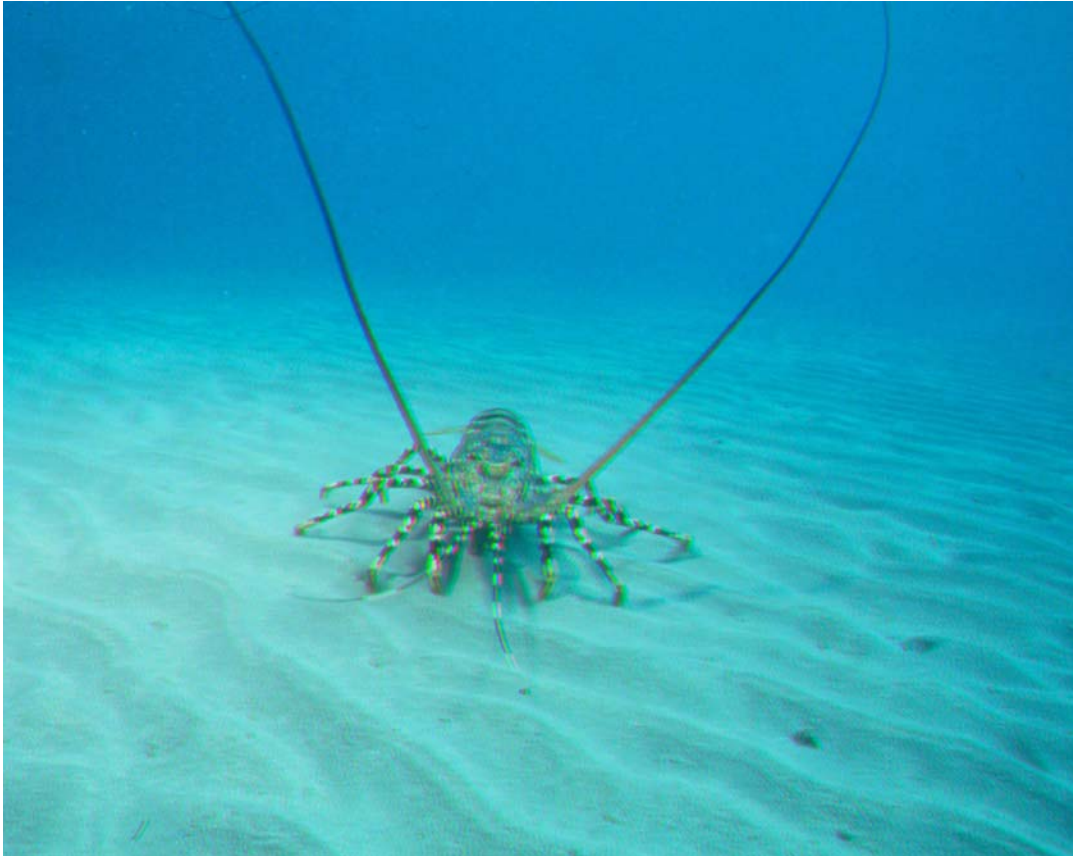# Biology, larval transport modelling and commercial logbook data analysis to support management of the NE Queensland rock lobster *Panulirus ornatus* fishery

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Dr D. Griffin, Mr D. M. Dennis, Mr T. D. Skewes.**

Biology, larval transport modelling and commercial logbook data analysis to support management of the NE Queensland rock lobster *Panulirus ornatus* fishery

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CSIRO Marine and Atmospheric Research

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1   NON-TECHNICAL SUMMARY

2002/008:

Biology, larval transport modelling and commercial logbook data analysis to support management of the NE Queensland rock lobster *Panulirus ornatus* fishery

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Objectives

1. The overall research objective is to collate fishery and biological information on the NE Queensland lobster population to permit an assessment of the status of the fishery, recommend sustainable management measures and identify future research priorities to fill information gaps that preclude sustainable and long-term management of the fishery.

2. Collate historical research information on adult and juvenile lobster geographic and size distribution, spawning and settlement grounds and map spatial data using Arcview software.

3. Collate information collected by the fishery on size and sex distribution, and distribution of breeding lobsters.

4. Recommend sustainable management measures.

5. Identify information gaps precluding efficient and sustainable management and prioritise future research to address these gaps.

6. Develop an oceanographic model of the mesoscale circulation in the NW Coral Sea.

7. Determine trajectories of larvae released by the NE Queensland lobster population and assess the fate of these larvae.

8. Determine the potential boundaries of the source and sink populations.

9. Identify and prioritise future oceanographic research to assist sustainable management.

10. Collate, validate and analyse all catch and effort data available from DPI&F logbook entries.

11. Validate logbook information through an observer program and recommend a cost-effective protocol for future programs.

12. Assess catch and effort trends of the NE Queensland lobster fishery and develop a stock status methodology.

13. Recommend future logbook data collection.

Outcomes achieved

1. Enhanced understanding of the geographic distribution of adult, juvenile, larval and breeding ornate rock lobsters *Panulirus ornatus* on the NE Queensland coast.
2. Enhanced knowledge of the age-structure of the commercially fished lobster population on the NE Queensland coast and inshore nursery grounds.
3. Development of an oceanographic model of the mesoscale circulation in the NW Coral Sea.
4. Enhanced understanding of the fate of ornate rock lobster larvae released from known breeding grounds around the northwest Coral Sea.
5. Improved understanding of the potential boundaries between the source and sink lobster populations on the NE Queensland coast.
6. Commercial lobster catch and effort data analysed and validated and future efficient protocols for log-book data collection adopted by fishery management.
7. Enhanced understanding of the lobster fishery catch and effort trends and sustainability of the fishery under historical levels of fishing.
8. Management regulations to ensure sustainable fishing recommended.
9. Research to address information gaps precluding effective fisheries management recommended.

Background

The Queensland lobster fishery operates between Cape York ($\sim11^{0}$S) and Princess Charlotte Bay ($\sim14^{0}$S) in the far northern section of the Great Barrier Reef Marine Park, and is managed by the Queensland Fisheries Service. The ornate rock lobster *Panulirus ornatus* comprises the vast majority of the catch and the Queensland population is part of a widely distributed stock bounded largely within the NW Coral Sea. The need for targeted research to support management of the Queensland lobster fishery arose as a result of dramatic increases in catch and effort after 1995 and concern that the increases were unsustainable. To address this concern a research proposal was formed, after management and industry consultation. The proposal was comprised of three subprojects; (i) data-mining and collation (ii) larval transport modelling and (iii) commercial logbook catch and effort data assessment, with the overall objective to collate fishery and biological information on the NE Queensland lobster population to permit an assessment of the status of the fishery, recommend sustainable management measures and identify future research priorities to fill information gaps that preclude sustainable and long-term management of the fishery.

Data-mining and collation

Historical information on the geographic extents of adult, juvenile and larval lobster populations, timing and locations of breeding and population age structure from CSIRO and PNG research programs was collated and mapped to evaluate our current understanding of the biology of the ornate rock lobster *Panulirus ornatus* on the NE Queensland coast. This information was supplemented by voluntary recording of lobster size and breeding status from commercial catches during 2001-2003, by fishers and DPI&F observers.

Adult ornate rock lobsters occur throughout the latitudinal range of the Queensland lobster fishery ($\sim11-14^{0}$S) and the preference for commercial fishing grounds around 12^{0}S (Margaret & Temple Bays) indicates lobsters are more abundant there. The age structure of the inshore populations indicates that the inshore reefs act as nursery habitat prior to offshore movement of sub-adult lobsters. Plankton surveys conducted in 1997 showed that ornate rock lobster larvae dominate the spiny lobster populations in the Coral Sea, comprised of *P. femoristriga*, *P. penicilattus*, *P. versicolor* and *P. polyphagus*. Small numbers of *P. femoristriga* and *P. versicolor* are taken by the commercial fishery. Most settling ornate rock lobsters were found on the shelf break adjacent to the Queensland fishery and further south, but this distribution may

have been atypical due to the presence of a Tropical Cyclone in that year. Larval duration for *P. ornatus* is about 4.5 to 7 months.

Berried female ornate rock lobsters occur throughout the range of the Queensland fishery and north to the far northern GBR and south to Cairns. However, deepwater breeding has also been recorded off Murray Island (10^0S) and Townsville (19^0S). The vast majority of records of breeding lobsters have come from shallow habitats accessible to divers and the size and extent of breeding populations in waters inaccessible to divers (>30 m), is largely unknown. Only 5% (165/3169) of female lobsters caught and measured by commercial fishers between 21 July 2001 and 19 July 2003 carried a spermatophoric mass or "tarspot" (157) or eggs (8), and the majority (80%) were recorded during November 2001. Berried females occur on the shallow reefs on the NE Queensland coast during January to March, but the low numbers of berried females recorded during this study and historically strongly suggests most hatching occurs in deep water inaccessible to divers. A simple analysis of the relative egg production suggested that the fishery may benefit from a maximum size limit to conserve egg production.

Migrations and small-scale movements of ornate rock lobsters on the NE Queensland coast are known exclusively from previous studies by Bell *et al.,* (1987). Results of the tag-recapture studies suggested that most of the population shows high fidelity within a reef system. In contrast to the extensive migrations undertaken by Torres Strait lobsters, lobsters on the NE Queensland coast moved only small distances from their original locations, and mostly off-shore. Sub-adult lobsters (~95 mm CL) move off-shore during March/April, to the mid-shelf reefs that are fished commercially.

Peak settlement of ornate rock lobsters at Cairns, Queensland occurs during winter (June-August) in most years, but the seasonality of settlement is highly variable. After settling, juvenile lobsters reside on the inshore reefs and these populations are comprised almost entirely of two year-classes (1+ and 2+ years old) smaller than 120 mm CL, similar to populations in Torres Strait. In contrast, the populations on the mid-shelf reefs that are commercially fished are comprised of several year-classes, up to 8 years old. The sampled monthly size distributions did not allow accurate resolution of age structure of the NE Queensland lobster population. Male lobsters were consistently and significantly larger than female lobsters in all months. Voluntary size data collected prior to the introduction of the 90 mm CL minimum size (2002) suggests that the fraction of lobsters taken below this limit was traditionally low (<10%).

Larval transport modelling

An oceanographic model of the mesoscale circulation in the NW Coral Sea was developed and validated by tracks of surface drifting buoys. The trajectories of lobster larvae released on the NE Queensland coast and other known breeding grounds were determined from simulations using the oceanographic model. A significant result was that the basic mechanism for the return of larvae to the NE Queensland coast is somewhat different to what it is on the other side of the country. In both cases, results of our quantitative model support previously hypothesized mechanisms. What is new is an important step towards a much enhanced ability to turn this understanding into scientifically-justifiable management actions.

The approximate boundary separating the "source" and "sink" populations was estimated from the simulations and in general agreed with previous oceanographic studies, such as Burrage (1993). The approximate boundary between the 'source' and 'sink' populations is indeed determined by the location of the bifurcation point of the South Equatorial Current. However, a slight twist on this is that the model region straddling the bifurcation point (our 'Cooktown' region from 17°S to 14°S) is better categorized as 'source' than 'sink'. The animation provided with this report shows how periods of strong SE currents occur in this region, often associated with the SE trade winds, taking the larvae into the northern zone where they mix with larvae originating there.

Future oceanographic research priorities include improving our understanding of the 'big picture', and it would be very valuable to consider the possibility of interactions between the NW Coral Sea 'stock' of *P. ornatus*, and others in the region. The model showed that many larvae are transported into the Solomon Sea but it is not certain whether this flux of larvae helps support an adult population there. As discussed above, the oceanographic model employed here was not able to accurately resolve the bifurcation region, separating the source and sink populations. Hence, once more sophisticated models are available this information gap should be addressed. The linked question of mortality of early stage larvae while they are still in this region should also be addressed before any firm conclusions are possible.

Commercial logbook catch and effort data assessment

Although DPI&F and the former QFMA have collected catch and effort data on the fishery via compulsory fisher logbooks since 1988, until recently this data had not been validated. The objectives of the DPI&F component of the project were to validate and assess the quality of the commercial catch and effort data, collect additional information on the fishery to that provided by the logbook system and if possible conduct a preliminary assessment of the status of the fishery.

A pilot observer program was developed and implemented to evaluate the effectiveness of using fishery observers to validate and enhance the commercial logbook data and collect additional biological information that could be used to monitor the status of the lobster stocks. A major outcome of the observer program was the collection of information on the operation of the fishery and the methods used for recording catch and effort. This information aided the assessment of the CFISH logbook data. Although there may be some under recording of 'lobster tails' and discarded catch the 'live lobster' component of the catch recorded in logbooks appears to be reliable. The observer surveys provided additional fishery information, such as depth, range of operation from the primary vessel and diver experience. Analysis of this data indicates a relationship between catch rate and diver experience, but no relationship with depth fished. The spatial resolution of the daily tender catch and effort data is coarse (~ 30 minute grid level) as tenders often fish up to 20 nautical miles from the primary vessel.

Trends in the Queensland lobster fishery catch, effort and catch rates from the CFISH database for 1988-2004 were investigated. Most of the data, especially since 1995, was recorded under the *harvest* fishery code. There is a small (53 tonne) amount of lobster catch recorded by trawlers north of 14 degrees latitude for the years 1988-96. A detailed assessment of the lobster catch data recorded under the *harvest* fishery code indicates that the data can be reliably used to monitor trends in fishing effort, catch and catch rates both spatially and temporally. Feedback was provided to the logbook section of DPI&F on errors and inconsistencies in the CFISH lobster data and this feedback has improved the reliability of the summary statistics used by fishery managers to monitor the status of the fishery.

The majority of the fishing effort and catch of Queensland east coast tropical rock lobster since 1996 was reported within the three 30-minute CFISH grids between Shelbourne Bay and Portland Roads in the middle section of the fishery. Annual trends in catch rates for these grids are, however, similar to catch rates for the northern and southern section of the fishery. Fishing effort in the northern section has been higher than average since 2001 due to higher catch rates that may reflect higher food availability and recruitment levels.

Logbook summary statistics clearly show the development of the 'live lobster' industry for the mid 1990's with effort and catch rapidly increasing to a peak in 2001. Concurrent declining catch rates in the Torres Strait lobster fishery also drove the rapid rise in effort as most of the fleet is endorsed to operate in both fisheries. Since 2001 fishing effort has declined to around one third of the 2001 level due to increased catch rates in Torres Strait and low prices for 'live

lobster' during 2003 as a result of the SARS virus closing restaurants in Asia and China. Although annual catch declined during 2002-03 as fishing effort decreased, the 2004 catch increased to over 170 tonne due to a small increase in effort and a large increase in catch rates. The higher catch rates appear to be the result of increased stock abundance and a contraction of the active fleet to a small group of efficient fishers.

Although there is a high level of latent effort the risk that all of this effort will be activated in the near future appears low. Even in the year of highest effort, 2001, when the shift of effort from the Torres Strait to the east coast was highest due to the lowest ever recorded catch rates in Torres Strait, only about a one third of the potential fishing effort was used. Harvest MAC is currently investigating mechanisms to reduce latent effort in the fishery.

A preliminary estimate of sustainable harvest levels was derived for the Queensland lobster fishery using an assessment based on the total catch and a standardised annual Catch Per Unit of Effort (CPUE) index derived from daily tender catch rates for the years 1988-2004. The Schaefer form of a Surplus-Production (Biomass Dynamic) model provided the best fit to the annual time-series of catch and CPUE data. Although the annual CPUE index is highly variable during the early years (1988-94) due to the very low levels of effort, there is enough of a general long-term trend (contrast) in the data for the model to obtain a biologically sensible fit. Nevertheless, a 17-year time-series is a relatively short data set to use in a Surplus-Production stock assessment model.

The model estimates three sustainability reference points; Maximum Sustainable Yield (MSY), the Fishing Effort required to catch the MSY (E_{msy}) and the Biomass of stock needed to produce MSY (B_{msy}). These estimates should be regarded as preliminary as they have a large error range (95% CI) and further work is required on the standardisation of catch and effort data and the development of alternative stock models. The preliminary assessment indicates that the average harvest over the last five years (1999-03, ~ 140 t) is sustainable whilst fishing at or above the 2001 level of harvest (~190 t) may not be sustainable. The current assessment results indicate that continuously harvesting more than 170 tonne per annum (MSY) could result in the stock biomass being driven below the level that maximises the productivity of the fishery (B_{msy}, ~ 150 t). Although the estimate of E_{msy} is ~7,600 tender days this reference point has a much wider error range than the estimate of MSY and may be an inappropriate reference point for this fishery.

Management and research recommendations

The preliminary stock assessment indicated a Maximum Sustainable Yield (MSY) of about 170 tonnes (whole weight), but conversion of catch into equivalent fishing effort is strongly influenced by which vessels conduct most of the fishing and effort-based control may not be appropriate. We recommend that DPI&F conduct an annual update of the commercial logbook data by incorporating CFISH data into the Fisheries Long Term Monitoring Program. We recommend that the DPI&F investigate options for validating the commercial catch data against buyer returns. Regular liaison by DPI&F observers is recommended to ensure that total daily tender catches and effort weights are recorded accurately. Implementation of a maximum size limit was recommended, to conserve egg production of the population but an appropriate limit would be negotiated between DPI&F and industry. The introduction of a developmental "southern" fishery was recommended to displace effort from the current fishery. The development of lobster aquaculture, based on seed collected to the south of the current fishery was recommended.

Research to determine the timing and strength of recruitment, growth of resident lobsters, size and extent of the breeding population, and fishery recruitment strength was recommended to address biological information gaps relevant to fishery management. Regional scale oceanographic modelling, resolution of the South Equatorial Current bifurcation and advection

across the continental shelf were recommended as high priority oceanographic research priorities. Collection of pre-logbook fishery catch and effort data from personal fisher records was recommended to extend the data used for stock status assessment.

Keywords: Ornate Rock Lobster, larval transport, logbook data, Queensland lobster fishery.

2   ACKNOWLEDGEMENTS

3   BACKGROUND

The NE Queensland lobster fishery operates between Cape York (~11^{0}S) and Princess Charlotte Bay (~14^{0}S) in the far northern section of the Great Barrier Reef Marine Park (Figure 3-1), and is managed by the Queensland Fisheries Service. Divers, using surface-supplied breathing apparatus take the vast majority of the catch live and there are no bycatch species taken, apart from small numbers of *Panulirus* spp. The lobsters are held in onboard tanks prior to dispatch to seafood handlers in Cairns, Queensland. The main market for live *Panulirus ornatus* is in mainland China via Hong Kong where it is sold for use as Sashimi. Annual catches prior to 1999 were around 40-60 t (whole weight) but a recent doubling of fishing effort (700 to 1400 primary boat days) has seen annual catches since 2000 increase to over 110 t. Current value of the fishery is ~AUD 6 million. There are 29 primary boat endorsements with 95 associated tender vessels in the fishery and potential exists for effort to more than double if latent license holders become active in the future.

The NE Queensland lobster *Panulirus ornatus* population is part of a widely distributed stock bounded largely within the NW Coral Sea. The species occurs along the Queensland coast, into Torres Strait and across southern Papua New Guinea and whilst breeding probably occurs throughout the entire range it is not known which populations contribute to recruitment to the adult populations. Plankton surveys (see Dennis *et al.,* 2001) and oceanographic surveys (eg. Burrage, 1993) undertaken in the Coral Sea indicated that lobster larvae released south of the NE Queensland fishery border (14°S) may be lost to the south in the East Australian Current (EAC); hence this region was thought to contain a sink population. Apart from information gleaned during extensive tagging studies conducted by CSIRO during the early 80's little is known of the biology and ecology of the NE Queensland lobster population, or its extent.

Assessment of the Torres Strait lobster fishery is aided by annual fishery-independent population surveys and fishery modelling conducted by CSIRO. The population surveys provide relative abundance indices for recruiting (1+ year old), and fished (2+ year old) lobsters that are referenced against absolute stock estimates determined in 1989 and 2002. However, this approach would probably not be economically feasible for the NE Queensland lobster population, given the wide geographic extent of the population and deep habitat (>20 m) occupied by lobsters. Nevertheless, comprehensive commercial catch and effort data is collected with the DPI&F logbook program and the effectiveness of this data for use in stock status assessment is assessed in sub-project 3 (Section 9) of this report.

The Queensland Fisheries Service, with the backing of the Queensland lobster fishers recently implemented new management restrictions to address the immediate concerns that the fishery may not be sustainable in the long-term. During late 2002, a seasonal fishery closure for the months October to January and a minimum size limit of 90 mm carapace length as well as a ban on taking berried or tarspot (spermatophoric mass) females were implemented.

This report outlines the results of the research tasks identified to address the information gaps identified for this fishery and the urgent management needs, given the high likelihood that both the Torres Strait and NE Queensland fisheries have been biologically overexploited. The research outcomes contained in this report will assist in identifying future priorities to assist sustainable management that will form the basis of future research applications.
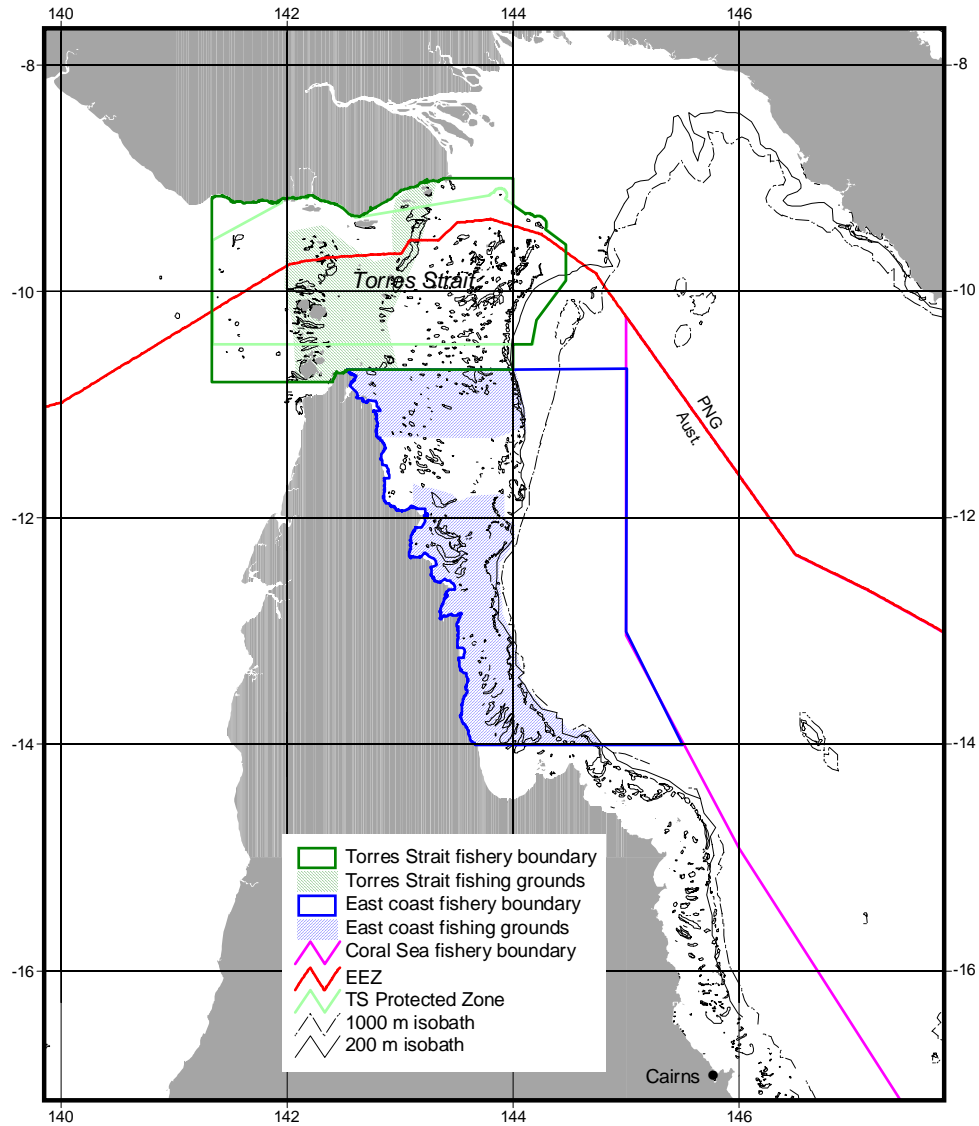
Figure 3-1. Map of northern Queensland and southern PNG showing boundaries of the Queensland and Torres Strait ornate rock lobster *Panulirus ornatus* fisheries, the Torres Strait Protected Zone (TSPZ), the Exclusive Economic Zone (EEZ) and the 200 and 1000 m isobaths.

4   NEED

The need for targeted research to support management of the NE Queensland lobster fishery has arisen as a result of the recent and dramatic increase in catch and concern that the increase is unsustainable. In response to this concern the Queensland Fisheries Service (QFS) issued an investment warning for the fishery on 31 May 2001 and new management was implemented in late 2002. Also, the NE Queensland lobster population is likely part of a wider distributed stock, shared by Australian and PNG fishers in Torres Strait and these fisheries were considered biologically over-exploited during the late 90s and managers are taking measures to ensure sustainability. In NE Queensland there is an urgent need to gain biological and fishery information to allow implementation of management measures that will ensure catches are sustainable.

The commercial catch is monitored by the DPI&F with a logbook program but no formal stock assessment has been undertaken using this data. However, effort and catch has doubled over the past three years, whilst CPUE has tended to decline. There is also a need to collate existing and new information on the biology of the NE Queensland lobster population to assess current impacts of fishing on the stock and so that future research can be prioritised and properly designed to ensure its cost-effectiveness. Future research would likely include field studies to assist stock assessment, breeding population studies, targeted oceanographic studies and efficient observer programs.

A critical need is knowledge of the extent of the breeding population and the fate of larval recruits on the NE Queensland coast. There is currently a desire from the industry to open areas south of 14°S, given these southern lobsters may be part of a sink population. However, for informed management decisions it is important to establish how well stocks are connected. Existing allozyme genetic data suggested that the NE Queensland coast lobster population was genetically indistinguishable from populations in Torres Strait or in the Gulf of Papua. It is likely, given the long larval life of lobsters (6 months) that the NE Queensland coast, Torres Strait and the eastern Gulf of Papua are source areas and larvae spawned there mix in the NW Coral Sea gyre and provide recruitment to these regions as well as to sink areas south of 14°S. If this is true, fishing occurs in the source area but not on the sink population; biological information is required to resolve this contrary situation.

5   OBJECTIVES

1.   The overall research objective is to collate fishery and biological information on the NE Queensland lobster population to permit an assessment of the status of the fishery, recommend sustainable management measures and identify future research priorities to fill information gaps that preclude sustainable and long-term management of the fishery.

2.   Collate historical research information on adult and juvenile lobster geographic and size distribution, spawning and settlement grounds and map spatial data using Arcview software.

3.   Collate information collected by the fishery on size and sex distribution, and distribution of breeding lobsters.

4.   Recommend sustainable management measures.

5.   Identify information gaps precluding efficient and sustainable management and prioritise future research to address these gaps.

6.   Develop an oceanographic model of the mesoscale circulation in the NW Coral Sea.

7.   Determine trajectories of larvae released by the NE Queensland lobster population and assess the fate of these larvae.

8.   Determine the potential boundaries of the source and sink populations.

9.   Identify and prioritise future oceanographic research to assist sustainable management.

10.   Collate, validate and analyse all catch and effort data available from DPI&F logbook entries.

11.   Validate logbook information through an observer program and recommend a cost effective protocol for future programs.

12.   Assess catch and effort trends of the NE Queensland lobster fishery and develop a stock status methodology.

13.   Recommend future logbook data collection.

6 SUB-PROJECT 1: DATA MINING AND COLLATION

6.1 Objectives

6.1.1 Collating historical data-sets

1. Collate historical research information on adult and juvenile lobster geographic and size distribution, spawning and settlement grounds and map spatial data using Arcview software.

2. Collate information collected by the fishery on size and sex distribution, and distribution of breeding lobsters.

3. Recommend sustainable management measures.

4. Identify information gaps precluding efficient and sustainable management and prioritize future research to address these gaps.

6.2 Methods

6.2.1 Collating historical data-sets

During development of this phase 1 research project it was recognised that many of the historical studies of the biology and ecology of *Panulirus ornatus*, undertaken by Australia and PNG in areas adjacent to the NW Coral Sea were relevant to the NE Queensland lobster population and assessment of the current fishery. Research outcomes from many of these studies including those of Bell *et al.,* (1987), Moore and MacFarlane (1984), MacFarlane and Moore (1986) were published and readily available, but much of the relevant information and raw data was contained in computer files or on data sheets. Most of the historical studies (prior to 1990) were aimed at identifying the life history of the Torres Strait lobster population, due to the increasing commercial catches during that time, and the importance of the fishery to the traditional inhabitants. In contrast, commercial catches from the NE Queensland fishery were relatively insignificant and less research effort was directed at understanding the biology and ecology of the NE Queensland lobster population. Nevertheless, extensive tagging studies and a puerulus collector program were conducted on the NE Queensland coast during the early 1980s, principally to identify the links between the Torres Strait and NE Queensland coast populations.

Given the relevance of this historical information on NE Queensland and Torres Strait lobster populations the task of collating the relevant data was identified as a priority prior to development of targeted biological research. In particular, this sub-project was aimed at identification of the information gaps for each phase of the lobster life history that prevented sustainable management practices. The collation of historical and current biological information also serves as background for the more detailed analyses of larval advection and stock status assessment in sub-projects 2 and 3.

Historical data held by CSIRO Marine Research was collated from data sheets and computer files in a Microsoft Access database (Table 1). Relevant biological data and information was also obtained from the scientific literature and from CSIRO reports as cited throughout this document and listed in references. Locations for geo-referenced data were standardised to the WGS84 map datum.

Table 1.   Tables containing historical and current biological and fishery data collated during 2002/008.

Table Name	Data Type	Period Covered	Number of records
Historical Data			
Eastcoast_tags	Size & sex	1980 (Feb-May)	4739
Lobster_morph	Relative size measures	1986-2003	6033
SS6/97 Larval Catch	Coral Sea larvae catches	May 1997	525
Cairns_settlement	Monthly counts of juveniles	1981-1985	60
Breed_survey_89-92	Breeding locations FNGBR	1989-1992	86
Breed_survey_92lf	Size, sex, reproductive status	February 1992	165
Breed_survey_96	Breeding locations FNGBR	February 1996	137
Breed_survey_96lf	Size, sex, reproductive status	February 1996	41
Collector_Catch	Counts of juveniles	1981-1982	11
Collector_lf	Size of juveniles	1981-1982	21
Current Data			
TripDetails	Trip dates & locations	July 01-Sept 03	135
Morphometric_details	Size, sex, moult stage	2001-2003	6532
Reproductive_details	Size, sex, reproductive status	2001-2003	165

6.2.2   Collating current biological data-sets

The voluntary collection of biological data by commercial lobster fishers and MG Kailis, Cairns was initiated in July 2001 and continued until July 2003. Records of breeding ornate rock lobster *Panulirus ornatus* females were reported on datasheets prepared by CSIRO Marine Research (CMR) (see Appendix 17). As a result of the implementation of the seasonal ban on fishing (October-January) in 2002 by the Queensland Fisheries Service (QFS), coinciding with the breeding season of *P. ornatus*, no breeding records were reported for the 2002/2003 season. Size frequency and mating records were reported by commercial fishers and MG Kailis on datasheets prepared by CMR (see Appendix 17). Size frequency data was also obtained by QDPI staff during observer trips, outlined in sub-project 3 (Section 9).

All biological data was error checked prior to entering into a Microsoft Access database.

6.2.3   Mapping distributions of adult, juvenile, larval and breeding lobsters

The geographic extents of adult, juvenile, larval and breeding ornate rock lobsters *Panulirus ornatus* were mapped using historical and current geo-referenced occurrences of each of the life stages in ArcView 3.1 software. Locations were standardised to the WGS84 map datum. The lobster geographic distribution data was drawn from voluntary commercial fisher records, research diver surveys, records of artificial collector catches and research plankton surveys.
The distribution of *P. ornatus* larvae, relative to the major influencing currents within the NW Coral Sea, was determined from plankton net catches at 13 widespread locations in May 1997. At each location six multi-level tows were conducted using a multiple opening closing device (MIDOC) attached to a large pelagic trawl with a nominal mouth opening of 70 m^2. A separate smaller net, with a nominal mouth opening of 1.5 m^2, was deployed to sample the surface 50

cm. All phyllosoma larvae and pueruli were fixed in 10% buffered formalin and subsequently identified to species at the Cleveland Marine Laboratory. Surviving pueruli were transferred to an aquarium onboard to allow positive identification once the lobsters had moulted and adopted juvenile colouration.

6.2.4 Movements and migrations

The local and extensive movements of ornate rock lobsters *Panulirus ornatus* have been reported in Bell *et al.,* (1987) and Moore and MacFarlane (1984), and detailed descriptions of methods and results are provided in these publications. The majority of lobsters were caught and released on the shallow inshore reefs. We summarised the results of these studies relevant to the NE Queensland lobster population and identified information gaps that may prevent informed management of the current fishery. Movements of tagged lobsters from release and recapture locations on the NE Queensland coast and in Torres Strait were redrawn from the original publications.

6.2.5 Reproduction

6.2.5.1 Breeding Locations

The recorded locations of breeding ornate rock lobsters *Panulirus ornatus* on the NE Queensland coast and in the NW Coral Sea, from historical research studies and current observations by fishers were mapped using ArcView 3.1 software. Although not a comprehensive range of breeding locations for *Panulirus ornatus*, this information indicated the known extent of the breeding grounds and locations that should be surveyed in future research studies.

6.2.5.2 Population egg production

The relative reproductive output of the NE Queensland coast lobster population was estimated using an established size-fecundity relationship for *P. ornatus* and the sampled size distribution, to provide a preliminary assessment of the possible impact of the fishery on egg production. The implementation of the closed season (October to January) in 2002, after the project was started, precluded the estimation of relative egg production from the population during the breeding season. However, a population sampled to the south of the fishery in September 2002 by a QDPI observer was used as a surrogate breeding population.

6.2.6 Age structure analyses

Age structure of the NE Queensland lobster population was assessed using size and sex data from tag-recapture studies and voluntary sampling by commercial fishers. Where possible, size modes were identified using component analysis (Mix; MacDonald and Pitcher, 1979). Ages were inferred from published growth equations (Phillips *et al.,* 1992, Skewes *et al.,* 1997) and comparative data recorded for the Torres Strait population. Settlement timing was inferred from studies conducted in Cairns and in Torres Strait.

6.3   Results/Discussion

6.3.1   Geographic distribution

6.3.1.1 Adult lobsters

The geographic extent of adult ornate rock lobsters *Panulirus ornatus* on the NE Queensland coast is known from commercial fisher records and historical research studies undertaken by CSIRO and PNG DFMR (Figure 6-1). Hence, the known locations of adult lobsters are restricted to areas accessible to divers (generally <30 m), and the size and extent of lobster populations in deep habitats remain unknown.

The geographic distribution of ornate rock lobsters is determined by its habitat preferences and requirements. By comparison with other tropical spiny lobsters the ornate rock lobster exhibits a broad habitat use, from deep (>200 m) oceanic waters to silted rubble areas near river mouths and mangroves (Pitcher, 1993). This broad habitat use explains why this species is found throughout the Indo-west Pacific, from the Red Sea and East Africa, to southern Japan, the Solomon Islands, New Caledonia and Fiji (Holthuis, 1991). The broad habitat preferences also explain the widespread distribution of this species on the NE Queensland coast, and it is likely in addition to their occurrence near-shore that ornate rock lobsters occur along the outer Great Barrier Reef. The very minor contributions of *Panulirus versicolor* and *Panulirus femoristriga* to the commercial catch (see 8.3.3) highlight that the inshore and mid-shelf reefs on the NE Queensland coast are dominated by *Panulirus ornatus*.

Adult lobsters occur throughout the latitudinal range of the Queensland lobster fishery (Figure 6-1). Although there has been no assessment of the abundance of lobsters throughout the fishery, the preference for commercial fishing grounds around 12^0S indicates lobsters are more abundant there, as confirmed in sub-project 3. Detailed information on commercial catch rates from log-book records are provided in sub-project 3 below.
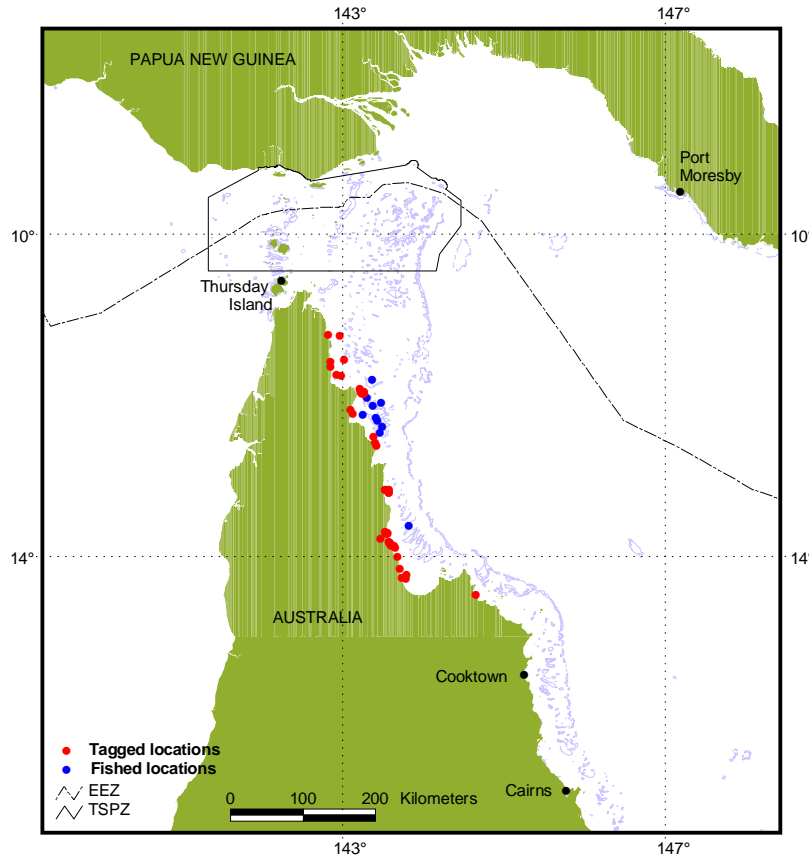
Figure 6-1. **Map of northern Queensland showing locations where sub-adult ornate rock lobsters *Panulirus ornatus* were recorded during commercial fishing operations during 2001-2003 and historical tag-recapture studies.**

6.3.1.2 Juvenile lobsters

The geographic distribution of juvenile or newly-settled ornate rock lobsters *Panulirus ornatus* is known from catch data for artificial collectors deployed and sampled by CSIRO researchers (Figure 6-2). The catch rates of juvenile lobsters were very low indicating that the conventional collectors used for spiny lobsters around the world are not effective for this species. Similarly very low catch rates were reported for this species in Torres Strait (Dennis *et al.,* 1997). Nevertheless, juvenile lobsters were caught throughout the NE Queensland lobster fishery indicating that settlement and nursery grounds coincide with adult habitat.
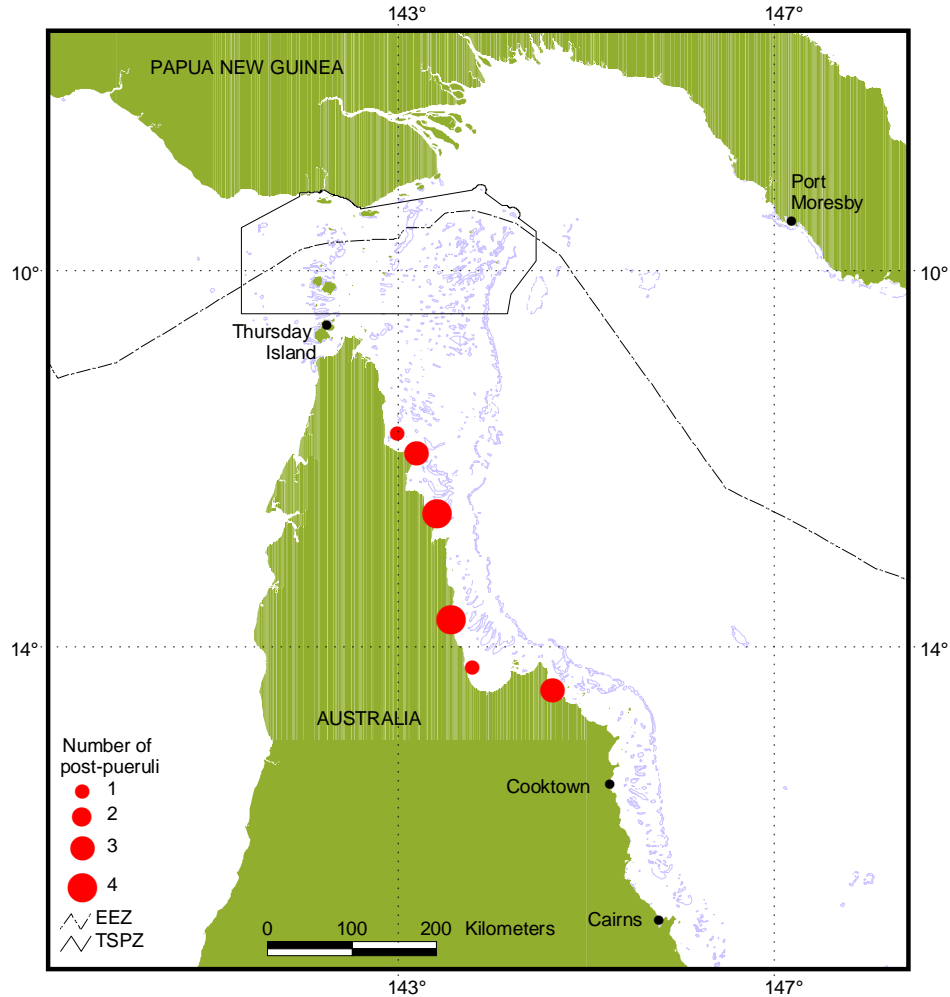
Figure 6-2. **Map of northern Queensland showing locations where juvenile (<20 mm CL) ornate rock lobsters *Panulirus ornatus* were sampled using artificial collectors during 1980-1982.**

6.3.1.3 Larval and post-larval lobsters

The distribution and abundance of larval and post-larval *Panulirus ornatus*, from plankton sampling undertaken in the Coral Sea during May 1997 were reported in Dennis *et al.,* (2001). A summary of the results of this research, relevant to the Queensland lobster fishery is provided here for completeness. Information provided here also serves as background for the more detailed study of larval advection in the Coral Sea as reported in sub-project 2 (Section 7).

The plankton sampling in May 1997 was conducted at 13 widespread locations in the NW Coral Sea (Figure 6-3). *Panulirus ornatus* larvae dominated the spiny lobster catch, comprised of *P. femoristriga*, *P. penicilattus*, *P. versicolor* and *P. polyphagus* (Dennis *et al.,* 2001). A small number of *P. versicolor* and *P. femoristriga* are taken by the Queensland lobster fishery.
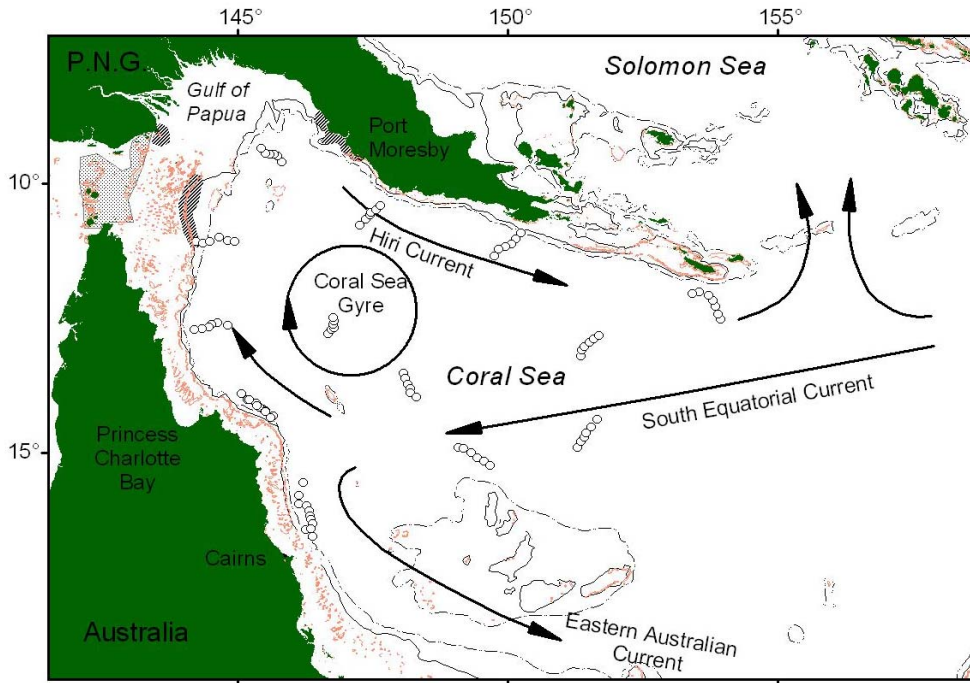
Figure 6-3. **Map of northwest Coral Sea showing the dominant ocean currents and locations (circles) sampled using plankton nets during May 1997. Hatched areas show locations of the known lobster breeding grounds. From Dennis *et al.,* (2001).**
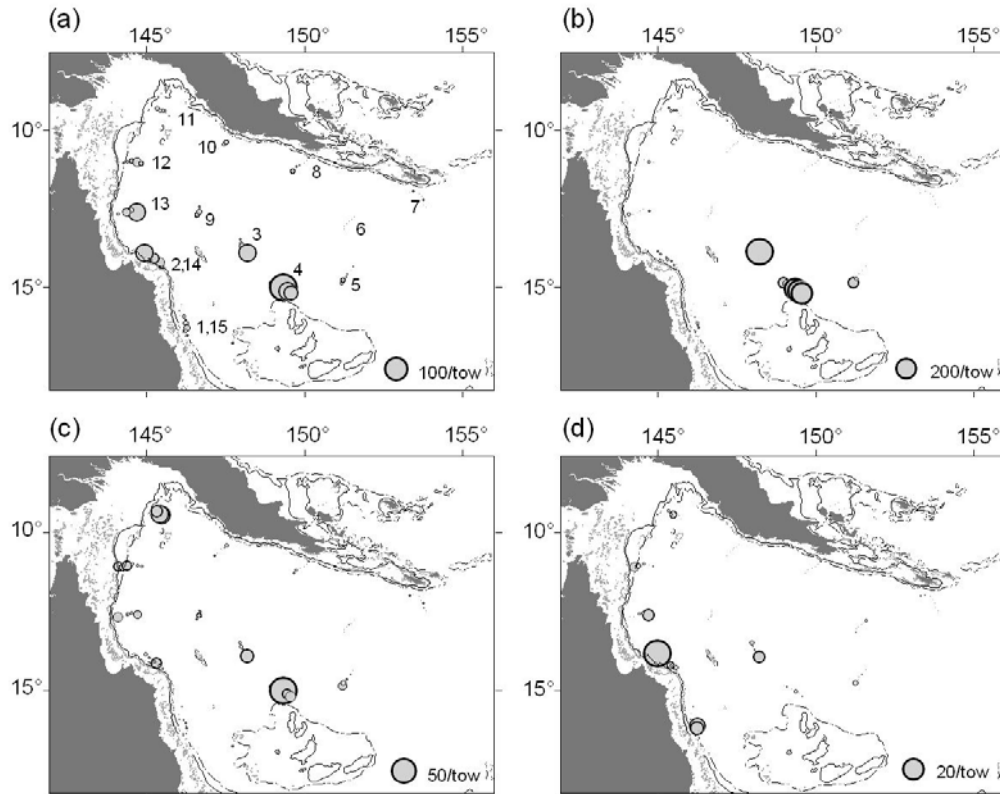
Figure 6-4. **Maps of the northwest Coral Sea showing distributions of (a) late-stage, (b) pre-gilled, (c) gilled and (d) puerulus stage larval ornate rock lobsters** ***Panulirus ornatus*** **sampled during May 1997. Filled circles are proportional to measured abundance.**

The geographic distribution of *Panulirus ornatus* larvae found in May 1997 provided a preliminary insight into the likely advection of this species from the known breeding grounds around the Coral Sea. However, as demonstrated by ocean current modelling in sub-project 2, the pattern of larval distribution may have been atypical due to the transit of Tropical Cyclone Justin across the Coral Sea just 2 months prior to sampling. Nevertheless, this study provided significant information on the transport and recruitment of *P. ornatus* larvae to the NE Queensland population and subsequent plankton sampling will benefit from the results.

Most *P. ornatus* pueruli were collected on the shelf break adjacent to the Queensland fishery and further south. This was not expected given that the Torres Strait population supports a much larger fishery and presumably a larger adult population, and it was thought that settling lobsters would be most abundant further north. There are two hypotheses that could explain the relatively higher recruit abundance off the NE Queensland coast. Firstly, 1997 was an atypical year due to Tropical Cyclone Justin and the northward transport of larvae may have been interrupted. Support for this hypothesis comes from the subsequent poor recruitment of 1.5 year old lobsters to the Torres Strait fishery in 1998 (Pitcher *et al.,* 2001). The second hypothesis suggests that relative mortality of settling lobsters is much higher on the Queensland coast compared to Torres Strait. Support for this hypothesis comes from sporadic high settlement of lobsters in near shore locations not suitable for adult lobsters (such as Cairns harbour, Lucinda wharf and Hinchinbrook channel). Importantly the fate of pueruli as they cross the Great Barrier Reef to settle near-shore is unknown. However, given the high abundance of planktivorous fishes on the GBR larval mortality is likely to be extremely high.

The absence of larvae in the NE Coral Sea suggests that by May most larvae have been transported from the NW Coral Sea breeding grounds to the Queensland continental shelf. The pueruli collected on the outer GBR would have been between 3.5 and 6 months old, given that hatching at the known breeding grounds occurs between late-November and mid-February (MacFarlane and Moore, 1986). These pueruli would have settled on the Queensland coast within a month, given they are non-feeding, suggesting a larval duration of 4.5-7 months. Peak settlement was found to occur in June in Torres Strait (Dennis *et al.,* 1997) and during winter (June-August) at Cairns (CSIRO unpublished data). However, in both studies there was considerable range in the timing of settlement.

Although the geographic distribution of larval *P. ornatus* was determined in this study (Dennis *et al.,* 2001a) the sources of these larvae remained largely unknown. In addition, an understanding of the location, size and extent of the breeding grounds of this species is critical to management of the fishery. Although this project provided more information on the breeding grounds of this species on the Queensland coast as discussed below, comprehensive knowledge of the distribution and size of the breeding population remains a key information gap.

6.3.2 *Reproduction*

6.3.2.1 *Breeding Locations*

Breeding grounds of *Panulirus ornatus,* determined during tagging studies by CSIRO and PNG researchers, diver and submersible surveys by CSIRO and as reported by commercial lobster fishers are widely distributed along the NE Queensland coast between Cairns and Cape York (the northern extent of the Queensland fishery; Figure 6-5). The extent of known breeding grounds is further extended to at least Townsville (19^0S) as mature females have been recorded from deepwater (130-145 m) trawl catches there (Bell *et al.,* 1987).

A total of 39 berried female lobsters were observed during extensive tagging studies by CSIRO between February 1980 and March 1983 (Bell *et al.,* 1987; Figure 6-5). Of these, 35 were caught in shallow water (1-5 m), two were captured on reef-edge habitat and two were found on open trawl ground (15-23 m) (Bell *et al.,* 1987). However, the frequency of occurrence at each depth was highly likely related to sampling intensity rather than density.

The vast majority of records of breeding lobsters have come from shallow habitats accessible to divers. In general, the distribution of breeding grounds on the NE Queensland coast, in waters inaccessible to divers (>30 m), is largely unknown due to the logistical difficulties in surveying these areas.

Of 3169 female lobsters caught and measured by commercial fishers between 21 July 2001 and 19 July 2003 a total of 165 (5%) were found bearing eggs or a spermatophoric mass from reefs off Temple Bay on the NE Queensland coast (Figure 6-6). The majority (80%) were recorded during November 2001. Only eight berried females were recorded by commercial fishers from Mason Reef ($120^0$6'S, $143^0$28'E). No berried female lobsters were recorded during the 2002/03 fishing season due to the implementation of the seasonal closure (October-January) in 2002.

There is a relative paucity of data on the breeding locations of ornate lobsters on the NE Queensland coast, given the extensive research and commercial fisher surveys conducted since 1980. However, breeding activity recorded during this study confirmed that the breeding grounds overlap with the area of commercial fishing on the Queensland coast. At Yule Island, PNG female ornate rock lobsters move temporarily into deep-water to spawn in high current areas and move back onto the shallow reefs (Dennis et al., 1992). Hence, since the commercial fishing grounds on the Queensland coast are adjacent to deepwater (>30 m) habitat, it is likely lobsters undertake similar spawning migrations there. Surveying deepwater habitat on the NE

Queensland coast to determine the size and extent of the breeding population remains a key research activity to address this information gap precluding effective management of the Queensland lobster fishery. Further, whether most breeding lobsters return to the shallow reefs or remain in deepwater in successive breeding seasons is unknown, but remains an important question to answer. The actual impact of the fishery on successive breeding populations will only be known once these important questions are answered.
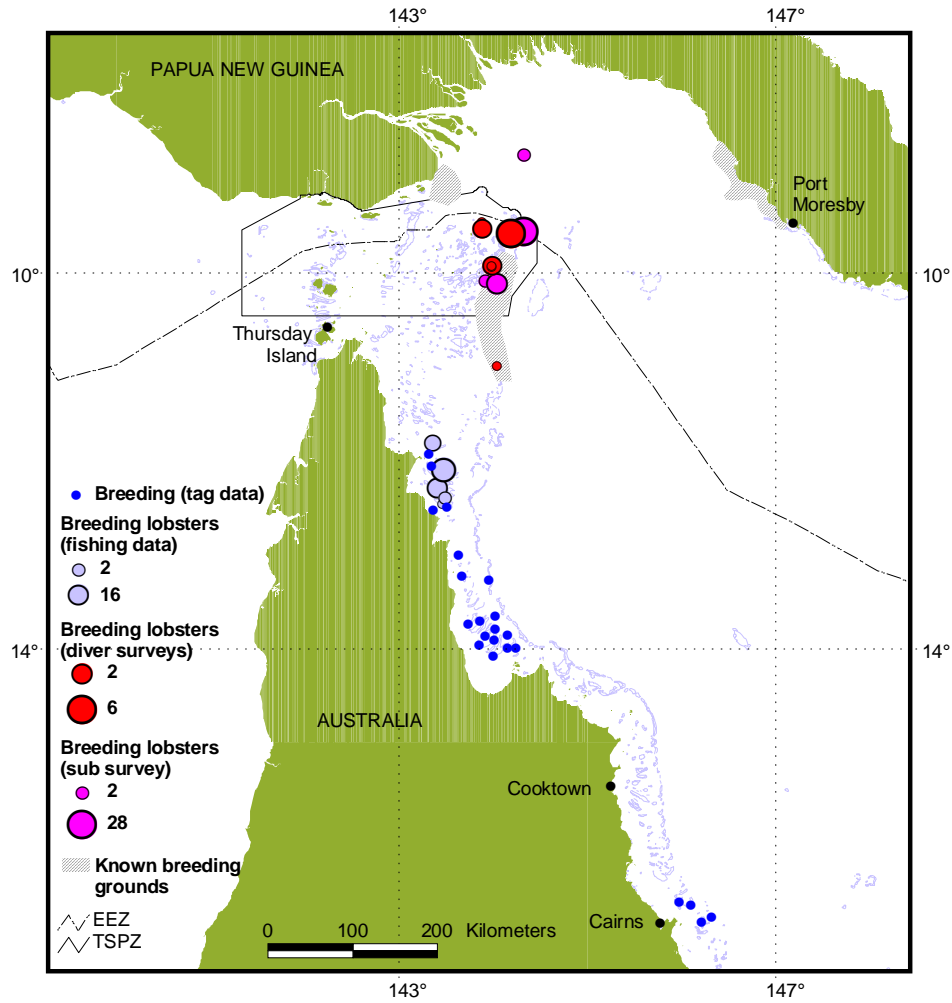
Figure 6-5. **Map of northern Queensland and southern PNG showing locations where berried female ornate rock lobsters *Panulirus ornatus* have been recorded by commercial and research divers and by submersible observations.**
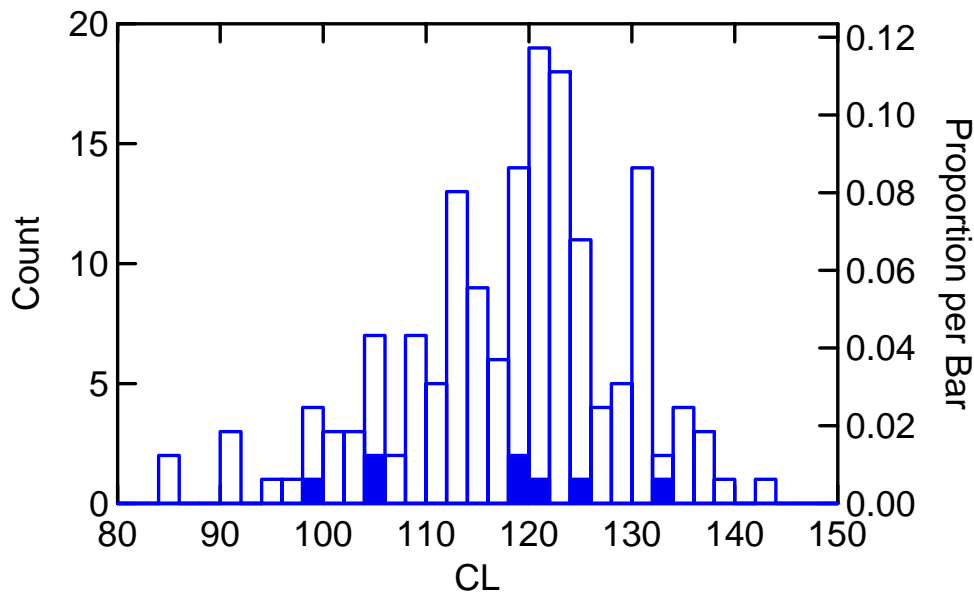
Figure 6-6. Size frequency distribution of female ornate rock lobsters *Panulirus ornatus* with spermatophoric masses (open bars) and eggs (filled bars) from the NE Queensland lobster fishery. Data was recorded voluntarily by commercial lobster fishers.

6.3.2.2 Timing of breeding

The timing of breeding for *Panulirus ornatus* was well documented at Yule Island, PNG by MacFarlane and Moore (1986). Berried females were recorded between November and April but most reproductive activity occurred between late-November and mid-February. The mean incubation period was 35 days at about 29^0C, and the mean period between hatching and oviposition was 4 days. The authors suggested that lobsters mated during migration from Torres Strait with females berried by late October and subsequent hatching in late November. During the breeding season females hatched a further two broods at intervals of about 40 days.

Bell *et al.,* (1987) reported the occurrence of berried females on the NE Queensland during the same period as recorded at Yule Island, PNG, with a peak from January to March. Berried females were caught by CSIRO divers on the far northern GBR during 16-28 February 1992 and 11-22 February 1996 (CSIRO unpublished data) but these periods were restricted to the dates of sampling.

Females with spermatophoric masses or eggs were recorded on the NE Queensland coast by commercial fishers between 17 October 2001 and 11 April 2002, but the vast majority (80%) were recorded during November 2001. There were no voluntary records for December or January (Table 2) as this is the seasonal down time for the fishery, even prior to the introduction of the seasonal closure. Hence, it is impossible to determine the mating patterns for these months. Nevertheless, nearly all (98%) fresh tarspots were recorded before December and all old tarspots were recorded after January (Table 2). Further, commercial fishers report that most fresh tarspots were observed in October/November (Ray Moore pers. comm.). It is, therefore, likely that most mating occurs early in the breeding season. The eight berried females were recorded in March 2002, but no berried females were recorded during the 2003 fishing season, likely due to the new regulations prohibiting the take of berried or tarspot females.

Table 2. **Numbers of female ornate rock lobsters *Panulirus ornatus* carrying fresh, used or old spermatophoric masses by month from voluntary data recorded by commercial lobster fishers during 2001-2003.**

Tarspot condition	Number of lobsters recorded						
	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Fresh	2	112	0	0	2	0	0
Used	0	19	0	0	0	2	0
Old	0	0	0	0	5	20	3
Total	2	131	0	0	7	22	3

As for the locations of breeding grounds, there is limited data available to determine the timing of breeding of ornate rock lobsters on the NE Queensland coast. Nevertheless, the available information suggests it is similar to that documented for this species at Yule Island, PNG. The reported peak in occurrence of tarspot females in November 2001 indicates that the 4 month seasonal ban (October to January) implemented in 2002 is appropriate to protect the breeding population from mating through to hatching.

6.3.2.3 Egg Production

Female reproductive output increases with carapace length (CL) according to the equation Fecundity = $10416 \times CL - 561793$ calculated by MacFarlane and Moore (1986), from size fecundity measures of lobsters sampled at Yule Island, PNG. The smallest berried female recorded at Yule Island was 78.6 mm CL. The smallest berried female found on the Queensland coast during extensive tagging studies by CSIRO between 1980 and 1983 was 88 mm CL (Bell *et al.,* 1987). Hence, given the minimum legal size of 90 mm CL, all female lobsters captured on the NE Queensland coast by the commercial fishery can be assumed to be capable of spawning.

A simple analysis of the relative egg production of the female ornate rock lobster population was used to assess likely impacts of the fishery and also the likely benefits of a maximum size limit to conserve egg production. A sample of female lobsters measured by a QDPI observer in September 2002 (Figure 6-7) was used for the analysis as a surrogate breeding population, as this sample was taken closest to the breeding season and large numbers of lobsters were measured. Although ornate rock lobsters produce up to three broods during the breeding season our analysis was based on only one brood.
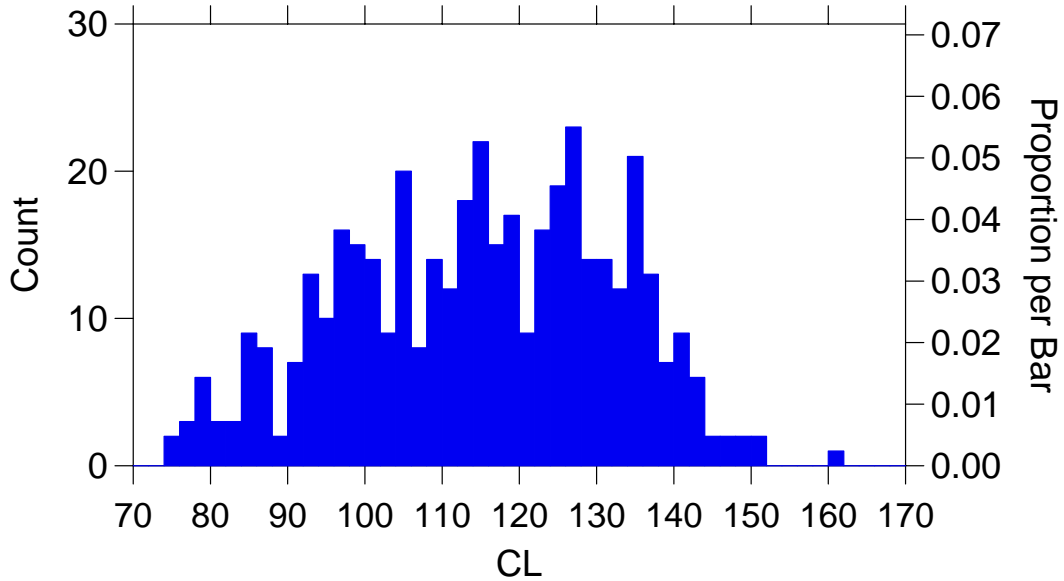
Figure 6-7. Size frequency distribution of female ornate rock lobsters *Panulirus ornatus* caught by the NE Queensland lobster fishery in September 2002. Data provided by Jo Atfield, QDPI. Note this sample was taken prior to the introduction of the minimum legal size limit (90 mm CL).

After fecundity was calculated for each female lobster, from MacFarlane and Moore's (1986) equation, the data was tabulated for each 5 mm CL interval to provide percent contributions (Figure 6-8). The number and percent of total lobsters in each 5 mm CL interval was also calculated. The cumulative distributions of egg production and numbers were calculated to allow a simple assessment of the impact of a maximum size limit on the fishery and the benefits to egg production (Figure 6-8).
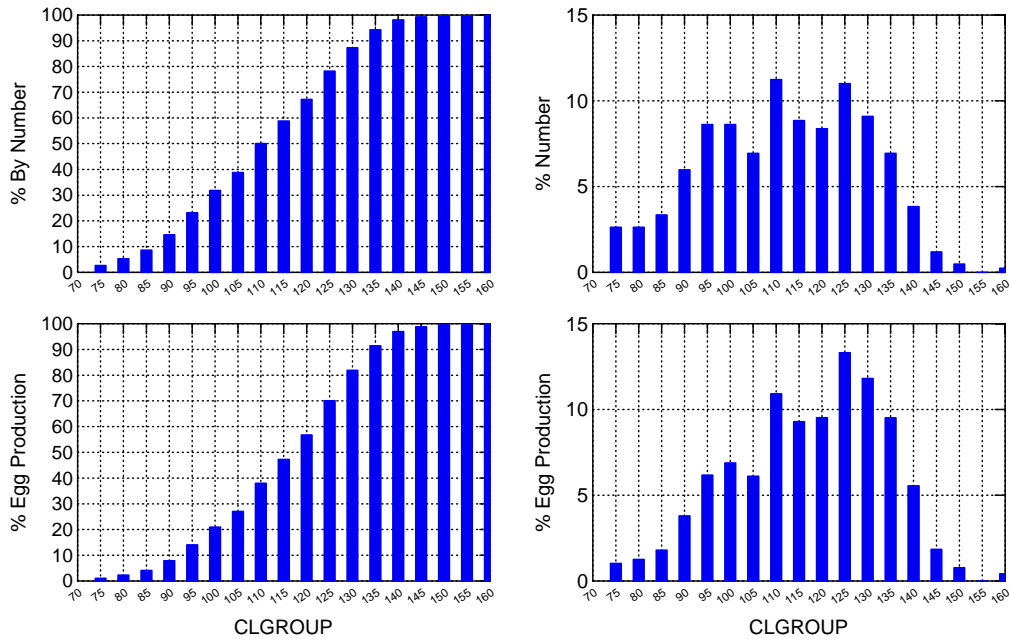
Figure 6-8.   Relative contributions in number and potential egg production of female ornate rock lobsters *Panulirus ornatus* for 5 mm size intervals in the NE Queensland population in September 2002. The x axis scale shows the lower margin of each interval.

The cumulative distributions of egg production and number by size interval showed that for the NE Queensland lobster population, females under 115 mm CL comprised 50% of the total number but contributed under 40% to total egg production (Figure 6-8). Female lobsters larger than 129 mm CL contributed 22% by number and 30% to egg production whilst those larger than 139 mm CL contributed 6% by number and 9% to egg production. This simple analysis demonstrates that it would be possible to implement a maximum size limit that would conserve a significant proportion of egg production without a major impact on fishery catch. This limit should be negotiated between managers and fishers and the benefit monitored.

The reproductive output of female lobsters is also determined indirectly by the reproductive status of conspecific male lobsters. Male lobsters must be physically capable of mating with female lobsters, and male reproductive output is dependent on the availability of appropriate size females. Only male *Jasus edwardsii* greater than 140 mm CL were observed courting females in the field in northern New Zealand, even though smaller males were abundant (MacDiarmid, 1989). Hence, the implementation of a maximum size limit would also serve to conserve potential mates for the large female lobsters.

An indicator of sexual maturity in male *Panulirus ornatus* lobsters is the relative length of the front walking legs (Figure 6-9; CSIRO unpublished data). The relative increase in the length of the second legs at ~110 mm CL, as noted also by MacFarlane and Moore (1986) for migratory groups, indicates the onset of sexual maturity. In any case, the current NE Queensland lobster population is comprised of comparatively larger male populations, which likely increases the breeding potential of the lobster stock. However, truncation of the male size distribution through selective fishing of large lobsters has the potential to further reduce reproductive success and subsequently egg production.

The likely impacts of over-fishing large ornate rock lobsters on reproductive output and reproductive success indicate that it would be prudent to implement management to conserve the larger cohorts of the population. Without baseline age structure information for this fishery it is impossible to assess whether the current population is in fact truncated.

The benefits to this fishery of implementing a maximum size limit are difficult to quantify, even though the analyses above indicate the potential gains in reproductive capacity of the population, with little reduction in fishery catches. The size fecundity relationship calculated for this species at Yule Island, PNG applied for females ranging from 75.4 to 121.0 mm carapace length (MacFarlane and Moore, 1986). We extrapolated this relationship for the larger lobsters (>121 mm CL) on the NE Queensland coast, but it is possible reproductive output of these larger lobsters may actually be relatively smaller. Further, MacFarlane and Moore (1986) recorded significantly reduced brood sizes (Mean 51.3%) later in the breeding season at Yule Island, PNG. Whether, this also occurs, and to what extent, on the NE Queensland coast is unknown. However, given there is no extensive breeding migration in this population, with subsequent deterioration in physiological condition as noted for the Yule Island population (Trendall and Prescott, 1989) brood size may in fact be maintained during the breeding season.
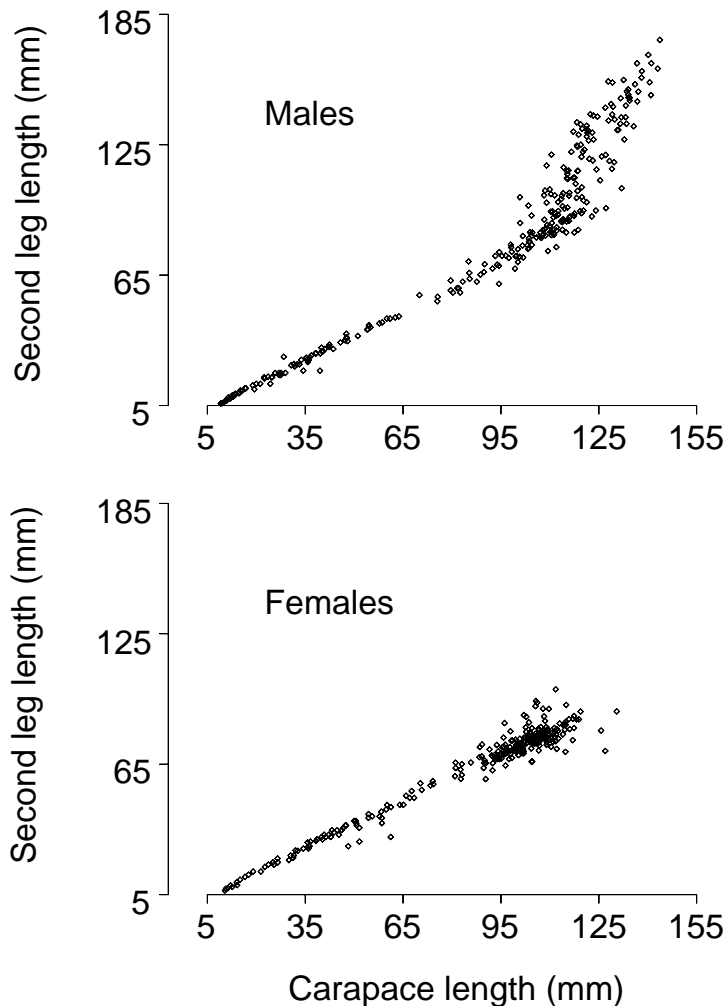
Figure 6-9. Relationships between second leg length and carapace length for male and female *Panulirus ornatus* as an indicator of size at sexual maturity.

6.3.3 Movements and Migrations

Of the 9632 ornate rock lobsters tagged on the NE Queensland coast during 1980-1983 only 245 (2.5%) were recaptured (Bell *et al.,* 1987). Only 24 of the 245 recaptures indicated significant (>4 km) movement away from the tagging site, suggesting most of the population shows high fidelity within a reef system. In contrast to the extensive migrations undertaken by Torres Strait lobsters (Figure 6-10), lobsters on the NE Queensland coast moved only small distances from their original locations, and mostly off-shore. More lobsters (62%) moved south from their site of capture and southerly movements were significantly more extensive than northerly movements (Mean distance travelled south was 70 km cf. 27 km for northerly movements).

Mass movements of ornate rock lobsters do occur on the NE Queensland coast as determined from incidental prawn trawl catches (Bell *et al.,* 1987, CSIRO unpublished data). However, both the timing and mean size of these migrations indicate they are not breeding movements. The modal size range of migratory lobsters sampled by Bell *et al.,* (1987) was 75-95 mm CL, significantly smaller than the size range of the population and migratory groups sampled in Torres Strait.

Further evidence of mass movements of small ornate rock lobsters was gained from changes in size distributions of near-shore populations sampled during the tag-recapture studies. Populations sampled at near-shore locations, Frenchman Reef and Roberts Point in February-May and March-May respectively showed a loss of large lobsters (Mean size ~95 mm CL) in the later sampling (Figure 6-11, Figure 6-12, redrawn from Bell *et al.,* 1987). The authors concluded that the large lobsters had moved off-shore from their juvenile habitat, and similar movements have been documented for *Panulirus argus* and *P. cygnus*. Anecdotal reports of incidental prawn trawl catches (CSIRO unpublished data) corroborate the timing of these migrations as large numbers of small lobsters are commonly caught during March/April. Under current management these lobsters must be returned to the sea.

From the results of the tagging studies Bell *et al.,* (1987) concluded that ornate rock lobsters on the NE Queensland coast do not participate in the annual breeding emigration out of Torres Strait. However, the patterns and timing of breeding emigrations on the NE Queensland coast remain largely unknown, principally because of the depth adjacent to the fishing grounds that are likely to support breeding populations, which precludes diving research. Whether lobsters migrate in successive years is also unknown, but is likely given the large size attained on the NE Queensland coast compared to Torres Strait, where breeding emigrations are one-way. Evidence suggests that off-shore juvenile movements occur during Autumn (March/April) but the reasons for these movements are unknown. However, extensive research on juvenile *P. argus* in Florida, USA suggests that such ontogenetic habitat shifts are heavily influenced by conspecifics (Childress and Herrnkind, 2001), and it may be depleted food and shelter availability on the near-shore NE Queensland coast that forces juvenile lobsters off-shore.

The key information gap remaining is the movement of adult lobsters to and from deep water adjacent to the commercial fishing grounds. These movements were not addressed by Bell *et al*, (1987) because both scientific divers and commercial fishers are not able to operate in deep water (>30 m) for extended periods. Documenting these movements to and from deep water is important for informed management because it determines when, where and for how long lobsters become inaccessible to the commercial fishery. It is possible some movements to deep-water, possibly breeding migrations, are one-way.
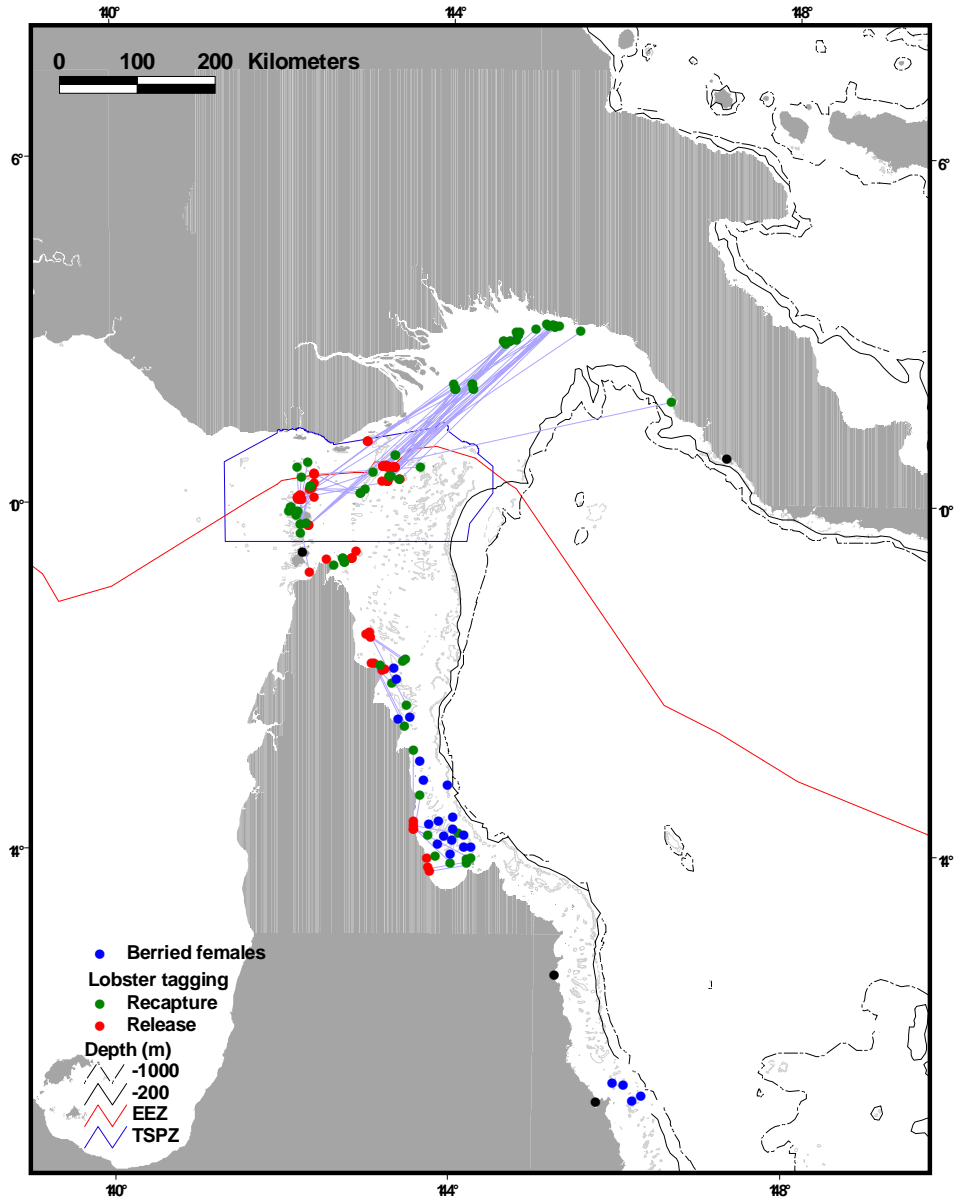
Figure 6-10.   **Map of north Queensland and southern PNG showing movements of ornate rock lobsters *Panulirus ornatus* and locations of berried female lobsters recorded during tag-recapture studies between 1980-1984 (redrawn from Bell *et al.,* 1987).**
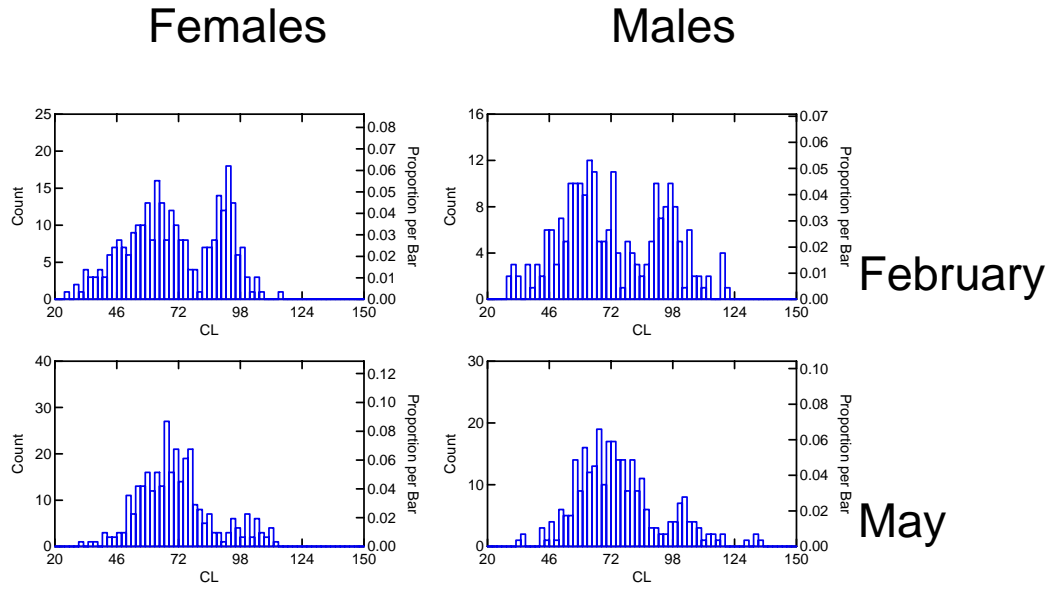
Figure 6-11. Size frequency distributions of male and female *Panulirus ornatus* sampled at Frenchman Reef (13^{0}43'S, 143^{0}33'E) on the NE Queensland coast in February and May 1980. Redrawn from Bell *et al.,* (1987)
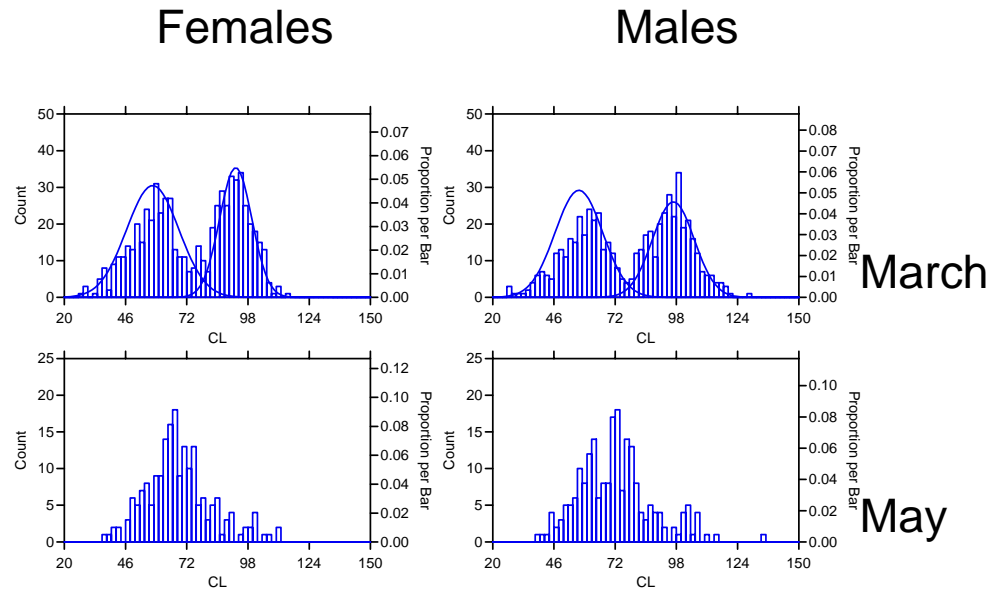
Figure 6-12. Size frequency distributions of male and female *Panulirus ornatus* sampled at Roberts Point (13^{0}52'S, 143^{0}35'E) on the NE Queensland coast in March and May 1980. Redrawn from Bell *et al.,* (1987). Normal curves show the size ranges of the component age classes.

6.3.4   Age structure analyses

6.3.4.1   Timing of settlement

For an accurate determination of size at age for *Panulirus ornatus* it is essential that both of these variables are estimated at initial settlement (t_0 in the von Bertalanffy curve, Fabens 1965). As the age of a spiny lobster at settlement can't be accurately determined from a morphological feature, such as scales and otoliths in fish, age must be inferred from the timing of settlement and hatching.

Despite rigorous attempts by CSIRO to collect recruiting ornate rock lobsters *Panulirus ornatus* using artificial collectors on the NE Queensland coast during 1980-1982 (CSIRO unpublished data), very few newly-settled lobsters have been caught and hence settlement timing is largely unknown. However, settlement timing was determined at Cairns, Queensland by divers monitoring lobsters settling onto wharf piles during 1981-1985. Peak settlement occurred during winter (June-August) in most years (Figure 6-13). However, when the data is averaged over all years the seasonality of settlement is shown to be highly variable, peaking between April and September.
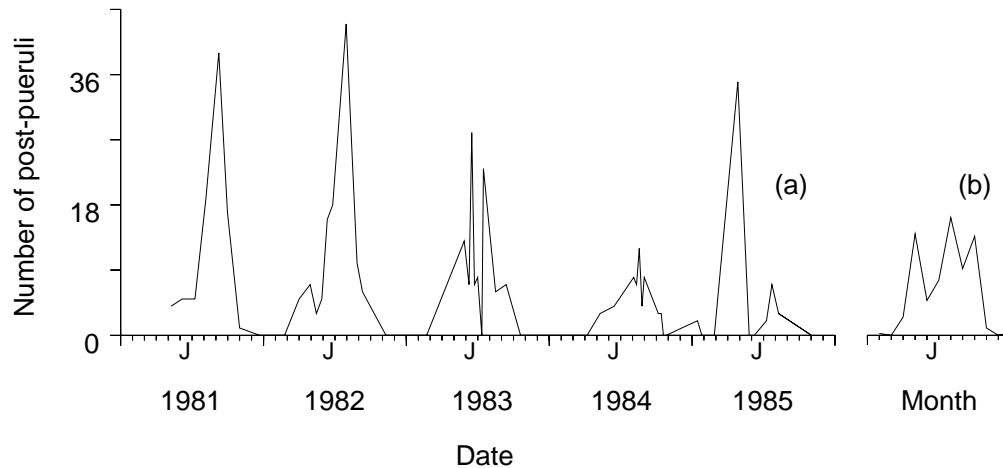
Figure 6-13.   Timing of settlement of ornate rock lobsters *Panulirus ornatus* on wharf piles in Cairns harbour, Australia during (a) 1981-1985 and (b) averaged over all years.

As was the case on the NE Queensland coast, attempts to collect recruiting lobsters in Torres Strait using artificial surface collectors (eg. Phillips, Lewis and Booth type designs) during 1992-1993 were largely unsuccessful (CSIRO unpublished data). Concurrent studies suggested that the failure of the collectors was mainly due to consistently low densities of recruits, combined with the high relative availability of suitable seabed habitats. Intensive searches of seabed transects in Torres Strait by CSIRO divers in 1992/93 showed that the density of newly-settled lobsters in natural habitat is very low (63 ha^{-1}, Dennis *et al.,* 1997). Further, pueruli must traverse ~100 km of shelf habitat in Torres Strait prior to settling in suitable juvenile habitat, and it is likely attrition is high during this journey.

6.3.4.2   Inshore "Sub-adult" Populations

The size distributions of lobsters collected on the shallow inshore reefs on the NE Queensland coast during tagging studies by CSIRO in 1980 were comprised almost entirely of two modes (Figure 6-14). Similarly the size distributions of sub-adult lobsters collected during annual surveys of the Torres Strait population are comprised of two modes representing 1+ and 2+ year old lobsters (Ye *et al.,* 2004).

In contrast to the size distributions for commercial catches taken on the Queensland mid-reefs, the majority of near-shore lobsters were smaller than 120 mm CL. Component analyses of these populations clearly resolved the two modes between February and April, with less certainty for the population sampled in May (Table 3). The mean sizes of 1+ and 2+ lobsters in May were similar to estimated mean sizes for the same year-classes sampled in May/June in Torres Strait by CSIRO during 1989 to 2003 (Figure 6-15). Both the inshore NE Queensland coast and Torres Strait populations are comprised entirely of sub-adult lobsters. 2+ year old lobsters on the NE Queensland coast move off-shore to "adult" habitat and in Torres Strait this year-class emigrates during spring as far as the eastern Gulf of Papua (Moor & MacFarlane, 1984).
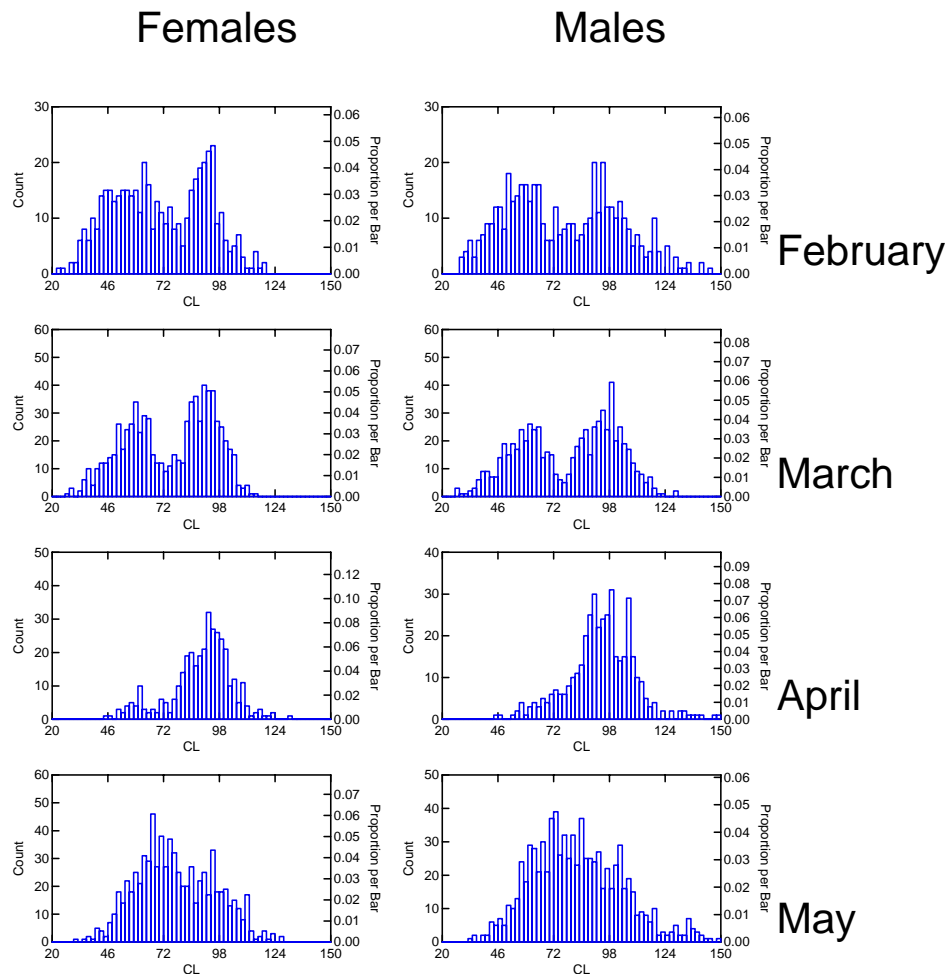
Figure 6-14.   Size-frequency distributions of ornate rock lobsters *Panulirus ornatus* sampled by research divers during tag-recapture studies on the NE Queensland coast between February and May 1980.

Table 3. **Estimated ages, proportions of the populations and mean sizes of ornate rock lobsters *Panulirus ornatus* collected on the NE Queensland coast during tagging studies by CSIRO in 1980, from component analysis (Mix; MacDonald and Pitcher, 1979). Figures in brackets are standard errors.**

		Age Group (Years)		
Month		1	2	3
February	Proportion (%)	45.9 (3.6)	54.1 (3.6)	
	Mean CL (mm)	51.9 (1.1)	90.9 (1.6)	
March	Proportion (%)	46.6 (1.7)	53.4 (1.7)	
	Mean CL (mm)	56.6 (0.6)	93.5 (0.5)	
April	Proportion (%)	7.7 (1.4)	92.3 (1.5)	
	Mean CL (mm)	58.9 (1.5)	94.1 (0.6)	
May	Proportion (%)	65.0 (6.2)	32.5 (6.7)	2.5 (1.0)
	Mean CL (mm)	69.1 (1.6)	97.9 (2.1)	131.7 (4.4)
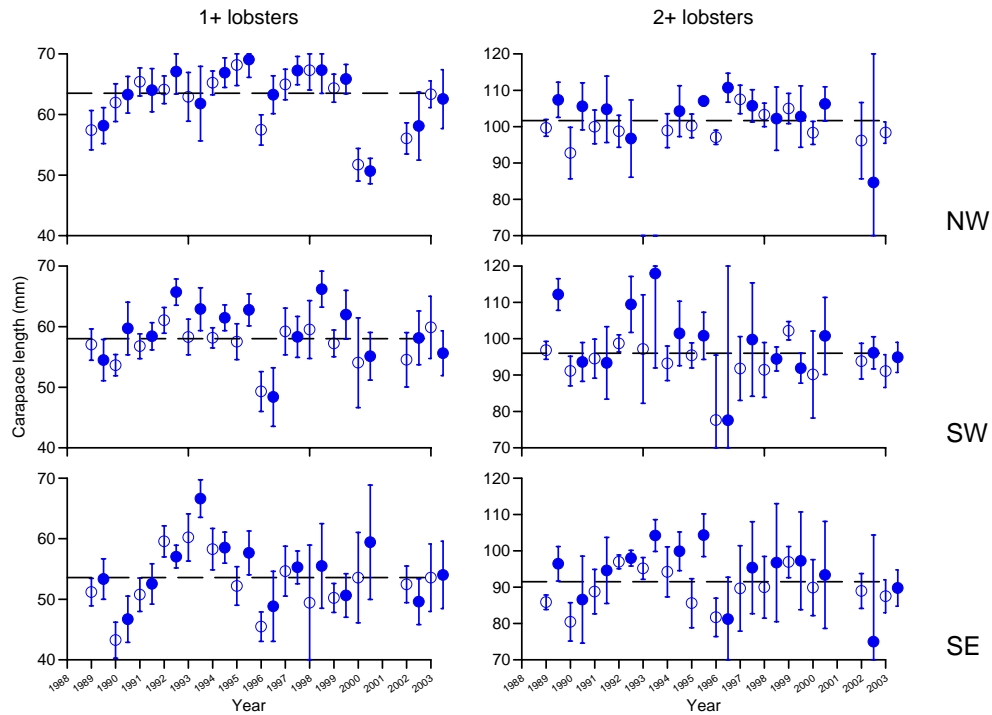
Figure 6-15. **Mean sizes of male (circles) and female (filled circles) 1+ and 2+ year old lobsters sampled during May/June in three quadrants of the Torres Strait fishery between 1989 and 2003. Error bars are standard errors. Dashed lines indicate the 15 year averages. From Ye *et al.,* 2004.**

6.3.4.3   Mid-shelf "Adult" Populations

A total of 8023 lobsters were measured from commercial catches taken on the NE Queensland mid-shelf reefs during the voluntary data collection program, including data collected by the QDPI observers. The size distributions of commercial lobster catches taken by the Queensland lobster fishery between July 2001 and July 2003 (Figure 6-16, Figure 6-17, Figure 6-18) indicated that the population was comprised of several year-classes, in contrast to the Torres Strait population, which is comprised of only two due to annual breeding emigrations of large lobsters. The voluntary size data, including data collected during observer trips, ranged from 32 to 187 mm CL for females and 34 to 195 mm CL for males, but small lobsters were returned live after measuring. Only lobsters greater than 60 mm CL and less than 180 mm CL are displayed here.

Male lobsters were consistently and significantly larger than female lobsters in all months suggesting males attain greater age (as discussed below). There was no truncation of the size distributions to suggest depletion of large lobsters due to fishing. However, there were less larger lobsters taken by the fishery in 2003 compared to 2001 or 2002. This may have been due to differences in areas fished between years as discussed in sub-project 3.

Voluntary collection of size data in 2001 and 2002 allowed an assessment of the impact of the minimum size limit, introduced at the end of the 2002 fishing season (September). Of the lobsters measured prior to October 2002 only 9% (447/4952) were smaller than the size limit (90 mm CL or 115 mm tail length). However, small lobsters were measured opportunistically during the observer trips to extend the size range, and these lobsters would not normally be taken. When this data is excluded the percent under 90 mm CL is reduced to 8% (321/4116). These low fractions of small lobsters suggest that fishers were already selecting for larger lobsters, prior to implementation of the size limit, and this was corroborated by commercial fishers. Targeting of larger lobsters is also promoted by the increased value per kilo for large size grades. Hence, the introduction of the size limit was both effective in conserving small lobsters and did not significantly impact catch rates of the fishery.

The age compositions of the commercial catches could not be resolved with certainty as component modes in the monthly size distributions were difficult to separate by eye or using modal analysis (Mix version 3.0; Figure 6-16, Figure 6-17, Figure 6-18). The majority of the commercial catch (85%) ranged in size between 90 and 140 mm CL and the calculated growth curve for *P. ornatus* from tag-recapture and aquarium data (Figure 6-19; Phillips *et al.,* 1992, Skewes *et al.,* 1997) indicates a corresponding age range of 2.5 to 6 years post-hatching. However, there is considerable error around the estimated growth curve for larger lobsters due to individual variation and a paucity of tag-recapture or aquarium data, and the age estimates may be inaccurate.
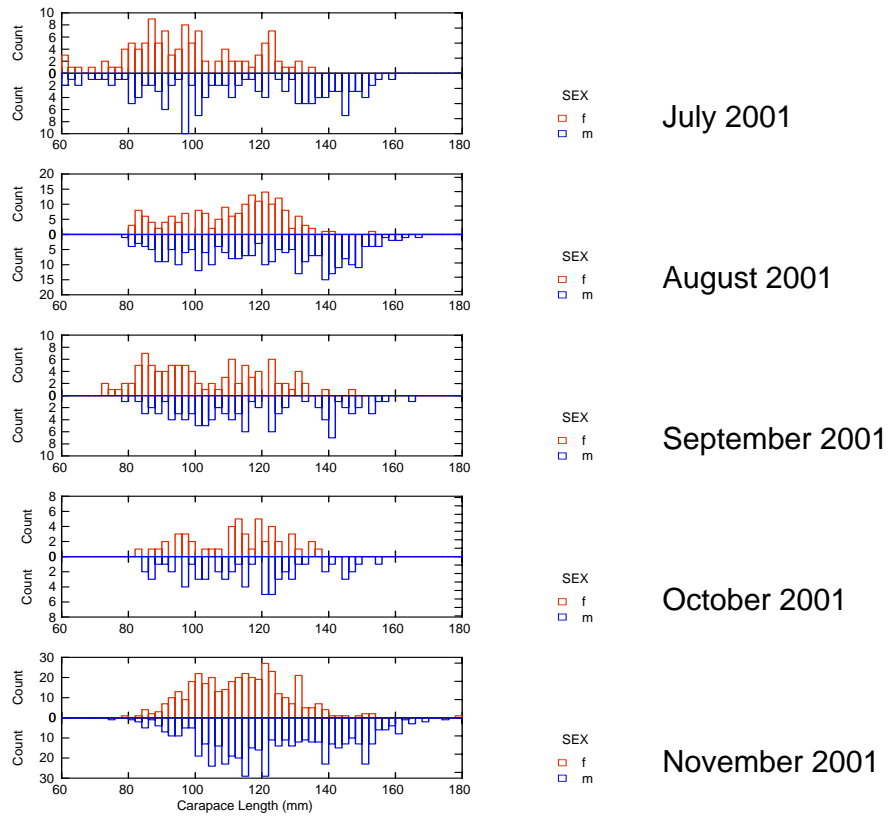
Figure 6-16. **Size-frequency distributions of *Panulirus ornatus* from commercial catches taken on the NE Queensland coast in 2001.**
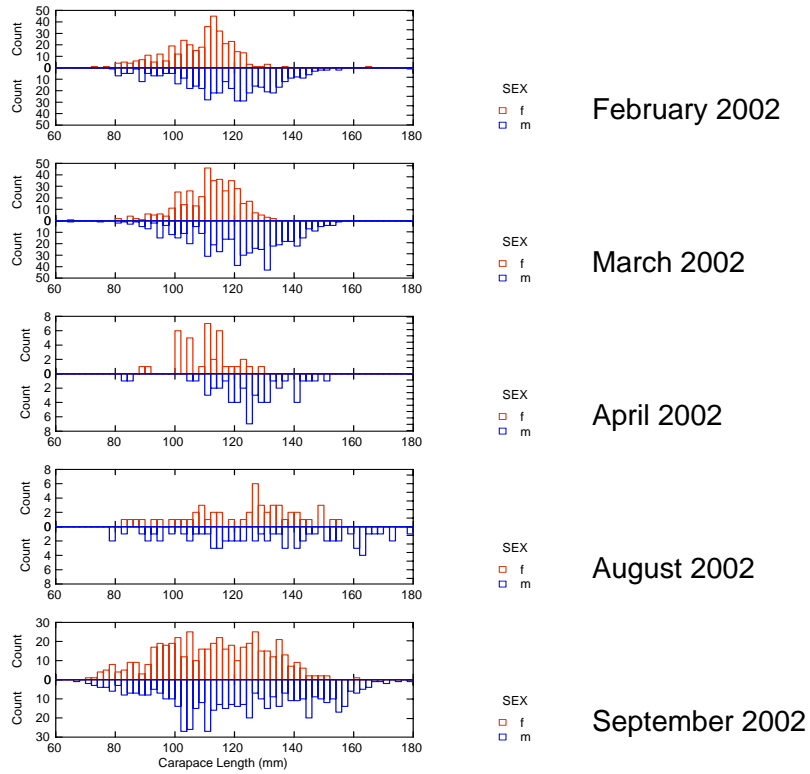
Figure 6-17. **Size-frequency distributions of *Panulirus ornatus* from commercial catches taken on the NE Queensland coast in 2002.**
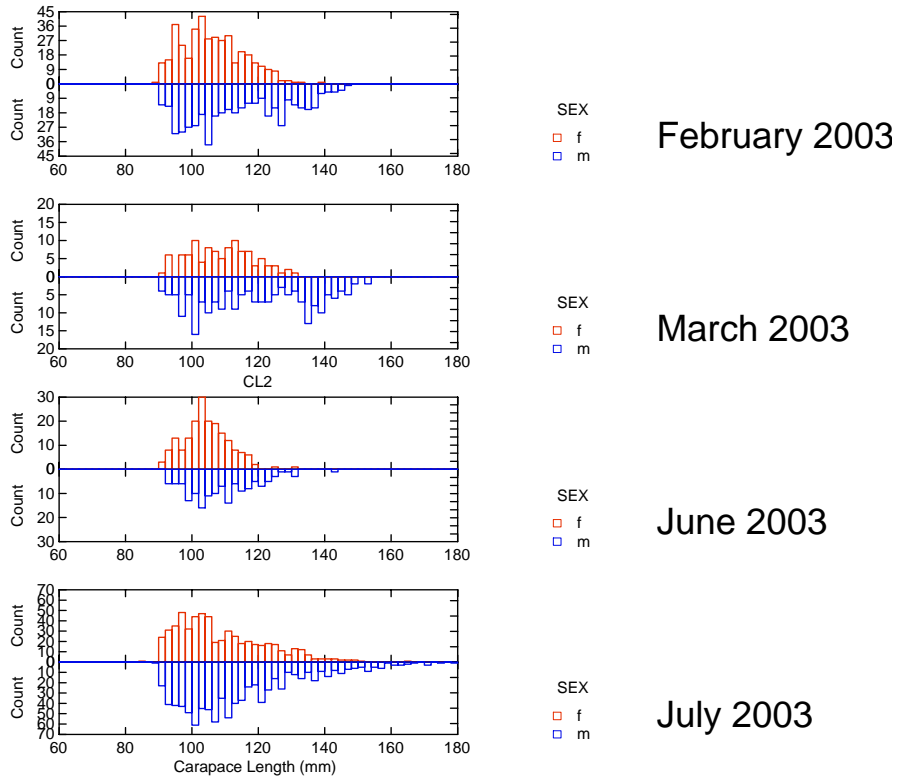
Figure 6-18. Size-frequency distributions of *Panulirus ornatus* from commercial catches taken on the NE Queensland coast in 2003
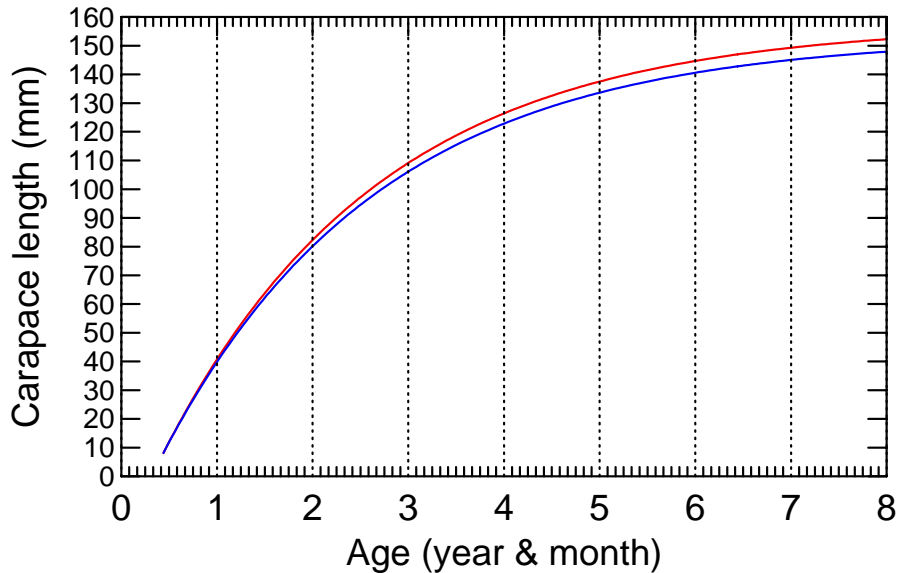
Figure 6-19. Von bertalanffy growth curves for male (solid line) and female (dotted line) ornate rock lobsters *Panulirus ornatus* from tag-recaptures on the Queensland coast (Phillips *et al.,* 1992; Skewes *et al.,* 1997).

The large number of size measurements taken by QDPI observer Jo Atfield in September 2002 permitted a simple analysis of age composition using modal analysis (Mix ver 3.0; MacDonald and Pitcher, 1979). Only the female size distribution (Figure 6-7) allowed a reasonable estimation (p=0.2215) of the modal composition of the population. Five modes were resolved corresponding with 2 to 7 year old age-classes (Table 1). Although the corresponding male lobster size distribution could not be resolved their greater maximum size suggests males attain at least 8 years of age, assuming similar growth rates for males and females.

The monthly size distributions were generally unsuitable for accurate estimation of age composition and this was, in part, due to the small numbers recorded in some months. The poor resolution of age modes may also be due to large individual growth variation and wide ranging settlement timing. Nevertheless, the intensive sampling of catch during September 2002 by a QDPI observer yielded a size distribution that could be analysed and similar sampling should be conducted in the future studies.

Table 4. **Estimated ages, proportions of the catch and mean sizes of female ornate rock lobsters *Panulirus ornatus* caught by the Queensland lobster fishery in September 2002 from modal analysis of the size distribution. Figures in brackets are standard errors.**

Age (yrs)	2	3	4	5	6&7
Proportion of the catch (%)	8.3 (3.8)	24.6 (7.6)	29.2 (4.2)	30.6 (4.4)	7.3 (4.9)
Mean CL (mm)	82.5 (2.9)	98.5 (1.4)	114.5 (2.1)	129.9 (1.9)	141.1 (3.3)

6.3.5 *Morphometric conversion ratios*

Morphometric data collected during research studies in Torres Strait and during laboratory experiments at the CSIRO Cleveland Marine Laboratories were used to establish conversion ratios for the commonly measured characters of the ornate rock lobster (Table 5). Where lobsters were weighed during voluntary size data collection the weights were converted to carapace length using the estimated conversion ratio. This conversion is strictly only applicable for lobsters less than 150 mm carapace length and it was anticipated that concurrent CL/weight measurements would be recorded during this study to ensure the conversion was accurate for all sizes. However, this data could not be obtained. The conversion ratio for tail weight versus total weight is used by both AFMA (Torres Strait) and DPI&F (Queensland lobster) to standardise commercial catch totals from tail weights and total weights reported in logbooks.

Table 5. **Morphometric relationships between several commonly measured characters of the ornate rock lobster *Panulirus ornatus*. R^2 indicates the regression coefficient. CL= carapace length, dorsally from the mid-point of the supra-orbital spines to the posterior mid-margin of the carapace (mm); TW = tail width, across ventral surface of the 2nd abdominal somite (mm); TL = tail length, from anterior middle of first abdominal somite to posterior middle of last abdominal somite (mm); TOTWT = total weight (grams); TAILWT = weight of removed tail (grams). TAILWT is approximately 42% of TOTWT.**

Sex	Relation	Relationship	Range	R^2
M	TW/CL	CL=(1.493×TW)-0.132	CL:6-160	0.998
F	TW/CL	CL=(1.371×TW)+2.485	CL:6-160	0.997
All	TW/CL	CL=(1.433×TW)+1.089	CL:6-160	0.992
All	TW/TL	TL=(1.920×TW)+1.413	TW:6-80	0.996

Sex	Relation	Relationship	Range	R^2
All	CL/TL	CL=(0.778×TL)+0.014	CL:6-140	0.994
All	TW/TAILWT	TAILWT=0.00114×(TW$^{2.97537}$)	TW:22-98	0.974
All	CL/TOTWT	TOTWT=0.00258×(CL$^{2.76014}$)	CL:6-150	0.992
All	CL/TAILWT	TAILWT=0.00097×(CL$^{2.77007}$)	CL:30-150	0.954
All	TOTWT/TAILWT	TOTWT=2.385*TAILWT	TOTWT<3KG	0.991

6.4 Conclusions

Historical information on the geographic extents of adult, juvenile and larval lobster populations, timing and locations of breeding and population size and age structure from CSIRO and PNG research programs was collated and mapped to evaluate our current understanding of the biology of the ornate rock lobster *Panulirus ornatus* on the NE Queensland coast. This information was supplemented by voluntary recording of lobster size and breeding status from commercial catches during 2001-2003, by fishers and QDPI observers.

The geographic extent of adult ornate rock lobsters *Panulirus ornatus* on the NE Queensland coast is known from commercial fisher records and historical diver surveys and little is known of the size and extent of lobster populations in deep (> 30 m) habitats. Adult lobsters occur throughout the latitudinal range of the Queensland lobster fishery (~11-14^{0}S) and the preference for commercial fishing grounds around 12^{0}S (Margaret & Temple Bays) indicates lobsters are more abundant there. Ornate rock lobsters are the dominant spiny lobster on the inshore and mid-shelf reefs on the NE Queensland coast.

Although trials of artificial collectors in Queensland waters have been largely unsuccessful, the geographic extent of juvenile or newly-settled ornate rock lobsters is known from the limited historical catches on collectors deployed at inshore locations. Juvenile lobsters were caught throughout the Queensland lobster fishery indicating that settlement and nursery grounds coincide with the extent of adult habitat. The age structure of the inshore populations indicates that the inshore reefs act as nursery habitat prior to offshore movement of sub-adult lobsters.

The distribution of larval and post-larval ornate rock lobsters in the adjacent Coral Sea is known from plankton catches made during May 1997. Ornate rock lobster larvae dominate the spiny lobster populations in the Coral Sea, comprised of *P. femoristriga*, *P. penicilattus*, *P. versicolor* and *P. polyphagus.* Most ornate rock lobster pueruli were collected on the shelf break adjacent to the Queensland fishery and further south but this distribution may have been atypical due to the presence of a Tropical Cyclone in 1997. The pueruli collected on the outer GBR would have been between 3.5 and 6 months old.

The geographic extent of breeding grounds of the ornate rock lobster on the NE Queensland coast is known from historical diver surveys and voluntary records provided by commercial lobster fishers. Berried females occur throughout the range of the Queensland fishery and north to the far northern GBR and south to Cairns. However, deepwater breeding has also been recorded off Murray Island (10^{0}S) and Townsville (19^{0}S). The vast majority of records of breeding lobsters have come from shallow habitats accessible to divers and the size and extent of breeding populations in waters inaccessible to divers (>30 m), is largely unknown due to the logistical difficulties in surveying these areas.

Only 5% (165/3169) of female lobsters caught and measured by commercial fishers between 21 July 2001 and 19 July 2003 carried a spermatophoric mass (157) or eggs (8), and the majority

(80%) were recorded during November 2001. No berried female lobsters were recorded during the 2002/03 fishing season due to the implementation of the seasonal closure (October-January) in 2002.

The timing of breeding for ornate rock lobsters on the NE Queensland coast is known from observations during historical diver surveys and the voluntary records of commercial fishers. Mating likely occurs during October/November with subsequent tarspot deposition. Berried females occur on the shallow reefs during January to March, but the low numbers of berried females recorded during this study and historically strongly suggests most hatching occurs in deep water inaccessible to divers.

A simple analysis of the relative egg production suggested that the fishery may benefit from a maximum size limit to conserve egg production. By example, in September 2002 female lobsters larger than 140 mm CL contributed 6% by number and 9% to egg production. It was impossible to determine if the reproductive output of the current population has been decreased through depletion of large lobsters since there is no baseline age structure information available.

Migrations and small-scale movements of ornate rock lobsters on the NE Queensland coast are known exclusively from previous studies by Bell *et al.,* (1987). Of 9632 ornate rock lobsters tagged only 245 (2.5%) were recaptured, and only 24 of these 245 recaptures indicated significant (4 km) movement away from the tagging site. These results suggested that most of the population shows high fidelity within a reef system. In contrast to the extensive migrations undertaken by Torres Strait lobsters, lobsters on the NE Queensland coast moved only small distances from their original locations, and mostly off-shore. Further information on the off-shore movements was gained from temporal changes in size distributions of near-shore populations. Small sub-adult lobsters (~95 mm CL) moved from the inshore reefs during March/April, and incidental prawn trawl catches corroborated this timing. Bell *et al.,* (1987) concluded that these lobsters had moved off-shore from their inshore juvenile habitat, as similar movements have been documented for other spiny lobsters.

Timing of settlement of ornate rock lobster on the NE Queensland coast is known from historical monitoring of settlement onto wharf piles in Cairns. Peak settlement occurred during winter (June-August) in most years, but the seasonality of settlement was highly variable.

The age structure of the ornate rock lobster population on the NE Queensland coast is known from historical dive surveys and voluntary size data collected by fishers. The populations on the shallow inshore reefs were comprised almost entirely of two year-classes (1+ and 2+ years old) smaller than 120 mm CL, similar to populations in Torres Strait. In contrast, the populations on the mid-shelf reefs that are commercially fished were comprised of several year-classes, up to 8 years old. The monthly size distributions did not allow accurate resolution of age structure of the NE Queensland lobster population. Male lobsters were consistently and significantly larger than female lobsters in all months. Voluntary size data collected prior to the introduction of the 90 mm CL minimum size suggests that the fraction of lobsters taken below this limit was traditionally low (<10%).

6.4.1 Life History

The historical and current biological information on the life stages of the ornate rock lobster *P. ornatus* collated in this study allowed a brief summary of the life cycle of this species on the NE Queensland coast.

The life cycle of the ornate rock lobster begins in winter when the newly-settled lobster takes up a benthic existence on the inshore reefs after 4 - 7 months of planktonic life in the Coral Sea. Settlement timing varies substantially between years with peaks occurring between April and September. Settlement occurs across a wide geographic range, including the extent of the

Queensland lobster fishery. Newly-settled lobsters remain on the inshore reefs until they reach about 2.5 years of age and about 95 mm CL. During March/April these lobsters move offshore to "sub-adult" habitat, mainly on the mid-shelf reefs of the NE Queensland coast. Available information suggests that lobsters subsequently show high reef fidelity and remain within the same reef system.

The breeding season extends from October to March and all lobsters larger than the minimum size limit (90 mm CL) are capable of breeding, but the reproductive success of male lobsters is likely related to their size relative to prospective mates. Most mating and tarspot deposition appears to occur early in the breeding season but the peak timing of subsequent hatching remains unknown. Given, that the NE Queensland lobster population comprises at least 6 year-classes it is likely females reproduce several times throughout their life.

6.4.2 Information Gaps

The collated historical and current biological information on the NE Queensland *P. ornatus* population highlighted several key information gaps and one of the main objectives of this research was to clearly identify the gaps that preclude sustainable management of the Queensland lobster fishery. Whilst in general, little is known about all stages of the ornate rock lobster life cycle, from settlement to reproduction, there are several key areas that should be addressed. The size and extent of the breeding population is a key information gap for the Queensland lobster fishery and the adjacent Torres Strait fisheries in development of an understanding of the stock/recruitment relationship for this shared stock. Relevant to documenting the size and extent of the breeding population is the lack of information on the movements of lobsters to and from deep water (>30 m), adjacent to the commercial fishing grounds. The relative strength of fishery-recruit year-classes is impossible to determine from logbook data, but this information would be useful to managers in forecasts of low stocks and separating environmental influences from impact of the fishery. The timing, distribution and relative strength of settlement on the NE Queensland coast would provide even earlier forecasts of likely future recruitment.

6.5   References

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7   SUB-PROJECT 2: LARVAL TRANSPORT MODELLING

7.1   Objectives

- Develop an oceanographic model of the mesoscale circulation in the NW Coral Sea.
- Determine trajectories of larvae released by the NE Queensland lobster population and assess the fate of these larvae.
- Determine the potential boundaries of the source and sink populations.
- Identify and prioritise future oceanographic research to assist sustainable management

7.2   Methods

This sub-project is essentially a re-application of one of the modelling methods developed during FRDC 97-139 by Griffin *et al.,* (2001b) for investigating the ocean dispersal of larvae of the Western Rock Lobster. We will therefore only briefly summarise the methods used and refer the reader to Griffin *et al.,* (2001) for further details.

7.2.1   *Ocean model*

We have used a mixture of ocean modelling approaches in order to simulate the circulation of the Coral Sea, just like Griffin *et al.,* (2001) did for the east Indian Ocean. Hence, instead of attempting to construct a hydrodynamic model, for example, that accurately represents the total velocity field, we have chosen to express the total velocity as a sum of separate components, each of which was estimated independently. The primary motive for doing this was to ensure that the meso-scale (tens to hundreds of km) circulation of the open ocean was modelled accurately by using the observations of sea-level anomaly made by satellites. The meso-scale circulation is what primarily determines the transport pathways over the distances of importance to this study, but modelling it accurately using hydrodynamic modelling was well beyond the scope of this study.

More specifically, we modelled the flow as the sum of four components:

1. weekly- to annually-varying velocities of scale large enough, i.e. greater than about 40km, to be recorded by satellites measuring sea level by altimetry. This component was estimated by making maps, on a 0.25 degree (latitude and longitude) grid, of sea-level at intervals of 5 days, using all available data from coastal tide gauges and the ERS-1, ERS-2 and Topex/Poseidon satellite altimeters. Cyclostrophic velocities were then estimated from the gradients of sea level following Griffin *et al.,* (2001). These fields differ slightly from geostrophic velocities by including the effects of the non-linear and friction terms in the diagnostic momentum equations, thereby capturing the asymmetries between cyclonic and anti-cyclonic eddies. Of importance to this study is that these fields are slightly convergent in cyclonic eddies, in agreement with the observation that drifting buoys tend to be captured by cyclonic eddies.
2. the time-mean of the ocean circulation. This component needs to be estimated independently from the first until a sufficiently accurate map of the geoid is available. We used two estimates of the mean circulation; one derived from the CSIRO Atlas of Regional Seas (CARS2000) of Ridgway and Dunn (2003) and another from the CSIRO global circulation model ACOM3.1 of Schiller (2004). The advantage of the former is that it is based entirely on observations, while its disadvantage for the present application is that we need current velocities rather than temperature and salinity. It is acceptable practice to estimate geostrophic velocities from temperature and salinity in the deep ocean, but much less so in the

vicinity of coastal boundaries, where geostrophy is less applicable. The geostrophic velocity fields will inevitably run into the coast at places and corrections need to be made before they can be used for tracking the motion of larvae. Fortunately, the ACOM3.1 model agrees very well with the CARS observations in our study region, so we have chosen to use its velocity fields in preference to those derived from CARS. We will only show results of experiments using the ACOM3.1 mean field, which is shown here (two of the three layers used) in Figure 7-1 and Figure 7-2. Being only an 'eddy permitting' model, ACOM3.1 does not fully resolve boundary layer structure, so the Hiri current, which runs along the southern coast of New Guinea (Burrage, 1993) is represented somewhat broader and farther offshore than it really is. Nevertheless, the main features of the South Equatorial Current bifurcating to form the Coral Sea Gyre and Hiri Current system to the north, and the East Australian Current to the south, are well represented.

3. near-surface, wind-driven flows that are too transient to be manifest as perturbations of sea-level. This component is not completely separable from either of the above, so some double-counting of the effects of winds is possible, although we think that compared with other model errors, this is unlikely to be a major problem. For this component we simply integrated the time-dependent depth-averaged Ekman layer equations using estimates of the wind stress from the NCEP/NCAR 40-year Reanalysis (Kalnay *et al.,* 1996), a fixed Ekman layer thickness of 50m and a linear interfacial friction coefficient of 0.0002 m/s. Importantly, an additional near-surface wind drift was estimated as being 1% of the 12-hourly NCEP/NCAR 10m wind velocity estimates. For both the Ekman layer velocity and the near-surface velocity calculations, we first subtract the time-mean of the wind forcing to minimize double-counting the time-averaged response to wind forcing, which is already present in component 2.

4. unresolved random velocities. Recognizing that the sum of the above components still under-represents observed energy levels at the sub-mesocale, we added two random velocities of distinct decorrelation time- and space scales. The first is random (between +/- 0.05m/s) over 25km and 5 days, while the second is random (between +/-0.1m/s) at the locations of tracked particles, every 8 hours.

Figure 7-1. **Mean from 1993 to 2000 of the near-surface current velocity of the NW Coral Sea according to version 3.1 of the Australian Community Ocean Model. The contour interval for the surface elevation field is 0.05m.**
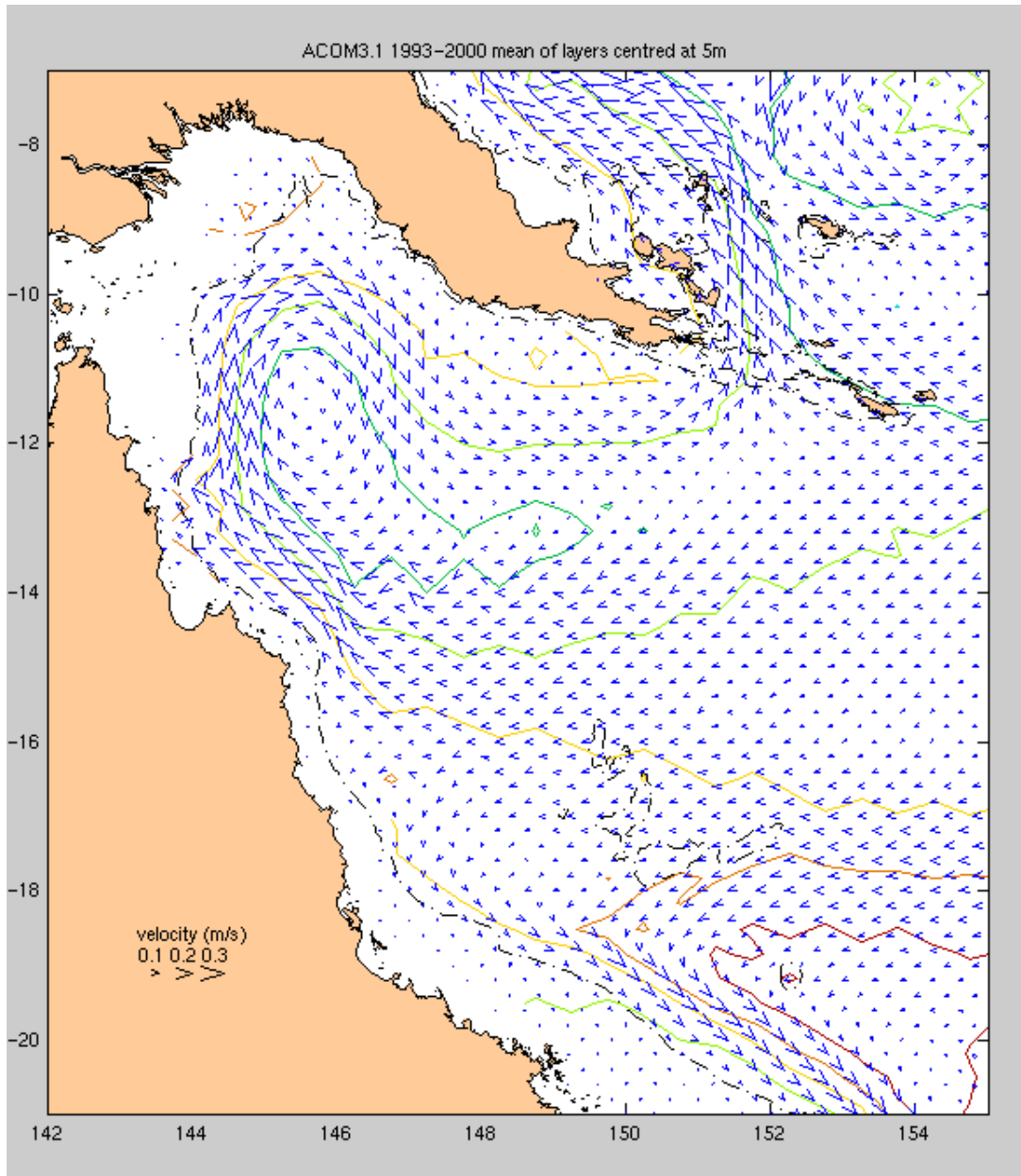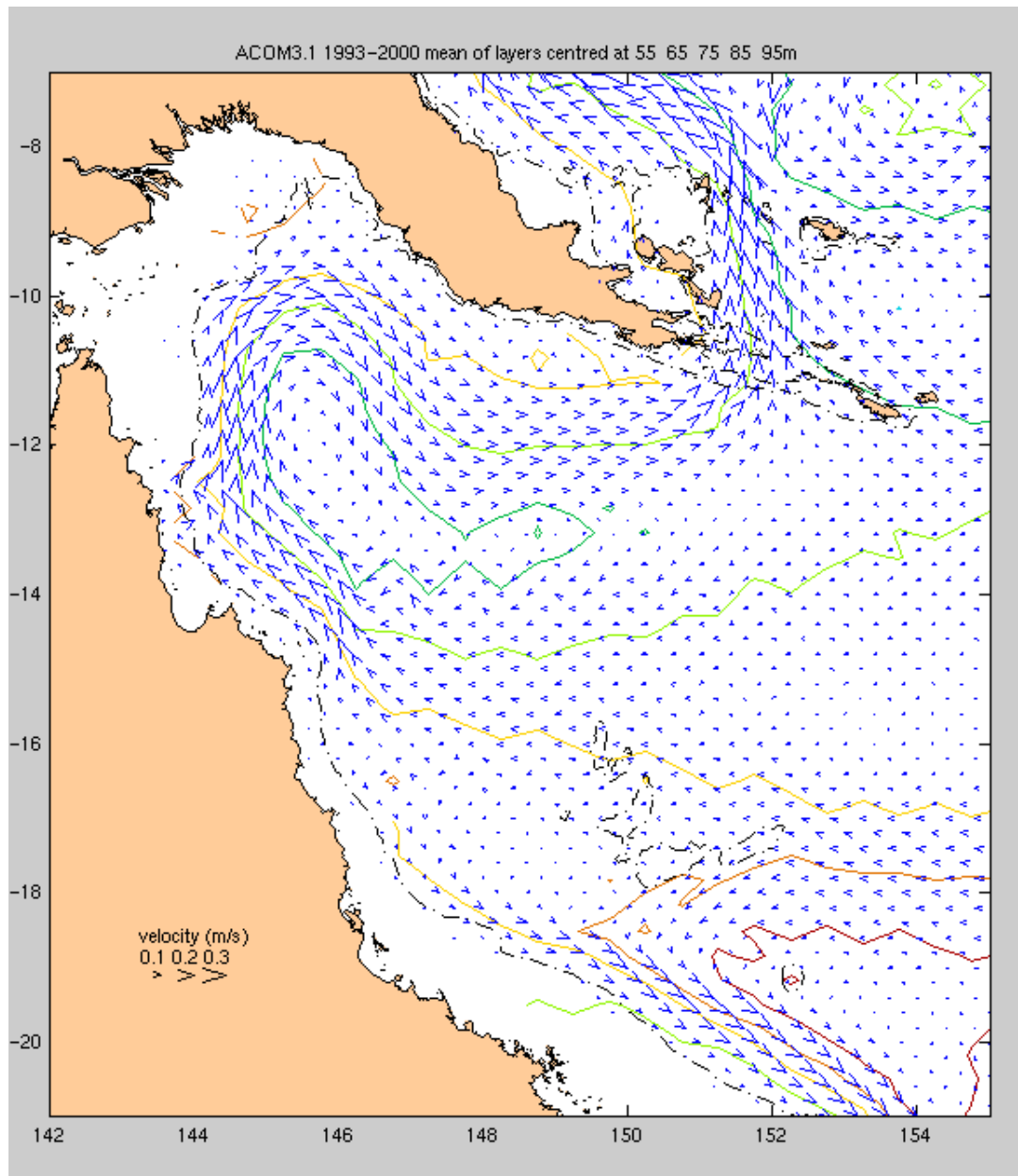
Figure 7-2. **Mean from 1993 to 2000 of the current velocity of the NW Coral Sea from 50 to 100m, according to ACOM3.1.**

7.2.2 Larval Transport Model

To model the advection processes operating on larval *P. ornatus*, we have used the individual-based, forward-stepping transport model of Griffin *et al.,* (2001), with minor improvements. The horizontal motion of model larvae is determined by interpolating the velocity fields (discussed above) at the position and depth of each larva, then using 4th-order Runge-Kutta integration to compute the larva's displacement over an eight-hour period. Being individual-based, it is relatively straightforward to implement rules that take the place of prognostic biological models controlling processes such as time and place of hatching, vertical swimming, mortality, growth, metamorphosis, and finally settlement of the puerulus. These are discussed below.

7.2.2.1 Hatching

Reproduction of *P. ornatus* is reviewed in section 6.3.2. Hatching occurs predominantly over a three-month period from late November (MacFarlane and Moore, 1986). We do not attempt to model the intra- or inter-seasonal variation of hatching, but simply release model phyllosoma at a constant rate from 21 November to 25 February. The larvae are released from the set of locations shown in Figure 7-3, which are spaced so that the total egg production varies as shown. This represents a simplification of what is known about the real distribution of egg production, and is intended only to represent the gross features, bearing in mind the fact that since the ocean model does not resolve the details of the currents over the continental shelf, the precise locations of the release points are of little consequence. In particular, we are not trying to reproduce the effect of the known spawning migration from the Torres Strait region to the Yule Island region, but assume there are equal numbers of egg production in both regions, partly as a 'what if' experiment and partly in recognition of the importance of spawning in the Murray Island region.
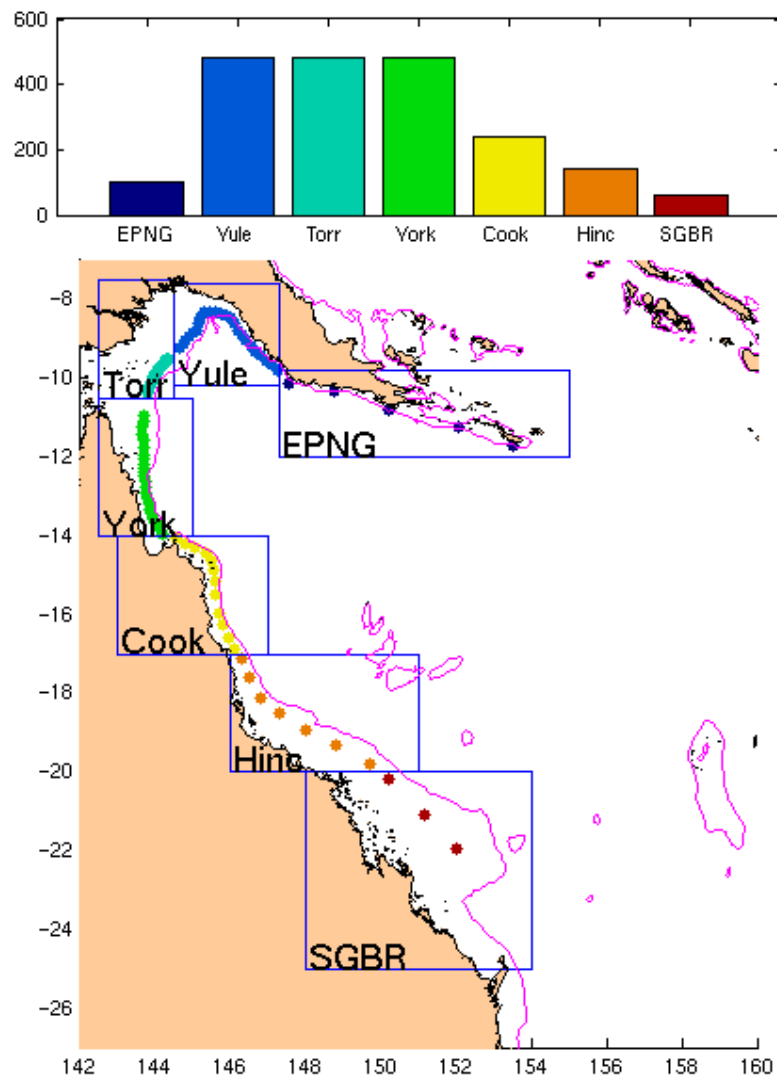
Figure 7-3. **Modelled relative intensities (top) and locations (bottom) of *P. ornatus* egg production within the NW Coral Sea.**

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7.2.2.2 Vertical Migration

Early-stage lobster larvae are competent swimmers but most of their swimming effort is believed to be directed at achieving a desired depth depending on the time of day (Rimmer and Phillips, 1979). Hence, we can model their horizontal transport simply by assuming they move at the velocity of the water at an appropriate depth depending on the time of day. As the larvae get bigger, the depth range of their diurnal excursions probably increases (Rimmer and Phillips, 1979). For *P. cygus*, there is evidence of a dependence on the state of the moon (and how rough the sea-state is), but neither exists for *P. ornatus*. Accordingly, we have applied Okham's razor to the vertical migration behaviour assumed by Griffin *et al.,* (2001) for *P. cygus*, and model vertical migration as shown in Figure 7-4. This is based on the fairly limited number (principally those of Dennis *et al.,* 2001) of existing observations of the vertical distribution of *P. ornatus* phyllosoma in the wild.
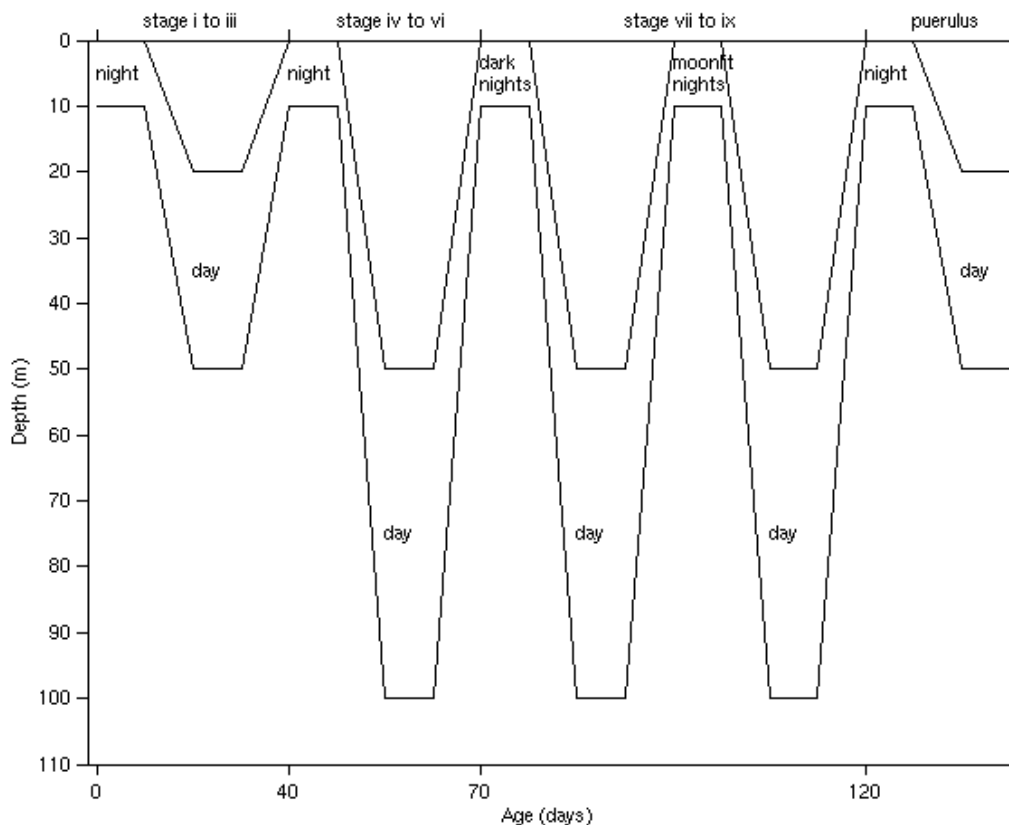
Figure 7-4. **Modelled vertical migration behaviour of *P. ornatus* larvae. When larvae are in the uppermost (0-10m) layer, their velocity is the sum of all velocity components described in the text. In the next deepest stratum (20-50m), the near-surface effect of the wind is omitted. In the deepest stratum, the Ekman layer component is also omitted.**

It is also possible that variations in the depth of the thermocline could affect vertical migration, but the available data are too few for general statements to be made. The same is true, to an even greater extent, for the vertical distribution of the prey items upon which the larvae are feeding.

7.2.2.3   *Growth, mortality, metamorphosis, swimming and settlement*

The real mortality rates (and how it varies by age, location, etc) are of course unknown, as are the triggers for metamophosis to the swimming, non-feeding puerulus stage. Figure 6-13 shows that at Cairns between 1981 and 1985, puerulus settlement occurred almost exclusively between April and October. In the model, we assume that once phyllosoma are at least 120 days old they can metamorphose to the puerulus if they find themselves in water less than 100m deep. Once metamorphosed, the model pueruli maintain a constant swimming speed of 0.1 m/s through the water, towards the nearest land. If they reach water less than 20 m deep within 30 days they are counted as settling but if adverse currents prevent that, they are assumed to die of exhaustion. This lower metamorphosis-age limit of 120 days sets an earliest possible settlement date of 20 March in the model. The upper limit is controlled, but less rigidly, by two assumed mortality rates: 0.003/day in the open ocean and 0.01/day in water less than 100 m. This is implemented using a random number generator the chosen probabilities of depth halve the deep ocean and continental shelf populations every 230 d and 70 d, respectively. The inclusion of these two mortality rates is the principal (and minor at that) change from the modelling used by Griffin *et al.,* (2001). The need for it will be discussed in relation to the results of the model.

7.3   Results

We have run the model for the years 1995-2000, tracking 2000 individuals for each year-class. Other years have also been run, but changes in the number of satellites operating make comparisons difficult. These six years provide enough comparison for the purposes of demonstration. We have also run the model many times with different parameter choices, and as part of the process of minimizing the artefacts of the model's approximations. It is beyond the scope of this pilot study to document the differences between these model runs. The lessons from those runs, of course, are embodied in this 'final' run, and the comments we will make on it.

The dispersal of the whole population of larvae within the NW Coral Sea, at intervals of two months, is shown in Figure 7-5 to Figure 7-10 , along with the wind-stress averaged over the previous month.
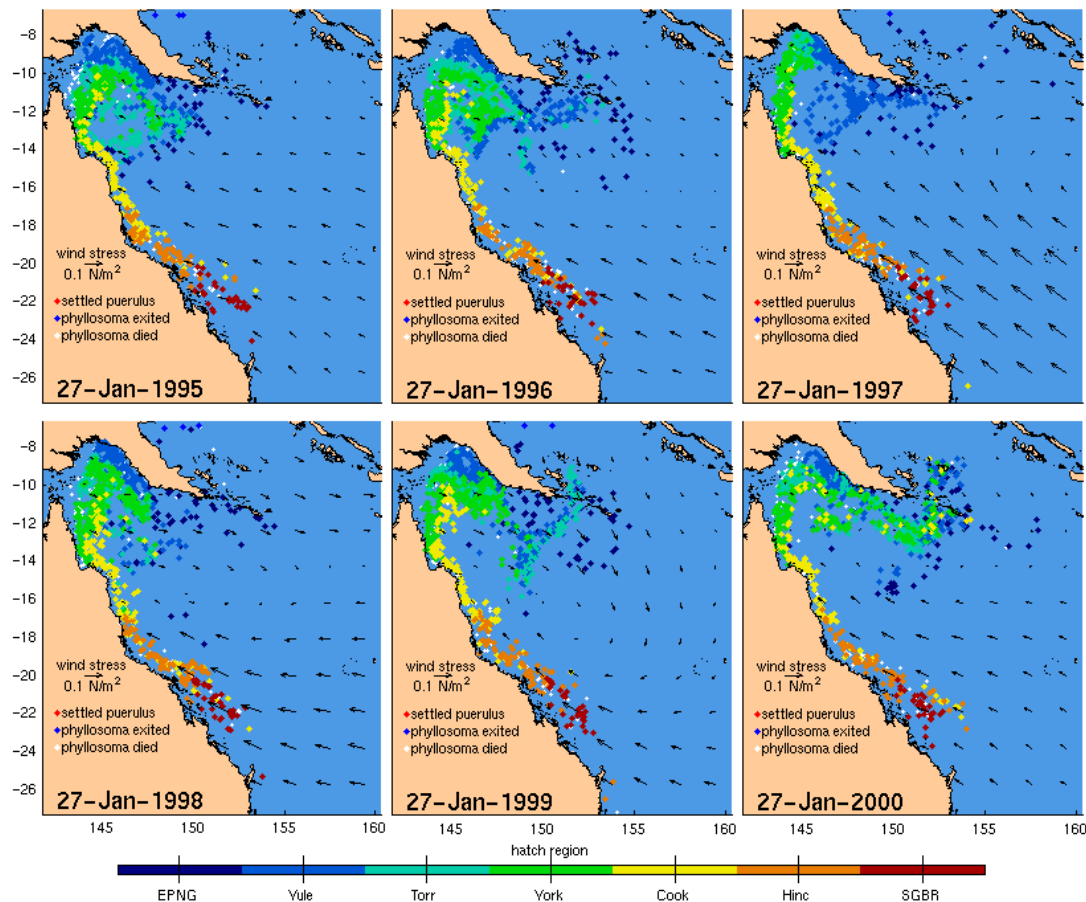
Figure 7-5. **Positions of individual model larvae in the Coral Sea on the dates shown, colour-coded by their place of origin if still alive, or coloured red if settled, white if dead or blue if exited the model domain. The wind-stress vectors are averages over the previous month.**

By 27 January (Figure 7-5), when 70% of the year-class has hatched, many larvae have already been carried a considerable distance from their place of origin. There has not yet, however, been much inter-mingling of the larvae that hatched from different regions. Significantly, few of these early-stage phyllosoma escape from the shelf waters south of about 12°S, because of the increased influence of the SE trades. The larvae in deep water south of that latitude originated from the shelf north of there.
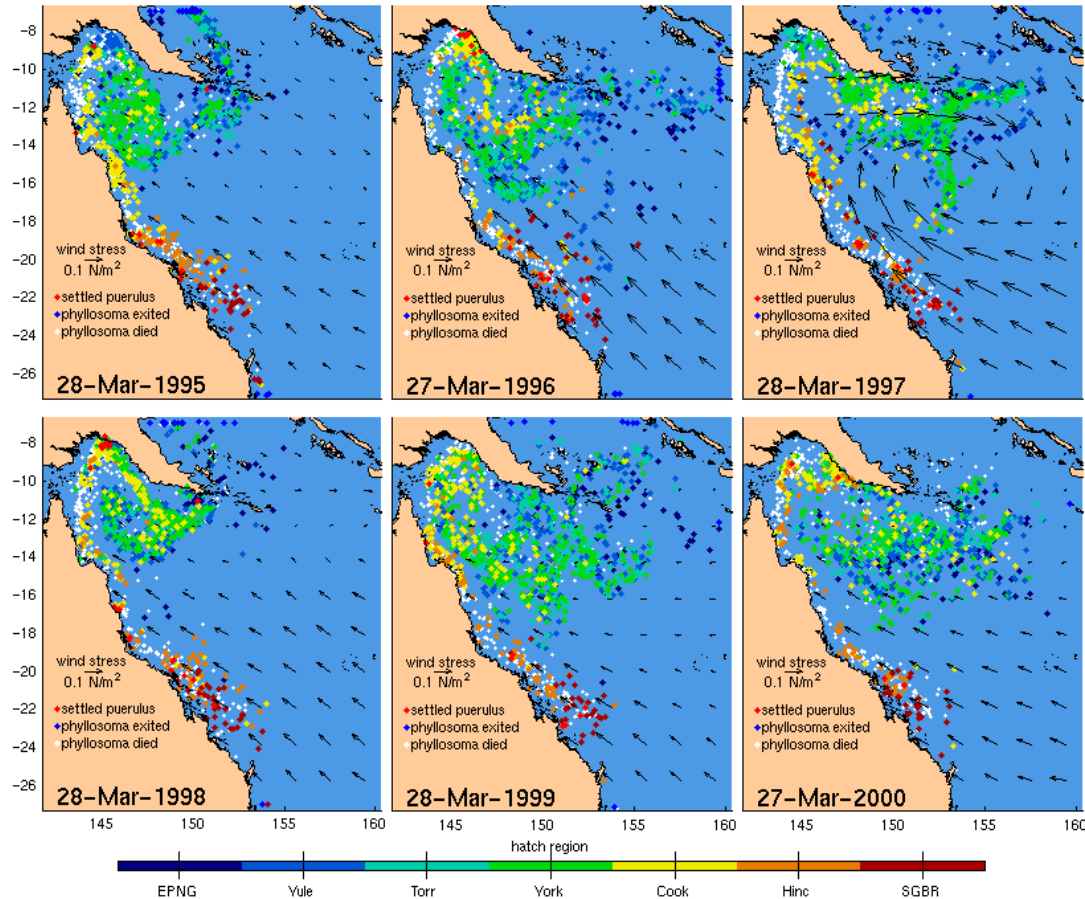
Figure 7-6. **Positions of individual model larvae in the Coral Sea on the 27th or 28th of March 1995 to 2000, colour-coded by their place of origin if still alive, or coloured red if settled, white if dead or blue if exited the model domain. The wind-stress vectors are averages over the previous month.**

By 28 March (Figure 7-6), a significant degree of mixing has occurred and in some years, many larvae have already exited the northern domain of the model. Some larvae that hatched at Yule Island are as far south as 21°S, while some larvae that hatched in the Hinchinbrook Island region are up near Yule Island. It remains the case that few larvae have left the shelf in the southern region, because the prevailing wind is still from the SE. Because of the assumed higher chance of predation (and in accord with observations that few phyllosoma are ever found in shelf waters), many of the model larvae in shelf waters are now 'dead'.

1997 stands out from the other years at this point because of Tropical Cyclone (TC) Justin, which was both strong and nearly stationary from the 3rd to the 14th of March. The group of larvae shown in the figure as being in the centre of the mean position of TC Justin are moving south rapidly at this time, on the eastern flank of the strong gyral circulation induced by the cyclone.
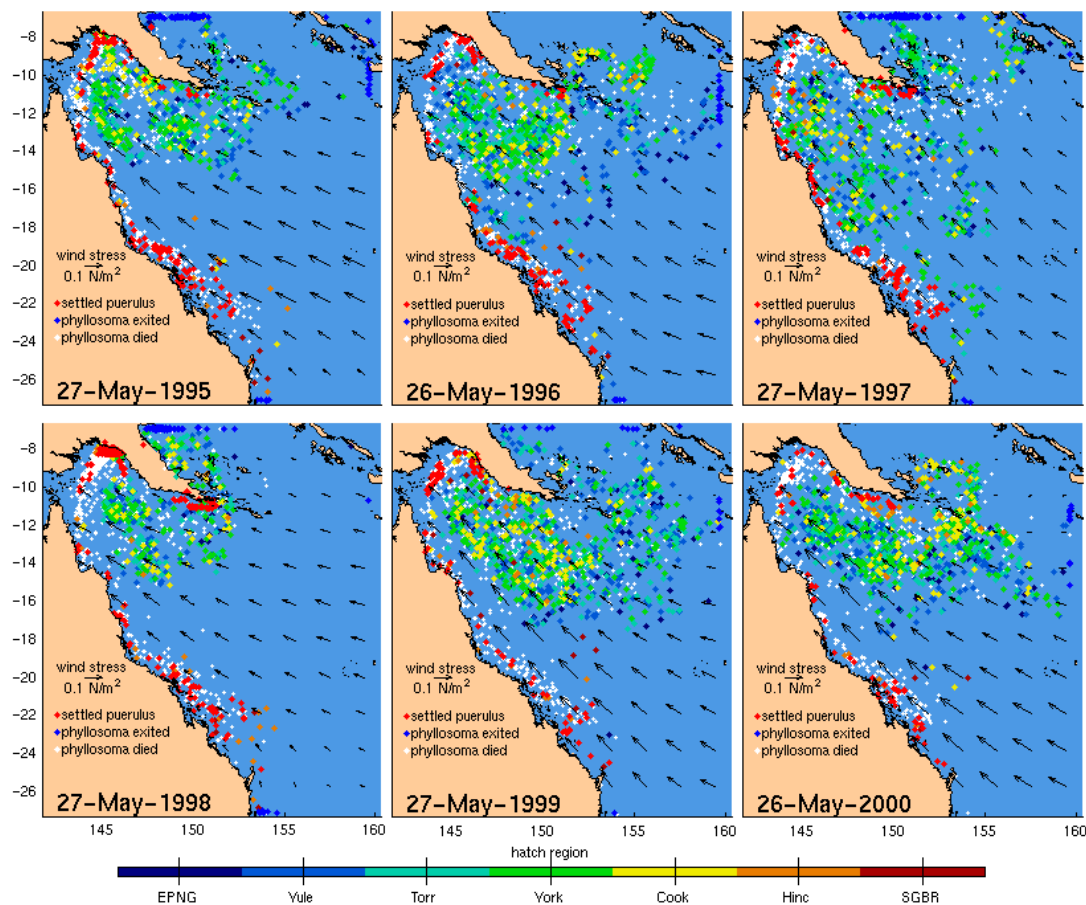
Figure 7-7. **Positions of individual model larvae in the Coral Sea on the 26 or 27th of May 1995 to 2000, colour-coded by their place of origin if still alive, or coloured red if settled, white if dead or blue if exited the model domain. The wind-stress vectors are averages over the previous month.**

By 27 May (Figure 7-7), the larvae in 1997 were clearly much more dispersed than in other years because of the strong cyclonic gyre. At the other extreme, larvae were least dispersed in 1998. Many phyllosoma (68%) have now reached the assumed minimum age for metamorphosis, so much settlement of larvae has occurred in the model. The onset of SE winds in the northern regions has helped to bring these larvae closer to shore. Mortality offshore has also taken a significant toll on the population, as has exiting from the model domain, principally northwards and eastwards, but also southwards in the East Australian Current.
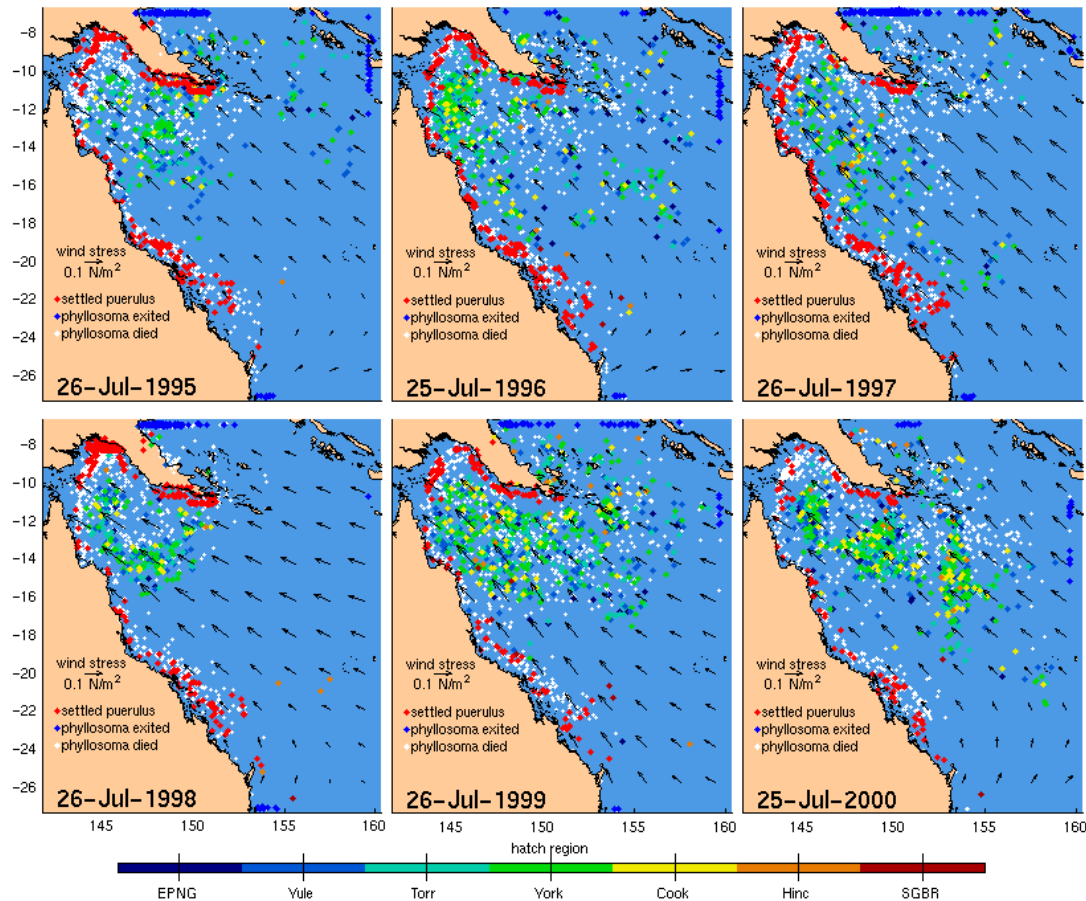
Figure 7-8. **Positions of individual model larvae in the Coral Sea on the 25th or 26th of July 1995 to 2000, colour-coded by their place of origin if still alive, or coloured red if settled, white if dead or blue if exited the model domain. The wind-stress vectors are averages over the previous month.**

By 26 July (Figure 7-8) of 1995 to 1998, the number of larvae still at sea was significantly reduced, with many having either left the model domain, settled on the coast, or died. This is true to a lesser extent in 1999 and 2000, when many were still at sea at this point.
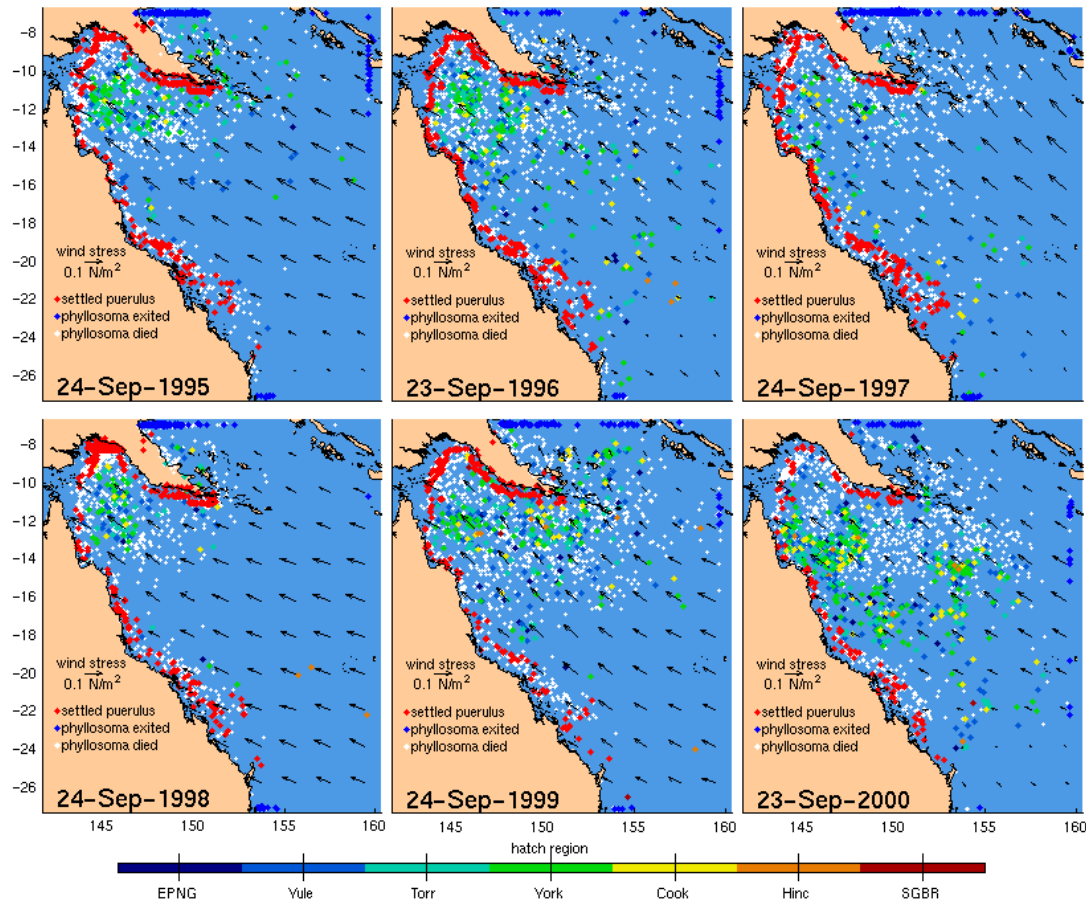
Figure 7-9. **Positions of individual model larvae in the Coral Sea on the 23rd or 24th of September 1995 to 2000, colour-coded by their place of origin if still alive, or coloured red if settled, white if dead or blue if exited the model domain. The wind-stress vectors are averages over the previous month.**

The dispersal and settlement processes continued to operate through the remainder of the year (Figure 7-9 and Figure 7-10), with 1999 and 2000 being the only years with considerable numbers of larvae still at sea by 23 November.
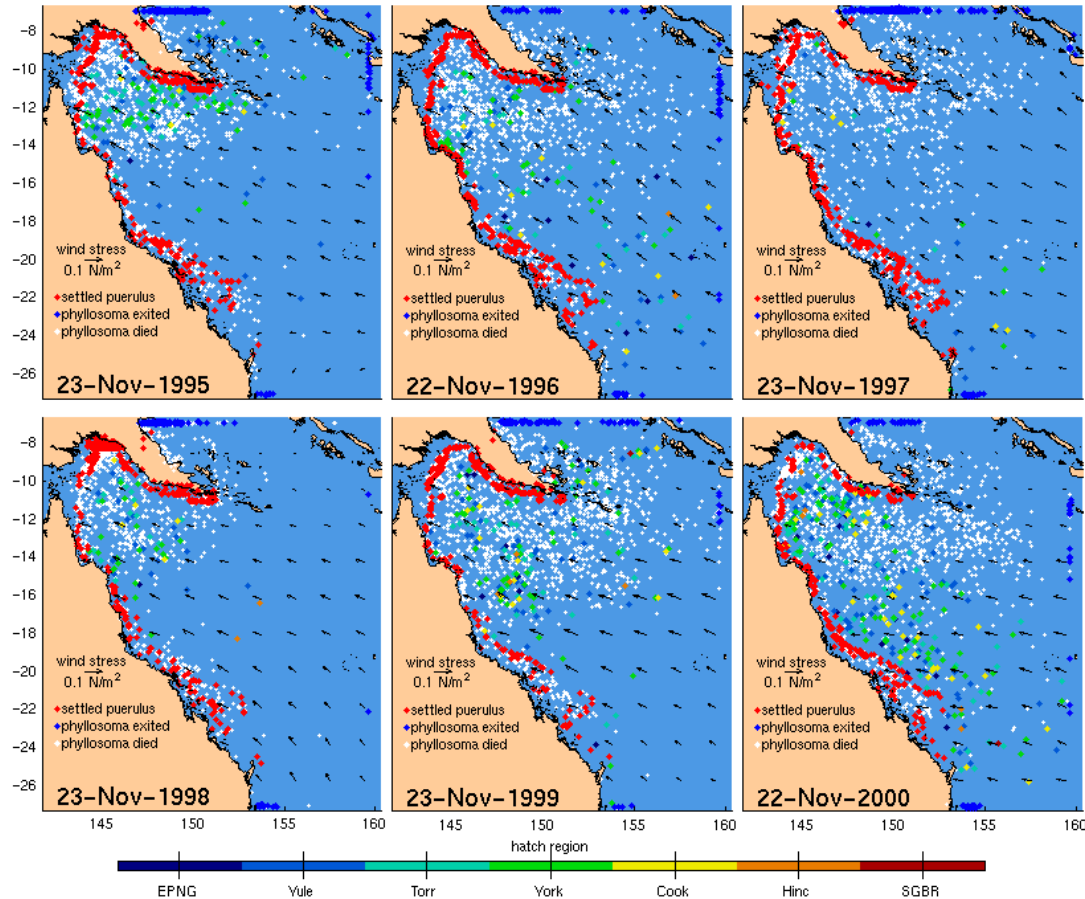
Figure 7-10. Positions of individual model larvae in the Coral Sea on the 22nd or 23rd of November 1995 to 2000, colour-coded by their place of origin if still alive, or coloured red if settled, white if dead or blue if exited the model domain. The wind-stress vectors are averages over the previous month.

It is not possible for the reader to tell from Figure 7-5 to Figure 7-10 how the larvae came to be where they were at any time, or how quickly they were moving, or to where. These can, however, be seen by viewing an animation provided with this report, of the daily positions of the larvae.

Possibly the most valuable lesson that can be learnt from viewing the animation is an appreciation of how dynamic and turbulent the ocean circulation is. Because of this, we have not tried to relate the details of the state of the model with the observations made during May 1997 by Dennis *et al.,* (2001). The model shows how the positions of aggregations of larvae changed significantly from day to day and week to week, so results would depend heavily on exactly when the model was sampled for each location. But doing that would be pointless, because the model could not possibly get the details of the distribution correct. That said, differences between the field observations and the model results, that possibly are significant, are that while Dennis *et al.,* (2001) found very few phyllosoma at their stations 1 and 15 off Cairns, and 7, 8 and 10 near the PNG coast (in our EPNG region), the model places many larvae off Cairns in May 1997 and off PNG in May in all years. We don't think those discrepancies undermine the validity of using the model results to conclude that the larvae sampled by Dennis *et al.,* (2001) could well have originated at any of the known hatching areas, and that they could subsequently have recruited to any of the known settlement areas. The model also highlights the fact that May 1997 was not an 'average' May, because of TC Justin, as already mentioned. This

makes that cruise valuable in the sense that a rare circumstance has been sampled, but also implies that further work is required to characterize the 'usual' distribution of larvae.
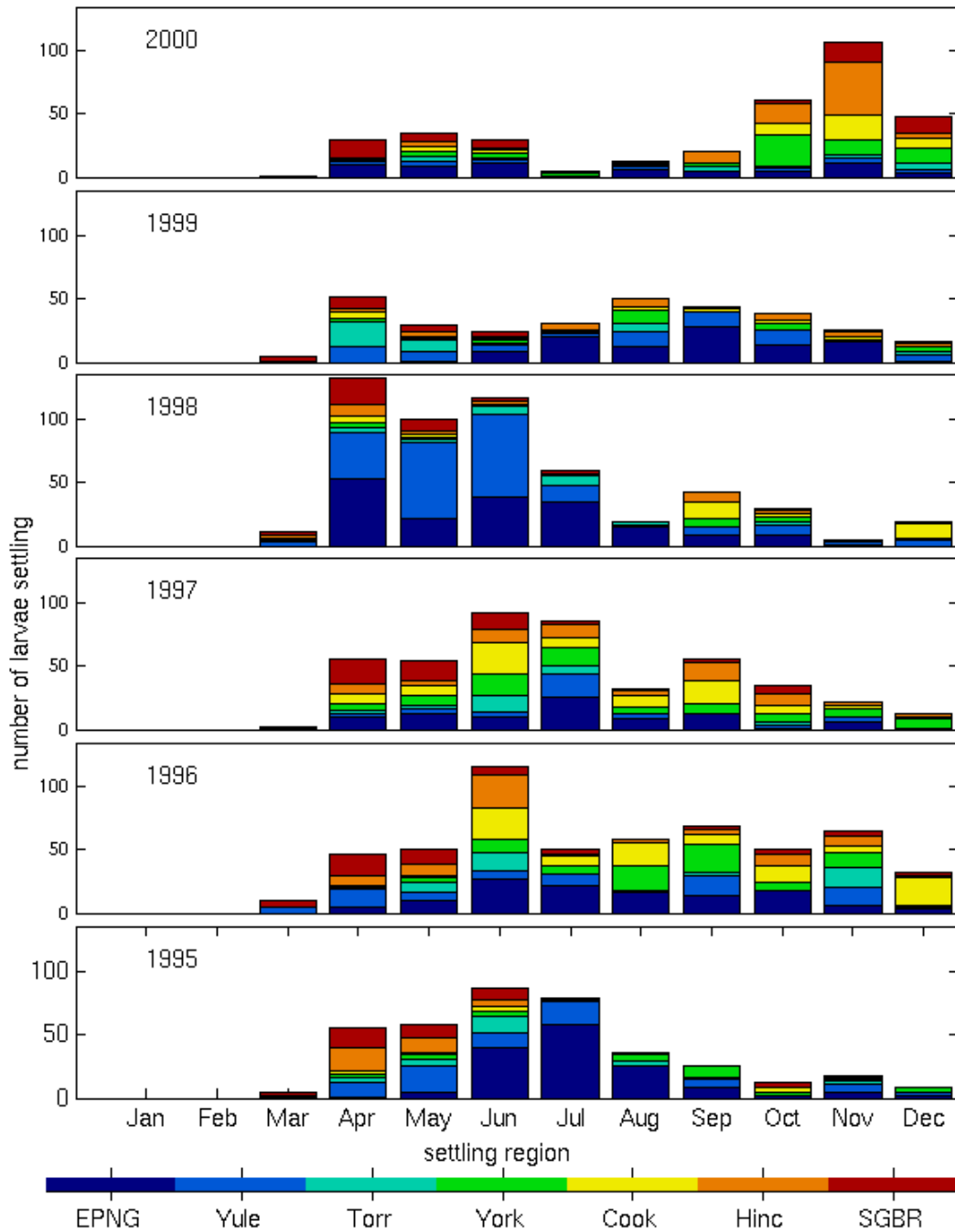
Figure 7-11. **Monthly-averaged rates of larval settlement in the simulation for the years from 1995 to 2000. The settling region is depicted by colour codes.**

The other way of analysing the model simulation for comparison with an observable statistic of the real population is to count the rate at which model larvae settle in the various regions named in Figure 7-3. Unlike *P. cygnus*, however, a large number of observed rates of puerulus settlement do not exist. Figure 7-11 shows how the monthly-averaged rate of settlement varied considerably from year to year, with settlement in 2000 being more protracted than in the other

years, especially in the southern regions. The strong settlement early in the season in the northern regions in 1998 is associated with the reduced degree of dispersal away from the principle spawning regions mentioned above. But recalling that the model of Griffin *et al.,* (2001) did not reproduce the large observed inter-annual variability of *P. cygnus* settlement rates (correlated in that case, for a reason that remains unknown, with the El Nino/La Nina cycle), it should be remembered that the inter-annual variability shown in Figure 7-11 is unlikely to be the whole story.
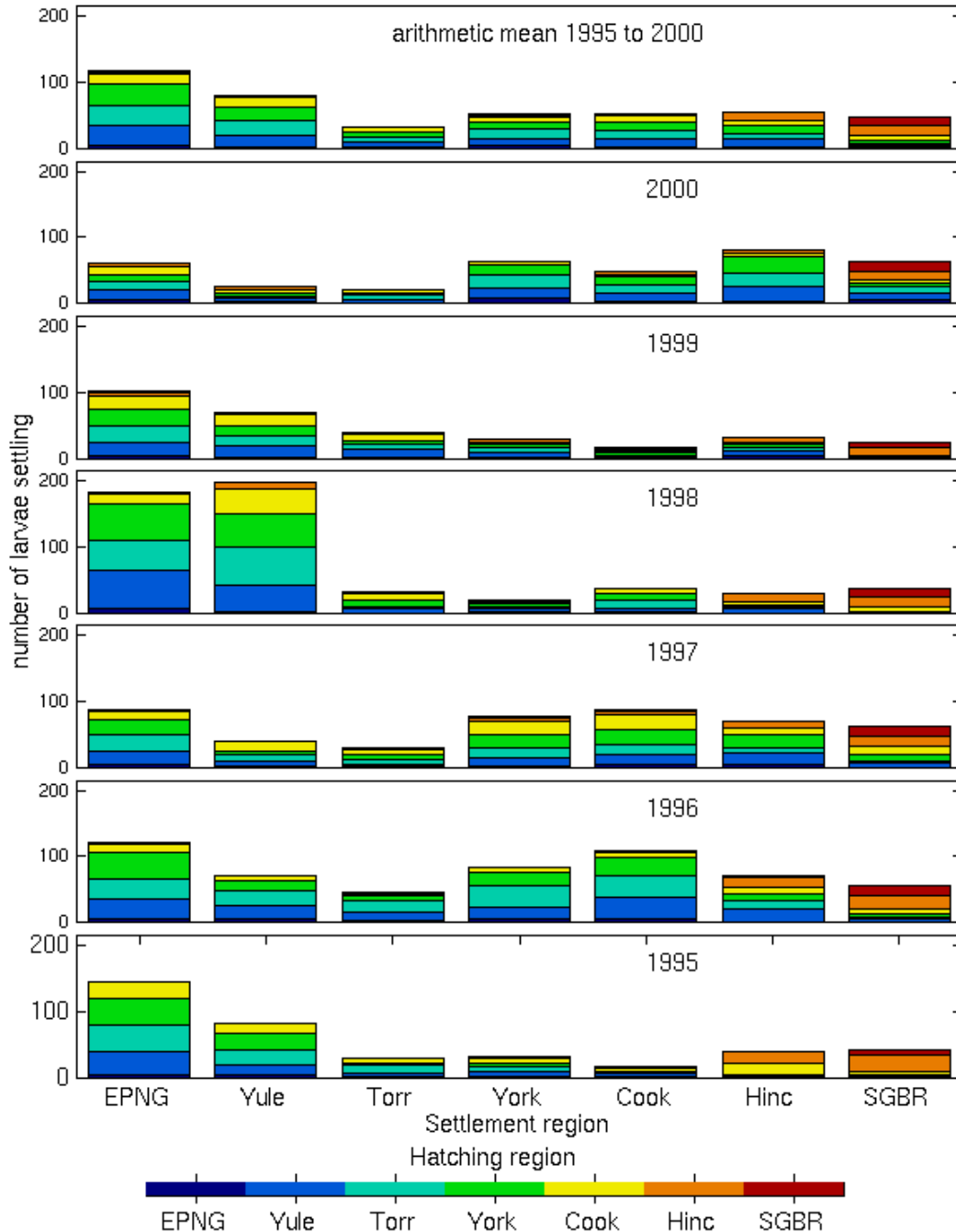
Figure 7-12. **Annual and multi-year-average number of larvae settling in the named regions, with the contributions from the various spawning populations distinguished.**

It can be seen from Figure 7-11 that settlement rates in the model are greatest in the Eastern Papua New Guinea region than elsewhere. This result is illustrated more clearly by Figure 7-12, which shows the annual (and longer term) averages of the larval settlement rates for each region. The Yule Island region received the next greatest number, while the Torres Strait region received the least. Thus, the rates of puerulus settlement in the model cannot sustain the assumed rates of egg production. But should they? Only if one assumes that juvenile and adult mortality and adult fecundity are comparable across wide areas, which is clearly not true. Nevertheless, it is perhaps surprising that the region of supposedly greatest adult abundance (Torres Strait) has the least rate of puerulus settlement. We will return to this point later.

Moving onto ways of analysing the model simulation for information that simply cannot be obtained by field observation, note that Figure 7-12 breaks the total larval settlement into contributions from the seven hatching regions. Hence, the strong settlement at Yule Island in 1998 comprised comparable numbers of larvae that were hatched in the Yule Island, Torres Strait, Cape York and Cooktown regions. These numbers mirror the assumed egg production rates (Figure 7-3), except for Cooktown, which is slightly over-represented. Likewise, settlement in the Torres Strait, Cape York and Cooktown regions is also drawn evenly from the same set of egg production regions.

The parentage of the settlement in the Hinchinbrook region is different to that of the regions north of it, including as it does a significant contribution from itself, and the SGBR region. Similarly, settlers to the SGBR region are principally from there or the Hinchinbrook region. The 2000 influx of puerulus originating in the northern region was mentioned above.
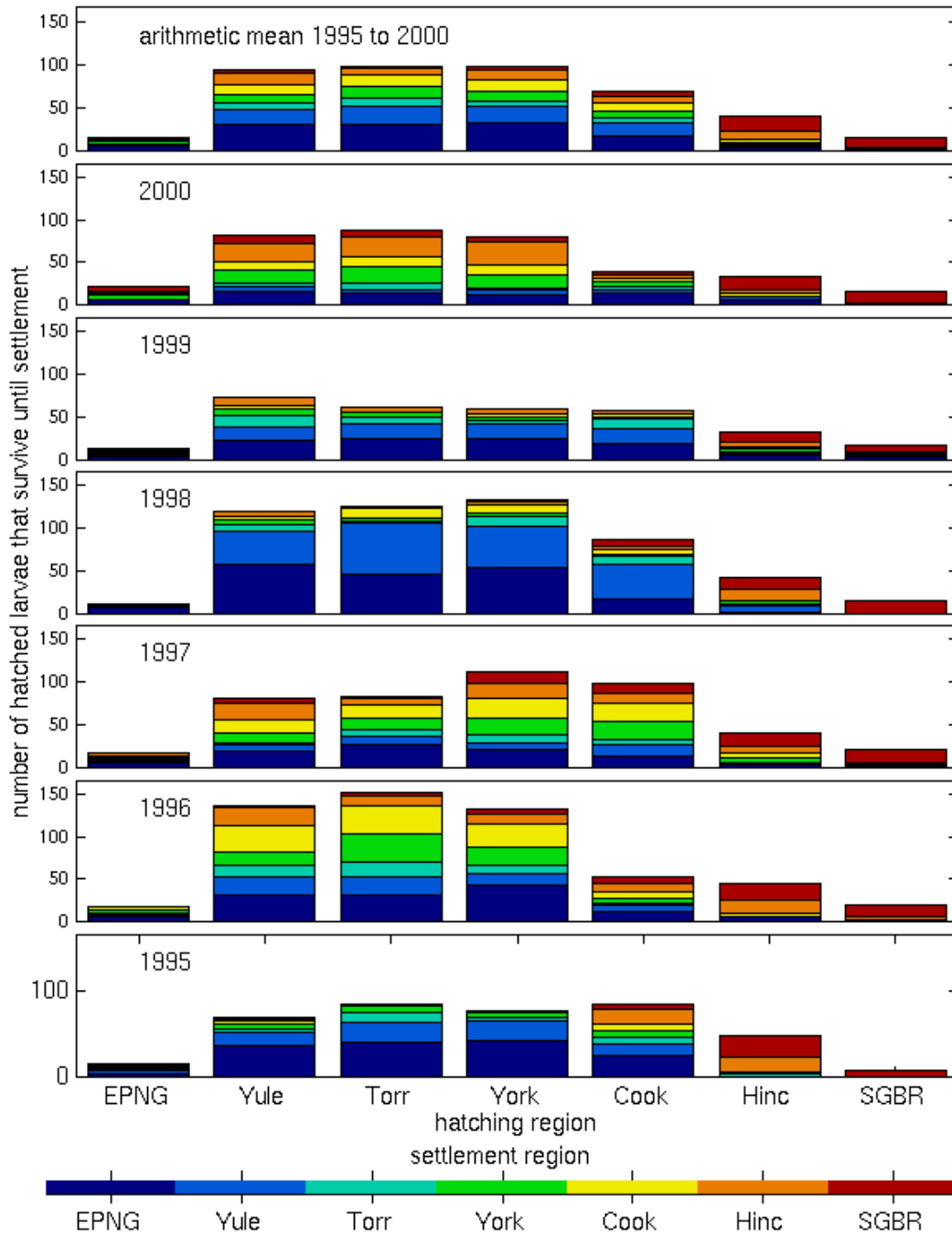
Figure 7-13. **Reproductive success rates of the named regions, with the regions that benefit from the egg production distinguished.**

The other way to view these same results is to count how many of the eggs produced in each region survive to settle eventually somewhere in the model domain. Figure 7-13 shows how this measure closely mirrors the assumed egg production, especially once the average is taken over the six years modelled. The Cooktown region, as mentioned above, is the region where a hatched phyllosoma has the highest probability of returning to the shelf as a puerulus.

Figure 7-11 and Figure 7-12 both showed how settlement in the model is greatest in the EPNG region, and that is clear again in Figure 7-13 If we do not believe, however, that settlement there

really is successful, then we should discount that contribution to the totals shown in Figure 7-13 when trying to use the model to prioritise efforts to increase or protect rates of egg production.

The complete tracks of those larvae that did successfully return to the coast (within the domain of the model) is shown in Figure 7-14 through to Figure 7-27. These sets of tracks are sorted in two ways, in order to help with the two ways of thinking about the role of larval advection in the life cycle of an exploited species. Consider the point of view of someone interested in some particular region. They might ask "on which stocks of adults does my region depend for recruits?" as well as "which regions depend on my adult stock for egg production?". The plots are numbered to step through regions 1 to 7, with part *a,* like Figure 7-12, answering the first question, and part *b* the second, like Figure 7-13.

The motive for examining the tracks of the larvae is to gain insight into the strengths and weaknesses of the various summary statistics arising from the model, by building insight into the advective processes operating on the larvae.

The dominating importance of the semi-permanent, cyclonic Coral Sea gyre to the transport of larvae that settle in the EPNG region of the model is clear from Figure 7-14. There are certainly differences from year to year, especially, for example, in 1997 when some of the tracks trace out the circumference of the large eddy driven by TC Justin, but the general nature of these groups of tracks is fairly uniform and constant. The tracks closely resemble those taken by satellite-tracked drifting buoys that have traversed the region, so we are fairly confident that the representation in the model of deep-ocean advective processes is accurate.

The same cannot be said, however, for how settlement of puerulus is represented in the model. This will be discussed in the next section.
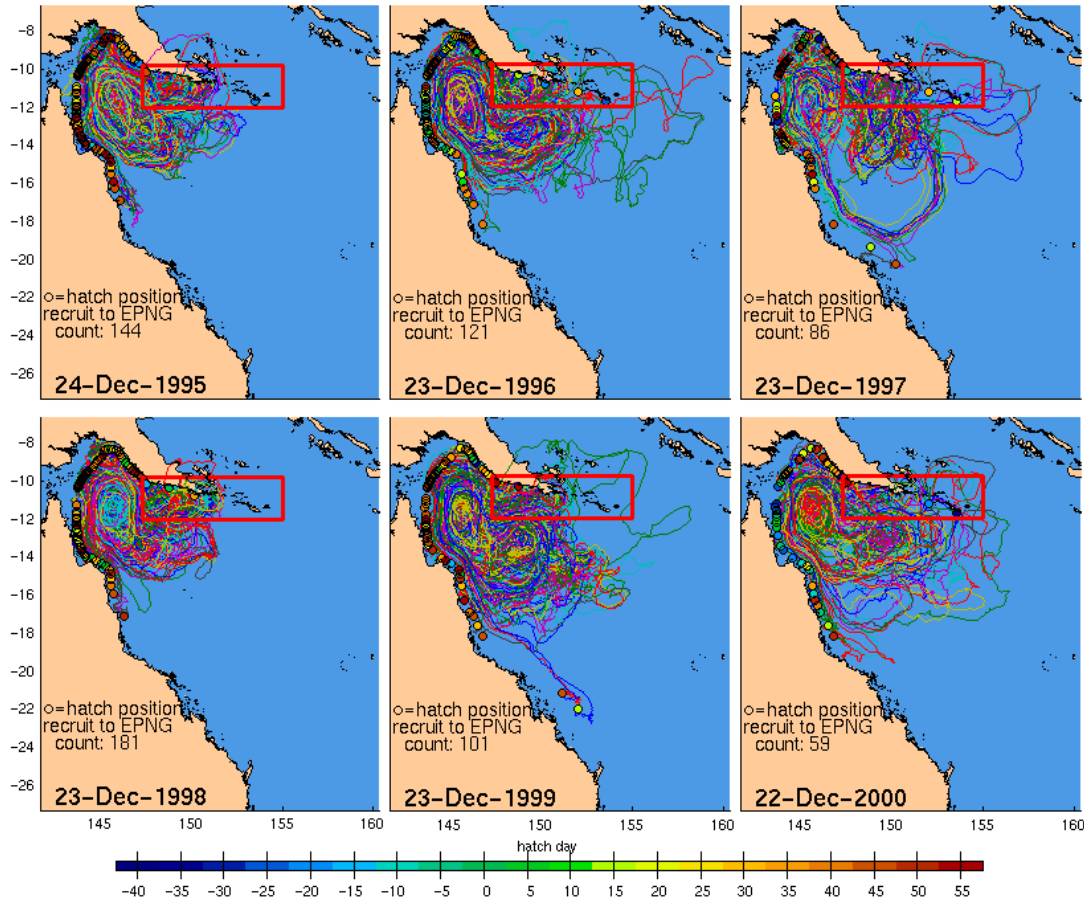
Figure 7-14. Tracks of larvae settling in the EPNG region (red box) Part *a*. Hatch locations are shown as small circles, coloured to indicate the day-of-year of hatching. Individual tracks are randomly coloured to help distinguish individuals.

The ensemble of trajectories of those larvae that hatched in the EPNG region (Figure 7-15) contrasts strongly with those of larvae that settled there. Many larvae quickly left the model domain eastwards and then northwards in the Hiri Current, but its stability was not so great that transport of larvae southwards is totally prevented. Indeed, many larvae were distributed throughout the region, some even to the southern boundary of the model.
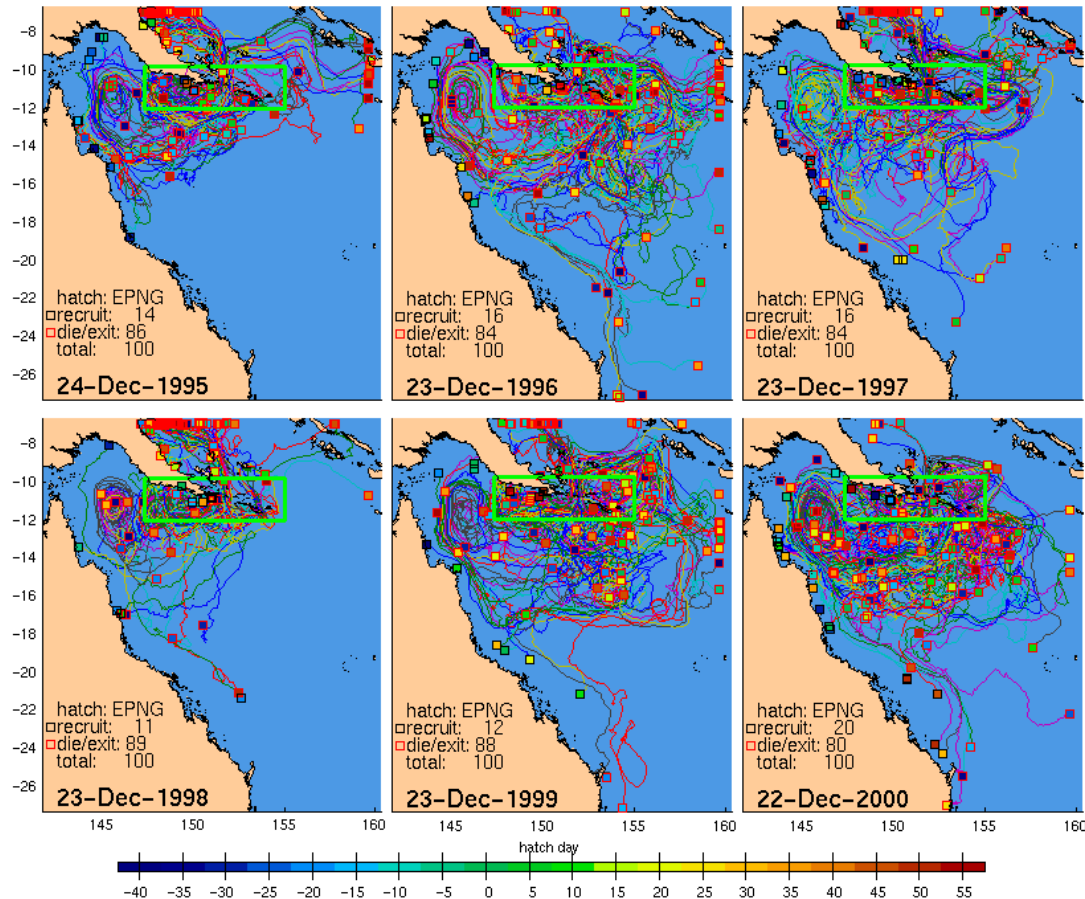
Figure 7-15. **Tracks of larvae that were hatched in the EPNG region (green box) Part *b*.**
Terminal locations are shown as small squares, red in the case of dieing
or exiting the model domain, black in the case of successfully settling.
The colour within the symbol indicates the day-of-year of hatching.

Larvae recruiting to the Yule (Figure 7-16), Torres (Figure 7-18) and York (Figure 7-20) regions followed very similar tracks to those that recruited to the EPNG region (Figure 7-14), and the same comments apply.
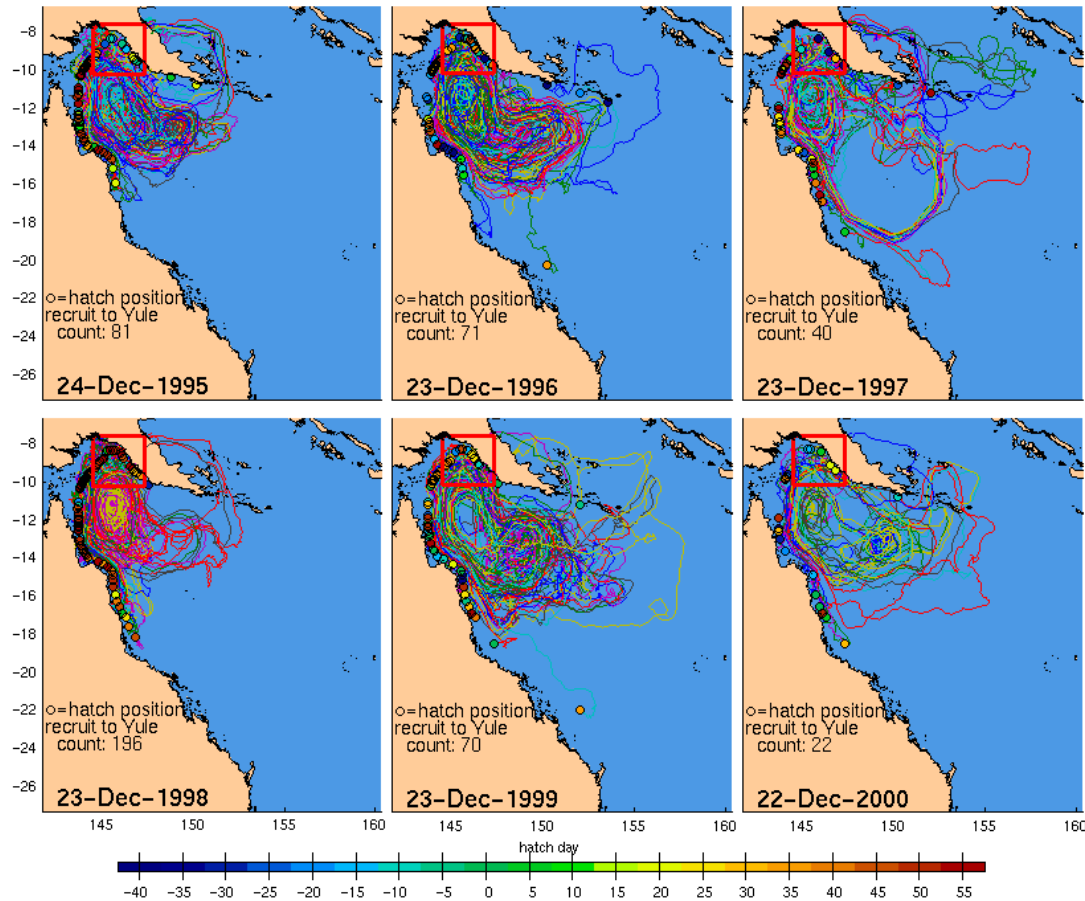
Figure 7-16. Tracks of larvae settling in the Yule region (red box) Part *a*. Hatch locations are shown as small circles, coloured to indicate the day-of-year of hatching. Individual tracks are randomly coloured to help distinguish individuals.

Similarly, larvae hatching in the Yule (Figure 7-16), Torres (Figure 7-19) and York (Figure 7-21) regions were dispersed like to those of the EPNG region (Figure 7-15).
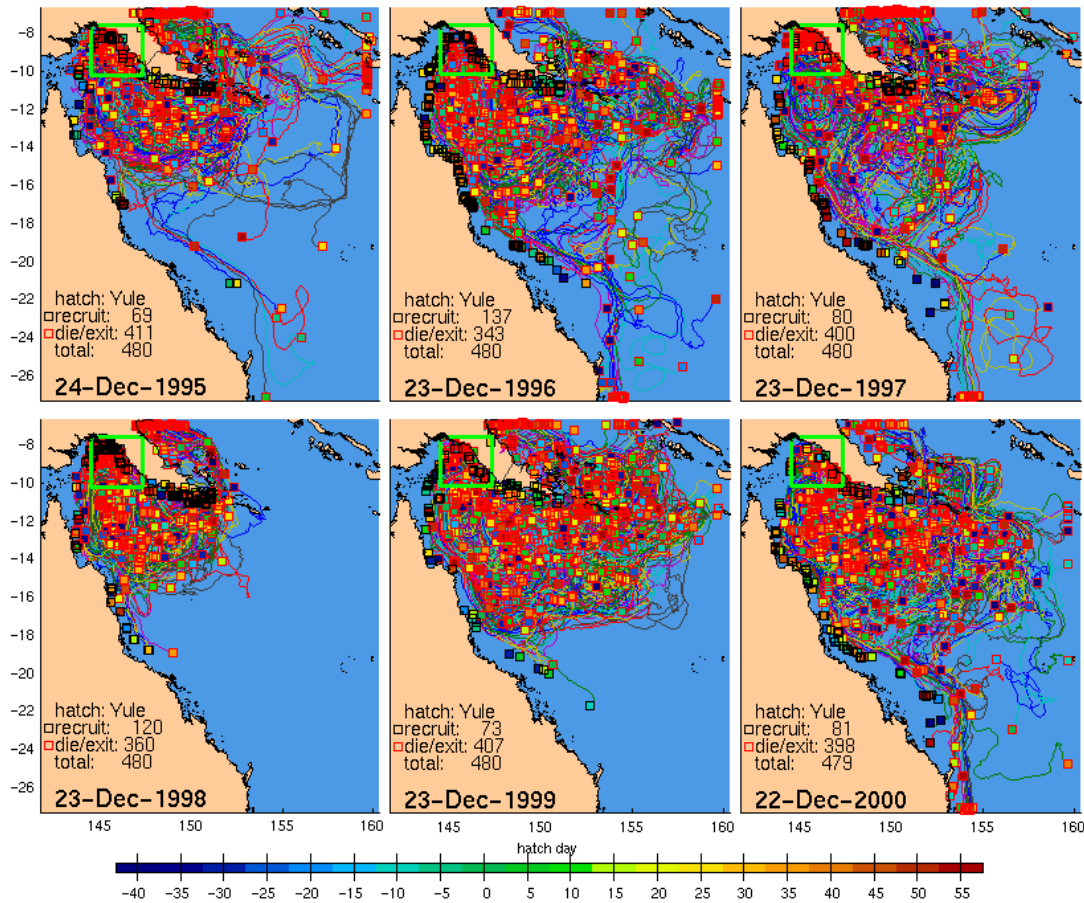
Figure 7-17.   **Tracks of larvae that were hatched in the Yule region (green box) Part *b*.
Terminal locations are shown as small squares, red in the case of dieing
or exiting the model domain, black in the case of successfully settling.
The colour within the symbol indicates the day-of-year of hatching.**
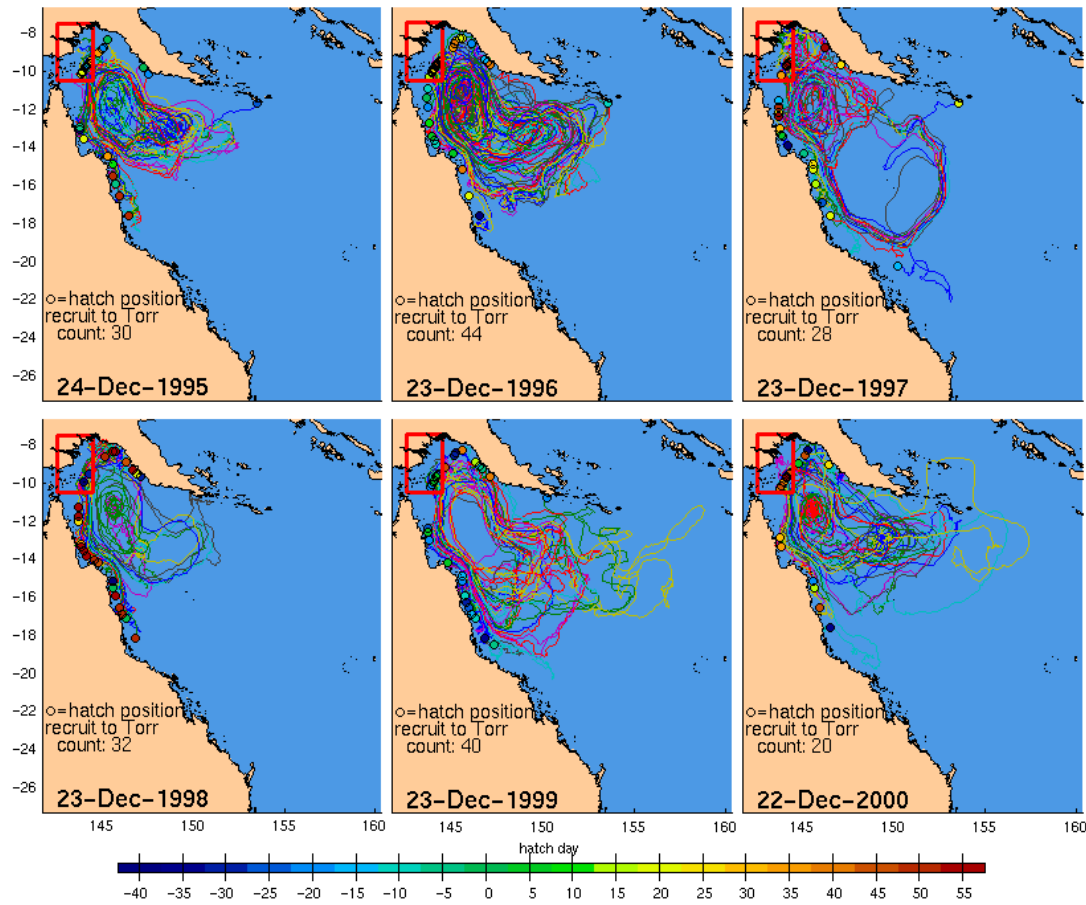
Figure 7-18. Tracks of larvae settling in the Torres region (red box) Part *a*. Hatch locations are shown as small circles, coloured to indicate the day-of-year of hatching. Individual tracks are randomly coloured to help distinguish individuals.
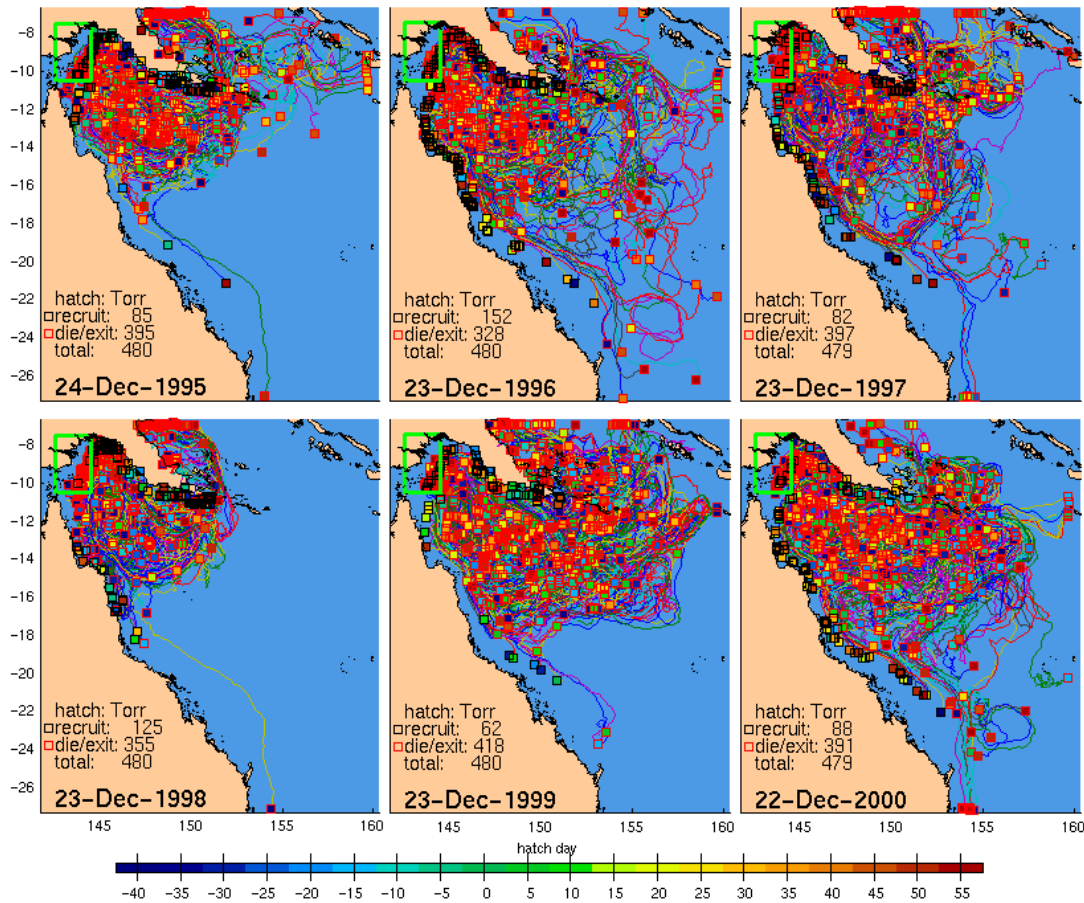
Figure 7-19. Tracks of larvae that were hatched in the Torres region (green box) Part *b*. Terminal locations are shown as small squares, red in the case of dieing or exiting the model domain, black in the case of successfully settling. The colour within the symbol indicates the day-of-year of hatching.
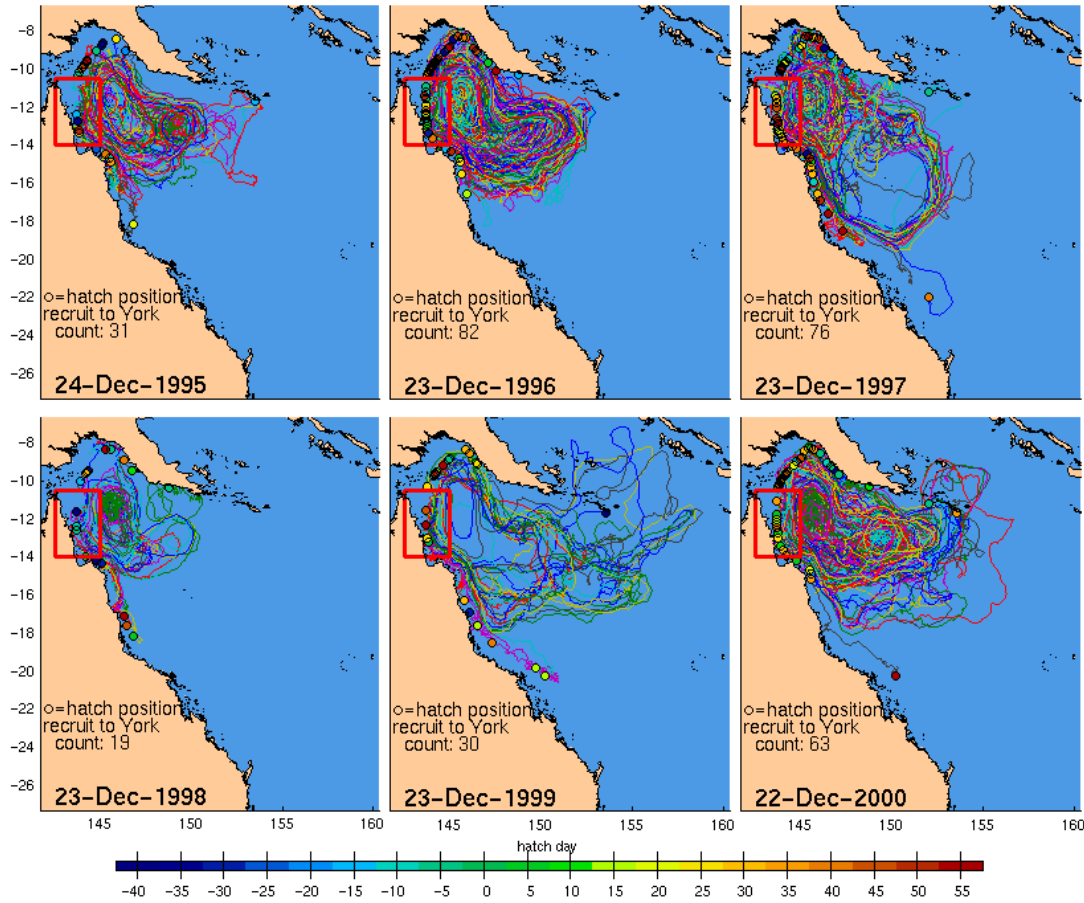
Figure 7-20. **Tracks of larvae settling in the York region (red box) Part *a*. Hatch locations are shown as small circles, coloured to indicate the day-of-year of hatching. Individual tracks are randomly coloured to help distinguish individuals.**
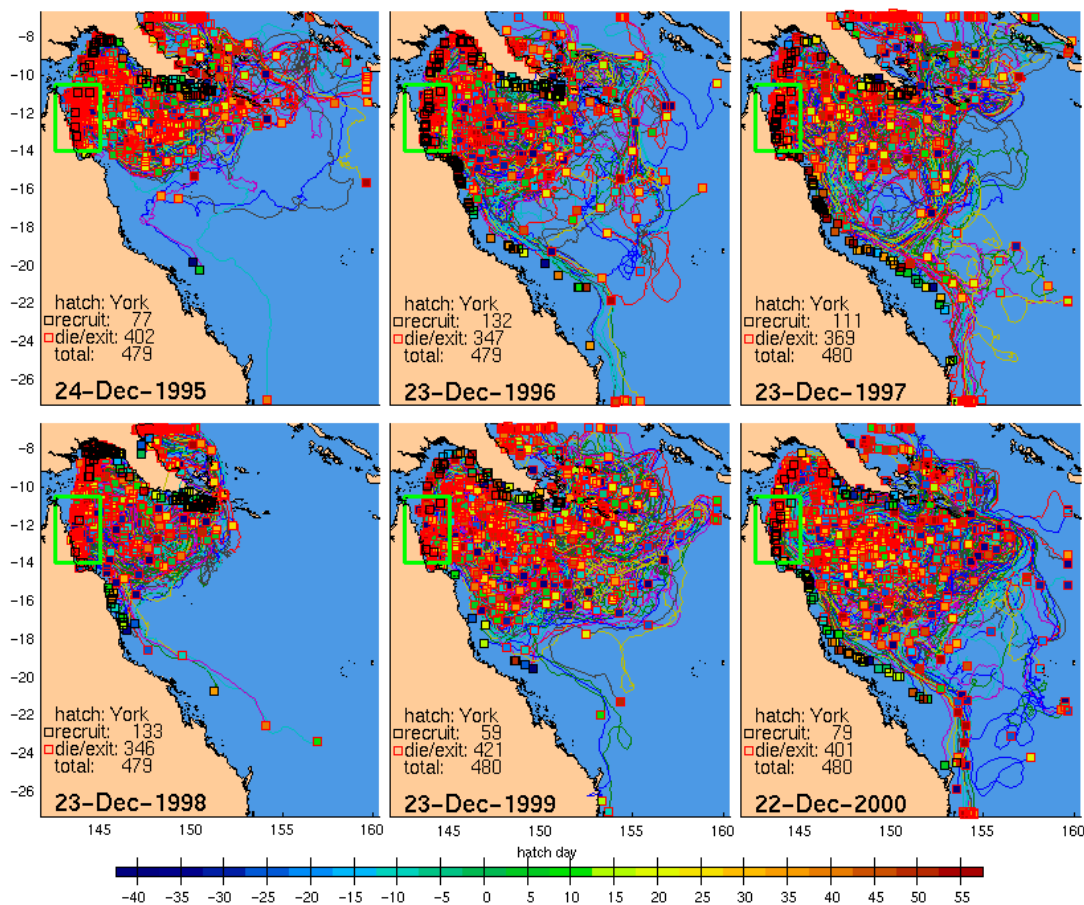
Figure 7-21. **Tracks of larvae that were hatched in the York region (green box) Part *b*. Terminal locations are shown as small squares, red in the case of dieing or exiting the model domain, black in the case of successfully settling. The colour within the symbol indicates the day-of-year of hatching.**

Tracks of those larvae that recruited to the Cook region combine elements of those that recruited to both north and south, which makes sense since it straddles the boundary between the two regions north and south of the bifurcation point of the South Equatorial Current, as shown in Figure 7-1 and Figure 7-2. Few of the larvae recruiting are from the south, because the assumed spawning is so much less in the southern region, so most of the tracks show the influence of the Coral Sea Gyre or the large, more south-easterly centred gyre driven by TC Justin in 1997, as discussed previously.
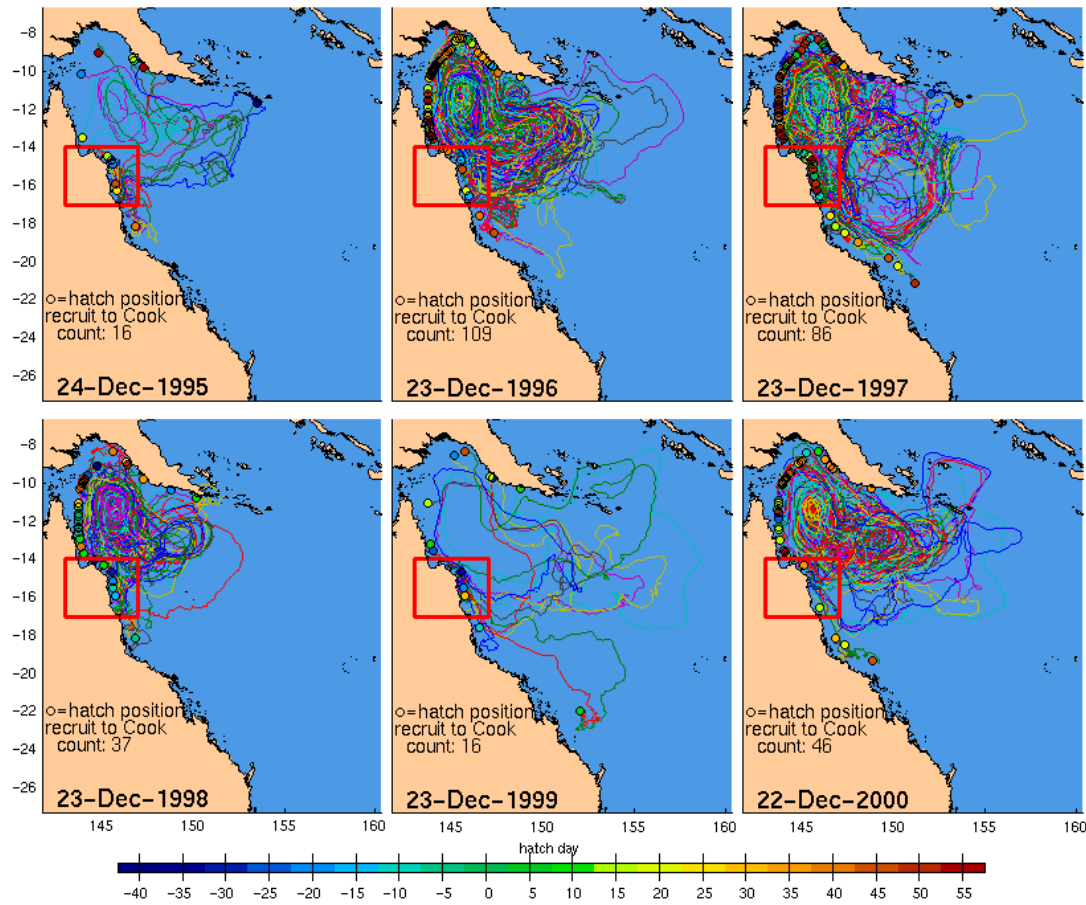
Figure 7-22. **Tracks of larvae settling in the Cook region (red box) Part *a*. Hatch locations are shown as small circles, coloured to indicate the day-of-year of hatching. Individual tracks are randomly coloured to help distinguish individuals.**

It was mentioned above that the larvae hatched in the Cook region had the highest probability of recruiting somewhere. Figure 7-23 shows the tracks responsible for this. Again these tracks combine elements of results for regions both north and south. We will discuss them in the next section.
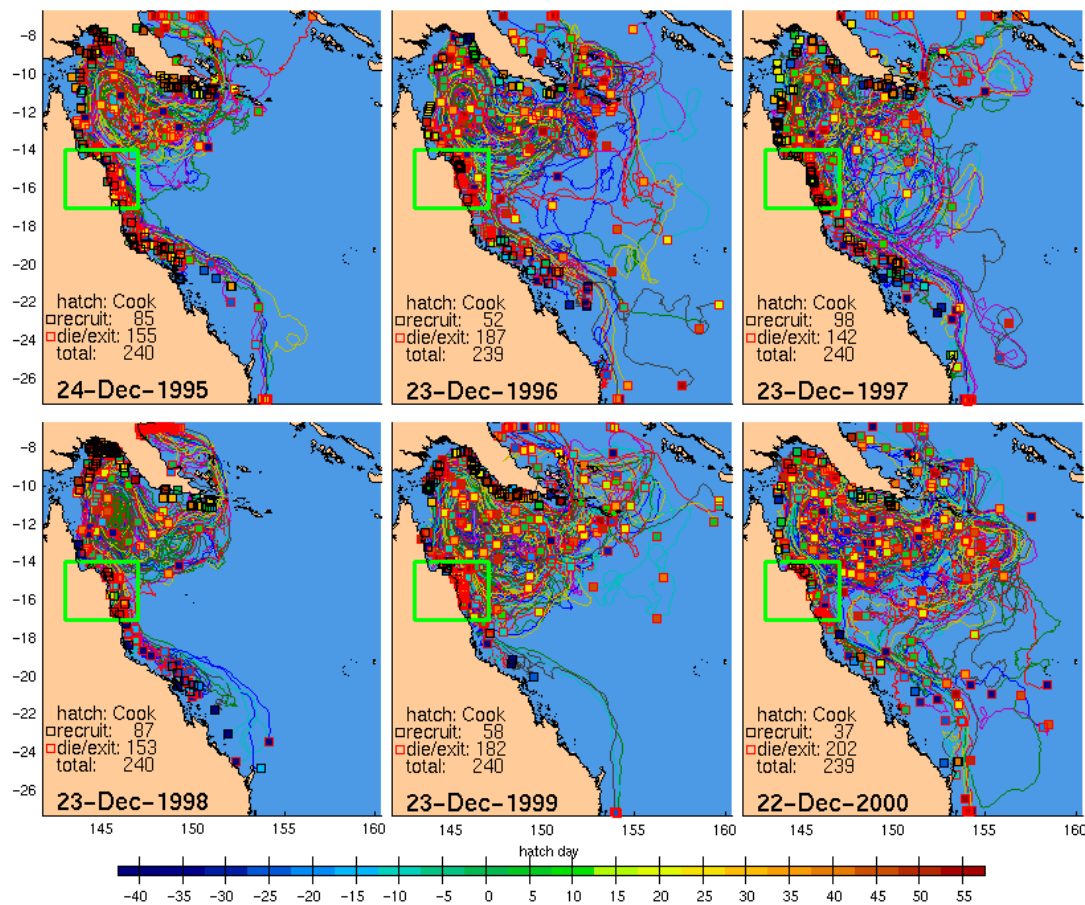
Figure 7-23. **Tracks of larvae that were hatched in the Cook region (green box) Part *b*. Terminal locations are shown as small squares, red in the case of dieing or exiting the model domain, black in the case of successfully settling. The colour within the symbol indicates the day-of-year of hatching.**

Trajectories of larvae recruiting to the Hinchinbrook (Figure 7-24) and SGBR (Figure 7-26) regions are different to those recruiting to the northern regions. Repeated orbits of the Coral Sea Gyre no longer dominate the picture. Larvae of northern origin came this far south in groups under the influence of large-scale perturbations of the mean flow.
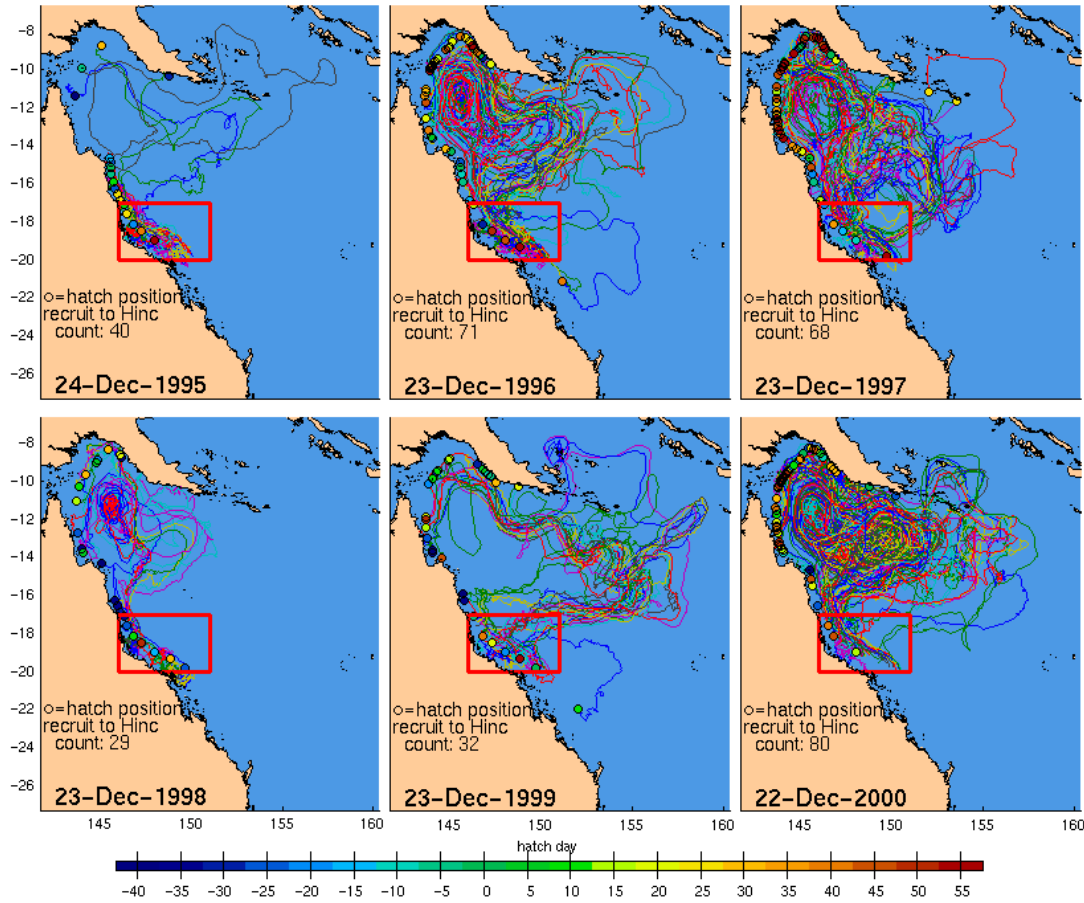
Figure 7-24. **Tracks of larvae settling in the Hinchinbrook region (red box) Part *a*. Hatch locations are shown as small circles, coloured to indicate the day-of-year of hatching. Individual tracks are randomly coloured to help distinguish individuals.**

Similarly, tracks of larvae hatched in the Hinchinbrook (Figure 7-25) and SGBR (Figure 7-27) regions are very different to those of larvae hatched in the north. The important thing to note from Figure 7-25 is that while those larvae escaping the region northwards subsequently follow deep-ocean orbits similar to those of larvae that were hatched in the north, the larvae that did not escape northwards all stayed within the bounds of the Great Barrier Reef. This point is discussed in the next section.
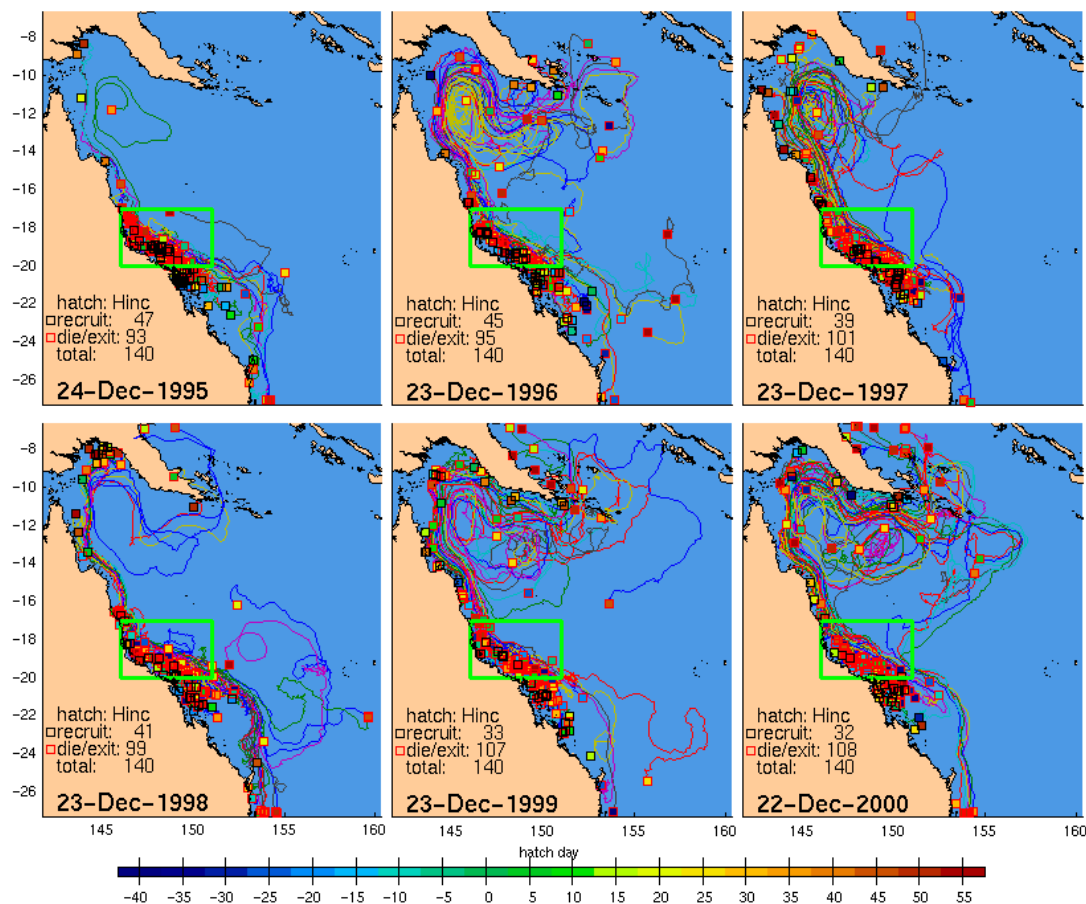
Figure 7-25. **Tracks of larvae that were hatched in the Hinchinbrook region (green box) Part *b*. Terminal locations are shown as small squares, red in the case of dieing or exiting the model domain, black in the case of successfully settling. The colour within the symbol indicates the day-of-year of hatching.**
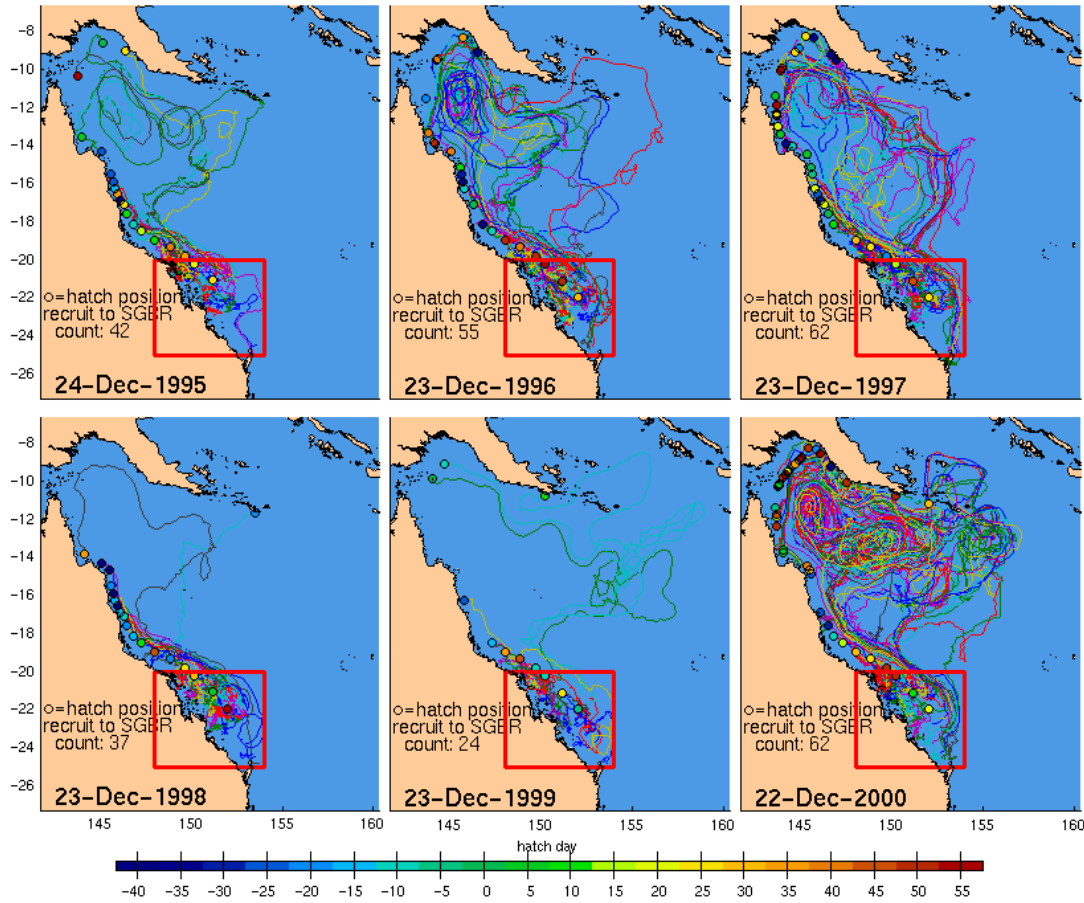
Figure 7-26. Tracks of larvae settling in the SGBR region (red box) Part *a*. Hatch locations are shown as small circles, coloured to indicate the day-of-year of hatching. Individual tracks are randomly coloured to help distinguish individuals.
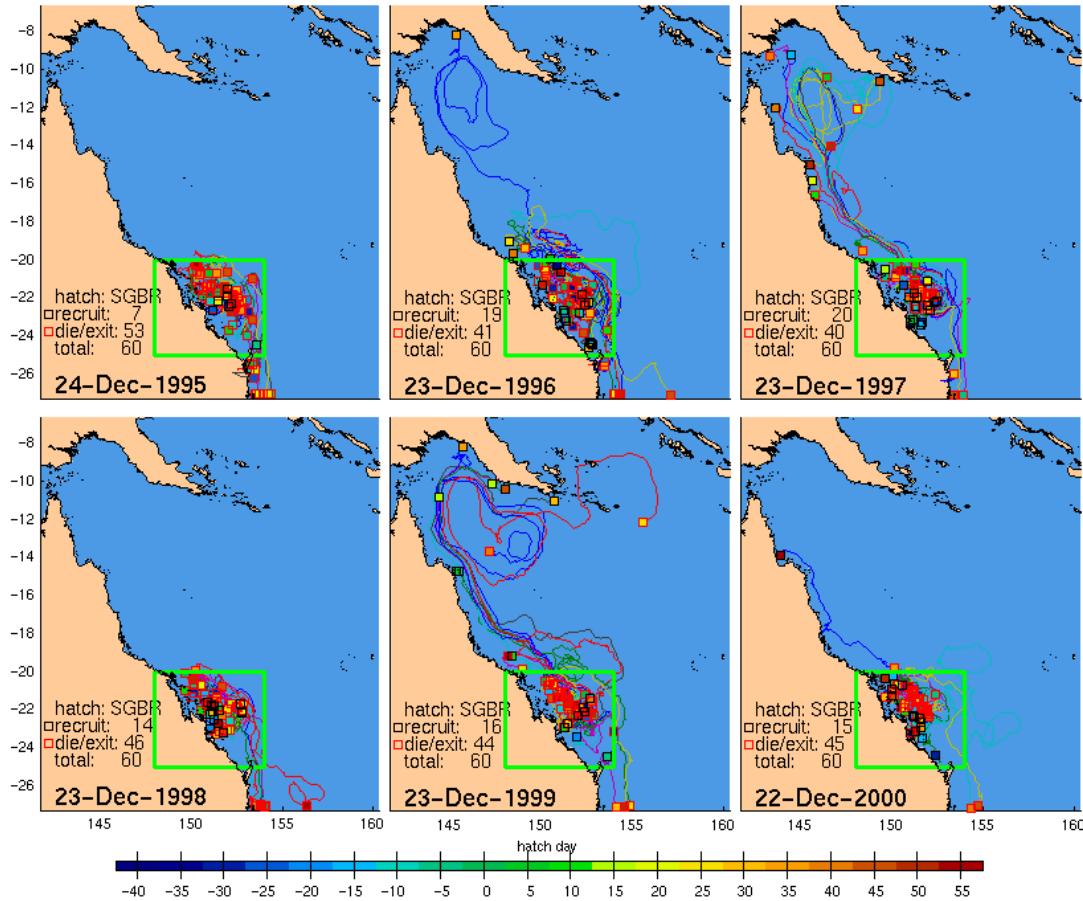
Figure 7-27. **Tracks of larvae that were hatched in the SGBR region (green box) Part *b*. Terminal locations are shown as small squares, red in the case of dieing or exiting the model domain, black in the case of successfully settling. The colour within the symbol indicates the day-of-year of hatching.**

7.4 Discussion

The salient features of the model results that we have flagged for further discussion are:
1. the very high rate of puerulus settlement in the EPNG region – potential mismatch with the assumed distribution of egg production
2. the slightly elevated probability of survival of larvae hatched in the Cook region
3. the high rate of retention in shelf waters of larvae hatched in the southern regions.

The early emergence, during model development, of point 3 is what motivated the inclusion of the two depth-dependent rates of mortality in this version of the model. This was not required for the Griffin *et al.,* (2001) application of the model to *P. cygnus* in Western Australia because the prevailing winds took all the early-stage larvae offshore. In Queensland waters, however, the SE trade winds in the southern regions do just the opposite. It is only in the more northern regions during the NW monsoon that larvae were taken offshore in the present model. In southern regions, the number of larvae surviving until settlement is very dependent on the prescribed rate of mortality in shallow water. In an experiment (not shown) with increased (times three) on-shelf mortality, the survival rate of larvae hatched in the Cook region was no longer higher than elsewhere (except in 1998), and survival in Hinchinbrook and SGBR regions was very low.

Hence, it is apparent that both points 2 and 3 are not results that have any weight until an estimate of on-shelf mortality, compared with that offshore, is available. Perhaps the more robust result from modelling the three southern regions is that while larvae hatched in the Hinchinbrook and SGBR regions are unlikely to recruit to the north, those hatched in the Cooktown region are as likely to do that as those hatched farther north.

Point 1, on the other hand, is a different issue. The continental shelf is extremely narrow throughout the EPNG region, so a model larva of sufficient age that encounters the 100m isobath (triggering metamorphosis) also encounters the 20m isobath, triggering settlement. Furthermore, the absence of tide gauges along the PNG coast means that our velocity fields are less accurate close to shelf in this region, potentially enhancing across-isobath transport. When the reduced strength, compared to reality, of the model's Hiri current is also taken into account, it is clear that there are several possibly erroneous reasons why the model's estimate of the number settling in the EPNG region is higher than elsewhere. It would clearly be very beneficial to our understanding of the population dynamics of this stock, to obtain quantitative estimates of the rate of puerulus settlement on the EPNG coast, and whether these individuals survive to maturity. We've assumed there is very little egg production in this region, but do not know this to be the case.

7.5   Conclusions

Recalling the objectives of this pilot project, we will conclude this section with the following:
- **Develop an oceanographic model.** This has been achieved, using the methods proposed, and been applied as planned.
- **Determine the trajectories of larvae.** This has also been achieved, with the significant result that the basic mechanism for the return of larvae to the coast is somewhat different to what it is on the other side of the country. In both cases, results of our quantitative model support previously hypothesized mechanisms. What is new is an important step towards a much enhanced ability to turn this understanding into scientifically-justifiable management actions.
- **Determine boundaries of the source and sink populations.** Until a more sophisticated model becomes available, our present understanding of the larval dynamics prompts the conclusion that the approximate boundary between the 'source' and 'sink' populations is indeed determined by the location of the bifurcation point of the South Equatorial Current, as hypothesized by Burrage (1993). As discussed above, however, a slight twist on this is that the model region straddling the bifurcation point (our 'Cooktown' region from 17°S to 14°S) is better categorized as 'source' than 'sink'. The animation provided with this report shows how periods of strong SE currents occur in this region, often associated with the SE winds, taking the larvae into the northern zone where they mix with larvae originating there.
- **Identify and prioritise future research.** To improve our understanding of the 'big picture', it would be very valuable to consider the possibility of interactions between this 'stock' of *P. ornatus*, and others in the region. The model shows that many larvae are transported into the Solomon Sea. Does this flux of larvae help support an adult population there? Conversely, we have not considered the potential importance of hatching of larvae east of our 'known' spawning regions. Considering that the South Equatorial current flows past a number of islands before reaching Australia, this possibility should be considered. Getting down to the details of our own region, the result discussed under the previous bullet depends somewhat on the accuracy of our simulation of the currents of the bifurcation region. If confirmation of this result is desired, further attention to the details of this region would be warranted. The linked question of mortality of early stage larvae while they are still in this region should also be addressed for any firm conclusions to be possible.

7.6   References

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8   SUB-PROJECT 3A. LOGBOOK DATA – OBSERVER PROGRAM

8.1   Background

The fishery for *Panulirus ornatus* on the east coast of Queensland began in the late 1970's as an extension of the Torres Strait fishery and was essentially managed as part of the Torres Strait fishery by the Queensland Fisheries Management Authority (QFMA). Most of the early lobster vessels fishing the Queensland east coast were based in Torres Strait and harvested lobsters by free diving from tenders. Lobsters were harvested by spearing and the product stored and sold as frozen tails. Since the ratification of the Torres Strait Protected Zone Treaty with Papua New Guinea in the mid 1980's the Torres Strait lobster fishery has been managed as separate and distinct fishery. The Australian Fisheries Management Authority (AFMA) under the Torres Strait Protected Joint Authority (PJZA) now manages the Torres Strait lobster fishery while the Queensland east coast tropical rock lobster fishery (ECTRLF) has continued to be managed by the QFMA. During a restructure of State Government departments in 2000 the QFMA was incorporated into the Queensland Department of Primary Industries & Fisheries (DPI&F).

During the 1980's the product unloaded from Torres Strait vessels operating on the Queensland east coast was mainly frozen lobster tails. This product was generally unloaded at Thursday Island and it is estimated that approximately 15 percent of the catch was from the Queensland east coast. Although the commercial lobster vessels currently operating in Torres Strait are starting to produce live lobsters for the export market most of the Torres Strait harvest is still unloaded as frozen 'lobster tails'. In contrast commercial lobster vessels operating on the Queensland east coast, including the Torres Strait based vessels, have been unloading mainly 'live lobster' since the early 1990's. The stimulus for shifting to live product was the lower catch rates on the Queensland east coast compared with Torres Strait and the higher value of the live product (Raymond Moore, pers. comm. 2003).

The current east coast lobster fleet consists of a small number of vessels (8) that are only licensed to operate in the Queensland lobster fishery and a larger group of vessels (20) that are also licensed to operate in the Torres Strait lobster fishery. In any year the dual licensed vessels tend to spend more time in the fishery that will provide the highest profitability. In contrast the single-license vessels are dedicated to harvesting live lobsters from the east coast section of the Queensland lobster fishery. Most of the live product is flown to processors in Cairns by light aircraft that can land on the beaches along the northern Queensland east coast. When working the southern part of the fishery vessels unload in Cooktown and truck the live product to Cairns.

Although CSIRO has conducted ongoing biological research on the Torres Strait lobster population since 1980 little research has been conducted on the east coast lobster stock. Fishery independent information on the structure of lobster stocks on northeast Queensland was collected by CSIRO in the early 1980s during a lobster-tagging program (Philips *et al.,* 1983). In addition commercial fishers have collected some information on the size and sex of lobsters on the Queensland east coast to CSIRO. The CSIRO research indicates that the east coast stocks do not migrate into Torres Strait nor take part in the annual breeding migration to Yule Island. The available data suggests that east coast lobsters undertake shorter migrations into deeper water on the Great Barrier Reef and live to an older age than the Torres Strait lobsters. Lobsters older than 4-5 years are not common in Torres Strait as all of the breeding lobsters migrate towards Yule Island. The lobsters around Yule Island have a high mortality due to the combination of high fishing pressure and poor physical condition induced by the stress of an extended migration and breeding.

Although DPI&F and the former QFMA have collected catch and effort data on the fishery via compulsory fisher logbooks since 1988, until recently this data had not been validated. Increasing catch and effort and declining catch rates raised concern about the status of the

stocks. This project was developed in response to those concerns. The objectives of the DPI&F component of the project were to validate and assess the quality of the commercial catch and effort data, collect additional information on the fishery to that provided by the logbook system and if possible conduct a preliminary assessment of the status of the fishery.

These objectives were achieved through: observer surveys on commercial vessels, a detailed analysis and assessment of the logbook data (Chapter 9) and development of a preliminary assessment of the status of the stock (Chapter 10). Three observer surveys were conducted between September 2002 to July 2003. These surveys tested the effectiveness of using fishery observers to validate and enhance the commercial logbook data and collect additional biological information that could be used to monitor the status of the lobster stocks.

8.2   Methods

8.2.1   Observer surveys

Three separate observer trips were conducted on board commercial lobster vessels that operate under the TRL01 license ('R' endorsement) within the ECTRLF. Although it was originally planned to conduct four seven-day trips evenly spread over the fishing season, three longer trips were completed instead. This was necessary due to the introduction of the seasonal closure between 1 October 2002 and 1 February 2003 and the limited number of suitable lobster vessels that were fishing in the Queensland east coast fishery during the 2003 season. A total of 29 days (Table 7) were spent onboard commercial lobster vessels during September 2002, February and July 2003.

During each observer trip, an observer spent some days on the tender vessels and some days on the primary vessels. Observing the fishing on board the tender vessels enabled detailed effort information to be collected, for example fishing depth, habitat type fished, length of dive and distance from the primary vessel. Observing from the primary vessels enabled the researcher to measure all lobsters caught as each tender unloaded their catch onto the primary vessel. Occasionally tenders unloaded several times per day. During the observer days based on the primary vessel it was possible to cost effectively obtain large quantities of biological data.

The data collected during the surveys is listed in Table 6 which compares the types of information that can be collected by observers with the current logbook system. One of the main benefits of the observer surveys is the additional information provided, both fishery related and biological. The datasheets used for the surveys are tabled in the appendices.

Table 6.   **Types of fishery catch and effort data and biological information that can be collected during DPI&F observer surveys and in compulsory commercial logbooks.**

| Data Type | *Description* | Information collected | |
		Observer Program	Commercial Logbooks
Effort	Fishery (East Coast or Torres Strait)	y	y
Effort	GPS position information for primary vessel	y	y
Effort	GPS position information for tender vessel	y	
Effort	Number of tenders working per day	y	y
Effort	Total number of hours fished per tender per day	y	y
Effort	Fishing Method (free diving or Hookah)	y	y (currently missing in database)
Effort	Searching patterns	y	

Data Type	Description	Information collected	
		Observer Program	Commercial Logbooks
Effort	Fishing depth (min., max. and average per tender)	y	
Effort	Diver statistics (i.e. experience level)	y	
Catch and Effort	Understanding how the catch and effort is recorded and whether the logbook captures accurate harvest data	y	
Catch	Weight of live lobsters	y	y
Catch	Weight of lobster tails	y	y
Catch	Total numbers of lobsters	y	Voluntary
Catch	Numbers of lobsters in 'live' and 'tails' product types	y	
Biological	Sex	y	
Biological	Size (mm carapace length)	y	
Biological	Reproductive stage of female lobsters (tar spot and egg bearing)	y	
Biological	Moult condition	y	
Biological	General physiological condition (identify stress, damage)	y	
Biological	Geographic information for analysis of spatial patterns in population structure	y	

Biological information was collected for the majority of individual rock lobsters captured during each survey. After the implementation of the minimum legal size limit on the 1st February 2003 it was still possible for the observer to opportunistically measure undersized animals (less than 90mm CL or 115 mm tail length) when observing from a tender vessel. The divers were able to provide undersized animals (if present on the reef being harvested) to the observer for measuring then return them to the reef unharmed. This opportunistic sampling enabled an observer to collect a representative snapshot of the undersized animals that occur on some of the inshore reef systems.

8.2.2 Vessel feedback

Feedback was provided to the masters/ owners of the vessels that participated in the observer program to thank them for their assistance, and to foster cooperation for future observer programs. Feedback included a summary of the results of the data collected during each trip so that crew were aware of the type of information collected and what it could be used for. It was also seen as an opportunity to thank crew for their support and assistance during each trip. Separate reports were produced for each vessel trip and these were only distributed to the master of the vessel to maintain confidentiality of individual vessel catch and effort data.

Feedback reports included various summaries where possible including:
- Total daily catch and effort of tropical rock lobster for the primary vessel;
- Average daily catch per tender;
- Map of the reef sites fished by tenders;
- Patterns of depth fished;
- Breakdown of product components (live/tails);
- Relationship between each diver's average daily whole catch weight and the number of years experience of each diver;
- Comparison of lobster sex ratios between different reef systems; and
- Lobster length-frequency distribution of overall and individual reef systems.

Copies of these reports have not been included with this report due to confidentiality agreements with each vessel, however copies have been sent to the Fisheries Research and Development Corporation (FRDC) separately and in confidence.

8.3   Results and discussion

Three observer surveys were conducted at different times of the season over a large spatial range. A total of 24 primary vessel days and 14 tender vessel days were observed. The surveys were able to cover approximately two percent of the fishery effort based on 2002 levels of fishing effort (1330 primary vessel days). The proportion of days spent on tenders decreased during the observer program as it was found to be more efficient to record individual tender catches and collect biological data during unload of lobsters from tenders onto the primary vessel. The observer days spent onboard tenders provided observations on the operation of individual tenders and an opportunity to measure undersized lobsters. These undersized animals were returned to the reef unharmed after being measured.

Observer effort was spread throughout the length of the fishery and covered the three main strata assigned by the project to assist with analysis of the logbook information. These strata divide the fishery into three broad zones; 'North' – above the Shelbourne Bay GBRMPA 'Green Zone', 'Middle' - from the 'Green Zone' down to 13° South, and 'South' - from 13° South to the southern boundary of the fishery at 14° South.

Table 7.   **Details of the three observer surveys**

Survey Number	Survey dates	Strata	Total Observer Days	Tender Observer Days
1	20th September - 1st October 2002	South	10	7
2	17th - 26th February 2003	North	8	4
3	16th - 21st July 2003	Middle & South	6	1

Although one of the objectives was to collect biological information on breeding females (egg-bearing and tar-spot females) during the main breeding season (October to February) to verify spawning times, the implementation of a seasonal closure (1st October to 1st February) to protect the breeding stock during the 2002 and subsequent breeding seasons prevented the collection of this data. The decision to implement this closure was made after this research was proposed.

8.3.1   Fishing Operations

The commercial vessels that participated in the observer program all targeted live lobster product. The primary vessels could hold up to 2 tonnes of live lobster in large live holding tanks. In addition the tenders to the primary vessels were set up with live holding facilities to maximise survival of captured lobsters until they were unloaded to the primary vessel.

An average fishing day was nine hours with tenders leaving the primary vessel about 7:30 am and returning about 5pm. When catch rates were high, tenders returned to the primary vessel in the middle of the day to unload catch. They also returned for midday breaks when conducting deeper dives. It was also observed that some of the days of fishing effort recorded in logbooks may represent a part-day fishing operation. These occur when part of the day is used to unload product from the primary vessel to a beach for transport back to Cairns via a light aircraft. Alternatively when the primary vessel has a lengthy steam between fishing areas.

During observer surveys, lobsters were captured using mesh bags and wire nooses. Meshed bags were placed over 'escape' holes in the reef surface, and lobsters were captured in the bags when trying to escape the diver via another entrance. Lobsters were also captured using a wire looped around the tail. The noose tightens as the lobster tries to escape by moving backwards.

While some divers preferred to fish the shallow reef tops (<2m) by standing in the bow of the tender to visually search for suitable bommies, others worked the deeper (10-18 m) 'back reef' areas using a sounder and GPS to locate suitable habitat. Reef edge habitats were also fished, where divers conducted fewer, longer dives and 'worked' their way along the reef edges. Although one inshore reef was fished in the north strata most of the fishing days observed were on offshore reef.
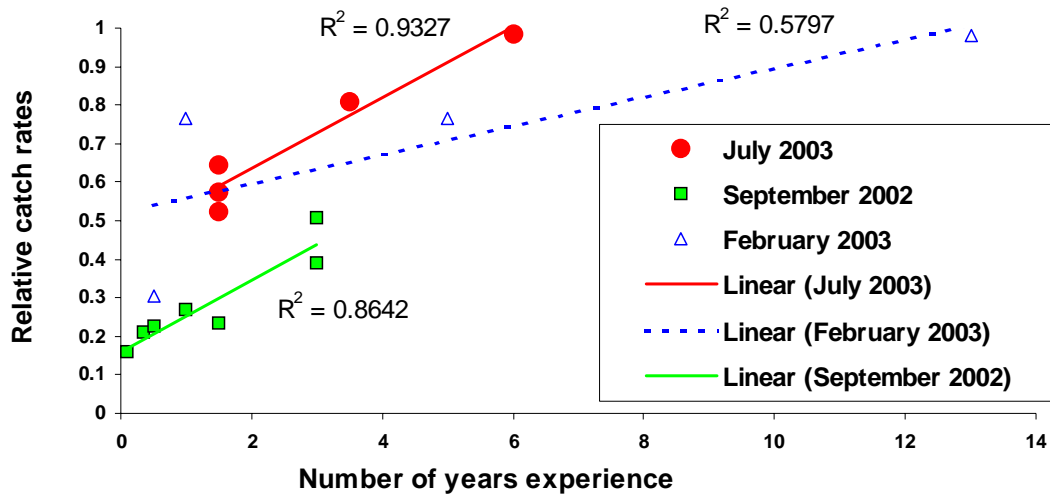
Figure 8-1. **Relationship between years of diver experience and individual diver 'live lobsters' catch rates. The data has been grouped into the three observer surveys to allow for seasonal and spatial effects on the diver catch rates.**

Analysis of individual diver catch rates indicates a strong linear relationship with years (seasons) of diver experience (Figure 8-1). The data for each survey was plotted separately to allow for area and seasonal variation in catch rates. The data for the September 2002 and July 2003 surveys produces lines with the same slope but different intercepts and a high R^2 value suggesting a strong relationship between experience and the catch rates of live lobsters. The higher intercept of the linear fit for the July survey catch rates indicates that the data was collected in a more productive area and/or season. The similar slopes indicate a similar relationship between catch rates and experience for the two surveys. The February 2003 data has one point for a diver with many years of experience and the slope of the line is lower suggesting that relationship between catch rate and experience may plateau after 5-6 years. This data set however has a lower R^2 due to the low number of data points (4) and leaving out that one diver produces a similar regression to the other two data sets.

The relationship between diver experience and catch rate identifies a need to standardise (if possible) the logbook data between individual divers. This is because individual daily tender catch rates reflect the experience of the diver as well as the stock biomass. A standardisation that accounts for diver experience would improve the reliability of the standardised daily tender catch rates as an index of stock abundance and a stock assessment based on these catch rates. Implementation of this would be difficult however, as changes would need to be made to the logbooks and the CFISH database. Due to confidentiality issues it may also be difficult to assign a unique diver code that could effectively track individual divers in the fishery. In addition this

standardisation could only be applied to future data. Although the skipper id field is currently used to flag the individual tender/diver daily fishing operations on each primary vessel (tender day operations) it is not a unique field that can be used to track the history of individual divers.

8.3.2 Processing of catch

Lobsters captured by each diver were stored in 'live holding tanks' on the tender then transferred to the larger holding tanks on the primary vessel. Generally the catch was unloaded from tenders at the end of each day, however when catch rates were high they often unloaded several times per day. On most of the observed tenders the quality control and product separation was performed during unload to the primary vessel. In contrast some divers conducted the initial quality control checks as they loaded their catch into the tender. Animals that were obviously of low quality were tailed, cleaned and stored in an esky containing ice.

The quality control inspection included checking for moulting animals, including those that were likely to moult over the next couple of days, stressed lobsters, and damaged lobsters ('drop tail', missing limbs). During unload to the primary vessel the low quality lobsters were placed to one side. The 'live catch' of each tender or diver (if more than one diver per tender) was then weighed and recorded. The quality live lobsters were then quickly placed one by one into the large live holding tanks on the primary vessel. The lobsters that had failed the quality checks were then tailed, cleaned, individually wrapped in plastic bags and frozen flat in trays. On some vessels the daily weight of lobster tails were recorded for each diver or tender prior to freezing of the product, whereas on other vessels the weight of tails was recorded during the unloading of the primary vessel.

Each day the quality and health of the lobsters in the holding tanks on the primary vessel was monitored. Dead or dying animals were discarded back into the sea. Low quality animals were removed and processed as frozen tails if still healthy. These removals from the live tanks were estimated (and sometimes weighed) and removal weights recorded. As the divers' pay is based on the weight of live product that reaches the seafood processors, any removals from the holding tanks, are recorded and subtracted from the divers tally of 'live catch'.

Three different methods were observed with regard to the processing and recording of the daily product weights, which could affect the accuracy of the daily harvest estimates.
1. Both the tails and live catch for each tender vessel were weighed each day. These weights were accurate estimates of the daily lobster harvest for each tender vessel.
2. Only the live catch for each tender vessel were weighed each day. The bulk weight of 'lobster tails' is only recorded during unload of the primary vessel. This method can over-estimate the total harvest, as animals that were removed from the live holding tanks and processed as tails are counted a second time during the unloading. This method also makes it difficult to calculate the total daily harvest if only a bulk weight of 'lobster tails' is recorded for each unload of the primary vessel.
3. The 'live lobster' catch for each tender vessel were weighed each day. The weight of any discards from the holding tanks was later subtracted from the skipper's running tally of live product for each diver or tender. The discards consist of lobsters that died in the holding tanks and low quality lobsters that were processed as tails. The skipper's tally at unload was then used to report catches in the logbook. This method would under-estimate the harvest of lobsters, as the weight of any 'discards' due to mortality in the holding tanks was subtracted from the initial 'live lobster' weight.

Ideally the total daily harvest of lobsters from the sea; 'live lobsters', 'lobster tails' and any discards (dead lobsters), should be weighed and recorded in the commercial logbooks at the time of unload from each tender. This can be done either by weighing all of the lobsters together and recording the weights in the logbook as 'live lobster', or alternatively provide the separate weights of 'lobster tails' and 'live lobster'. The second and third observed processing methods

highlight the need for education of fishers on this issue. Fishers need to understand that to monitor the stock status, accurate estimates are needed of the total daily tender weights for all lobsters that are removed from the population both as harvest and discards. In terms of stock assessment, the weights and types of product that are unloaded from the primary vessels is not important. This issue appears to stem from the difference between the purpose of the logbook data and the requirement for the vessel master to track individual diver catch records for payment purposes.

8.3.3 Biological Data

Biological data was collected from 3283 lobsters representing over 95% of the total numbers of lobsters harvested during the three observer surveys. The data collected included size (carapace length), gender, moult condition, breeding condition of females, and general comments on the condition of the lobsters. This data which is summarised in Table 8 and Figure 8-2 was also provided to CSIRO so that they could combine it with other biological data collected from industry members in recent years and CSIRO research studies conducted during the 1980's.

Table 8. **Summary of the biological data collected by the observer program. The numbers in brackets show the size range of all animals measured. The averages are based on only legal sized animals (>90 mm CL).**

Area of fishery	Sample size	Survey timing	Percentage males	Average CL males	Average CL females
North	945	February	52%	111 (34 - 147)	102 (32 - 138)
Middle	1349	July	61%	112 (90 - 165)	106 (84 - 165)
South	989	September & July	51%	126 (75 - 180)	115 (72 – 160)

The summarised size data (Table 8) shows that male lobsters were generally larger than female lobsters. This is typical of this species and reflects the difference in growth curves of males and females (Figure 6-19). The mean and maximum size of animals measured in the southern area of the fishery was larger than for the middle and northern areas. This indicates that the population structure in the south includes a higher proportion of older lobsters.

The size frequency distribution of the lobsters measured during the observer surveys (Figure 8-2) also shows the larger mean size and size range of lobsters in the southern strata. Although the maximum size of lobsters measured in the middle area is larger than for the north there are less lobsters in the 120 to 140 mm carapace size range. This skews the size structure for the middle stratum towards the minimum size limit of 90 mm carapace length compared with the northern and southern areas. This may be a result of the high fishing pressure that has occurred in the middle section of the fishery over last eight years. As high fishing mortality tends to lower the mean size (and age) of the population structure. Alternatively the variation between strata may reflect seasonal differences or spatial variation (inshore versus offshore) within the strata. Ideally several observers need to be operating in different areas of the fishery at similar times to account for seasonal effects.

In the south lobsters over 140 mm CL were predominantly male and less than 140 mm CL predominantly female. In contrast this gender switch occurs at 120 mm CL in the north. In the middle stratum males comprised 61 percent of the catch and were more abundant than females in all of the size categories. Surveys at other times of the year are needed to determine whether the gender shift in the middle stratum is a seasonal trend driven by changes in catchability or a difference in the stock structure between the strata.

The left-hand side of the size distribution for the south stratum (Figure 8-2) is indicative of commercial catches prior to a minimum size limit. Most of the data for the south was collected during the September 2002 survey that was conducted prior to the implementation of the 90 mm CL minimum size limit. In the northern area, lobsters from an inshore/coastal reef system were opportunistically measured. The inshore reef system had a large resident population of small lobsters with minimum sizes of a 32 mm CL female and a 34 mm CL male. The observer program was able to opportunistically sample lobsters from inshore regions, and sample lobsters smaller than the minimum legal size. The opportunistic sampling of undersize lobsters can provide information that cannot be retrieved from processor product grading information nor collected by commercial fishers, as it is an offence to be in possession of undersize animals without a permit.
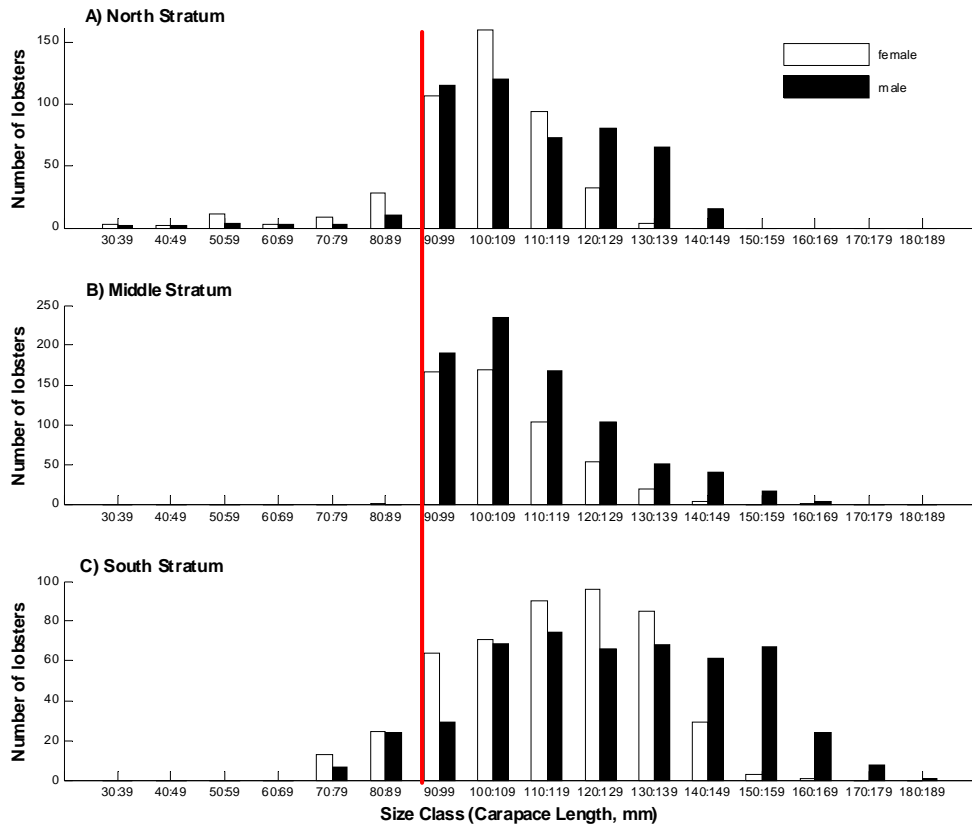
Figure 8-2 Size distributions of lobsters measured by the observer program, grouped by gender and area. The dotted line indicates the minimum legal size limit of 90 mm carapace length. The Y axes are scaled independently as the samples sizes varied between strata.

Based on all observer data it was estimated that on average 12 percent of lobsters captured were not suitable for live product and were processed into frozen tails. However, during the February 2003 survey up to 23 percent of the daily catch of lobster was processed as tails as there were more stressed lobsters. The average for the entire February survey was 16 percent. It is likely that the stress condition was a result of heat induced by unusually high water temperatures. The inter-segmental integument of these lobsters was distended with fluid similar to oedema (Figure 8-3) and a froth of bubbles formed in the gills.

The fishers commented that prior to the observer boarding the vessel the mortality rates had been up to 40 percent as water temperatures during February were recorded up to 31° C in the northern region of the fishery during early and mid-February when slight north-easterly winds prevailed. The occurrence of this stress declined with the onset of the south-easterly winds and lower water temperatures around mid-February.

Very little byproduct to the ornate lobster was recorded during the three observer surveys. A small number of green crays (*Panulirus versicolor*), less than 1% of the total catch, were observed in the catch from the southern strata. In addition some *Panulirus femorostriga*, were observed in the catch from the northern strata. The fishers refer to the later as 'champagne crays' due to the small white dots on their bodies. This name is only used locally and is not one of the standard common names quoted in the taxonomic references.
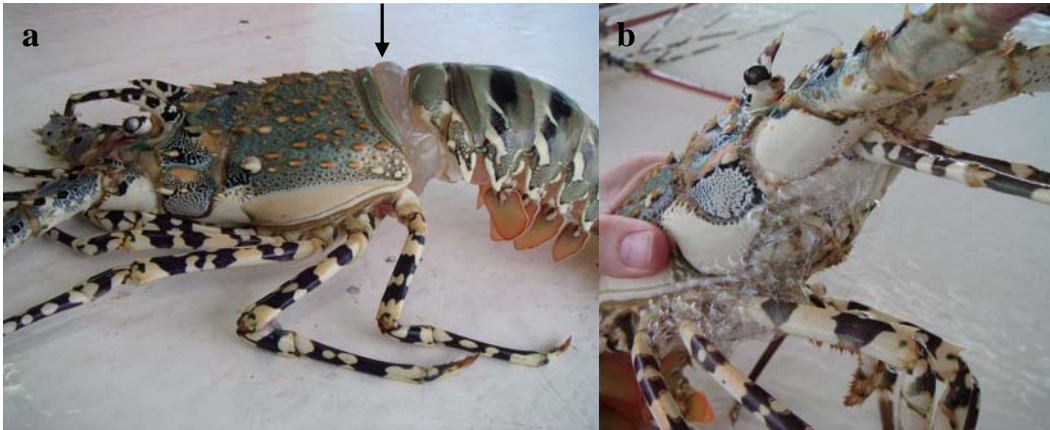
Figure 8-3. Lobster suffering stress caused by high water temperatures: a) demonstrating signs of bloating; and b) bubbling from the gills.

Other biological data that was/could be collected during the survey was the interaction of the fishery operation with protected, threatened or endangered species. No interactions with these species were recorded during fishing operations of tender or primary vessels. Future surveys could monitor interactions and validate the presence or absence of reported interactions in logbooks.

8.3.4   Anecdotal Information

Anecdotal information on the fishery was collected during the observer program and at meetings of the Queensland Rock Lobster Association (QRLA) and HarvestMAC.   This information assisted with understanding the history and operation of the fishery and interpretation of the commercial logbook data.

Anecdotal information from fishers suggests that the ratio of tailed product to live product during live lobster fishing is highly seasonal. The ratio may be almost zero during the middle of the season (May-June) and highest during the pre-breeding period (September to November) due to lobsters moulting prior to breeding. Fishers have also noted high discard rates during periods of high water temperature (up to 40%). These comments correlated with the discard rates observed during the observer program (see Biological Data section).

Information from commercial operators suggested that some vessels in the fleet might not be recording their catch of tails in the commercial logbooks. This is partly a result of the methods used to process the catch. On some vessels the live lobsters are measured each day as they are unloaded from the tenders while the tailed product is only weighed during unload of the primary vessel. The commercial logbooks are designed to record the daily catch of 'live lobster' and 'lobster tails' per tender or diver and there is no provision for a bulk total of tailed product. It

also appears that some fishers may be entering an estimated weight of tailed product for each daily tender record based on the total weight of tailed produced for an entire fishing trip.

Fisher comments suggests that the distance travelled by tender vessels on a daily fishing trip could be up to and possibly greater than 20 nautical miles from the primary vessel. The distances travelled are affected by weather, with larger distances possible when the wind is low and there is no rain. As the daily logbook only records the position of the primary vessel researchers need to consider the distances that tenders can travel from the primary vessel when analysing the spatial distribution of the logbook catch records. A circle surrounding a primary vessel with a radius of 10 to 20 nautical miles may encompass up to three or four different reef systems and can span across four 30-minute CFISH grids. Although the logbook reporting system suggests that much of the position data is at a 6-minute grid level of precision, the data can only be confidently summarised to the 30-minute grid level.

8.4 Conclusions

A pilot observer program was developed and implemented to evaluate the effectiveness of using fishery observers to validate and enhance the commercial logbook data and collect additional biological information that could be used to monitor the status of the lobster stocks. A major outcome of the observer program was the collection of information on the operation of the fishery and the methods used for recording catch and effort. This information aided the assessment of the CFISH logbook data. Although anecdotal information and analysis of the logbook data suggest there may be some under recording of 'lobster tails' and discarded catch the 'live lobster' component of the catch recorded in logbooks appears to be reliable.

The observer surveys provided additional fishery information that is not available from the logbook system, such as depth, range of operation from the primary vessel and diver experience. Analysis of this data indicates a relationship between catch rate and diver experience, but no relationship with depth fished. Although the daily position information of the primary vessel may be accurately recorded in logbooks, the spatial resolution of the daily tender catch and effort data is coarse (~ 30 minute grid level) as tenders often fish up to 20 nautical miles from the primary vessel.

An ongoing observer program could provide information on the age structure of lobster stocks using gender and length frequency data collected by the observers. This data would assist stock assessment and monitoring of the impact of fishing on the east coast lobster stock. Overall the results suggest that a long-term observer program based on the methods tested in this project could effectively validate and enhance the commercial logbook information and collect additional biological data to assist with monitoring the status of the lobster stock.

9   SUB-PROJECT 3B. LOGBOOK DATA – ASSESSMENT OF LOGBOOK DATA

9.1   Background

Although the Department of Primary Industries and Fisheries (DPI&F) and the former Queensland Fisheries Management Authority (QFMA) have collected catch and effort data on the fishery via compulsory fisher logbooks since 1988, until recently a detailed assessment and analysis of this data had not been conducted. This project was developed in response to concerns about increasing catch and effort and declining catch rates and the need to assess and validate the commercial harvest records. One of the objectives of the DPI&F component of the project was to validate and assess the quality of the commercial catch and effort data and to analyse spatial and temporal trends in the data.

Figure 9-1. A page from the TRL04 logbook, which is currently used in the Queensland and Torres Strait commercial rock lobster fisheries.

As many of the fishers that operate in the ECTRLF also operate in the Torres Strait Tropical Rock Lobster Fishery (TSTRLF) a common logbook has been used for both fisheries since March 1996. Prior to 1996 a common logbook was used across a number of the Queensland fisheries. The data collected from the two fisheries is separated and AFMA (Canberra) maintains a database for the TSTRLF logbook data while the ECTRLF data is entered into the Queensland state CFISH database system maintained by the logbook section of DPI&F.

The current version of the logbook used in both fisheries is the TRLO4 (Figure 9-1), which was introduced in February 2003 as an update to the TRL03 logbook. The TRL04 logbook collects information by tender vessel on the fishing method (hookah, free-diving), total daily hours fished and the weights of 'live lobster' and 'lobster tails' harvested. A new voluntary field to record the numbers of lobsters captured in addition to the weights will allow estimates of the

average size of lobsters in the harvest. The daily position of the primary vessel is recorded in the TRL04 logbook as latitude and longitude. This is a change from the TRL03, which provided several options for recording position.

In 2002 the Queensland Rock Lobster Association (QRLA) conducted an audit of the ECTRLF harvest by collating product weights from processor facilities for the 2000 to 2001 period. The logbook section of DPI&F compared the independently recorded catch data with the logbook records for 2000/2001 and found that the logbook estimate of total catch was within a few tonne (less than 3% difference) of the total catch from the processor records. This suggests that catch data record by fishers in the logbooks for recent years is reasonably accurate.

Until recently the catch and effort information collected from various fisheries were stored within different databases in the CFISH system. The harvest fisheries data, which includes ECTRLF data, were initially stored within the *collection* database within the CFISH system. During late 2003 the data in the various databases (*trawl, mixed and collection*) were combined into one database called *cefish* to improve the efficiency of CFISH system and data extraction procedures.

Although the fishery managers have tracked catch and effort in the fishery using the logbook data, a thorough analysis of the data and its suitability for use in stock assessment had not been conducted prior to this project. The rapid expansion of the 'live lobster' fishery in recent years on the Queensland east coast instigated the need to assess the data and if possible, develop biological reference points for sustainable harvest levels. This chapter assesses the CFISH data and analyses the trends in catch, effort and catch rates both temporally and spatially.

9.2 Methods

9.2.1 Data Extraction and Assessment

A series of SQL queries were used to extract all of the relevant logbook data for tropical rock lobster from the *operation_species* and *operation* tables in the CFISH system. The *operation* table contains the daily vessel operation information and the *operation_species* table contains the catches of each species. The ornate tropical rock lobster (*P. ornatus*) catches are defined by the species code 703015, 'lobster – tropical rock', in the CFISH database. There are only two daily records of the species code 703800, 'lobster – cray tails' and five records of the species code 73000, 'lobster –unspecified', in the database.

The extracted data was loaded into tables in a Microsoft Access database. A series of queries were used to examine and rearrange the data into a single table of daily tender catch and effort. Each record in the new table contained all of the catch, fishing effort and position information for each daily tender record that was originally entered from fisher logbooks. Catch has been recorded both as *'whole'* or *'live lobster'* and *'lobster tails'*. A standard conversion ratio of 2.325 was used to transform the weights of *'lobster tails'* into the equivalent of *'whole' or 'live lobster'* weight.

A series of queries were used to summarise the data contained in many of the key fields. Where appropriate, additional fields were added to assist with the analysis of trends in the data. A 'part day' or 'full day of fishing' code was assigned to records where the number of hours fished were recorded. A spatial 'strata' code was also assigned based on the accuracy and type of position data reported. This 'strata' code was used to analyse spatial trends in the data. The summarised data was compared with the results of summaries compiled by the logbook section and the Queensland Lobster Association to ensure that all of the data had been extracted and correctly imported into the research database. This process identified a number of errors and inconsistencies, which were followed up by checking data records against the original fisher logbook sheets. The information obtained from the observer component of the project aided the

interpretation of the logbook data and identification of potential improvements to the logbook system.
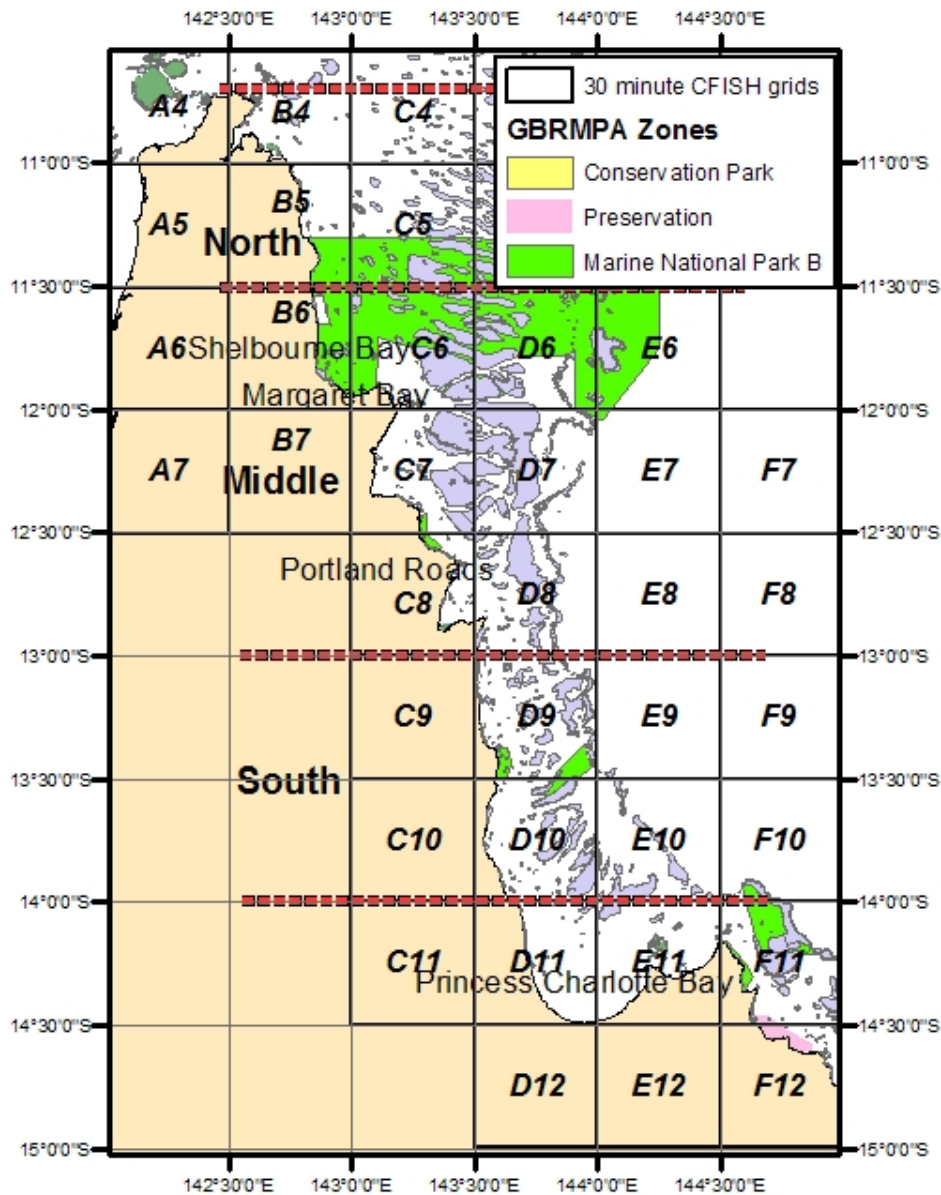
Figure 9-2. **CFISH grids and stratification of the fishery into North, Middle and South (red dotted lines).**

As the CFISH data was split into *trawl, mixed* and *collection* subsections when the project commenced, download scripts were initially run on all three sections to ensure that all of the lobster data was obtained. In August 2004 all of the lobster data was downloaded from the combined database *(cefish)* and re-analysed. This was done to include the complete logbook data for 2003 in the final analyses for this report and to ensure that the problems identified by the project had been addressed. As most of the lobster logbook records for 2004 were entered by early November the data was downloaded a final time and the analysis updated to include the trends for 2004.

9.2.2 Spatial stratification of the data

Eight spatial regions or strata were applied to the logbook information to assist with the checking and analysis of the data (Table 9). Strata 1 to 3 were used to divide the fishery into the north, middle and southern sections of the fishery on the Queensland east coast (Figure 9-2). The area of the fishery on the west side of the Cape York (strata 4) is essentially unfished although it is part of the area of the fishery as defined under the management arrangements. Stratum 5 was used to flag records that had only 'east coast' as the position information. These records were assumed to be within the fishery so were used in the analysis of total catch and effort. They could not however be used in the spatial analysis of the data. Strata code 6 was used to flag records that were within the boundaries of the Torres Strait Lobster Fishery according to the position information associated with the records. Strata code 7 was applied to the small number of records that are in CFISH grids to the south and east of the fishery and on landlocked 30-minute CFISH grids. A strata code of 8 was applied to records that had no useful position information.

9.2.3 Analysis of spatial and temporal trends

The spatial and temporal trends in catch, effort and catch rates were analysed using data for all records except those that were identified as being within the legislative boundaries of the Torres Strait Rock Lobster Fishery. Data from the entire time-series (1988-04) was used to summarise the annual trends in catch and effort. Due to the low number of records in the earlier years and to exclude data where there were less than five vessels operating in the fishery, only the years 1996-04 were used for the analysis of catch rate trends and seasonal trends in the data.

Table 9.   Strata assigned to assist with the spatial analysis of the data.

Strata	Name of strata	Description
1	North	Between Northern Boundary of EC fishery and the Northern edge of East Coast Northern Green Zone. CFISH grids: B4, B5, C4, C5, D4, D5 Note: the sections of grids B4, C4 & D4 north of latitude an 10° 41'S are part of the Torres Strait Fishery.
2	Middle	Between Southern boundary of Northern Green Zone and South of Cape Direction (13° S) and includes the Margaret Bay. CFISH grids: C6, C7, C8, D6, D7 & D8
3	South	Between 13° S and the Southern Boundary of the fishery (14°) CFISH grids: D9, D10, E9 & E10
4	West	Gulf of Carpentaria, between the 25 nautical mile offshore line and the shore, south of latitude 10° 48'S
5	Fishery General	East Coast- No further detail of position information provided. Assumed to be within legal boundaries of ECTRLF.
6	Torres Straits	Records inside the boundary of the Torres Strait Lobster Fishery
7	Outside Fishery	Records not allocated to strata 1 to 6.
8	No position data	Records with no useful position information.

9.2.4 Licence data

DPI&F and the former QFMA maintain records of the licence data for both the Torres Strait and East Coast lobster fisheries. In 1996 QFMA implemented a limited entry policy, which prevented the addition of new primary vessel and tender licences to the Queensland Tropical Rock Lobster fishery. As a result of this policy records have been maintained on the number of valid primary vessel and tender licences since 1996. As licence renewals or transfers can occur at any time, the number of active primary tender vessel licences can change slightly during the fishing season. To account for the slight variation in endorsements during the season, licence

information was downloaded for the 1st July each year since 1996. It was assumed that there would be fewer vessels with non-current licences in July than during the Christmas/New Year period when vessels were usually in port for refitting and crew holidays. The licence data allowed identification of primary vessels that were endorsed to fish both the Torres Strait and Queensland east coast lobster fisheries (dual endorsed vessels) and estimation of the annual potential fishing effort.

9.2.5   Estimation of potential and latent effort

Annual fishing times of single and dual endorsed vessels were analysed for trends in the average and maximum number of primary vessel days fished each season. The potential primary and tender effort of the fleet was calculated based on the number of primary and tender licences current at the 1st July each year and the total number of days in the fishing season minus an allowance for downtime. The potential numbers of primary and tender days were then compared to observed annual effort to estimate the latent effort in the fishery.

9.3   Results and discussion

9.3.1   Data Assessment

The initial process of downloading, summarising and checking the contents of various fields in the *collection* database identified a number of errors and inconsistencies in the lobster data. These errors and inconsistencies have been addressed by project staff liaising with the logbook section of DPI&F. The following analysis is based an on all the lobster records present in the CFISH database during early November 2004. At that time most of the logbook data for the 2004 lobster fishing season had been entered. Analysis of this download shows that the logbook section of DPI&F has addressed the problems identified by the project. This has improved the accuracy and reliability of data summaries produced from the CFISH database for the Fishery Managers.

9.3.1.1   *Lobster data recorded under fishery codes other than harvest*

The records within the CFISH database are grouped by fishery codes that are based on the logbooks used in the various Queensland fisheries. The main fishery codes are *harvest*, *line*, *mixed*, *net/crab* and *trawl*. A recent addition is the *Charter* fishery code used to record catches of charter fishing vessels. Although most of the catch of the east coast lobster fishery was entered under the *harvest* fishery code a check was conducted of the lobster catches recorded under the other fishery codes in the CFISH database.
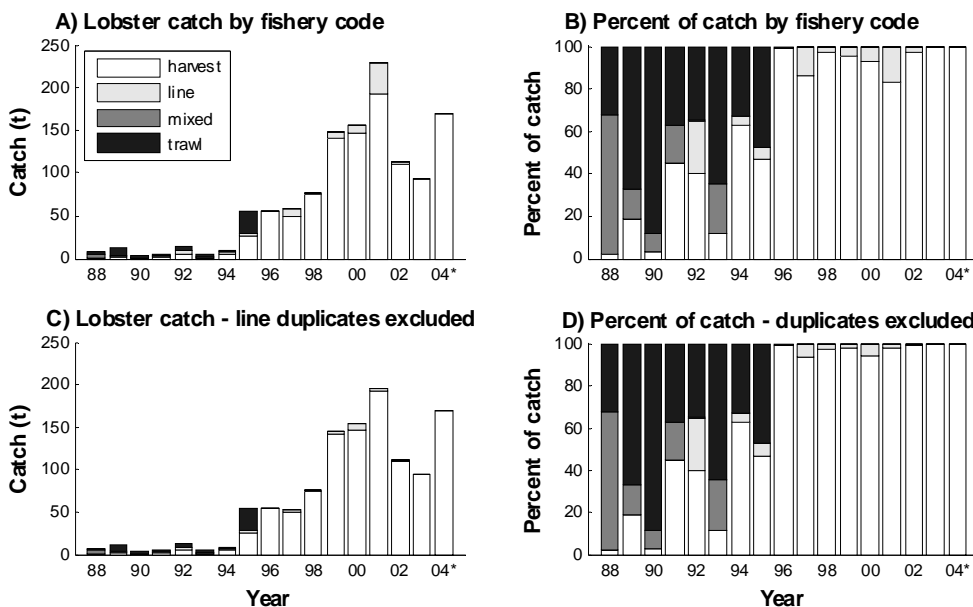
Figure 9-3. Analysis of the amount of lobster catch recorded under the *harvest, line, mixed and trawl* fishery codes.* Note that the 2004 summaries are based on incomplete data.

The summary of lobster data presented in Figure 9-3 is based on all *harvest* records and the subsets of records north of 14 degrees latitude for the *line*, *mixed*, *net/crab* and *trawl* fishery codes. This restriction was needed to reduce the size of the data extractions to a manageable size and eliminate records that were not relevant to area of the lobster fishery. The *Charter* and *net/crab* fishery data was not included in Figure 9-3 as there are only 27 records with a total catch of about 0.1 tonne under the *Charter* code and one record under the *net/crab* code.

Although the recorded lobster catch from trawlers for the entire Queensland east coast during 1988-99 is 220 tonnes, 146 tonnes of this catch was from three deep-water grids (J18, K18 and K19) southeast of Innisfail (18° S latitude). Most of this catch was listed under the general lobster code (703000) and should be recoded as 'barking cray' (703040), which is targeted by trawlers in that area. Prior to the late 1990's it was legal for trawlers operating on Queensland east coast to retain tropical rock lobster obtained as byproduct during prawn trawling operations. There is a small amount (53 tonne) of lobster catch recorded by trawlers north of 14 degrees latitude for the year 1988-96. Except for 1995 when the catch was 25 tonnes, the annual lobster catch of the trawl fishery was about four tonnes. The daily lobster catches recorded by individual trawlers north of 14 degrees is similar to that observed by Clive Turnbull (pers. comm.) whilst conducting lobster tagging (1984) and prawn sub-sampling (1993-94) studies on commercial trawlers operating in Torres Strait. There are higher catches recorded during 1995 that suggest some of the trawlers encountered groups of migrating lobsters.

Although a considerable quantity of lobster has been recorded under the *line* fishery code for the years 1997-02, most of these records were identified as duplicates of catch recorded under the *harvest* fishery code. There are large blocks of daily vessel records in the *line* fishery data that match with the same vessels, dates and catches in the *harvest* fishery data. For these blocks of data the sum of the daily individual tender catches stored under the *harvest* records exactly match the daily primary vessel catch records for lobster, stored under the *line* records. The effect of excluding the duplicate records in the *line* data is shown in Figure 9-3. The highest level of duplication was 34.4 tonnes of catch in 2001, which if included as additional catch makes the estimated catch for that year about 30 tonnes higher than the results of the

independent lobster catch audit conducted by the Queensland Rock Lobster Association. During the years prior to 1994 a small quantity of catch was also recorded under the *mixed* fishery code, possibly due to a variety of logbooks being used during those years. In addition a small quantity of lobster was retained in the area of the ECTRLF as byproduct of prawn trawling operations prior to 1997.

As most of the lobster catch, especially since 1996, were stored under the *harvest* fishery code and there are problems in trying to compare the fishing effort associated with the various fishery codes, the remainder of the data assessment and analysis is based on just the *harvest* fishery records. The total annual catches shown in Figure 9-3 were however, used in the stock assessment model where it is important to capture the total annual removals of lobsters from the population in the stock model.

9.3.1.2 Feedback to database section

An important output of the project was the feedback provided to the logbook section of DPI&F when project staff visited Brisbane to discuss problems identified in the data. Checks of potential errors in the electronic data were made against the paper copies of the log sheets and the electronic records were corrected if necessary. The feedback to the logbook section also included a PowerPoint slide show that could be used to enhance their background knowledge of the east coast rock lobster fishery. The main problems that were identified and discussed with the logbook staff are detailed below.

9.3.1.2.1   Recording of tender catch and effort

An error was identified in the design and set up of the *collection* database data entry forms and the method in which the data entry forms were linked to the operation species and operation data tables. It was found that when a tender had reported catches of both 'live lobster' and 'lobster tails' two operation numbers per tender vessel fishing day where created in the database. Previously it was assumed that each combination of 'boat_record_number', 'operation_date' and 'operation_number' uniquely identified each 'daily tender day' of fishing in the database. As a result of this assumption the queries used to summarise the fishing effort double counted effort when tenders had recorded both 'live lobster' and 'lobster tails'.

This error was reported to the database managers, and subsequently fixed by re-assigning the operation numbers associated with each logbook entry. The data was then re-extracted from the CFISH system. Analysis of the new summaries of the data identified significant differences in the estimates of tender vessel effort between the first and second extracts (Figure 9-4). The new annual estimates of tender effort were up to 15 percent less than the original estimates.

A) Original and revised estimates of effort   B) Percent decrease in the estimate of effort
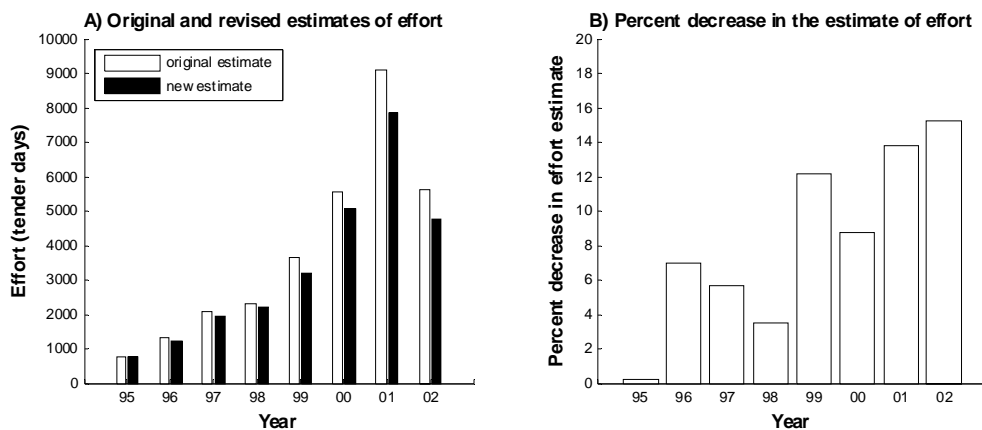
Figure 9-4   The absolute (A) and percent (B) reduction in the estimated annual effort (tender days) as a result of the changes made in the CFISH database to associate the daily catches of 'live lobster' and 'lobster tails' with a single operation number.

9.3.1.2.2   Reporting of 'lobster tails'

As the majority of vessels fishing on the east coast in recent years have targeted live product it was expected that reassignment of operation number and catch types would have reduced the estimates of daily tender effort by almost a half rather than 18 percent. The observer surveys indicate that there is a small component of 'lobster tails' associated with 'live lobster' catches (12% on average). Similarly the CFISH data for the years since 1995 indicates that when tenders have reported both 'live lobster' and 'lobster tails' the later comprise about 9 percent of the total catch weight. However, the number of tender days where both catch types were reported comprises only 13 percent of the total records since 1995. The logbook data also indicates that for 76 percent of the primary vessel days and 82 percent of the daily tender days only 'live lobsters' were reported. Catches consisting entirely of 'lobster tails' were reported for only five percent of the tender days.

The possible explanations for the low percentage of records reporting both 'live lobster' and 'lobster tails' are:
▪ The majority of the fleet was only capturing live animals with no 'lobster tails' as by-product. The observer surveys suggest that this is an unlikely explanation.

▪ The on-board processing methods were such that the 'lobster tails' were only weighed upon unload of the frozen product, and therefore not reported on a daily basis. However there was little evidence in the logbook records of vessels reporting bulk data upon unload.

▪ That on dual endorsed vessels 'live lobsters' were reported on a daily basis in the logbook and the 'lobster tails' were weighed and reported upon unload in the Torres Straits and therefore not recorded as part of the Queensland east coast catch.

▪ The entire product unloaded from tenders was weighed and reported as 'live lobsters'. The dead and low quality lobsters were then removed and processed.

Through communication with commercial fishers (including members of the QRLA at the January 2003 meeting), observation of the on-board processing, and further investigation of data trends, it was found that the answer was most likely a mixture of the above possible explanations. Observer surveys estimated that 'lobster tails' comprised on average 12 percent of the 'live lobster' catch. Discussion with members of the QRLA at the January 2003 meeting suggested that 'lobster tails' component of the catch varied between 5 to 50 percent, depending

on the time of the year and weather conditions. It was agreed that on average, 10 percent would be a good estimate of the average proportion of 'lobster tails' in the total lobster harvest.

9.3.1.2.3   Other data entry issues

The following data entry errors and inconsistencies were identified and discussed with the logbook staff during the initial analysis of the lobster data.

Incorrect species coding: There were 206 records of trunk and 4 records of gutted product types (weight type codes) in the database. These were not valid product types for Tropical Rock Lobster. A 112 tonnes of barking crays were coded as Tropical Rock Lobster (703015) within the CFISH *Trawl* database. These records were identified from the position information and fishing method reported and appropriate species code applied.

- Duplicate records: Cases were discovered of the same catch being entered due to fishers recording their catch in two separate logbooks. This was also combined with entry of daily totals for primary vessels along with duplicate reporting of daily tender catches.

- Incorrect species/ product coding: There were a number of records of 'gilled and gutted' or 'trunked' product, which had been assigned a lobster species code. Checks against the original log sheets revealed that these records were for fish species that had been incorrectly coded.

- Weight conversion factors: 20 records of tails catch had been assigned a weight conversion factor code of 1, instead of 2. These records were therefore not multiplied by the correct conversion factor of 2.325.

- Re-analysis of the CFISH data during September 2004 indicated that most of these issues had been addressed.

9.3.1.3   Bulk data

The data was checked for bulk record entries by subtracting the start date from the end date of each operation. Only five bulk records were found for one vessel during 2000. The bulk records were flagged, as they cannot be used for estimation of average daily tender catch rates. These records also create a problem when estimating total daily tender effort, as there may have been more than one tender operating from the primary vessel. It is possible that some of the daily primary vessel records that have only one operation number associated with them, indicating only one tender, may also represent bulk data. A check of these records indicates that some have high catch rates, up to 600 kilograms per day so they may in fact represent the catch of two or more tenders. Unfortunately there is no way to check these records to determine if they are the combined catch from several tenders or just unusually high catch rates.

9.3.1.4   Hours fished per day

In 1991 a fishing hours field was added to the logbooks. The percentage of daily fishing records with fishing time recorded has varied annually between 38 and 96 percent coverage of the data (Figure 9-5). The average number of hours fished per day has increased from 4 hours to almost 8 hours in 2003 suggesting that fishers are working longer days than they have in the past.
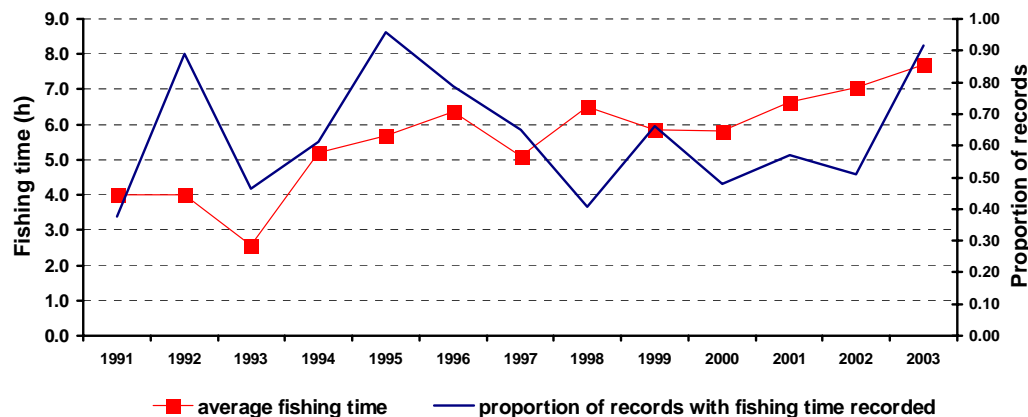
Figure 9-5.   **Average daily fishing times and the proportion of records with fishing time recorded.**

Although the recorded fishing times range from less than half an hour (the zero category in Table 10) to 16 hours most of the records are between 4 to 9 hours and there is a clear mode at 8 hours. The daily catch rates (Table 10) increase with fishing time to 49 kilograms per day at nine hours. At higher fishing times the catch rates are variable due to the low number of records and the inherent variability of catch rate data. The two fishing times less than one hour may be errors as the catch rates are high for such a short time period.

Table 10.   **Distribution of fishing time and the daily catch rates associated with each fishing time interval.**

Fishing time (Rounded to hours)	Number of records	Catch Rate (kg / tender day)
0	2	24
1	257	9
2	695	9
3	968	15
4	2,248	20
5	1,706	27
6	2,355	28
7	2,054	28
8	6,122	40
9	2,005	49
10	141	73
11	2	39
12	13	153
13	1	13
14	1	93
16	1	70

A 'part-day'/ 'full-day' code was applied to each daily record to assist with standardisation of the catch rate data for the stock assessment models. The observations made during the commercial observer surveys and the information in Table 10 suggest that a part-day code should be assigned to records where the recorded fishing time was less than 4.5 hours. A full-day code was assigned where fishing time was greater than or equal to 4.5 hours. Records with no fishing time recorded were assigned a 'null' code.

Table 11. **The percentage of records assigned a 'null', 'part-day' or 'full-day' code.**

year	Percent of records assigned a 'null' code	Percent of assigned a 'part-day' code	Percent assigned a 'full-day' code
1988	100.0	0.0	0.0
1989	100.0	0.0	0.0
1990	100.0	0.0	0.0
1991	62.4	37.6	0.0
1992	11.1	86.1	2.8
1993	53.6	46.4	0.0
1994	38.9	28.9	32.2
1995	4.0	32.1	63.8
1996	21.5	29.5	49.0
1997	34.8	30.8	34.4
1998	59.4	13.2	27.4
1999	33.7	30.9	35.3
2000	52.2	21.1	26.7
2001	42.9	15.8	41.3
2002	49.2	7.1	43.8
2003	8.3	8.7	82.9

An average of 66 percent of records since 1991 have fishing time recorded and approximately half of these records were assigned a 'part-day' fishing code (Table 11). The proportion of days assigned a 'part-day' code is much lower in recent years indicating that fishers are generally working longer hours and more intensively than they did in the 1990's.

9.3.1.5 *Fishing method*

Although the log sheets are designed to record whether lobsters are caught by 'hookah diving' or 'free diving' all of the records in CFISH have been assigned a general 'diving' code with the exception of 104 records in 2001 and 60 records in 2002 that have no code assigned. It is quite likely that at least some of the records should have been assigned a 'free diving' code. Anecdotal comments from commercial fishers suggest that both hookah and free-diving methods have been used extensively in this fishery, although hookah is now the major fishing method. It is important to distinguish between the two fishing methods as CSIRO (Pitcher *et al.,* 2002) have shown hookah diving can produce significantly higher catch rates than 'free diving' within the Torres Strait fishery.

9.3.1.6 *Spatial information*

Analysis of the fields containing the spatial data revealed that six percent of the records (1,666) reported only colloquial reef names used by fishers or were labelled as 'East Coast'. Commercial fishers assisted in identifying these colloquial reefs names in order to assign a grid reference. The list of colloquial reef names was forwarded to the logbook sections of DPI&F and AFMA so that the colloquial reef names could be assigned position reference. This has increased the quantity of data available for spatial analysis.

A 'position precision' code is used to flag the method and accuracy of recording the position data recorded by fishers on their logsheets.
The codes are:
- Null or zero; no position data.
- 0.25; 30-minute CFISH grid reference, i.e. 30 nautical miles.
- 0.005; 6-minute CFISH grid reference, i.e. 6 nautical miles.
- 0.008; a latitude and longitude reference.
- 0.004; a specific reef reference name was provided instead of a grid or latitude and longitude.

Table 12 shows the changes in reporting of vessel fishing positions over time. In the early years (1988-90) all of the records were at the 30-minute CFISH grid reference level. In the early 1990's the option of recording a specific reef reference name (position precision code 0.004) instead of a grid reference was added to the logbooks and most fishers adopted this option. The problem with this option however is the ambiguity associated with some of the common reef names and the use of non-standard colloquial names. The uptake of Global Positioning Systems (GPS) by fishing vessels during the 1990's has made it easier to report a latitude and longitude reference. Therefore the new TRL04 logbook only has provision for recording the daily latitude and longitude position reference of the primary vessel. This change is clearly reflected in the 2003 records.

The observer program noted that tenders often travel up to 20 nautical miles away from the primary vessel during fishing operations. As fishers are only required to report the daily position of the primary vessel the spatial resolution of the catch data is in reality course, therefore the results of spatial analysis at a finer level than the 30-minute grids should be viewed with caution.

Table 12.   The position reporting method as percentage of the annual number of records.

year	null or zero	Reef name	Latitude & longitude	6 minute grid	30 minute grid
1988	0.0	0.0	0.0	0.0	100.0
1989	0.0	0.0	0.0	0.0	100.0
1990	0.0	0.0	0.0	0.0	100.0
1991	38.3	0.0	0.0	0.0	61.7
1992	0.0	94.5	0.0	1.9	3.6
1993	3.6	78.6	0.0	7.1	10.7
1994	0.0	61.1	3.3	0.0	35.6
1995	2.0	76.5	1.6	0.8	19.1
1996	6.2	85.7	0.2	1.1	6.8
1997	3.0	79.3	7.5	6.7	3.6
1998	4.0	56.1	7.0	4.6	28.3
1999	4.9	70.8	16.0	1.5	6.9
2000	10.0	82.2	5.9	0.8	1.1
2001	2.4	84.7	0.1	0.8	12.0
2002	3.5	75.4	0.1	19.0	2.1
2003	1.8	0.0	98.2	0.0	0.0

9.3.1.7 Spatial stratification of the data

A small proportion of the records (1.8%) have fishing positions recorded within the boundaries of the Torres Strait Rock Lobster Fishery. These records account for only five percent (50.6 tonnes) of the total catch for the years 1988-04. Although the highest proportion of Torres Strait data was in the early years (1998-94), an average of 42 percent of the data and 50 percent of the catch, the total number of records in the database for those years was low (936 records). Since 1994 the Torres Strait records have comprised only 1 percent of the data and 3.4 percent of the catch. The year with the highest level of Torres Strait catch was 1998 with 11.7 tonnes; this however represents only 13 percent of the catch and 2.1 percent of the records for 1998. All of the records that were coded as having a Torres Strait position (strata 6) were excluded from any further analysis of the data.

The north, middle and south strata account from most of the records in the database and were analysed separately to determine annual and seasonal trends in catch and effort. The remaining strata, 4, 5, 7 and 8 comprise a small amount of the data so were grouped together as 'other' in the analyses. Only 1.3 percent of records had no useful position information (strata 8) while 0.5

percent of records had positions that were outside of the bounds of the fishery (strata 7). These records may be largely errors as many of the positions are on land or in unlikely/impossible fishing locations. The records with an 'East Coast' position reference (strata 5) comprised 2.5 percent of data and there are only 19 records for the Gulf of Carpentaria section of the fishery (strata 4).

9.3.1.8   Distribution of Catch and Effort by CFISH grids

The majority of the fishing effort and catch of Queensland east coast tropical rock lobster is reported within three 30-minute CFISH grids (Figure 9-6). The three grids are; C5 which represents the fishing area north of the Shelbourne Bay Cross Shelf Marine National Park, C6 which covers the reefs east of Margaret Bay and C7 which includes the reefs between Margaret Bay and Portland Roads. The latter is the most heavily fished and with 50 percent of the catch and effort of the entire fishery during the years 1996-03. During the 2000-01 period grid C7 accounted for just over 60 percent of the total fishing effort but by 2003 this had decreased to 26 percent as effort shifted to the northern section (grid C5) of the fishery. The most heavily fished grid in the southern section of the fishery (strata 3) is grid D10, which includes the reef system to the north of Princess Charlotte Bay. This grid however still only accounts for about six percent of the fishing effort during the years 1996-03.
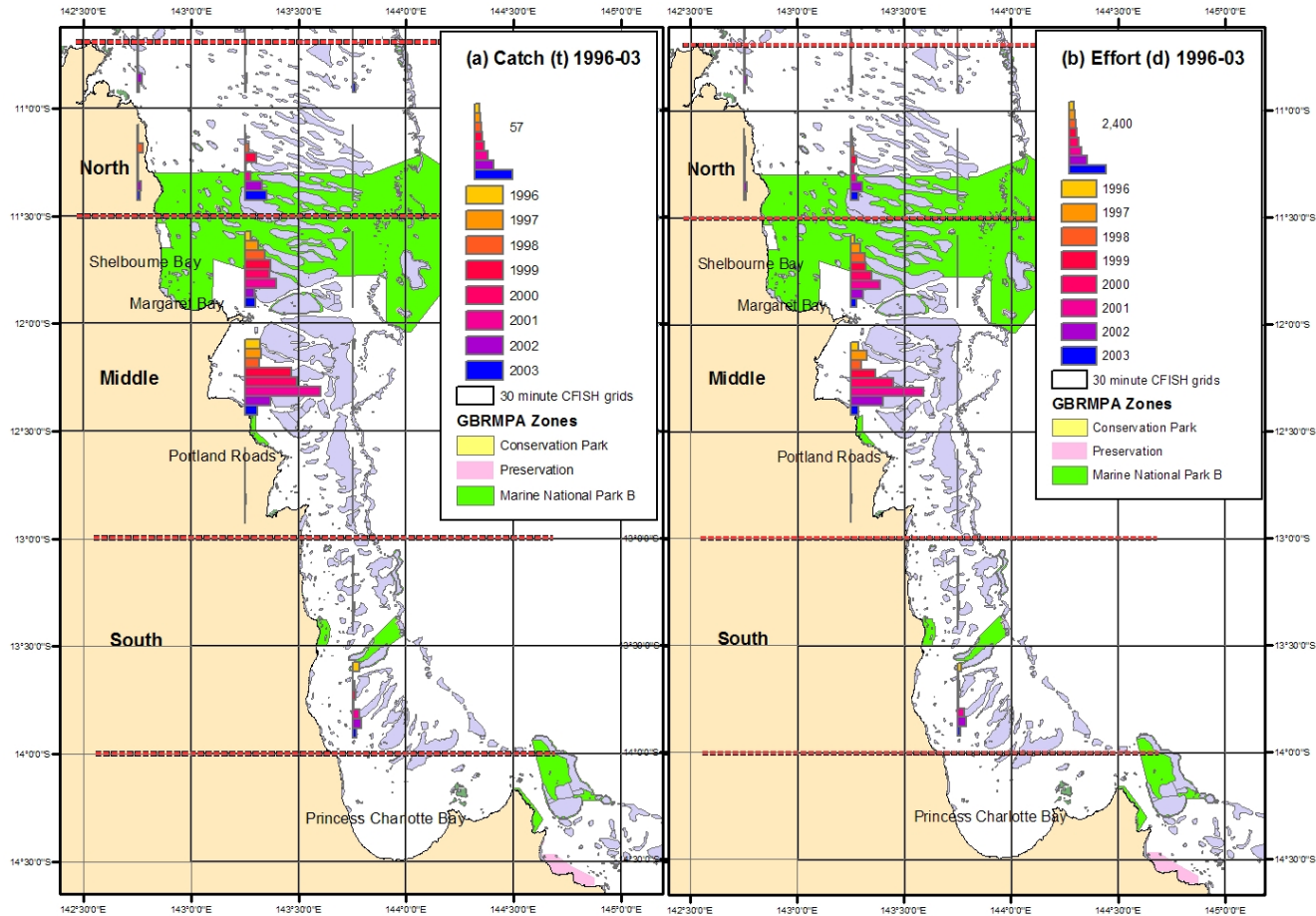
Figure 9-6 Map of the fishery showing the catch and effort for the years 1996 to 2003. The red dotted lines indicate the divisions between the north, middle and south strata.

9.3.2   Annual Trends in catch and effort

9.3.2.1   Catch

Since the start of logbook records in 1988 the annual recorded catch of the fishery (Figure 9-7) has ranged from 137 kg in 1990 to 192 tonnes in 2001. As the 'live lobster' export fishery developed during the late 1990's the annual catch rapidly increased from very low levels in the early 1990's to a distinct peak in 2001. The peak in catch reflects a peak in fishing effort in 2001 (Figure 9-8) that was partly driven by low catch rates in the Torres Strait Rock Lobster Fishery. Note that the final totals presented for 2004 may be higher than shown.
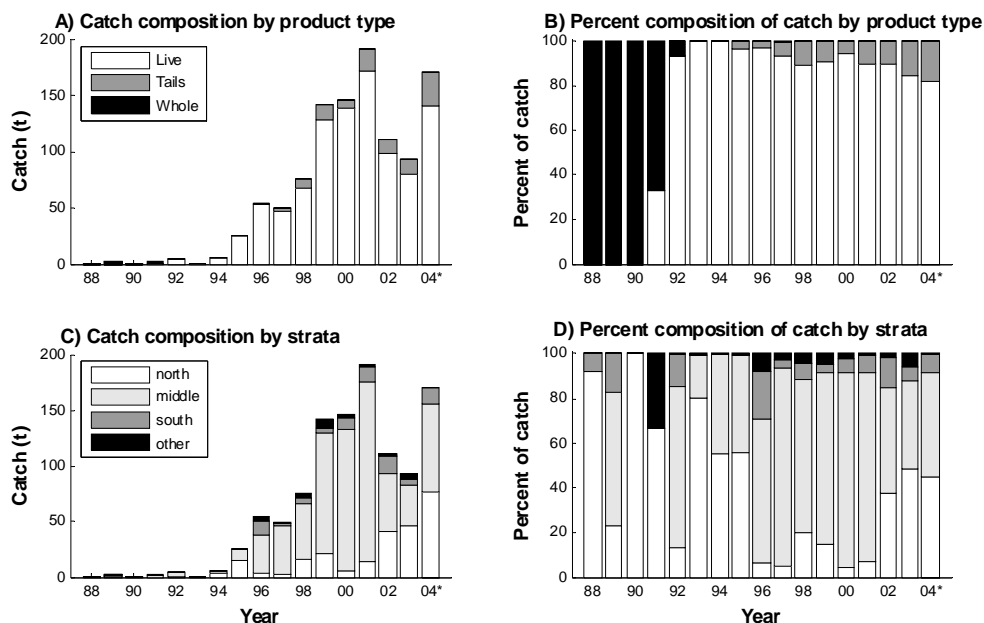
Figure 9-7.   Annual size and composition of the catch by product type (A & B) and strata (C & D). The weight of 'lobster tails' product was converted to equivalent whole weight. * Note that the 2004 summaries are based on incomplete data.

During the early years of logbook records all or most of the catch was recorded as whole frozen lobster (Figure 9-7). In contrast since 1992 most of the recorded catch is live lobster. The small percentage (~10%) of lobster tails since 1995 is largely a by-product of live lobster fishing operations. Prior to 1996 the small amounts of catch recorded was often harvested in the north stratum. In contrast most of the catch for the years 1996-2001 was derived from the middle stratum of the fishery. In recent years about 40 percent of the catch has come from the north stratum.

9.3.2.2   Effort

The tenders, which usually have only one diver, are the basic fishing unit; therefore the best measure of fishing effort currently available for this fishery is the number of 'tender fishing days'. The number of 'primary vessel fishing days' (days on which catch was recorded for a primary vessel) is an unstandardised measure of fishing effort as the number of tenders and divers varies markedly between primary vessels, depending on the number of tender licences assigned to the primary vessel. Figure 9-8 clearly shows the large change in fishing effort during the 1988-03 time-series of logbook data. Effort as 'primary vessel days' and 'tender days' rapidly increased to a peak in 2001 as the live export fishery developed on the Queensland east

coast. The number of primary vessels operating in the fishery also increased to a maximum of 26 in 2000. Most of the increase in effort occurred in the middle section of the fishery (Margaret Bay to Portland Roads). In 2002-04 effort declined substantially and a proportion of the remaining fishing effort was redirected into the northern section of the fishery.
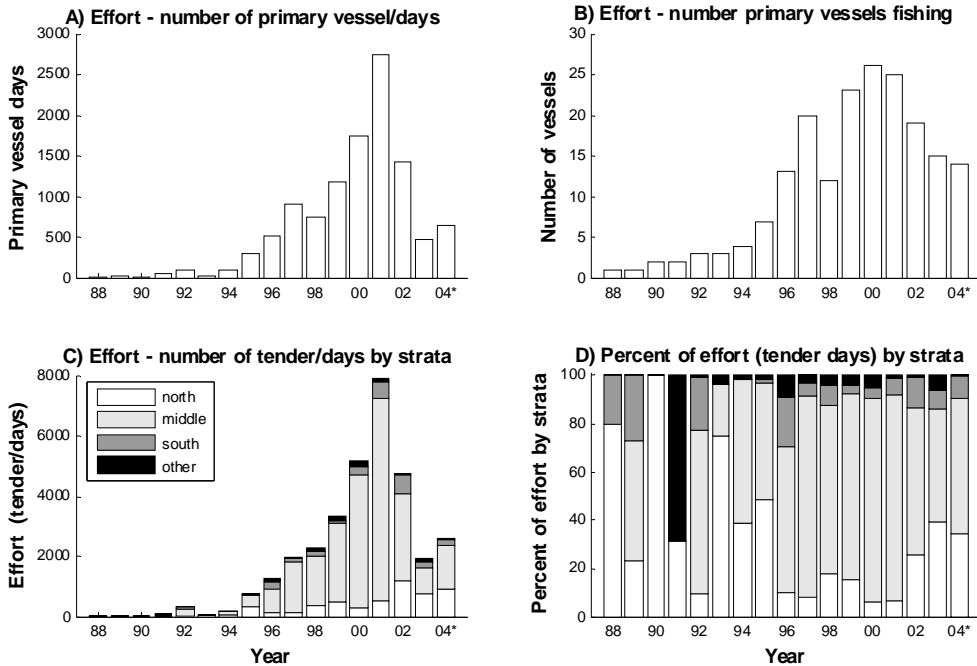
Figure 9-8. **Annual fishing effort as primary vessel days (A), number of primary vessels fishing (B) and number of tender days fished (C). Figures C and D also illustrate the distribution of effort across the strata. * Note that the 2004 summaries are based on incomplete data.**

9.3.2.3 Catch rates – Catch Per Unit of Effort (CPUE)

Catch rate data since 1996 is presented, as prior to that year the number of records in the database was very low and the number of primary vessels fishing each year was less than five. The low number of records results in highly variable catch rates that are more indicative of the average CPUE of specific primary vessels and fishing areas than the overall stock abundance.

Since 1996 the average catch rate based on all records has varied between 23 and 66 kilograms whole weight per tender day (Figure 9-9A). During the years 1999-01 catch rates decreased as fishing effort reached a peak in 2001. This trend in catch and effort was part of the stimulus for this project to examine the available data in more detail. The lowest catch rates in the time-series occurred in 2001-02. Although fishing effort was much lower in 2003-04 than 2001 catch rates have been much higher.

A) Annual catch rates for all records and each strata

B) Annual fishing effort for all records and each strata
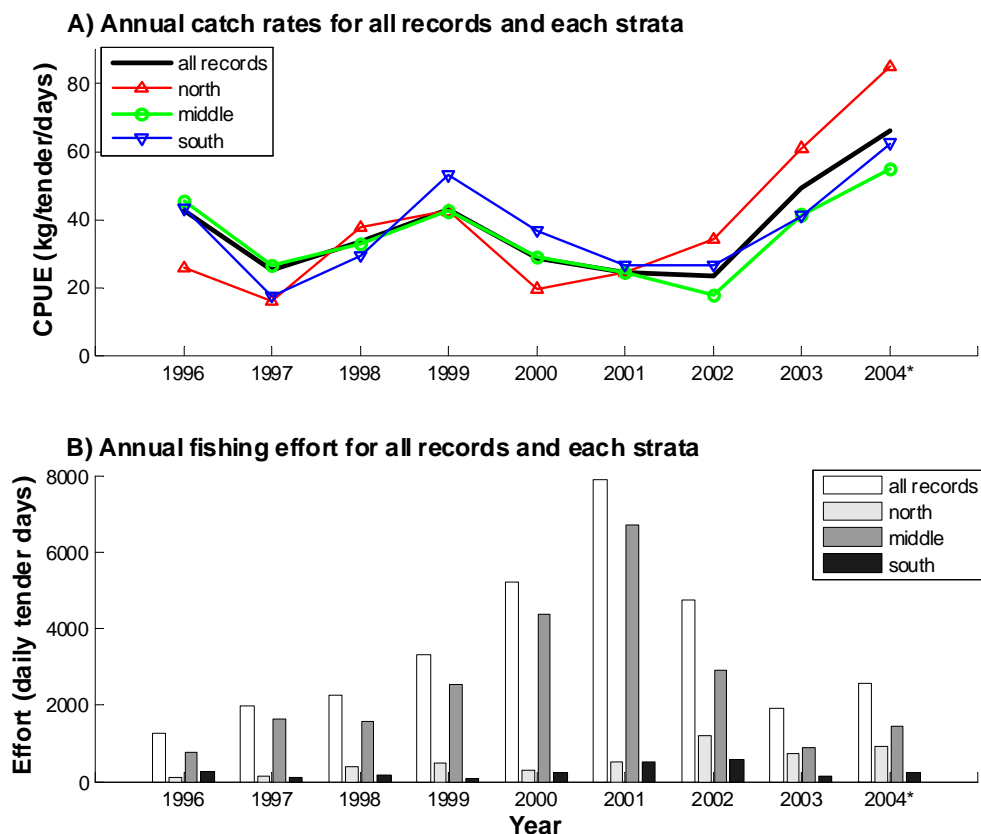
Figure 9-9.   **(A) Annual catch rates in kilograms per tender day for all records and by strata. (B) Fishing effort for all records and by strata. * Note that the 2004 summaries are based on incomplete data.**

Analysis of catch rates by strata shows that the three main fishing areas have followed the same general trend. The catch rates of the middle strata are closest to the overall trend, which reflects the concentration of effort in the middle strata. The lowest and highest catch rates occurred in the northern strata in 2000 and 2003 respectively. The shift of effort into the north stratum in recent years is probably due to the higher catches in that area in recent years. Anecdotal information from fishers suggests that the higher catch rates in the north may be associated with higher food availability, as they have observed high abundances of 'bastard' shell, which they fishers believe is a source of food for lobsters. 'Bastard' shell is a complex of black lip (*Pinctada spp.*) and mussel (*Mytilus spp.*) shellfish.

9.3.3   Seasonal Trends

9.3.3.1   Catch and effort

The monthly catch and effort data since January 1996 (Figure 9-10) indicates a slight season pattern in the fishing effort and catch. The consistently low fishing effort during November to January for the years 1996 to 2002 is likely due to a close down of fishing operations during the months around Christmas. This period is the height of the cyclone season so most fishers return to port for the festive season and to refit their vessels in the New Year. This trend is also shown in the Figure 9-11, which shows the average effort and catches for the years 1996-01. The anomalous spike in fishing effort and catch in September 1999 is largely due to the records of one primary vessel which appears to have maintained high catch rates for an extended period. In

2002, a seasonal closure was implemented to protect breeding populations during the summer breeding period. The closure dates are the 1st October until the 1st February in the subsequent year. Although the closure prevented fishing in October when catch rates were historically high, it is likely fishers were able to maintain overall catches by re-distributing their effort during the year.
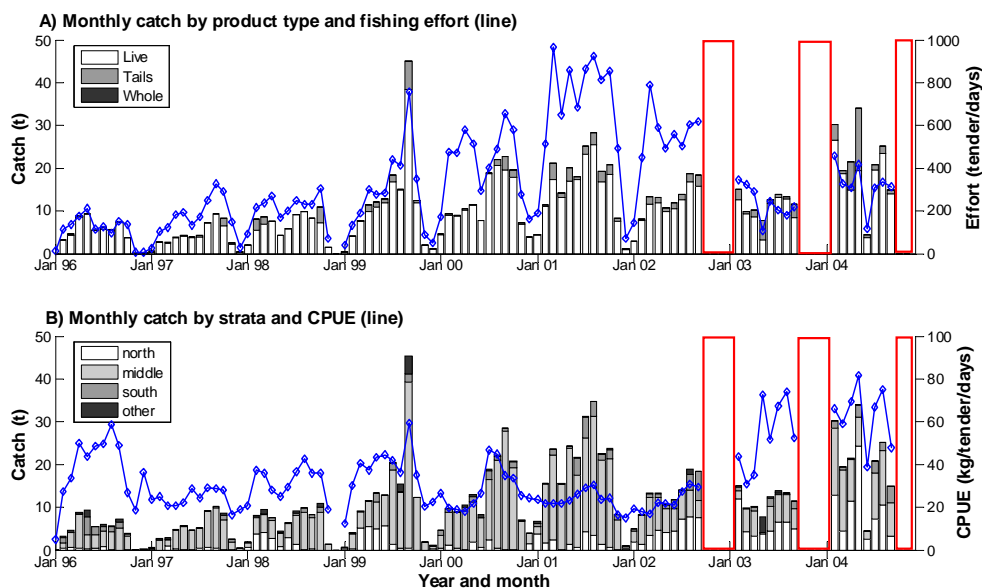
Figure 9-10.   **Monthly catch, effort and catch rates for the period January 1996 to May 2004. The rectangles indicate the four-month seasonal closure that was first implemented in October 2002. * Note that the 2004 summaries are based on incomplete data.**

Although monthly effort during 2003-04 was much lower than during 2000-02 the monthly catch rates (Figure 9-10B) were much higher than average for those years. The improved catch rates during 2003-04 could reflect either increased abundance of the lobster stock and/or an increase in the average fishing power of the active fishing fleet. Examination of the daily tender catch rates for primary vessels that have fished over the last four years suggest that the increased catch rates are due to an increase in stock abundance.

Data for the years 1996-01 was used to plot the average monthly fishing effort, catch and catch rates (Figure 9-11). The 2002-03 years were not included due to the implementation of the seasonal closure in 2002. The bars on the average plots indicate the lowest and highest values for each month in the time-series. The trends for a season of low fishing effort (1996) and high fishing effort (2001) were also plotted for comparison on each figure. It is interesting to note that the year of highest effort and catch (2001) had the lowest catch rates. The catch and effort is relatively flat over the year with a tendency for the highest levels to occur around August-September.
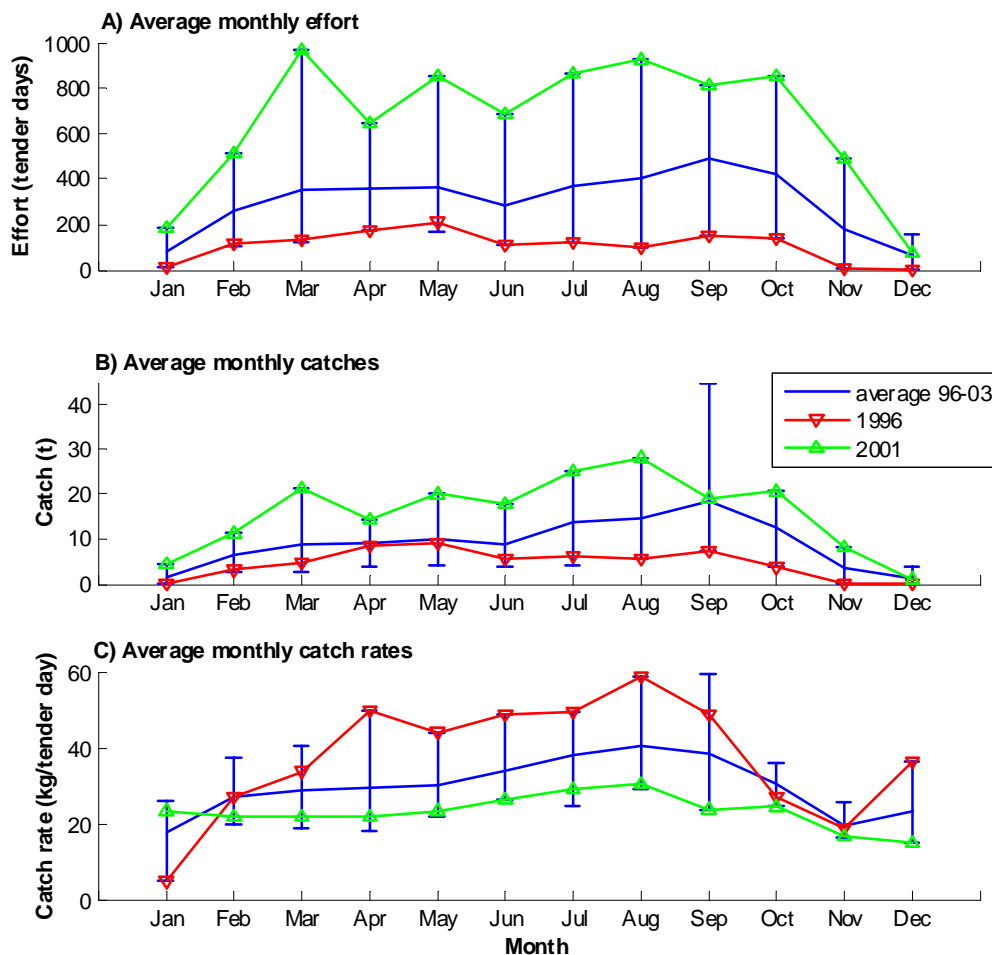
Figure 9-11. Average monthly fishing effort, catch and catch rates for years 1996 to 2001. The range bars indicate the highest and lowest value for each month. Each figure also shows the monthly values for a year of low fishing effort (1996) and high fishing effort (2001).

The plots suggest some seasonality in the catch rate with lower monthly catch rates recorded during November to January and higher monthly catch rates during July to September. In 1996, the monthly catch rates were well above average from April to September. In contrast the monthly catch rates for 2001 are all below the average with the exception of January. Catch rates during December-January tend to be variable due to the lower fishing effort during those months.

9.3.4 Licence data

The current east coast lobster fleet consists of 8 primary vessels that can only fish the Queensland east coast and another 20 primary vessels that are also licensed to operate in the Torres Strait lobster fishery. There are 94 tender licences assigned to the 28 primary vessels and 63 of these tenders are endorsed to fish in Torres Strait. The large number of dual endorsed primary vessels and tenders result in a fleet that is highly mobile and reacts to differences in catch rates between the two fisheries.

9.3.5   *Estimation of potential and latent effort*

Primary vessels cannot fish every day of the season as some of the potential fishing days are spent steaming and unloading or in port for vessel re-fits and crew holidays. A comparison of the maximum number of days fished by a primary vessel in each year with the number of days in the season (Figure 9-13) shows that prior to the seasonal closure implementation vessels are capable of fishing up to 269 days or 74 percent of a full year season. The average of the fleet however is much lower and peaked at 110 primary days during the 2001 season.

During years with a seasonal closure a higher percentage of the remaining season can be fished as the closure provides compulsory time for a refit and holidays. In the 2002 season, which was closed to fishing for three months, up to 212 primary days or 78 percent of the fishing season was fished. The decrease in the number of 'Days in season' during 2002 and 2003 (Figure 9-12) is a result of the introduction of the four-month seasonal closure. As the closure was first implemented in October 2002, January of 2002 was open to fishing resulting in an extra month of fishing time in 2002 compared to 2003.
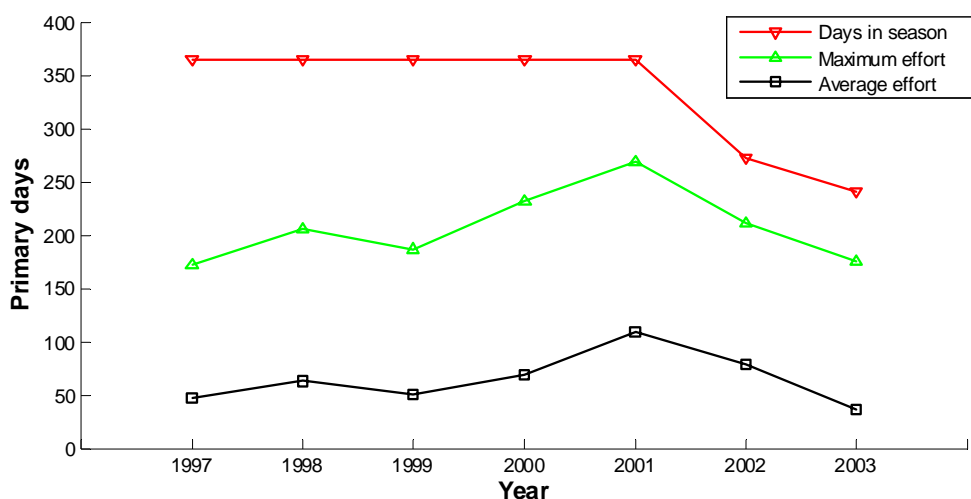
Figure 9-12.   **Average, maximum and potential fishing days per vessel per year**

A 'downtime' allowance of 25 percent for a full season and 20 percent for a year with a seasonal closure was used to estimate the annual potential fishing efforts shown in Figure 9-13. These allowances are based on the observed maximum primary day fishing effort (Figure 9-12).

Figure 9-13(A) shows that even during the years of highest effort (2000-02) there were a few licensed primary vessels that did not fish. Figure 9-13(B & C) show that even in the year of highest fishing effort (2001) there was still a large latent effort in the fishery. The large latent effort exists both as primary vessel days and tender days. Figure 9-13(D) shows that in 2001 the number of days fished were still only about 30 percent of the potential tender day effort.
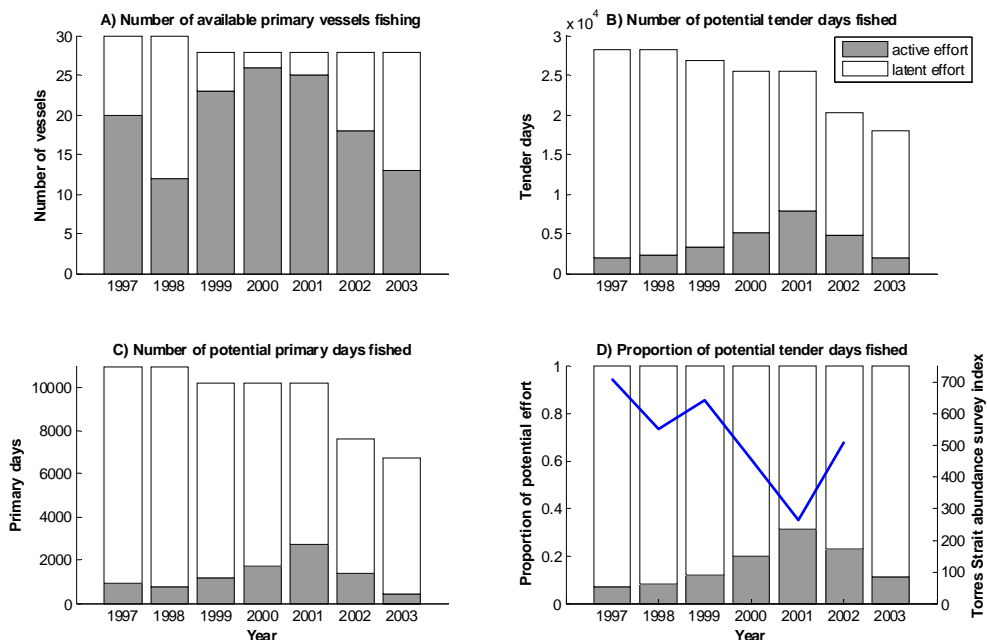
Figure 9-13.   **A comparison of potential and active effort, quantified as number of vessels, primary days and tender days. The scale on figure B is in ten's of thousands of tender days.**

The line in Figure 9-13(D) shows the CSIRO lobster abundance index for Torres Strait (Ye *et al.,* 2004). This index is estimated using fishery independent diver surveys conducted during May-June of each year. The fishing effort in the east coast lobster fishery appears to be inversely related to the Torres Strait abundance index. This is a result of dual endorsed vessels moving between the two fisheries to obtain the highest catch rates and profits.

Anecdotal information from fishers and processors suggests that the decline in fishing effort during 2002-03 was mainly due to dual endorsed vessels redirecting effort into the Torres Strait Lobster Fishery. Catch rates in that fishery increased significantly after the record low recruitment in 2000-01. Fishers operating on the Queensland east coast have also reported an increase in the abundance of smaller sized lobsters in recent years. This suggests a stronger recruitment in this fishery that is probably correlated with the increased recruitment observed in Torres Strait during recent years.

9.4   Conclusions

The CFISH commercial catch and effort records for the years 1988-2004 were accessed to determine the quality of the data available on Queensland east coast tropical rock lobster stocks. Trends in catch, effort and catch rates were then investigated. Although some lobster catch has been recorded under *line*, *mixed* and *trawl* fishery codes most of the data, especially since 1995, was recorded under the *harvest* fishery code. Much of the lobster data recorded under the *line* code appears to be a duplicate of data recorded under the *harvest* code. There is also a small (53 tonne) amount of lobster catch recorded by trawlers north of 14 degrees latitude for the year 1988-96.

A detailed assessment of the lobster catch data recorded under the *harvest* fishery code indicates that the data is generally reliable and can be used to monitor trends in fishing effort, catch and catch rates both spatially and temporally. Feedback was provided to the logbook section of

DPI&F on errors and inconsistencies in the CFISH lobster data. The feedback has improved the reliability of the summaries statistics used by Fishery Managers to monitor the status of the fishery. Further improvements could be made by educating fishers on the importance of accurately recording the total daily tender weights of all lobsters that are removed from the population including the discards and 'lobster tails'. Fishers tend to focus on recording the catch of 'live lobster' product and tend to ignore the poor quality lobsters that are discarded or 'tailed' and frozen.

The majority of the fishing effort and catch of Queensland east coast tropical rock lobster since 1996 was reported within the three 30-minute CFISH grids between Shelbourne Bay and Portland Roads in the middle section of the fishery. Annual trends in catch rates for these grids are however similar to catch rates for the northern and southern section of the fishery. Fishing effort in the northern section has been higher than average since 2001 due to higher catch rates that may reflect higher food availability and recruitment levels.

Logbook summary statistics clearly show the development of the 'live lobster' industry for the mid 1990's with effort and catch rapidly increasing to a peak in 2001. Declining catch rates in the Torres Strait lobster fishery also drove the rapid rise in effort as most of the fleet is endorsed to operate in both fisheries. Since 2001 fishing effort has declined to around one third of the 2001 level due to increased catch rates in Torres Strait and low prices for 'live lobster' during 2003 as a result of the SARS virus closing restaurants in Asia and China. It is unlikely that the reduction in effort was due to implementation of the seasonal closure in 2002, since fishers historically did not fish in November-January and their effort could be re-distributed throughout the year. Although annual catch declined during 2002-03 as fishing effort decreased, the 2004 catch increased to over 170 tonne due to a small increase in effort and a large increase in catch rates. The higher catch rates appear to be the result of increased stock abundance and a contraction of the active fleet to a small group of efficient fishers.

Although there is a high level of latent effort the risk that all of this effort will be activated in the near future appears low, as only 8 primary vessels are restricted to fishing on the east coast. Even in the year of highest effort, 2001, when the shift of effort from the Torres Strait to the east coast was highest due to the lowest ever recorded catch rates in Torres Strait, only about one third of the potential fishing effort was used. Harvest MAC is currently investigating mechanisms to reduce latent effort in the fishery.

9.5   References

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10 SUB-PROJECT 3C. ASSESSMENT OF THE STATUS OF THE QUEENSLAND EAST COAST LOBSTER STOCK

10.1 Background

The third objective of the DPI&F component of the project was to conduct a preliminary assessment of the status of the fishery if the catch and effort data was sufficiently reliable to apply a surplus production model. Although the recorded catch and effort in the ECTRLF was low prior to 1995 the data since 1995 is starting to provide a reliable time-series of catch and effort with sufficient contrast to fit a simple Surplus-Production (biomass dynamic) model. The Schaefer and Fox formulations of a Surplus-Production model were fitted to the total catch and standardised catch rates to provide an initial estimate of the sustainable harvest level for this fishery. Although the results of this study should be regarded as preliminary they provide managers and industry with a "ball-park" estimate of the potential sustainable harvest of the ECTRLF.

10.2 Methods

10.2.1 Data standardisation

The process of standardising the tropical rock lobster catch rates was similar to that used by Haddon and Hodgson (2000) for the Northern Prawn Fishery. Ideally catch rates or Catch per Unit of Effort (CPUE) is an index of the abundance of the species being fished. Other factors however, such as fishing method (free driving, hookah diving), the measure of fishing effort (hours, daily tender days), fisher experience, spatial variation in the distribution of the stock and seasonal changes in catchability of lobsters also influence the observed CPUE. The standardisation processes adjusts the annual CPUE time-series to more accurately reflect changes in the biomass of the lobster stock by attempting to account for the variation in catch rates that are caused by factors other than changes in stock abundance.

A Generalised Linear Model (GLM) was used to analyse daily tender catch records from all daily tender records flagged as being located within strata 1 to 3 (Figure 9-2). The response variate was the natural logarithm of the daily tender catches. The GLM included factors to account for variations in lobster catch rates caused by spatial variations in catches (strata) and part day versus a full day of fishing (Pday). There is also considerable variation between primary vessels in the average efficiency of the tenders fishing to each primary vessel therefore primary vessel was included as a factor in the standardisation of the data.

The statistical software Genstat 6 was used to carry out the analysis and the GLM included the following components:
- Catches – the daily tender weight of live product plus tailed product converted to equivalent whole weight.
- Year – a factor coded 1988 to 2004.
- Month – a factor coded January to December.
- Strata – a factor coded 1 (North), 2 (Middle) and 3 (South).
- Pday – a factor coded 0 (no fishing hours recorded), 1 (part day fished, <4.5 hours fished), 2 (full day fished, >= 4.5 hours fished).
- Vessel – a factor coded as an identifier for each primary vessel.

10.2.2 Surplus-Production Model

Surplus-production models are the simplest analytical method available that provides a full fish stock assessment (Haddon 2001). These models ignore age or size structure and do not

explicitly consider natural mortality, growth and recruitment. The most commonly used of these is the Schaefer form of the surplus production model. Only three main parameters are estimated which makes it simple and convenient to apply. These are the intrinsic population growth rate (*r),* the population carrying capacity (*K*; virgin stock size) and catchability coefficient (*q*). This model is well described by (Punt 1993), (Prager 1994) and (Haddon 2001) and relies on the annual standardised Catch Per Unit of Effort (CPUE) index being proportional to the trend in stock abundance. The Fox form of the production model was also applied to the standardised data.

Population biomass was calculated according to the simple function:

$$B_{t+1} = B_t + f(B_t) - C_t,$$

where $f(B_t) = rB_t\left(1 - \dfrac{B_t}{K}\right)$ was the Schaefer form and $f(B_t) = \log_e(K)rB_t\left(1 - \dfrac{\log_e(B_t)}{\log_e(K)}\right)$

was the Fox form of surplus production.

B_{t+1} was the exploitable biomass at the start of fishing year *t+1, r* was the intrinsic rate of population growth, *K* was the average unexploited equilibrium biomass (carrying capacity) and C_t was the observed catch during fishing year *t*. Initial biomass in the first year was calculated by setting it equal to *K*.

Standardised catch per unit effort data was used as an index to estimate biomass through

$\hat{cpue_t} = qB_t$.

The production models were fitted in Excel using solver by maximising the log-likelihood:

$$-\log\ell = \frac{n}{2}\left(\log_e(2\pi) + 2\log_e(\hat{\sigma}) + 1\right) + LLpen,$$

where *n* was the number of fishing years in the catch rate time-series,

$\hat{\sigma} = \sqrt{\sum_t \dfrac{\left((\log_e(cpue_t) - \log_e(\hat{cpue_t}))\right)^2}{n}}$ and, *LLpen* was a penalising term to minimise the

probability that the starting biomass B_1 was greater than carrying capacity *K*.

10.3 Results and discussion

10.3.1 Data standardisation

The standardisation attempts to account for factors other than stock abundance that could impact on catch rates. These factors included month (seasonality), strata (area within the fishery), whether a part of full day was fished and primary vessel (diver experience and infrastructure support). Ideally factors such as fishing method (free diving versus hookah diving) and diver experience should also be included in the standardisation process. Information on these however, is not currently available from the CFISH data. There is no method of identifying and tracking the fishing history of individual divers and 'hookah diving' appears to have been set as the default fishing method. There is however considerable variation in the average daily tender CPUE of different primary vessels. This appears to be related the level of experience and dedication of the primary vessel's divers and the infrastructure support provided by the primary vessel. The use of 'primary vessel' as a factor attempts to account for the variability between primary vessels in the average fishing efficiency of the divers.

The GLM that best accounted for the variability in CPUE included the year, month, Pday, strata and vessel terms as factors. All of these factors were highly significant (P < 0.001) and accounted for 32.7 percent of the total variance. The standardised CPUE index is a close match

to the arithmetic mean of the daily tender catch records (mean annual CPUE). During the years 1997-2002 (Figure 10-1a) the standardised and mean CPUE are almost identical due to the large number of fishers operating during those years and the extensive seasonal and spatial coverage of the fishery. In 2003-04 standardised CPUE is slightly lower than the mean CPUE reflecting a shift in the vessels operating in the fishery. During the last two years many average and low catch rate primary vessels have either not fished or returned to fishing in Torres Strait leaving a smaller number of more efficient primary vessels operating on the Queensland east coast. In addition the northern section of the fishery has a slightly higher overall CPUE. Prior to 1994 only a few vessels sporadically operated in the Queensland fishery resulting in a highly variable mean annual CPUE. Due to the very low number of records the CPUE is strongly influenced by vessel, month and area fished, hence the larger adjustments in the standardisation for those years.

10.3.2 Preliminary stock assessment results

The standardised CPUE data was fitted to both the Schaefer and Fox formulations of the Surplus-Production model. The Fox form was discarded, as the model parameter estimates were not biologically sensible. The Fox fit suggests there was a very large population in 1988 (~1,400 t) that was fished down to ~480 tonnes by 2004 and the estimate of growth is extremely low (0.03) resulting in an MSY of 15 tonnes per annum. In contrast the Schaefer model fit indicates a smaller stock biomass (~300 t) with medium value growth parameter of 2.28 resulting in an MSY of ~170 tonne.

Due to the very low number of records for the initial years of the time-series it was not appropriate to calculate the initial biomass in the first fishing year using the relationship $B = cpue / q$ (Hilborn and Walters 1992). Instead the options of setting the initial biomass equal to K (Punt 1990) or estimating the initial biomass directly (Haddon 2001) were investigated. Estimating the initial biomass increased the growth parameter to a level that caused the model CPUE to become chaotic.

The effect of excluding the last two years of the time-series (2003-04) was also investigated. These years have a significant impact on the model results as they include information on a period of low fishing effort and increasing catch rates. The fit of the Schaefer model to the 1988-02 CPUE produces similar results to the Fox model, a large initial biomass of ~690 tonnes that was fished down to ~300 tonnes by 2002. Adding in the 2003-04 data removes this "one-way-trip" effect by providing information that the model can use to better estimate growth parameter (r).

The model CPUE (Figure 10-1b) closely tracks the decline in the standardised CPUE during 1999-02 and to a lesser extent the increase over the last two years. The model CPUE for the years 1988-94 is similar to a five-year moving average of the standardised CPUE. The stock biomass (Figure 10-1c) has declined from being equal to the virgin or unfished stock biomass (which was an assumption of the model) to close to half of virgin (K), which for a Schaefer model is equal to B_{msy}. Since 2002 the stock biomass has increased to about 80 percent of virgin.
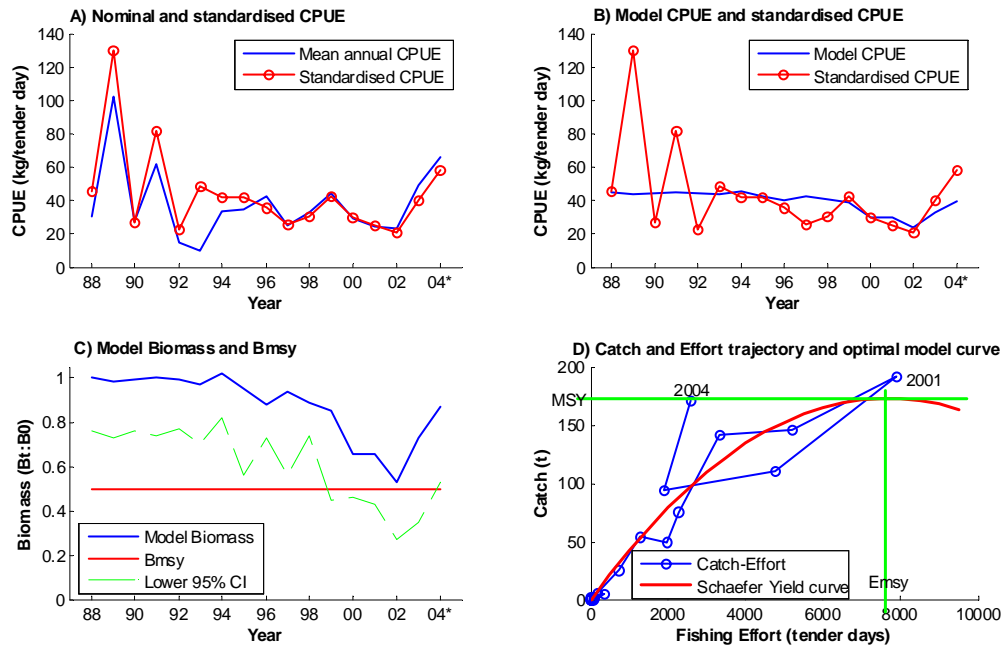
Figure 10-1. **Standardised CPUE and Schaefer model results.* Note that the 2004 summaries are based on incomplete data.**

The yield curve (Figure 10-1d) produced by the Schaefer model is a good fit to the observed trajectory of fishing effort versus catch. The 2001 catch was above the estimate of MSY (~170 t), which is the highest point on the curve. The 2001 fishing effort was also slightly higher than the estimate of E_{msy} (~7,660 tender days), which is the point on the X-axis directly below the MSY. The current logbook records indicate the 2004 catch has reached the estimate of MSY with only one third of E_{msy} estimate. This suggests that E_{msy} may not be an appropriate sustainability or limit reference point for this fishery. Due to the shape of the yield curve estimates of MSY have much smaller error ranges than E_{msy}.

The model was bootstrapped but the large model residuals resulted in an extremely wide range of fits, many of which were biologically unreasonable. This resulted in extremely wide 95 percent confidence ranges for all of the model parameter estimates. Therefore the estimates presented should be regarded as preliminary. Additional years of catch and effort data should improve the model estimates. Further work may by able to improve the standardisation of the CPUE data and alternative models for this fishery should be developed and compared to the Schaefer model results.

10.4 Conclusions

This report provides managers and industry with a preliminary estimate of sustainable harvest levels for the ECTRLF. The assessment is based on the total catch and a standardised annual Catch Per Unit of Effort (CPUE) index derived from daily tender catch rates for the years 1988-2004. The Schaefer form of a Surplus-Production (Biomass Dynamic) model provided the best fit to the annual time-series of catch and CPUE data. The population parameters estimated by the model include an index of the ability of the population biomass to replace itself through growth and reproduction (*r*), the maximum stock size that the environment can support (*K*) and a catchability coefficient (*q*) that relates fishing effort to catch.

A Generalised Linear Model (GLM) was used to standardise the annual catch rate data to ensure that the CPUE index best reflected the underlying stock biomass, which is one of the main

assumptions when fitting a Surplus-Production model. The standardisation attempts to account for factors other than stock abundance that could impact on catch rates. These factors included month (seasonality), strata (area within the fishery), whether a part of full day was fished and primary vessel (diver experience and infrastructure support).

Although the annual CPUE index is highly variable during the early years (1988-94) due to the very low levels of effort, there is enough of a general long-term trend (contrast) in the data for the model to obtain a biologically sensible fit. A 17-year time-series is a relatively short data set to use in a Surplus-Production stock assessment model, especially when most of the changes in fishing effort occurred within the last ten years. A longer time-series of catch and effort data with variation in the level of fishing effort and CPUE will improve the stock assessment. The recent addition of the data for the 2003-04 improved the fit of the model by providing data on a period when there was low fishing effort and increasing CPUE.

The model estimates three sustainability reference points; Maximum Sustainable Yield (MSY), the Fishing Effort required to catch the MSY (E_{msy}) and the Biomass of stock needed to produce MSY (B_{msy}). These estimates should be regarded as preliminary as they have a large error range (95% CI). Further work is required on the standardisation of catch and effort data and the development of alternative stock models. This preliminary assessment indicates that the average harvest over the last five years (1999-03, ~ 140 t) is sustainable whilst fishing at or above the 2001 level of harvest (~190 t) may not be sustainable. The current assessment results indicate that continuously harvesting more than 170 tonne per annum (MSY) could result in the stock biomass being driven below the level that maximises the productivity of the fishery (B_{msy}, ~ 150 t). Although the estimate of E_{msy} is ~7,600 tender days this reference point has a much wider error range than the estimate of MSY and may be an inappropriate reference point for this fishery.

10.5 References

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11 RECOMMENDATIONS FOR MANAGEMENT AND RESEARCH PRIORITIES

11.1 Management

The management regulations introduced by the Queensland Fisheries Service in 2002, during this research project (Table 13), combined with the existing area closures and those introduced by the Great Barrier Reef Marine Park Authority under the 2003 zoning plan (Figure 9-2; Marine National Park Zones, Preservation Zones and Conservation Zones; see http://www.gbrmpa.gov.au/corp_site/management/zoning/zoning_maps.html for detailed maps) will go a long way towards conserving the NE Queensland lobster population and ensuring the fishery is biologically sustainable. Given the high reef fidelity of *Panulirus ornatus*, indicated from tag-recapture studies (Bell *et al.,* 1987), lobsters within the marine parks in the Queensland lobster fishery will be effectively protected from commercial and recreational fishing. In addition, a significant proportion of the NE Queensland fishing grounds are not accessible to divers due to inaccessible depth (generally >30 m).

The seasonal closure (1 October to 1 February), combined with the ban on take of berried or tarspot females, effectively protects the breeding population. Further, research outcomes in this study suggest berried females occupy depths inaccessible to divers during most of the breeding season.

Table 13.   Management regulations applied to the Queensland lobster fishery.

Management Regulation	Commercial	Recreational
Minimum Size		
Panulirus ornatus	115 mm tail length/90 mm carapace length	115 mm tail length/90 mm carapace length
Panulirus spp.	NA	NA
Possession Limits *Panulirus* spp.		
Above 14^0S	NA	3 per person/ 6 per boat
Below 14^0S	NA	5 per person/ 10 per boat
Protected Species		
Panulirus spp.	Egg bearing & tarspot female lobsters	Egg bearing & tarspot female lobsters
Closed Seasons		
Panulirus spp. Above 14^0S	1 October to 31 January	1 October to 31 January
Closed Areas		
Above & Below 14^0S	GBRMPA National Parks (eg Shellburne cross-shelf transect), Conservation Parks, Preservation Zones & Buffer Zones	GBRMPA National Parks (eg Shellburne cross-shelf transect), Conservation Parks, Preservation Zones & Buffer Zones
Equipment Restrictions		
Lobster fishers	Collection by hand spear, hand net and noose only	No SCUBA

Fishing Restrictions

Primary & tender vessels	Maximum 1 person fishing at any time	NA

Additional management and monitoring recommendations that could further support the long-term sustainable management of the fishery are addressed below.

11.1.1 Priority: High. Sustainable fishery catch

The preliminary stock assessment indicates that annual catches above 170 tonnes, the current estimate of Maximum Sustainable Yield (MSY), may not be sustainable and could result in the stock dropping below the Biomass required to produce MSY (Bmsy). This estimate of MSY is close to the largest recorded catch of 192 t in 2001. The estimate of MSY was determined from a Surplus-production model with a relatively short 17 year data-set, and the precision of this estimate will be improved with the addition of reliable catch and effort data in future years.

Although the estimate of the level of Fishing Effort required to catch MSY (Emsy) is ~ 7,700 tender days, this estimate has a wide error range. The conversion of catch into equivalent fishing effort is strongly influenced by which vessels conduct most of the fishing in any particular year as there is considerable variation between primary vessels in the average daily tender catch rate. An example of this is the 2004 season where the recorded catch has reached MSY with only ~ 2,600 tender days of fishing effort. Therefore, an effort-based control may not be the most appropriate means of limiting the catch of this fishery to levels that are sustainable.

11.1.2 Priority: High. An annual audit of commercial catch data and published analysis of trends in the commercial catch and effort data

DPI&F should conduct an annual audit of the commercial logbook data by comparing the logbook catches with processor records. The CFISH analysis procedures developed by this projects could be easily adapted to produce summary fishery statistics that could be updated and published annually. These summaries would be an essential first step towards monitoring the status of this valuable northern Queensland fishery. They would also address the requirement under the EPCB Act for regular publication of catch statistics for the fishery.

11.1.3 Priority: High. Validation of catch data

We recommend that the DPI&F investigate options for validating the commercial catch data against buyer returns.

11.1.4 Priority: High. Logbook recording requirements

It is critical that commercial catch and effort data entered into the compulsory logbooks are standard across the industry. To facilitate this standardisation the DPI&F could regularly liaise with fishers to emphasize the need for accurate recording in the compulsory logbooks. Regular liaison would ensure that the total daily tender weights would include all lobsters that are removed from the population, including the discards and 'lobster tails'. The total daily tender harvest weights are needed to reliably monitor stock status. It appears that at least some fishers may not be recording the component of the catch that is discarded or processed as 'lobster tails' and/or may be entering into the logbooks 'live lobster' weight records that have been adjusted to account for the discards that occur between capture and unload of the primary vessel.

11.1.5 Priority: Low. Maximum size limit for female lobsters

Egg production by the NE Queensland lobster population could be increased through the implementation of a maximum size limit for females, and as suggested by our preliminary analysis this regulation should only result in a small reduction of catch. It is difficult to assess the most appropriate maximum size limit, as there are no baseline size data available to indicate the age structure and egg production of the virgin population. The limit could be negotiated between DPI&F and industry, taking into account the potential reduction of catch and the decreasing market price per kilo with lobster size. Alternatively, future research could be designed to determine an appropriate maximum size limit. A maximum size limit for females only was implemented in the West Australian rock lobster fishery to conserve egg production and upper and lower size ranges have been employed to regulate recreational fish catches such as the dusky flathead *Platycephalus fuscus*, in Queensland.

11.1.6 Priority: High. Developmental "southern" fishery

The potential benefits of displacing fishing effort from the "source" population to the "sink" population are obvious, given that a large proportion of lobsters in the "sink" area are effectively surplus production. However, as identified by the ocean current modelling the straddling region ('Cooktown' defined as 17^0S to 14^0S) does supply some recruits to the north when strong SE winds produce north flowing currents. Nevertheless, fishing in the more southern zones (below 17^0S) would have little impact on recruitment to the current fishery as few recruits travel northward. The boundary of the source and sink areas could not be defined accurately in this study (and is identified as an area for future targeted research) and the ocean current modelling showed that in any case the boundary is likely to vary significantly between years. Hence, the northern limit of a developmental "southern" fishery should be set as conservatively as practically possible. The fishery could be opened for one year to a limited number of fishers and monitored through logbooks and observers. The main benefit to be achieved from a "southern" fishery would be the displacement of existing effort, and this would depend on the fishers locating commercially viable quantities of lobsters.

11.1.7 Priority: Low. Developmental "southern" aquaculture

The potential to develop lobster aquaculture, based on *Panulirus ornatus* recruits collected south of the existing fishery, is highlighted by expansion of this practice in Vietnam (Williams *et al.,* 2004). Nevertheless, the sustainability of this practice on the NE Queensland coast should be critically assessed, as it was for the western lobster fishery in the FRDC project 1998/302 (Phillips, B. F., 2002). Given the high mortality of lobsters during the settlement phase it would be more effective to collect seed lobsters whilst they are planktonic. The further south these lobsters were collected the less likely there would be any impact on recruitment to the current fishery.

The viability of a commercial enterprise based on grow-out of seed lobsters is contingent on locating and capturing commercial quantities of pueruli. Given the relative failure of previous attempts to capture *P. ornatus* from artificial collectors, future attempts could be directed to the effectiveness of towed nets. As suggested for the southern adult fishery, the exploratory fishing could be done by commercial fishers with advice from oceanographers on the most likely locations of late-stage lobster larvae. The viability of this practice in Queensland would also benefit from previous FRDC funded research on the dietary requirements of the ornate rock lobster under culture conditions (Williams, FRDC Project No. 2000/212).

11.2 Research

11.2.1 Priority: High. Resolution of advection across the shelf

Advection of pueruli across the continental shelf was not addressed in this study and larvae were assumed to have settled once they had reached water less than 20 m deep. However, the transport of larvae from the outer barrier reef to the inshore nursery grounds has not been studied, and may provide valuable information on important settlement areas and early larval mortality. This study would benefit from concurrent plankton sampling.

11.2.2 Priority: High. Breeding population surveys

The size and extent of the breeding population on the NE Queensland coast remain unknown, despite extensive research diver surveys and voluntary monitoring by commercial fishers. During the breeding season only 1.4% of 1900 female rock lobsters collected by divers on the NE Queensland coast for tagging studies carried eggs (Bell *et al.,* 1987). However, the majority of the diver surveys were done in shallow water (<10 m) and it is likely berried females remain in deep water during the breeding season, and return to the shallow reefs only after their eggs have hatched, as was found for *P. ornatus* at Yule Island, PNG (MacFarlane and Moore, 1986; Dennis *et al.,* 1992). Hence, surveys of likely breeding grounds should target deeper inter-reefal areas close to known productive fishing grounds. The continental shelf break should also be surveyed since breeding ornate rock lobsters have been found at depths 130-145 m off Townsville (Bell *et al.,* 1987) and at depths 40-120 m off the far northern Great Barrier Reef (Prescott and Pitcher, 1991). However, deep water surveys are logistically difficult and expensive and this research may need to be combined with another research task to be cost-effective.

11.2.3 Priority: High. Resolution of the SEC bifurcation

As more sophisticated oceanographic models become available the bifurcation of the SEC should be resolved with greater precision to allow accurate determination of the boundary between the "source" and "sink" populations.

11.2.4 Priority: Medium. Catch and effort records for the years prior to 1995

Investigate the option of obtaining personal records from fishers that have operated in the fishery since the early 1980's to provide catch and effort data for the years prior to 1995. This data could improve the accuracy of the stock assessment. There was insufficient time and resources in the one-year project to pursue this option.

11.2.5 Priority: Medium. Fishery-independent surveys

Fishery-independent population surveys have been conducted annually in Torres Strait since 1989 to estimate the absolute and relative abundance of recruiting (1+ year old) and fished (2+ years old) lobsters (Pitcher *et al.,* 1997). The data from the surveys are critical in stock status assessments since there are currently no alternative estimates of abundance from comprehensive log-book data. In contrast, the DPI&F log-book program captures comprehensive catch and effort information, and with some amendments as suggested in sub-project 3, this data should be suitable for stock status assessments.

As identified during the development of this research proposal, fishery-independent population surveys may not be feasible or cost-effective for the NE Queensland fishery, given its wide geographic extent and wide ranging water depth. However, targeted research diver surveys could provide valuable information on fishery recruit strength and targeted video surveys in deep-water could provide information on populations inaccessible to the commercial fishery and variability in the breeding populations (as identified in recommendation 11.2.2).

Targeted diver and video surveys could be done annually or bi-annually during the seasonal closure (October-January) to provide managers with current information on recruit and deep-water breeding stock abundance. Diver and video surveys could be done inside and outside of closed areas to allow comparisons of relative abundance on fished and un-fished reefs. Further, if lobsters were tagged inside and outside of closed areas the recapture rates would help confirm whether lobsters in closed areas were effectively protected from fishing.

11.2.6 Priority: Medium. Regional-scale larval transport modelling

The domain of the ocean current model developed in sub-project 2 was restricted mainly to the NW Coral Sea to allow assessment of sources and advection of lobster larvae within the geographic extent of the Australian and PNG fisheries. However, results of the model clearly indicated significant loss of larvae from this domain, particularly northward to the Solomon Sea, and it is highly likely some larvae settling on the NE Queensland coast have origins outside of this domain. Further, the wide geographic extent of this species in the Indo-west Pacific, combined with the extended larval duration, suggests there would be mixing of larvae from different origins over large areas. Hence, for a comprehensive assessment of the sources and sinks of *P. ornatus* larvae the domain of the model could be widened to encompass northern Papua New Guinea, Solomon Islands, New Caledonia and southern Queensland.

Methods developed in the present study would be used in more regional scale modelling.

11.2.7 Priority: Medium. Integrated stock assessment

A more integrated assessment of the ornate rock lobster stock status should be sought using catch and effort data from each of the fishery jurisdictions that share the NW Coral Sea population, including the Queensland, Australian and PNG Torres Strait sectors. This research should start with a scoping study to assess the feasibility of integrated assessment. Subsequently, an integrated approach to modelling all the three fisheries together could be developed.

11.2.8 Priority: Low. Recruitment timing and strength

The only information available on recruitment timing on the NE Queensland coast was obtained from diver surveys of wharf piles in Cairns harbour, well to the south of the NE Queensland fishery. Artificial collector trials on the NE Queensland coast and in Torres Strait have been largely unsuccessful and it is unlikely further trials would shed any light on the variability of recruitment on the NE Queensland coast.

Peak settlement timing in Torres Strait was inferred from back calculation of growth of juvenile lobsters sampled by divers and a similar approach could be taken to determine settlement timing on the NE Queensland coast.

11.2.9 Priority: Low. Growth of resident repeat-breeding lobsters

The growth of *Panulirus ornatus* (Phillips *et al.,* 1992; Skewes *et al.,* 1997) on the NE Queensland coast and in Torres Strait was estimated from tag-recapture data obtained in the early 1980s. Most lobsters were caught on coral reefs in shallow water (3-10 m) at a time when there was limited fishing on the NE Queensland coast and the largest recaptured lobster was less than 140 mm CL. However, voluntary data recorded in this study showed lobsters attain at least 187 mm CL and 195 mm CL for females and males respectively. Hence, the age composition of the large cohorts in the NE Queensland population remains unknown.

This information gap could be addressed through a voluntary size data collection program and modal progression analysis. However, cohorts were difficult to separate in this study, likely due to the wide geographic extent of collected data, and intensive size data collection from one location would be required.

12 BENEFITS

The outcomes of this research project directly benefit the commercial fishers in the Queensland lobster fishery by allowing more informed and sustainable management. As the Queensland fishery operates on a stock shared with two other jurisdictions in Torres Strait, managed by AFMA and the PNG NFA, this benefit indirectly flows to these Torres Strait fisheries. In addition, more informed management and sustainable fishing will also indirectly benefit the traditional fishery in Torres Strait. These benefits also flow to the associated seafood processing companies by allowing greater certainty in future commercial catches.

The collation of existing and new information on the biology of the lobster population on the NE Queensland coast provides managers and the rock lobster industry with a baseline database to use when considering the likely impacts of the commercial fishery or the impact of new management. This baseline database also indicates the inadequacy of our present understanding of the biology of this species and permits prioritisation of research objectives to address the critical information gaps, such as size and extent of the breeding population.

The development of an oceanographic model, simulation of larval lobster advection and prediction of regions that provide recruits to the Queensland lobster fishery benefits the management of the stock as a whole. In particular, the finding that breeding lobsters from the Torres Strait and Queensland fisheries contribute recruits to each other highlights the need for cooperation between the managers.

The recommendations to improve the quality of commercial logbook data will benefit the Queensland fishery by ensuring future stock status assessments are based on accurate catch and effort data. Future integrated stock assessment to cover the entire stock will also benefit from these recommendations.

The comparisons of catch and effort trends in the Queensland lobster fishery with those in the Torres Strait fishery benefit informed management of the stock by highlighting interactions between the fisheries as a result of changes in stock abundance. In particular, the changing patterns of fishing effort for dual endorsed licences, in response to differences in stock abundance, highlight the need for integrated monitoring of effort by management.

The management recommendations will benefit the fishery by providing a framework that managers and industry can build on to ensure the fishery is both biologically sustainable (eg. catch below MSY) and environmentally sustainable under the guidelines of the DEH.

One of the main outcomes of this research project was the identification of the information gaps that preclude effective management and research that needs to be done to address these gaps. Whilst not immediately quantifiable, the benefits of subsequent research projects will flow to the Queensland and Torres Strait fisheries and the associated industries.

The identification of developmental southern fisheries that have the potential to increase catch and production, through culture of seed lobsters, has future benefits for the current commercial fishery and future enterprises. The larval dispersal modelling benefits the development of future sustainable culture practices by indicating the best and most sustainable sources of seed lobsters.

Although minor, the benefits of this research flow indirectly to the recreational sector by ensuring lobsters will be available to be fished by recreational fishers.

13 FURTHER DEVELOPMENT

Further development of the results of this research will come in the form of future research proposals to address the information gaps that preclude effective management of the Queensland lobster fishery.

The results of this research, in combination with established commercial lobster fishing in Vietnam, highlight the potential for the development of lobster culture as a sustainable industry in Queensland. To facilitate this, the outcomes of this research should be used as background to a future study aimed at assessing the most efficient culture practices, including seed collection. The economic feasibility of this practice will also benefit from previous FRDC funded research on the dietary requirements of the ornate rock lobster under culture conditions (Williams, FRDC Project No. 2000/212).

The results of this research, building on previous biological research, highlighted the co-dependencies of each of the fishery jurisdictions sharing the ornate rock lobster stock in the NW Coral Sea. Future development of integrated research and management objectives, with funding and staff from Australian and PNG agencies, should be actively encouraged. The logistic difficulties in conducting integrated stock assessment are obvious, but should not preclude the future cooperation between the Department of Primary Industries and Fisheries, AFMA and the PNG NFA. This cooperation would include audits of the logbook data and maintenance of the combined database.

14 PLANNED OUTCOMES

The mapped geographic extents of adult, juvenile, larval and breeding populations of the ornate rock lobster *Panulirus ornatus* on the NE Queensland coast have contributed to a better understanding of the biology and ecology by the fishery managers. Although not pre-empted by the outputs of this research, new management regulations implemented in 2002 were introduced after discussions between the Queensland Fisheries Service, CMR and QDPI research staff.

The simulations of dispersal of lobster larvae on the NE Queensland coast from the oceanographic model developed here contributed to the enhanced understanding of the links between the Queensland and Torres Strait fisheries by fisheries managers. The animations of larval dispersal and summary figures have been presented at Queensland HarvestMac meetings and at lobster working group meetings on Thursday Island. The identified boundary between the "source" and "sink" populations, although not determined precisely, has given the Queensland fishery managers and GBRMPA managers a more precise measure of the benefits of displacing fishing effort into the source population and of establishing culture practices based on seed collected south of the current fishery.

Identification of errors and omissions in catch and effort data collected by the compulsory logbook program has already resulted in rectification of erroneous data from the CFISH database and more precise assessment of data trends. The outputs of the surplus production model, based on validated catch and effort data, have provided managers and industry with a preliminary estimate of sustainable levels of annual catch and annual effort.

The combined outputs of the research sub-projects permitted the recommendation of management options and research priorities to address the long-term sustainability of the fishery.

15 CONCLUSION

Historical information on the geographic extents of adult, juvenile and larval lobster populations, timing and locations of breeding and population size and age structure from CSIRO and PNG research programs was collated and mapped to evaluate our current understanding of the biology of the ornate rock lobster *Panulirus ornatus* on the NE Queensland coast. This information was supplemented by voluntary recording of lobster size and breeding status from commercial catches during 2001-2003, by fishers and QDPI observers.

Adult lobsters occur throughout the latitudinal range of the Queensland lobster fishery (~11-14^0S) and the preference for commercial fishing grounds around 12^0S (Margaret & Temple Bays) indicates lobsters are more abundant there. Ornate rock lobsters are the dominant spiny lobster on the inshore and mid-shelf reefs on the NE Queensland coast. Juvenile lobsters occur throughout the Queensland lobster fishery indicating that settlement and nursery grounds coincide with the extent of adult habitat. The age structure of the inshore populations indicates that the inshore reefs act as nursery habitat prior to offshore movement of sub-adult lobsters.

Berried females occur throughout the range of the Queensland fishery and north to the far northern GBR and south to Cairns. However, deepwater breeding has also been recorded off Murray Island (10^0S) and Townsville (19^0S). The vast majority of records of breeding lobsters have come from shallow habitats accessible to divers and the size and extent of breeding populations in waters inaccessible to divers (>30 m), is largely unknown due to the logistical difficulties in surveying these areas. Only 5% (165/3169) of female lobsters caught and measured by commercial fishers between 21 July 2001 and 19 July 2003 carried a spermatophoric mass (157) or eggs (8), and the majority (80%) were recorded during November 2001.

Mating likely occurs on the NE Queensland coast during October/November with subsequent tarspot deposition and berried females occur on the shallow reefs during January to March, but the low numbers of berried females recorded during this study and historically strongly suggests most hatching occurs in deep water inaccessible to divers. A simple analysis of the relative egg production suggested that the fishery may benefit from a maximum size limit to conserve egg production.

Migrations and small-scale movements of ornate rock lobsters on the NE Queensland coast are known exclusively from previous studies by Bell *et al.,* (1987). In contrast to the extensive migrations undertaken by Torres Strait lobsters, lobsters on the NE Queensland coast moved only small distances from their original locations, and mostly off-shore.

Peak settlement occurs during winter (June-August) in most years, but the seasonality of settlement is highly variable.

The populations on the shallow inshore reefs were comprised almost entirely of two year-classes (1+ and 2+ years old) smaller than 120 mm CL, similar to populations in Torres Strait. In contrast, the populations on the mid-shelf reefs that are commercially fished were comprised of several year-classes, up to 8 years old. Male lobsters were consistently and significantly larger than female lobsters in all months. The fraction of lobsters taken prior to the introduction of the minimum size limit (90 mm CL) was traditionally low (<10%).

An oceanographic model of the mesoscale circulation in the NW Coral Sea was developed and validated by tracks of surface drifting buoys. The trajectories of lobster larvae released on the NE Queensland coast and other known breeding grounds were determined from simulations using the oceanographic model. A significant result was that the basic mechanism for the return of larvae to the NE Queensland coast is somewhat different to what it is on the other side of the

country. In both cases, results of our quantitative model support previously hypothesized mechanisms. What is new is an important step towards a much enhanced ability to turn this understanding into scientifically-justifiable management actions.

The approximate boundary separating the "source" and "sink" populations was estimated from the simulations and in general agreed with previous oceanographic studies, such as Burrage (1993). The approximate boundary between the 'source' and 'sink' populations is indeed determined by the location of the bifurcation point of the South Equatorial Current. However, a slight twist on this is that the model region straddling the bifurcation point (our 'Cooktown' region from 17°S to 14°S) is better categorized as 'source' than 'sink'. The animation provided with this report shows how periods of strong SE currents occur in this region, often associated with the SE winds, taking the larvae into the northern zone where they mix with larvae originating there.

Future oceanographic research priorities include improving our understanding of the 'big picture', and it would be very valuable to consider the possibility of interactions between the NW Coral Sea 'stock' of *P. ornatus*, and others in the region. The model showed that many larvae are transported into the Solomon Sea but it is not certain whether this flux of larvae helps support an adult population there. As discussed above, the oceanographic model employed here was not able to accurately resolve the bifurcation region, separating the source and sink populations. Hence, once more sophisticated models are available this information gap should be addressed. The linked question of mortality of early stage larvae while they are still in this region should also be addressed before any firm conclusions are possible.

A pilot observer program was developed and implemented to evaluate the effectiveness of using fishery observers to validate and enhance the commercial logbook data and collect additional biological information that could be used to monitor the status of the lobster stocks. A major outcome of the observer program was the collection of information on the operation of the fishery and the methods used for recording catch and effort. This information aided the assessment of the CFISH logbook data. Although anecdotal information and analysis of the logbook data suggest there may be some under recording of 'lobster tails' and discarded catch the 'live lobster' component of the catch recorded in logbooks appears to be reliable.

The observer surveys provided additional fishery information that is not available from the logbook system, such as depth, range of operation from the primary vessel and diver experience. Analysis of this data indicates a relationship between catch rate and diver experience, but no relationship with depth fished. Although the daily position information of the primary vessel may be accurately recorded in logbooks, the spatial resolution of the daily tender catch and effort data is coarse (~ 30 minute grid level) as tenders often fish up to 20 nautical miles from the primary vessel.

An ongoing observer program could provide information on the age structure of lobster stocks using gender and length frequency data collected by the observers. This data would assist stock assessment and monitoring of the impact of fishing on the east coast lobster stock. Overall the results suggest that a long-term observer program based on the methods tested in this project could effectively validate and enhance the commercial logbook information and collect additional biological data to assist with monitoring the status of the lobster stock.

The CFISH commercial catch and effort records for the years 1988-2004 were accessed to determine the quality of the data available on Queensland east coast tropical rock lobster stocks. Trends in catch, effort and catch rates were then investigated. Although some lobster catch has been recorded under *line*, *mixed* and *trawl* fishery codes most of the data, especially since 1995, was recorded under the *harvest* fishery code. Much of the lobster data recorded under the *line* code appears to be a duplicate of data recorded under the *harvest* code. There is also a small (53

tonne) amount of lobster catch recorded by trawlers north of 14 degrees latitude for the year 1988-96.

A detailed assessment of the lobster catch data recorded under the *harvest* fishery code indicates that the data is generally reliable and can be used to monitor trends in fishing effort, catch and catch rates both spatially and temporally. Feedback was provided to the logbook section of DPI&F on errors and inconsistencies in the CFISH lobster data. The feedback has improved the reliability of the summaries statistics used by Fishery Managers to monitor the status of the fishery. Further improvements could be made by educating fishers on the importance of accurately recording the total daily tender weights of all lobsters that are removed from the population including the discards and 'lobster tails'. Fishers tend to focus on recording the catch of 'live lobster' product and tend to ignore the poor quality lobsters that are discarded or 'tailed' and frozen.

The majority of the fishing effort and catch of Queensland east coast tropical rock lobster since 1996 was reported within the three 30-minute CFISH grids between Shelbourne Bay and Portland Roads in the middle section of the fishery. Annual trends in catch rates for these grids are however similar to catch rates for the northern and southern section of the fishery. Fishing effort in the northern section has been higher than average since 2001 due to higher catch rates that may reflect higher food availability and recruitment levels.

Logbook summary statistics clearly show the development of the 'live lobster' industry for the mid 1990's with effort and catch rapidly increasing to a peak in 2001. Declining catch rates in the Torres Strait lobster fishery also drove the rapid rise in effort as most of the fleet is endorsed to operate in both fisheries. Since 2001 fishing effort has declined to around one third of the 2001 level due to increased catch rates in Torres Strait and low prices for 'live lobster' during 2003 as a result of the SARS virus closing restaurants in Asia and China. Although annual catch declined during 2002-03 as fishing effort decreased, the 2004 catch increased to over 170 tonne due to a small increase in effort and a large increase in catch rates. The higher catch rates appear to be the result of increased stock abundance and a contraction of the active fleet to a small group of efficient fishers.

Although there is a high level of latent effort the risk that all of this effort will be activated in the near future appears low, as only 8 primary vessels are restricted to fishing on the east coast. Even in the year of highest effort, 2001, when the shift of effort from the Torres Strait to the east coast was highest due to the lowest ever recorded catch rates in Torres Strait, only about a one third of the potential fishing effort was used. Harvest MAC is currently investigating mechanisms to reduce latent effort in the fishery.

This report provides managers and industry with a preliminary estimate of sustainable harvest levels for the ECTRLF. The assessment is based on the total catch and a standardised annual Catch Per Unit of Effort (CPUE) index derived from daily tender catch rates for the years 1988-2004. The Schaefer form of a Surplus-Production (Biomass Dynamic) model provided the best fit to the annual time-series of catch and CPUE data. The population parameters estimated by the model include an index of the ability of the population biomass to replace itself through growth and reproduction (r), the maximum stock size that the environment can support (K) and a catchability coefficient (q) that relates fishing effort to catch.

A Generalised Linear Model (GLM) was used to standardise the annual catch rate data to ensure that the CPUE index best reflected the underlying stock biomass, which is one of the main assumptions when fitting a Surplus-Production model. The standardisation attempts to account for factors other than stock abundance that could impact on catch rates. These factors included month (seasonality), strata (area within the fishery), whether a part of full day was fished and primary vessel (diver experience and infrastructure support).

Although the annual CPUE index is highly variable during the early years (1988-94) due to the very low levels of effort, there is enough of a general long-term trend (contrast) in the data for the model to obtain a biologically sensible fit. A 17-year time-series is a relatively short data set to use in a Surplus-Production stock assessment model, especially when most of the changes in fishing effort occurred within the last ten years. A longer time-series of catch and effort data with variation in the level of fishing effort and CPUE will improve the stock assessment. The recent addition of the data for the 2003-04 improved the fit of the model by providing data on a period when there was low fishing effort and increasing CPUE.

The model estimates three sustainability reference points; Maximum Sustainable Yield (MSY), the Fishing Effort required to catch the MSY (E_{msy}) and the Biomass of stock needed to produce MSY (B_{msy}). These estimates should be regarded as preliminary as they have a large error range (95% CI). Further work is required on the standardisation of catch and effort data and the development of alternative stock models. This preliminary assessment indicates that the average harvest over the last five years (1999-03, ~ 140 t) is sustainable whilst fishing at or above the 2001 level of harvest (~190 t) may not be sustainable. The current assessment results indicate that continuously harvesting more than 170 tonne per annum (MSY) could result in the stock biomass being driven below the level that maximises the productivity of the fishery (B_{msy}, ~ 150 t). Although the estimate of E_{msy} is ~7,600 tender days this reference point has a much wider error range than the estimate of MSY and may be an inappropriate reference point for this fishery.

The overall objective of this research was to recommend management and research to address the long-term sustainability of the lobster fishery. Management recommendations included:
- A Maximum Sustainable Yield (MSY) of about 170 tonnes (whole weight) was calculated using the preliminary stock assessment, but conversion of catch into equivalent fishing effort is strongly influenced by which vessels conduct most of the fishing and effort-based control may not be appropriate.
- DPI&F should conduct an annual update of the commercial logbook data by incorporating CFISH data into the Fisheries Long Term Monitoring Program.
- DPI&F should investigate options for validating the commercial catch data against buyer returns.
- Regular liaison by DPI&F observers is recommended to ensure that total daily tender catches and effort weights are recorded accurately.
- Implementation of a maximum size limit was recommended, to conserve egg production of the population but an appropriate limit would be negotiated between DPI&F and industry.
- Introduction of a developmental "southern" fishery was recommended to displace effort from the current fishery.
- The development of lobster aquaculture, based on seed collected to the south of the current fishery was recommended.

Research recommendations included:
- Determine the timing and strength of recruitment, growth of resident lobsters, size and extent of the breeding population, and fishery recruitment strength to address biological information gaps relevant to fishery management.
- Regional scale oceanographic modelling, resolution of the South Equatorial Current bifurcation and advection across the continental shelf were recommended as high priority oceanographic research priorities.
- Collection of pre-logbook fishery catch and effort data from personal fisher records was recommended to extend the data used for stock status assessment.

APPENDIX A: INTELLECTUAL PROPERTY

Data collected and collated in sub-projects 1-3 are currently stored at CMR Cleveland, CMR Hobart and QDPI Cairns. This data would be made available to other research agencies through written approval from FRDC and the custodian agency.

APPENDIX B: STAFF

Name	Position	Qualifications	Time(%)
C.Roland Pitcher	Project leader, CMR	PhD	5
David Griffin	Physical Oceanographer, CMR	PhD	50
Neil Gribble	Senior Fisheries Biologist, QDPI	PhD	10
Darren Dennis	Marine Ecologist, CMR	BSc Hons	30
Joanne Atfield	Fisheries Biologist, QDPI	BSc	100
Tim Skewes	Marine Ecologist, CMR	BSc	10
Clive Turnbull	Senior Fisheries Biologist, QDPI	BSc	10

APPENDIX C: COMMUNICATION AND EXTENSION OF RESULTS

An information leaflet (below) defining the methods and objectives of the research sub-projects was produced by CMR and QDPI staff to promote this research project to industry. The DPI&F and fishery processors assisted in disseminating the information leaflets to the fishing industry in August 2002.

A three-page colour results summary was constructed following the September observer trip, and provided to skipper and crew for feedback.

The research methods and objectives and progress to date were presented in a 30 minute PowerPoint presentation (available from D. Dennis on request) at the QDPI Harvest MAC meeting in Brisbane on 11 November 2002. Harvest MAC members include the Queensland lobster fishery managers, lobster fishers and GBR managers and the presentation promoted extended discussion as to the long-term development of the fishery. As a result we were asked to attend the next Harvest MAC meeting in April 2003 to present further progress towards the research objectives.

A media release containing printed information (below) and still and video footage was produced by the CMR communications group (Contact: Bryony Bennett) and reviewed by Kylie Paulsen FRDC and disseminated on 9 December 2002. As a result the research featured on Brisbane ABC news, a copy sent to Kylie Paulsen, FRDC, and in The Australian newspaper on 11 December. The story was also shown in Sydney and Canberra, and nationally on the World Today show.

Media Release

Leane Regan	**02 6276 6478**
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CSIRO Media Releases are available on the Internet: http://www.csiro.au

CSIRO

9 December, 2002   Ref 02/241

SCIENTISTS TRACK SEAFARING LOBSTERS

Marine scientists are tracing the 2000-kilometre journey of billions of lobster larvae in the swirling currents off northern Australia, to help safeguard the future of Queensland's $7 million ornate rock lobster fishery.

Computer modelling will link ocean current data with details of the lobster's life cycle, movements and harvest and help identify factors important to managing the export fishery.

Queensland's ornate rock lobster fishery operates in the far northern section of the Great Barrier Reef Marine Park, between 14ºS and Cape York. Lobsters harvested in the fishery begin life in October to January at breeding grounds off the Queensland coast and in the Gulf of Papua.

Lobster larvae – called phyllosoma – hitch a ride in the Coral Sea Gyre, a current that circles between Australia and Papua New Guinea. Four to six months later, the young lobsters switch to neighbouring currents, returning them to adult habitats off northern Queensland and the Torres Strait.

A larval transport model, to be developed by CSIRO oceanographer Dr David Griffin, will unravel these epic journeys, identifying when, where and why rock lobsters enter and leave the fishing grounds, and in what numbers.

The model will use ocean current maps based on a 10-year sequence of sea-level measurements from the US-French satellite, Topex/Poseidon.

'Sea level is to an oceanographer what atmospheric pressure is to a meteorologist,' Dr Griffin says. 'Ocean currents run along lines of equal sea level, and are faster where the lines bunch together, so they can be read in a similar way to a weather map.'

Dr Griffin will combine the ocean current maps with the daily movement patterns of the lobster phyllosoma, which generally swim deeper during the day, and back toward the surface at night.

Because current strength and direction varies with water depth, these daily ups and downs influence the direction of the young lobsters' overall journey.

'We need to understand the links between larval behaviour and the major currents: where they meet, their strength and seasonal and yearly variations,' Mr Dennis says.

'Then we can address questions such as which lobster populations contribute recruits to the fishery, and what proportion of the fishery relies on larvae coming out of the Coral Sea Gyre.

'This is important to assessing the status of the fishery, to judging the effectiveness of no-take zones, and to setting management conditions that support a profitable industry without jeopardising its long-term future.

'For example, the modelling will test the theory that larvae spawned by adults in breeding grounds south of Lizard Island might be swept south by the East Australia Current.

'If this is found to be true, south of Lizard Island might be a good place to displace some of the current fishing effort, because these lobsters do not contribute recruits to the fishery.'

The study will also collate information on the geographical distribution of various sized lobsters, and their settlement, breeding and nursery grounds, and identify information gaps that preclude efficient management.

Scientists from QDPI will travel as 'observers' on commercial vessels operated by QRLA members, to validate logbook records and collect details such as lobster size, sex, and breeding condition.

They will also examine catch and effort data collected by fishers and processors to determine trends, develop methods of stock assessment, and assess future data-collection needs.

'We will spend time out in the fishery seeing how the lobsters are captured, and understanding how the fishing effort and catch is reported,' Joanne Atfield of QDPI says.

Results of the study will assist management of the Torres Strait and Papua New Guinea ornate rock lobster fishery, which share the same stock.

The study, funded by the Fisheries Research and Development Corporation, involves scientists from CSIRO Marine Research and the Queensland Department of Primary Industries (QDPI) Agency for Food and Fibre Sciences.

The Queensland Rock Lobster Association (QRLA), which represents the fishery's commercial operators, is a partner in the research.

Contacts:
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Joanne Atfield, QDPI, (07) 4035 0155, joanne.atfield@dpi.qld.gov.au
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Kylie Paulsen, Fisheries Research and Development Corporation, (02) 6285 0415 kylie.paulsen@frdc.com.au

A PowerPoint presentation of research progress for all sub-projects (available from D. Dennis on request) was made to the Queensland Rock Lobster Association (QRLA) at the Cairns Cruising Yacht Squadron on 21 January 2003. The meeting was attended by QRLA chairman James Fogarty and several Queensland lobster fishers.

APPENDIX D: VOLUNTARY DATA COLLECTION DATASHEETS

Boat Name (optional): _____

Please return completed (full) sheets to Jim Fogarty (QRLA) Cairns

CSIRO MARINE RESEARCH

LOBSTER BREEDING RECORDS   QUEENSLAND EAST COAST FISHERY

VOLUNTARY RESEARCH DATA COLLECTION

(Please record information for all lobsters with tarspots and/or eggs, and a small sample (about 10-20) of other lobsters caught with the breeding lobster/s)

DATE	LOCATION REEF OR LAT/LONG	CARAPACE LENGTH (MM)	TARSPOT SEE CATEGORIES BELOW	EGGS SEE CATEGORIES BELOW	Please record the sexes and carapace lengths of about 10-20 other lobsters caught on the same day (eg. F 89, M 88, F 90 etc.)

TARSPOT CATEGORIES: 0= No Tarspot, 1= Fresh Tarspot, 2= Used Tarspot, 3= very old (depleted) Tarspot

EGG CATEGORIES: 0= No eggs and swimmerets clean, 1= Eggs bright orange and no eyes visible, 2= Eggs dark orange/red and eyes visible, 3= Eggs brown and eyed, 4= Eggs just hatched (Empty egg capsules visible on swimmerets under tail)

**LOBSTER SIZE RECORDS   QUEENSLAND EAST COAST FISHERY
VOLUNTARY RESEARCH DATA COLLECTION**
(Please record the sizes and sexes of about 50-100 lobsters for each month,
preferably from the middle of each month)

CSIRO
MARINE RESEARCH

Date:_____   Boat Name (Optional):_____

Carapace Length	Sex	Comments Eg. Tarspot, moult stage (hard/soft)	Carapace Length	Sex	Comments Eg. Tarspot, moult stage (hard/soft)

APPENDIX E: OBSERVER PROGRAM TENDER CATCH INFORMATION DATASHEET

Dory catch information- East Coast Lobster   Queensland Government
Department of Primary Industries

Primary vessel: ……………………………………………….

Location (reef name(s)): …………………………………………….

Primary Lat   …………………………   Long …………………………...

Date: ……. / …….. / 2003   Number dories working: …………

	Diver 1	Diver 2	Diver 3	Diver 4	Diver 5	Diver 6	TOTALS
Total Weight							
Weight Live							
Weight Tails							
Total Number							
Number Males							
Number Females							
Number Other Crays							
Weight Other Crays							
Number hours fished							
Fishing Method							

APPENDIX F: OBSERVER PROGRAM TENDER EFFORT INFORMATION DATASHEET

Dory effort information- East Coast Lobster

Queensland Government
Department of Primary Industries

Location (reef name(s)): ……………………..

Date: ……. / …….. / 2003

Dory Diver Name (#years exp):…………………..

Dory Driver Name: ………………………

Primary vessel name: ………………………………..

Primary vessel location
Lat: Long:

Time Depart   Time Return
Primary: ………… Primary: ………………

Obs #	TIME	LAT ………	LONG ………	DEPTH	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
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APPENDIX G: OBSERVER PROGRAM CATCH SAMPLING DATA SHEET.

P. ornatus catch sampling- East Coast Lobster

Primary vessel name: ………………………………..

Primary vessel location
Lat: Long:

Date: ___ / ___/ _____

Carapace Length (mm)	Sex	Moult Condition	Breeding Condition	Comments