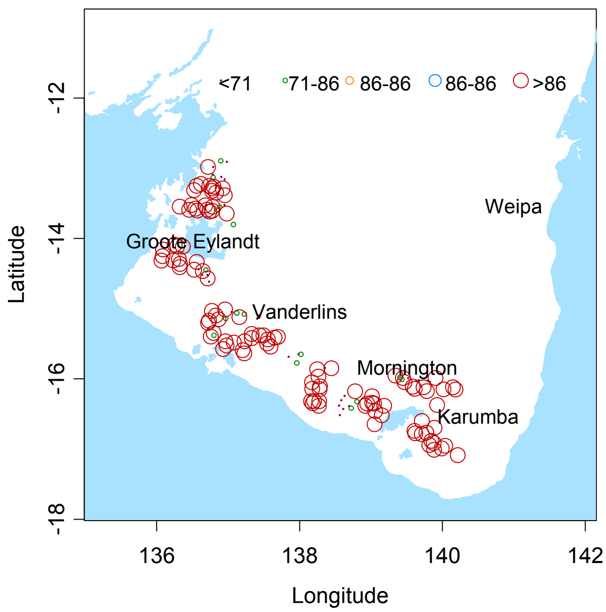


Figure 62: Distribution of average individual weight (g) of the cuttlefish (*Sepiidae*) caught in the survey of August 2002

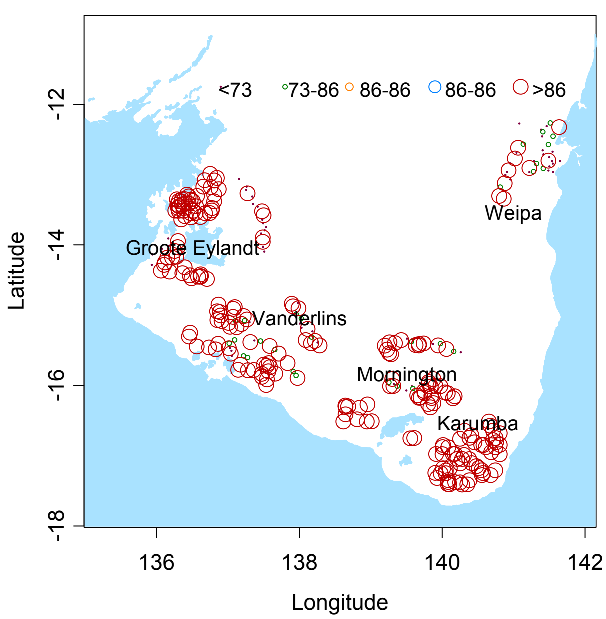


Figure 63: Distribution of average individual weight (g) of the cuttlefish (*Sepiidae*) caught in the survey of January 2003

9.5.2 Size Frequency Distribution

No size frequency data was recorded for *Sepiidae*.

9.6 Results - Squid

Squid (*Loliginidae*) were undifferentiated by species during the surveys. They seem fairly widely distributed in the Gulf of Carpentaria. The maximum catch rate recorded in the survey of August 2002 was more than 9 squid per standard net tow (Figure 64). The most abundant areas were Karumba and south-west Vanderlins.

The spatial distribution of the squid in January 2003 did not change very much (Figure 65). However, the catch rates in January were, in general, lower than those in August, with some catch rates of >5 squid per standard net trawl, almost half the maximum value seen in August. Vanderlins still had the highest catch rates, in comparison with other areas. Offshore sites had lower catch rates than the sites closer to the coast, with the exception of Groote area. Squid may be distributed mainly in the shallow waters less than 45m deep along the coast of the Gulf of Carpentaria.

The mean individual weight of squid in August 2002 ranged from <72g to >106g, a quite narrow distribution (Figure 66). The areas closer to the coast were more likely to have smaller squids, particularly in north Groote and Karumba. This gradient towards the offshore in mean individual weight was even more evident in January/February 2003 (Figure 67). This trend seems applicable to many species; the larger the animal, the further offshore they tend to live. Data deficiency was also encountered in presenting the mean individual weights in Figure 66 and Figure 67.

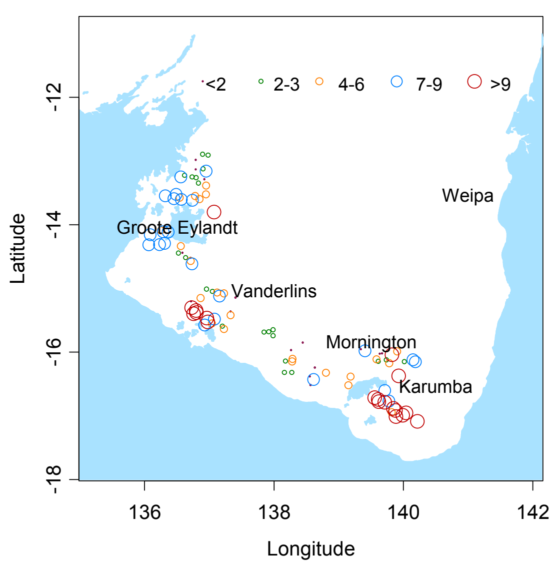


Figure 64: Spatial distribution of squids (*Loliginidae*) (no/hr) in the survey of August 2002

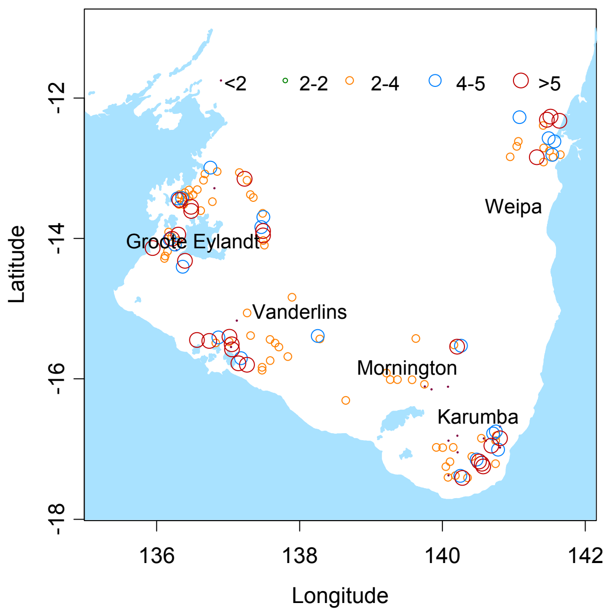


Figure 65: Spatial distribution of squids (*Loliginidae*) (no/hr) in the survey of January/February 2003

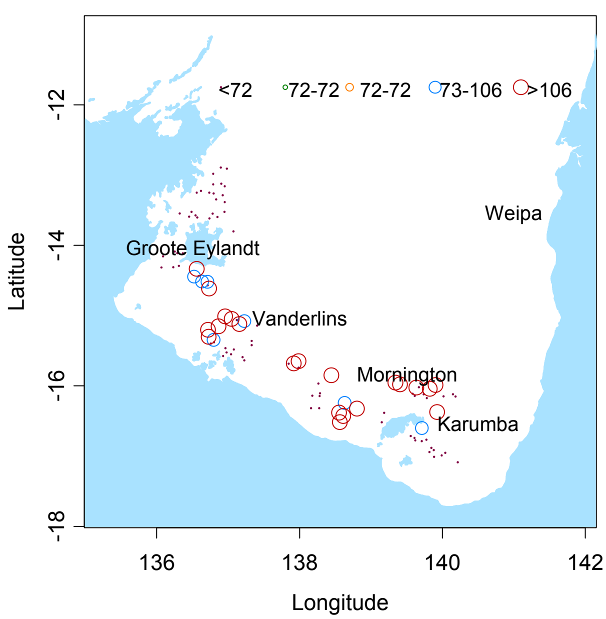


Figure 66: Distribution of average individual weight (g) of the squid (*Loliginidae*) caught in the survey of August 2002

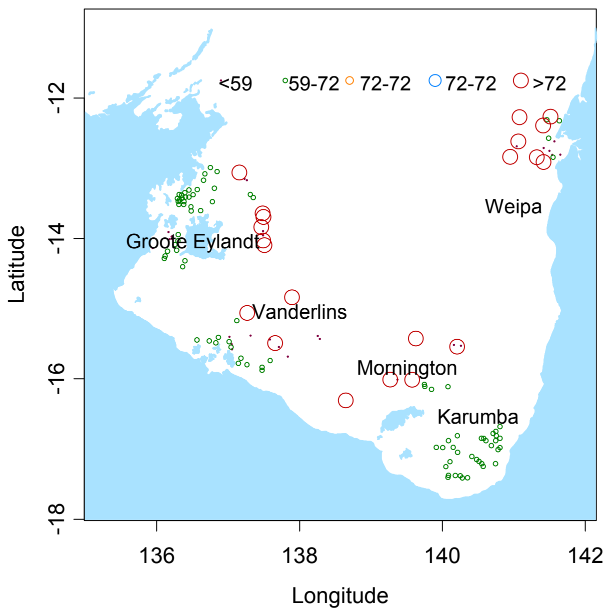


Figure 67: Distribution of average individual weight (g) of the squid (*Loliginidae*) caught in the survey of January/February 20023

9.7 Results - Octopus

Order *Octopoda* was recorded only in the August 2002 survey. They were very sparsely distributed throughout the survey area, with the maximum grade of catch rates only >4 octopus per standard net tow (Figure 68). It seems that *Octopoda* were not distributed in very shallow waters along the coast, but are more likely to occur in the mid-depth waters. Individual weights ranged from 34-76g (Figure 69).

9.8 Conclusions

The most abundant byproduct species caught during the two prawn surveys were mud scallops (*A. pleuronectes*), mud bugs (*T. indicus*), cuttlefish (*Sepiidae*) and squid (*Loliginidae*). The surveys provide valuable information about their spatial distributions of density and size. Some results from these two surveys contrast with the existing knowledge about the same species recorded in other places. For example, mud bugs (*T. indicus*) are believed to occur in shallow waters less than 25m. Our surveys show mud bugs have a fairly high catch rate even in waters as deep as 50m. Reef bugs (*T. orientalis*) are reported to have longevity of approximate 5-6 years. However, the length frequency distribution from these two surveys cannot fully support this claim. As these byproduct species have not been subject to extensive study, particularly in the Gulf of Carpentaria, further investigation is required.

The spatial distribution of some byproduct species exhibited interesting patterns. For example, mud scallop has high catch rates in Mornington, but very low density in Karumba (Figure 32 and Figure 33). The order of magnitude of this difference is 10 times. It is normally believed that distribution of marine animals is related to sediments.

Should relevant data be available, a correlation analysis may reveal the real mechanism of the spatial distribution for each species.

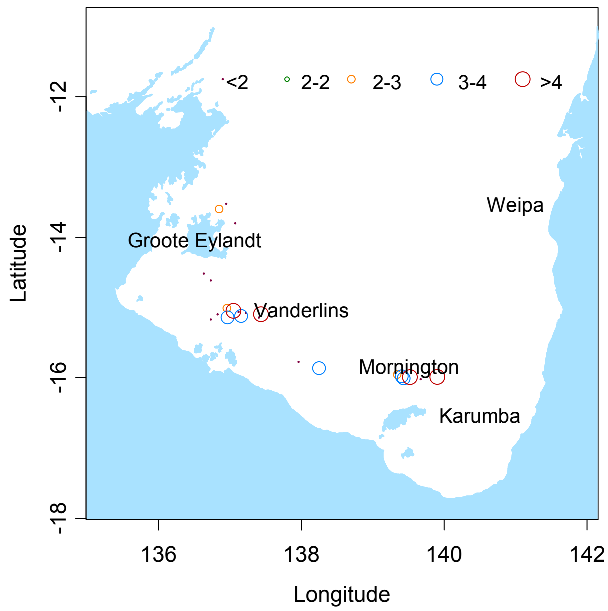


Figure 68: Spatial distribution of octopus (Order Octopoda) (no/hr) in the survey of August 2002

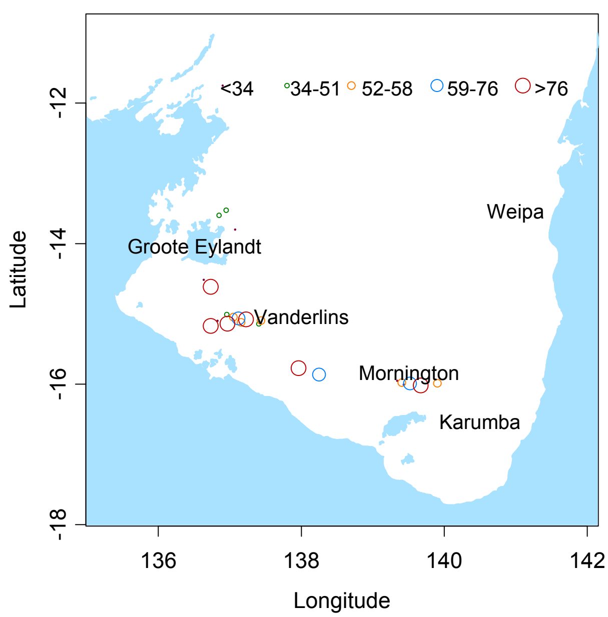


Figure 69: Distribution of average individual weight (g) of the octopus (Order Octopoda) caught in the survey of August 2002

9.9 References

Adam, W. and W. J. Rees. 1966. A review of the Cephalopod family Sepiidae. Sci. Rep. John Murray Exped. 11: 1-165.

Courtney, AJ And Williams, LE. 2002. Bugs. pp.22-26. In Queensland's Fisheries Resources-current condition and recent trends 1988-2000. Ed. By L.E. Williams. Department of Primary Industry, Brisbane. 180 pp.

Dredge, MCL. And Williams, LE. 2002. Scallop. pp.51-54. In Queensland's Fisheries Resources-current condition and recent trends 1988-2000. Ed. By L.E. Williams. Department of Primary Industry, Brisbane. 180 pp.

CHAPTER 10 FUTURE SURVEY COSTS

The total cost of the future surveys proposed is higher than was budgeted for in 2002/03. There are several reasons for this:

Staff Costs (Increased by $7,350)

Staff salary costs have increased, partly because general pay rates have increased, but also because, based on the experience of the past year, we have found it necessary to increase the amount of time spent carrying out the research. The large volume of data collected has meant that it has taken far longer than we expected to process all the data from the surveys in 2002/03. Difficulties in the identification of squid and cuttlefish have meant that some of the analysis of these animals is still continuing. We have also had to put more CSIRO staff to sea than we expected.

Operating Costs (Increased by $56,306)

Vessel charter costs are higher than we expected when we proposed the budget for 2002/03. We had originally planned to use a research trawler but both the vessels that we had planned to use became unavailable and we have used commercial NPF trawlers for the surveys so far. Although the cost is higher, we believe that using these commercial vessels has been beneficial for the project in the long term. We have costed vessel charter at $3800 per day for this proposal.

CSIRO Head Office in Canberra has this year imposed a new levy (Corporate Levy) on all CSIRO projects and this has resulted in an increase in the cost of this proposal.

Travel Costs (Increased by $7,340)

Travel costs have increased, partly as a result of general increases, but also because we have had to increase the number of CSIRO staff travelling to the NPF.

August Survey 2003

Staff	***Time***	***Costs***	
Project Manager	6 weeks	$15,492	
Statistician/Modeller	9 weeks	$19,139	
Field Manager/Biologist	6 weeks	$18,052	
Field Biologists	14 weeks	$29,775	
Total Salaries		**$82,458**	
Operating			
Data entry		$7,200	
Freight/sample storage		$5,000	
Consumables		$4,000	
Nets		$5,000	
Trawler charter		$83,600	
CSIRO Support Levy		$76,505	
Total Operating		**$181,305**	
Travel			
Airfares		$6,000	
Transit accommodation & expenses		$2,760	
Total Travel		**$8,760**	
Total Module Cost			**$272,523**

January Survey 2004

Staff	*Time*	*Costs*	
Project Manager	6 weeks	$15,492	
Statistician/Modeller	10 weeks	$19,746	
Field Manager/Biologist	6 weeks	$18,052	
Field Biologists	19 weeks	$45,412	
Total Salaries		**$98,702**	
Operating			
Data entry		$11,200	
Freight/sample storage		$6,000	
Consumables		$5,000	
Nets		$5,000	
Trawler charter		$114,000	
CSIRO Support Levy		$94,629	
Total Operating		**$235,829**	
Travel			
Airfares		$9,000	
Transit accommodation & expenses		$3,980	
Total Travel		**$12,980**	
Total Module Cost			**$347,511**

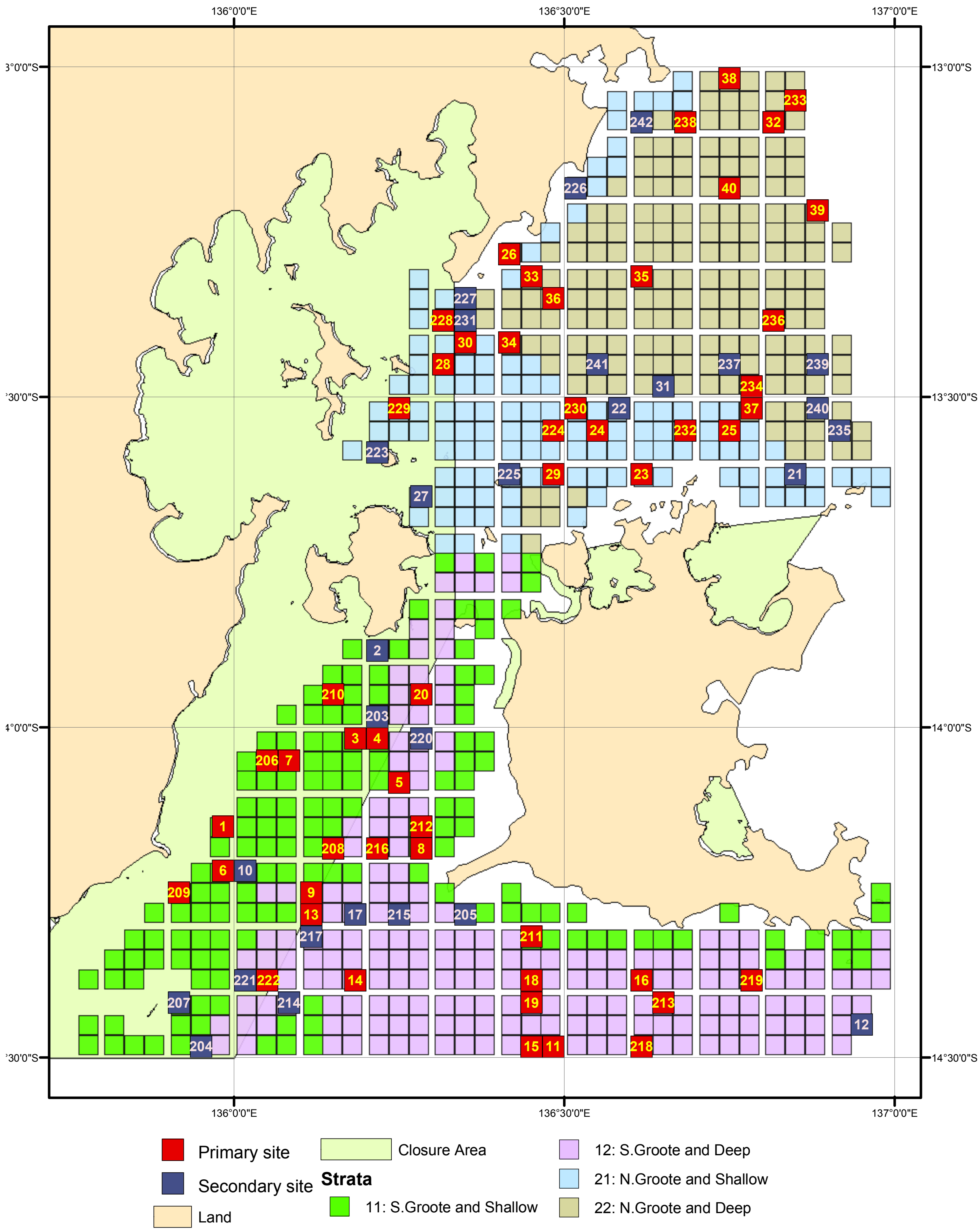
Total Cost – August and January	**$620,033**

CHAPTER 11 PRIMARY AND SECONDARY SITES FOR THE RECRUITMENT INDEX SURVEY

This Chapter provides the details of primary and secondary site positions. In this survey, each site number is unique within a survey. Sites finally used within the survey would be mainly primary and some secondary sites. The secondary sites were to be used as backup sites in case primary sites were untrawlable.

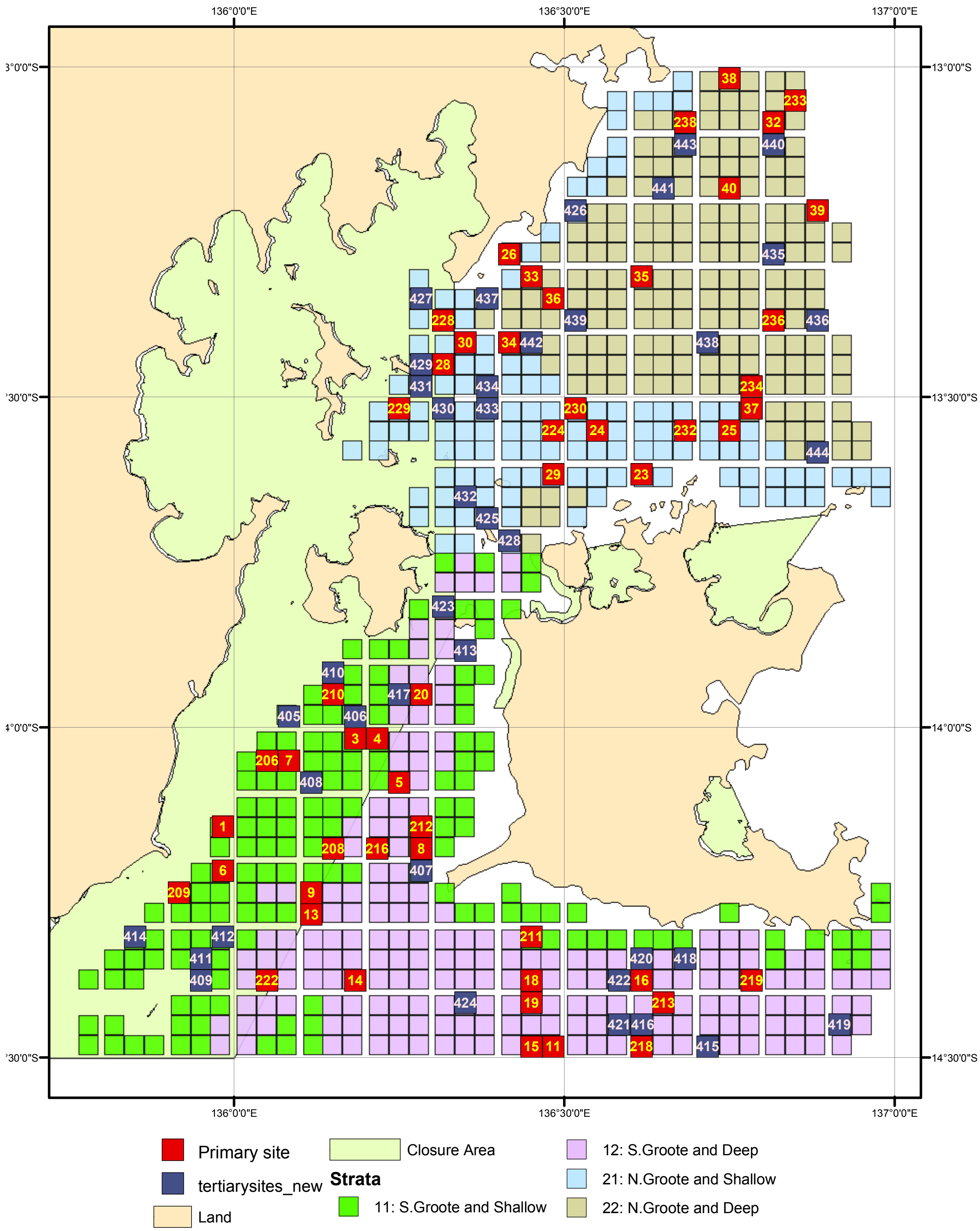
NPF survey sites in Groote
(Primary sites and Secondary sites)

(January 2003)



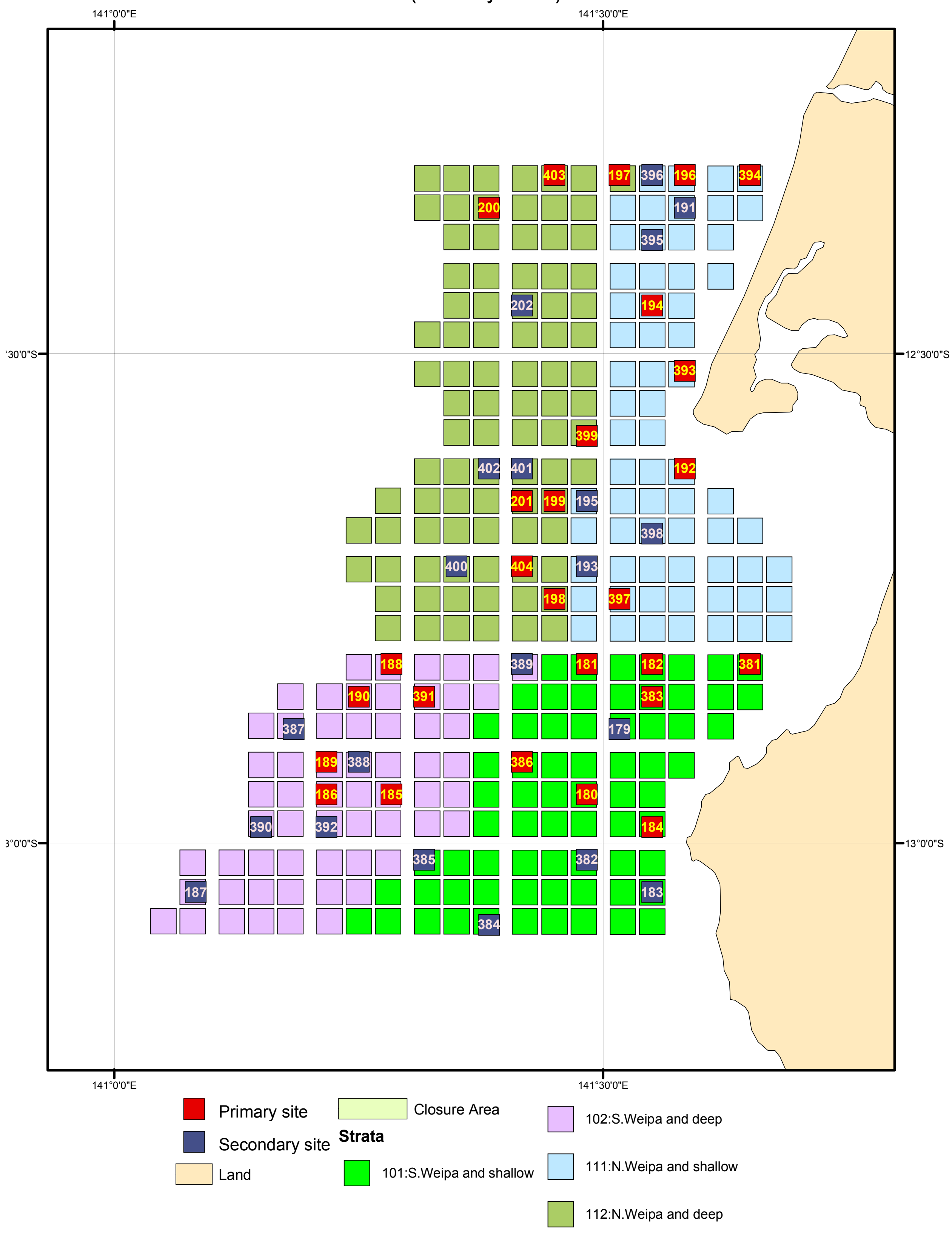
NPF survey sites in Groote
(Primary sites and Tertiary sites)

(January 2003)

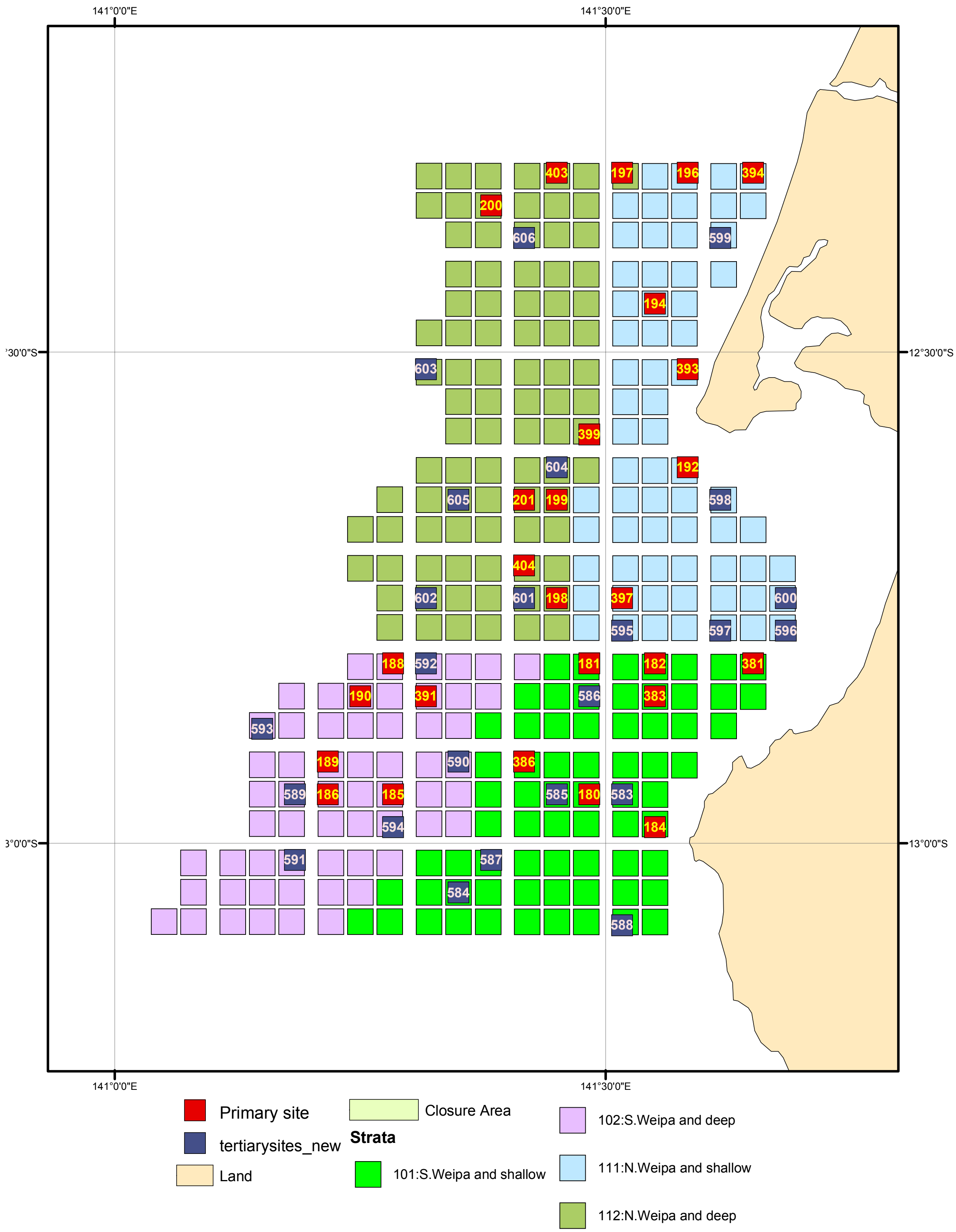


NPF survey sites in Weipa (Primary sites and Secondary sites)

(January 2003)

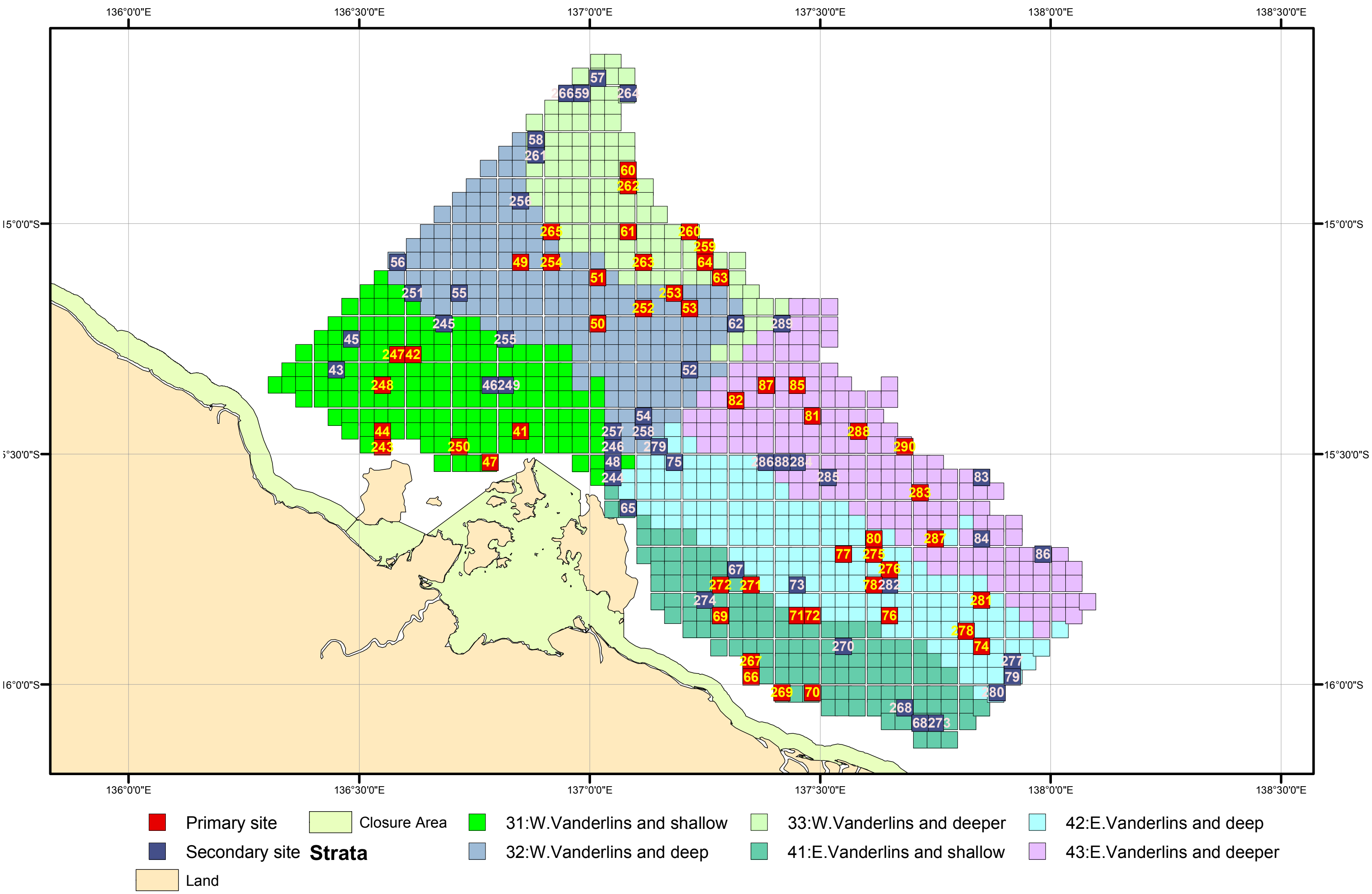


NPF survey sites in Weipa
(Primary sites and Tertiary sites)
(January 2003)



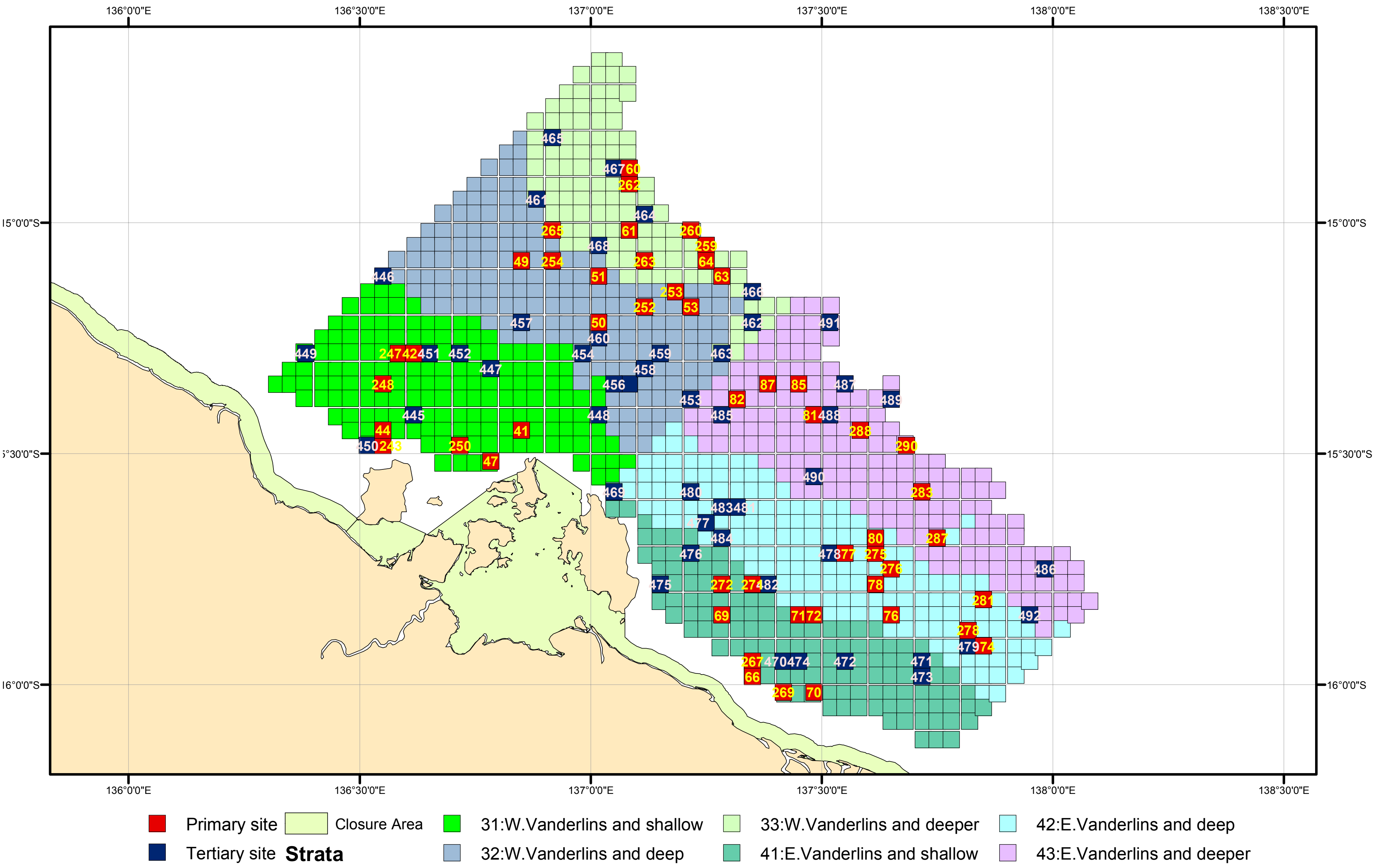
(January 2003)

NPF survey sites in Vanderlins (Primary sites and secondary sites)



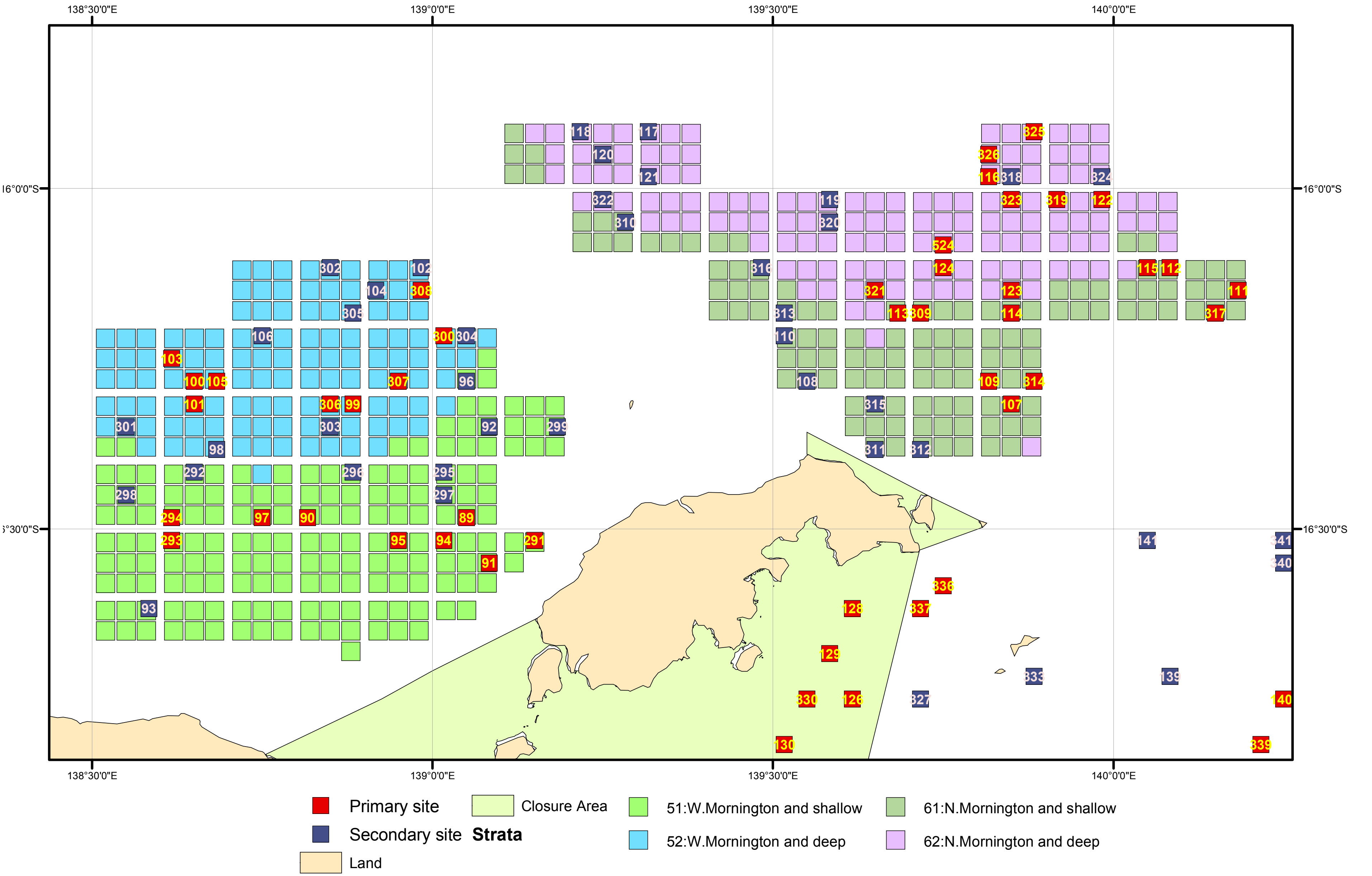
(January 2003)

NPF survey sites in Vanderlins (Primary sites and Tertiary sites)



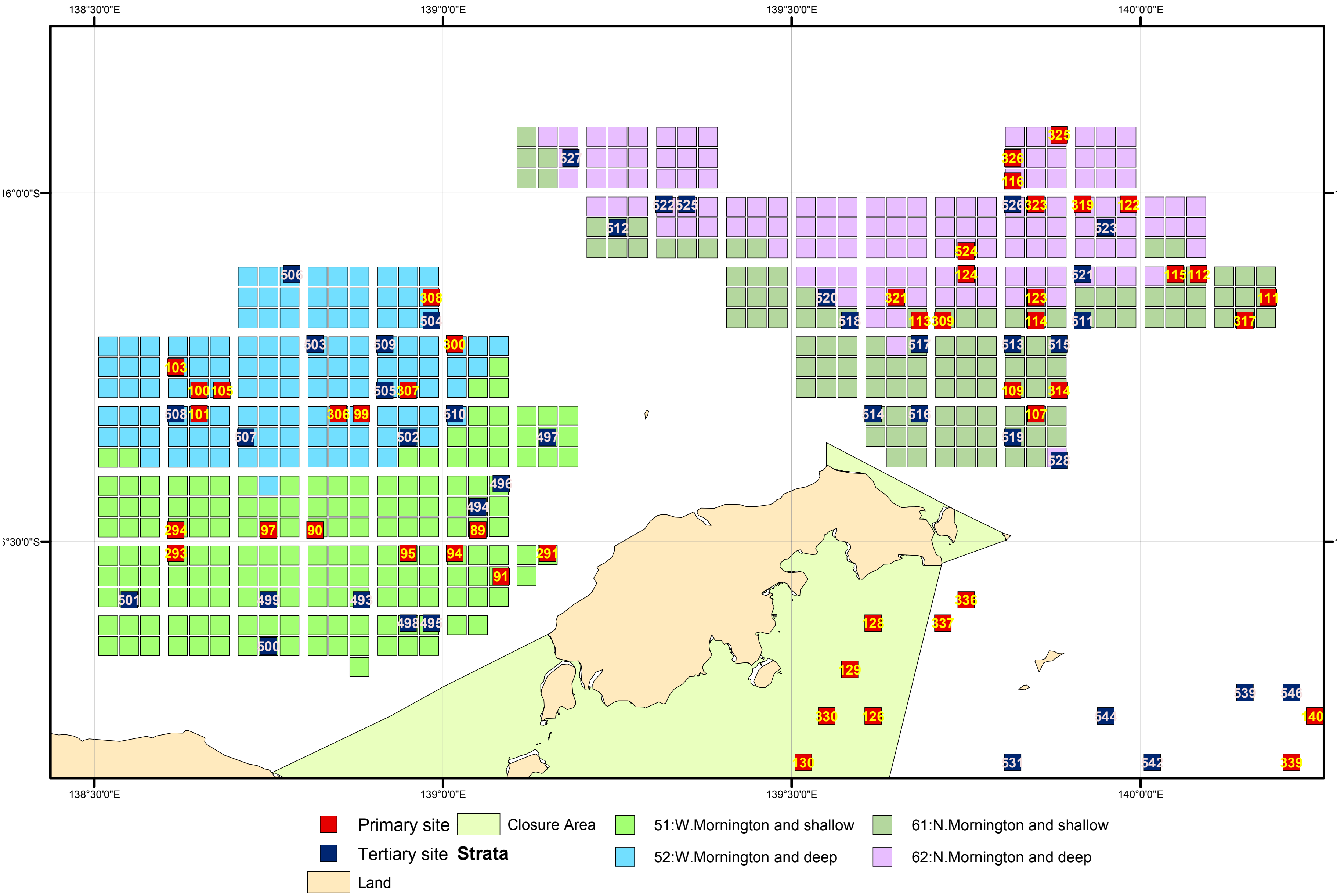
(January 2003)

NPF survey sites in Mornington (Primary sites and Secondary sites)



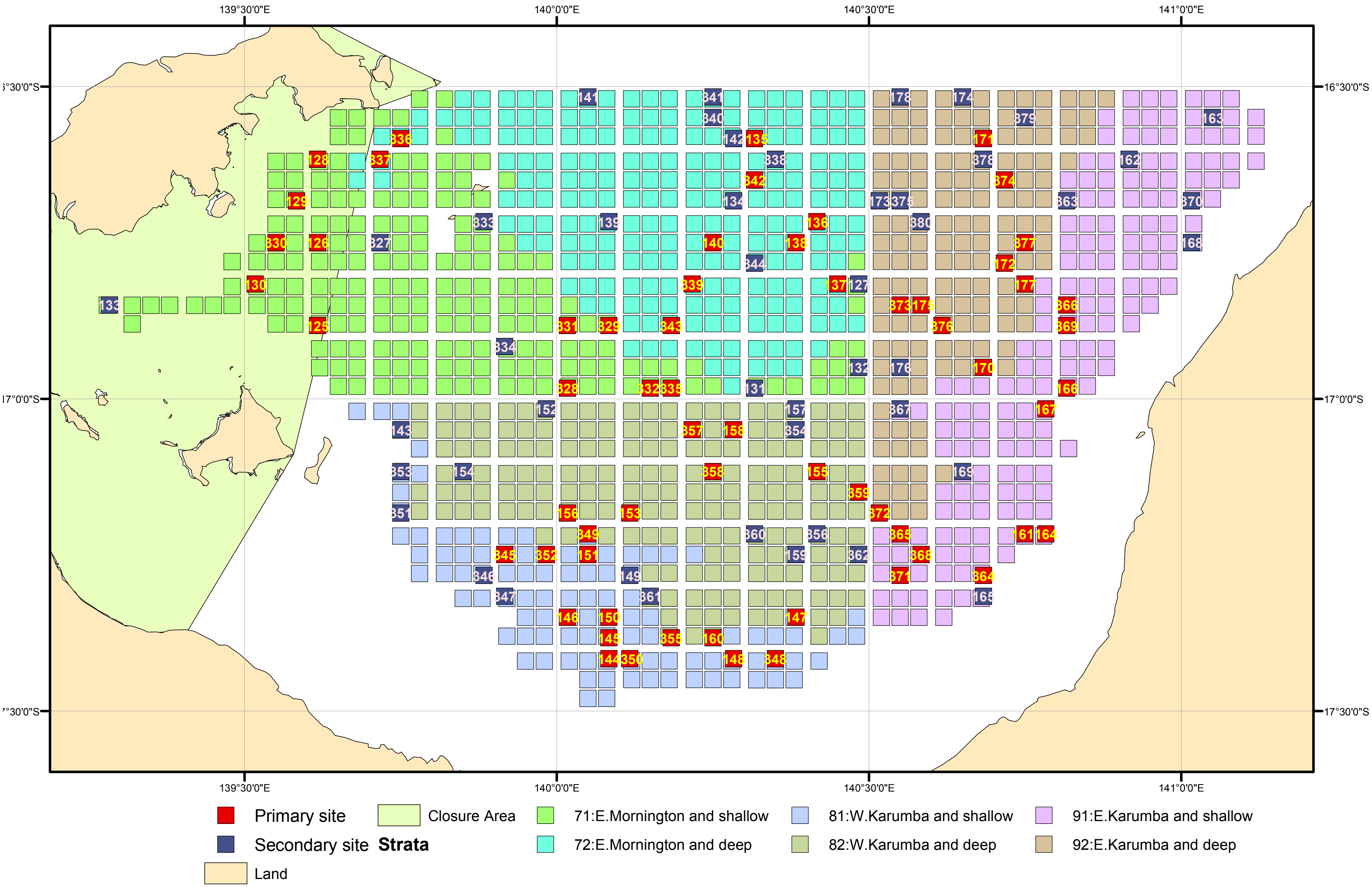
(January 2003)

NPF survey sites in Mornington (Primary sites and Tertiary sites)



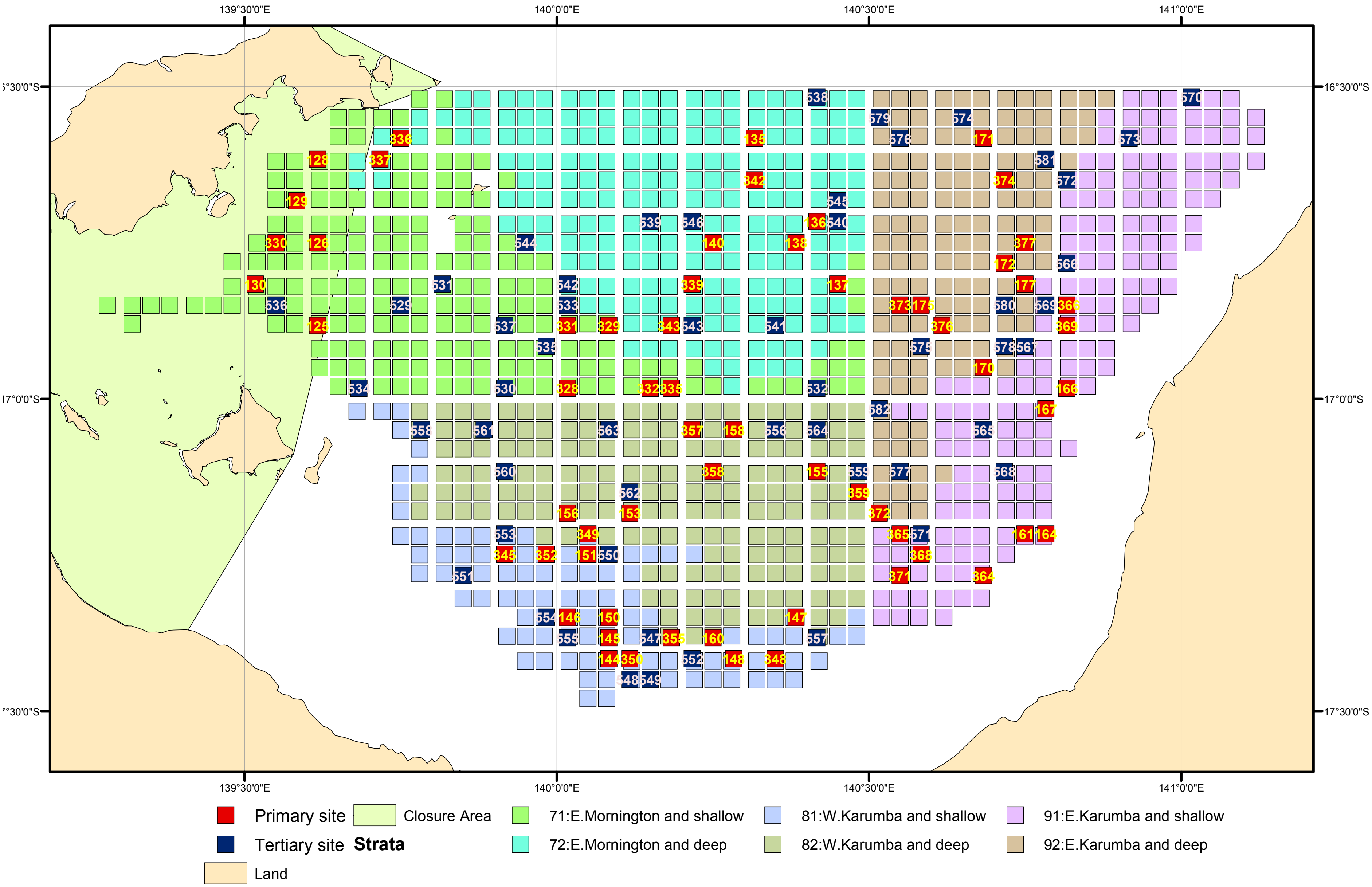
(January 2003)

NPF survey sites in Karumba (Primary sites and Secondary sites)



(January 2003)

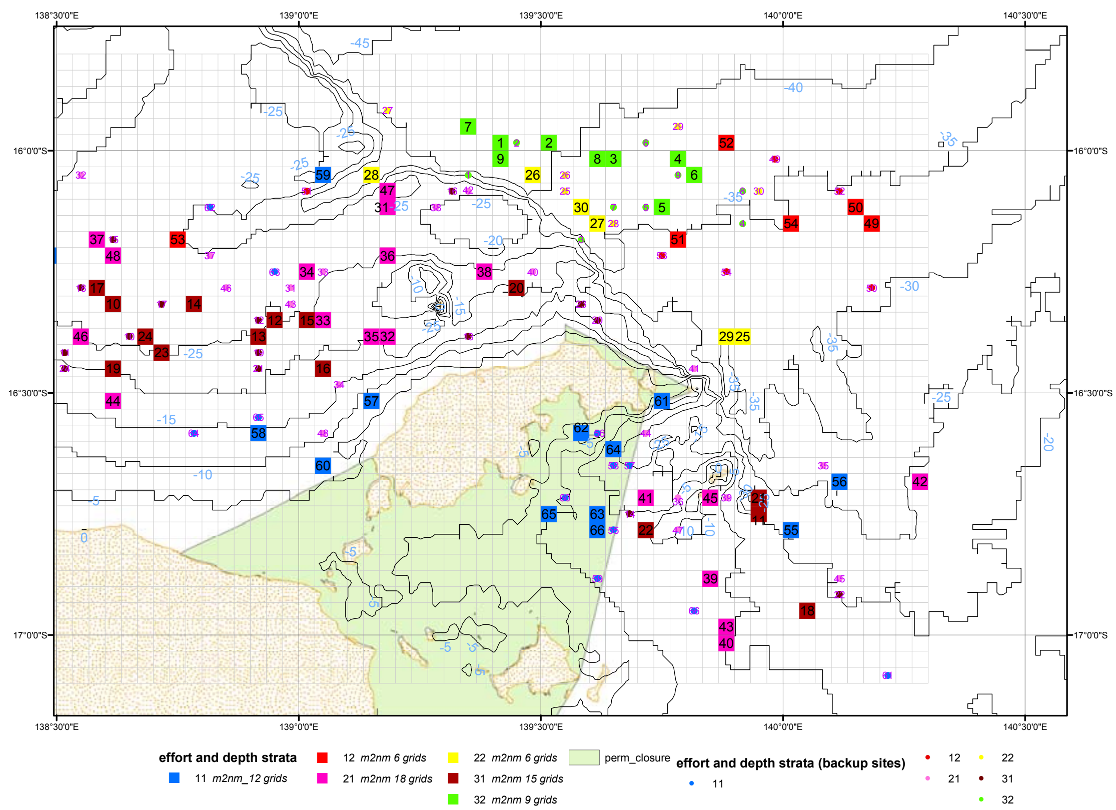
NPF survey sites in Karumba (Primary sites and Tertiary sites)



CHAPTER 12 PRIMARY AND SECONDARY SITES FOR THE SPAWNING INDEX SURVEY

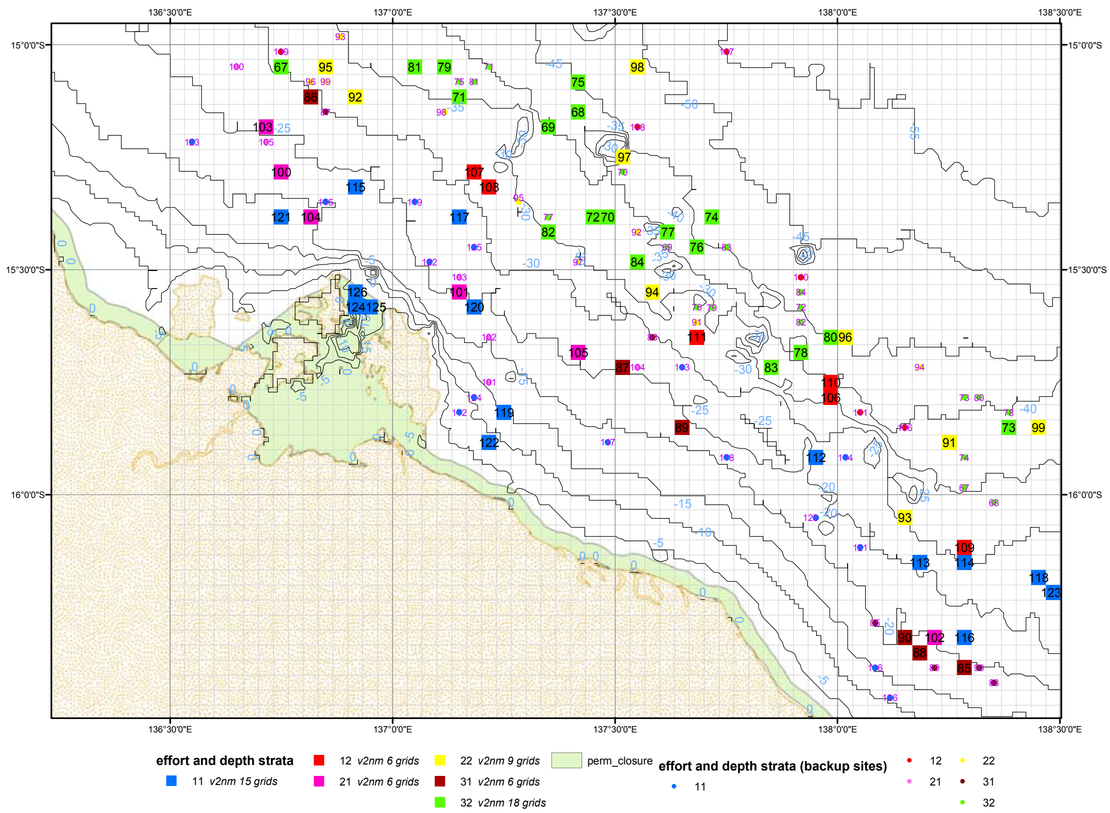
This Chapter provides the details of primary and secondary site positions. In this survey, each site number is unique within a survey. Sites finally used within the survey would be mainly primary and some secondary sites. The secondary sites were to be used as backup sites in case primary sites were untrawlable.

NPF survey sampling sites (2nm grid) in Mornington



Location of 2-nm sampling grids for Mornington Island. The primary sampling grids are completely colour-filled according to their depth and effort stratum. Secondary (backup) sampling grids are denoted by a coloured dot within the grid. Legend codes: digit 1 = effort stratum (1=low, 2=medium, 3=high); digit 2 = depth stratum (1=<30m, 2=>30m). e.g. “11 m2nm_12 grids” means “Effort stratum 1 (low), Depth stratum 1 (<30m), 12 grids were selected in this category.

NPF survey sampling sites (2nm grid) in Vanderlins



Location of 2-nm sampling grids for the Vanderlins. The primary sampling grids are completely colour-filled according to their depth and effort stratum. Secondary (backup) sampling grids are denoted by a coloured dot within the grid. Legend codes are as for the previous map.

NPF survey sampling sites (2nm grid) in Groote

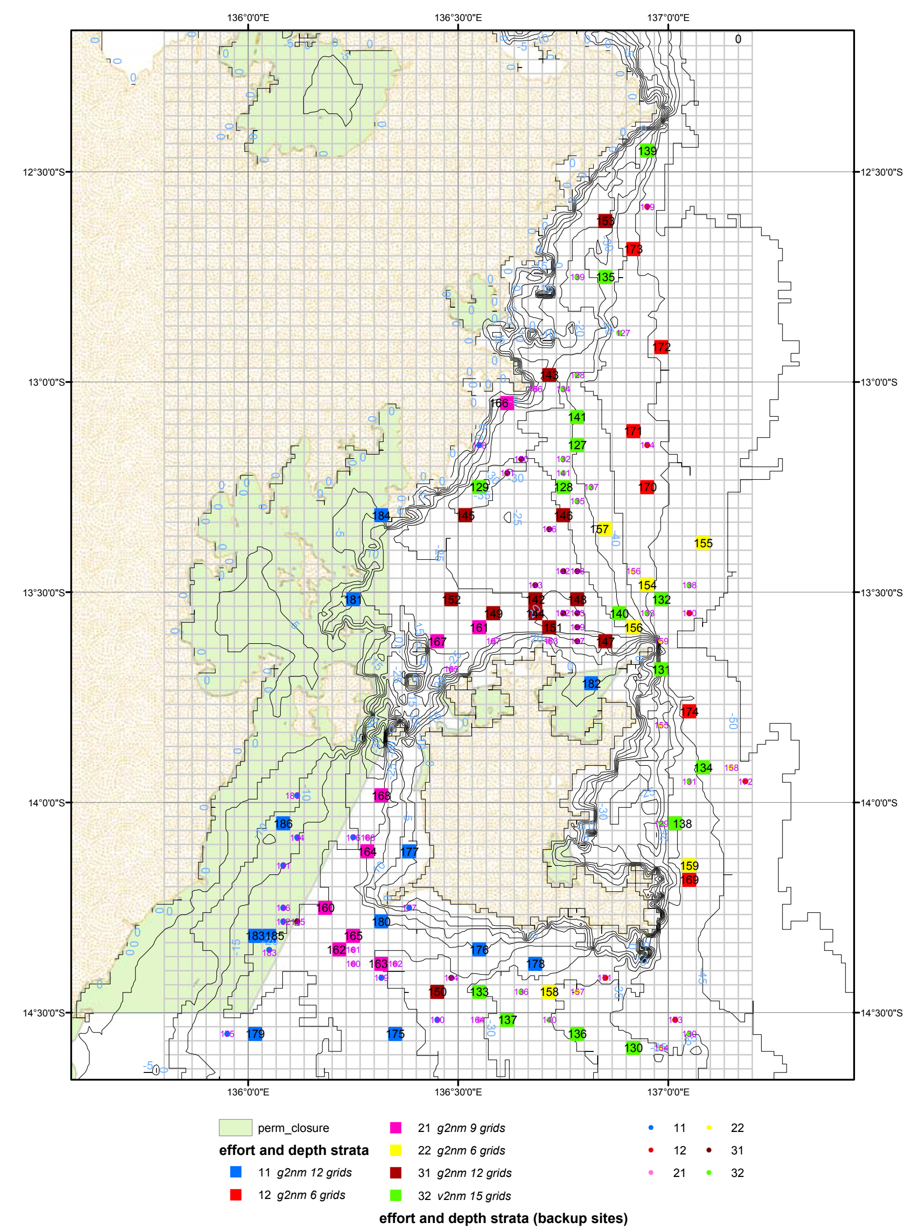


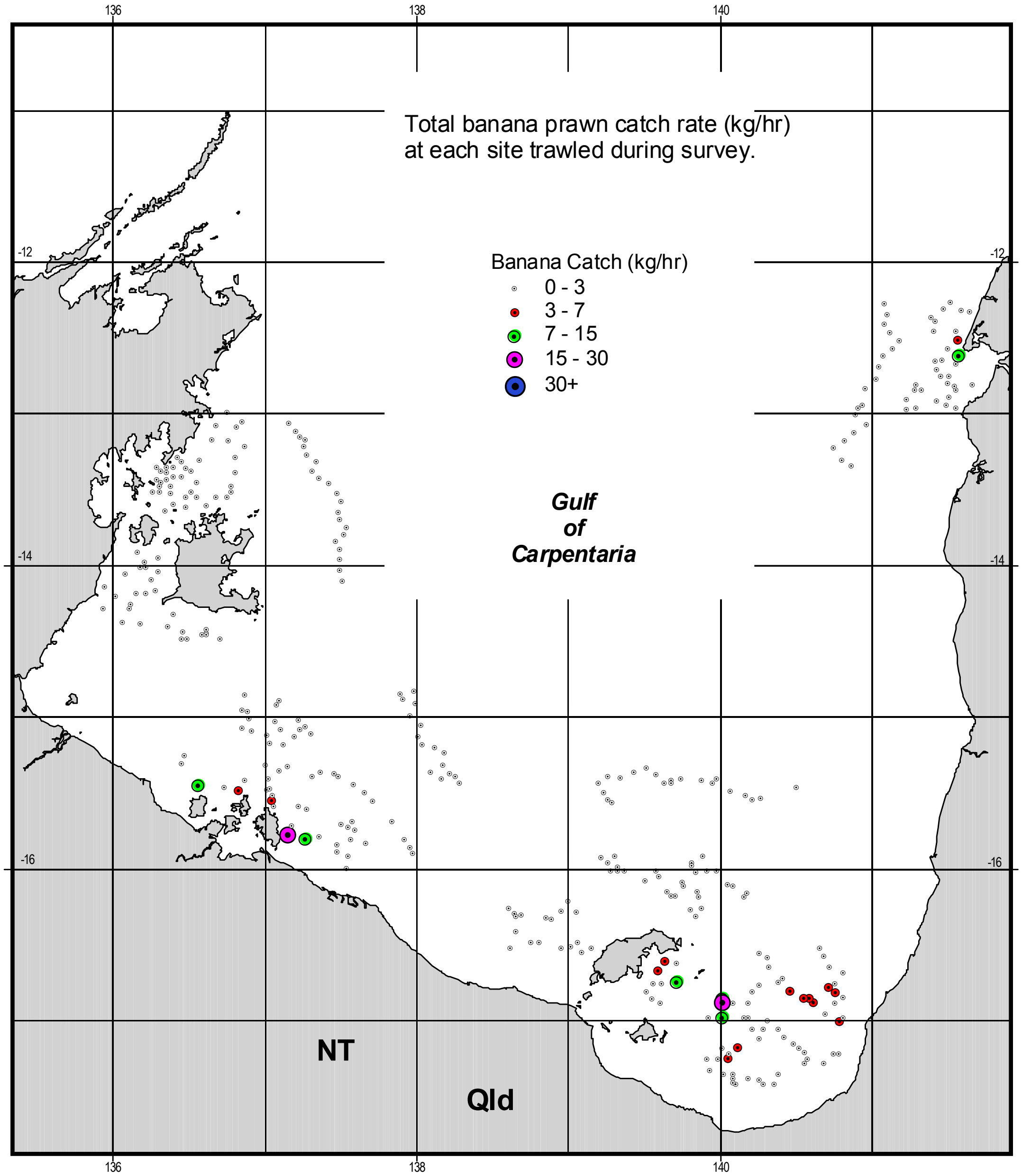
Figure 70: Location of 2-nm sampling grids for Groote Eylandt. The primary sampling grids are completely colour-filled according to their depth and effort stratum. Secondary (backup) sampling grids are denoted by a coloured dot within the grid. Legend codes are as for the previous map.

CHAPTER 13 DENSITY BY SPECIES FOR THE RECRUITMENT INDEX SURVEY

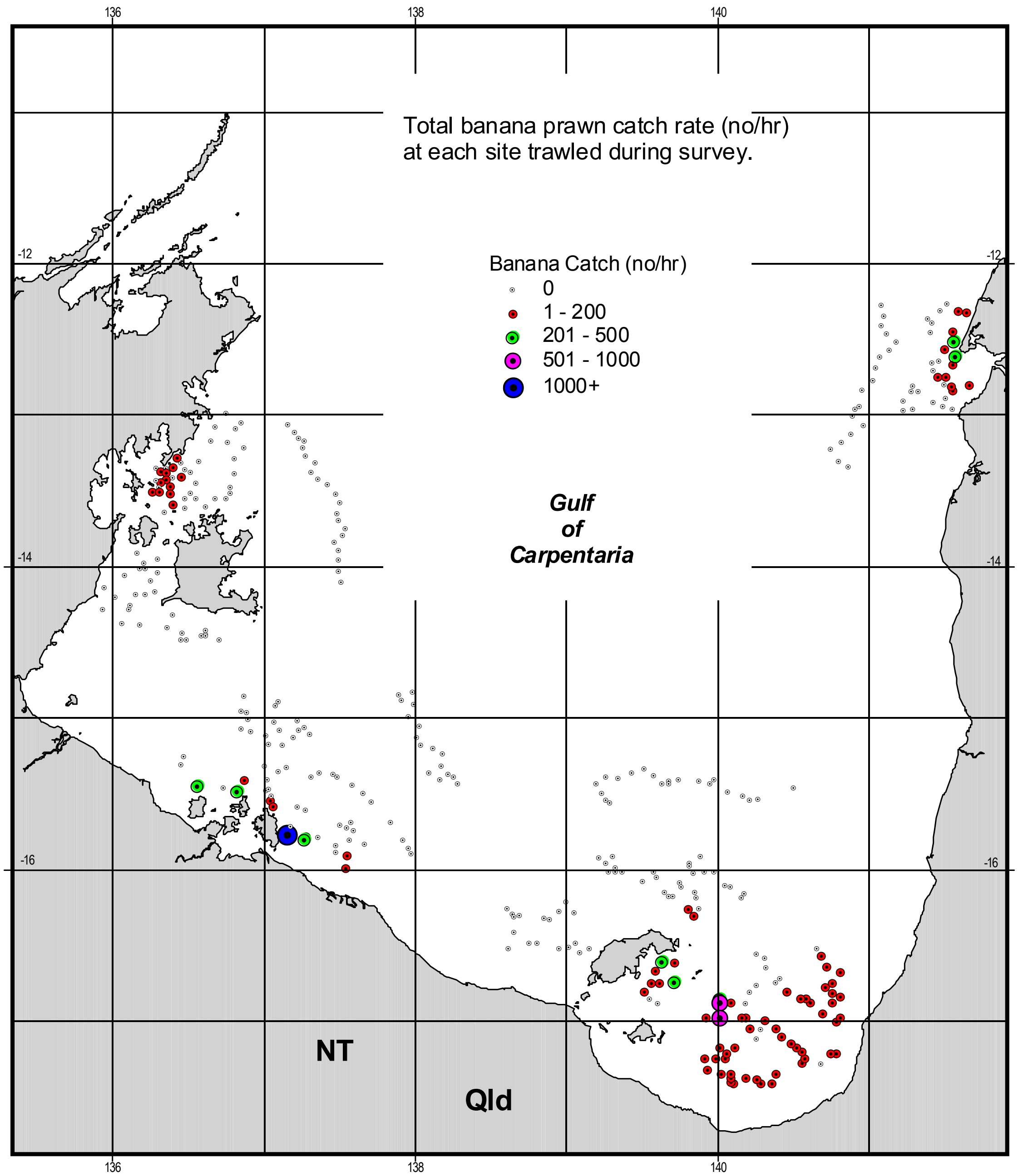
The following figures provide catch rates (kg/hour and numbers/ hour) and size (count/pound) of prawns by species for each site for the Recruitment Index (January 2003) survey. These plots include all sizes of prawn caught.

CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results

AFMA Australian Fisheries Management Authority



CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results

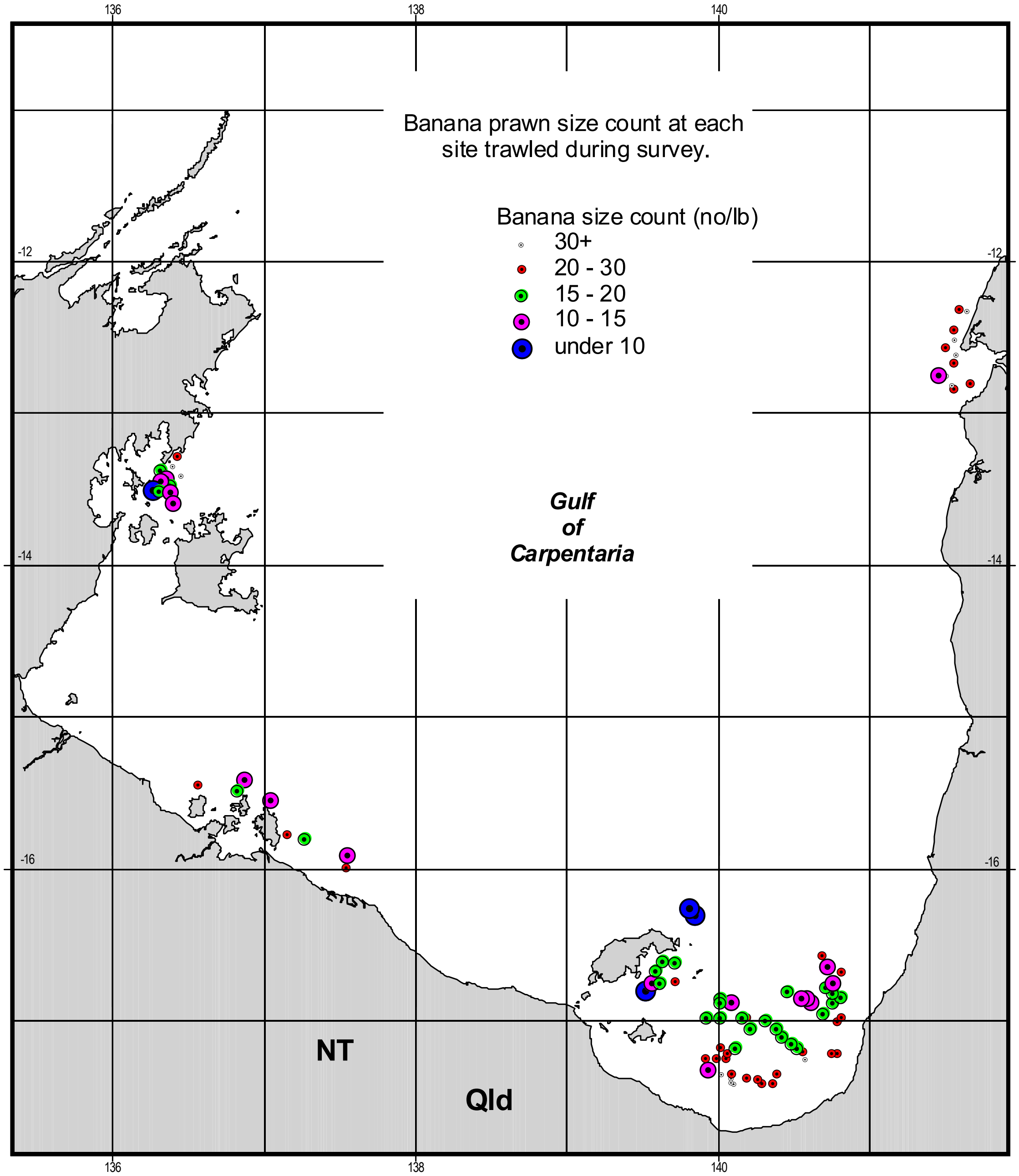


CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results

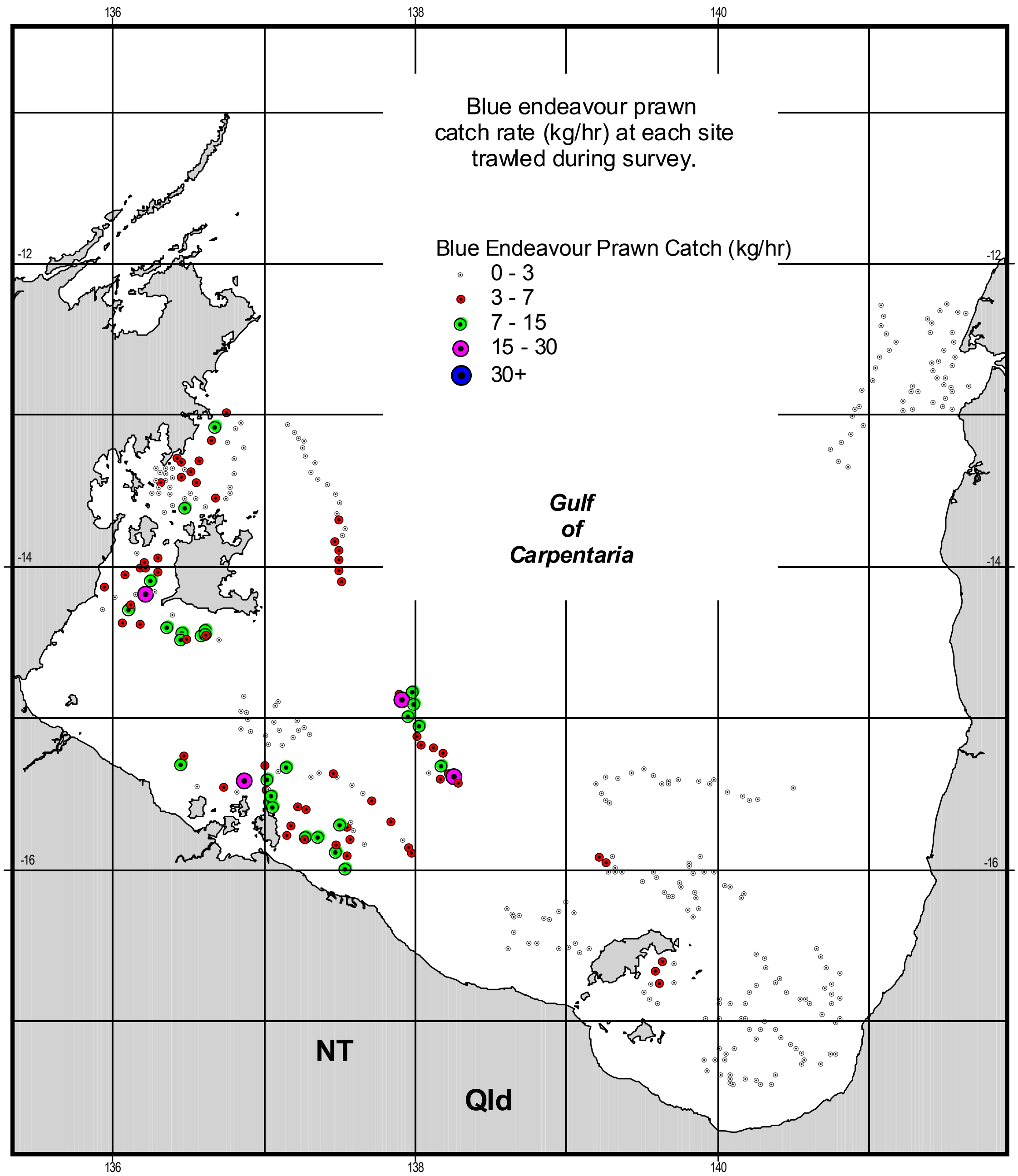
CSIRO

AFMA Australian Fisheries Management Authority

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

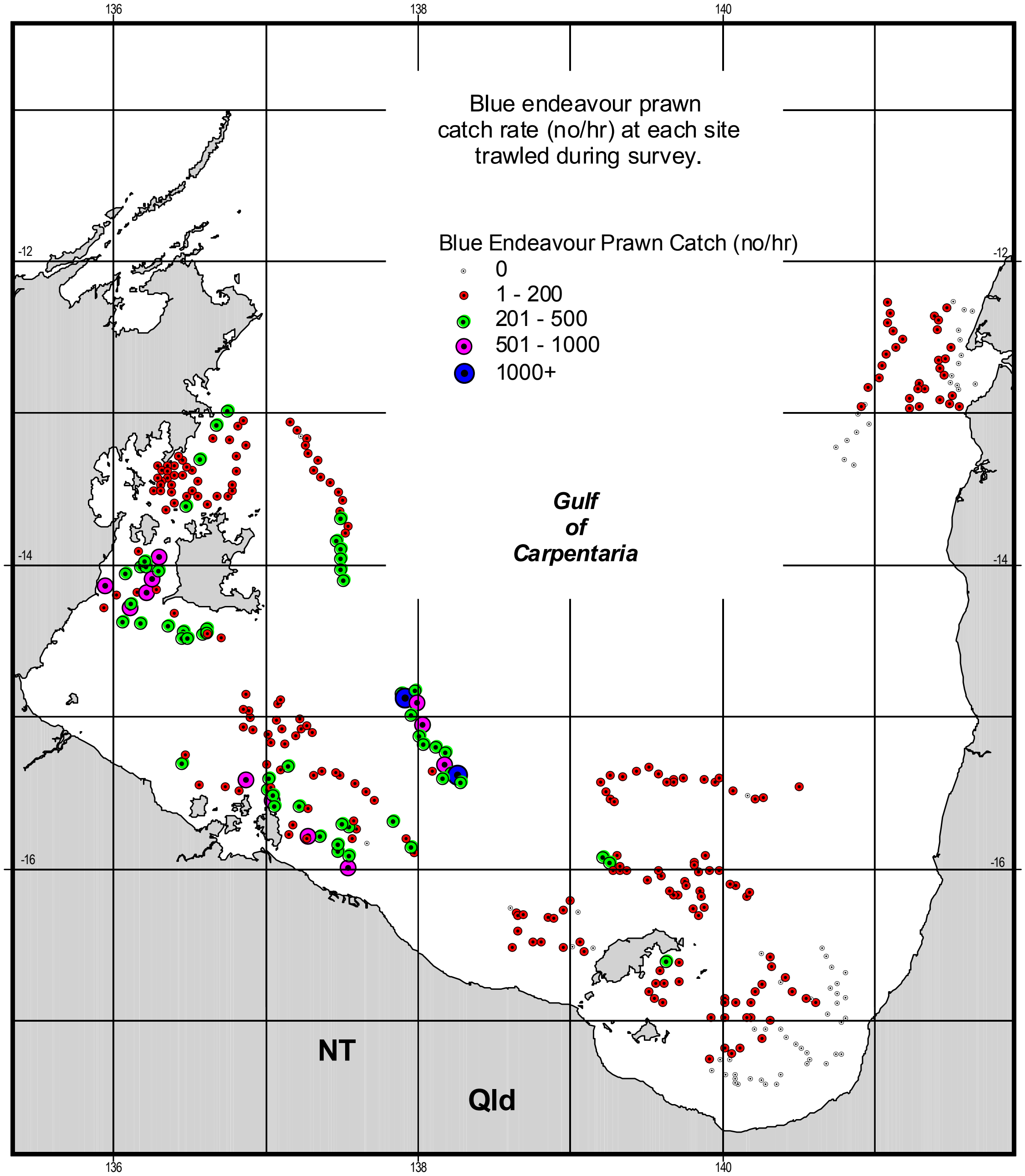


CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results

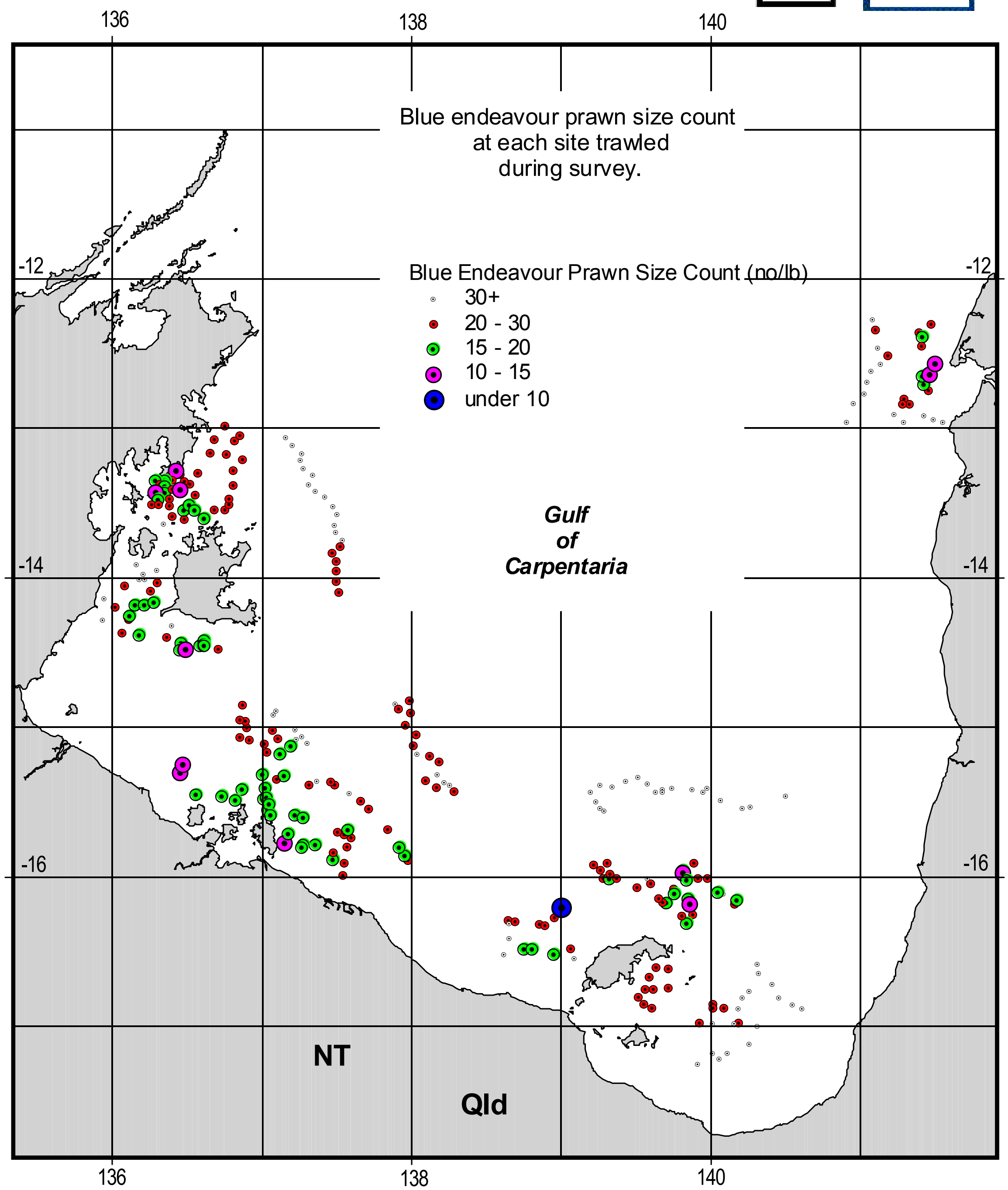


CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results

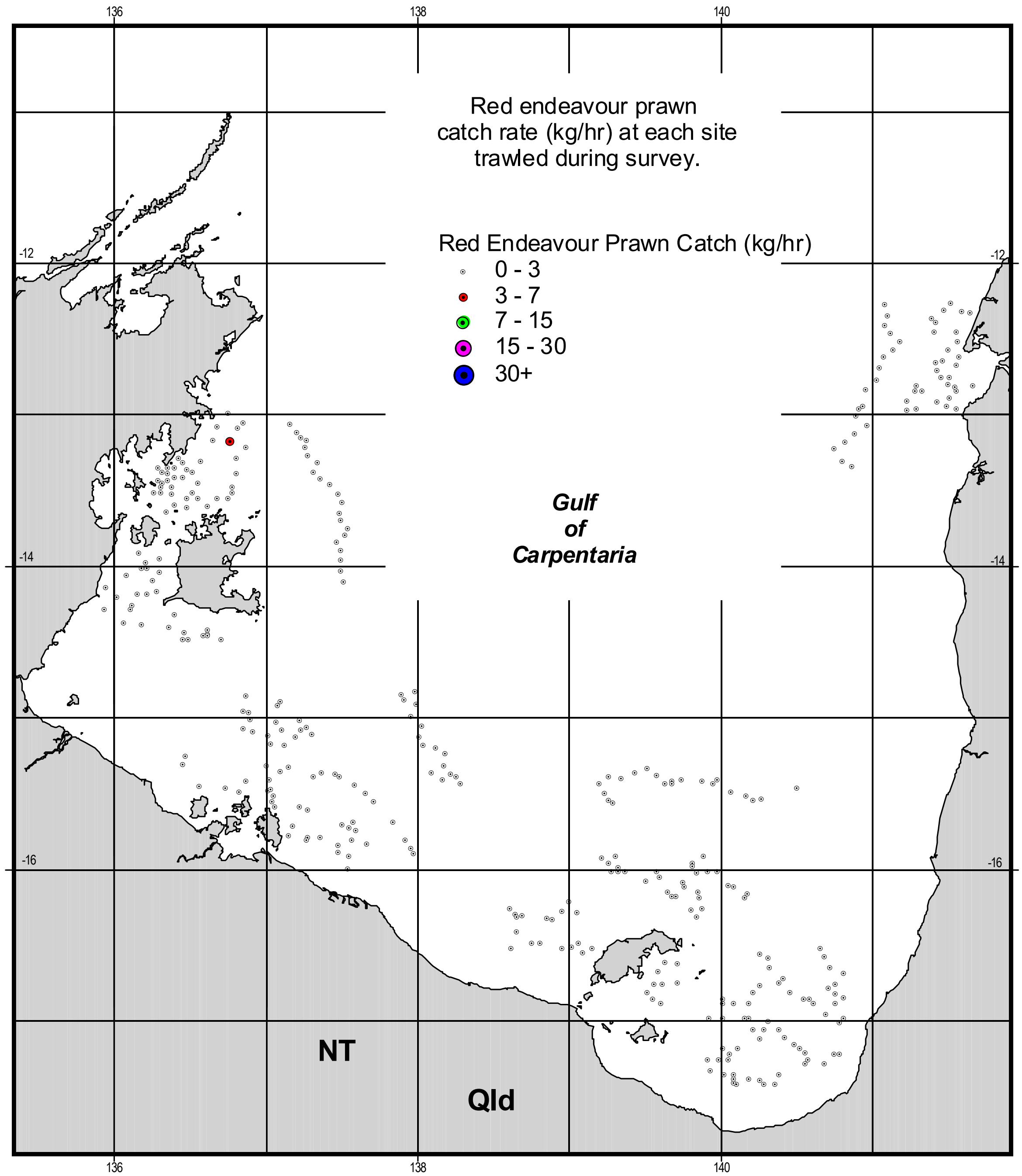
AFMA Australian Fisheries Management Authority



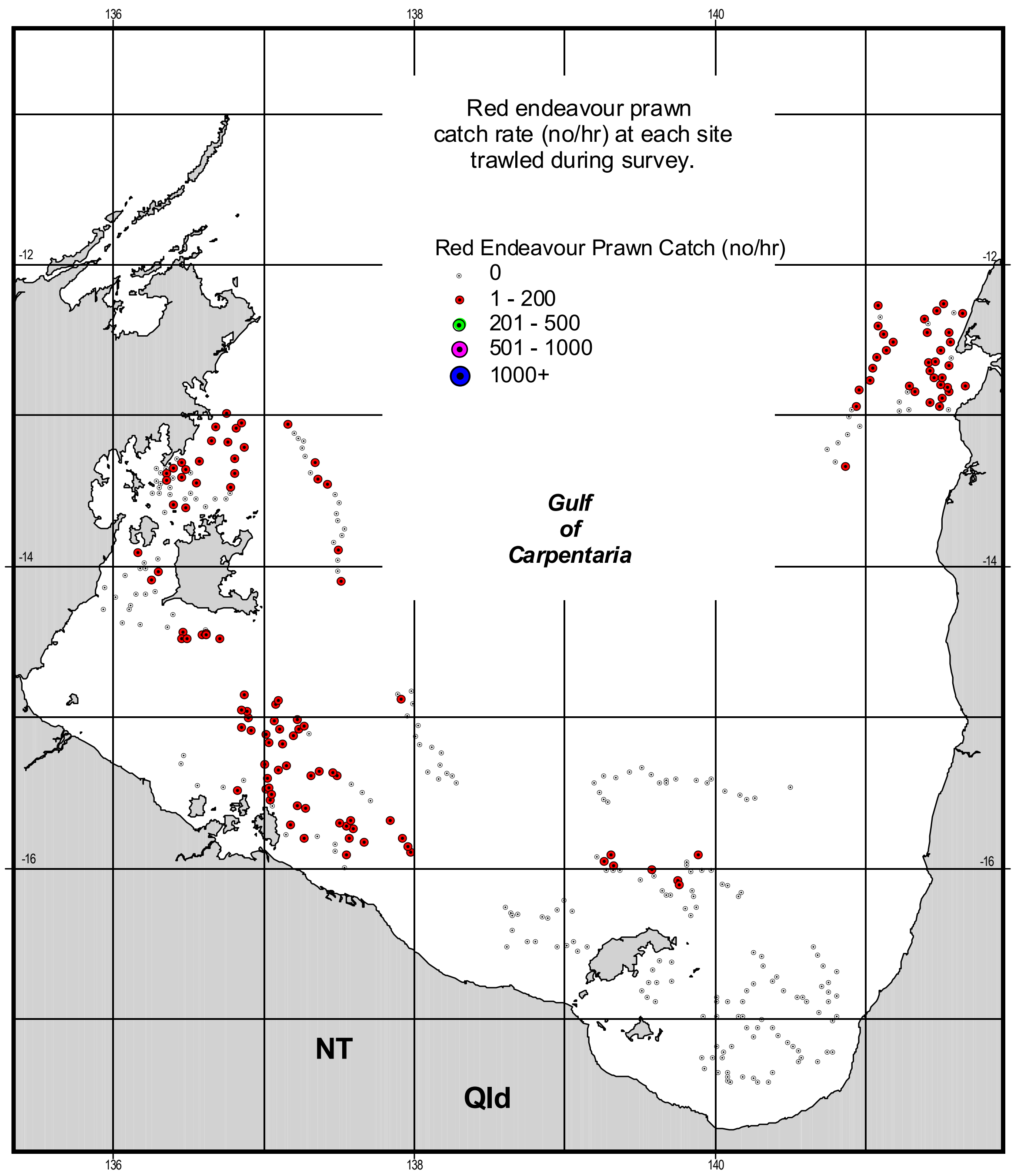
CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



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NPF Monitoring Cruise - January 2003
Preliminary Results

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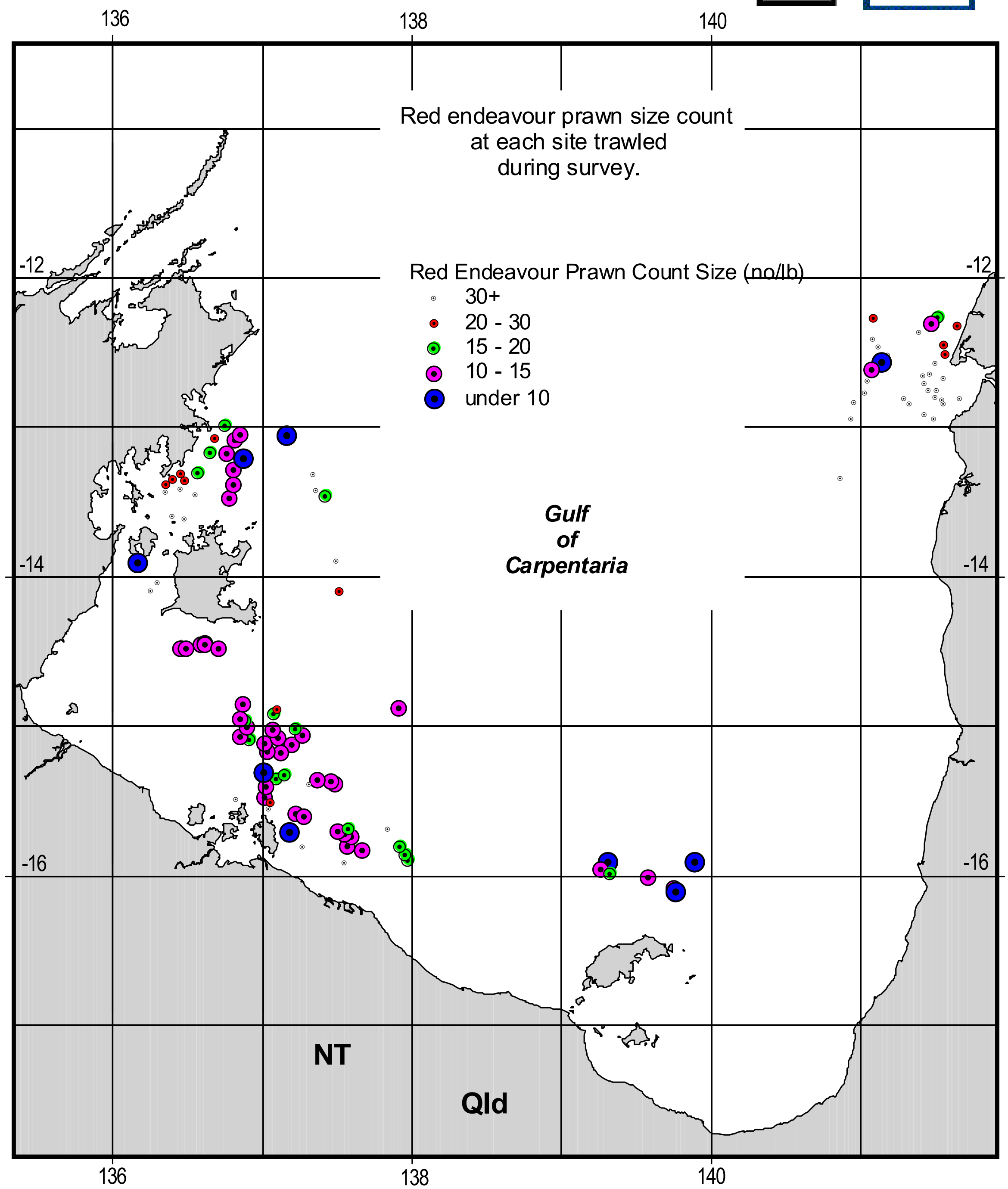
FISHERIES RESEARCH & DEVELOPMENT CORPORATION



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NPF Monitoring Cruise - January 2003
Preliminary Results

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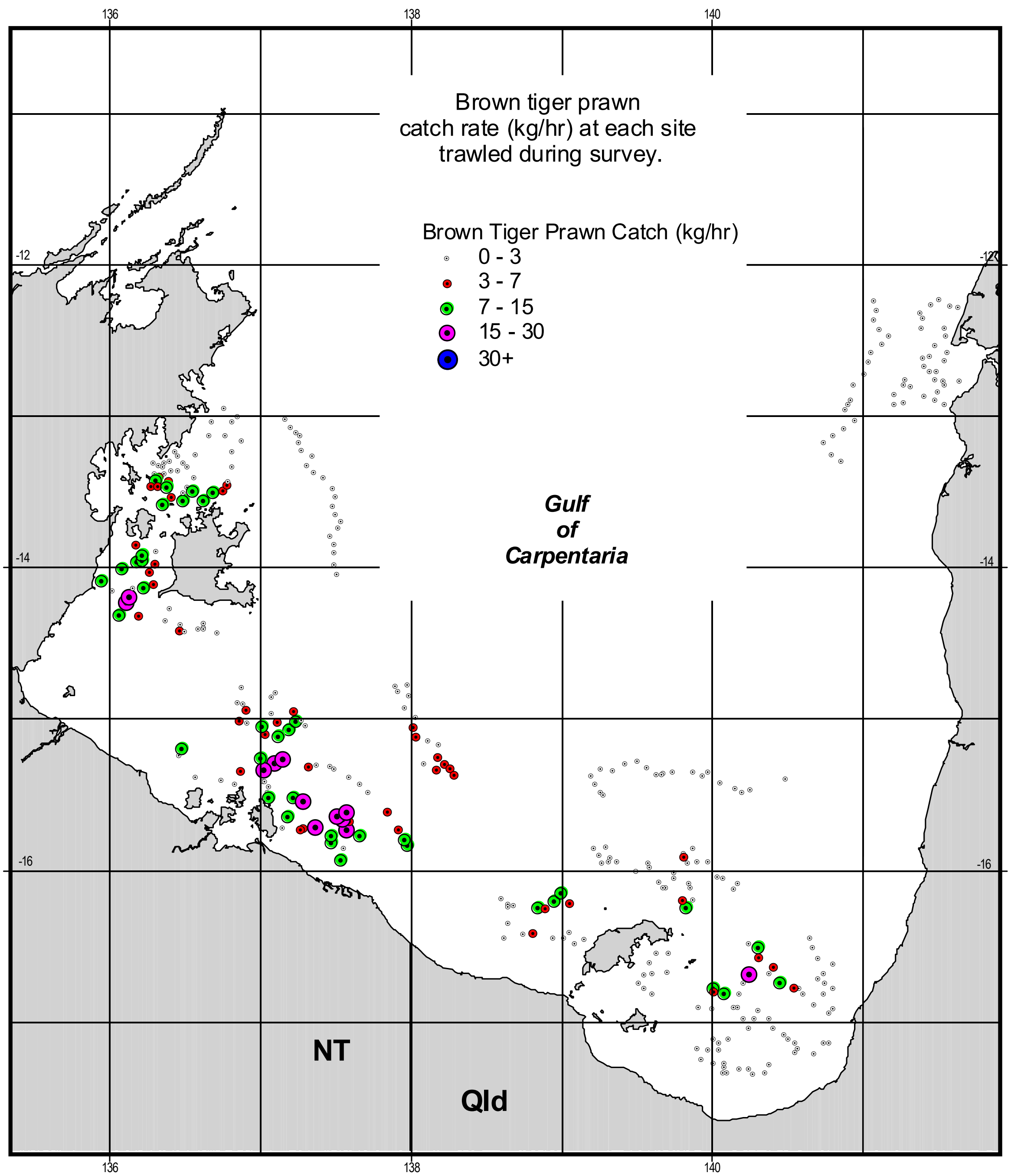
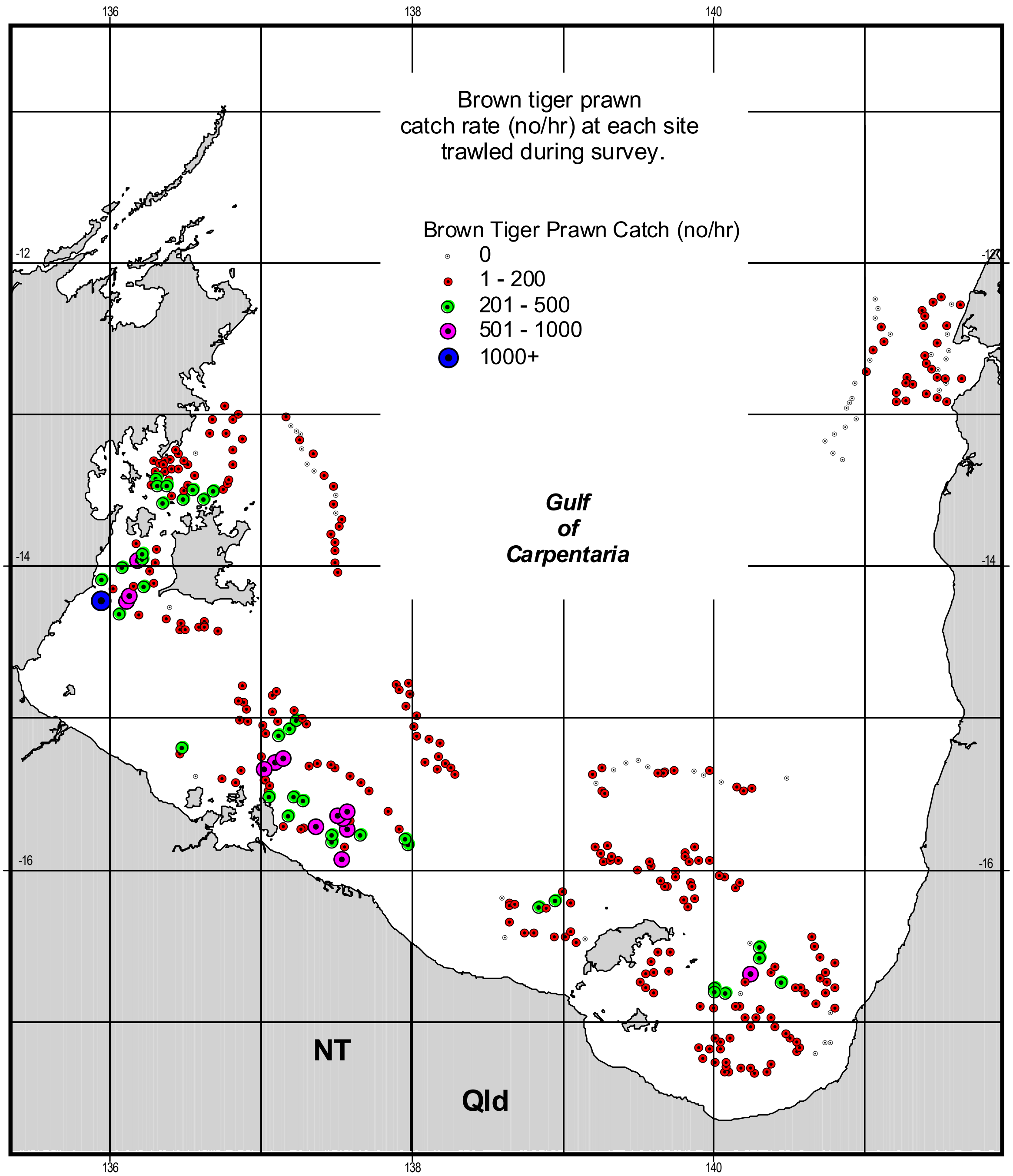
FISHERIES RESEARCH & DEVELOPMENT CORPORATION



CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



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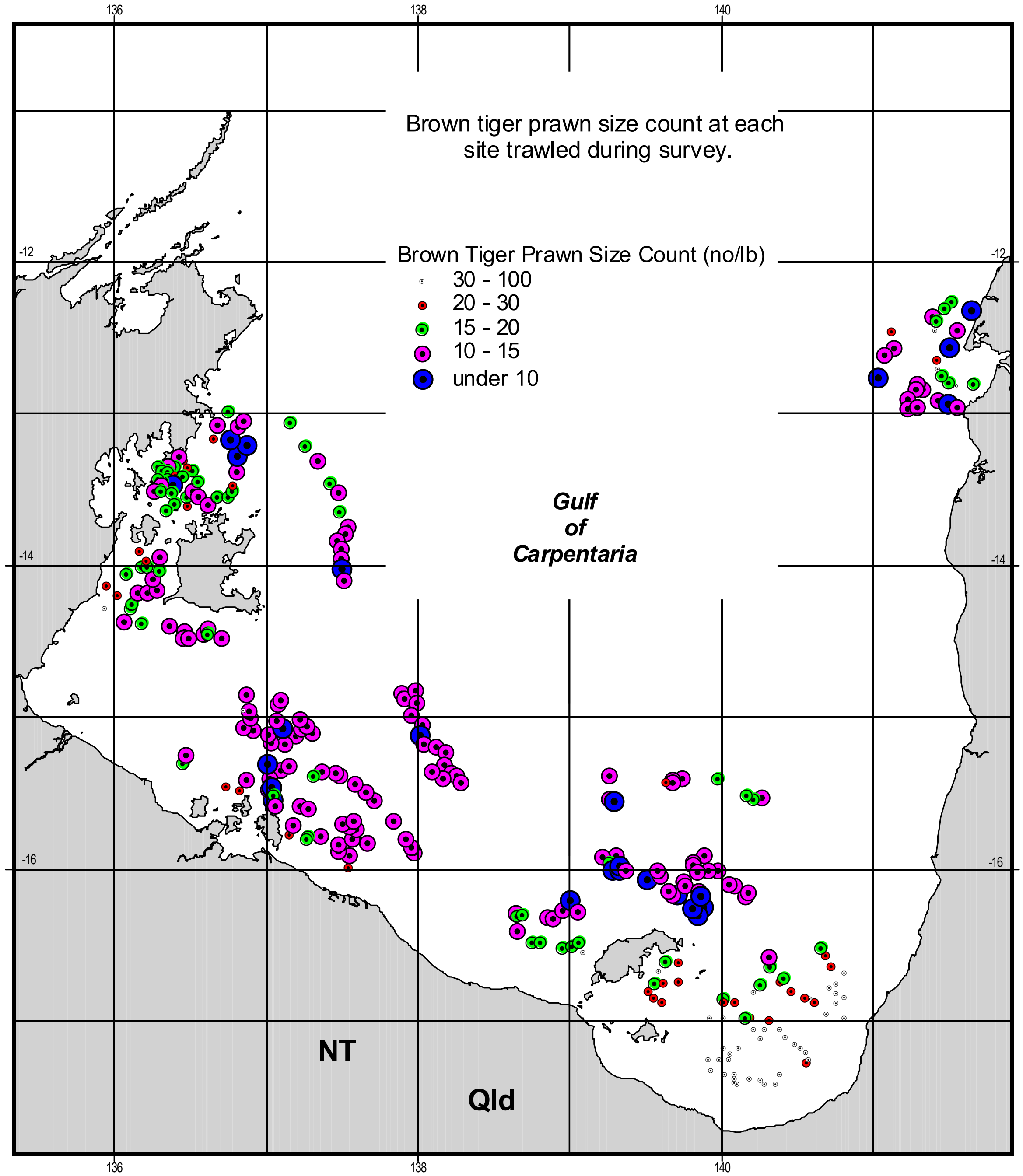
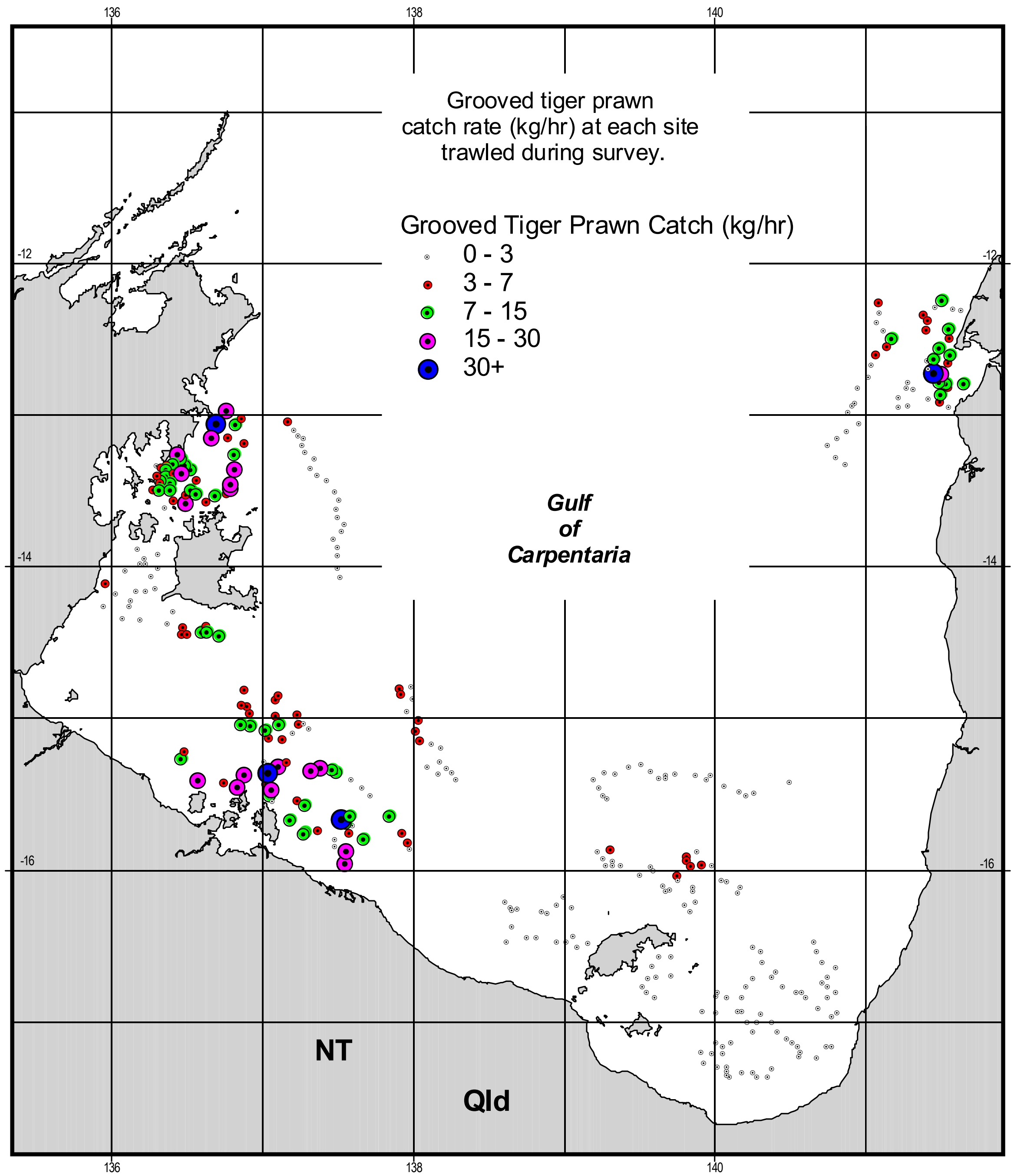
CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results

AFMA Australian Fisheries Management Authority

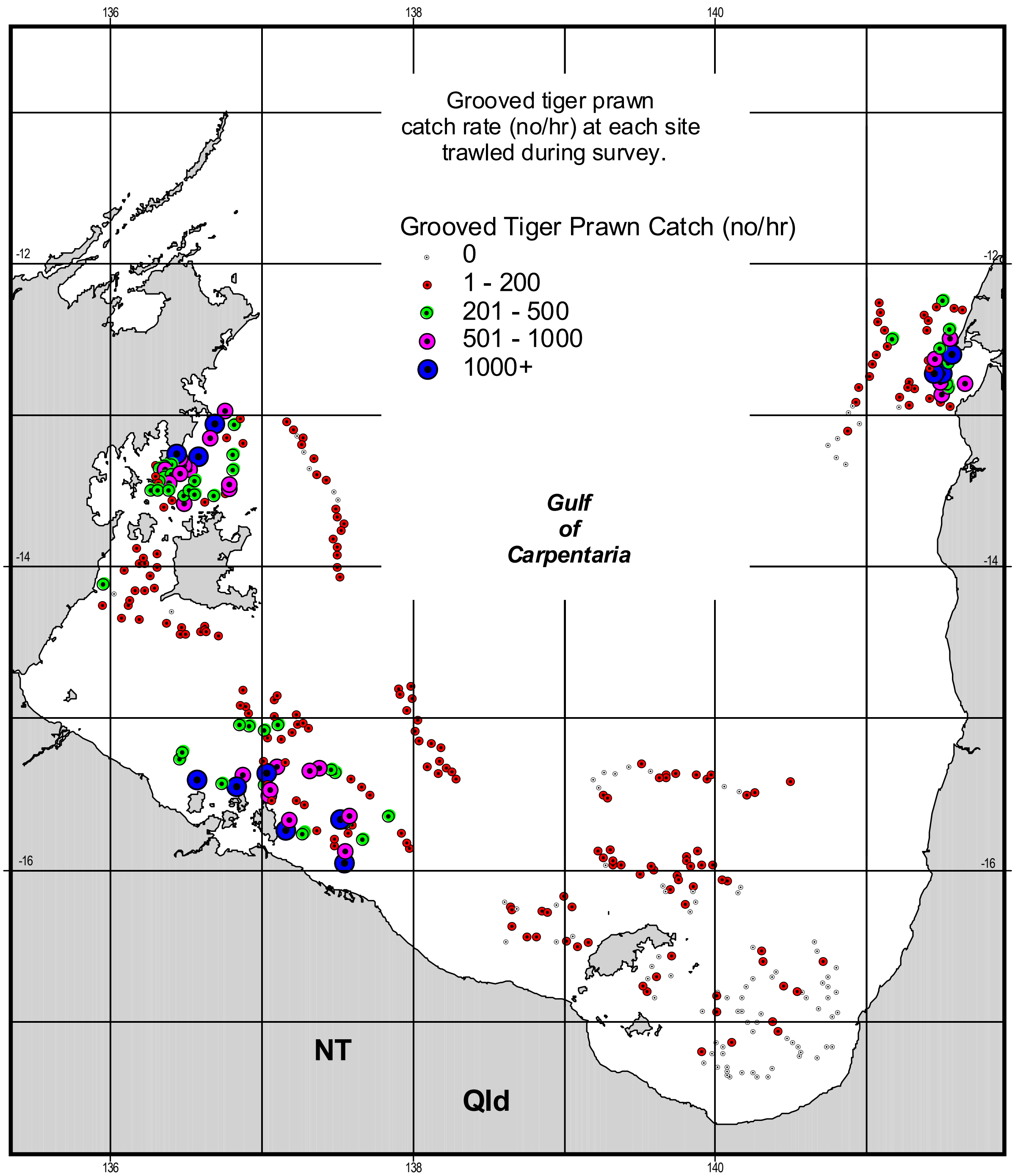
FISHERIES RESEARCH & DEVELOPMENT CORPORATION



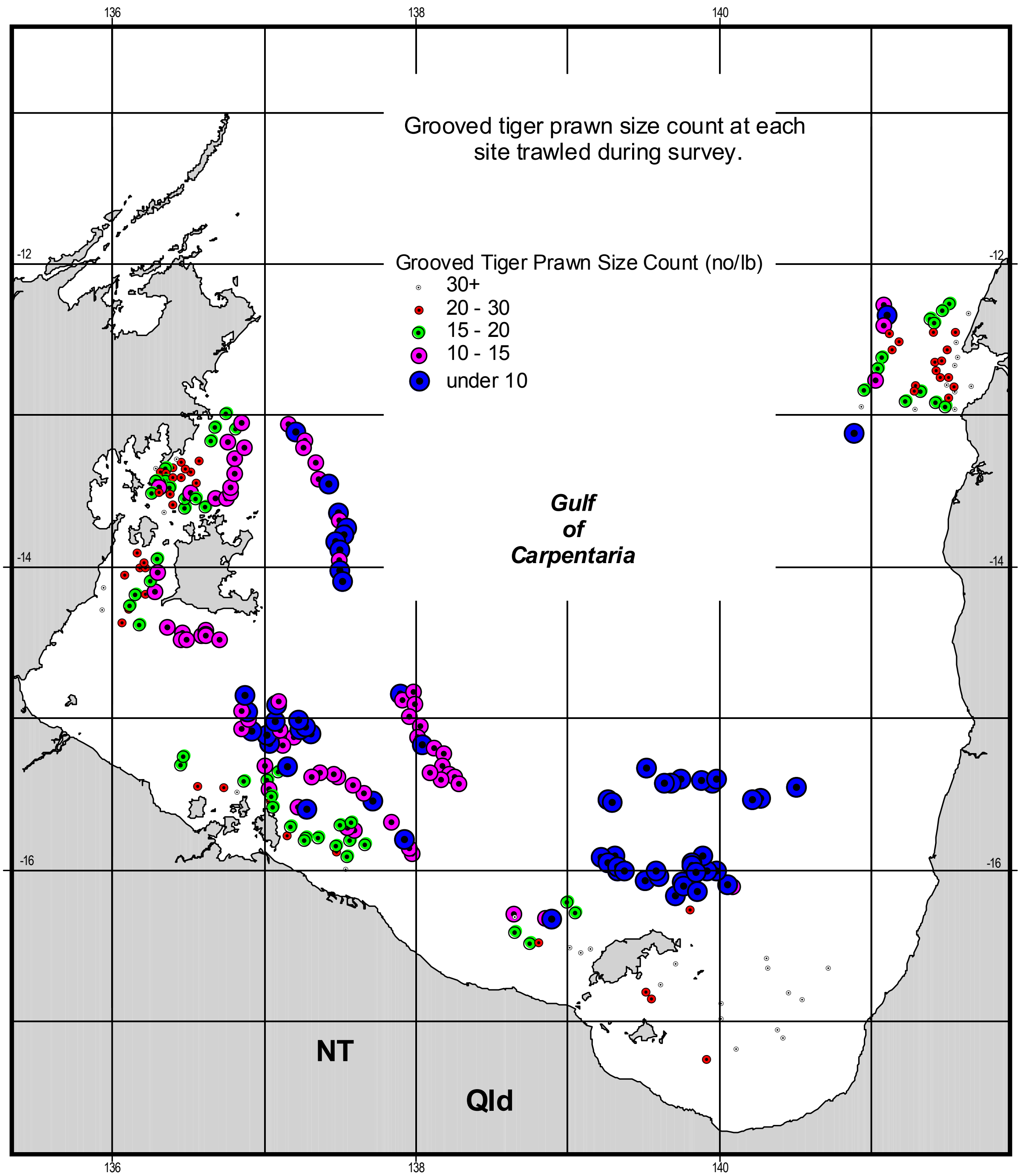
CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



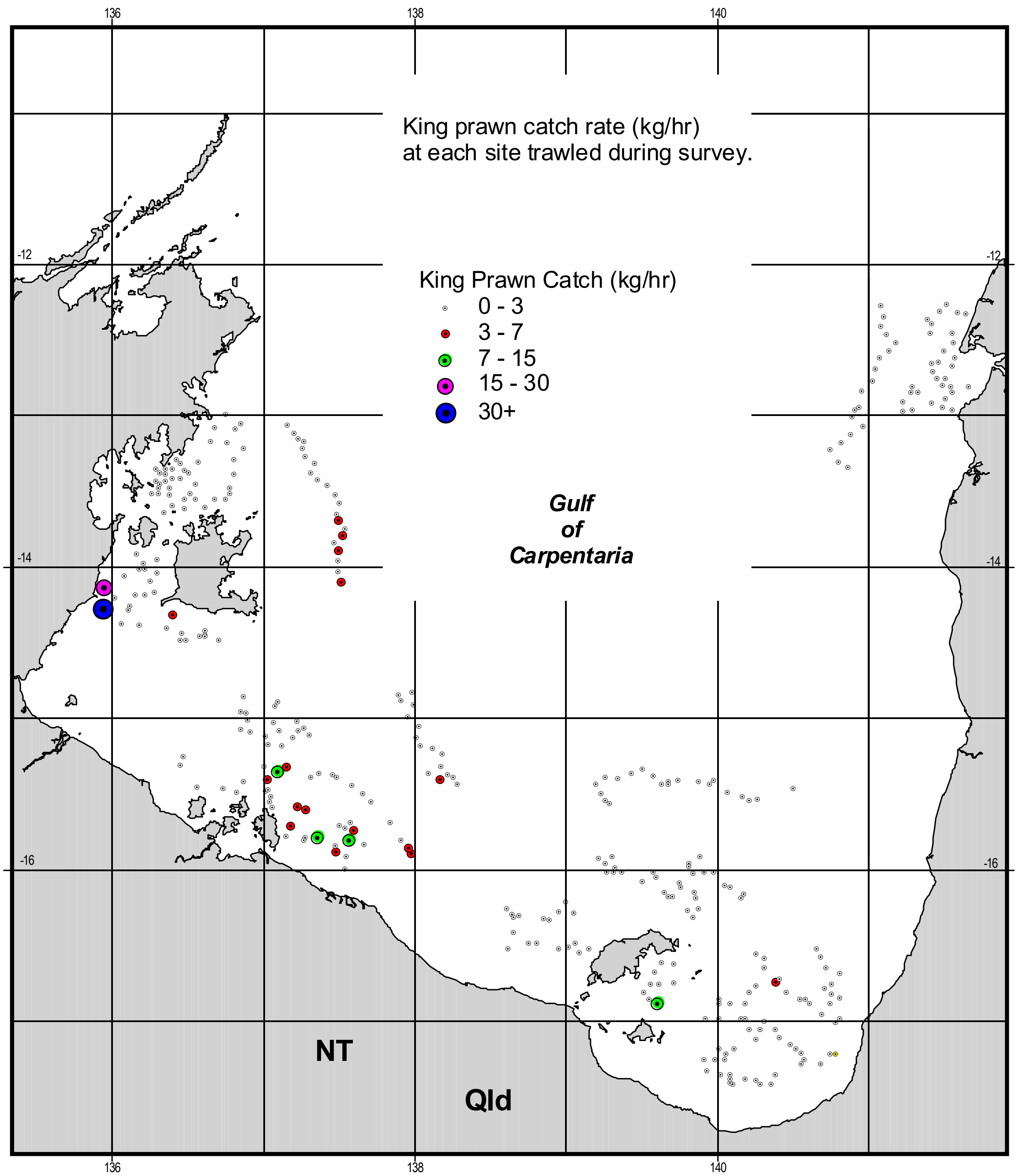
CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results

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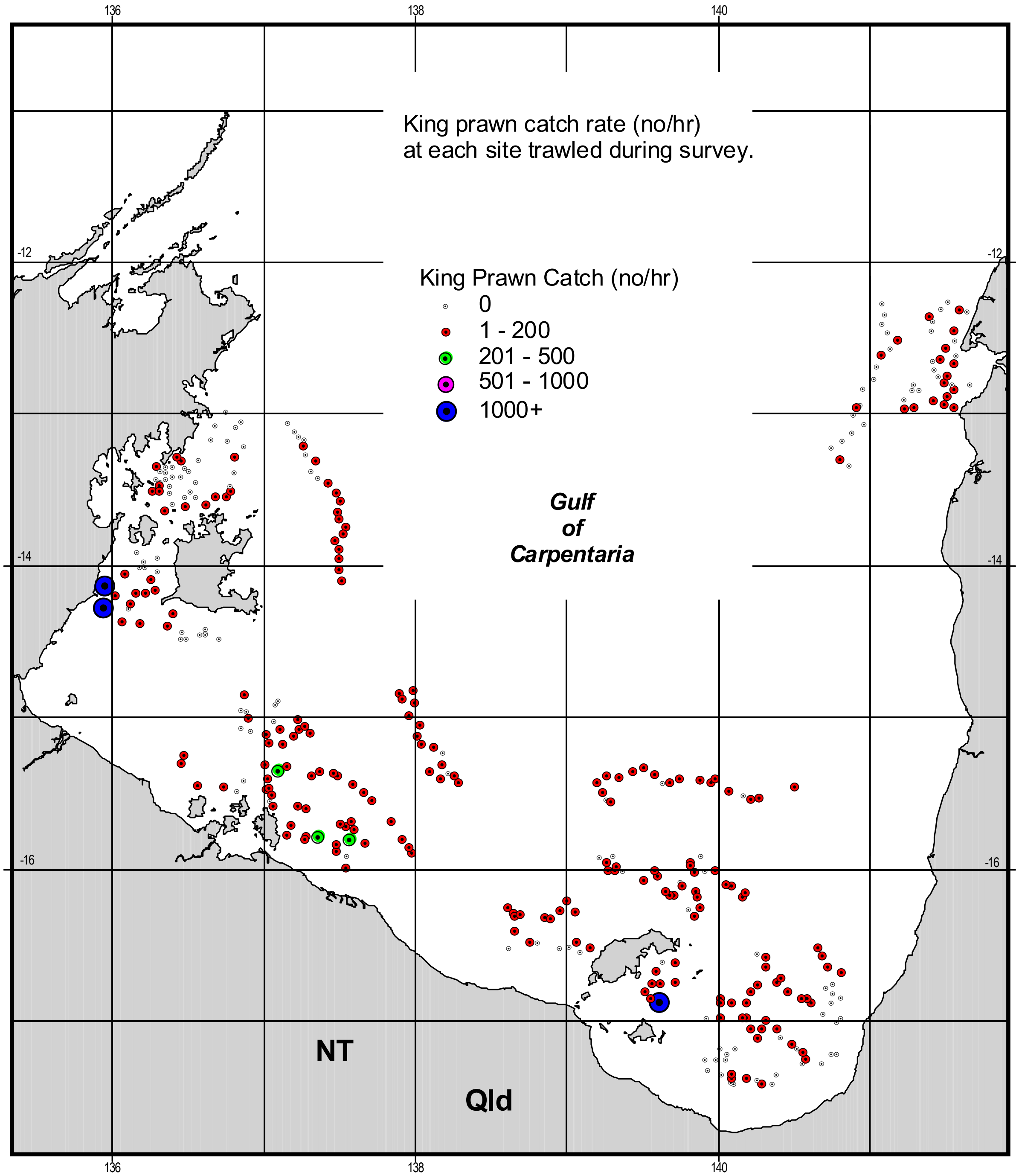
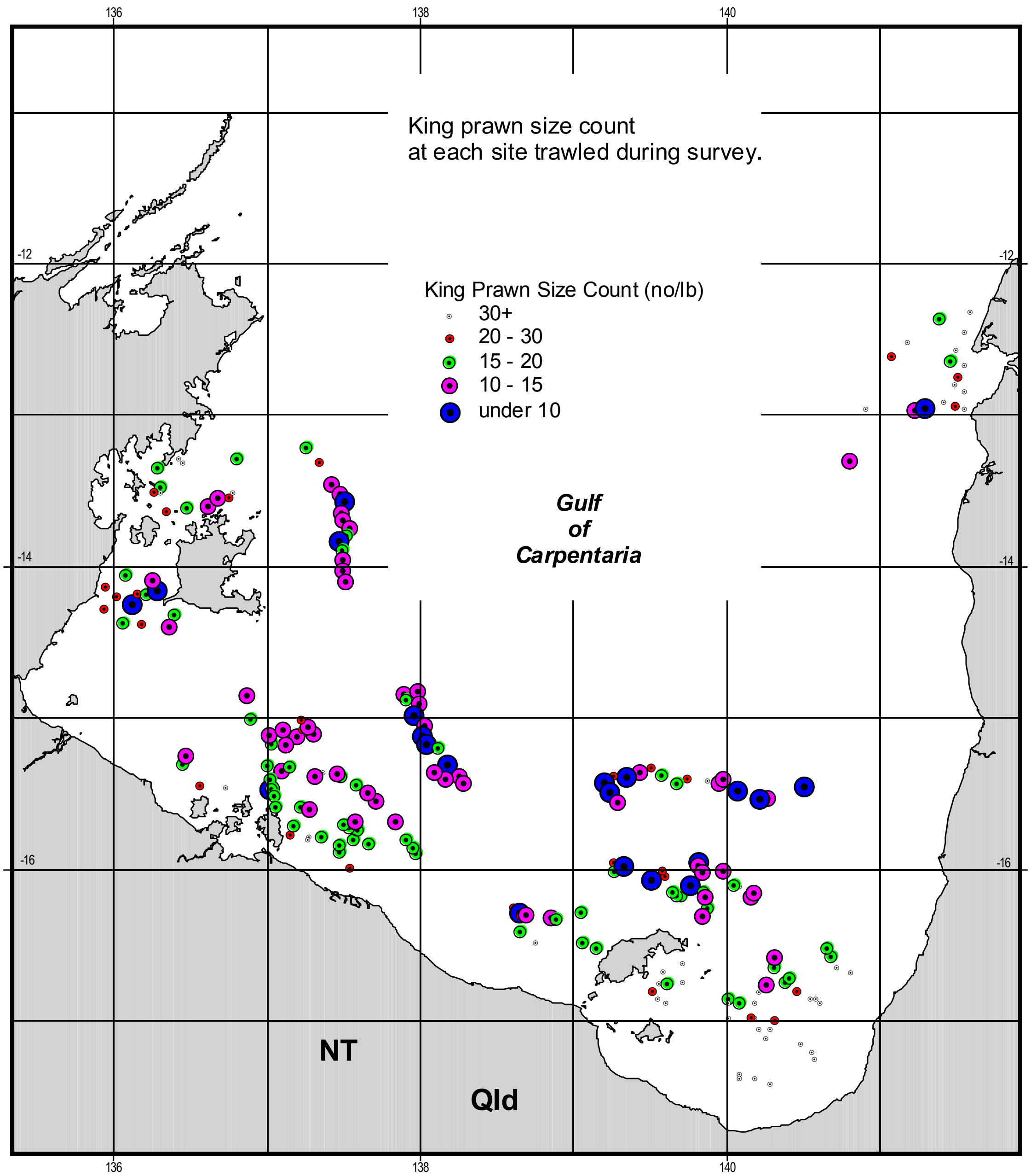


CSIRO Marine Research
NPF Monitoring Cruise - January 2003
Preliminary Results



CHAPTER 14 DENSITY BY SPECIES FOR THE SPAWNING INDEX SURVEY

The following figures provide catch rates (kg/hour and numbers/hour) and size (count/pound) of prawns by species for each site for the Spawning Index (August 2002) survey. These plots include all sizes of prawn caught.

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Preliminary Results

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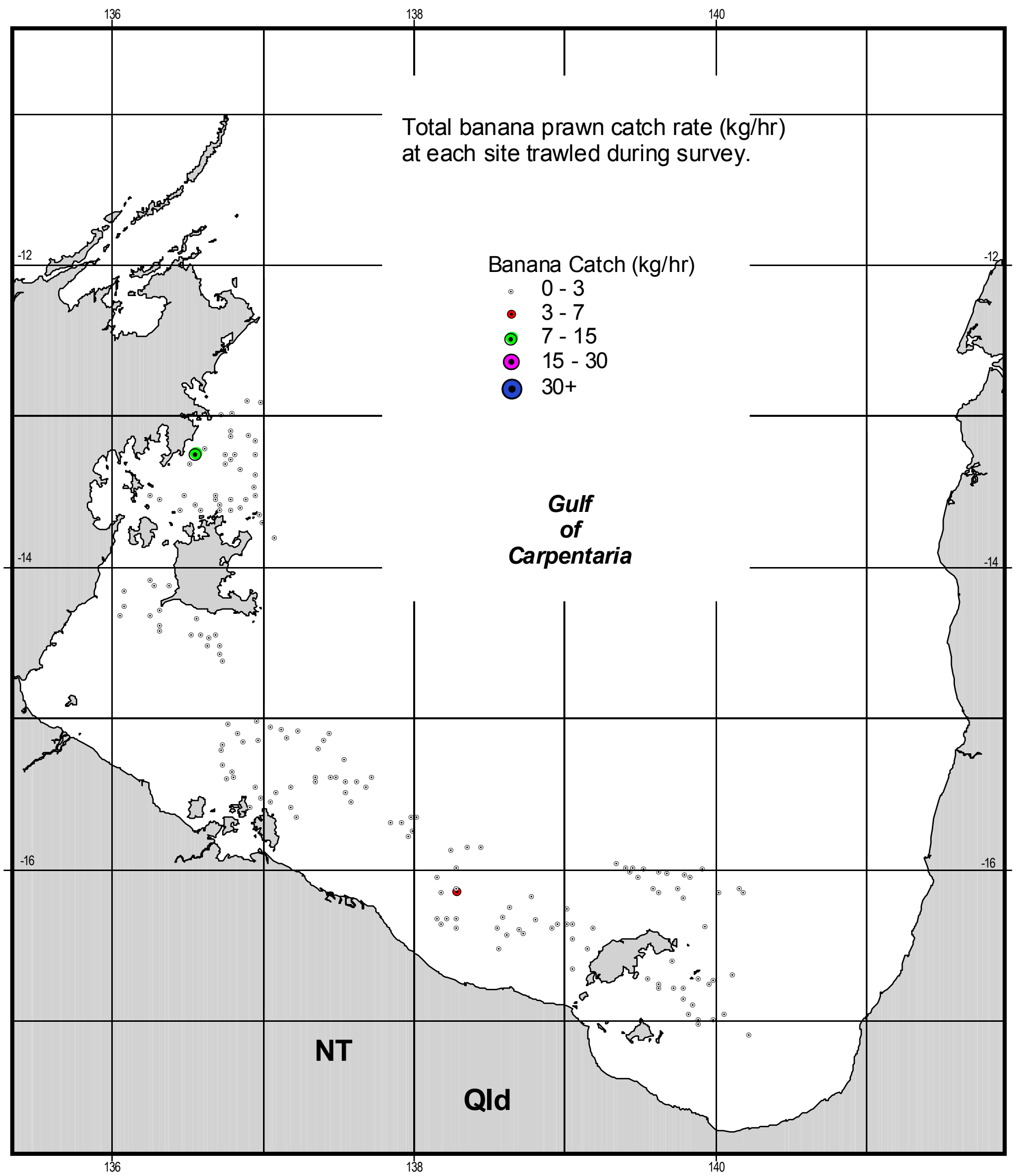

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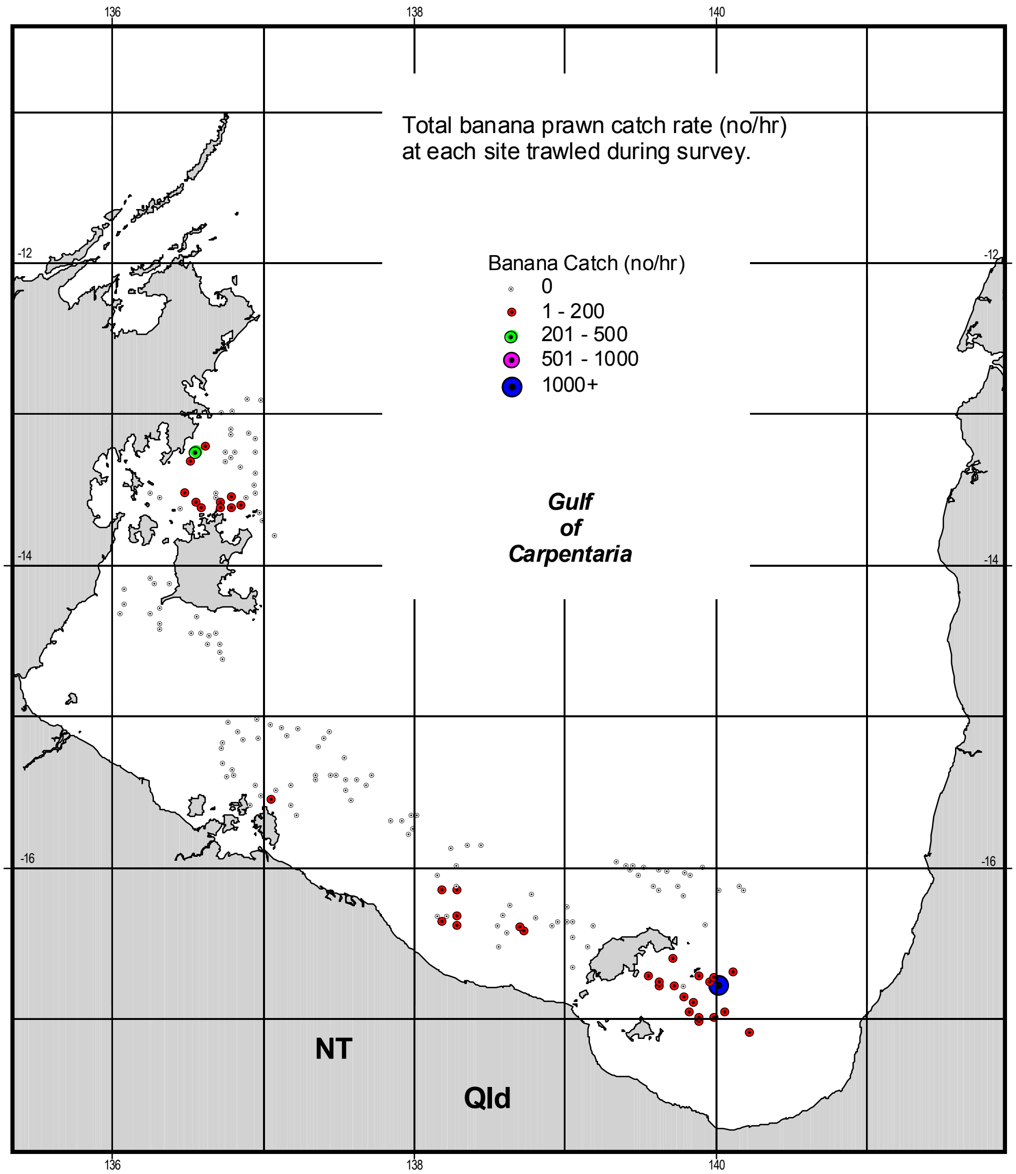
NPF Monitoring Cruise - August 2002
Preliminary Results



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Preliminary Results

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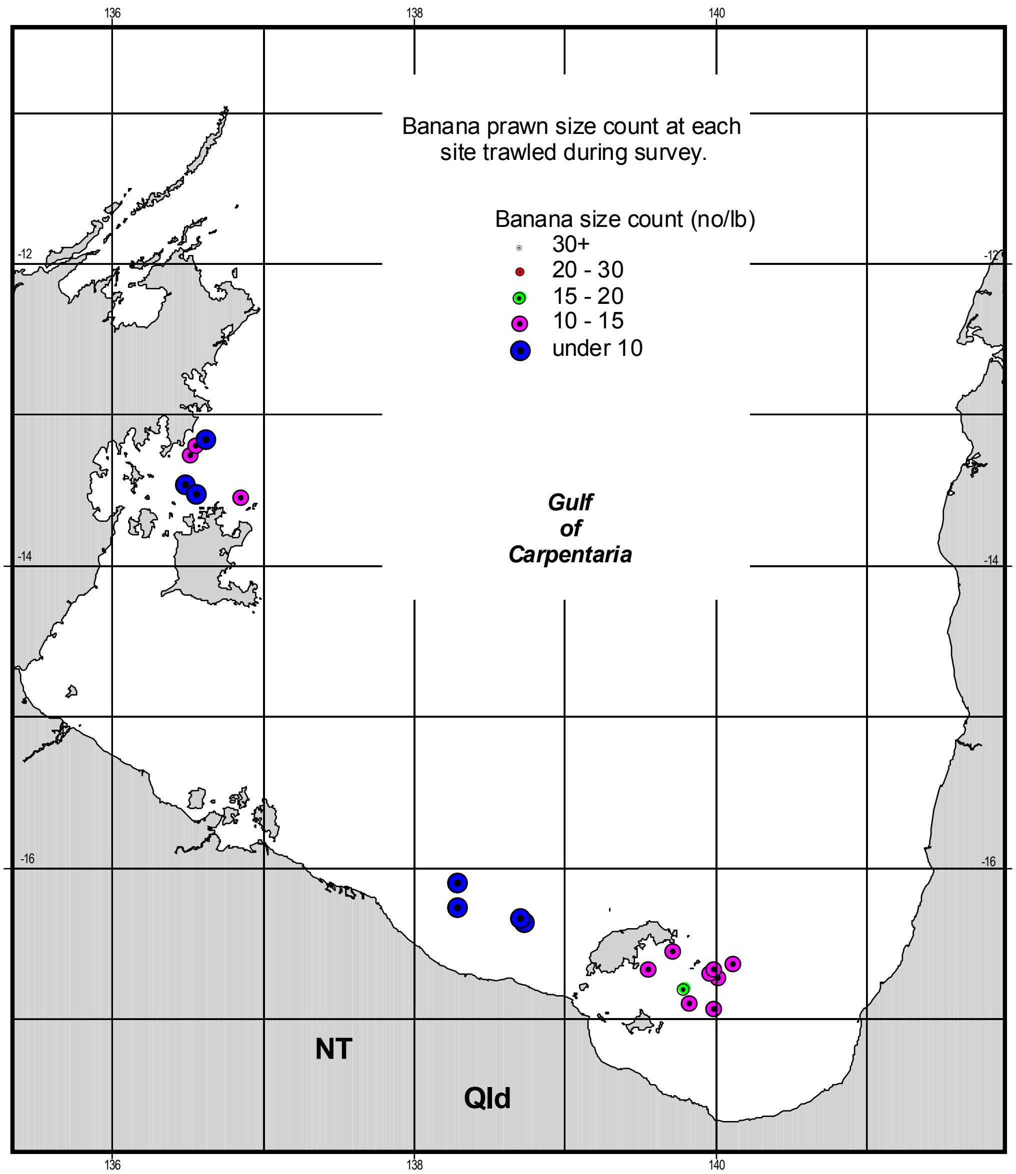

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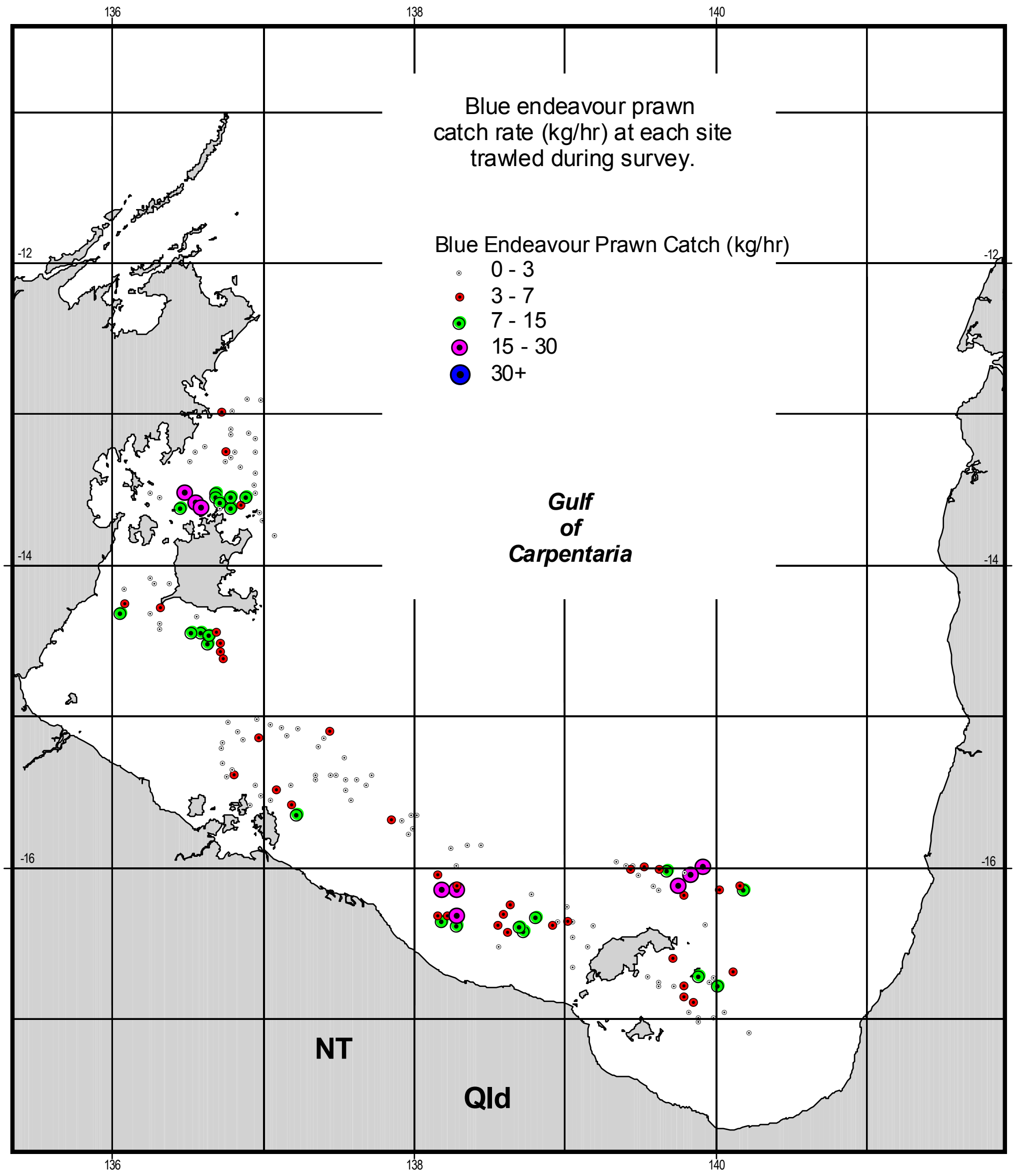
Preliminary Results



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Preliminary Results

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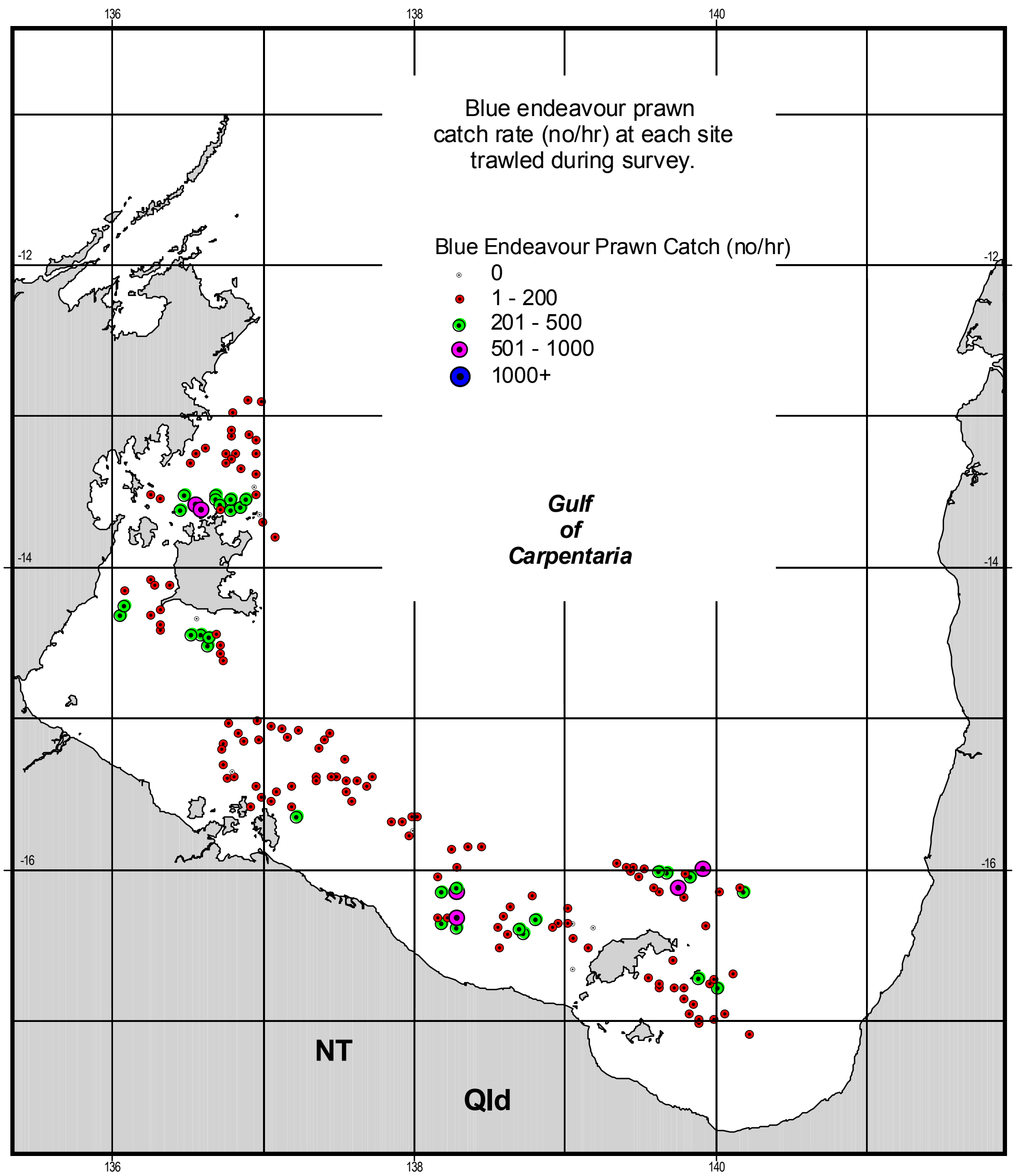

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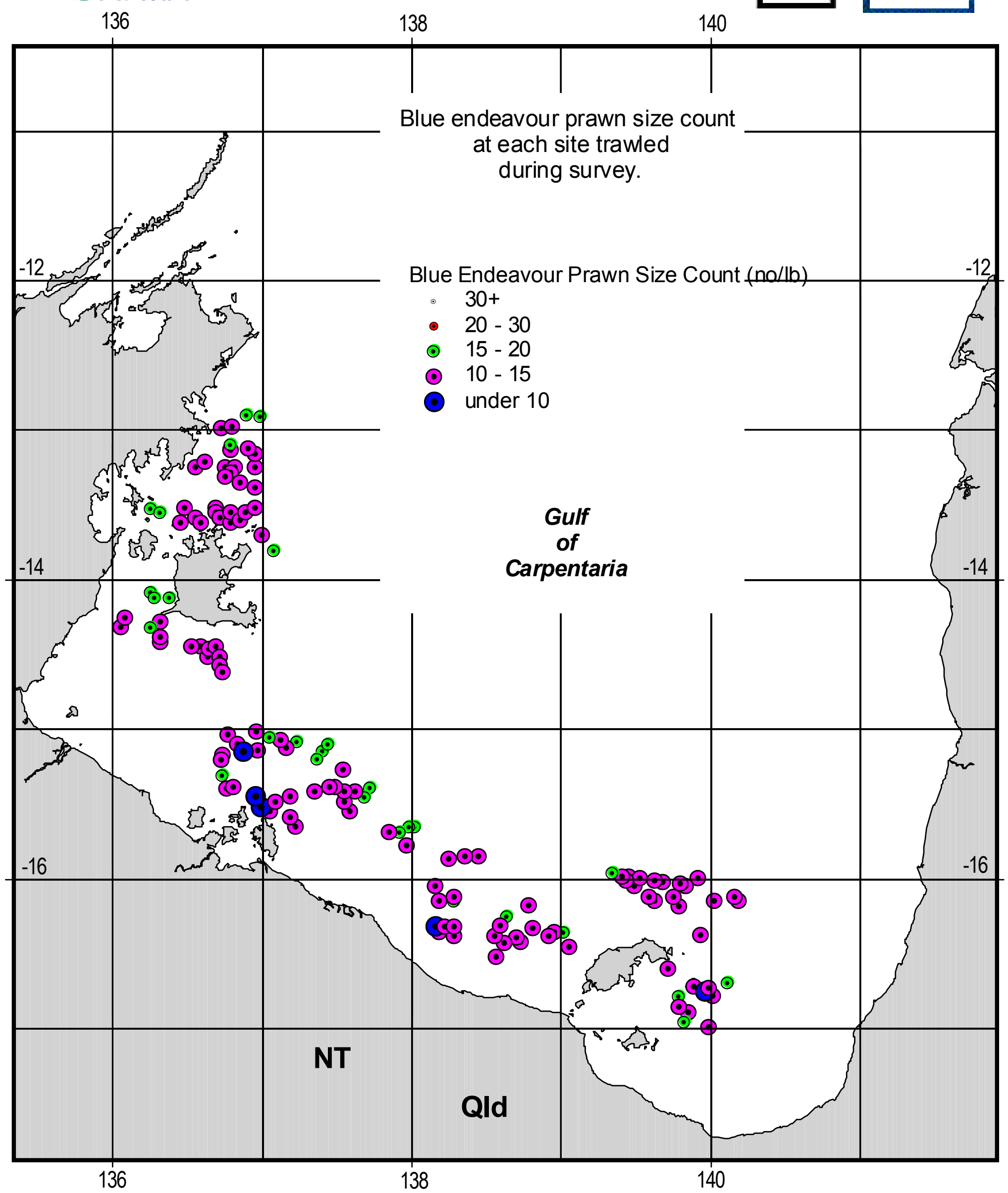
NPF Monitoring Cruise - August 2002
Preliminary Results



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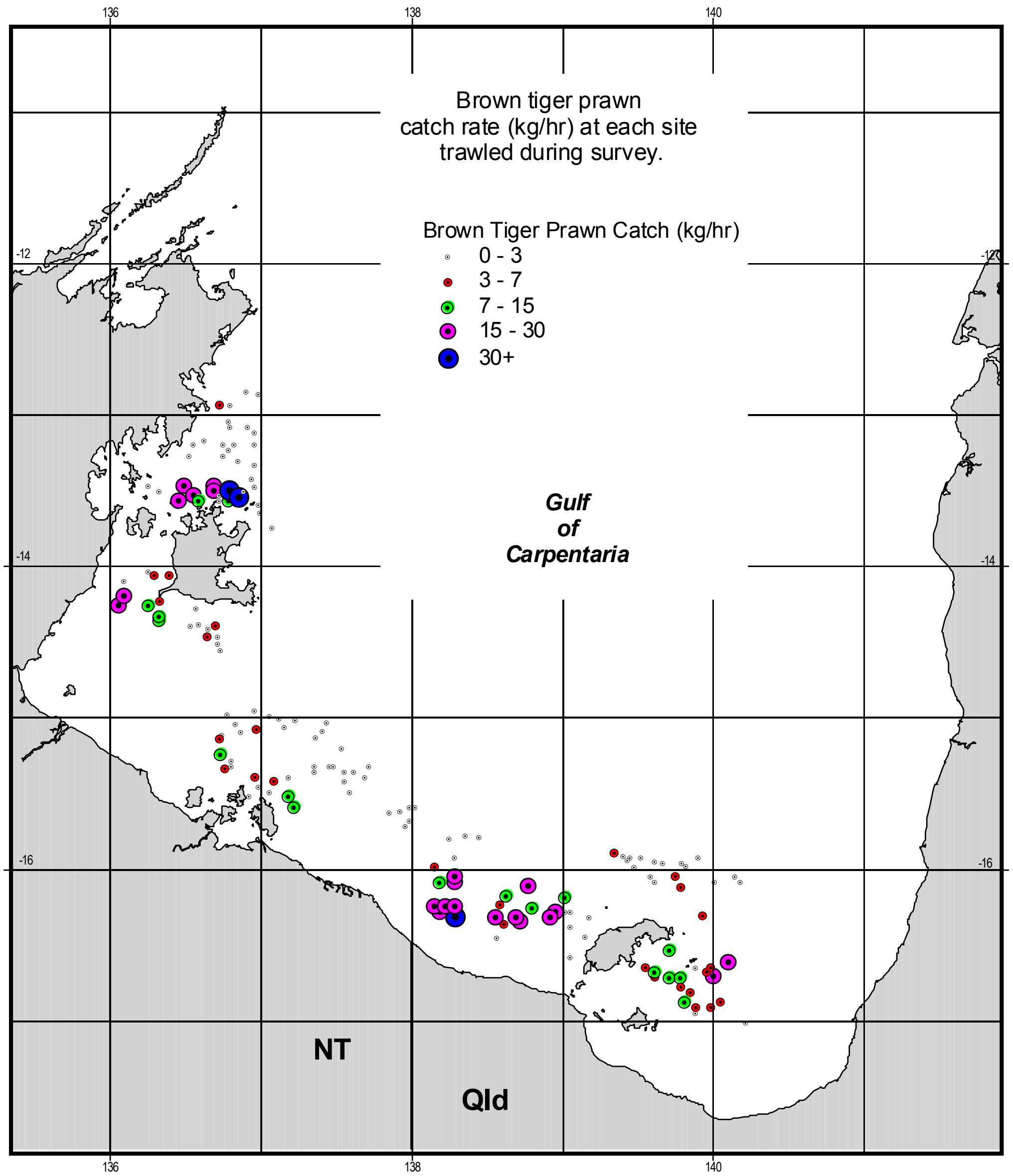
Preliminary Results



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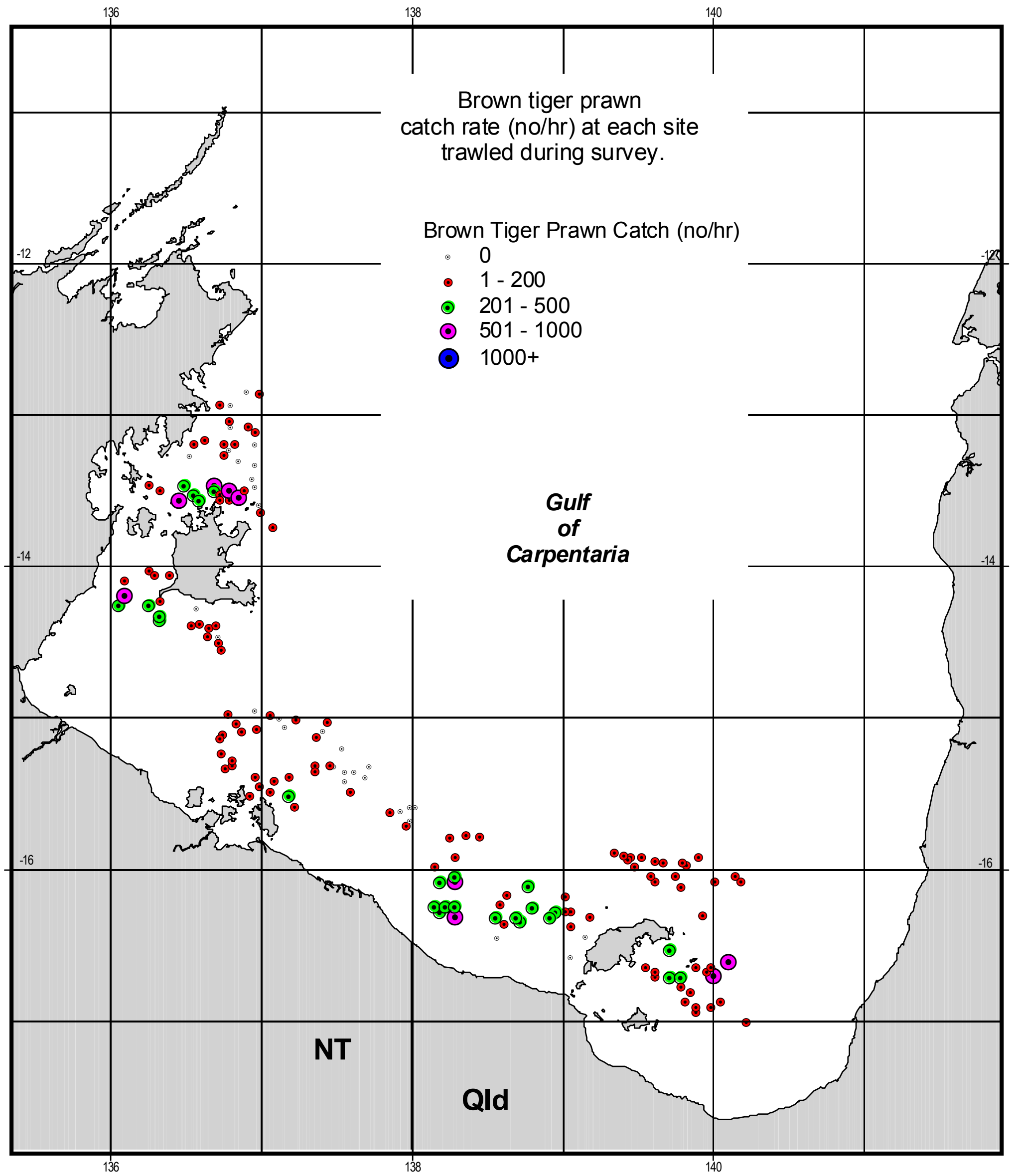

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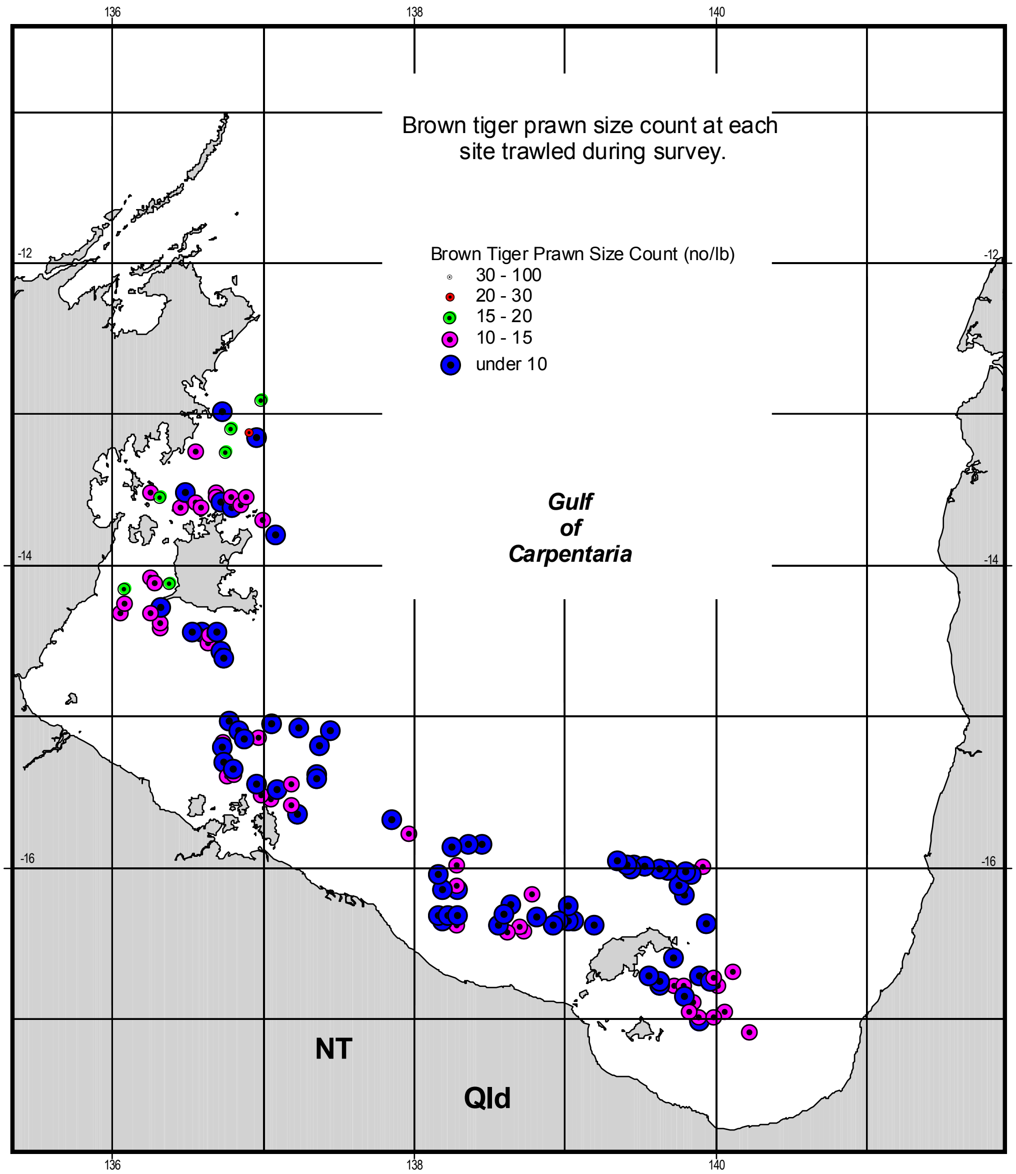
Preliminary Results



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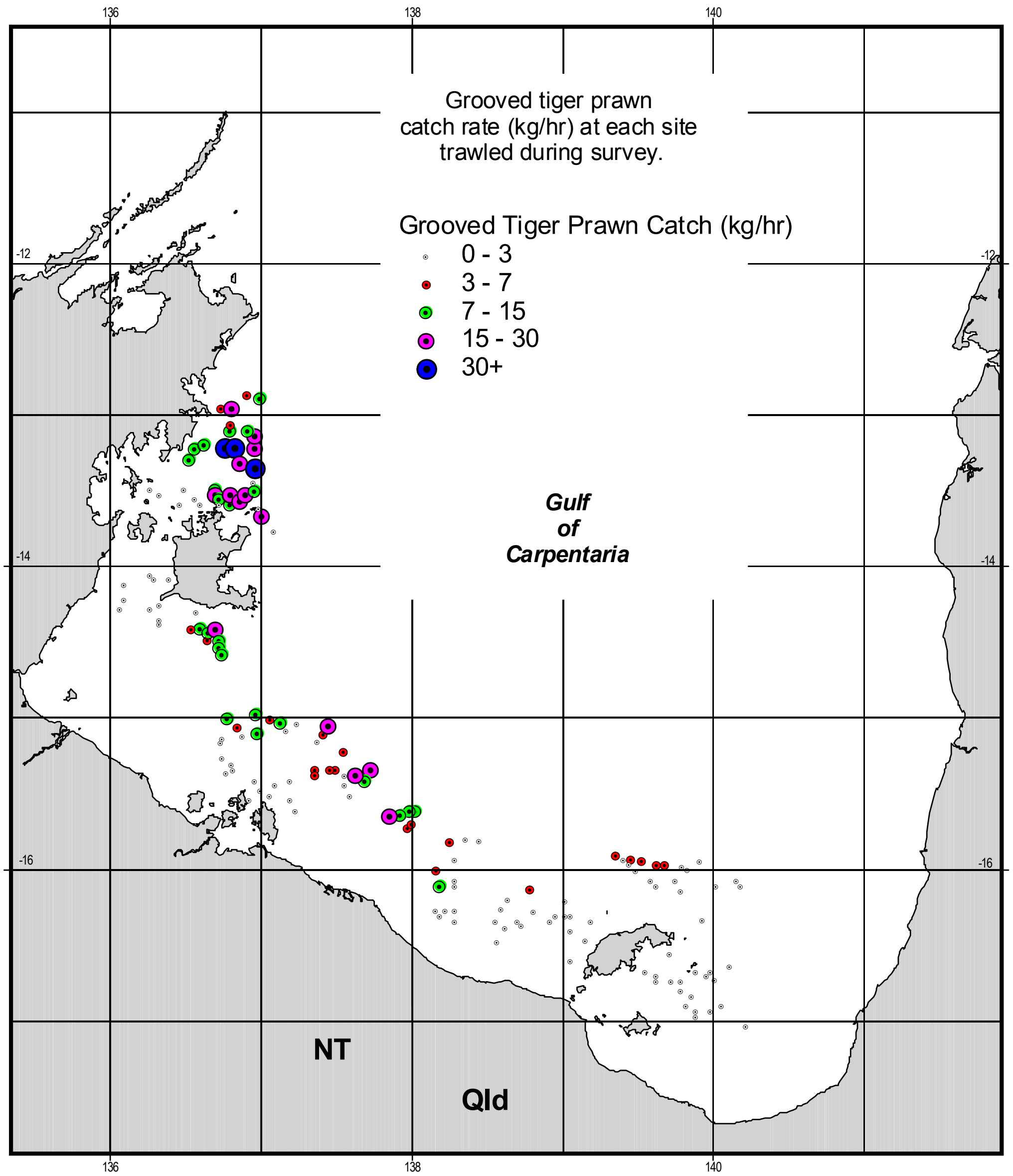

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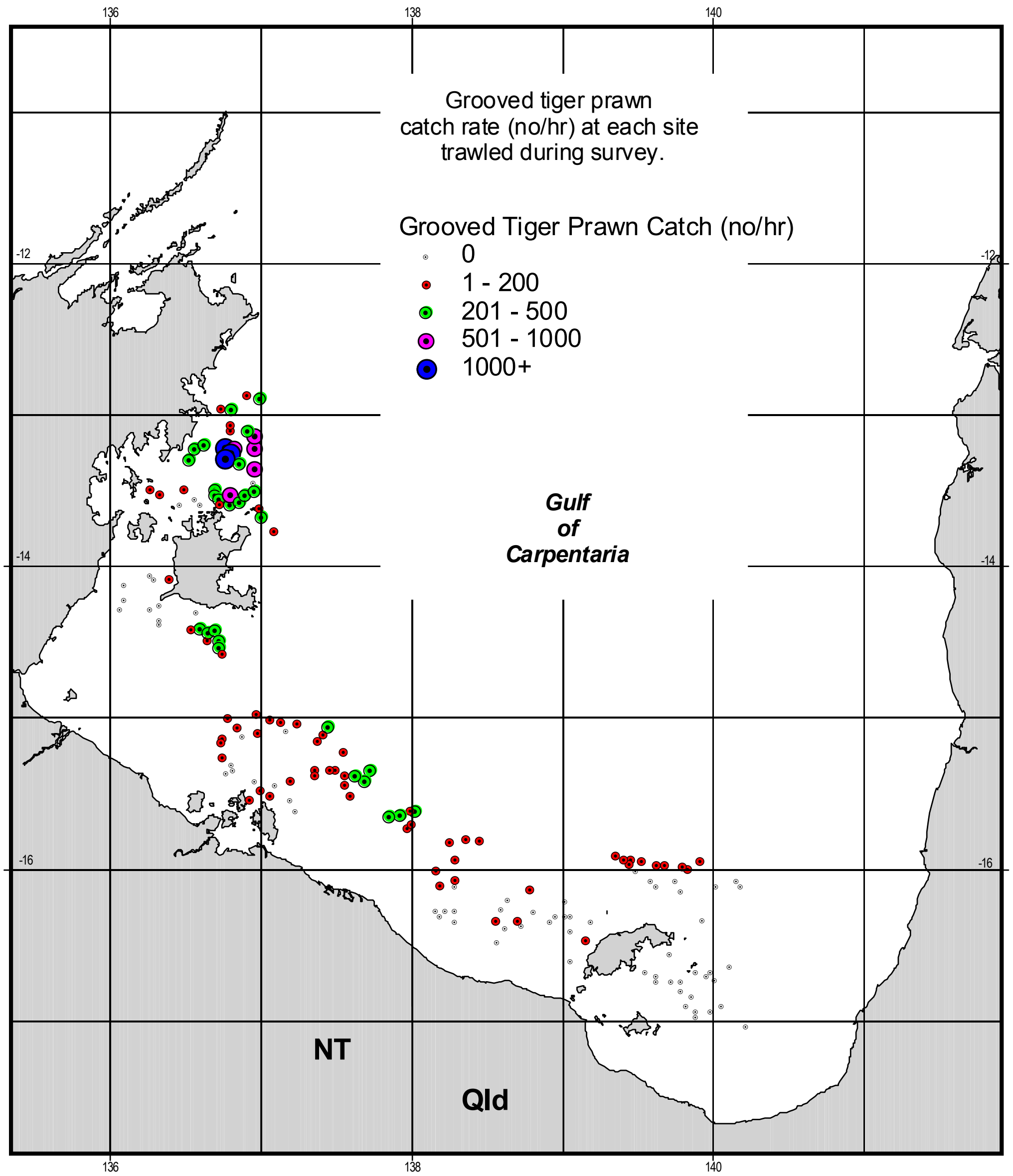

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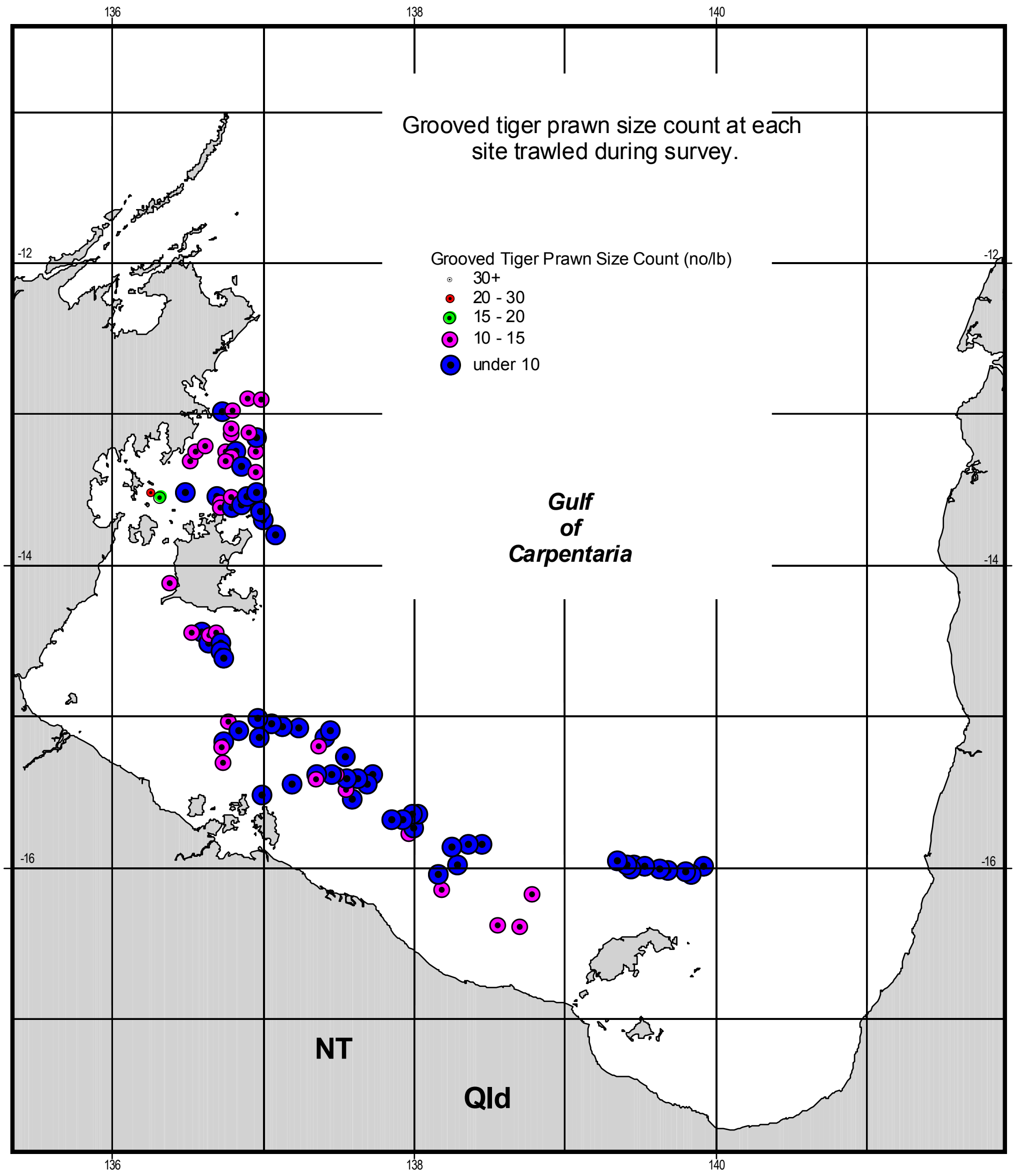

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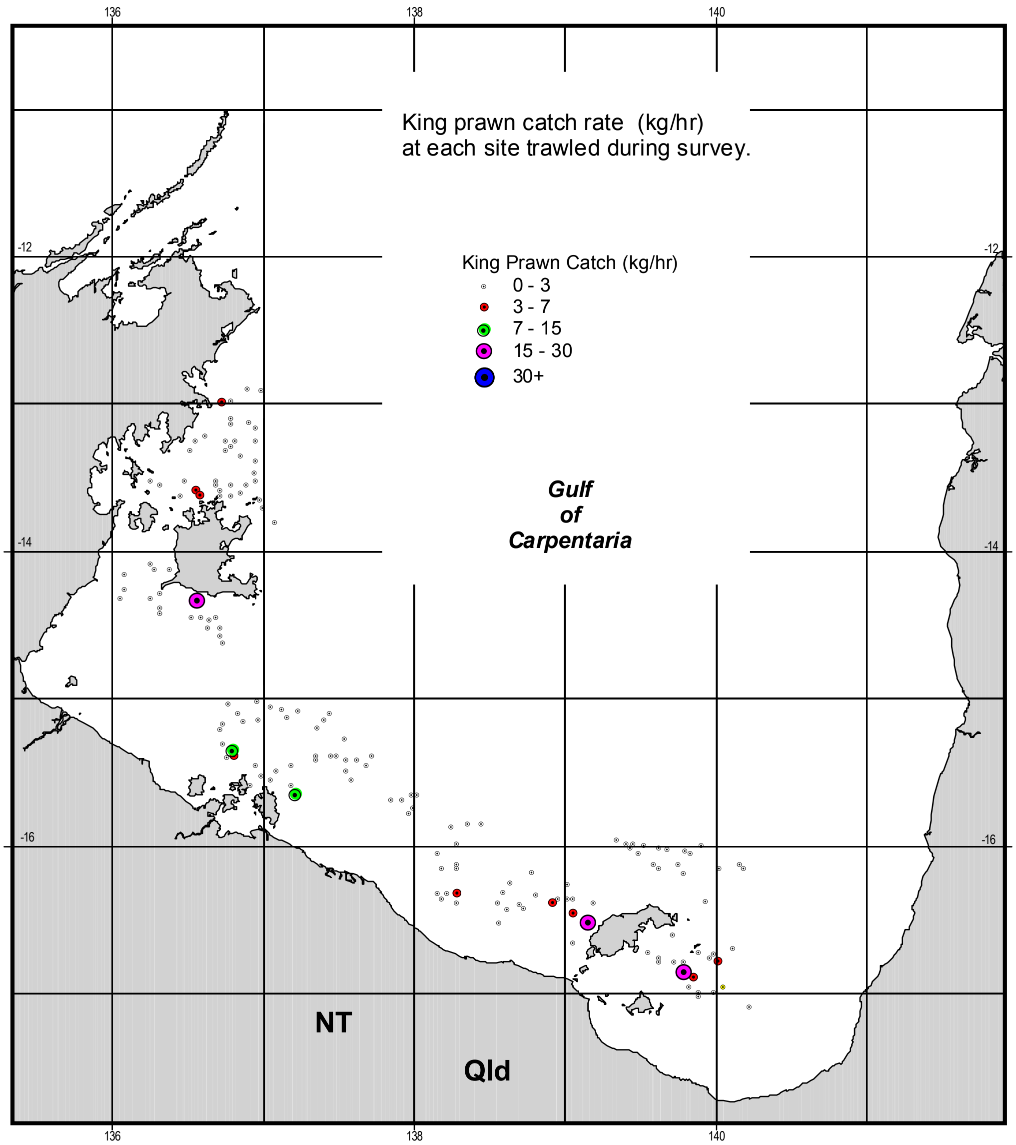

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Preliminary Results

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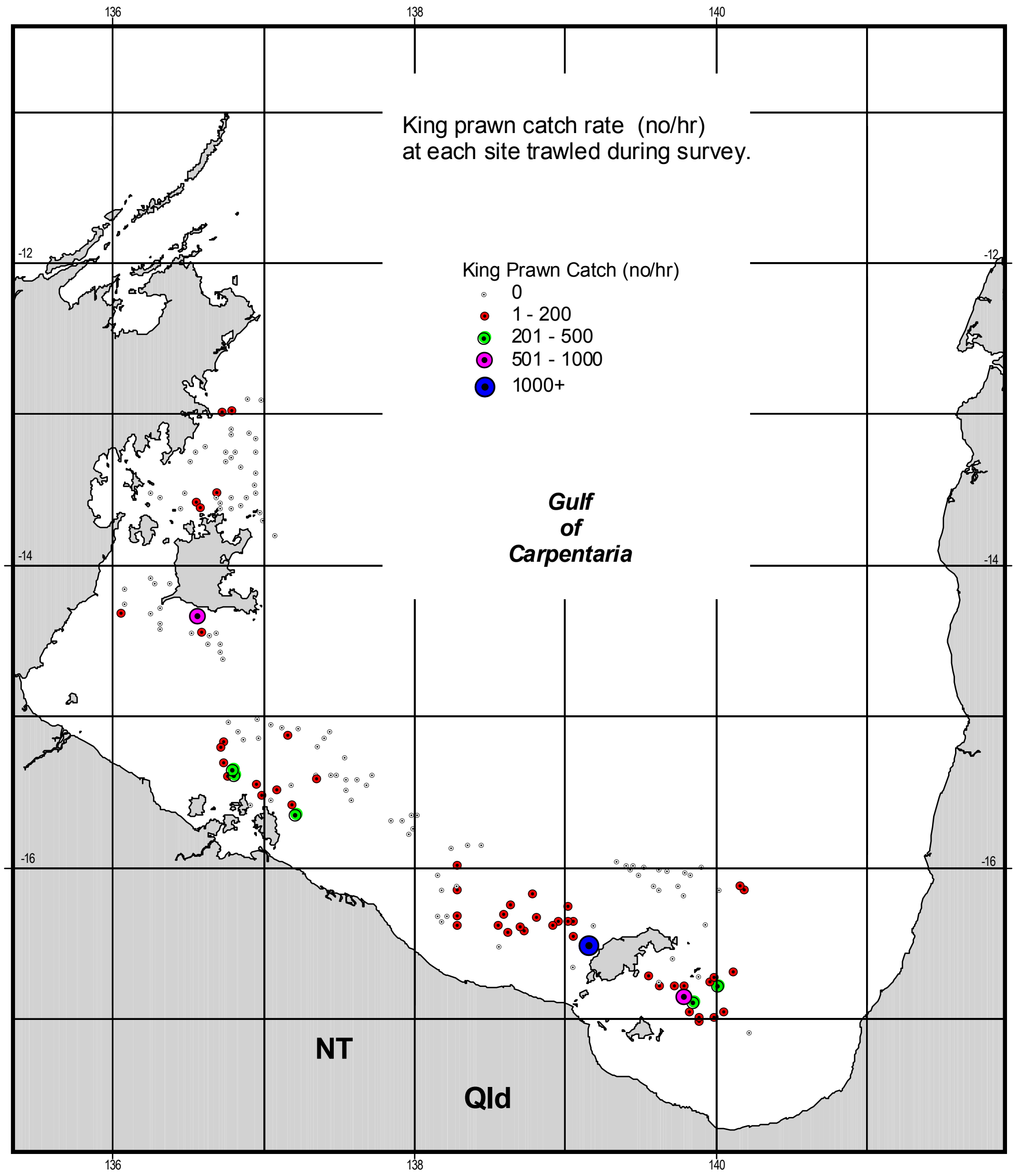

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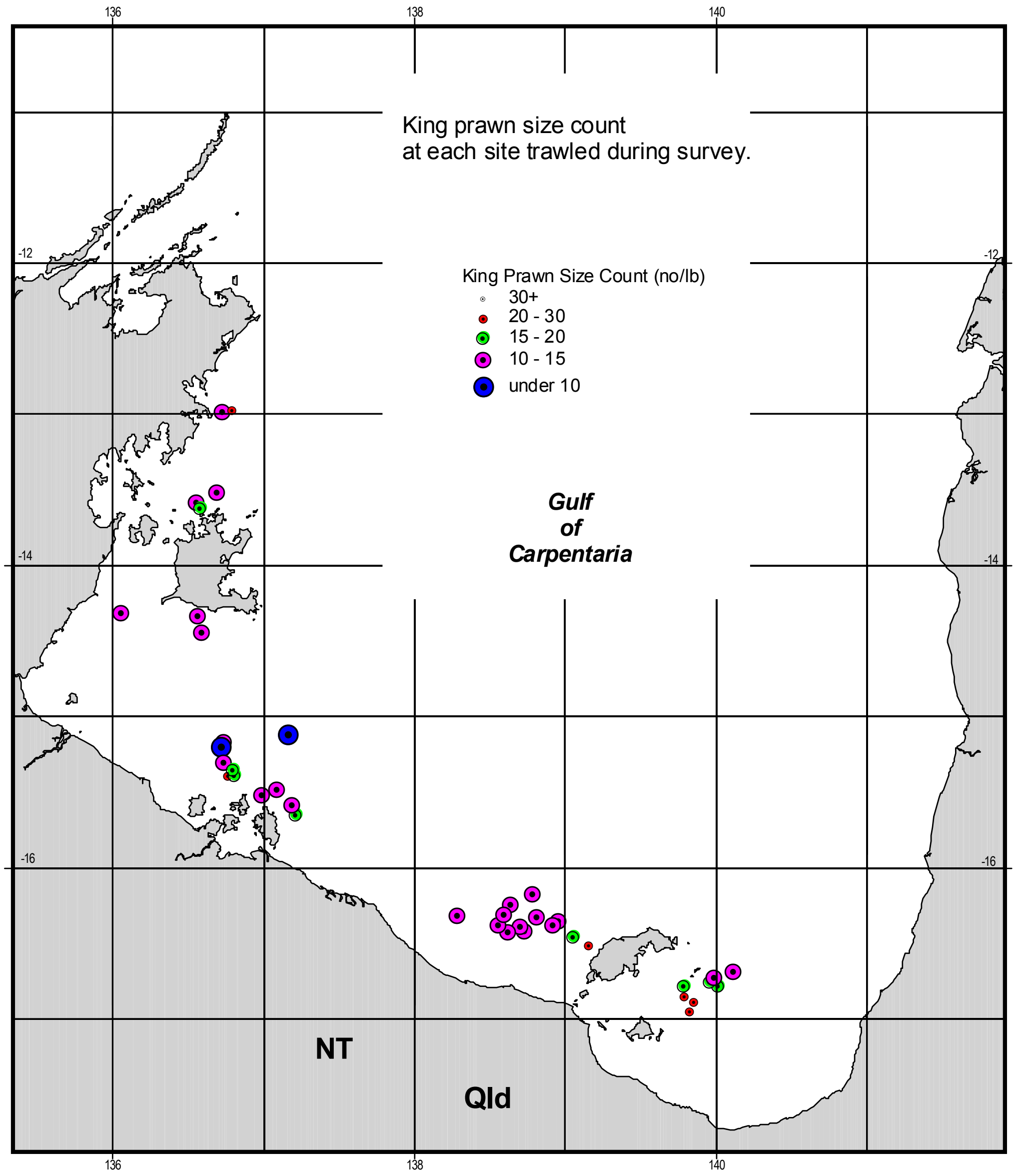
Preliminary Results



CSIRO Marine Research
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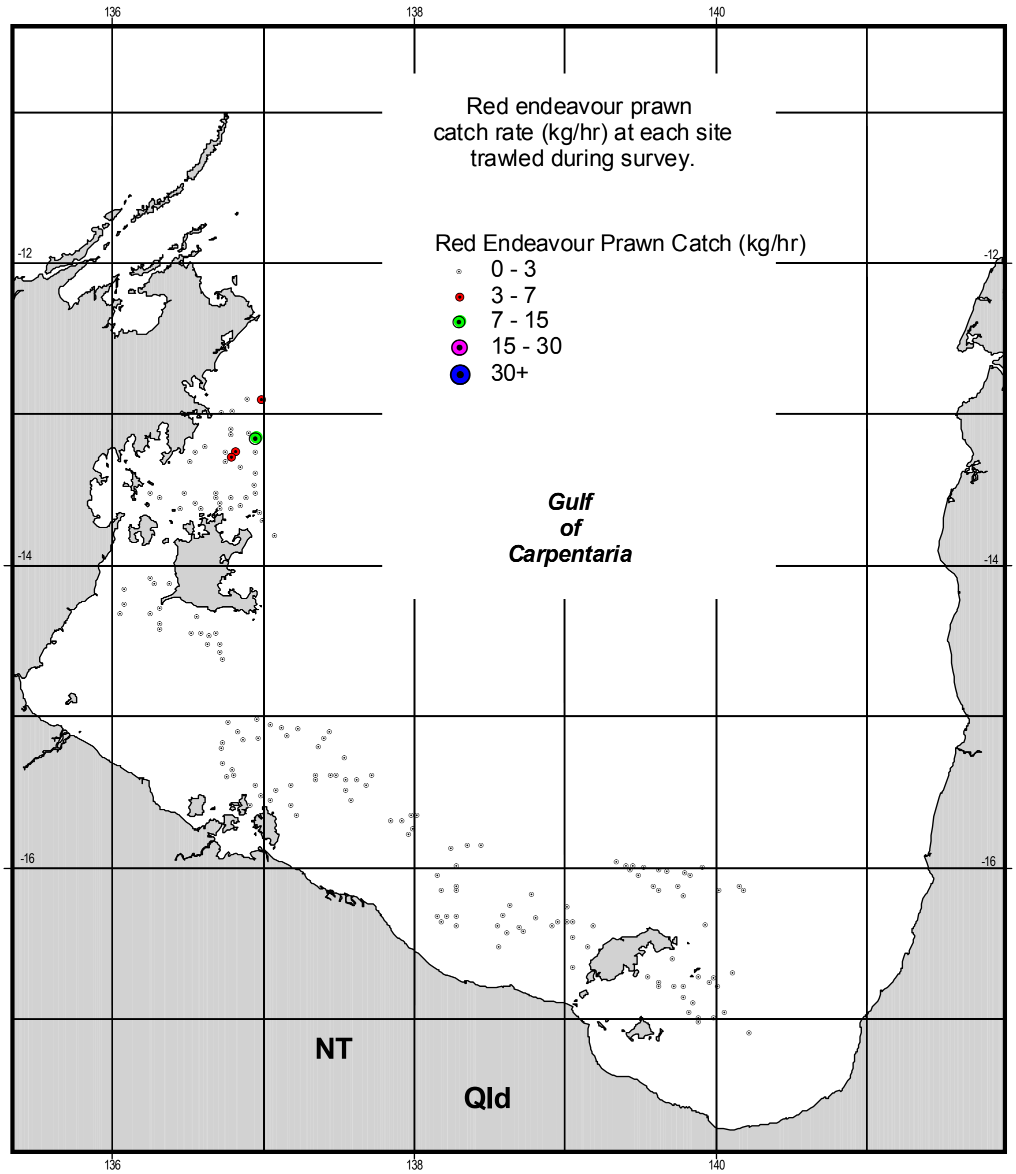

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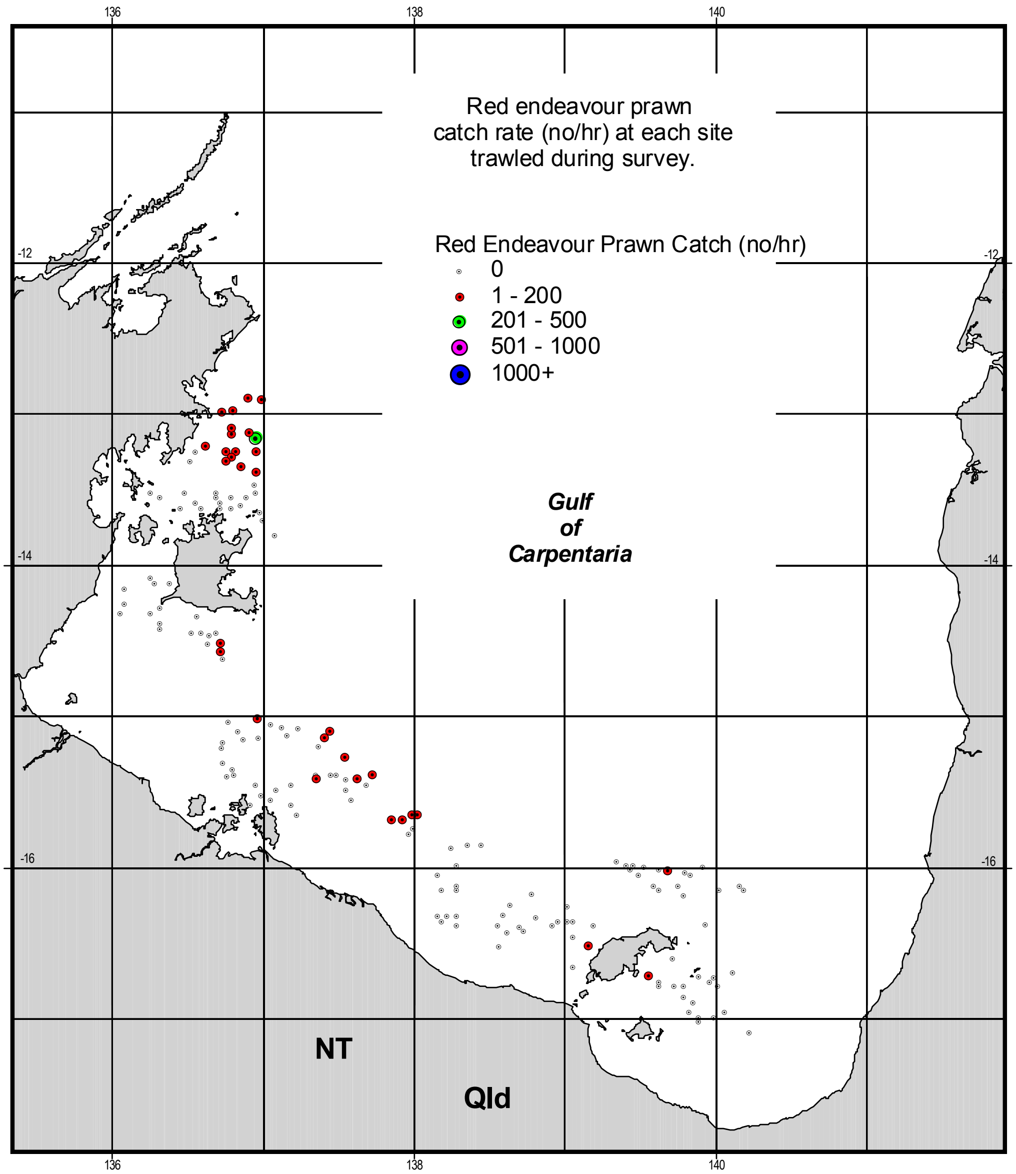

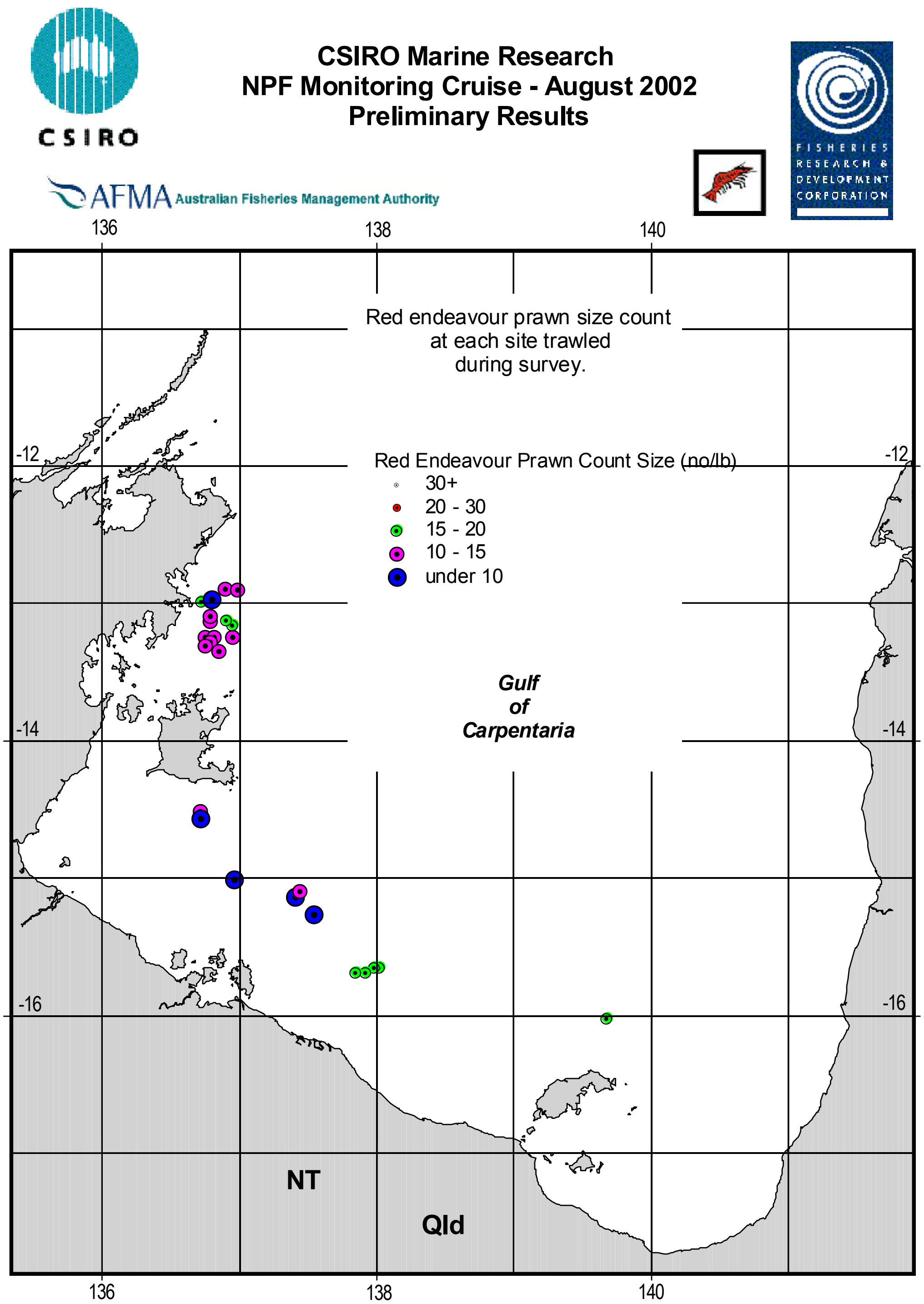
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Red endeavour prawn size count
at each site trawled
during survey.
Red Endeavour Prawn Count Size (no/lb)
30+
20 - 30
15 - 20
10 - 15
under 10
Gulf
of
Carpentaria
NT
Qld
136
138
140
-12
-14
-16

CHAPTER 15 EXAMPLES OF DATA SHEETS

The following pages provide the data sheets used in the Recruitment Index survey.

Group Summary Measurements

Sample No [ ]

				Subsample								Total								
Net Side (P/S)	Species Name	Sample Group	Sex	Count	Count Qual[4] (tick one)			Weight (g)	Weight Qual (tick one)			Count	Count Qual (tick one)			Weight (g)	Weight Qual (tick one)			Comments
					M	G	B		M	G	B		M	G	B		M	G	B	

[4] M = measured value; G = good estimate; B = bad estimate

Shot Details

Sample No [ ] Shot No [ ] Actual trawl duration (mins) [ ]

Start datetime [/ / :] End datetime [/ / :] dd/mm/yy hh:mm

Vessel name [ ] Area [ ]

Position

	Latitude Deg	Latitude Min	Longitude Deg	Longitude Min
Start		.		.
End		.		.

Start depth (m) [ ] End depth (m) [ ]

Moon	New	1st	Full	Last

Tide	N	N-S	S	S-N

Wind direction [ ] Wind speed (knot) [ ] Wave height (m) [ ]

WQ logger deployed [ ] Sediments [ ]

Gear change (Y/N) [ ] If Y, fill out Gear Change Details

Downtime events Count [ ] If >0, fill out Downtime Details

Gearbreak events Count [ ] If >0, fill out Gearbreak Details

Bycatch

	Port Weight (kg)	Starboard Weight (kg)	Quality (tick one)[5] M	G	B
Weight sent to lab (kg)					
Total weight (kg)					

Gear Change Details (as listed on Configuration Sheet)

	Port		Starboard
Net type		Net type	
TED type		TED type	
BRD type		BRD type	

Downtime Events

Event No	Time down (min)	Reason	TED/BRD	Comments

Gearbreak Events

Net side	Break description	Comments

[5] M = measured weight; G = good estimate; B = bad estimate

Length Weight Frequency - individual animals

Site No ______ **Seq No** ______ **Page No** ___ of ___ **Sample No** ______

Net Side	Species Name	Sample Group	Length (mm)	Sex (M/F)	Mat (R/U)	Moult State (S/)	Bop (Y/N)	Length Qual[6] (tick one)			Weight (g)	Weight Qual[1] (tick one)			Alive (Y/N)
								M	G	B		M	G	B	

[6] M = measured value; G = good estimate; B = bad estimate