June 2002

Catch analysis and productivity of the deepwater dogfish resource in southern Australia

R. Daley J. Stevens K. Graham

Centrophorus harrissoni

Deania calcea

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NSW FISHERIES

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FRDC Project 1998/108

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National Library of Australia Cataloguing In Publication entry:

Daley, Ross K., 1968- .
Catch analysis and productivity of the deepwater dogfish
resource in southern Australia.

Bibliography.
ISBN 1 876996 19 6.

1. Dogfish - Australia, Southern. 2. Fishery resources -
Australia, Southern. I. Stevens, J. D. (John Donald),
1947- . II. Graham, K. J. III. CSIRO. Division of Marine
Research. IV. Title.

597.360994

Funding: Fisheries Research & Development Corporation and CSIRO Marine Research

Photographs: © CSIRO Marine Research
Front cover: Dogfish specimens from the CSIRO Fish Collection
Inside cover: Large catch of *Deania* and *Centroscymnus* spp ready for sorting and processing aboard an SET vessel

Printing: Information Solution Works, Hobart

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OBJECTIVES:

1. Estimate the annual retained and discarded catch of deepwater dogfish by geographical area and depth strata within the Southern Shark, Western Australian Shark, South East Trawl, Great Australian Bight Trawl and Dropline fisheries.

2. Examine dogfish catch and effort data by region and depth strata for changes in catch rate with time.

3. Determine population structure (size distributions and sex ratio) of principal dogfish species by region and depth strata.

4. Assess the biological productivity of the major upper and mid-slope dogfish species from data on age, growth and reproduction.

5. Obtain qualitative estimates of the mortality of the discarded component of the dogfish catch.

6. Survey wholesale markets, retail markets and processors for information on species composition and marketing practices.

7. Estimate the annual dogfish catch by analysing wholesale market sales data.

NON-TECHNICAL SUMMARY

About 14 species of dogfish (Squalidae) are commercially exploited in southern Australian waters. Although previously targeted for their liver oil, they are now mainly utilised for flesh, even though levels of arsenic and mercury in some species exceed maximum levels permitted by the Australian Food Standards Code.

The total catch in the year 2000 was estimated to be approximately 1500 t (whole weight) with a landed value of approximately $1.5 million. Although this catch weight exceeds any single species of shark in Australia, apart from gummy shark, catches of dogfish are essentially unregulated.

Fishery logbook data alone for dogfishes were not adequate to assess stocks for management purposes. Only very limited species-specific data were available with common names frequently confused. Discards were seldom recorded in logbooks. There was also confusion over whether catch weights represented live weight or carcass weight.

Some steps have been taken to improve collection of fishery data for future assessments. Fishery-specific identification sheets were prepared for the Southern Shark Fishery and

the South East Trawl fishery. An improvement in dogfish data quality for the South East Trawl was achieved in year 2000 and subsequently. Bycatch Action Plans will in future require reliable data for byproduct and bycatch species, as well as target species.

Together with fishery data, independent survey data and wholesale market sales data were examined to determine the species composition and trends in abundance. Fishery and market practices and changes to management regimes were examined to help interpret trends. The biology of 14 dogfish species was examined in order to assess their vulnerability to fishing.

The dogfish catch consists of two distinct ecological groupings: upper-slope: 200–650 m and mid-slope: 650–1200 m. These groups have different habitats, species compositions, reproductive biology and vulnerability to capture. Fishery, market and independent survey data indicate that some upper-slope species have been depleted. These groups need separate consideration by the Australian Fisheries Management Authority and Environment Australia.

Upper-slope species were targeted in the Southern Shark Fishery for their livers between 1993–1998. Targeting subsequently ceased when catch rates rapidly declined. The carcasses were generally discarded because of high mercury content. Upper slope species remain a valuable byproduct in the South East Trawl Fishery where most (70–90%) of the catch is taken off southern NSW.

The reported catches, catch rates and market data for upper-slope dogfish showed consistent evidence for a declining resource. Since 1986, catch rates of upper-slope dogfish by SET trawlers declined by 75%. Industry logbook data for 1993–1999 indicated that catches of *Centrophorus* spp off NSW decreased by 59% during that period. These reduced catches were reflected in Sydney Fish Market data for greeneye and Endeavour dogfishes which showed a significant decline in sales from 1993–1998.

Species of *Centrophorus* appear to be particularly vulnerable to over-fishing. They have litters of only one or two. They are long lived (tentatively up to at least 46 years). They are fished throughout their vertical distributions and at least one species has a small endemic distribution. *Centrophorus* spp are at risk of extirpation and *Centrophorus harrissoni* may even be at risk of extinction. These species have been nominated for protection under the Environment Protection and Biodiversity Conservation Act. If these species are listed then threat abatement plans will be prepared for these species and AFMA are required to comply with such plans. These plans would list threatening processes that are likely to include some fishing activities.

It is unlikely that catch restrictions alone would enable *Centrophorus* spp to recover. Other measures such as seasonal closures or closed areas may be considered as part of recovery programs. These measures need to be of appropriate scale. Dogfishes have specific habitat requirements. Species differ in their depth and topographic distribution and there is evidence that some species migrate. It would be difficult to develop effective recovery plans without further study of movements and critical habitat.

Mid-slope dogfish, mainly *Deania calcea* and *Centroscymnus* spp, are exploited by SET trawlers. Catches and catch rates of these species increased after 1992 when the introduction of Individual Transferable Quotas for some species in the South East trawl encouraged fishers to find alternative unregulated species. The relaxation of some mercury laws after 1995 lead to the development of new markets for livers as well as for the carcasses. These changes have resulted in increased targeting and reduced discarding. Market sales have increased in recent years. Independent catch rates from CSIRO research vessels showed no inter-annual trends and extremely high natural variance. Although there is currently no statistical evidence that mid-slope species have been depleted their biology suggests that their management be approached with caution.

Preliminary ageing studies suggest mid-slope species are long lived (up to 54 years for *Deania calcea*). The species examined do not mature until they are near maximum size. Although they have larger litter sizes (up to 19 for *Centroscymnus coelolepis*), mid-slope dogfishes have distinct intervals between pregnancies. Previous studies suggest that these intervals may be up to four years and some species may only have one or two litters per lifetime.

KEYWORDS: dogfish, Squalidae, deepwater fisheries, Australia.

1. INTRODUCTION

1.1. Background

At least 14 species of deepwater dogfish (family Squalidae) are regularly taken as target or mixed-catch species in a number of fisheries around southern Australia. They are exploited for their meat (marketed as flake or boneless fillets) and livers, which are processed for their squalene content. Most are caught by South East Trawl (SET) trawlers, with smaller quantities taken by operators in the Southern Shark Fishery (SSF), NSW trawl and dropline fishery, the South East Non-Trawl Fishery (SENT), the Great Australian Bight Trawl Fishery (GABT) and the WA Shark Fishery. Catches of dogfish are reported to comprise a total of 6.1% (combined dogfish and black shark categories) of the quantified Australian shark catch; at 8.9%, gummy shark is the only shark category that exceeds the dogfish catch (*Australian shark Assessment Report*, 2001). Despite these high catches, there are currently no catch limits on deepwater dogfish and there are concerns that current catches may not be sustainable (Andrew *et al.*, 1997).

The deepwater dogfish fishery can be divided into two depth zones, each with different species composition and fishery practices: upper-slope (200–649 m) and mid-slope (650–1200 m). The main upper-slope species are Endeavour (*Centrophorus* spp) and greeneye (*Squalus* spp) dogfishes. *Centrophorus* dogfish were briefly targeted by SSF and WA Shark fishers in the 1990s. But upper-slope species are now seldom targeted, and have become a relatively minor, albeit important, component of trawl catches. Vessels in the SET now take the largest mid-slope dogfish catches, frequently targeting platypus sharks (*Deania* spp) and smallspine sharks (*Centroscymnus* spp).

Sales of deepwater dogfish carcasses were banned by Victorian State Laws for a period until 1995. These laws were introduced due to concerns that the flesh contained excessive mercury. These mercury regulations were relaxed in November 1995 and carcass sales subsequently became the driving market force in the exploitation of dogfish around Victoria and Tasmania.

In some areas, dogfish were initially targeted mainly for their liver-oil (Johnson, 1997) which is high in squalene, a hydrocarbon that is refined in Australia and exported for use mainly in cosmetics production (Heller *et al.*, 1957; Blumer, 1967; Burandeen and Richards-Rajadurai, 1986; Summers, 1987; Deprez *et al*., 1990; Z. Yasuda, Deep Sea Oils Ltd., Tasmania, personal communication). The oil also contains DAGE (diacylglyceryl ethers) which is claimed to boost the immune system and is also being investigated as an aid in treatments for cancer and sunburn (Z.Yasuda, Deep Sea Oils Ltd., Tasmania, personal communication; Deprez *et al*., 1990).

Dogfish can be difficult to identify to species level, and a variety of confused common names has been used in logbooks and databases. For example, ‘greeneye dogfish’ has been used both to refer to *Squalus mitsukurii* specifically as well as a collective term for all species of *Squalus*. Similarly ‘Endeavour dogfish’ has been used to refer specifically to *Centrophorus moluccensis*, as well as a collective term for three species of *Centrophorus*. Among mid-slope species, the name ‘black shark’ has caused particular confusion. Fishers use the name ‘black shark’ for *Centroscymnus* spp, whereas scientists use that name for *Dalatias licha*. As a consequence of these problems, large proportions of fishery logbook, observer and market data has been aggregated into ‘dogfish’ and ‘mixed shark’ categories at the data collation stage. As a consequence, the potential to use this data to assess catches is limited.

From the 1970s until 1992, greeneye dogfish and ‘other shark’ were marketed in NSW through the Sydney Fish Market (SFM), but sales data did not distinguish species. Since 1992, SFM sales data have been separated into greeneye, Endeavour, and roughskin (*Deania* and *Centroscymnus* spp) dogfishes. At the Melbourne Fish Markets (MFM), the relatively small quantities of upper-slope species have mostly been sold as ‘mixed shark’.

The recent large landings of mid-slope dogfish have been marketed as 'black' (*Centroscymnus* spp) and 'pearl' (*Deania* spp) shark.

No appraisal of the dogfish fishery has been made for southern Australia. Previous examinations of dogfish catches were limited to a few fishery independent research surveys. Upper-slope surveys off NSW showed that the abundance of some sharks had declined dramatically in the 20 years since the inception of the fishery. The greatest change in catch rates was for *Centrophorus* spp which declined from 126 kg/hr in 1976–1977 to 0.4 kg/hr in 1996–1997 (Graham, *et al*., 1997). Upper-slope dogfish catches in other areas have not previously been examined. Reported catch rates for mid-slope sharks are highly variable, ranging from 5–1222 kg/h, with differences between regions and no inter-annual trends (Davenport and Deprez, 1989).

Although little is known of the biology of the species involved, sharks are generally considered vulnerable to fishing because they grow slowly, attain maturity at a late age and have few young (Davenport and Deprez, 1989; Hoenig and Gruber, 1990; Manire and Gruber, 1993). The low productivity of the deepwater environment may make deepwater dogfish particularly vulnerable, especially if they are targeted. There is significant risk that some species of dogfish will face significant depletion or extirpation. *Centrophorus* spp are particularly vulnerable because they have extremely small litter sizes and, in at least one species, a small endemic distribution (Last and Stevens, 1994; Johnson, 1997).

The reproductive biology of deepwater sharks is difficult to study because of segregation by size, sex and reproductive stage (Kobayashi, 1986; Baba *et al*., 1987; Wetherbee, 1996) making it difficult to obtain samples representative of entire populations. The majority of species have no defined breeding season (Girard and Dü Buit, 1999) making it difficult to determine gestation period and annual fecundity. Reported litter sizes range from one (*Centrophorus uyato*) to twenty nine (*Centroscymnus coelolepis)*, and it is likely that dogfish breed less than once per year (Yano and Tanaka, 1987; Johnson, 1997). Methods used for ageing deepwater sharks include counting rings in the dorsal spines (Irvine, 2000; Machado and Figueredo, 2000) and radiometric ageing (Fenton, 2001). Previously published age estimates range up to 70 years but none have been validated (Clarke *et al.,* 2002a&b).

Information on diet and feeding can aid in understanding the ecological role of dogfish. Deepwater dogfish are normally caught by demersal trawls, bottom set lines and traps (Sedbury and Musick, 1978) suggesting a bottom feeding and scavenging habit. However, some species have been caught on mid-water longlines (Litvinov, 1990; Stevens and Wayte, 1999) and other studies have identified pelagic prey items including cephalopods, myctophids, medusae and crustaceans (Clarke and Merret, 1972; Sedberry and Musick, 1978; Yano, 1991). This suggests some species are active benthopelagic feeders. Dogfish have been observed from a deep-sea submersible swimming rapidly up to two metres above the bottom (Sedberry and Musick, 1978). Dogfish also feed on commercially important teleosts (Clark and King, 1989; Ebert *et al.*, 1992; Wetherbee, 2000).

1.2. Need

Additional information is needed for assessment of the status of deepwater dogfish. The species composition of both targeted and discarded components of each fishery and from the market sector needs to be determined. As much of the available catch data are not species-specific, this will require examination of catches involving sea-time and port visits.

Fishery logbook data are available from AFMA for the SET and Southern Shark Fishery, as well as for minor dogfish fisheries. This information can be analysed to estimate the total catch and to examine trends in catches as indicators of changes in abundance. Similarly wholesale figures, available from Melbourne and Sydney fish markets, can be used to estimate total catches, and to examine changes in abundance. Additional fishery-independent catch and effort data are available from CSIRO research vessels, mainly for mid-slope dogfish.

Fishery catch figures may be influenced by changes to fisheries management, market forces, discarding, catch reporting, fisheries practices or abundance. Therefore trends in catch and effort data need to be interpreted carefully. For correct interpretation, it will be essential to develop a detailed knowledge of marketing and fishery practices, particularly targeting, discarding and reporting of catches.

To assess the vulnerability of deepwater dogfish species, data on population parameters such as age at sexual maturity, longevity and fecundity are required, along with information on distribution, home range and movements.

1.3. Objectives

Objectives for this study, as stated in the original FRDC application were:

1. Estimate the annual retained and discarded catch of deepwater dogfish by geographical area and depth strata within the Southern Shark, Western Australian Shark, South East Trawl, Great Australian Bight Trawl and Dropline fisheries.

2. Examine dogfish catch and effort data by region and depth strata for changes in catch rate with time.

3. Determine population structure (size distributions and sex ratio) of principal dogfish species by region and depth strata.

4. Assess the biological productivity of the major upper and mid-slope dogfish species from data on age, growth and reproduction.

5. Obtain qualitative estimates of the mortality of the discarded component of the dogfish catch.

At the start of the study, it was found that surveys of wholesale markets and an assessment of the landed catch were required to better interpret the fishery data. Additional objectives to address this part of the study were:

6. Survey wholesale markets, retail markets and processors for information on species composition and marketing practices.

7. Estimate the annual dogfish catch by analysing wholesale market sales data.

2. ASSESSMENT OF MARKETED CATCH

Objective 6. Survey wholesale markets, retail markets and processors for information on species composition and marketing practices

Objective 7. Estimate the annual catch by analysing wholesale market sales data

2.1. Introduction

It was apparent at the start of this study that the fishery data reported in logbooks, and by the fishery agencies themselves, were difficult to interpret. For example, common names were frequently confused and catch data were recorded as a mixture of whole weight and carcass weight. In an effort to better interpret the fishery data, wholesale and retail outlets in Sydney and Melbourne were visited to observe the species composition and marketing practices of dogfish products.

Industry sources indicated that at least 90% of all dogfish landings are wholesaled through the Sydney Fish Market (SFM) and the Melbourne Fish Market (MFM). These markets were then surveyed during several visits (Table 2.1) to determine:

- the main suppliers and/or origin of catch
- the species composition of dogfishes consigned to the markets
- handling practices by suppliers (to calculate conversion ratios from carcass weight to live weight)
- monthly sales and average price at the wholesale markets
- retail practices and sales
- assessment of liver sales
- estimated total live weight equivalent of the marketed catch

2.2. Methods

Sources of supply
Markets were visited to determine the key species for sale and the leading suppliers. Consignments were examined prior to sale and details from fish box labels recorded. Information collected included: total carcass weight, scientific name, common name used in market place, vessel name and port of landing (used to infer the catch location).

Species identification
As carcasses of most deepwater dogfish are sold with the head and paired fins removed, the identification of the species was determined from the colour and texture of the skin, the colour, size and shape of the dorsal spines, and the size of the dorsal fins. Species composition information was used to assist in interpreting fishery data that was not species-specific. Fillets from retail outlets were identified using the Australian Seafood Handbook (Yearsley *et al*., 1999).

Handling practices by suppliers
Methods of preparing carcasses and livers for wholesale markets were examined by observing how the different species were presented in the fish markets, or by observing the handling practices on board trawlers. The observed methods for a number of species were later repeated in laboratory experiments to determine conversion factors for liver or carcass weights to whole weights. One conversion factor was provided by industry.

Trends in wholesale market volume and price

Monthly carcass wholesale data were obtained for the SFM and MFM from their respective web-sites:

Sydney (Feb. 1992–Nov. 1999):
http://www.sydneyfishmarket.com.au /servlet/DRRegister?action=monthsearch

Melbourne (Aug. 1997–Dec. 2000):
http://www.chsmith.com.au/fish-prices/melbourne.html.

Information was obtained for the following dogfish marketing categories:
SFM: greeneye shark, Endeavour shark, roughskin shark and black roughskin shark.
MFM: black/pearl shark. Some dogfish sales at both markets could not be analysed because they were sold in mixed shark categories, or mixed with teleosts.

Data for SFM were separated into the regions where supplies originated: Sydney, southern NSW (from ports south of Sydney), and northern NSW (from ports north of Sydney).

For each species, the monthly data consisted of the weight (kg) of carcasses sold and average price per kg. Trends in the monthly sales and sales volume were examined using regression analysis, as potential indicators of abundance of dogfish in the source fisheries. Changes in the average monthly price were also examined using regression analysis. Total annual sales were used to calculate total catch estimates.

Market based estimate of annual catch

The estimated annual live-catch of dogfish was calculated from the market sales data by converting carcass weight to live weight using the conversion factors determined for each species (Section 2.3.3).

Retail practices and sales

Retail marketing practices for carcasses were examined during visits to outlets in Melbourne, Sydney and Hobart. The common name on labels was recorded together with the price per kg. Changes in availability and price were used as qualitative indicators of abundance and consumer demand.

Assessment of liver sales and products

Dogfish livers are not sold at major wholesale markets, and statistics on dogfish livers or liver products are not collated by the Australian Bureau of Statistics, and none were made available from processors. Therefore a qualitative assessment of the demand for livers and its possible influence on catches was undertaken.

Leading buyers of livers were identified through industry consultation. Processors were asked for information relating to source of livers, price paid, methods of extracting oil, methods of refining oil and markets for refined products.

2.3. Results

2.3.1. Sources of supply

In all, 13 visits to wholesale markets, retail markets and processors were made (Table 2.1). Major suppliers were identified as those with the highest total weight of consignments observed during market visits. These suppliers were later surveyed by questionnaire (Section 3.2, Appendix C**)** for further information to help with the interpretation of data from the commercial fishery.

The market surveys found that most catches of *Squalus* and *Centrophorus* spp were caught off NSW and marketed through the SFM, while most mid-slope species (*Centroscymnus* and *Deania* spp) were consigned to either Sydney or Melbourne by trawlers operating from Victorian ports (Table 2.2)

Table 2.1: Details of market visits

Date	Supplier	Market type	City
21/4/99	Deep Sea Oils Ltd.	Liver-oil refiner & exporter	Hobart
28/9/99	Melbourne Wholesale Fish Market	Carcass wholesalers	Melbourne
28/9/00	R. F. McLoughlin	Carcass & liver wholesaler	Melbourne
28/9/00	Queen Victoria Markets	Carcass retailers	Melbourne
18/4/00	Melbourne Wholesale Fish Market	Carcass wholesalers	Melbourne
18/4/00	Queen Victoria Markets	Carcass retailers	Melbourne
19/4/00	Sydney Fish Market	Carcass wholesalers & retailers	Sydney
20/4/00	Sydney Fish Market	Carcass wholesalers & retailers	Sydney
14/11/00	Melbourne Wholesale Fish Market	Carcass wholesalers	Melbourne
14/11/00	Queen Victoria Markets	Carcass retailers	Melbourne
15/11/00	Melbourne Wholesale Fish Market	Carcass wholesalers	Melbourne
16/11/00	Sydney Fish Market	Carcass wholesalers & retailers	Sydney
17/11/00	Sydney Fish Market	Carcass wholesalers & retailers	Sydney

Table 2.2: Sources of supply and weights by species of dogfish sold at Sydney and Melbourne wholesale markets during visits

	Carcass Weight (t)					
	Centrophorus uyato	*Centroscymnus spp*	*Deania spp*	*Squalus megalops*	*Squalus mitsukurii*	Total
Melbourne Fish Market						
Victorian sources	0.22	5.74	6.29	-		12.25
NSW sources	-	-	-	0.06		0.06
Sydney Fish Market						
NSW sources	0.16	0.06	0.45	0.44	0.12	1.23
Victorian sources	-	0.64	0.64	-	-	1.28
Totals	0.38	6.44	7.38	0.50	0.12	14.82

2.3.2. Species identification

Carcasses totalling 12.3 t were examined at the MFM, and 2.5 t were examined at the SFM (Table 2.2). All carcasses were readily identifiable to genus, and most to the species level. The species identified within the market groupings of dogfish were:

SFM: Greeneye shark: *Squalus* spp
Endeavour shark: *Centrophorus* spp
Roughskin shark: *Deania* spp and *Centroscymnus* spp
Black roughskin shark: *Centroscymnus* spp

MFM: Black shark: *Centroscymnus* spp
Pearl shark: *Deania* spp

During the market surveys, supplies to both the SFM and MFM were dominated by mid-slope species (*Deania* and *Centroscymnus* spp) that comprised 93.3% of all dogfish consignments (Table 2.2). *Deania* spp and *Centroscymnus* spp (mainly *C. crepidater*) represented 49.8% and 43.5% of the total respectively. The remaining 6.7% were shelf and upper-slope species with *Centrophorus* spp, *Squalus megalops* and *S. mitsukurii* representing 2.6%, 3.4% and 0.8% of the total respectively. Advice from fishers confirmed the market observations (Table 2.1) that roughskin shark consigned by NSW vessels consisted almost totally of *Deania* spp (mainly *D. calcea*) and included only small quantities of *Centroscymnus* spp.

2.3.3. Handling practices by suppliers

All dogfish are sent to the wholesale markets headed and gutted. However, the method of processing differed among species, resulting in different recovery rates. For large upper-slope sharks such as *Centrophorus* spp and *Squalus mitsukurii*, the head is usually removed in front of the gill area and the body is opened along the ventral midline. The gut is removed but the belly flap is retained (Figure 2.1a).

For some of the smaller *Squalus megalops* and mid-slope sharks such as *Deania* spp and *Centroscymnus* spp, the head is usually cut off behind the pectoral fins and discarded with the gill area and belly flap (Figure 2.1b). A number of whole *Deania* and *Centroscymnus* spp were processed in this manner in the laboratory and carcass weight to whole weight conversion factors calculated (Table 2.3).

The method of storing livers varied between vessels but returns are maximised if the livers are placed in lined containers or polythene bags, and then refrigerated until landed for sale directly to processors.

Figure 2.1a: Lower waste method of processing dogfish carcasses

Figure 2.1b: Higher waste method of processing dogfish carcasses

Table 2.3: Carcass weight to whole weight conversion factors

Species	Proportional carcass weight (% whole weight)	Conversion factor	Source
Centrophorus spp	60	1.66	Industry
Centroscymnus spp	29–35, (n=69)	3.09	Present study
Deania spp	36–40, (n=17)	2.64	Present study

2.3.4. Trends in wholesale market volume and price

Market sales are presented for the Sydney and Melbourne Wholesale Fish Markets for the period 1992–2000. This information was accessed from the websites of these markets that gave monthly sales of the main groupings of dogfish species.

Sydney Fish Market

Greeneye shark (*Squalus* spp)
Market observations found that about 80% of greeneye shark comprised *S. megalops*, which is primarily a small, outer shelf/upper-slope species. The remainder consisted of small quantities of *S. mitsukurii* and/or *Squalus* sp. F (Table 2.2).

A total of 675 t of greeneye shark carcasses was sold between February 1992 and November 1999. Monthly volumes declined significantly (P <0.001) during this period (Figure 2.2a). Total volume for the 12 months to January 1993 was 149.8t, but this fell to 50.3 t for the twelve months to November 1999. Almost all (99.5%) greeneye shark originated from NSW (southern NSW 56%, northern NSW 23%, general NSW 14% and Sydney trawlers 6.5%). Consignments from southern NSW were generally lowest in winter and highest in summer (Figure 2.2b) whereas consignments from northern NSW showed the opposite trends (Figure 2.2c).

Through the period examined, there was no significant change (P >0.5) to the average monthly price of around $2/kg (Figure 2.2d). The aggregate value of sales for the period was approximately $1.3 million. There was a significant (P <0.001) decline in the average monthly sales value (Figure 2.2e), reflecting the decline in market consignments. The value of consignments during the 12 months to January 1993 was $255K. In the twelve months to November 1999, the value had declined to $104K, 41% of initial levels.

Endeavour shark (*Centrophorus* spp)
A total of 405 t of Endeavour dogfish carcasses were sold between February 1992 and November 1999. There was a significant (P <0.001) downward trend in monthly sales volume (Figure 2.3a). A total of 83.3 t were sold in the12 months to January 1993 but only 20.4 t were sold during the 12 months to November 1999. The overall decline in volume largely reflected a significant (P <0.001) reduction in consignments from southern NSW where the majority (53%) of the total originates (Figure 2.3b).

The average monthly price was relatively high with no significant change (P >0.25), averaging $3.33/kg during the period (Figure 2.3d). Total sales value was $1.3 million. Monthly sales declined significantly (P <0.001) during the period (Figure 2.3e), falling from $257K in the 12 months to January 1993 to $70K in the 12 months to October 1999.

Roughskin shark (*Centroscymnus* spp and *Deania* spp)
The sales volume of roughskin shark carcasses was the highest of any dogfish category at the SFM, totalling 684.9 t between February 1992 and November 1999. Total volume for the most recent year on record (the twelve months to November 1999) was 77.3 t. Almost

all consignments to January 1996 were from southern NSW vessels; thereafter, most of the catch originated from Victoria (Figures 2.4a–c). Southern NSW landings were 48% of the 685 t total, and 36% came from Victoria. Other supplies originated from Sydney trawlers (8%), general NSW sources (6%) and northern NSW (2%).

There was no overall trend in total market volume during the period (Figure 2.4a) although trends were evident in supplies from different regions. Consignments originating in southern NSW peaked during the first year of records in December 1992 at 16.5 t, but subsequently declined (Figure 2.4b). With the relaxing of mercury laws in November, 1995, supplies from Victoria-based trawlers markedly increased sales volume in 1996 (Fig. 2.4c). The monthly sales peaked at 18.9 t in March 1996, after which there was a downward (although not significant) trend ($P = 0.2$).

The average monthly price/kg has risen steadily and significantly ($P < 0.001$) from $1.74/kg in the twelve months to February 1993 to $3.66 in the twelve months to November 1999 (Figure 2.4d). Sales value increased during the period from $74K in the twelve months to February 1993, to $285k in the twelve months to November 1999. The total value of carcass sales over the period was $1.96 million (Figure2.4e).

A small proportion (3%) of the roughskin shark sales consigned to the SFM by Victoria-based trawlers was marketed separately as ‘black roughskin’ shark and comprised mainly *Centroscymnus* spp. Separate figures for this black roughskin shark were recorded between March and November 1999 with sales totalling $80K at an average price of $3.63/kg, similar to the price for roughskin shark during the same period.

Melbourne Fish Market

Greeneye and Endeavour sharks
The relatively small quantities of these species that were consigned to the MFM were usually mixed with other sharks. Consequently, no separate figures were available.

Roughskin (black/pearl) sharks (*Centroscymnus* and *Deania* spp)
At the MFM, *Centroscymnus* species are sold as black shark, and *Deania* spp as pearl shark. The origin of consignments is not listed in sales figures for the Melbourne markets. However, market observations identified Victorian trawlers as the main suppliers.

Sales between August 1997 and January 2001 totalled 603 t. Monthly volumes increased significantly ($P < 0.001$) during the period (Figure 2.5a). Annual volume rose from 54 t in 1998 to 158 t in 2000.

The average price paid for carcasses in the year 2000 was $3.03/kg (Figure 2.5b), slightly higher than the average price of $2.87/kg paid in 1997. Sales totalled $1.79 million during the period examined. The value of annual sales rose from $310K in 1998 to $817K in 2000. Monthly sales increased significantly ($P < 0.001$) (Figure 2.5c).

Figure 2.2: Monthly sales of greeneye shark—Sydney Fish Market

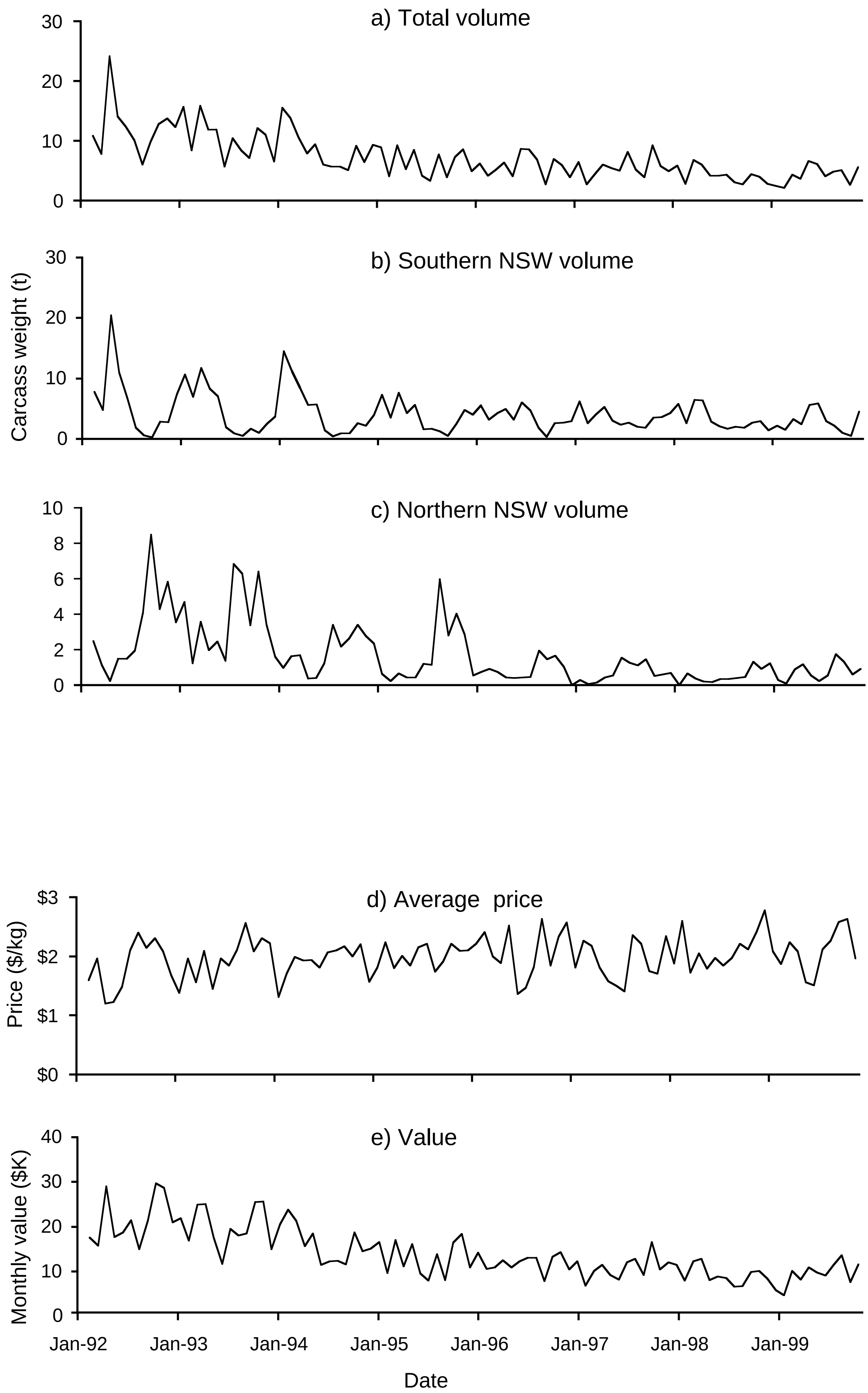


Figure 2.3: Monthly sales of Endeavour shark—Sydney Fish Market

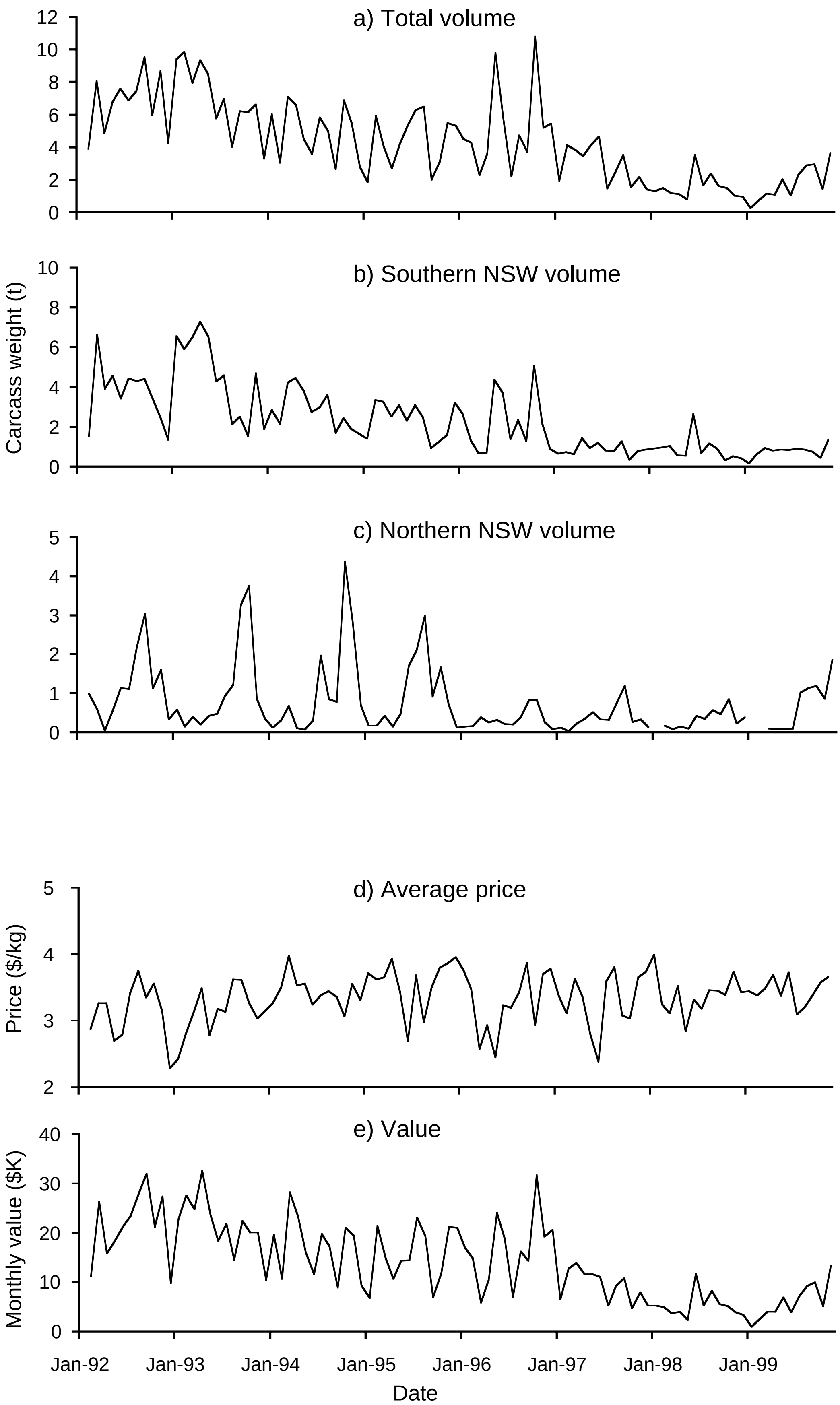


Figure 2.4: Monthly sales of roughskin shark—Sydney Fish Market

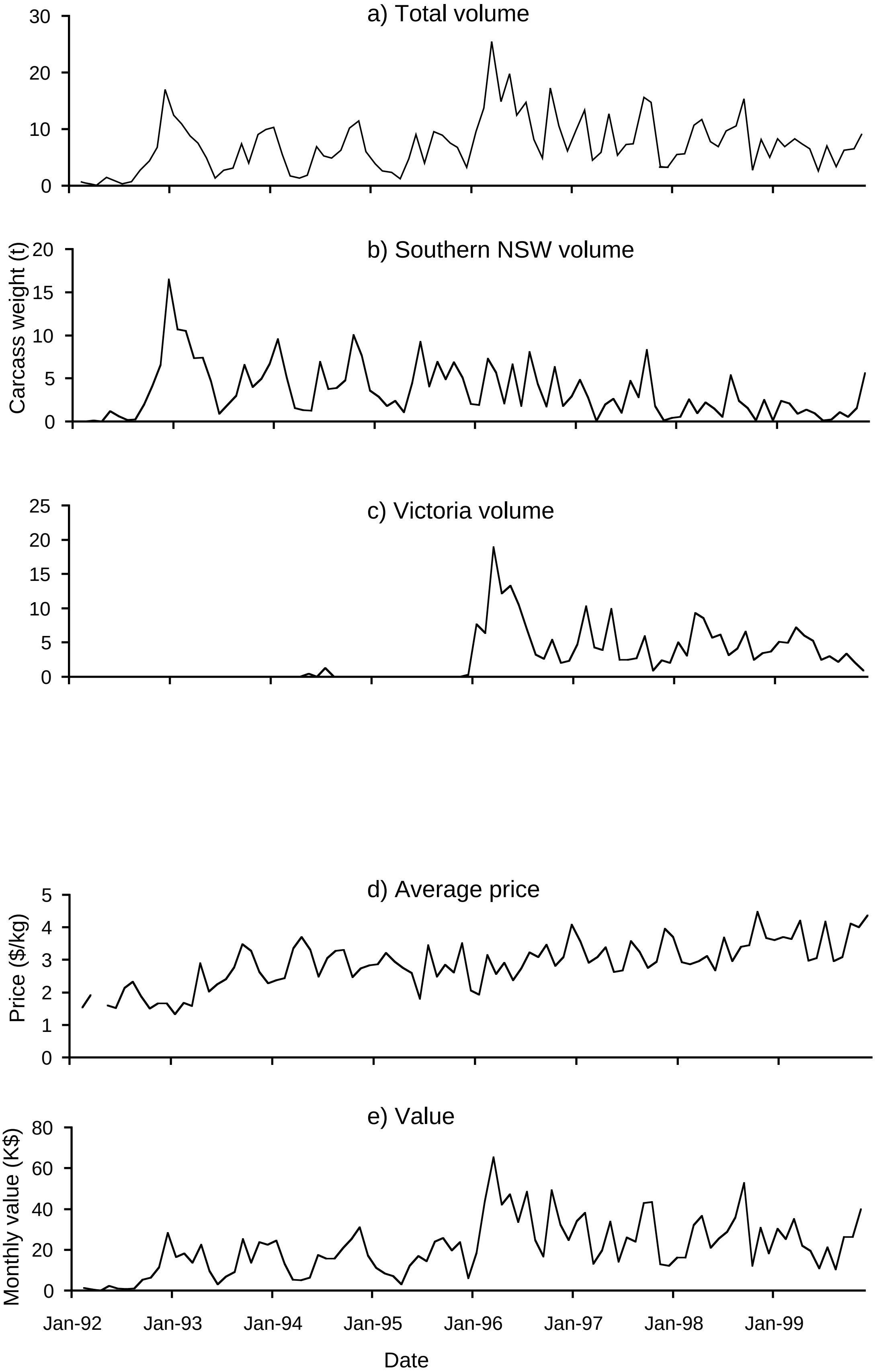
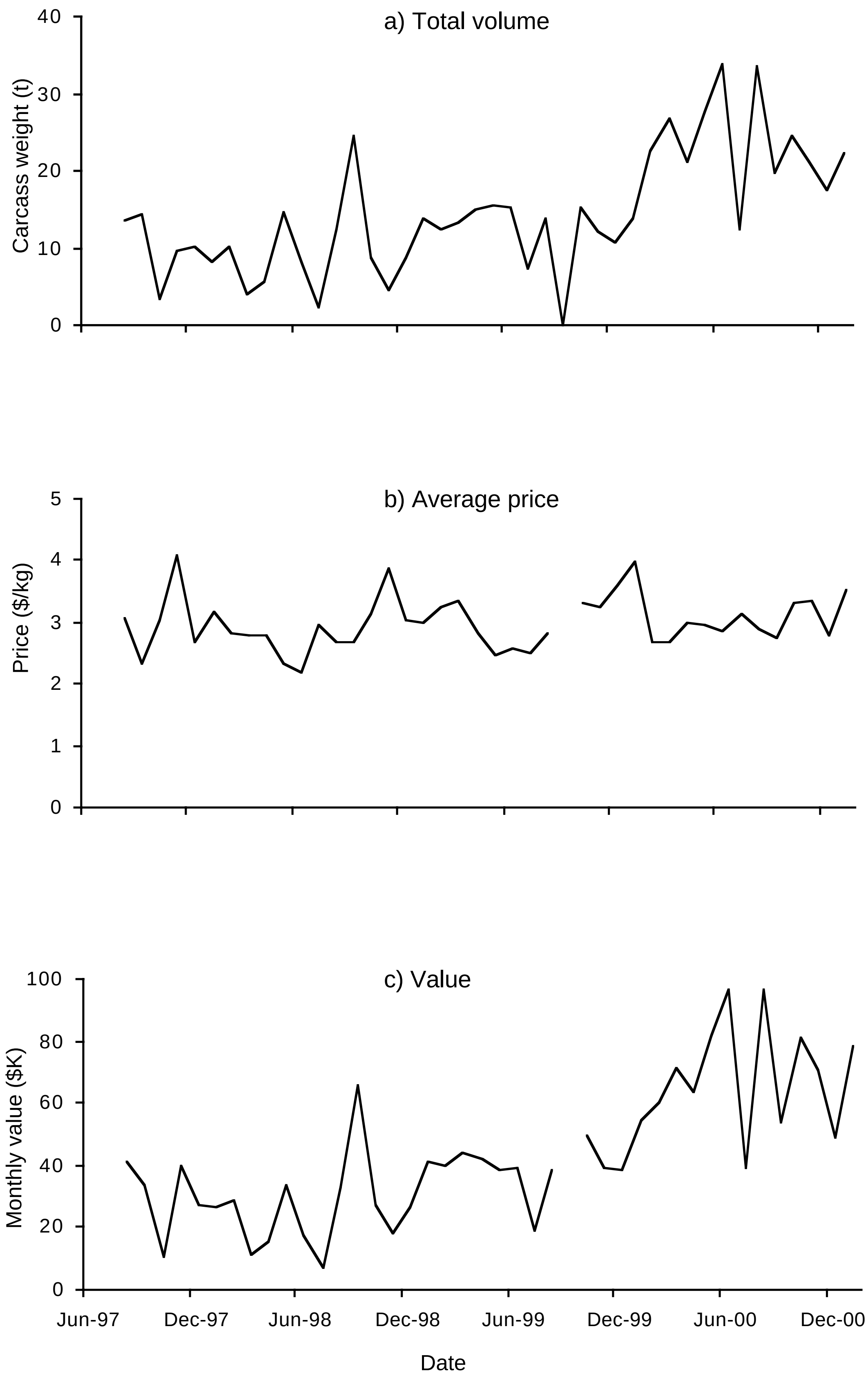


Figure 2.5: Monthly sales of roughskin (black/pearl) shark—Melbourne Fish Market



2.3.5. Market based estimate of annual catch

Wholesale carcass figures were used to estimate the live weight of catches. Carcass sales of Endeavour and roughskin sharks through the SFM and MFM totalled 298 t for the most recent twelve monthly period available. This included an estimated 20 t of Endeavour shark for the MFM (industry advice). The estimated live weight equivalent of the marketed catch for this period was approximately 791 t (Table 2.4). Greeneye sales were not included in this estimate as they consisted largely of *Squalus megalops*, a shallow water species.

As trade figures for either livers or liver-oil were not publicly available (Section 2.3.7), it was not possible to develop total catch estimates from liver production.

Table 2.4: Annual carcass sales and estimated whole weight of Endeavour and roughskin sharks from SFM and MFM sales data

Sales category	Period	Carcass weight (t)	Conversion factor	Whole weight (t)
Melbourne Fish market				
Endeavour shark *	Dec. 98–Nov. 99	20	1.67	**33**
Roughskin shark #	Jan.–Dec. 2000	158	2.81	444
Sydney Fish Market				
Endeavour shark	Dec. 98–Nov. 99	20	1.67	**33**
Roughskin shark #	Dec. 98–Nov. 99	100	2.81	281
Total		**298**		**791**

*Sales figures for Endeavour shark are not collated separately at Melbourne Market but industry sources and market visits suggests they are currently sold in similar amounts at both Sydney and Melbourne Markets.

The conversion factor used for mid-slope species combines conversions derived for *Deania* spp and *Centroscymnus* spp (Table 2.3) and assumes the commercial mid-slope catch is 64% *Centroscymnus* spp and 36% *Deania* spp (advice from industry).

2.3.6. Retail practices and sales

All dogfish were sold as fillets with the skin removed. Fillets were distinctively very long and thin (Figure 2.6) and could be reliably identified. The prices ranged between $8.50 and $9.50/kg during September 1999, but had risen to $11.50–$12.50 by November 2000. This increase in price suggested that consumer demand was high.

Centroscymnus spp or *Deania* spp were sold as 'flake' in eight of nine stalls that sold dogfish at Queen Victoria Market (Melbourne) on 28 September 1999. The remaining stall sold *Deania* spp as 'pearl shark', a name normally used only in the Victorian wholesale sector. *Centrophorus* spp fillets were purchased from one Tasmanian supermarket belonging to a major chain. These fillets were sold as 'flake' and had been purchased from a wholesaler as 'Endeavour flake'.

Figure 2.6: Dogfish fillets on sale at a Melbourne retailer

2.3.7. Assessment of liver sales and products

Processors prefer livers from *Centrophorus* spp which have the highest squalene content: 67–89% (Peyronel *et al*., 1984; Hernández-Perez *et al*., 1997). Livers from species such as *Centroscymnus crepidater* and *Deania calcea* have lower squalene content (43 and 56% respectively) (Davenport and Deprez, 1989) and attract lower prices. Livers from *Squalus* spp contain no squalene and are not retained for sale. Fishers report that the price received for livers declined from $7/kg to $2.40/kg during recent years because of the decline in catches of *Centrophorus* spp and targeting of species with lower squalene. The price was also affected by improvements in the profitability of synthetic squalene synthesis, lower world commodity prices and other economic factors affecting the cosmetics industry.

Oil is extracted from livers by heating or freezing. Heating tends to remove more of the oil but may degrade it, while freezing yields better quality oil. Declines in local supplies have lead to imports of unrefined oil from overseas sources including New Zealand. In the refining process, the liver oil is fractionated by distillation or other means with squalene the most valuable component of the oil.

Most of the refined product is exported, but some is encapsulated for the domestic neutraceutical market. Recent developments in the use of the DAGE fraction of the oil offer the potential for better prices in the future. Brochures from the manufacturer Deep Sea Oils promote squalene as an anti-oxidant and DAGE for its ability to boost the immune system. However, the newly developing market for DAGE is currently highly variable.

2.4. Discussion of dogfish markets

Total weight of deepwater dogfish carcasses sold through the SFM and MFM for the most recent twelve months of records (Melbourne up to Nov 99, Sydney up to Dec 2000) was approximately 300 t which sold for $1.51 million. This carcass production represents about 790 t of live weight but must be regarded as a conservative estimate of total catch. It does not include 'dogshark' or 'mixed shark' categories from SFM or the 'Other shark' category from MFM, both of which contain a proportion of deepwater dogfish. In addition, sharks discarded by the fishery are not included.

Fishers and agents reported that sales of upper-slope dogfish were higher in the past. This observation is supported by the market data for deepwater dogshark which show declining supplies of the upper-slope greeneye and Endeavour sharks. This trend for the upper-slope species reflects the catch history of the NSW sector of the SEF that showed a dramatic decline in the stocks of some species of sharks and rays (Andrew *et al.*, 1997). In contrast, Victorian and Tasmanian landings of the mid-slope dwelling roughskin shark species are increasing, although consignments derived from NSW trawlers are decreasing.

Greeneye shark sales through the SFM have been reported since at least the early 1970s (SFM Annual Reports). Sales gradually increased from about 26 t in 1974/75 to 128 t in each of 1984/85 and 1985/86. In the following years to 1991/92, annual volumes were mostly between 105 and 120 t. As this study shows, the annual volume then peaked at 150 t for the 12 months ending January 1993 but has declined since. The marketed catch is now mostly *Squalus megalops*. In preceding years, greeneye shark sales probably included a greater proportion of the larger *Squalus* sp. F and *S. mitsukurii* that were caught in relatively large numbers on the NSW upper-slope in the 1970s (Graham *et al*., 2001). The relatively low price now paid for greeneye shark (compared to other species) reflects the small size of *S. megalops*. Small quantities of the larger *S. mitsukurii* are landed in Victoria and usually marketed as 'other shark'.

Four species of Endeavour dogfishes (*Centrophorus harrissoni, C. moluccensis, C. squamosus* and *C. uyato*) are caught and marketed off southern Australia. All but *C. squamosus* (always caught in low numbers) were prolific around SE Australia at the start of the SET but stocks are now depleted (Graham *et al*., 2001). The decline in the *Centrophorus* market volumes is correlated with the overall decline in dogfish catches in the SET off southern NSW (Figure 3.4a). The relatively high price paid for Endeavour shark carcasses and for their livers, indicates that demand has remained steady and the reduced volume was because of declining abundance.

Clearly defined seasonal peaks in both greeneye and Endeavour shark production are evident in the NSW data (Figs 2.2–2.3). During the early 1990s, most landings from southern NSW were in the late summer–autumn period, although this was less defined in later years. In contrast, the northern NSW data shows sharp peaks in production during winter–spring. These temporal differences in monthly supply between northern and southern NSW may reflect seasonal movements by greeneye and Endeavour sharks or, seasonal differences in fishing practices such as target species and/or depths.

No data are available for roughskin shark landings prior to 1992, but it is likely that they were relatively small. After the advent of the Individual Transferable Quota management system in 1992 (Tilzey, 1994), there was increased targeting of non-quota species such as deepwater sharks, to supplement catches of managed species. Catches prior to 1996 by trawlers based in Victoria were limited to mainly liver markets by the ban on landing shark meat with high mercury levels. The enforcement of these mercury-content regulations was relaxed in November 1995, even though the levels of arsenic and mercury in *Deania calcea* and *Centroscymnus* spp still exceed maximum levels permitted in food by the Australian Food Standards Code (Davenport, 1995; Turoczy *et al.*, 2000). The relaxing of these laws lead to increased targeting of the mid-slope dogfishes, particularly off western Tasmania and western Bass Strait. (Figures 3.6b–c). Consignments of roughskin shark from Victorian trawlers to both Sydney and Melbourne subsequently increased. The rising market price for roughskin shark at both the SFM and MFM infers no lack of demand for the product. It is therefore probable that the decline in consignments from southern NSW is because of reduced catch rates on NSW grounds.

Endeavour sharks and larger greeneye sharks are prepared for marketing in a manner similar to that used for school and gummy sharks and results in a relatively high carcass-weight to whole-weight ratio (Table 2.3). In contrast, roughskin sharks are usually taken in large catches and are normally butchered in a faster manner that removes more of the head and all the belly flap. This method of preparation, and their more slender form, results in about twice as much waste as for Endeavour sharks.

All dogsharks are retailed as fillets, and usually with the description ‘flake’ (Victoria and Tasmania) or ‘boneless’ (NSW). It is this boneless characteristic that maintains much of the demand for shark meat, including fillets from dogfish. The recommended marketing name for *Centrophorus* spp is ‘Endeavour dogfish’, and for *Deania* spp and *Centroscymnus* spp, ‘roughskin shark’ (Yearsley *et al*., 1999). The name ‘roughskin shark’ is considered particularly unattractive to wholesale and retail customers in Melbourne where the name ‘Pearl shark’ is often substituted for catches of *Deania* spp This common name follows the FV ‘Empress Pearl’, the leading market supplier.

3. ASSESSMENT OF COMMERCIAL FISHERIES

Objective 1. Estimate the annual retained and discarded catch of deepwater dogfish by geographical area and depth strata within the Southern Shark, WA Shark, South East Trawl, Great Australian Bight Trawl and Dropline fisheries

Objective 2. Examine dogfish catch and effort data by region and depth strata for changes in catch rate with time

Objective 5. Obtain qualitative estimates of the mortality of the discarded component of the dogfish catch

3.1. Introduction

Catches of deepwater dogfish were reported from seven fisheries and catch data were available from a number of sources. To help interpret and analyse the data, fishery practices including targeting, discarding and reporting were examined through interviews and field observations. With this background information, catch data from each fishery were assessed.

3.2. Methods

Fisheries examined
Fishery practices and catch data from seven fisheries with significant dogfish catches were examined. These fisheries were:

- South East Trawl (SET)
- Southern Shark (SSF)
- South East Non-Trawl (SENT)
- NSW dropline and trawl
- Great Australian Bight Trawl (GABT)
- WA Shark
- Western Deepwater (WDW)

Interpretation of fishery data
Fishery logbook data were used to estimate the annual retained catches of dogfish. To interpret fishery catch data and to standardise the logbook data, fishers supplied information on their targeting, discarding, and reporting practices, and the species composition of catches.

A questionnaire (Appendix C) was developed to standardise information collected on fishery practices during telephone and face-to-face interviews with fishers. The questionnaire was completed during phone conversations, port visits and during field work aboard commercial vessels. Port visits in Tasmania and Victoria were conducted by CSIRO officers, and in NSW by AFMA logbook officers.

Operators of 55 vessels (SET: 27, SENT: 3, NSW: 2, SSF:15, GABT: 5, WA Shark: 2, WDW: 1) were interviewed by telephone or in person in October 1999 and questionnaires completed for most. Respondents who reported significant shark catches were again interviewed (using a modified questionnaire) in June 2000 to determine any changes in fishery practices or catches.

Information collected from questionnaires was validated by observations made during field work, and by Integrated Shipboard Monitoring Program (ISMP) and AFMA observers. Relevant ISMP and AFMA observer data were also sourced for fishery catch composition and discard information.

Dogfish identification sheets (Appendix D) were produced to improve species-specific logbook data for catches, The sheets were distributed by AFMA to SET vessels. Research catch composition data were also used to interpret the species composition of commercial fishery data.

Field and port observations

Four trips were made on commercial trawlers (Table 3.1) to check fishery practices and catch composition to further aid in the interpretation of logbook data. Station and catch & effort data were recorded for each trawl. Station data consisted of depth, start and finish time, latitude and longitude. For catch & effort data, catches were sorted and live weight and/or numbers of each species were recorded; large catches were sub-sampled. The total retained marketable catch of *Deania* and *Centroscymnus* spp carcasses was determined from logbook entries of the weight of carcasses and livers retained.

In addition, samples of dogfish were supplied to CSIRO Marine Research from trawlers targeting market fish and orange roughy (*Hoplostethus atlanticus*) around Tasmania. These samples were principally for biological studies, but species composition and distribution data were also obtained.

Commercial catch analysis

Fishery logbook data were collated and analysed to:

- calculate the total reported catch of dogfish from each fishery
- determine species composition of the current catch in the each fishery
- determine trends in annual catch in each fishery
- determine trends in catch per unit effort (CPUE) in the SET
- determine regional and depth differences in species composition and catch rate across the SET and SSF

Logbook catch data and catch returns were analysed for six fisheries (Table 3.2); attempts to acquire voluntary logbook data from the WA Shark Fishery were unsuccessful. The data were used to determine annual production and trends in annual catch. Trends in CPUE were also calculated for the SET from logbook catch and effort data; CPUE was not calculated for other fisheries. The SET and SSF data were analysed on a regional basis (Figure 3.1) but for minor dogfish fisheries, data were collated across the range of each fishery.

Where sufficient data were available, total live-catch weights were estimated for the main species-groups in each of the fisheries examined. Because most of the logbook data were not species-specific, the species composition was inferred from market and research data, or from the depth-ranges of the catches. As the depth ranges of the main dogfish species were known, catches from particular depths were assigned to the known species in that depth category (Table 3.3). Where retained catches were recorded as carcass weights, the previously determined conversion factors (Table 2.4) were used to estimate live-catch weights.

Table 3.1: Field surveys

Start date	Finish date	Return Port	Fishing areas	Vessel
17/7/99	21/7/99	Hobart	E. Tas.	FV 'Saxon Progress'
4/10/99	11/10/00	Melbourne	W. Tas.	FV 'Empress Pearl'
8/4/00	17/4/00	Port Welshpool	E. Bass St; E. Tas	FV 'Empress Pearl'
21/8/00	26/6/00	Strahan	W. Bass St.; W. Tas.	FV 'Empress Pearl'

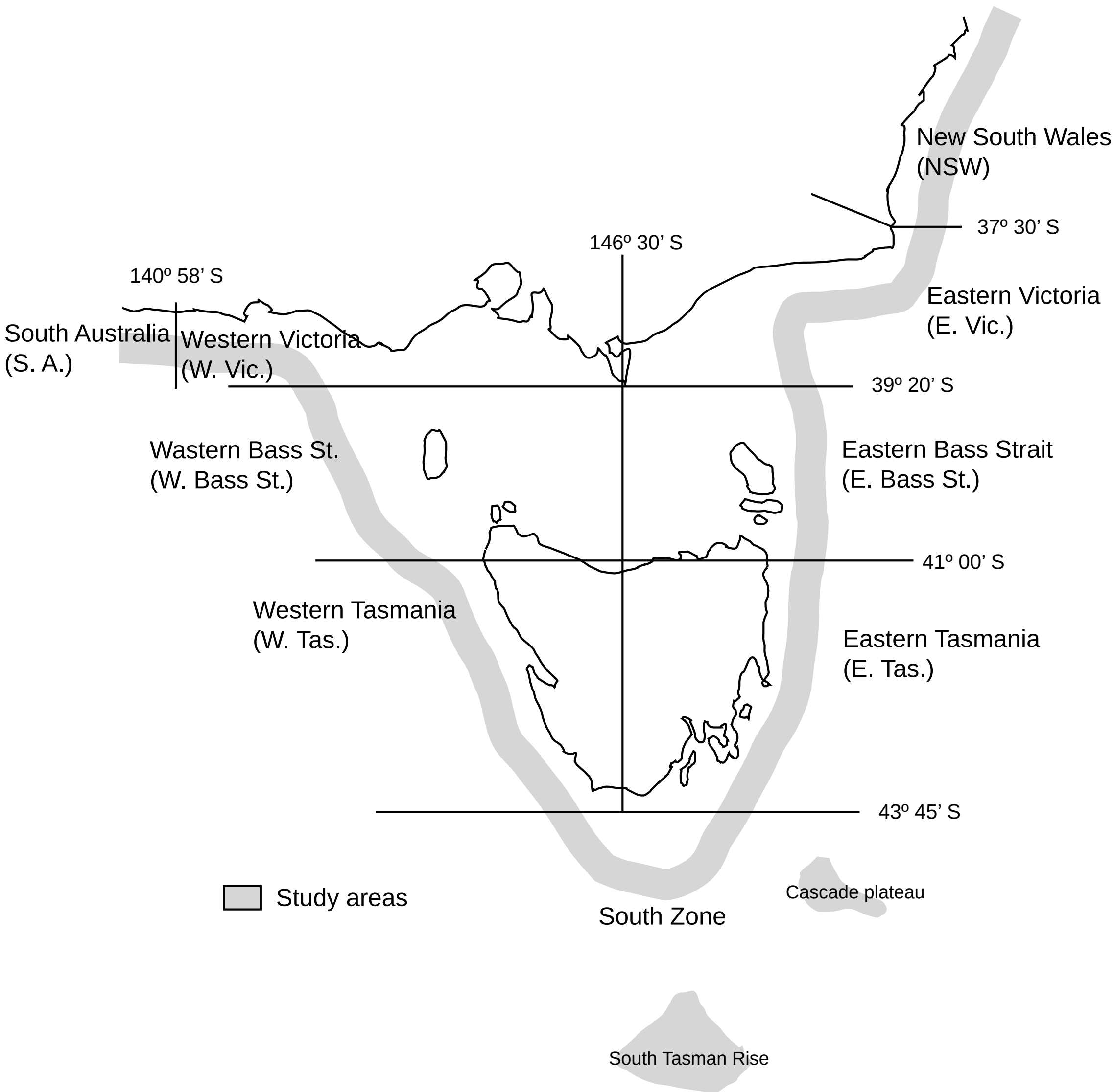
Table 3.2: Sources of fishery data utilised for dogfish catch analyses

Data set	Data source	Logbook type	Catch verification	Period examined	Species breakdown
SET observer	ISMP	ISMP	ISMP	1992–1998	Mostly species-specific
SET logbook	AFMA	SEF1B	None for dogfish	1985–2000	Recently improved
SSF logbook	AFMA	GNO1	AFMA field trip	1970–1998	Dogfish category
SENT logbook	AFMA	GNO1	None for dogfish	1997–1999	Partly
GABT logbook	AFMA	GB01	None for dogfish	1987–1998	Partly
WDW logbook	AFMA	WDT01	None for dogfish	1993–1997	Partly
NSW Catch Statistics	NSW Fisheries	Fishers catch returns	None for dogfish	1990–2000	Partly

Table 3.3: Depth categories used in analysis of fishery and research data

Depth range	Depth category	Main species likely to be present
200–399 m	Inner upper-slope	*Squalus megalops, S. mitsukurii,*
400–649 m	Outer upper-slope	*Centrophorus* spp, *S. mitsukurii*
650–1200 m	Mid-slope	*Deania* spp, *Centroscymnus* spp, *Etmopterus* spp, *Dalatias licha*

Figure 3.1: Regions used in the analyses of fishery and research catch data



3.3. Results

3.3.1. South East Trawl Fishery

Fishery practices

Trawlers operating in depths from 200–650 m are not currently targeting dogfish. However, dogfish catches remain an important component of 'mixed fishing' for some vessels working in this depth zone. In the past, at least one trawler has targeted *Centrophorus* spp off NSW.

In the 650–1200 m depth category, there is now significant targeting of deepwater dogfish. The introduction of individual transferable quotas (ITQs) for major commercial species in 1992 and the relaxing of Victorian restrictions on mercury content in sharks in 1995 resulted in the targeting of non-quota species on the mid-slope, including *Deania* spp and *Centroscymnus* spp.

Most vessels that primarily target orange roughy on seamounts normally discard all dogfish because they attract comparatively low prices and cannot compete with high valued orange roughy for processing time. *Dalatias licha* and *Etmopterus* spp are usually discarded from catches on all grounds as their fillets are considered to be too soft and of low quality. In all depths, dogfish too small for marketing (juveniles and small species) are discarded. Although significant quantities of the relatively small spiky dogfish (*Squalus megalops*) are marketed in NSW as 'greeneye shark' (Section 2.3.4), this species is frequently discarded by Victorian trawlers.

Very few living dogfish were seen in catches during numerous field observations (R. Daley, K. Graham, personal observations). As trawl duration during commercial trawling was usually in excess of three hours, almost all dogfish are dead when brought on deck, and discarded catch was not returned to the sea until sorting of the catch was completed.

Reporting of targeted catches has improved recently, but there is still some confusion over the method of recording weight. Logbook officers from AFMA indicated that dogfish catches should be recorded as whole weight, but all of ten trawler skippers contacted subsequently stated that recorded weight represented the estimated carcass weight. All logbook catch data have been treated as carcass weight.

Species composition

Information on the species composition of dogfish catches in the SET was derived from several sources:

- year 2000 logbook data
- port and field observations
- research survey data
- ISMP and AFMA observer data

Year 2000 logbooks: As a result of the distribution of dogfish identification sheets to industry (Appendix D), 82% of the catch for the year 2000 was identified to at least genus level (Table 3.4). Mid-slope species (*Deania* and *Centroscymnus*) represented 78% of the total catch. However, most of the upper-slope dogfish catch (64%) was only identified to family; the remainder comprised greeneye shark (*Squalus* spp) with relatively small amounts of Endeavour shark (*Centrophorus* spp).

Port and field observations: The catch composition data from port and field observations are summarised in Table 3.5. The samples from orange roughy trawlers (port collections) were from seamounts south of Tasmania and comprised mainly *Etmopterus granulosus* (> 72%). Marketable species such as *Deania* and *Centroscymnus* spp were a relatively small proportion of the dogfish catch from this area. In contrast, field observations on board trawlers working off the east and west coasts of Tasmania (Table 3.5) found catches were principally composed of *Deania* and *Centroscymnus* spp, *Deania* spp formed the greater proportion in the east and *Centroscymnus* spp were more common in the west.

Research survey data: Comparative data from mid-slope research surveys by the Tasmanian fisheries agency (DPIWE) are included in Table 3.5. These data were consistent with the field-trip observations off Tasmania. Catch composition data from CSIRO (Section 4) and NSW Fisheries research trawling were also accessed to infer species composition.

ISMP observer data: The proportions of dogfish species in SET catches recorded by ISMP observers during 1992–1998 are collated for each region in Table 3.6. The data suggest that *Squalus megalops* was the dominant upper-slope species off NSW and eastern Victoria, and that *S. mitsukurii* was more abundant in other regions. Mid-slope catches comprised mainly *Deania calcea* in most regions, although *Dalatias licha* was reported as the major catch off southern Tasmania. A high proportion of the dogfish catch in the western regions (western Tasmania to SA) was unclassified. There are discrepancies between the species composition from ISMP data and other data sources. These problems are discussed (Section 3.4).

AFMA observer data: Dogfish catches were examined from 167 commercial trawls on the South Tasman Rise in 1998 from deeper than 650 m. *Etmopterus granulosus* dominated the catch (77% by weight). *Centroscymnus crepidater* (3%) and *C. plunketi* were also taken. No *Dalatias licha* were taken.

Table 3.4: SET dogfish catch composition—year 2000 logbook data, all depths

Species	Reported catch (t carcass wt)
Upper-slope species	
Unidentified Squalidae	77
Centrophorus spp	8
Squalus megalops	13
Squalus mitsukurii	22
Mid-slope species	
Deania spp	200
Centroscymnus spp	183
Deania and *Centroscymnus*	21
Dalatias licha	15
Total	538

Table 3.5: Species composition (% by weight) of mid-slope dogfishes collected from around Tasmania *

	Port observations			Field observations		DPIWE
Species	Cascade Plateau	S. Tasman Rise	S. Tas.	E. Tas.	W. Tas.	E & W Tas.
Centrophorus spp	-	-		0.4		-
Centroscymnus coelolepis		2.2	0.7	4.6	3.6	0.1
Centroscymnus crepidater	8.5	11.2	6.2	15.1	58.2	52.0
Centroscymnus owstoni	-	3.8	0.2	6.3	6.3	6.5
Centroscymnus plunketi	1.8	7.4	6.2	4.9	1.3	-
Dalatias licha	0.2	0.4	0.2	0.6	2.0	0.6
Deania calcea	3.7	1.8	2.0	53.3	23.0	38.9
Deania quadrispinosa	-	0.2		0.4	2.8	0.8
Etmopterus granulosus	85.7	72.8	80.7	14.2	2.8	1.9
Etmopterus lucifer	-	-	-	0.2	-	-
Etmopterus sp. B	-	-	2.7	-	-	-
Total Sample weight (kg)	433	445		1236	608	

*Estimates based on port and field sampling, 1999–2001, and research surveys by DPIWE in 1988–1989.

Table 3.6: SET dogfish catch composition (% of total catch) reported by ISMP observers from 1992–1998

Region	NSW	E. Vic.	E. Bass	E. Tas.	S. Tas.	W. Tas.	W. Bass	W. Vic.	SA	Total
Shelf & upper-slope species										
Centrophorus harrissoni	<0.1									<0.1
C. moluccensis	0.1	0.5		1.3					2.5	0.5
C. uyato	1.0	<0.1								0.4
Squalus acanthias	<0.1									<0.1
Squalus megalops	65.4	13.1		0.7						26.7
Squalus mitsukurii	1.4	9.0	44.5	48.4	1.2	11.0	0.9	37.1	33.4	16.1
Squalus sp. C				0.3						<0.1
Mid-slope species										
Centrophorus squamosus				0.1	3.5					0.2
Centroscymnus crepidater	<0.1				0.3					<0.1
Centroscymnus owstoni	<0.1					4.8	6.3	1.2	11.0	1.9
Centroscymnus plunketi	<0.1									<0.1
Dalatias licha	0.6	2.3	6.9	16.9	91.4	11.0	8.4	0.6	4.4	8.4
Deania calcea	30.3	74.8	48.7	24.5	2.3	6.3	2.7	6.1	18.0	28.5
Deania quadrispinosa	1.2	0.3					0.3			0.5
Etmopterus pusillus				0.1						<0.1
Unclassified										
Squalidae				7.8	1.3	66.9	81.5	55.0	30.8	16.7
Total sample weight (kg)	53571	22403	524	8383	9152	145	3947	25194	19018	142337

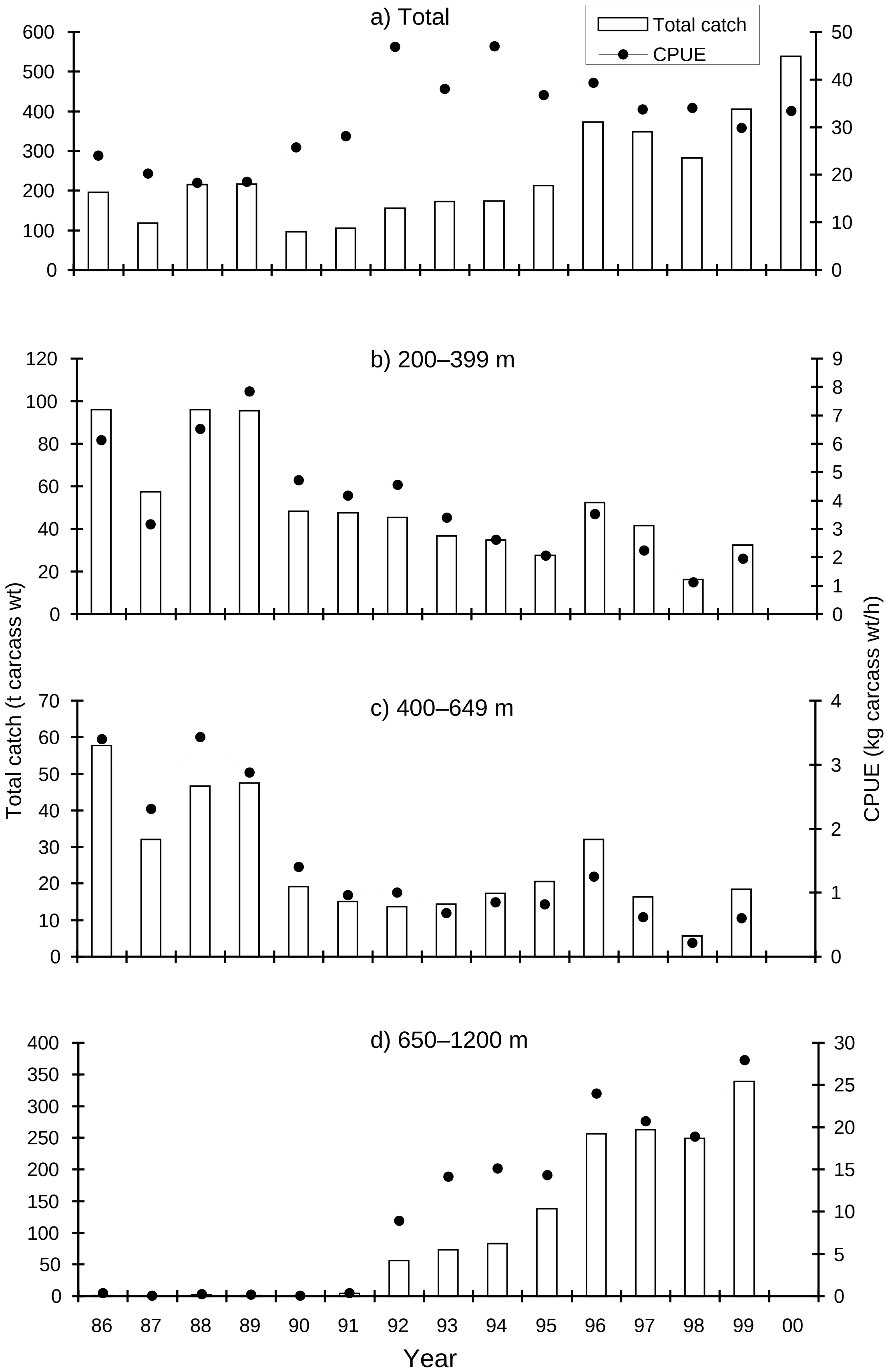
Analysis of reported catch

Catch data from the SET are entered into the AFZIS (Australian Fishing Zone Information Service) database at the Bureau of Resource Sciences, Canberra.

Logbook data from all vessels in the SET for trawls between 200 and 1200 m were analysed for the years 1986–2000. The data included details of locality, depth, and retained catch for each tow (sometimes including the weight of retained livers). Most skippers interviewed during the industry questionnaire indicated they did not report discards.

The total reported dogfish catch across all depths between 1986–2000 was 3,647 t carcass-weight. Overall, there was a significant ($P < 0.05$) increase in total catch (Figure 3.2a). The highest annual total catch of 538 t was taken in 2000. No overall trend in CPUE was apparent.

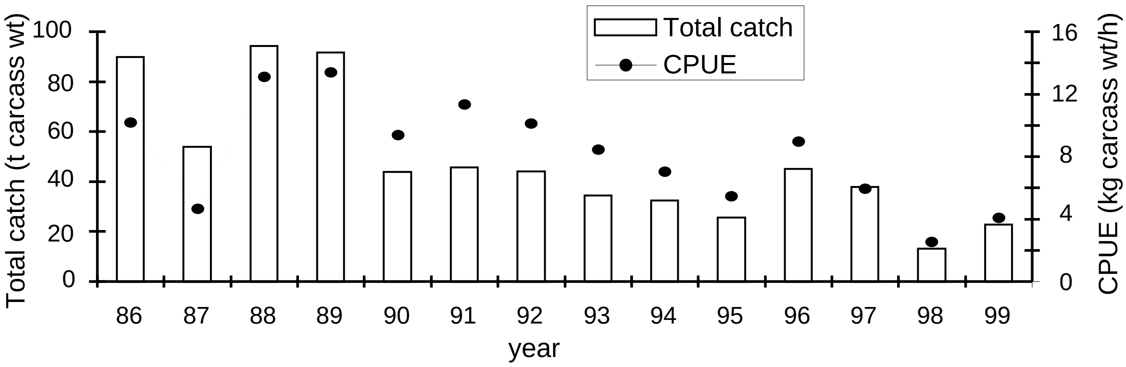
Figure 3.2: Annual catches and CPUE in the SET—all areas



Data for the years 1986–1999 were divided into depth categories (Table 3.3**)** for further analysis:

200–399 m
The total reported catch for 1986–1999 was 736 t with almost 93% of the catch from this depth range reported from off NSW. There were downward trends in both annual total catch and CPUE (P <0.02) (Figure 3.2b). For the NSW component, there was a highly significant decline in the annual catch (P<0.005) and a downward trend in CPUE (P <0.1) (Figure 3.3). This suggests abundance of *Squalus megalops* or other dogfishes has declined. The relatively small catches from other regions in 200–399 m were not analysed.

Figure 3.3: Annual catches and CPUE in the SET: NSW, 200–399 m



400–649 m
The total reported catch in 1986–1999 was 382 t. Annual catches showed a downward trend (P <0.01) during the period and CPUE also declined significantly (P <0.002) (Figure 3.2c). About 70% of the catch was taken off NSW where there was a significant (P <0.002) decline in both catch and CPUE (Figure 3.4a). This suggests *Centrophorus* spp and/or *Squalus mitsukurii* have declined in abundance. There were insufficient data to show trends in the small catches reported from other regions (Figure 3.4b–d).

650–1200 m
Catches in the 650–1200 m category represent most of the total dogfish catch in the SET during recent years (about 80% for 1999 and 2000). The total reported catch in 1986–2000 was 3600 t carcass wt. Annual catches and CPUE increased significantly (P <0.05) from 1986 –1999 (Figure 3.2d), largely reflecting changes in fishery regulations, mercury laws and market acceptance (Section 3.4).

Off NSW, significant catches were reported from about 1993 with annual catches fluctuating between 5 and 35 t, and a maximum CPUE of 70 kg/h (Fig. 3.5a). Catches off eastern Victoria in 1992–1999 were between 50 and 100 t/year; CPUE was initially very high (e.g. 450 kg/h in 1992) when dogfish were targeted for their livers off Lakes Entrance (E. Vic.), but in later years declined to 50–100 kg/h, although catches remained high (Fig. 3.5b). Significant catches were also reported off western Tasmania (40–140 t/year; Fig. 3.6b), western Bass Strait (30–60 t/year; Fig. 3.6c), and South Australia (20–43 t/year; Fig. 3.6d). Reported catches off eastern Bass Strait and eastern Tasmania were less than about 10 t/year. Reported catches from western Victoria were less than 20 t/year. Some vessels from Portland that took large dogfish catches were operating off western Tasmania and Bass Strait.

Field work for this study (in 1999–2000) was conducted on trawlers targeting mid-slope sharks around Tasmania. Dogfish catch rates were much higher than the mean CPUE calculated from logbook data. Mean catch rates of commercial sharks (carcass weight) were 499 (± 1 SE=98) kg/h off eastern Bass Strait, and 131 (± 11) kg/h off eastern Tasmania. Catch rates off western Tasmania and Bass Strait were 319 (± 19) kg/h and 312 (±34) kg/h respectively.

Figure 3.4: Annual catches and CPUE in the SET— areas with significant catches in 400–649 m

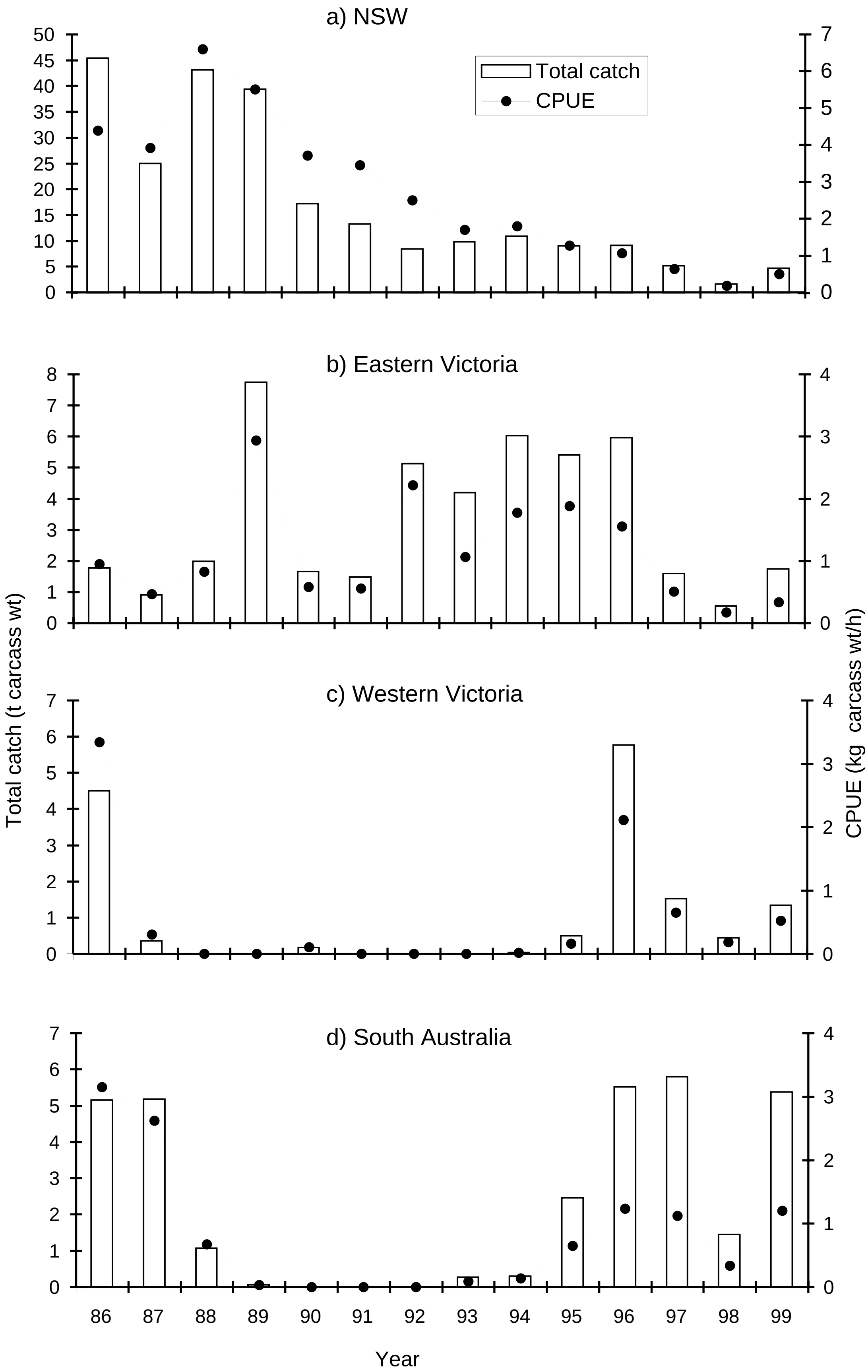


Figure 3.5: Annual catches and CPUE in the SET—eastern areas, 650–1200 m

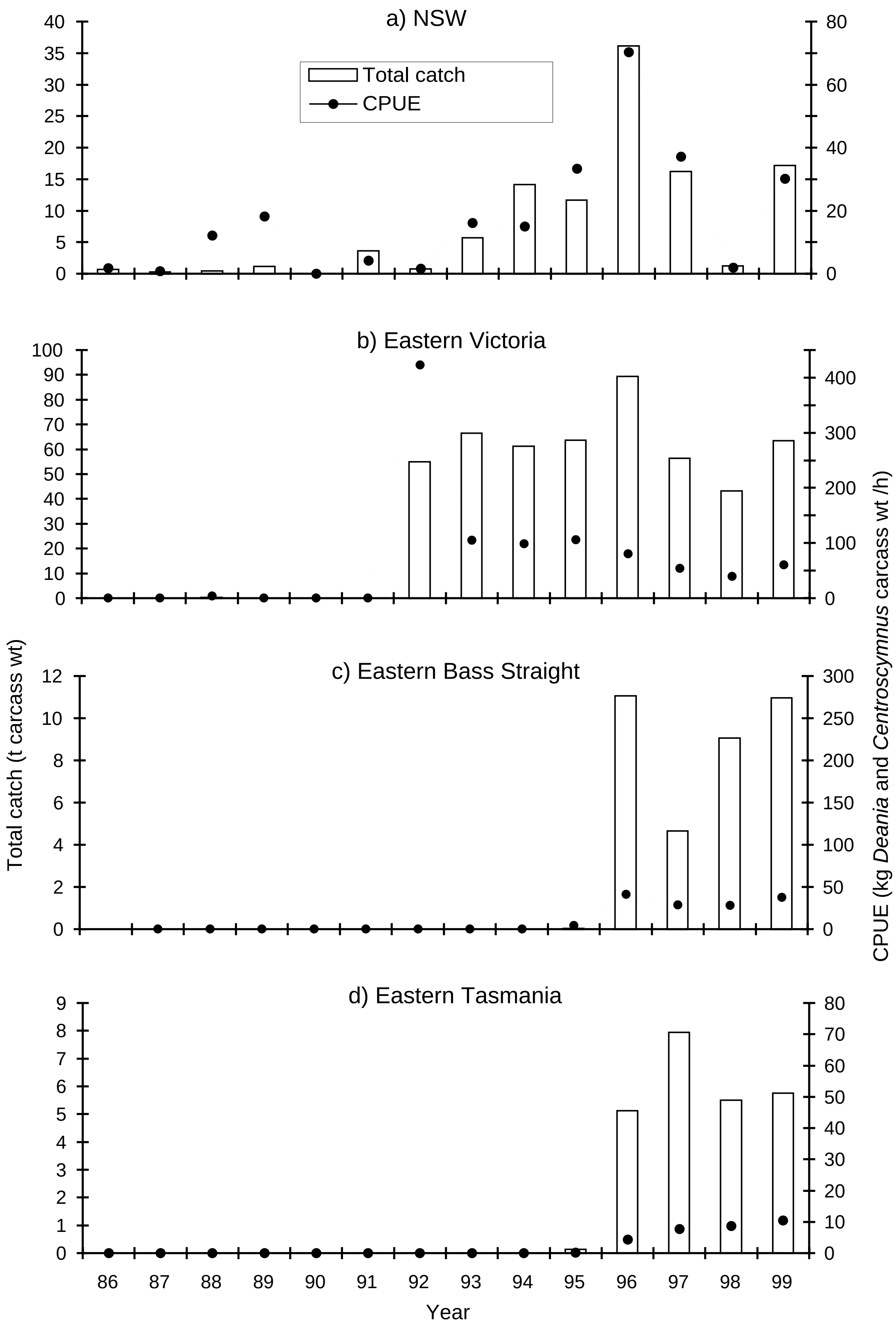
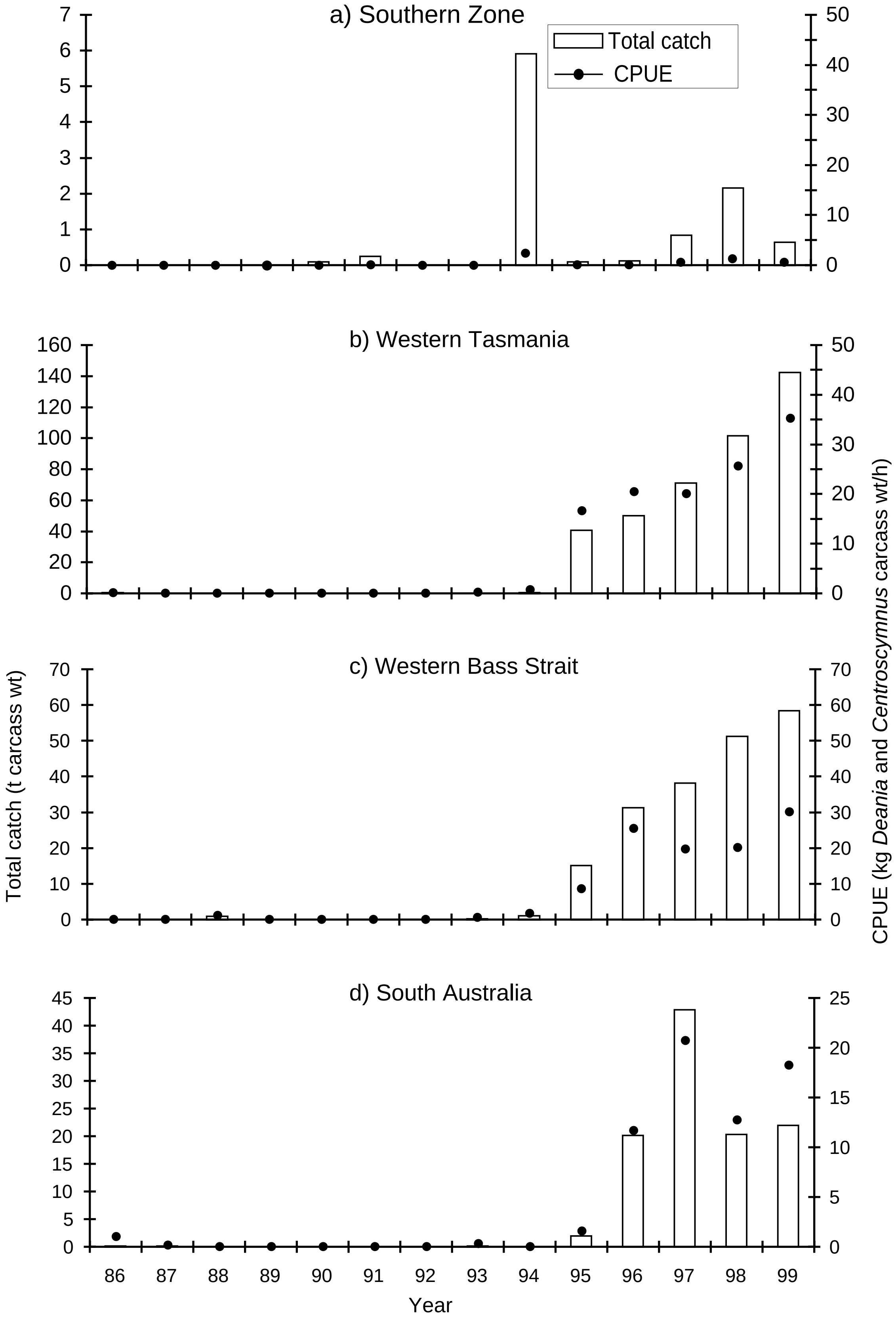


**Figure 3.6: Annual catches and CPUE in the SET—
Southern and western areas, 650–1200 m**



3.3.2. Southern Shark Fishery

Fishery practices

Deepwater dogfish were targeted using deep-set gillnets on the upper-slope (200–600 m) off eastern Victoria and south of Kangaroo Island, SA. Catches were often associated with rough or steep ground. Almost all (95%) of the reported catch from Victoria was taken by one vessel, and the SA catch by two vessels. The two SA vessels targeted principally *Centrophorus uyato* while the Victorian vessel targeted a range of species, including ling (*Genypterus blacodes*), blue eye (*Hyperoglyphe antarctica*) and *Centrophorus* spp. Livers were utilised but carcasses were mostly discarded due to mercury content regulations. By the time these restrictions were relaxed in 1995, targeting of *Centrophorus* spp had all but ceased because of declining catches, and other factors.

Dogfish catches were reported in logbooks from 1986. Until 1996, fishers in Victoria recorded shark catches on a shot by shot basis, and South Australian data were collected as a mixture of both monthly and daily catches. From 1997, data for the SSF as a whole were recorded in daily logbooks. Until 1997, catch and effort data were entered into separate computer databases in Victoria (CandE), Tasmania (MAPPER) and South Australia (GARFIS). All data from 1997 were collated into the SSF Monitoring Database (SSMD) by AFMA.

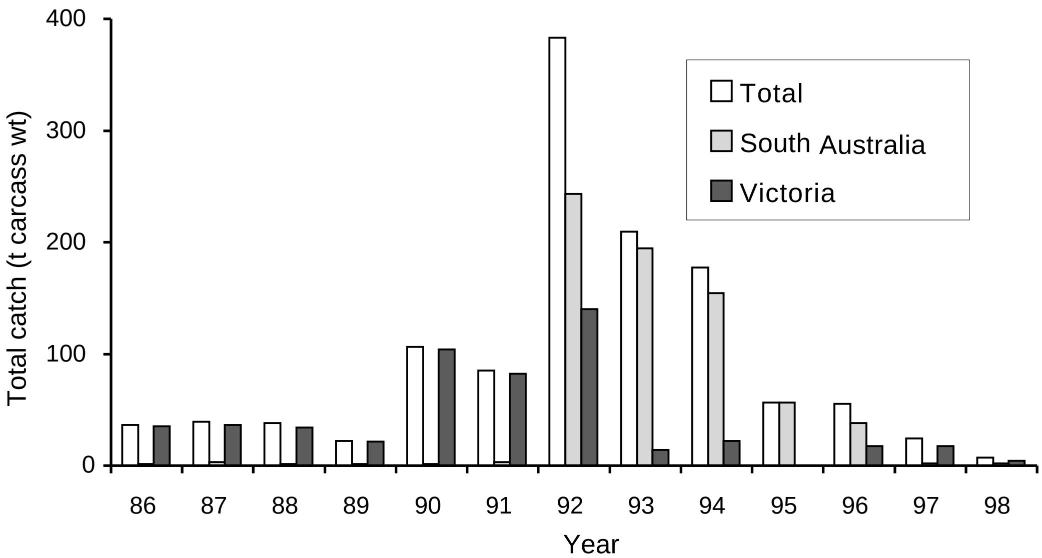
Species composition

Logbook data for dogfish catches in the SSF is not species-specific. However, Johnson (1997) reported that catches off Kangaroo Island, SA, consisted of 88% *Centrophorus uyato*, 8% *Squalus mitsukurii*, 3% *Dalatias licha* and 1% *Centroscymnus crepidater*. Industry sources suggest catches off eastern Victoria probably comprised mainly *Centrophorus uyato.* Surveys indicate the catch probably included some *C. harrissoni* (Figure 4.1).

Analysis of reported catch

Logbook data were examined for 1970–1998 but no significant catches of dogfish were recorded until 1986. A total of 1948 t of dogfish was reported in the period 1986–1998. The first significant annual catch was 35 t reported in 1986 from eastern Victoria, and until 1992 almost all the reported catch was caught from this area (Figure 3.7). Fishing for deepwater dogfish commenced of SA in 1992 and the annual total catch peaked at 383 t that year. Catches then declined quickly in both areas to a total of 7 t by 1998 and targeting ceased. During the industry survey, fishers off S.A. and Victoria stated that there were now few *Centrophorus* spp left in the areas where these species were targeted.

Figure 3.7: Annual dogfish catches in the Southern Shark Fishery



3.3.3. NSW Trawl and Dropline fisheries

Fishery practices

Most recent catches were reported by trawlers operating on slope grounds off Sydney and Newcastle north of the SET boundary (33º 35'S) where dogfish catches are a component of 'mixed fish' trawling or a bycatch of deepwater-prawn trawling operations. Occasional targeting of mid-slope species occurs.

The NSW dropline fishery previously targeted *Centrophorus* spp on rough upper-slope grounds. This state managed fishery operates within the geographic boundaries of the SET.

The NSW catch statistics are collected monthly from fishers and reported on an annual basis. Prior to 1990/91, all shark catch returns were aggregated and there were no species specific data for dogfish. In later years, new catch returns included categories for Endeavour, greeneye and roughskin dogfishes.

The NSW returns are intended for reporting of State managed fisheries only, but for a time there was confusion among NSW fishers, resulting in some double reporting of catches to both the Commonwealth and State authorities. The apparent high level of upper-slope dogfish catches reported between 1991–1997 (see Analysis of reported catch, below) is, in part, attributable to double reporting. It is very likely that a substantial proportion of the reported catches for that period came from SET waters. The marked decline from 1997–1998 reflects the elimination of SET catches from the NSW statistics.

Catches were recorded as a mixture of carcass and live weights; the latter were converted to carcass weight for this report.

Species composition

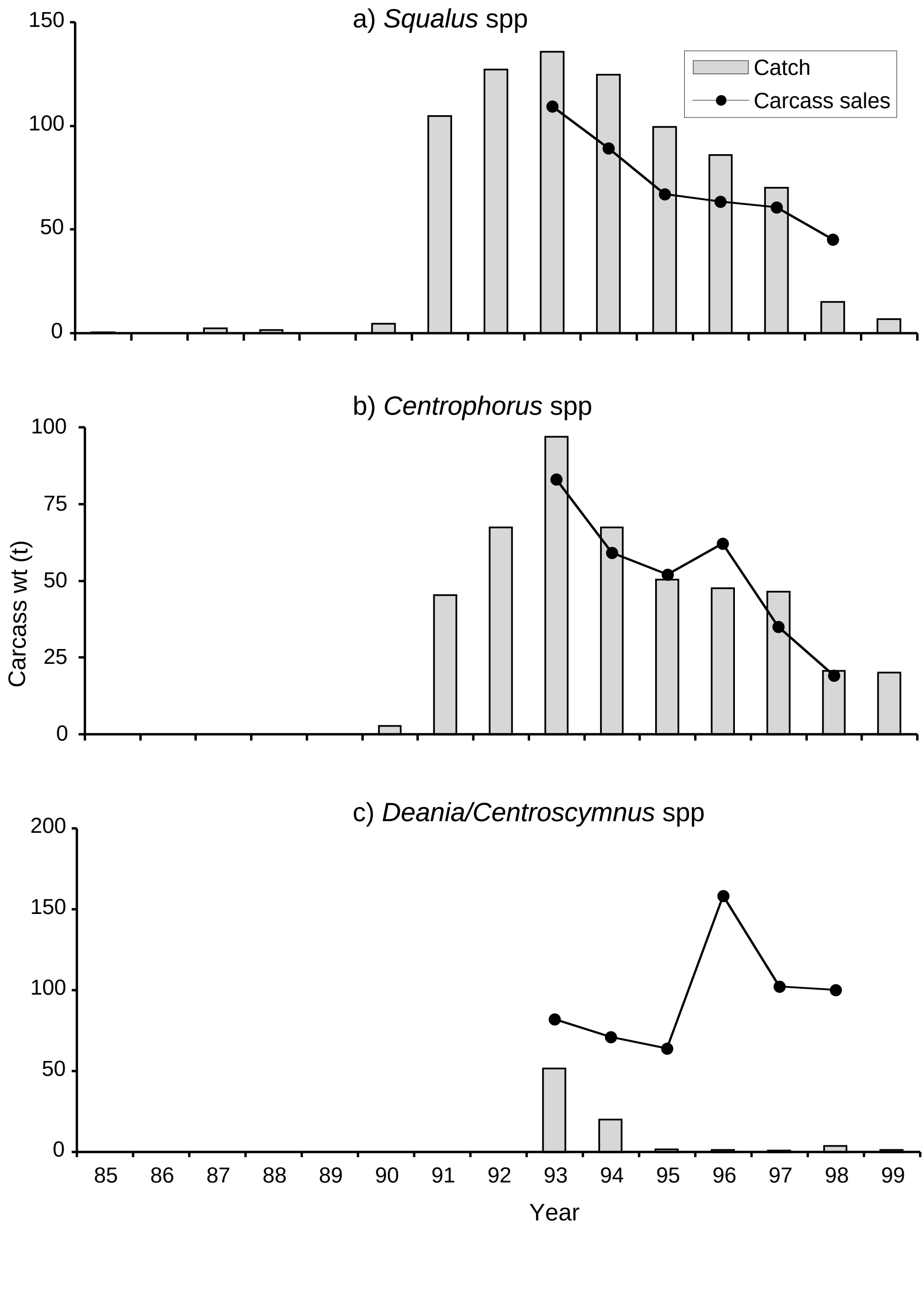
Endeavour (*Centrophorus* spp), greeneye (*Squalus* spp), and roughskin (*Deania* spp) dogfish were recorded in the statistics.

Analysis of reported catch

Reported catches of *Squalus* spp peaked at 136 t in 1993 before declining to 7 t in 1999 (Figure 3.8a). A small catch (3 t) of *Centrophorus* was first reported separately in 1990 (Figure 3.8b); this increased to 97 t in 1993 before declining to about 20 t in 1998. The decrease in reported catches of *Squalus* and *Centrophorus* spp is strongly correlated with declining carcass sales for these species at Sydney Fish Market (Figures 3.8a–b) and suggests that abundance of these species has declined.

Significant catches of *Deania* spp were recorded only in 1993 and 1994 (Figure 3.8c). Catches did not correlate with sales figures for Sydney Fish Market as much of the supply is obtained outside NSW (Section 2.3.4).

Figure 3.8: Annual catches reported in NSW State catch returns and carcass sales at Sydney Fish Market



3.3.4. South East Non-Trawl Fishery

Fishery practices

Fishers report taking significant quantities of *Centrophorus* spp on droplines set for blue eye and ling off eastern Victoria in the early 1990s. The carcasses were initially discarded due to mercury restrictions, but the livers were retained. After 1995, both carcasses and livers were marketed. Data for this fishery were collated with SSF data prior to the 1997 introduction of ITQs for the SENT.

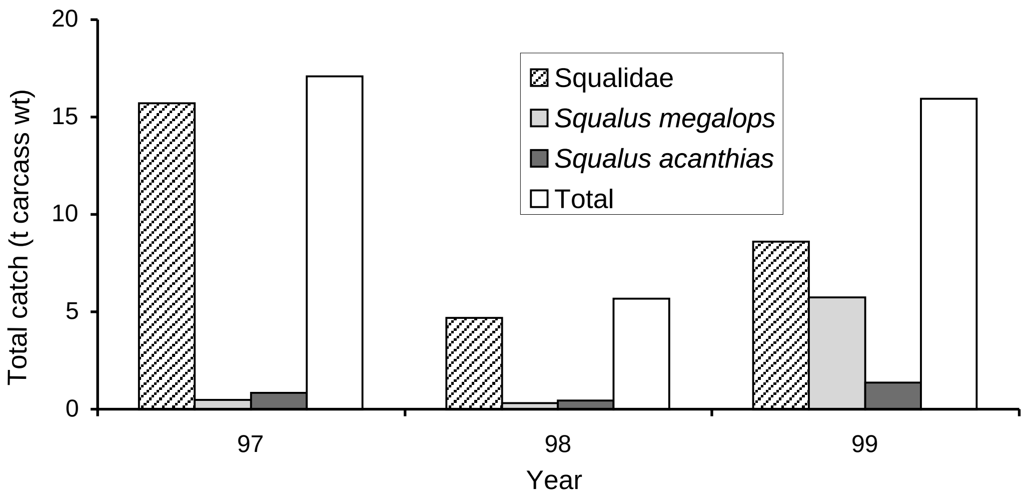
Species composition

The fishery data were a poor indicator of species composition as only 25% of the catch was identified to species, and the remaining 75% identified only as Squalidae. Of the catch that was identified, *Squalus megalops* and *S. acanthias* represented 17% and 7% of the total respectively. *Dalatias licha* and *Deania calcea* together comprised about 1% of the total.

Analysis of reported catch

Data collated from logbooks were available from AFMA for the three years since 1997 when quota management was introduced into the fishery. A total of 38.6 t of dogfish, mostly *Squalus* spp, was reported for this period (Figure 3.9).

Figure 3.9: Annual Catches reported in the South East Non-Trawl Fishery



3.3.5. Great Australian Bight Trawl Fishery

Fishery practices
Most trawling in the GABT fishery is on the continental shelf. However, some larger vessels targeting orange roughy take deepwater dogfish on the mid-slope. Some of these large vessels are based in Portland and move between the GABT and the SET in response to catch rates in the GABT and the amount of quota they have remaining for the SET. Some skippers indicated that they now target deepwater sharks if fishing for other species is poor.

Catches are reported in shot by shot logbooks with data available for 1987–98. Species identification was limited with about half the dogfish catch recorded only as Squalidae. Logbook data were collected by AFMA and covered the period 1987–98.

Species composition
The common shelf species *Squalus acanthias* accounted for less than 1% of the reported catch. The key upper-slope species recorded were *S. mitsukurii* (17%) and *Centrophorus* sp. (10%). The most abundant species identified were the mid-slope *Deania* spp (26%). The total catch of *Dalatias* was small (2%). During industry consultation, fishers stated that the main species caught were *Deania calcea* and *Centroscymnus* spp and that *Centrophorus* was rarely caught.

Analysis of reported catch
Only 27.3 t of dogfish were reported from waters deeper than 200 m in the 12 years to 1998. Annual total catches were highly variable with the highest catches reported in 1987 (6.1 t) and 1989 (8.3 t). In 1987, 1993 and 1994 reported catches were less than 100 kg and in 1995 there was no reported catch. There were no overall trends in total catch or CPUE. The average catch rate for alls species combined was 54.1 kg /h which was similar to that determined from fishery-independent data for waters off South Australia (Figures 4.13a–c).

3.3.6. Western Deepwater Fishery

Fishery practices
The Western Deepwater is a trawl fishery operating from the 200 m isobath to the 200 nm limit of the EEZ between Cape Leuwin and Northwest cape. Unlike some eastern trawl fisheries, there are no large aggregations of commercial fishes (Williams, Koslow and Last, 2001). The fishery takes a mixture of scale fishes, including ruby fish (*Etelis coruscans*, Lutjanidae), and big spine boarfish (*Pentaceros decacanthus*, Pentacerotidae) as well as crustaceans (Alan Williams CSIRO Marine Research, personal communication). Dogfishes are not targeted.

Catch data were recorded in a shot by shot logbook (Table 3.2). The data were collated by AFMA for the period 1993–1997.

Species composition
Catches were recorded as either dogfish or greeneye. It is not clear which species were taken, although presumably most of the catch was *Squalus* spp. A number of species of sharks have previously been recorded from the area including *Centroscyllium kamoharai*, *Centroscymnus* spp, *Dalatias licha*, *Deania* spp, *Etmopterus* spp, *Squalus* spp and *Zameus squamulosus* (Williams *et al*., 1996).

Analysis of reported catch
The average depth of shots that included dogfishes was 365 m. A total of 3.7 t were recorded between 1993–1997.

3.3.7. Western Australian Shark Fishery

Fishery practices

During the years 1996–99, this (mainly) gill-net fishery targeted deepwater dogfish for their livers. *Centrophorus uyato* was the main species targeted because of the high squalene content of its livers. Only the livers were retained and carcasses were discarded. Smaller quantities of *Squalus mitsukurii* were also caught but discarded.

Analysis of reported catch

The dogfish catch in this fishery was estimated from liver sales figures provided by industry (liver weight = approximately 25% whole weight). Total catch for the four years of the fishery was estimated to be 316 t. The estimated annual catches were 135 t (live wt.) in 1996 and 1997 but only 23 t in each of 1998 and 1999. There was no targeting of deepwater dogfish by the WA Shark Fishery in 2000.

3.3.8. Estimated annual catches

The total annual commercial catch for the years 1999 and 2000 is estimated to have been be about 1500 t (Table 3.7) valued at aproximately $1.6 million. Almost 80% of the total was caught in mid-slope depths, and over 90% came from SET vessels.

Table 3.7: Estimated commercial dogfish catches across southern Australia

Fishery	Species group	Reported catch (t carcass weight)	Conversion factor	Total catch (t whole weight)
SET	upper-slope	120	1.7	204
	mid-slope	419	2.8	1173
SSF	mainly upper-slope	7	1.7	12
SENT	mainly mid-slope	13	2.8	36
NSW	mainly upper-slope	30	1.7	51
GABT	mainly mid-slope	2	2.8	6
WA Shark	upper-slope	0		
WDW		<1		
Total		**591**		**1482**

3.4. Discussion of commercial fisheries

Detailed analyses of fishery data rely on accurate recording of catch weight and species composition. In both these areas, there was confused and inaccurate reporting. Logbook catch weights for most species should be entered as live weight according to AFMA, but all fishers contacted during this study recorded carcass weight in their logbooks. Carcass weight is preferred by fishers who can more accurately record the weight to be processed and landed. Potentially catch data can be verified against landed catch, but landings data has not been collated for dogfish in the SET catch. In addition, this type of catch verification for elasmobranches is difficult when the head is removed during processing and catch inspectors do not have taxonomic training. Recording of discarded dogfish catches is limited and recorded as estimates of whole weight.

Species identification was generally at a low level of accuracy in most logbook databases, especially before the year 2000. After the distribution of dogfish identification sheets during this study, logbook data for mid-slope species mostly improved to at least genus level. However, 65% of the upper-slope dogfish catch for 2000 was identified only as Squalidae. Analysis of the ISMP data (Table 3.6) also revealed problems with dogfish identification. The ISMP data for catches off NSW were consistent with market observations and recent research survey results, and seemed to be accurate. However, a high proportion of the dogfish catch in some other regions was recorded only as Squalidae, and the data for several regions appeared to contain errors in species identification made either in the field or at the time of data entry. *Squalus mitsukurii* is relatively uncommon on the upper-slope but the ISMP data indicated that *S. mitsukurii* was the major upper-slope dogfish catch in several regions. It is most likely that those catches were comprised mainly of the smaller, abundant *S. megalops*. It also appears that all *Centrophorus* spp caught off Victoria, Tasmania and SA have been reported as ‘Endeavour’ dogfish and subsequently entered into the database as *C. moluccensis*. Most *Centrophorus* caught south of NSW, and off SA, are likely to be *C. uyato*, with possibly some small catches of *C. harrissoni* off eastern Bass Strait and Tasmania (Section 5).

The ISMP data for mid-slope catches suggest that *Dalatias* occurs more frequently than was indicated by the other sources. Observers in the ISMP program did not report *Etmopterus granulosus* in any catches. In contrast, *E. granulosus* was the dominant dogfish species off southern Tasmania during research catches and in AFMA observer data but catches of *Dalatias licha* were negligible (Section 4). In other regions, it is likely that *Centroscymnus* spp have been recorded as *Dalatias* in the ISMP observer data due to confusion over the name ‘black shark’. Fishers use this common name mainly for *Centroscymnus*, whereas scientists use it for *Dalatias*.

There is a need to improve the standard of dogfish data collection both at sea and with data entry. The confusion in logbook entries between carcass weight and live weight should be standardised. Dogfish identification by both fishers and ISMP observers should improve when new shark and ray field guides are distributed (Daley *et al*., 2002). Some problems with ISMP data were workshopped at the annual ISMP meeting in 2002.

The logbook data for the year 2000 represent the only direct information on the species composition of commercial catches. However, it is probable that the species mix of the catch reported prior to 2000 was similar and consisted mainly of *Deania* spp and *Centroscymnus* spp. Other species, particularly *Etmopterus* spp are also abundant in some parts of the fishery but are seldom reported because they are not part of the retained/landed catch. Knowledge of discarding therefore relies on accurate ISMP data.

Trawlers in the SET currently take almost all of the deepwater dogfish catch. Logbook data from SET trawlers are from about 1986 so there is little detailed information available about the commercial dogfish catches in the early years of the fishery. Off NSW, the upper-slope fishery developed during the 1970s and, as there was limited market acceptance of dogfish carcasses at that time, it is likely that initial high catch rates led to a significant level of discarding of all species. During the 1980s, substantial quantities of dogfish were marketed in NSW but as shown by the logbook data, annual catch and catch-rates have now declined to very low levels. Upper-slope trawling around Victoria and Tasmania developed mainly during the 1980s but relatively small catches were reported from all areas. It seems that Victorian regulations that restricted the mercury content allowable in sharks may have inhibited landings of the larger upper-slope species of dogfishes such as *Centrophorus*. It is likely that substantial quantities of dogfish were discarded by trawlers off Victoria and Tasmania before those restrictions were eased in 1995.

Over 90% of the SET dogfish catch in the 200–400 m depth range was reported from NSW waters and consisted of ‘greeneye’ sharks. Observer data (Table 3.6), recent research survey data (Andrew *et al*., 1997) and market observations (Section 2.3.4) indicate that greeneye shark catches consist almost totally of *S. megalops*.
During the early years of the fishery, catch rates of *S. megalops* and *S. mitsukurii / Squalus* sp. F. off NSW were relatively high and of similar magnitude (Graham *et al*., 1997). The decline in NSW catches (Figure 3.3) probably relates to the fishing down of the larger, more marketable *S. mitsukurii* and *Squalus* sp. F. While *S. megalops* is still relatively abundant (at least off central NSW), it is seldom targeted because of its small size (Graham *et al*., 2001). *Squalus mitsukurii* is now rare off NSW, although more common in this depth range off western Victoria (K. Graham, personal observation). The deeper upper-slope catches (400–650 m) also came mainly from NSW (about 70%). Although *Centrophorus* spp were abundant in this depth zone in the early years of the fishery off NSW, catches of *Centrophorus* spp are now comparatively small (Graham *et al.*, 2001). The ISMP data also indicates very small catches of *Centrophorus* in all regions, confirming the now depleted state of the *Centrophorus* stocks in the SET.

The introduction of the ITQ management system, the development of a market for dogfish livers, and the relaxing of the mercury content regulations appear to be major factors which influenced the targeting of mid-slope dogfish. In 1992, management controls in the form of Total Allowable Catches (TACs) and ITQs for 15 species groups of teleosts were introduced into the SET (Tilzey, 1994). This led to significant exploitation of mid-slope dogfish which were outside any management controls. Off NSW, trawlers began targeting *Deania calcea* and marketed both livers and carcasses. Trawlers operating off eastern Victoria initially targeted mid-slope dogfish only for their livers as carcasses could not be sold due to the Victorian regulations on mercury content in sharks. Initial high catch rates and close access to the MFM made targeting of *Deania* and *Centroscymnus* spp for livers alone economically viable out of Lakes Entrance. For trawlers operating at greater distances from the Melbourne markets, targeting dogfish remained non-viable until 1995/96, and catches remained relatively low in other regions. The mercury regulations were relaxed in late 1995 allowing carcasses to be landed and sold in Melbourne. Fishers in more distant regions then began to target *Deania* and *Centroscymnus* for both carcasses and livers, and reported catches increased significantly in 1996 (Figure 3.2d, 3.5, 3.6). The Victorian mercury content restrictions also influenced fishing for dogfish in the SSF and SENT. Before 1996, upper-slope *Centrophorus* were targeted in both fisheries, but only their livers were retained. Both livers and carcasses were marketed in later years.

4. ASSESSMENT OF FISHERY-INDEPENDENT DATA

Objective 3. Examine dogfish catch and effort data by area and depth strata, and assess any changes in catch rate over time

4.1. Introduction

From 1976–1997, considerable research trawling was done in continental slope depths around southern Australia. Although none of the surveys were designed to assess the abundance of sharks, it was thought that the accumulated catch data would provide good background information into the deepwater dogfish stocks. CSIRO data from research vessels FRV 'Soela' (1984–1989), FRV 'Southern Surveyor' (1991–1994) and a number of chartered SET vessels were examined. The CSIRO data was mainly from grounds off Bass Strait and Tasmania. Published and unpublished data from FRV 'Kapala' surveys (1976–1997) on the NSW upper and mid-slopes were also reviewed. Additional data was collected aboard SET vessels during commercial fishing.

4.2. Methods

CSIRO station and catch & effort data were collated from 66 shots in the 400–650 m depth range, and 597 shots in the 650–1200 m depth range **(**Appendix E). Electronic records and paper copies were checked to ensure data quality. The original paper copies were checked to assess the reliability of species identification, and to ensure the data had been correctly entered. All catch data were recorded as live weight. Data for *Centroscymnus coelolepis* and *C. owstoni* were pooled for some analyses because these species had been confused with each other in some early cruises. Similarly, catch data for *Deania* spp were pooled as were data for *Etmopterus* spp.

Available catch data were assigned to appropriate depth categories (Table 3.3), and regions (Figure 3.1). Mid-slope catches from tows on seamounts off Tasmania were analysed separately from tows on relatively flat grounds. For each species, the mean catch rate (kg/hour) was calculated for each region, depth category, and time period (usually annual). Although there was variation in mesh size and net spread on the survey vessels, no attempt was made to standardise catches with gear size.

Statistical comparisons of differences in catch rates were made using t-tests.

4.3. Results

4.3.1. Upper-slope: 200–649 m

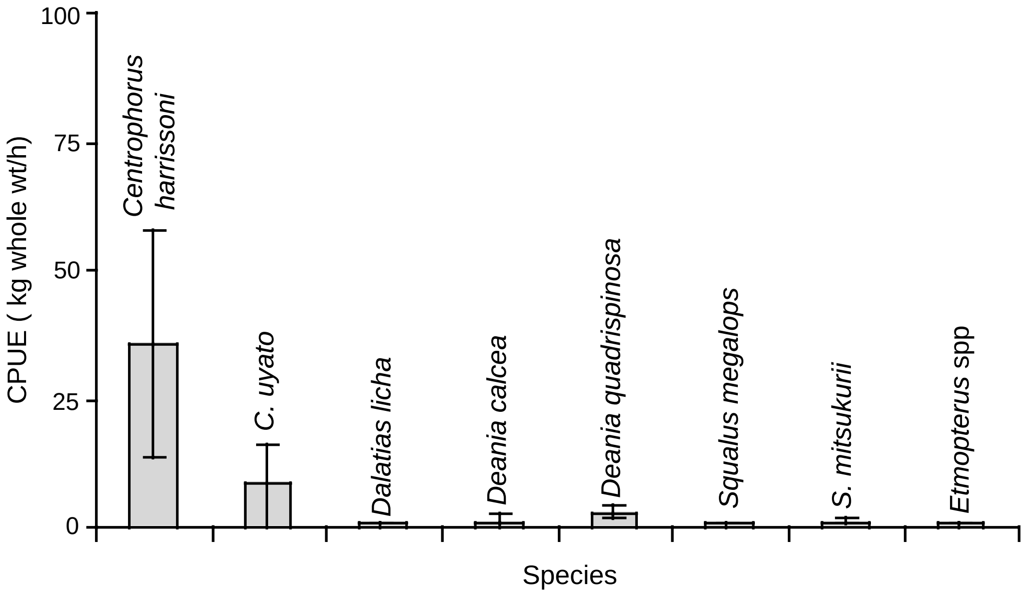
Historical and recent upper-slope dogfish catch data from FRV 'Kapala' surveys off southern NSW (Sydney–Montague Island) and eastern Victoria (Gabo Island) were collated in the report for FRDC Project 96/208 (Andrew *et al.*, 1997) and in Kapala Cruise Report No. 117 (Graham *et al.*, 1997). The principal findings for those areas are summarised below. Dogfish catch rates, collected on a chartered commercial trawler during FRDC Project 98/204, are presented for the Portland area. All other data are from CSIRO surveys.

Southern NSW
FRV 'Kapala' (1976–1997): Mean catch rates of *Squalus megalops* were about 180 kg/h off Sydney, and 30 kg/h off Ulladulla during 1997 when gear much smaller than that on commercial trawlers was used. These catch rates were not significantly different to those recorded 20 years earlier. In contrast, the 1997 mean catch rates off Sydney and Ulladulla for *Squalus mitsukurii* / *Squalus* sp. F (< 3 kg/h), and *Centrophorus* spp (< 1 kg/h) were less than 5% of their original levels in 1977. All species of *Squalus* were caught mainly in 200–400 m, while the greatest catches of *Centrophorus* spp were from 350–600 m.

North-eastern Victoria
FRV 'Kapala' (1976–1997): Mean catch rates of *Squalus megalops* in 1997 were about 30 kg/h, similar to the 42 kg/h recorded in 1976–1977. Mean catch rates of *S. mitsukurii* and *Centrophorus* spp were both less than 0.1 kg/h in 1997, compared to 8 kg/h and 203 kg/h respectively, in 1977.

FRV 'Soela' (7 tows; 1985): The average depth of seven trawls off Gabo Island was 447 m. The mean catch rate for combined species off eastern Victoria was 50.5 kg/h (Figure 4.1). *Centrophorus harrissoni* and *C. uyato* had the highest catch rates at 35.3 and 8.1 kg/h respectively.

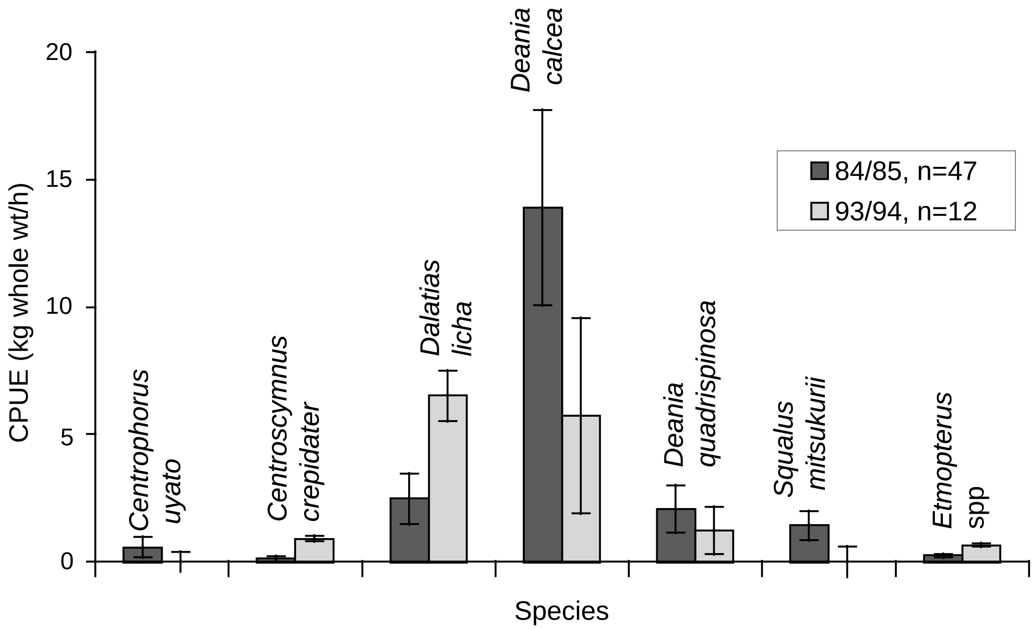
Figure 4.1: Dogfish average catch rates from FRV 'Soela' research surveys—eastern Victoria, June 1985, 440–455 m, 110 mm mesh (n=7) (mean ± 1 SE)



Eastern Tasmania

FRV ‘Soela’, FRV ‘Southern Surveyor’ (59 tows; 1984–1994): Although the average depth of trawls was 471 m, most dogfish were taken in the 500–650 depth range and comprised a mix of upper and mid-slope species. Catches were relatively small with a mean combined species catch rate of 18.5 kg/h. *Deania calcea* had the highest mean catch rate of 11.5 kg/h (Figure 4.2).

Figure 4.2: Dogfish catch rates from FRV ‘Soela’ research surveys—eastern Tasmania, 1984–1994, 400–650 m, 110 mm mesh (mean ± 1 SE)



Western Victoria

FV ‘Zeehan’ (2000–2001; 75 tows): Dogfish catches taken during recent experimental trawling and gear trials between Portland and Beachport (FRDC Project 98/204) provide some indication of current relative abundance. The most abundant dogfish was *Squalus megalops* with a mean catch rate of 34.4 (± 1 SE = 8.4) kg/h from 100–200 m (61 tows). In the 300–600 m depth range (75 tows), the mean catch rate for *S. mitsukurii* was 4.4 (±0.7) kg/h and for *Centrophorus uyato*, 1.4 (± 0.6) kg/h. Small numbers of *Dalatias licha* were also taken in the deeper trawls.

4.3.2 Mid-slope: 650–1200 m

NSW mid-slope data were summarised from FRV 'Kapala' exploratory surveys in 1987–1989. All other data were from CSIRO survey cruises by research and chartered vessels. Catch rates are presented as kg (whole weight)/hour, but are not standardised for gear size. Kapala surveys used 30 m headline trawls, CSIRO research vessel surveys were with 35 m headline trawls, and chartered commercial vessels used 40 m headline nets.

New South Wales

FRV 'Kapala' (174 tows; 1987–1989): The mean catch rate for all species across all mid-slope depths between Port Stephens and Bateman's Bay was 130 kg/h. *Deania calcea* comprised about 80% of this total (103 kg/h) while *Centroscymnus* spp (13%) and combined *Etmopterus* & *Centroscyllium* spp (7%) were relatively minor components of the dogfish catch (Figure 4.3). Catches of *Deania calcea* were consistently greatest from 800–1000 m (Figure 4.4).

Figure 4.3: Dogfish catch rates from FRV 'Kapala' research surveys—NSW, 1987–1989, depth 700–1200 m, 90 mm mesh (1987–1988) and 45 mm mesh (1987–1989) (mean ± 1 SE)

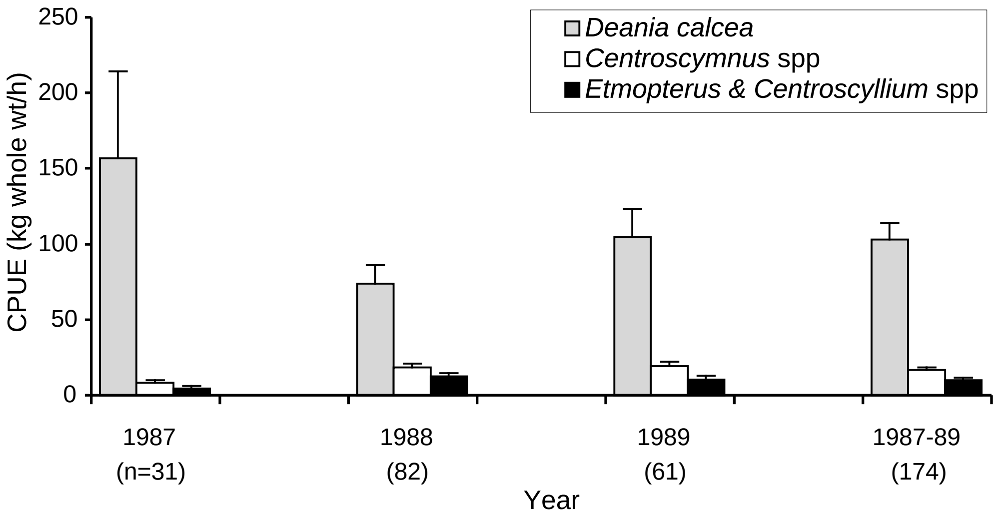
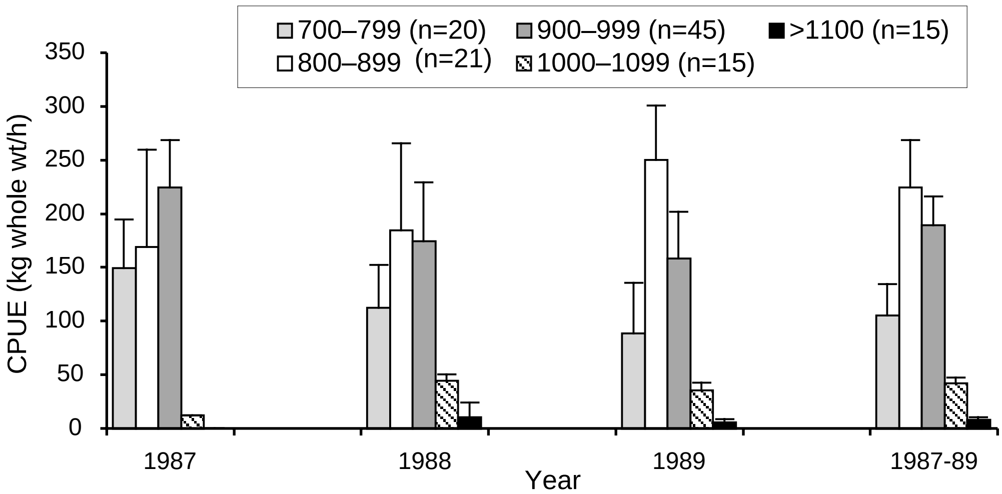
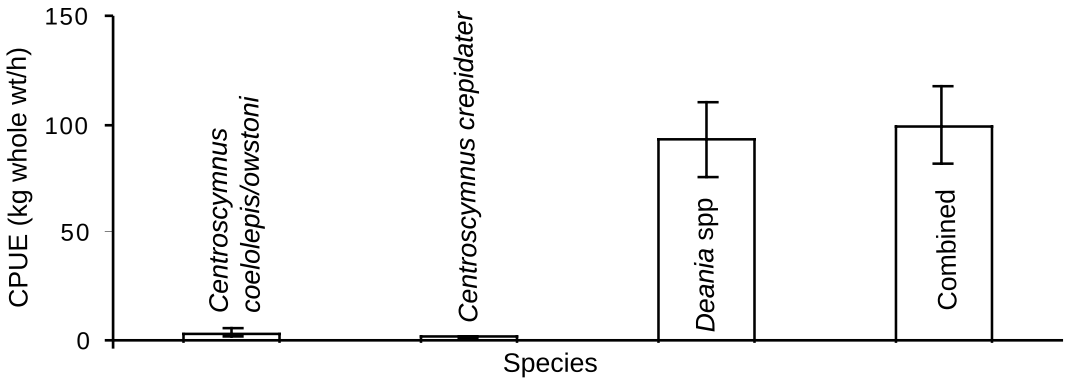


Figure 4.4: Deania calcea catch rates from FRV 'Kapala' research surveys—NSW, 1987–1989, 700–1200 m (100 m intervals), 90 mm mesh (1987–1988) and 45 mm mesh (1989) (mean ± 1 SE)



FRV 'Soela' (23 tows; May 1988): Catch rates by 'Soela' on the ground off Brush Island (southern NSW) were similar to those recorded for 'Kapala'. The mean combined-species catch rate was 100.1 kg/h and the main catch was *Deania* spp (92 kg/h). Mean catch rates of all other species were less than 5 kg/h (Figure 4.5).

Figure 4.5: Dogfish catch rates from FRV 'Soela' research surveys—NSW, 1988, 650–1200 m, 110 mm mesh (n=23) (mean ± 1 SE)

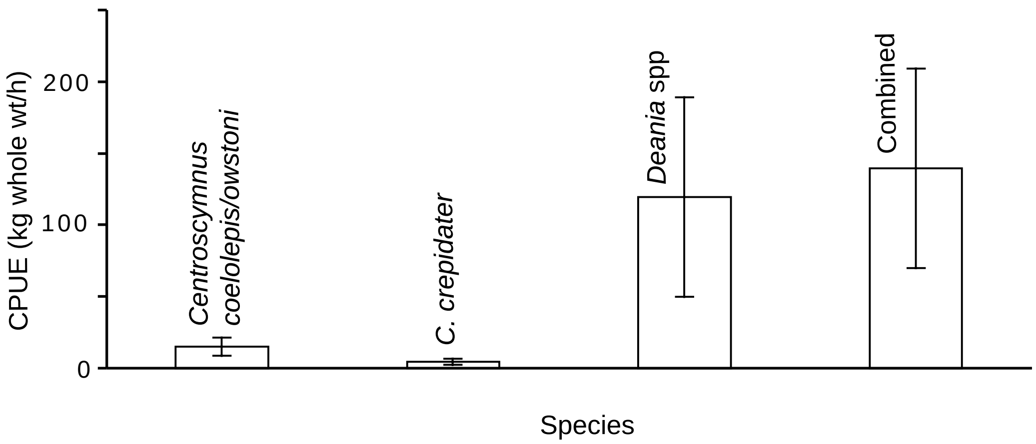


North-eastern Victoria

FRV 'Kapala' (5 tows: 1983–1984; 2 tows: 1988): Mean catch rate for *Deania calcea* was 88 kg/h; average catch rates of other species were less than 10 kg/h.

FRV 'Soela' (4 tows; May 1988): The average combined-species catch rate was 139.1 kg/h with *Deania* spp the main component (119.3 kg/h). Catch rates for *Centroscymnus* spp were less than 15 kg/h, and for *Etmopterus* spp less than 1 kg/h (Figure 4.6).

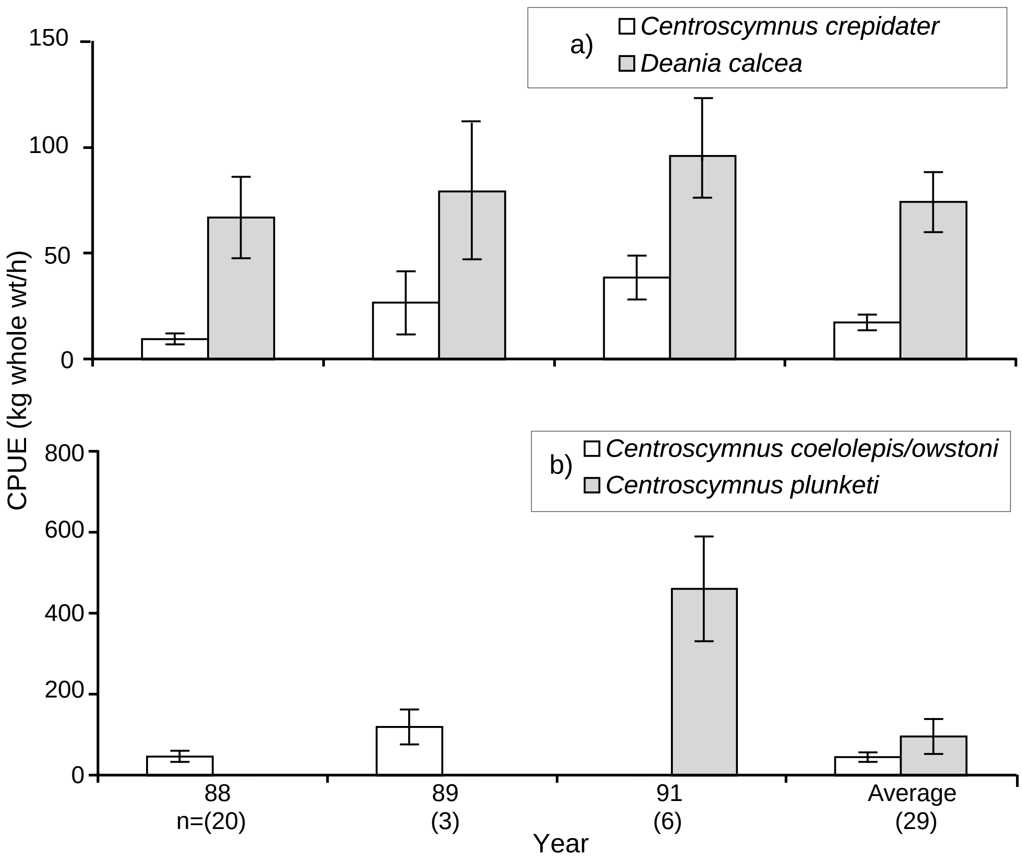
Figure 4.6: Dogfish catch rates from FRV 'Soela' research surveys—eastern Victoria, 1988, 650–1200 m, 110 mm mesh (n=4) (mean ± 1 SE)



Eastern Bass Strait

FRV ‘Soela’, FRV ‘Southern Surveyor’, chartered SET vessels (29 tows; 1986–1991): Data were available for surveys in 1988 (20 tows), 1989 (3 tows), and 1991 (6 tows). The most consistent catch was *Deania* spp with mean catch rates from 70–100 kg/h over the three years (Figure 4.7a). Mean catch rates for *Centroscymnus crepidater* were less than 50 kg/h while those of *C. owstoni* and *C. coelolepis* (combined) exceeded 100 kg/h in 1989 (Figure 4.7b). Catches in 1991 were dominated by *C. plunketi* (460 kg/h), but this species was not caught in 1986 or 1989. Catch rates for this species had extremely high natural variance.

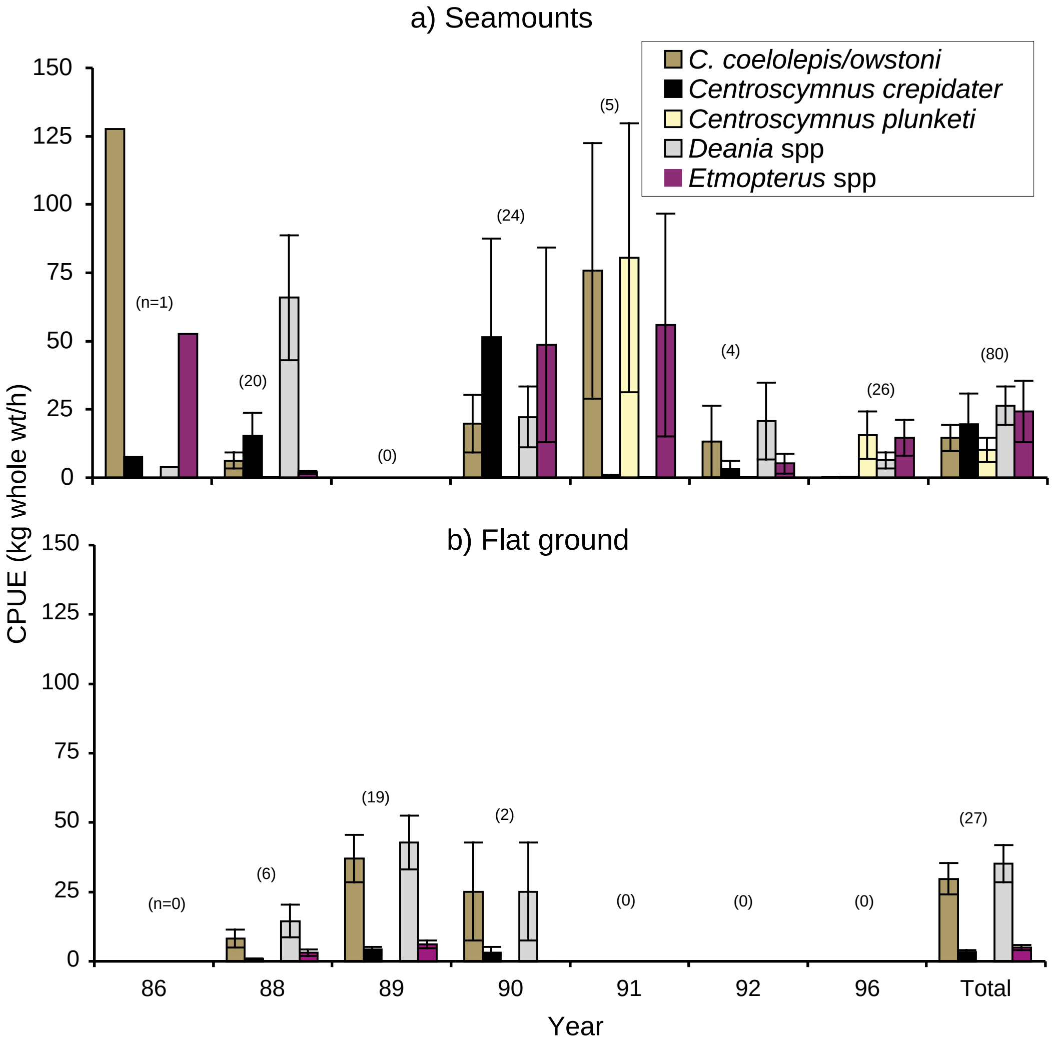
Figure 4.7: Dogfish catch rates from CSIRO research surveys— eastern Bass Strait, 1988–1991, 650–1200 m, 110 mm mesh (mean ± 1 SE)



Eastern Tasmania

FRV Soela, FRV 'Southern Surveyor', chartered SET vessels (107 tows1986–1996): Fishery-independent sampling off eastern Tasmania was mainly carried out on orange roughy (*Hoplostethus atlanticus*) grounds, including St. Helens Hill seamount. Catches on relatively flat ground were analysed separately to those catches from steep ground and/or seamounts (Figure 4.8). For all species, catches on steep ground were highly variable within years, although catch rates averaged across all sampling were relatively low with only *Deania* and *Etmopterus* spp exceeding 25 kg/h (Figure 4.8a). Flat ground catches were less variable and were dominated by two species groups: *Deania* spp and *Centroscymnus coeloepis*/*C. owstoni* with overall mean catch rates of 35 kg/h and 30 kg/h (Figure 4.8b).

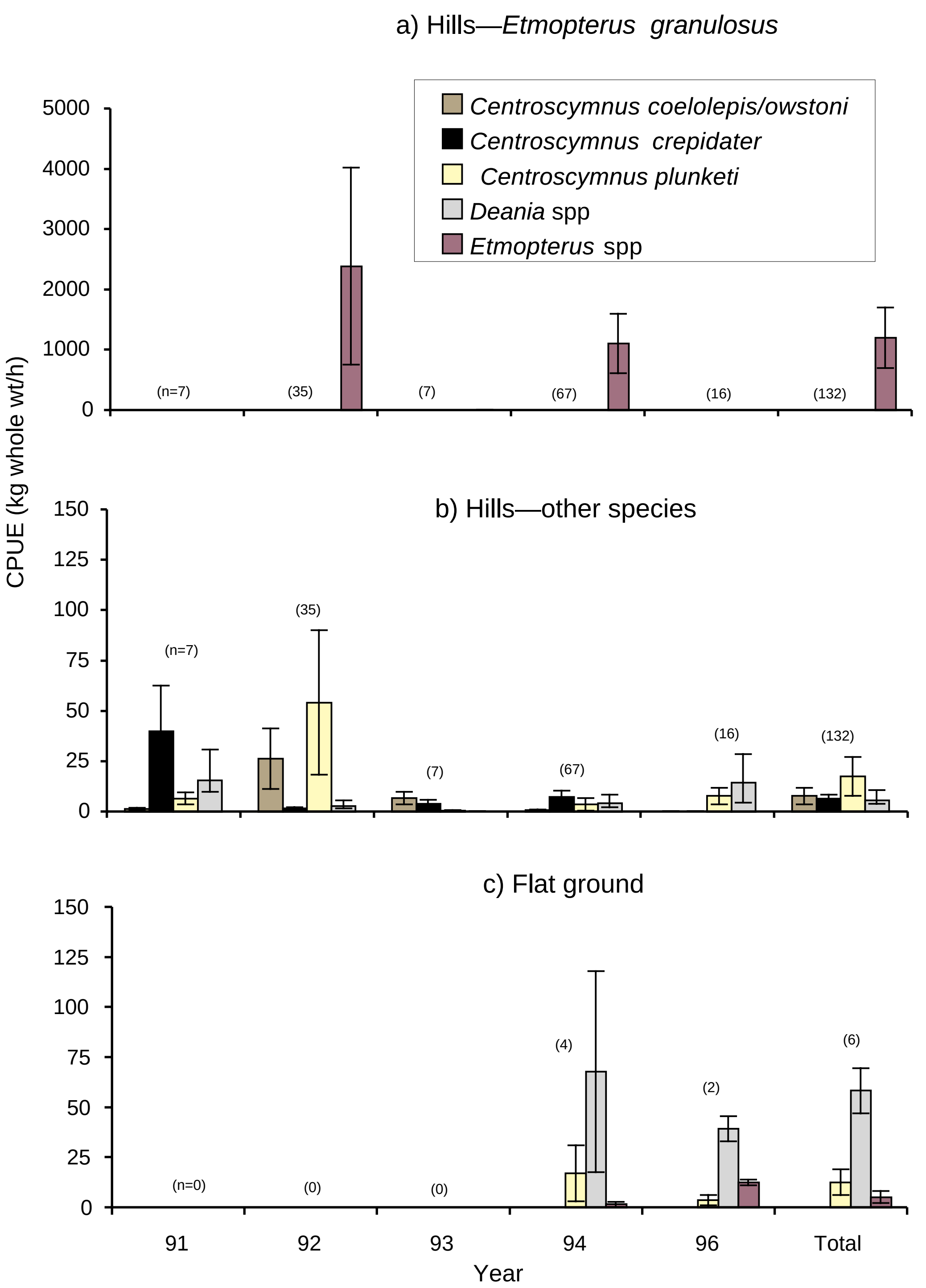
Figure 4.8: Dogfish catch rates from CSIRO research surveys— eastern Tasmania, 1986–1996, 650–1200 m, 110 mm mesh (mean ± 1 SE)



Southern Zone

FRV 'Soela', FRV 'Southern Surveyor', chartered SET vessels (138 tows; 1991–1996): Catch rates were calculated separately for seamounts and flats (Figure 4.9). *Etmopterus* spp (mainly *E. granulosus*) were caught mainly on seamounts, and catches included single shots of 14 and 32 tonnes in February 1992. The average catch rate for *Etmopterus* spp on seamounts was 1143 kg/h (Figure 4.9a), significantly (P<0.01) higher than the catch rate for this species on flat ground. Catches of other species on seamount grounds averaged less than 20 kg/h (Figure 4.9b). The few flat ground tows caught mostly *Deania* spp with an overall mean catch rate of 58 kg/h (Figure 4.9c).

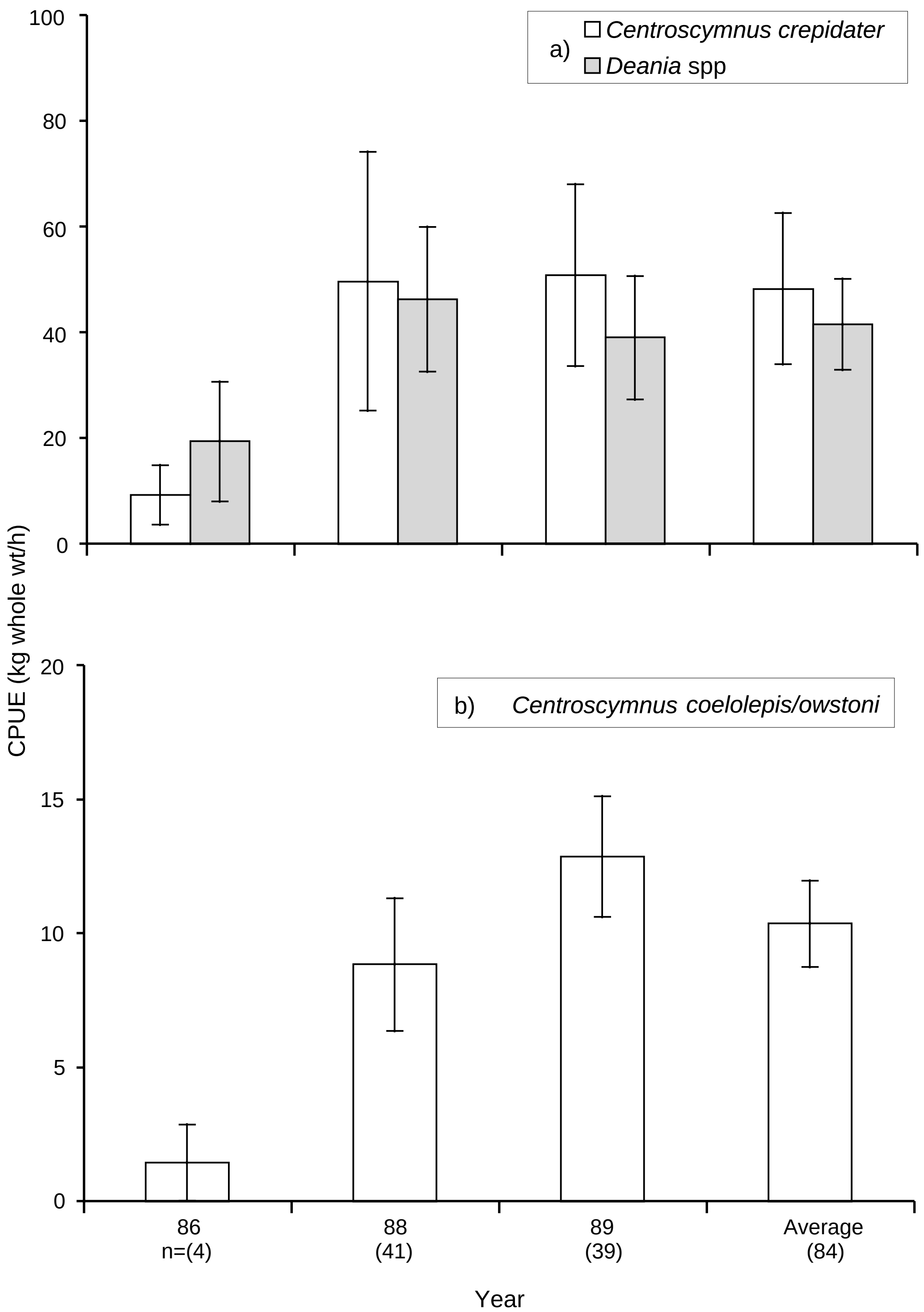
Figure 4.9: Dogfish catch rates from CSIRO research surveys—southern zone, 1991–1996, 650–1200 m, 110 mm mesh (mean ± 1 SE)



Western Tasmania

FRV 'Soela': (84 tows; 1986–89): Trawling off the west coast of Tasmania was mainly on flat ground. The average combined-species catch rate was 101 kg/h. Catches comprised mainly *Deania* spp (overall mean 42 kg/h) and *Centroscymnus crepidater* (48 kg/h; Figure 4.10). Average catch rates for *C. coelolepis/C. owstoni* were less than 15 kg/h in any year (mean 10.3 kg/h). Catch rates of *C. plunketi*, *Dalatias licha* and *Etmopterus* spp were less than 1kg/h.

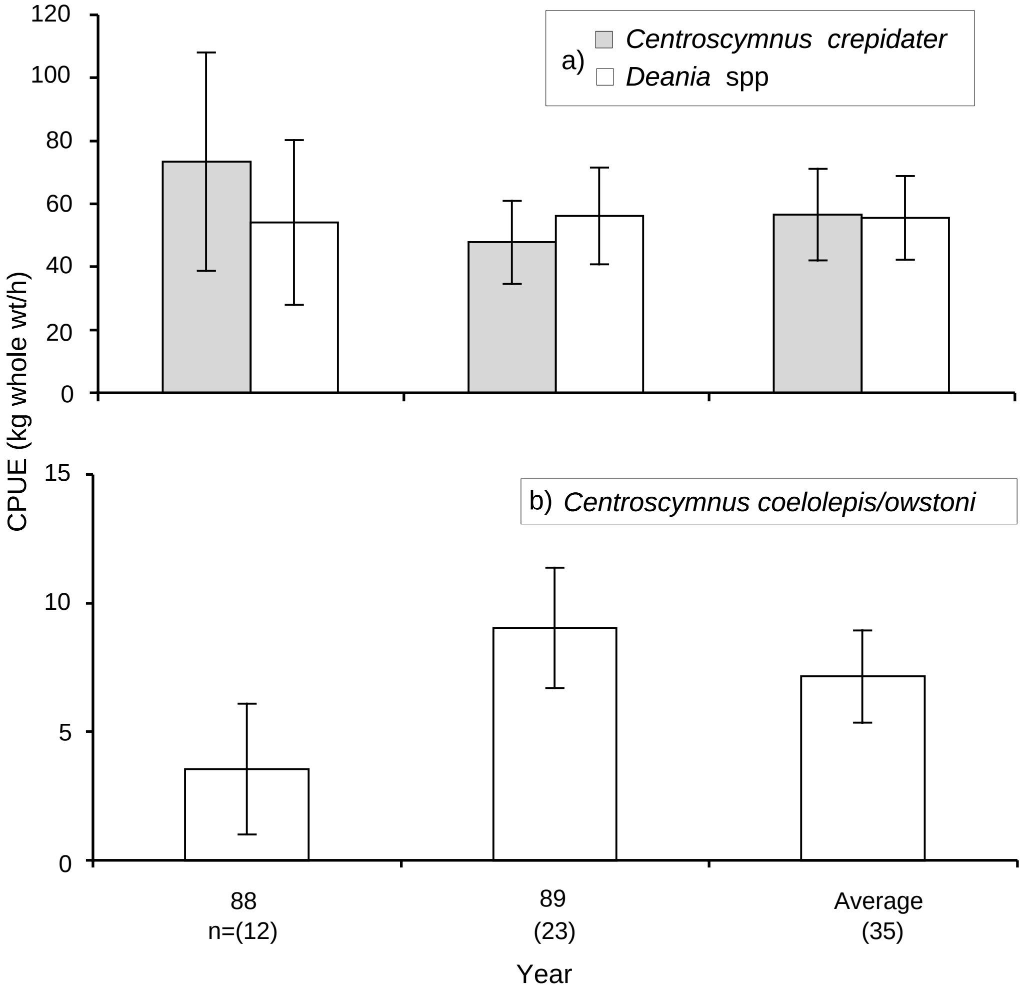
Figure 4.10: Dogfish catch rates from FRV 'Soela' surveys— western Tasmania, 1986–1989, 650–1200 m, 110 mm mesh (mean ± 1 SE)



Western Bass Strait

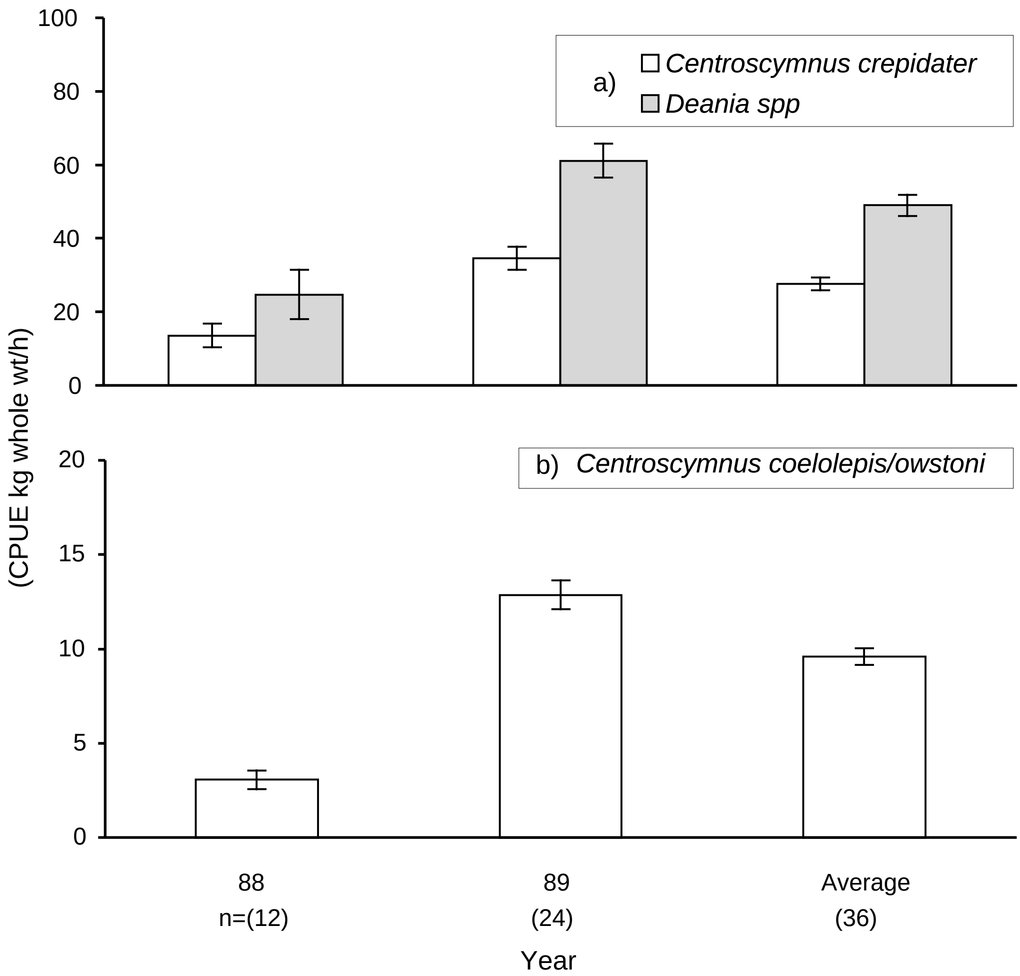
FRV ‘Soela’ (35 tows; 1988–89): The western Bass Strait trawls were mainly along the flat mid-slope west of King Island. The overall mean combined-species catch rate was 141.5 kg/h. Average catch rates were highest for *Centroscymnus crepidater* (56 kg/h) and *Deania* spp (55 kg/h); other *Centroscymnus* spp were less than 15 kg/h (Figure 4.11b). Catch rates for *Etmopterus* spp were negligible and *Dalatias* was absent from catches.

Figure 4.11: Dogfish catch rates from FRV ‘Soela’ research surveys—Western Bass Strait, 1988–1989, 650–1200 m, 110 mm mesh (mean ± 1 SE)



Western Victoria
FRV 'Soela' (36 tows; 1988–1989): Sampling was mainly on flat grounds near Portland. The average combined-species catch rate was 91.9 kg/h. Principal species were *Deania* spp (overall mean catch rate 49 kg/h), *Centroscymnus crepidater* (28 kg/h), and *C. coelolepis/C. owstoni* (10 kg/h) (Figure 4.12).

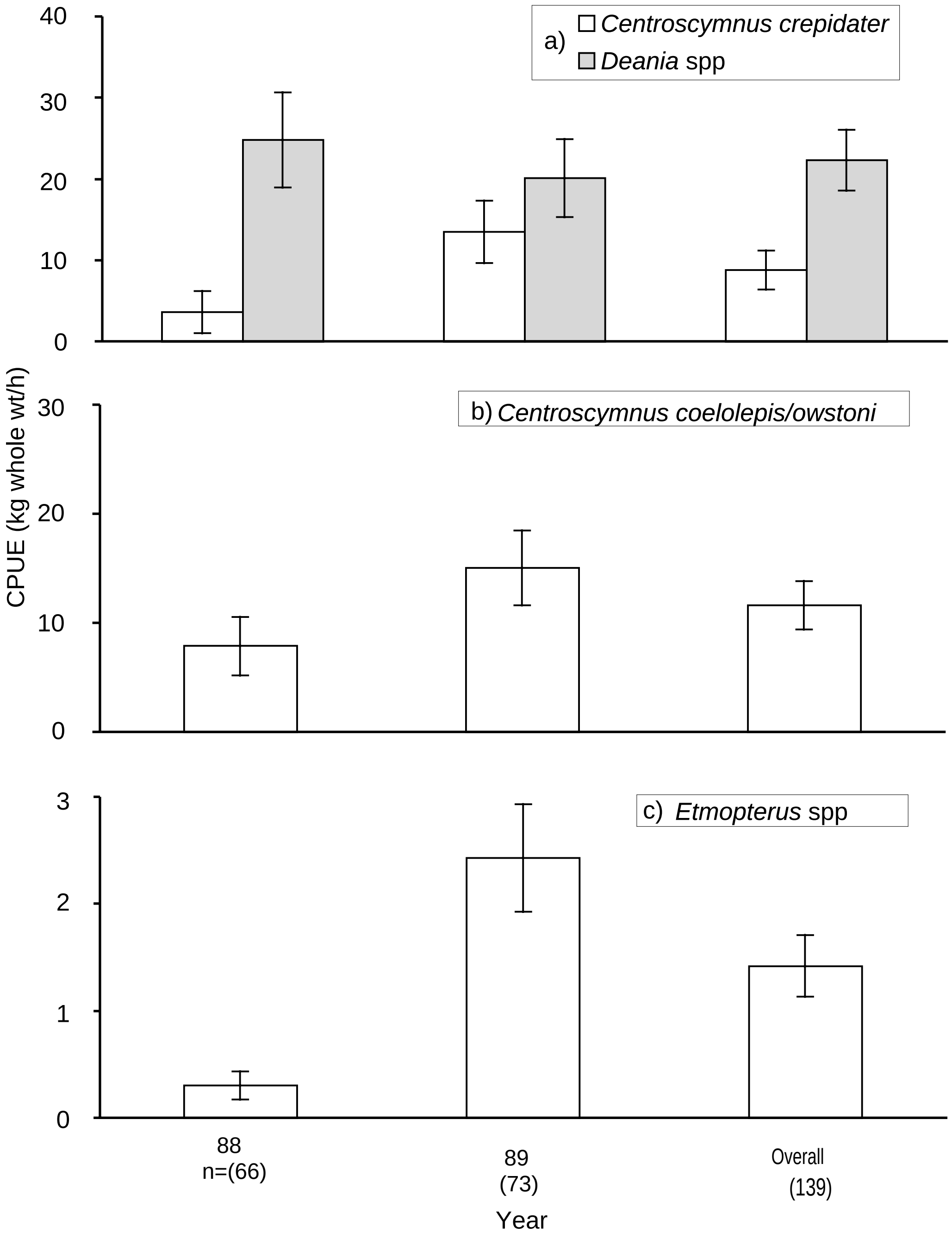
Figure 4.12: Dogfish catch rates from FRV 'Soela' research surveys—western Victoria, 1988–1989, 650–1200 m, 110 mm mesh (mean ± 1 SE)



South Australia

FRV 'Soela' (139 tows; 1988–1989): Trawls off South Australia were on relatively flat grounds. The overall mean combined-species catch rate was 44 kg/h. In the two years sampled, mean catch rates for *Deania* spp were about 20 kg/h, and for the various *Centroscymnus* spp, less than 15 kg/h (Figure 4.13). Catches of *Etmopterus* spp were negligible and there were no catches of *C. plunketi* or *Dalatias licha.*

Figure 4.13: Dogfish catch rates from FRV 'Soela' research surveys—South Australia,1988–1989, 650–1200 m, 110 mm mesh (mean ± 1 SE)



4.4. Discussion of fishery-independent data

Upper-slope

The Kapala surveys from 1976–1997 provided fishery-independent data on the impact of trawling on NSW upper-slope dogfish stocks (Andrew *et al.,* 1997). However, there were insufficient data from other areas to determine any changes in dogfish abundance. The Kapala surveys found that, apart from *Squalus megalops*, all dogfish stocks on the southern NSW upper-slope had declined to very low levels. That study concluded that trawling over 20 years was the most likely and predominant cause of the decline of shark stocks.

Dogfish catch rates off eastern Victoria (Gabo Island) and Tasmania during CSIRO surveys in 1984–1994 were very low compared to those attained by Kapala off Gabo Island in 1977, at the start of the deepwater trawl fishery. The low catch rates by CSIRO suggest that commercial fishing had already substantially reduced dogfish abundance by 1984 when the CSIRO surveys began. This is consistent with Kapala surveys in 1979–81 that found that the relative abundance of NSW upper-slope dogfish had declined to about 20% of the 1976–77 levels after only five years of fishing (Graham *et al*., 2001). Catch rates of *S. megalops* off Portland (western Victoria) in 2000–2001 were comparable to those off southern NSW (Graham *et al.,* 1997), while average catch rates for *S. mitsukurii* and *Centrophorus uyato* were relatively small (< 5 kg/h). However, no earlier data are available to assess whether trawling has impacted on the stocks of upper-slope dogfishes off western Victoria.

Mid-slope

Catch data for most areas were mainly from unstructured exploratory surveys and were insufficient to show any inter-annual trends in catch rates. For most species, catch rates were highly variable, even within a given area and year. It is likely that many dogfish species form aggregations which would explain the infrequent but very large catches of *Etmopterus granulosus* and *Centroscymnus plunketi*. Other factors suggest that some deepwater dogfishes undertake migrations (Section 5). These factors may contribute to catch rates that are highly variable over small spatial and temporal scales. These effects could not be distinguished from changes in abundance using existing CSIRO data.

A large number of exploratory trawls was conducted by Kapala on NSW mid-slope grounds from 1983–1988, although trawling was confined to relatively flat areas. Results of a stratified survey between 700–1200 m in 1989 found that about 80% the overall fish catch consisted of dogfish, with *Deania calcea* alone comprising 61% of the total catch (Graham, 1990). *Deania calcea* was caught on all mid-slope grounds around SE Australia (see below) but the mean catch rate (across all depths and grounds) of 103 kg/h off NSW was the highest for any area. The *Kapala* surveys were completed before there was any commercial trawling on the NSW mid-slope.

Exploratory and survey trawling south of NSW was done on both relatively flat grounds, and on seamounts or pinnacles targeting orange roughy. The most abundant dogfishes were *Etmopterus granulosus*, *Centroscymnus* spp and *Deania* spp. Each genus was represented in all areas on both hills and flat ground, and were frequently caught concurrently. However, *E. granulosus* was most abundant on seamounts, particularly south of Tasmania where single catches as large as 32 t were taken. On the flatter grounds off western Tasmania, Bass Strait, and Victoria, catch rates for *Deania* and *Centroscymnus* were higher.

In summary, overall mean catch rates for dogfish (pooled for all species) caught on flat ground were similar for each area, ranging between 100 and 150 kg/h. This is similar to published average catch rates of 150 kg/h for dogfish on the mid-slope during the mid-80’s (Davenport and Deprez, 1989). The average catch rate recorded off South Australia for combined dogfish species was 44 kg/h which is similar to previously published values of 31 kg/h for the Great Australian Bight (Newton and Klaer, 1991).

The species composition differed among the areas studied. *Deania* dominated the dogfish catches off NSW and eastern Victoria where waters are generally warmer. *Centroscymnus* spp were caught in higher numbers in western regions. *Etmopterus* spp were most abundant on the seamounts.

5. DEEPWATER DOGFISH BIOLOGY

Objective 3. Determine population structure (size distributions and sex ratios) of principal dogfish species by region and depth strata

Objective 4. Assess the biological productivity of the major upper and mid-slope dogfish species from data on age, growth and reproduction

5.1. Introduction

Distributional, length-frequency and biological data for 14 species of deepwater dogfishes are presented. These are species either marketed for their flesh and/or livers, or are commonly caught and discarded by trawlers operating in mid-slope depths. Data are not presented for *Squalus megalops*, which is principally a shallow water species.

Length-frequency data for many species were collected from a range of trawl-gear. NSW mid-slope catches in 1989 were made with trawls fitted with a 45 mm mesh codend; all other NSW data were from trawls with 90 mm codend mesh. Most CSIRO data were from trawls rigged with 110 mm mesh codends.

5.2. Methods

Data sources

Biological data were obtained from three sources:

- historical data sets from trawl surveys by CSIRO and NSW Fisheries research vessels
- specimens collected by industry
- specimens dissected during field work on board commercial vessels

Data collected were location, size, sex, reproductive information and stomach contents. For some specimens collected by industry, only the date and general area of capture was provided. Dogfish examined at sea were dissected when fresh while specimens obtained from trawlers after their return to port were either examined fresh or frozen for later examination. Material for ageing and growth studies was collected for some species.

Length and weight measurements

All lengths and weights given in this report are total length (TL), unless otherwise stated. Where fork length (FL) was measured, data were converted to TL using FL-TL relationships. Total weight was recorded on a calibrated spring balance or electronic balance (smaller specimens). Lengths and weights were recorded by sex. Most length data refer to catches in trawls fitted with 90–110 mm mesh codends; some NSW size data were from surveys with 45 mm mesh codends.

Reproductive parameters

Clasper length and degree of clasper calcification were recorded for all males; testes weight was recorded for some samples. For females, the reproductive stage (Table 5.1), maximum ovum diameter (MOD), uterus width (some samples) and ovary weight (some samples) were recorded. For stage 3 females, the number of eggs with yellow yolk were counted. For pregnant (Stage 4) females the number and size of each pup were recorded; pups longer than about 10 cm were sexed.

The onset of maturity for males was determined from relative clasper length and degree of clasper calcification. Size of sexual maturity for females was determined from the condition of the ovary and the reproductive tract (Table 5.1). Where sufficient data were available, average monthly MODs and gonosomatic index (GSI) were calculated.

Litter sizes were determined from the number of embryos or intra-uterine ova.

Table 5.1: Female reproductive stages

Stage		Condition of ovary	Condition of uterus
1	Immature	Ova mostly < 2mm diameter	Uteri similar in width to oviducts; uterine walls not thicker than those of oviducts
2	Resting	Ova mostly > 2mm diameter but without yellow yolk	Uteri distinctly wider and with thicker walls than oviducts
3	Preovulatory	Ova enlarged and with yellow yolk	Uteri expanded and with thick vascularised walls
4	Pregnant	Developing or resting ova in ovary	Ova or embryos in utero
5	Spent	Developing or resting ova in ovary	Uteri expanded, flacid and empty

Age and growth samples

Samples for age and growth studies were collected from a representative size range for most species. Dorsal spines were collected, and a block of four vertebrae was dissected from the vertebral column from below the first dorsal spine. Ageing samples were stored frozen until ready for examination. A sub-sample of spines and vertebrae were sent to Fisheries WA for examination using x-ray radiography. The remaining samples were provided to Deakin University for on-going ageing studies.

Diet

Stomach contents were examined from a range of sizes of each species. Food items were identified to the lowest possible taxon. Dietary data are presented as frequency of occurrence in those stomachs that contained food.

5.3. Results

5.3.1. *Centrophorus harrissoni*

Most data were collected during FRV 'Kapala' surveys in 1976–1997.

Distribution

This species is probably endemic to eastern Australia. It was previously reported from both the east and west coasts of Australia (Last and Stevens, 1994), but the WA form is now thought to be a separate species (P. Last, CSIRO Marine Research, personal communication). The eastern population is recorded from northern NSW to eastern Tasmania. NSW captures were between 270 and 1050 m with greatest abundance between 400 and 800 m.

Population structure

Data summary:

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1976–77	270–605	708	46–96	455	42–112	Female 2.30:1
Tas.	1984–86	260–560	0		4	78–86	Female 1.00:0

The 1976–1977 NSW catches were dominated by mature males (85–95 cm) (Figure 5.1) with a smaller but significant proportion of mature females (> 95 cm); juveniles comprised a relatively small proportion of the total catch. All specimens from Tasmania were juveniles.

Length–weight relationships

Male	Weight (g) = 0.0011 TL (cm)$^{3.4}$	(n = 98)	$R^2 = 0.98$
Female	Weight (g) = 0.0013 TL (cm)$^{3.3}$	(n = 50)	$R^2 = 0.98$

Reproduction

Data summary:

	Immature TL (cm)		Mature TL (cm)		Litter size	
	n	Range (cm)	n	Range	n	Range
Male	23	50–84	56	80–98		
Female	29	58–102	30	98–112	28	1– 2, mostly 2

Male: Length at first maturity was between 80 and 85 cm (Figure 5.2c). The smallest specimen with fully calcified claspers was 80 cm and the largest immature male was 84 cm.

Female: Length at first maturity was about 100 cm. The smallest pregnant female was 98 cm and the largest immature specimen was 102 cm.

Of 28 pregnant females, 24 contained two pups or candled ova, and four contained single embryos. Two of the pregnant females contained a single candled ovum and a developing embryo (13 and 27 cm). The largest embryo measured 37 cm and the smallest neonate was 42 cm, indicating that pups are about 40 cm at birth.

The MODs ranged from 36 to 70 mm with the ova increasing in size as the embryos developed (Figure 5.2d). This is characteristic of a continuous breeding cycle where the female again becomes pregnant immediately after giving birth. The data were insufficient to show any reproductive seasonality (Figures 5.2 b–c), and gestation period and fecundity could not be estimated.

Figure 5.1: length frequency distribution for *Centrophorus harrissoni*

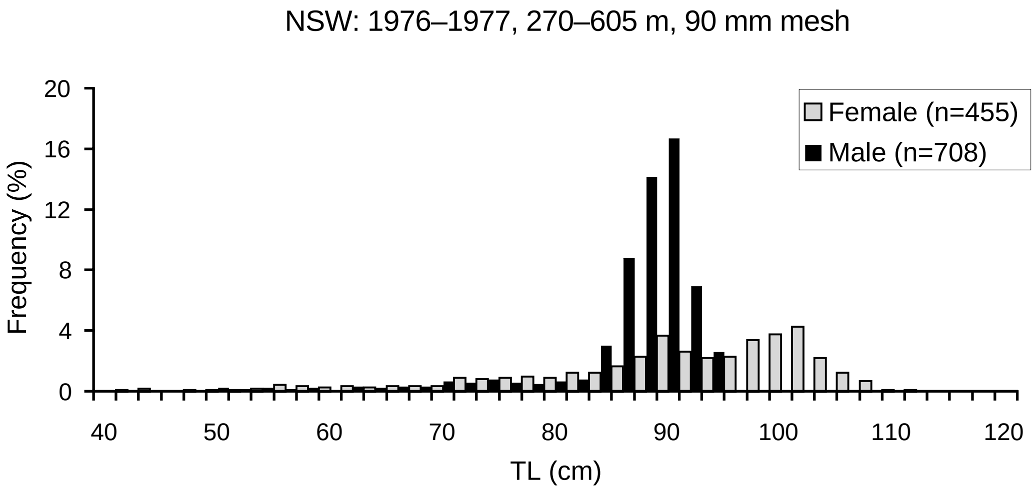
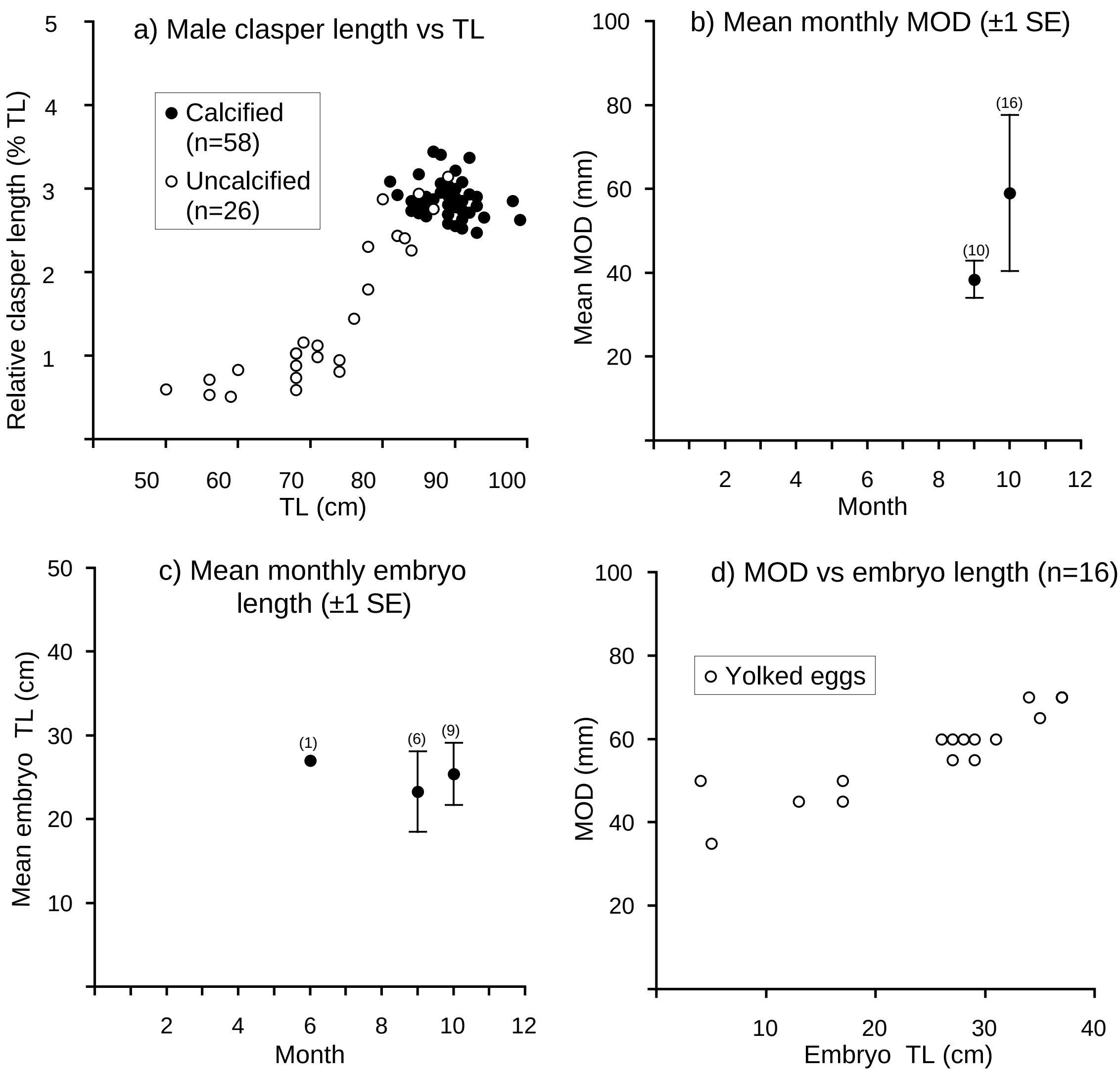


Figure 5.2: Reproductive parameters for *Centrophorus harrissoni*



Ageing
No ageing samples were collected

Diet
Stomach contents of 52 females (58–108 cm) and 64 males (50–99 cm) were examined from catches off NSW. Food items were found in 67% of stomachs, with lantern fishes (Myctophidae) dominating the contents (Table 5.2).

Table 5.2: Frequency of occurrence of prey items in dogfish stomachs

			Frequency of occurrence (%)							
Species	**No. of stomachs**	**% with food**	**Lantern fish**	**Bathypelagic teleost**	**Demersal teleost**	**Unidentified teleost**	**Shark**	**Cephalopod**	**Crustacean**	**Cetacean**
Centrophorus harrissoni	116	67	83		5	11		16	1	
Centrophorus moluccensis	11	91	60		20			40	20	
Centrophorus uyato	102	57	44	2	19	26		25	12	
Centroscyllium kamoharai	100	12		25		17		42	25	
Centroscymnus coelolepis	94	36	3		8	58		42		28
Centroscymnus crepidater	148	45	16	4	2	27		17	4	
Centroscymnus owstoni	230	50	4		10	20		72		
Centroscymnus plunketi	46	76			57	17	17	14		
Dalatias licha	14	29			100					
Deania calcea	409	35	80	3	3	6		14		
Deania quadrispinosa	108	74	92			5		1		
Etmopterus granulosus	369	28	4	4	25	32		25	4	
Etmopterus sp. B	221	32		4	3	12		82	1	
Squalus mitsukurii	35	63	9		36	32		23	45	

5.3.2. *Centrophorus moluccensis*

All data were collected from FRV 'Kapala' surveys off NSW between 1976 and 1997; most data were from 1976–1977.

Distribution

This species occurs off Australia, southern Africa, possibly around southern India and Sri Lanka, and in some areas of the western Pacific including the Philippines, Indonesia and Japan (Last and Stevens, 1994). The reported depth range is 125–820 m. In Australia, *C. moluccensis* is distributed between 15ºS and 40ºS along the east and west coasts. There are no confirmed records from Tasmania or the south coast of Australia. Catch rates off central NSW (Sydney and Ulladulla) were highest in 330–550 m (Graham *et al.*, 1997).

Population structure

Data summary:

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1976–77	220–605	1034	40–78	264	40–93	Female 0.26:1

Mature males dominated the NSW catches (Figure 5.3). Overall, males were 74% of the catch but sex ratios differed by area: 96% of the catch off Sydney were males (n=1048) whereas the smaller catches off Ulladulla were mainly (immature) females (84%; n=250) (Andrew *et al.*, 1997).

Length–weight relationships

Male	Weight (g) = 0.0023 TL(cm)$^{3.2}$	(n = 76)	R^2 = 0.97
Female	Weight (g) = 0.0040 TL (cm)$^{3.1}$	(n = 35)	R^2 = 0.93

Reproduction

Data summary:

	Area	Immature TL (cm)		Mature TL (CM)		Litter size	
		n	Range	n	Range	n	Range
Male	NSW	3	45–52	3	71–78		
Female	NSW	3	43–69	7	88–93	7	Invariably two

The small number of observations made it difficult to define reproductive parameters.

Male: The smallest mature male was 71 cm and the largest immature male was 52 cm.

Female: The length of the smallest mature female was 88 cm and the largest immature specimen was 69 cm. Seven pregnant females were observed, each with a candled ovum in each uterus indicating a litter size of two. No embryos were observed so the size at birth was not determined. The smallest free-swimming neonate was a 32 cm male. Two pregnant females had yolked eggs in the ovary (MOD 15–20 mm) suggesting a continuous reproductive cycle. There were insufficient data to determine whether fertilization was seasonal, and so it was not possible to determine fecundity or the gestation period.

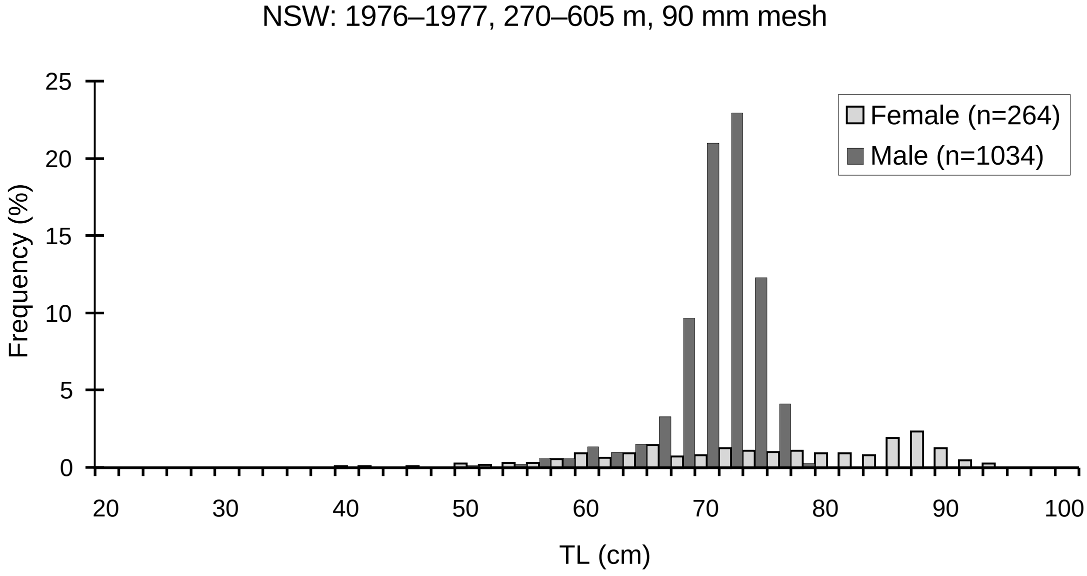
Ageing

No ageing samples were collected

Diet

Stomach contents of eight females (43–93 cm) and three males (45–52 cm) were examined from catches off NSW. Dietary items were found in 10 of the stomachs. Lantern fishes were present in six stomachs, cephalopod remains were in three, and two stomachs contained demersal fish or crustaceans (Table 5.2).

Figure 5.3: Length frequency distribution for *Centrophorus moluccensis*



5.3.3. *Centrophorus uyato*

Data were collected from FRV 'Kapala' surveys off NSW during 1977–1989, and off Portland, western Victoria during 2000–01.

Distribution
Currently recorded as cosmopolitan, *C. uyato* has a broad but localised distribution which includes the Indian, Atlantic and Pacific Oceans. In Australia, it is restricted to temperate waters around southern Australia from central NSW to the west coast of western Australia. However, the taxonomy is uncertain, and eastern and western populations require more detailed examination and could represent separate species.

The reported depth range is between 50 and 1400 m (Last and Stevens, 1994). Off NSW, *C. uyato* was caught in 220–740 m with main catches in 400–600 m (Graham *et al*., 1997). Catches off Portland were also in the 400–600 m depth range.

Population structure
Data summary:

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1976–77	220–605	2567	38–93	1043	40–112	Female 0.41:1
W. Vic.	2000–01	350–600	30	40–88	23	40–103	Female 0.77:1

Overall, the 1976–1977 catches off NSW comprised mainly large males in the 85–95 cm length range (Figure 5.4), but some regional variation was evident. The relatively small catches off Sydney (n=193) consisted almost totally of mature females (91%) between 95 and 112 cm TL. In contrast, the much larger catches off Ulladulla and Eden–Gabo Island were dominated by males (75%) (Andrew *et al*., 1997).

A total of 53 specimens were measured during recent experimental trawling off western Victoria (FRDC Project 98/204). Most of the 30 males and 23 females were juveniles less than 80 cm TL; only three males (83–88 cm) and nine females (97–103 cm) were mature.

Length–weight relationships

Male	Weight (g) = 0.0009 TL (cm)$^{3.3}$	(n = 176)	R^2 = 0.98
Female	Weight (g) = 0.0010 TL (cm)$^{3.4}$	(n = 155)	R^2 = 0.98

Reproduction
Summary of combined NSW and Western Victoria data:

	Immature TL (cm)		Mature TL (cm)		Litter size	
	n	Range	n	Range	n	Range
Male	30	40–83	44	81–92		
Female	44	58–102	42	96–108	37	Invariably one

Male: Length at first maturity was about 80 cm (Figure 5.5a). The smallest specimen with fully calcified claspers was 81 cm and the largest immature male was 83 cm.

Female: The length of first maturity in females was about 100 cm. The smallest preovulatory and pregnant females were 96 cm, and the largest immature female was 102 cm.

Litter size was invariably one; 37 pregnant females had either a single pup (n = 27) or a single uterine ovum (n = 10). Size at birth was about 45 cm; the largest embryo was 45 cm and the smallest free-swimming neonate was 44 cm.

The MOD range was 25–85 mm, and the length of embryos ranged from 17 to 44 cm. Ova diameter increased with embryo length (Figures 5.5d), indicating a continuous fertilisation cycle. Data on MOD and embryo length (Figures 5.5b–c) suggest females breed throughout the year, consequently gestation period and fecundity could not be determined from the data collected.

Ageing

No ageing samples were collected.

Diet

Stomach contents of 61 females (44–108 cm) and 41 males (45–92 cm) were examined from catches off NSW and Portland (W. Vic.). Food items were found in 57% of the stomachs. Lantern fishes, demersal teleosts and cephalopods were the main components of the diet (Table 5.2).

Figure 5.4: Length frequency distribution for *Centrophorus uyato*

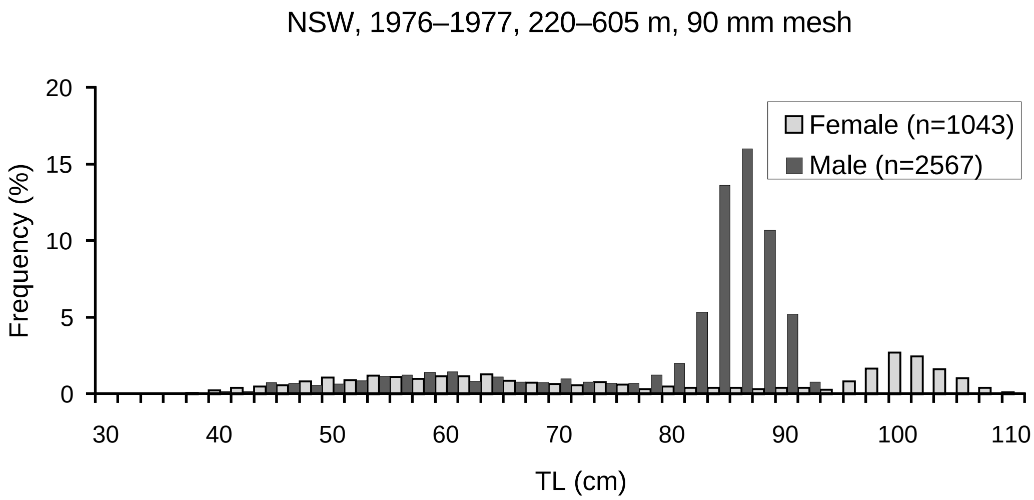
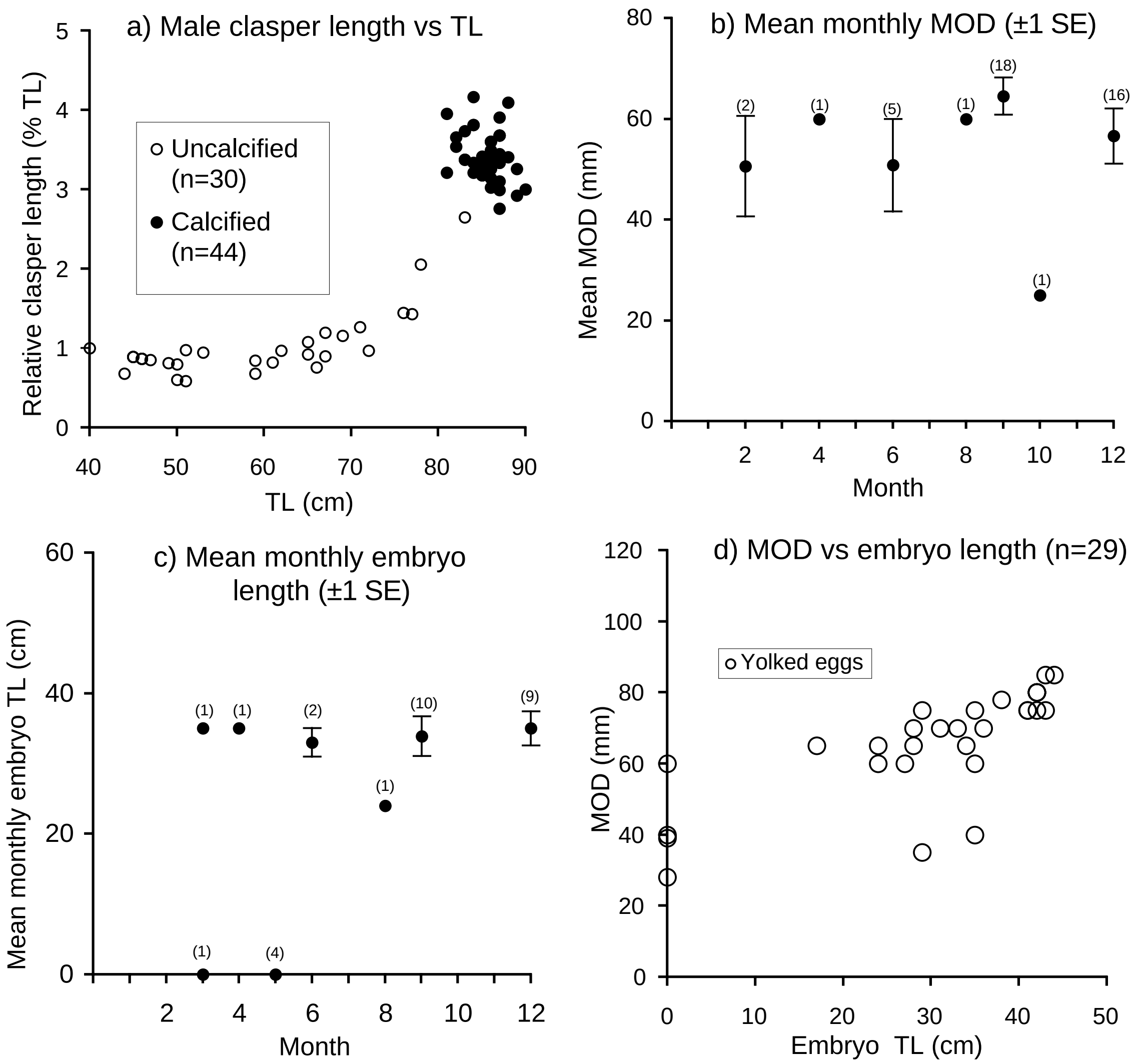


Figure 5.5: Reproductive parameters for *Centrophorus uyato*



5.3.4. *Centroscyllium kamoharai*

All data were collected off NSW during FRV 'Kapala' mid-slope surveys.

Distribution
This species is currently recorded from the east and west coasts of Australia, including Tasmania, and from southern Japan. It is occasionally caught by trawlers in depths between 700 and 1200 m (Last and Stevens, 1994). The NSW catches were in 820–1225 m, with the greatest abundance in depths greater than 1000 m.

Population structure
Data summary (* codend mesh 45 mm):

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1988	820–1225	322	33–56	156	31–62	Female 0.50:1
NSW	1989 *	820–1225	111	31–54	113	30–63	Female 1.00:1

The data showed that the smaller codend mesh used in 1989 retained a greater proportion of juveniles, compared to the 1988 catches (Figure 5.6). There was also a greater proportion of mature females in the 1989 catches suggesting possible segregation by sex.

Length–weight relationships

Male	Weight (g) = 0.0138 $TL(cm)^{2.7}$	(n = 83)	$R^2 = 0.91$
Female	Weight (g) = 0.0008 $TL(cm)^{3.5}$	(n = 70)	$R^2 = 0.88$

Reproduction
Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	19	31–44	51	44–54		
Female	NSW	48	33–57	116	53–63	16	5–22, average=12

Male: Maturity in males occurs at about 44 cm (Figure 5.7a). The smallest male with calcified claspers and the largest male with uncalcified claspers were both 44 cm TL.

Female: Females mature at about 55 cm. The largest immature female was 57 cm, the smallest preovulatory female was 53 cm, and the smallest pregnant female was 54 cm.

Litters ranged from 3–22 pups, with an average of 12. The size at birth was not clear; the largest embryo was 16 cm (n=3) but the smallest free-swimming specimen was 31 cm.

The MODs were between 17 and 37 mm, and embryo lengths ranged from 5 to16 cm. The largest preovulatory eggs (35–37 mm diameter) were in females with candled ova, indicating a MOD of about 36 mm at ovulation. None of the pregnant females had yolked eggs developing in the ovary, which is consistent with a non-continuous breeding cycle. However, the limited reproductive data (Figures 5.7b–d) showed no evidence of a seasonal cycle, and it was not possible to determine annual fecundity or gestation period.

Ageing
No ageing samples were collected.

Diet
Stomachs of 53 females (33–63 cm) and 47 males (31–57 cm) were examined but only 12% contained food (Table 5.2). Most of the food items were small bathypelagic cephalopods and crustaceans. A number of small bathypelagic teleosts, including *Evermannella* sp. (Evermannellidae) and *Photichthys argenteus* (Photichthyidae) were also present.

Figure 5.6: Length frequency distributions for *Centroscyllium kamoharai*

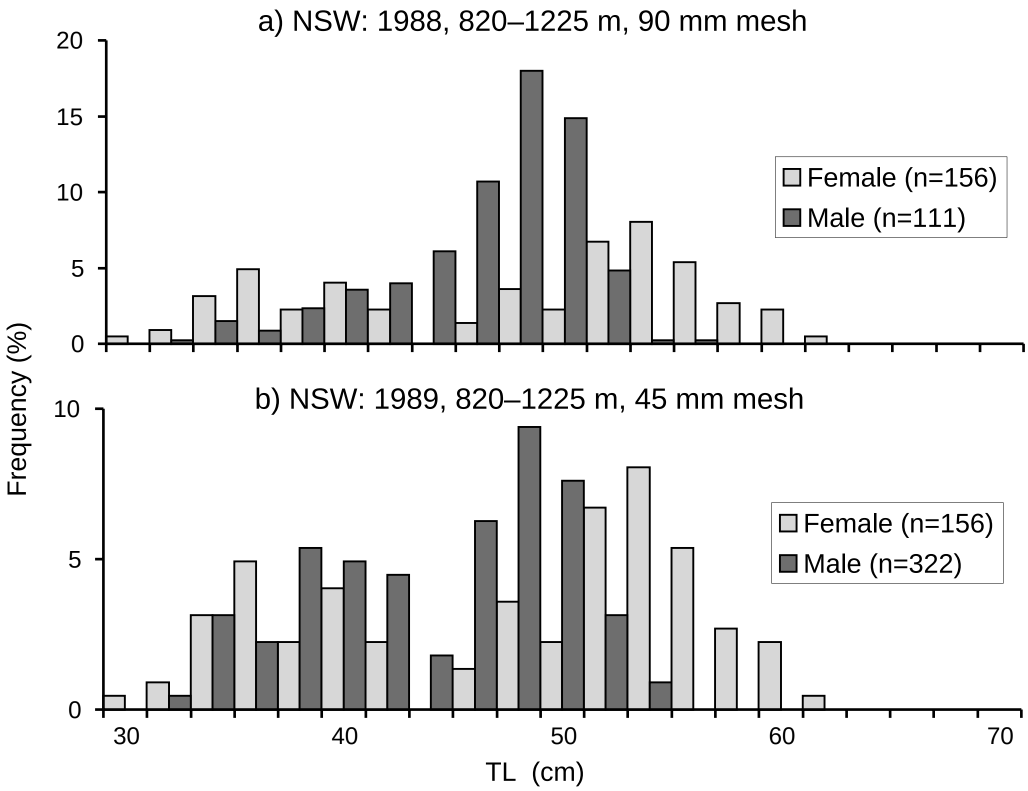
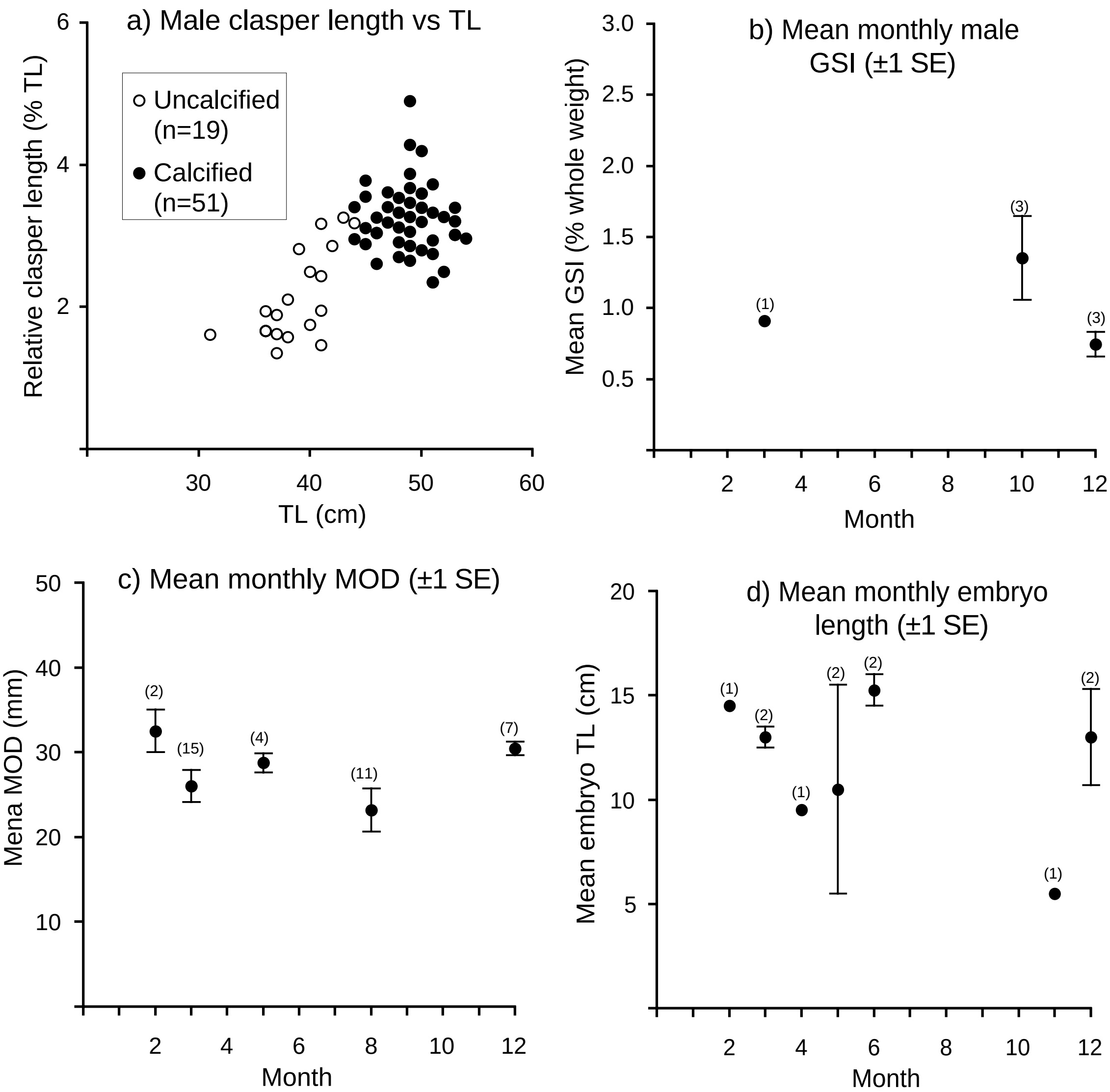


Figure 5.7: Reproductive parameters for *Centroscyllium kamoharai*



5.3.5. *Centroscymnus coelolepis*

Data are from relatively small catches by FRV 'Kapala' off NSW, from CSIRO research catches off Tasmania and from commercial catches around Tasmania.

Distribution

This species is widely distributed around Australia, New Zealand, southern Japan, and the North and South Atlantic with an overall depth range of 270–3700 m. It occurs locally around south-eastern Australia, including Tasmania, from central NSW to Beachport, South Australia. Its reported depth range is between 770 and 1400 m (Last and Stevens, 1994). Catch rates are generally highest in depths greater than 1000 m (present study; Gordon and Swan, 1997).

Population structure

Data summary (* codend mesh 45 & 90 mm):

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1987–89 *	940–1200	79	48–93	46	50–112	Female 0.59:1
Tas.	1989–01	650–870	107	67–101	30	80–120	Female 0.28:1

The size structure of NSW catches was very different to that of Tasmania (Figure 5.8). Catches from NSW were comprised almost totally of immature specimens less than 80 cm, compared to the Tasmanian captures that were mostly larger than 85 cm. Catches off both NSW and Tasmania had greater numbers of males than females.

Length–weight relationships

Male	Weight (g) = 0.0410 TL (cm)$^{2.6}$	(n = 34)	$R^2 = 0.52$
Female	Weight (g) = 0.0016 TL (cm)$^{3.3}$	(n = 5)	$R^2 = 0.90$

Reproduction

Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range (cm)	n	Range	n	Range
Male	NSW	32	55–85	11	85–93		
Male	Tas.	10	67–92	86	84–99		
Female	NSW	16	55–106	2	109–110	1	12
Female	Tas.	12	79–99	19	92–120	14	8–19, average=12

Male: Most males mature between 85 and 90 cm (Figure 5.9a). The largest male with uncalcified claspers was 91 cm and the smallest with calcified claspers was 84 cm.

Female: Females mature at about 110 cm. The largest immature female was 106 cm while the smallest pregnant female was 110 cm.

Litter sizes ranged from 8–19 with an average of 12; the maximum embryo length was 32 cm. The MOD range was 10–50 mm but no yolked eggs were observed in the ovaries of pregnant females, consistent with a non-continuous female reproductive cycle. There were insufficient data to show any reproductive seasonality (Figures 5.9b–c) or to determine annual fecundity or gestation period.

Ageing

Vertebrae and spines were collected from two females of 88 and 93 cm TL. Preliminary attempts to age these specimens using x-radiography in collaboration with Fisheries WA were unsuccessful .

Diet

Stomach contents of 21 females (62–110 cm) and 73 males (55–101 cm) were examined. Dietary items were found in 36% of stomachs and consisted mainly of teleosts and squids (Table 5.2). Much of the food was in the form of large bite-sized chunks, with several stomachs containing cetacean remains. The teleosts included relatively large demersal species such as slickheads (Alepocephalidae) and orange roughy (*Hoplostethus atlanticus)*, as well as small lantern fishes.

Figure 5.8: Length frequency distributions for *Centroscymnus coelolepis*

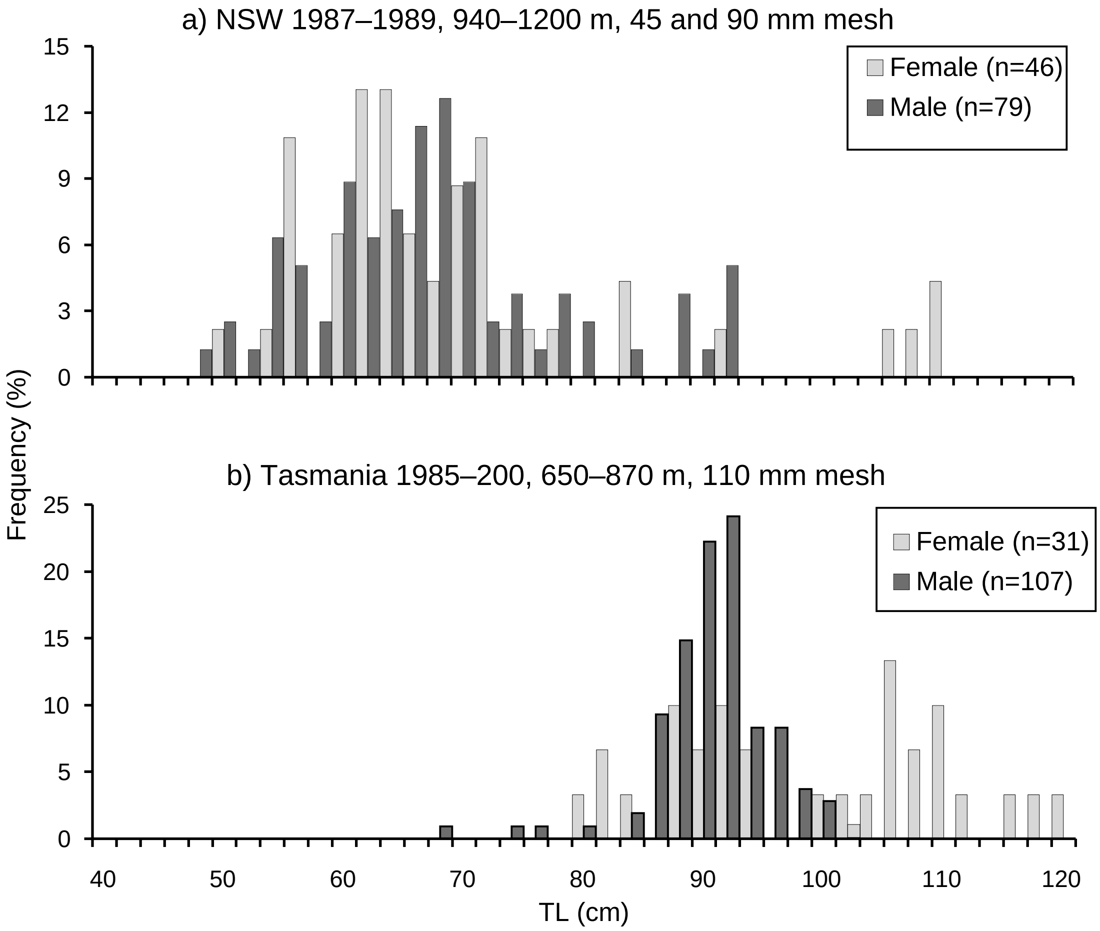
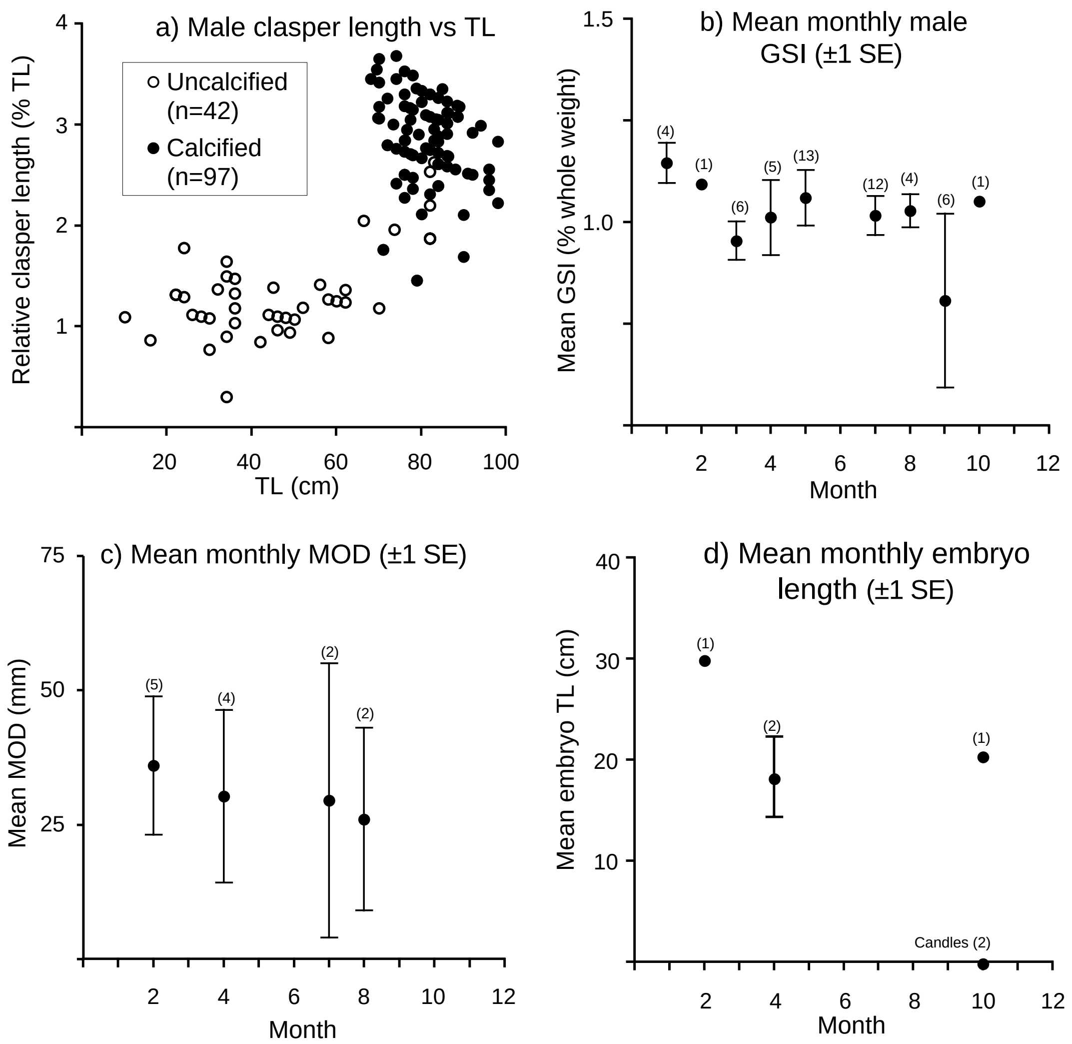


Figure 5.9: Reproductive parameters for *Centroscymnus coelolepis*



5.3.6. *Centroscymnus crepidater*

Data are from FRV ‘Kapala’ surveys of the NSW mid-slope, and from CSIRO records of research and commercial catches off Tasmania.

Distribution
This species is found off Australia, New Zealand, India, Madagascar and Chile, and also has a broad but patchy distribution along the continental slope of the eastern Atlantic. Its reported depth range is 270–1300 m (Last and Stevens, 1994).

In Australia, it has been recorded from temperate waters south of 30ºS, and is mainly caught in depths between 780–1100 m. Off NSW, *C. crepidater* was caught between 560 and 1200 m, although most were taken in 800–1000 m. Tasmanian data were from catches in 650–900 m.

Population structure
Data summary (* codend mesh 45 mm):

			Male size (cm)		Female size (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1988	800–1200	129	36–62	161	32–88	Female 1.25:1
NSW	1989 *	820–1225	325	30–60	298	30–64	Female 0.92:1
Tas.	1987–01	650–900	276	30–94	436	30–103	Female 1.58:1

Size structure and sex ratios varied between regions. Catches off NSW were almost totally juveniles, with only two specimens larger than 70 cm (Figures 5.10a–b); the overall sex ratio was 1:1. The 1989 catches in trawls with a small mesh codend contained a greater proportion of juveniles smaller than 50 cm (Figure 5.10b) compared to 1988. In contrast, juveniles were rare in all Tasmanian catches (Figure 5.10c). A total of 447 individuals were sampled during recent commercial operations around Tasmania, of which 64% were females. However, the sex ratio seemed to differ from shot to shot suggesting some depth-related segregation of the adults.

Length–weight relationships

Male	Weight (g) = 0.0017 TL (cm)$^{3.2}$	(n = 37)	$R^2 = 0.93$
Female	Weight (g) = 0.0098 TL (cm)$^{2.8}$	(n = 85)	$R^2 = 0.91$

Reproduction
Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	28	35–58	0			
Male	Tas.	0		96	73–122		
Female	NSW	49	34–81	1	91	1	6
Female	Tas.	11	79–94	18	87–120	7	3–9, average =6

Male: Males matured at about 62 cm TL (Figure 5.11a); the smallest male with calcified claspers was 63 cm and the largest with uncalcified claspers was 62 cm.

Female: Female maturity occurred at about 82 cm or smaller; the smallest pregnant specimen was 82 cm.

Eight pregnant females were observed. Litter size was 3–9 with an average of six. The maximum embryo length was 32 cm and smallest free-swimming neonates were also 32 cm, indicating this is the size at birth. The female data were consistent with a non-continuous reproductive strategy. Pregnant females had only small unyolked eggs in the ovary (Figure 5.11f) while the MOD of preovulatory females was up to 90 mm. Spent females had only small unyolked eggs of 6–13 mm. The MOD and GSI data showed no seasonal trends although average ovary weight tended to be higher in autumn

(Figures 5.11b–e). Pregnant females were collected in most months (Figure 5.11e) suggesting females breed throughout the year, consequently gestation period and fecundity could not be determined from the data collected.

Ageing
Samples were collected from 38 females (71–98 cm) and 23 males (68–77 cm). Preliminary attempts to age the specimens using x-radiography in collaboration with Fisheries WA were unsuccessful.

Diet
Stomach contents of 104 females (34–98 cm) and 44 males (32–76 cm) were examined. Dietary items were found in 45% of stomachs (Table 5.2). The NSW data were mostly from small specimens and the stomach contents comprised mainly lantern fishes and small squids. The larger Tasmanian specimens contained a higher proportion of cephalopods and some large teleosts including two orange roughy. Cartilage, probably from a shark or ray, was also found in one stomach.

Figure 5.10: Length frequency distributions for *Centroscymnus crepidater*

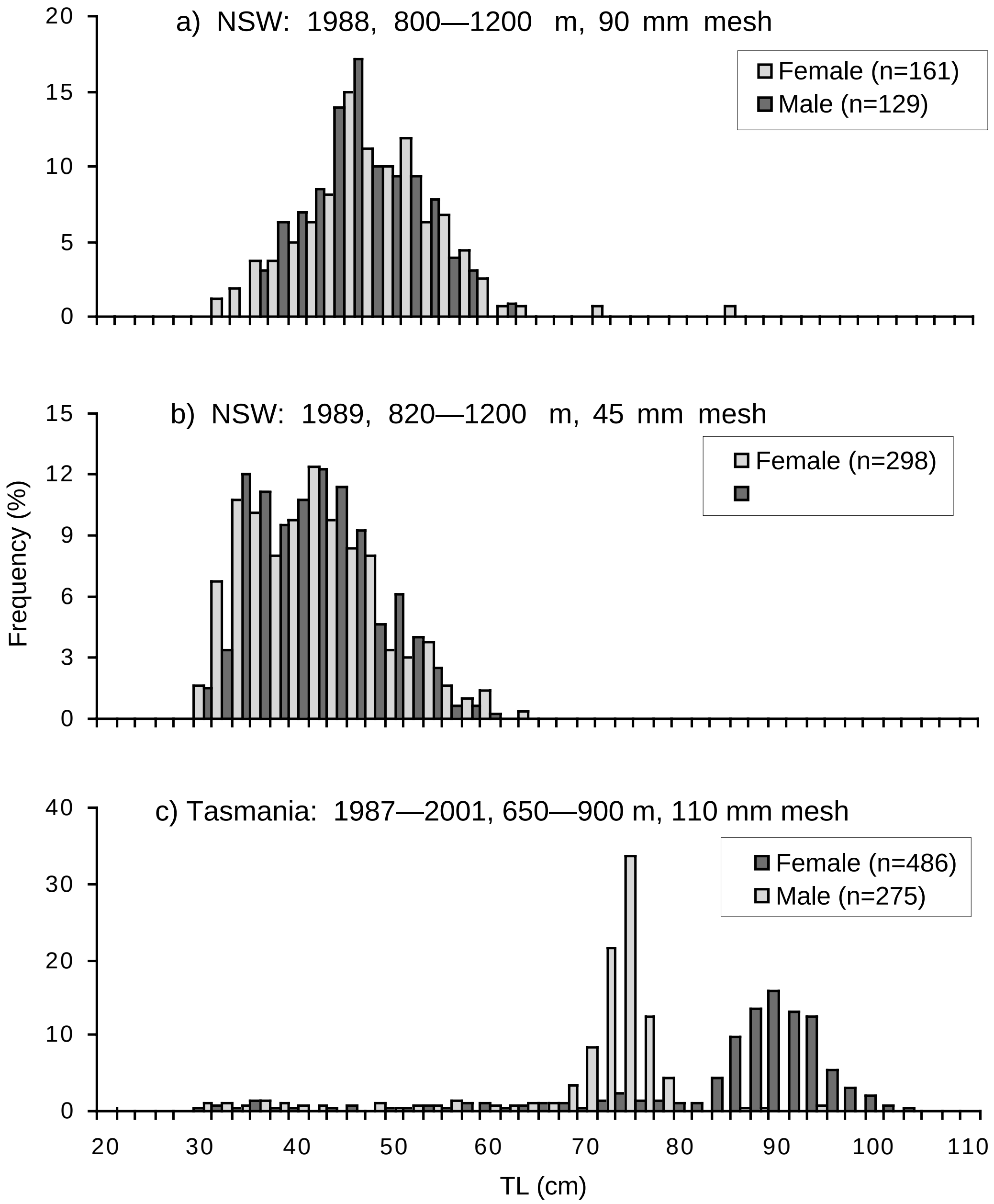
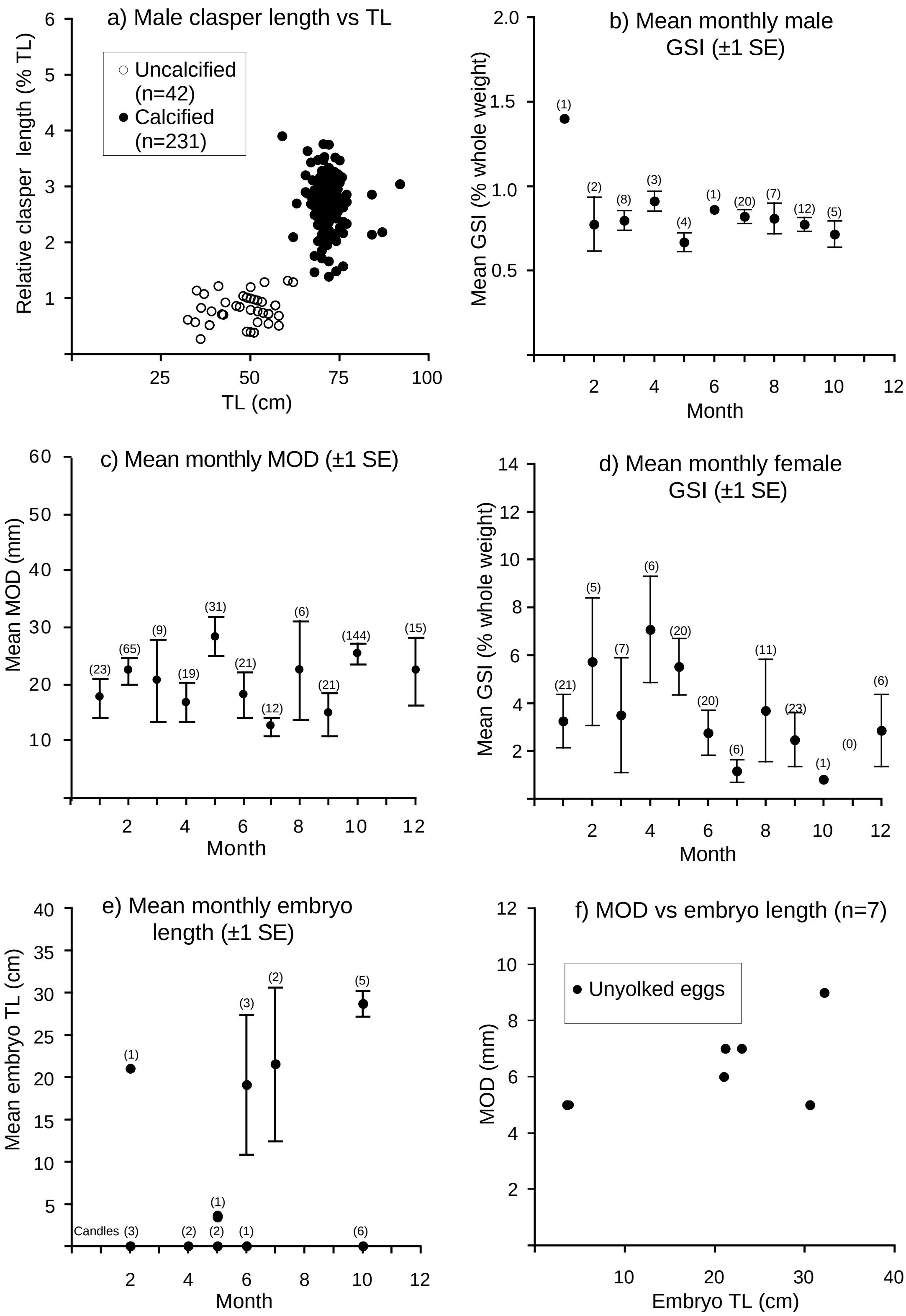


Figure 5.11: Reproductive parameters for *Centroscymnus crepidater*



5.3.7. *Centroscymnus owstoni*

Data are from FRV ‘Kapala’ surveys of the NSW mid-slope, and from CSIRO records of research and commercial catches off Tasmania.

Distribution

This species is found off Australia, northern New Zealand, southern Japan, and in the Gulf of Mexico, in a depth range of 500–1400 m (Last and Stevens, 1994). In Australia, it occurs south of 30ºS from central NSW to Shark Bay (WA), including Tasmania and southern seamounts. Off NSW and Tasmania, most specimens were caught in 900–1200 m.

Population structure

Data summary (* codend mesh 45 mm):

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1988	800–1200	435	30–85	594	30–109	Female 1.37:1
NSW	1989*	800–1200	293	28–88	270	25–113	Female 0.92:1
Tas.	1985–01	650–1100	75	32–96	85	60–120	Female 1.10:1

There were marked differences in population structure between Tasmania and NSW (Figure 5.12a– c). Juveniles smaller than 70 cm were rare in catches off Tasmania but dominated the NSW catches, particularly in 1989 when the small-mesh codend was used. The Tasmanian catches comprised mainly adult males and a mixture of immature and mature females larger than 70 cm.

Length–weight relationships

Male	Weight (g) = 0.0059 TL (cm)$^{3.0}$	(n = 87)	R^2 = 0.98
Female	Weight (g) = 0.0030 TL (cm)$^{3.2}$	(n = 93)	R^2 = 0.98

Reproduction

Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	35	41–76	45	73–88		
Male	Tas.	18	32–77	60	73–94		
Female	NSW	103	31–103	9	102–113	2	5 –13
Female	Tas.	33	59–90	53	82–120	0	

Male: Males mature at about 75 cm. The largest male with uncalcified claspers was 79 cm and the smallest with calcified claspers was 73 cm (Figure 5.13a).

Female: First maturity for females was about 95 cm but varied: the smallest pregnant female was 89 cm and the largest immature female was 103 cm.

Two pregnant females were observed. Litter size was 5–13. The size at birth seems to vary. The maximum embryo length was 32 cm while several free-swimming neonates of 25–30 cm were caught.

The female data were consistent with a non-continuous reproductive strategy. Ovaries in pregnant and spent females contained only small unyolked eggs (MOD up to 7 mm), while MODs of preovulatory females were up to 60 mm. There were no seasonal trends in MOD or GSI data (Figures 5.13 b–d) and so it was not possible to determine gestation period or annual fecundity.

Ageing

Samples were collected from 9 females (94–107 cm) and 5 males (75–83 cm). Preliminary attempts to age specimens using x-radiography were unsuccessful.

Diet

Stomachs of 116 females (35–112 cm) and 114 males (32–94 cm) were examined. Dietary items were found in 50% of stomachs (Table 5.2). In NSW specimens (n=189), the diet was predominantly squids, including *Histioteuthis* spp In contrast, stomach contents of specimens from Tasmania were dominated by orange roughy. Most of the dogfish sampled around Tasmania were collected during commercial operations targeting orange roughy. While dogfish from these commercial trawls may have fed on orange roughy in the net, some of the stomachs contained well-digested chunks of this species suggesting predation prior to capture.

Figure 5.12: Length frequency distributions for *Centroscymnus owstoni*

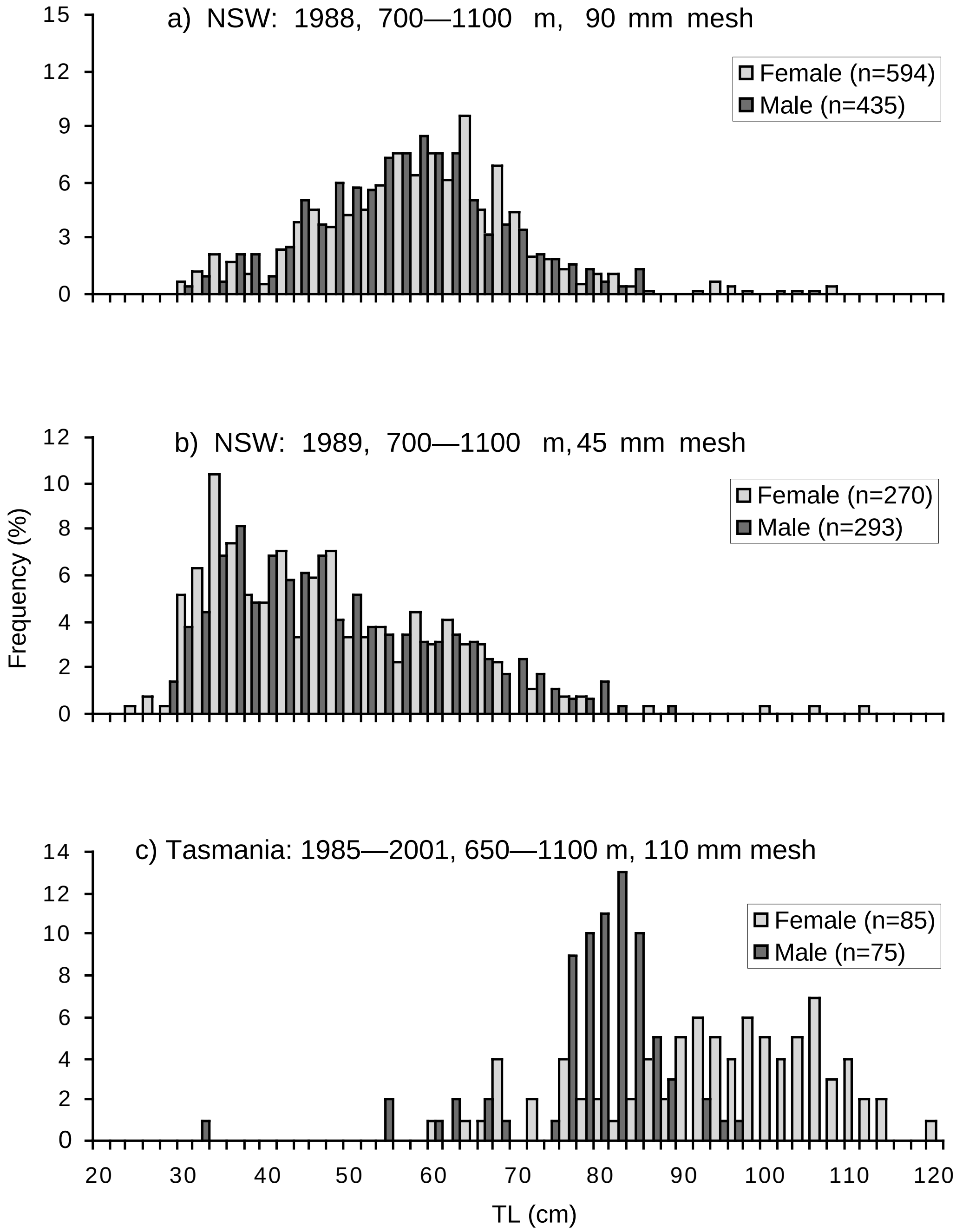
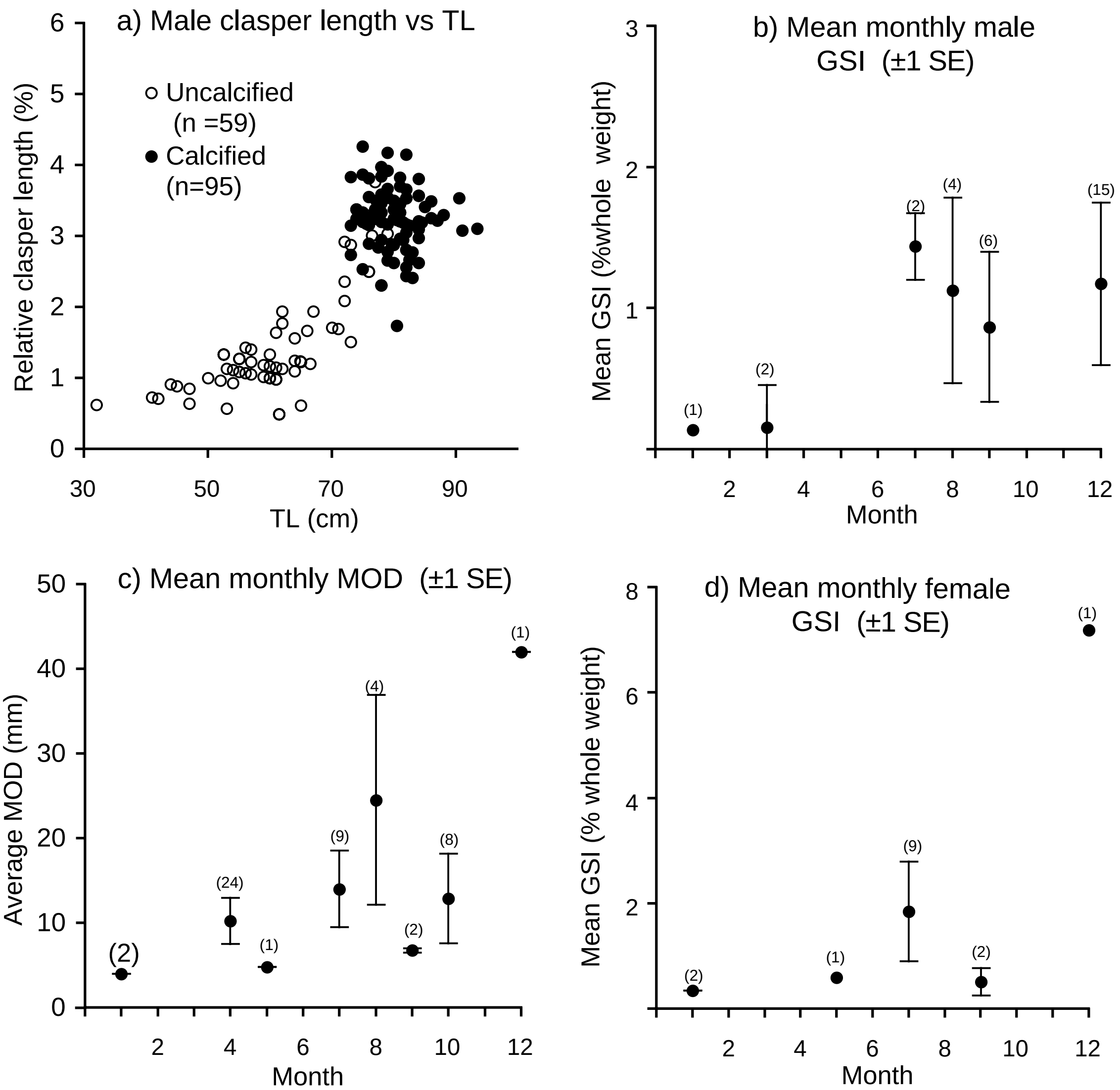


Figure 5.13: Reproductive parameters for *Centroscymnus owstoni*



5.3.8. *Centroscymnus plunketi*

All data were collected by CSIRO from research and commercial catches off eastern Bass Strait and Tasmania.

Distribution
Restricted to southeastern Australian and New Zealand waters in 240–1550 m (Last and Stevens, 1994). In this study, specimens were collected from 700–1000 m.

Population structure
Data summary:

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
Tas.	1984–01	700–1000	45	52–133	67	66–154	Female 1.50:1

Specimens sampled ranged in length from 52–154 cm, but no distinct size classes were evident (Figure 5.14). The largest specimen measured was 154 cm, substantially smaller than the maximum size of 170 cm reported by Last and Stevens (1994).

Length–weight relationships

Male	Weight (g) = 0.0004 TL (cm)$^{3.6}$	(n = 16)	$R^2 = 0.99$
Female	Weight (g) = 0.5863 TL (cm)$^{2.9}$	(n = 25)	$R^2 = 0.85$

Reproduction
Data summary:

		Immature TL		Mature TL		Litter size	
	Area	n	Range	n	Range	n	Range
Male	Tas.	12	52–106	36	108–133		
Female	Tas.	30	66–143	34	137–154	0	

Male: Size at first maturity was about 108 cm (Figure 5.15a). The smallest male with fully calcified claspers was 108 cm. Two 106 cm specimens had partly calcified claspers and another of this size had uncalcified claspers.

Female: Size at first maturity was about 140 cm. The smallest preovulatory female was 137 cm and the largest immature specimen was 143 cm. Litter size or size at birth could not be determined as no pregnant females were collected. The size at birth is reported to be 32–36 cm by Last and Stevens (1994).

Ovaries of some mature females contained 7–27 developing ova with MOD up to 80 mm. However, 60% of mature females had resting ovaries with small ova (MOD of 3–11 mm) suggesting a non-continuous reproductive cycle with a significant interval between pregnancies. The limited data on ova size and GSI showed no evidence of a seasonal cycle (Figures 5.15b–d)

Ageing
Samples were collected from 2 females (122–124 cm) and 13 males (117–142 cm). Preliminary attempts to age specimens using x-radiography were unsuccessful.

Diet
Stomach contents were examined from 27 females (83–159 cm) and 19 males (55–124 cm) and food items were found in 76% of the stomachs. The diet was dominated by demersal teleosts (Table 5.2), particularly orange roughy, whiptails (Macrouridae) and cods (Moridae). Other stomachs contained cephalopods and sharks, including several *Etmopterus granulosus* and a juvenile *C. plunketi*.

Figure 5.14: Length frequency distribution for *Centroscymnus plunketi*

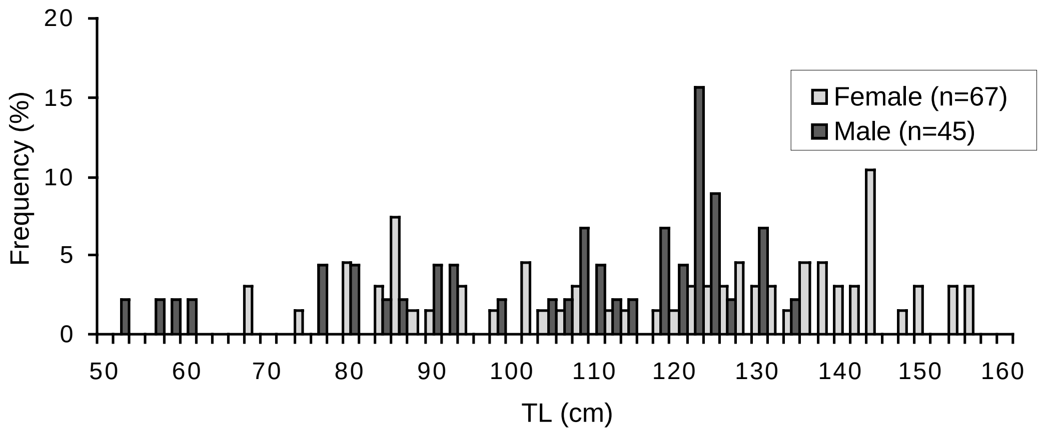
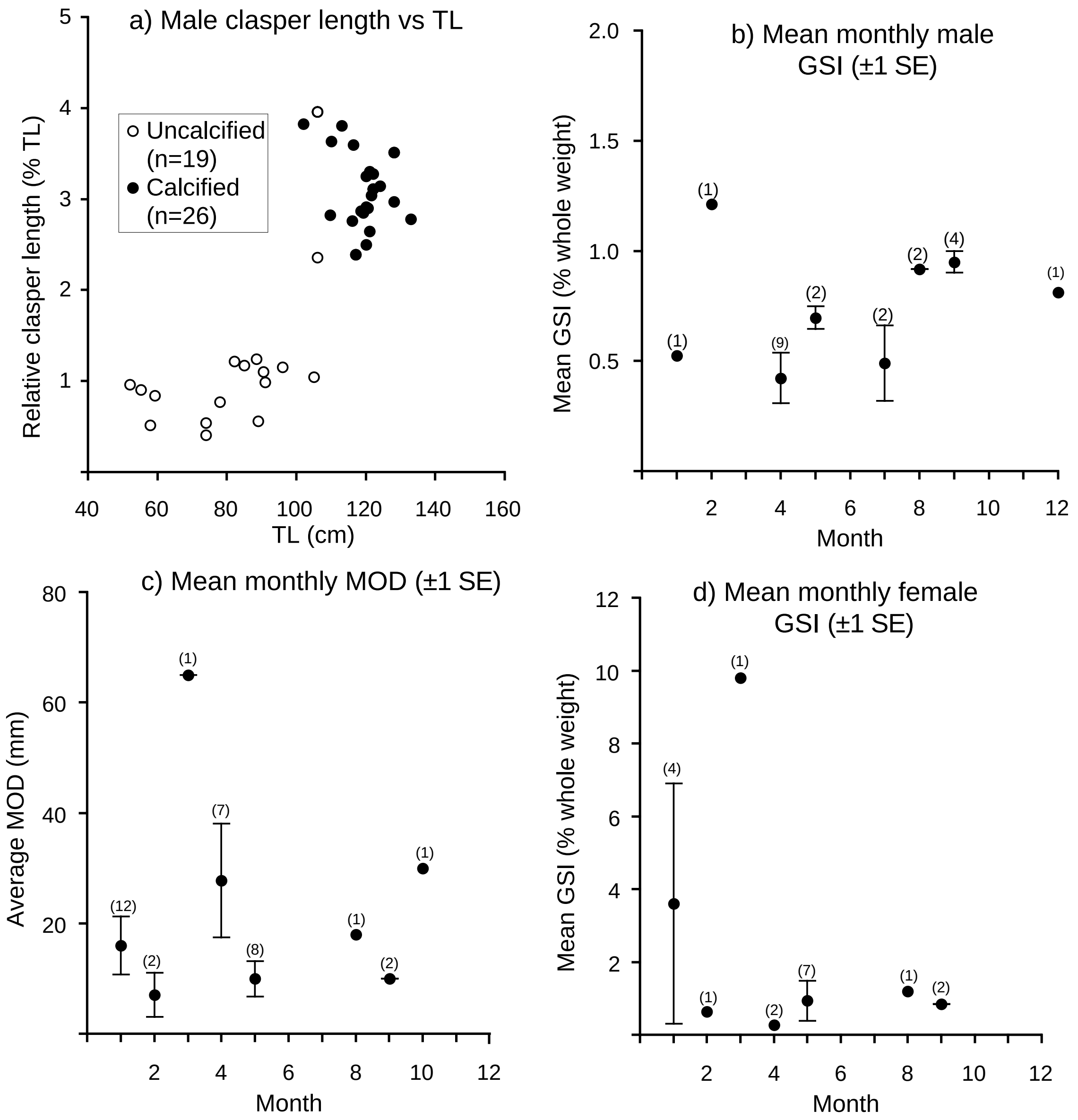


Figure 5.15: Reproductive parameters for *Centroscymnus plunketi*



5.3.9. *Dalatias licha*

The small amount of data available was from NSW, Tasmania, and western Victoria.

Distribution

This species is widely distributed in the Atlantic, Indian, and Pacific Oceans. It is mainly demersal (sometimes pelagic) on the outer continental shelf, continental slope and seamounts from 40–1800 m. In Australia, *D. licha* occurs south of 20º S and is caught mainly between 450–850 m (Last and Stevens, 1994).

Population structure

Data summary:

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1987–01	600–900	5	40–115	2	44–142	
Tas.	1984–01	450–1000	16	40–117	40	40–151	Female 2.50:1

The NSW and Tasmanian data were insufficient to define the population structure. The Tasmanian sample comprised mainly juveniles but included eight specimens longer than 100 cm TL. The largest specimen was 151 cm, close to the maximum size of 160 cm reported by Last and Stevens (1994).

Length–weight relationships

Male	Weight (g) = 0.0008 TL (cm)$^{3.41}$	(n = 11)	R^2 = 0.98
Female	Weight (g) = 0.0008 TL (cm)$^{3.43}$	(n = 17)	R^2 = 0.99

Reproduction

Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	4	40–51	1	115		
Male	Tas.	14	40–109	3	113–117		
Male	W. Vic.	5	87–106	0			
Female	NSW	1	44	1	142	1	10
Female	Tas.	34	37–104	4	127–151	3	7–11, average=9
Female	W. Vic.	2	83, 114	0			

Male: There were insufficient data to estimate size at first maturity. Of the few observations, the largest male with uncalcified claspers was 109 cm and the smallest male with calcified claspers was 113 cm. Males of 102 cm and 106 cm had partly calcified claspers.

Female: The smallest mature female was 127 cm. Size at maturity for females is reported to be around 120 cm (Last and Stevens, 1994).

Four pregnant females were observed; litter sizes ranged from 7–11 with an average of 9. Embryo sizes ranged from 38–43 cm and several neonates in catches measured 39–42 cm. This indicated a size at birth of about 40 cm, compared to 30 cm reported by Last and Stevens (1994).

Pregnant and spent females had resting ovaries with small eggs (3–8 mm MOD), suggesting a non-continuous breeding cycle. There were insufficient data to determine reproductive seasonality, fecundity or gestation.

Ageing

Samples were collected from 2 females (122–124 cm) and 13 males (117–142 cm). Preliminary attempts to age specimens using x-radiography in collaboration with Fisheries WA were unsuccessful.

Diet

Stomach contents of seven females (40–127 cm) and seven males (109–117 cm) were examined. Dietary items were found in 29% of stomachs. All prey items were demersal teleosts including whiptails and an orange roughy (Table 5.2).

5.3.10. *Deania calcea*

Data are from FRV 'Kapala' surveys of the NSW mid–slope, and CSIRO surveys off Tasmania.

Distribution

Deania calcea has a wide but disjunct distribution in the eastern Atlantic Ocean, and in the Pacific Ocean off Chile, southern Japan and in temperate waters around Australia and New Zealand (Last and Stevens, 1994). It occurs mainly on the continental slope as well as on seamounts in 70–1450 m. Locally this species is common around SE Australia in 600–1100 m. Catch rates off NSW were greatest in 800–1000 m (Graham, 1990).

Population structure

Data summary (* codend mesh 45 mm):

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1988	600–1100	753	30–92	1086	29–116	Female 1.44:1
NSW	1989 *	700–1200	696	26–92	789	29–118	Female 1.13:1
Tas.	1984–01	400–900	595	30–94	422	29–122	Female 0.71:1

Length-frequency distributions were similar off NSW and Tasmania when trawls with similar large-mesh codends were used (Figures 5.16a, c). The NSW catches in 1989, taken in nets with 45 mm mesh codends, contained a higher proportion of juveniles smaller than 70 cm (Figure 5.16b).

The NSW catches in 1988–1989 comprised more females than males, and this pattern was consistent across all depths. In contrast, the combined data for Tasmania showed a substantially higher number of males than females, suggesting a regional (latitudinal) difference between NSW and Tasmania.

Length–weight Relationships

Male	Weight (g) = 0.0031 TL (cm)$^{3.0}$	(n = 111)	$R^2 = 0.98$
Female	Weight (g) = 0.0044 TL (cm)$^{3.0}$	(n = 254)	$R^2 = 0.97$

Reproduction

Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	41	31–83	62	75–93		
Male	Tas.	27	31–80	274	73–97		
Female	NSW	332	28–107	395	93–118	3	1–9, average=4
Female	Tas.	155	29–104	884	93–120	7	2–17, average=8

Male: Males mature at around 80 cm (Figure 5.17a). The largest male with uncalcified claspers was 83 cm and the smallest male with calcified claspers was 75 cm.

Female: Despite the abundance of mature females in the catches, few were caught in breeding condition off either NSW or Tasmania. Of the 727 females examined from NSW catches, 395 were judged to be mature but of these, only three were pregnant and 48 had developing (yellow-yolked) ova. Similarly, 884 mature females from Tasmania were examined; seven were pregnant and 68 were preovulatory.

Size at first maturity was around 100 cm but varied. The smallest preovulatory female was 93 cm and the largest immature specimen was 107 cm. The smallest pregnant female was 105 cm.

Litter numbers ranged from 1–17 with an average of seven. Size at birth is around 30 cm; the maximum embryo size was 33 cm and the smallest neonate was 28 cm. Most free-swimming specimens between 28 and 32 cm had visible umbilical scars. It is likely that a number of females recorded with only one or two embryos had already released most of their pups before capture or they were aborted in the trawl, as their embryos were around full-term size (30–32 cm TL).

In preovulatory females, the MOD range was 15–60 mm. The ovaries of the pregnant females examined contained small undeveloped eggs, rather than large, yolked preovulatory eggs (Figure 5.17f). This indicates a non-continuous breeding cycle. There were no seasonal trends evident in the MOD, GSI or pup length (Figure 5.17b–e) and so it was not possible to determine annual fecundity or gestation.

Ageing

Samples were collected from nine females (98–109 cm). Preliminary attempts to age specimens using x-radiography in collaboration with Fisheries WA were unsuccessful.
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Diet

Stomach contents of 181 females (31–116 cm) and 228 males (32–92 cm) were examined. Dietary items were found in 35% of stomachs (Table 5.2). Lanternfishes were the major prey, with small squids of relatively minor importance.

Figure 5.16: Length frequency distributions for *Deania calcea*

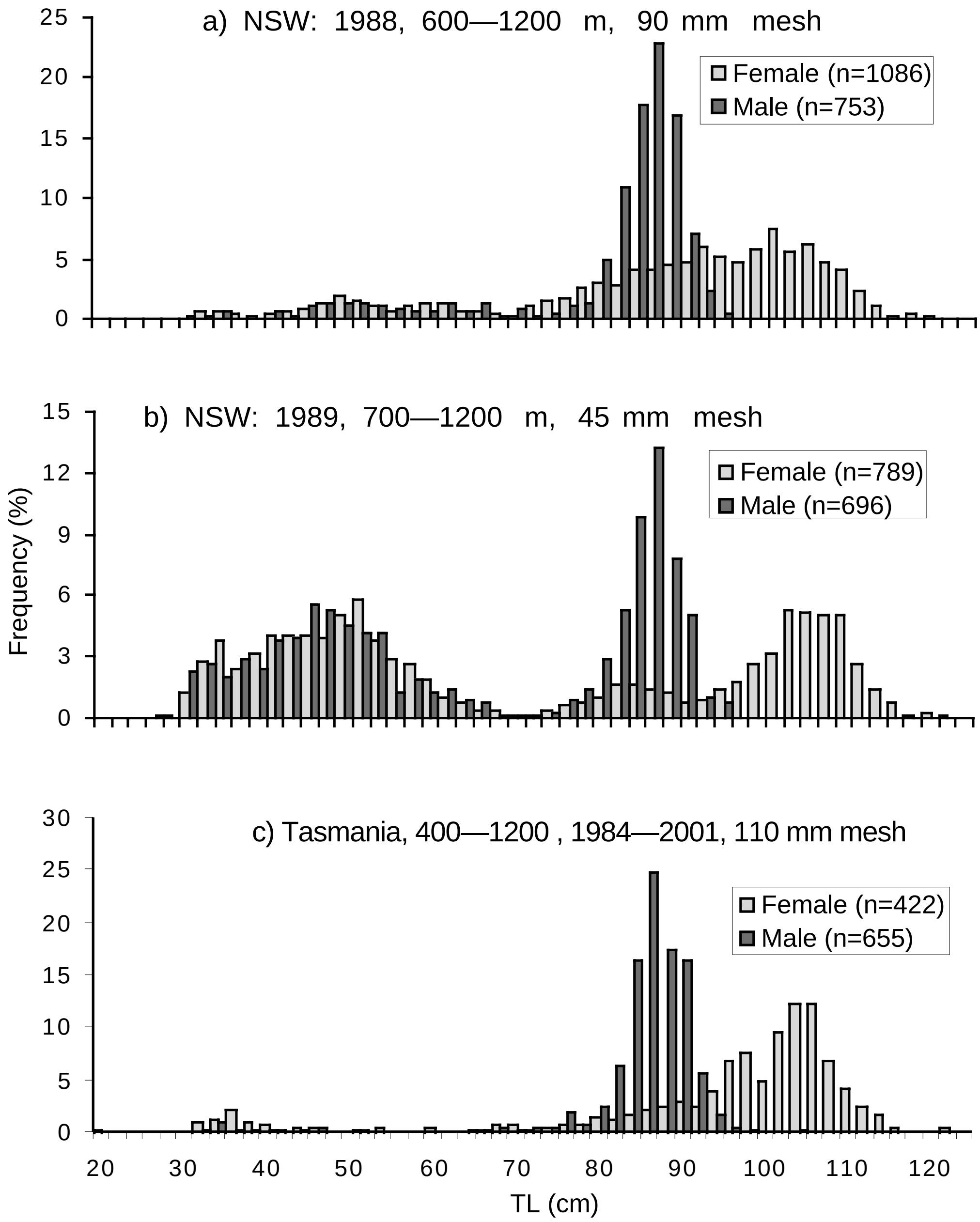
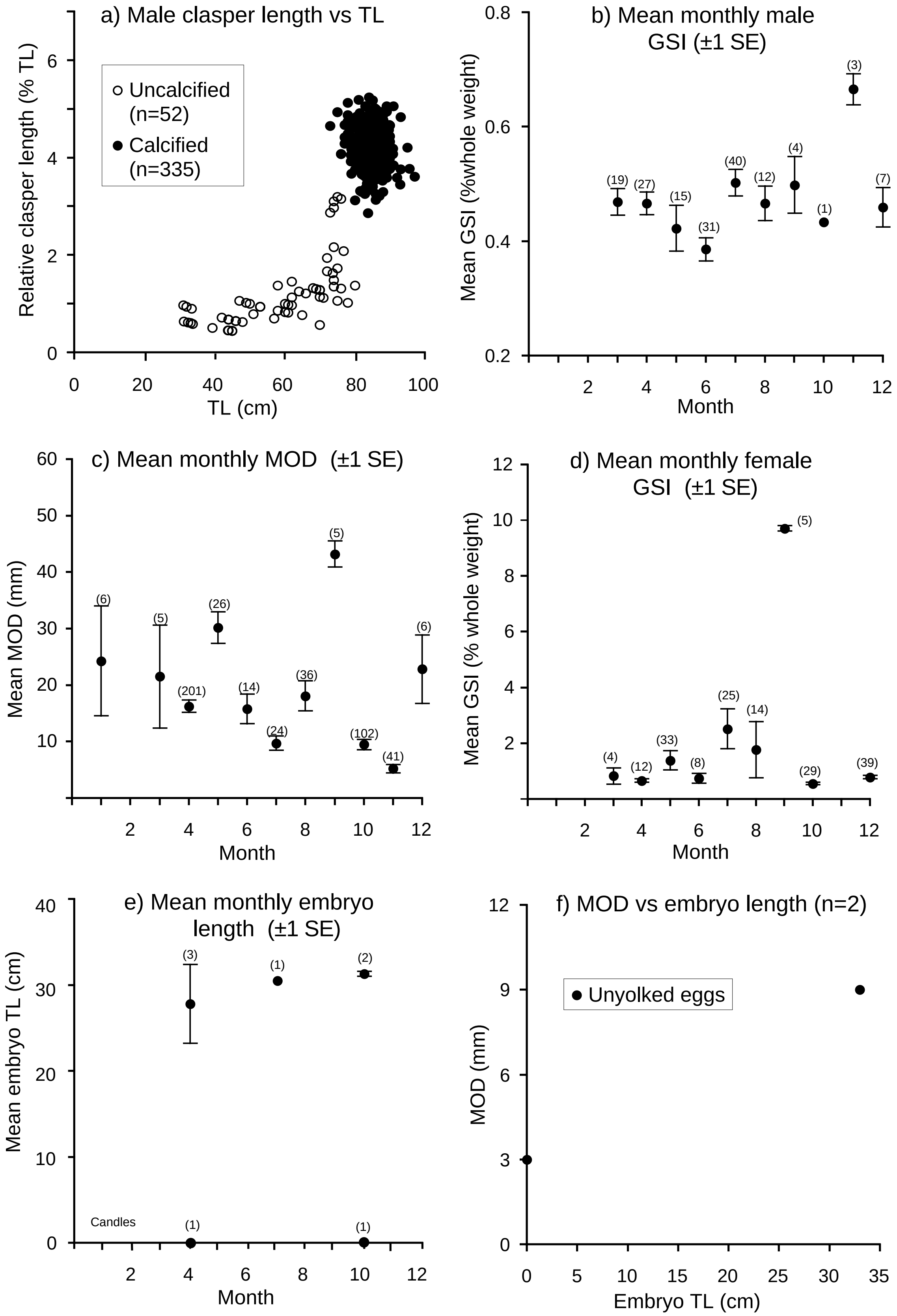


Figure 5.17: Reproductive parameters for *Deania calcea*



5.3.11. *Deania quadrispinosa*

Most data were collected during FRV 'Kapala' surveys in 1976–1997.

Distribution
This species is found around Australia, northern New Zealand and southern Africa in a depth range of 150–820 m (Last and Stevens, 1994). Locally, *D. quadrispinosa* is found around southern Australia from Moreton Island (Queensland) to Perth (Western Australia), including Tasmania; it has also been recorded off Port Headland (Western Australia). Off NSW, *D. quadrispinosa* was caught between 220 and 1040 m, with its greatest abundance in 500–800 m.

Population structure
Data summary (* codend mesh 45 & 90 mm):

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW *	1987–89	600–1000	104	30–96	128	25–112	Female 1.23:1
NSW	1996–97	500–650	112	50–92	54	50–118	Female 0.49:1

Catches off NSW comprised mainly juveniles smaller than 70 cm TL (Figure 5.18). The 1987–1989 catches included a distinct mode of mature males in the 85–100 cm size range; the 1996–1997 catches from shallower water contained very few large males, while large females were rare in all catches during both sampling periods.

Length–weight relationships

Male	Weight (g) = 0.0014 TL (cm) $^{3.2}$	(n = 76)	$R^2 = 0.99$
Female	Weight (g) = 0.0006 TL (cm) $^{3.4}$	(n = 77)	$R^2 = 0.98$

Reproduction
Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	39	52–87	43	80–101		
Male	Tas.	8	62–83	5	80–90		
Female	NSW	37	52–110	10	108–117	3	13–17
Female	Tas.	13	64–81	4	102–109	1	8

Male: Males mature at about 80–90 cm (Figure 5.19). The largest male with uncalcified claspers was 87 cm and the smallest male with calcified claspers was 80 cm.

Female: The largest immature female was 110 cm while the smallest mature female was 102 cm.

Three pregnant females (114–117 cm) were collected off Bermagui (NSW) in 2001; one contained 13 embryos 22–23 cm in length, and each of the others contained 17 candled ova in their uteri. A single pregnant female (102 cm) collected off eastern Tasmania contained eight embryos. The smallest neonate was 25 cm, similar in size to the largest embryo (23 cm), and probably close to the size at birth.

The ovaries of preovulatory females contained 17–24 developing ova with MOD between 16 and 40 mm. The pregnant females had small, undeveloped ova (MODs <10 mm) in the ovaries, consistent with a non-continuous breeding cycle. There were insufficient reproductive data to determine seasonality or gestation period.

Ageing
No samples were collected for ageing.

Diet

Stomach contents of 41 females (40–110 cm) and 57 males (40–100 cm) were examined. Dietary items were found in 74% of stomachs. Lanternfishes were present in almost all stomachs containing food (Table 5.2).

Figure 5.18: Length frequency distributions for *Deania quadrispinosa*

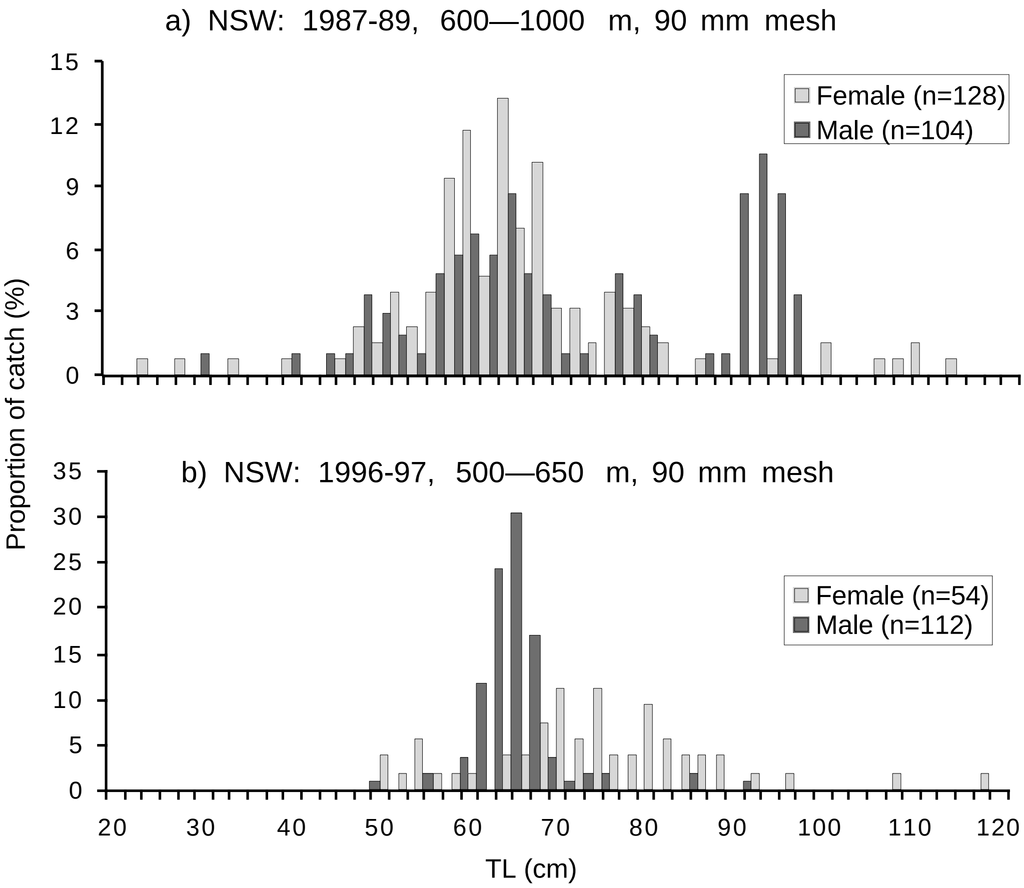
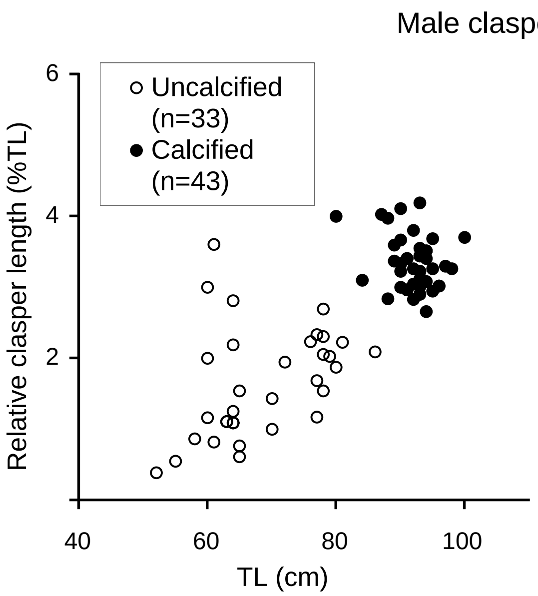


Figure 5.19: Reproductive parameter for *Deania quadrispinosa*



5.3.12. *Etmopterus granulosus*

All data were collected by CSIRO from commercial and research catches around Tasmania.

Distribution

This species is circumglobal around the southern hemisphere in depths between 220 and 1430 m (Last and Stevens, 1994). In Australian waters, *E. granulosus* is found in mid-slope depths (830–1200 m) off eastern and western Bass Strait, and around Tasmania. It appears to prefer steep ground and is reported by fishers to form large schools around pinnacles. Specimens collected during the present study were from seamounts around Tasmania.

Population structure

No length data were analysed. The specimens examined were not representative of the overall population, but were selected for reproductive studies.

The size range of males (n=286) was 31–74 cm TL, and for females (n=698) was 21–83 cm.

Length–weight relationships

Male	Weight (g) = 0.0042 TL (cm) $^{3.0}$	(n = 142)	$R^2 = 0.88$
Female	Weight (g) = 0.0024 TL (cm) $^{3.2}$	(n = 270)	$R^2 = 0.84$

Reproduction

Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	Tas.	89	31–59	197	50–74		
Female	Tas.	71	21–69	643	60–83	19	6–16, average=10

Male: Males mature from 50–60 cm. The smallest specimen with calcified claspers was 50 cm and the largest specimen with uncalcified claspers was 59 cm (Figure 5.20a); 50% of males were mature at 55 cm.

Female: The length at first maturity for females is from 60–65 cm. The smallest preovulatory female with yellow yolked eggs was 60 cm, and the smallest pregnant female was 64 cm.

Nineteen pregnant females had litters of 6–16 embryos, with an average of 10. The size at birth was 21–23 cm. The largest MOD of preovulatory females was 43 mm. The MODs of pregnant females were less than 5 mm (Figure 5.20f), and for spent females, less than 13 mm. This suggests a non-continuous female cycle. There were no trends in MOD, GSI or embryo length (Figures 5.20b–e). Pregnant females were collected in most months (Figure 5.20e) suggesting females breed throughout the year, consequently gestation period and fecundity could not be determined from the data collected.

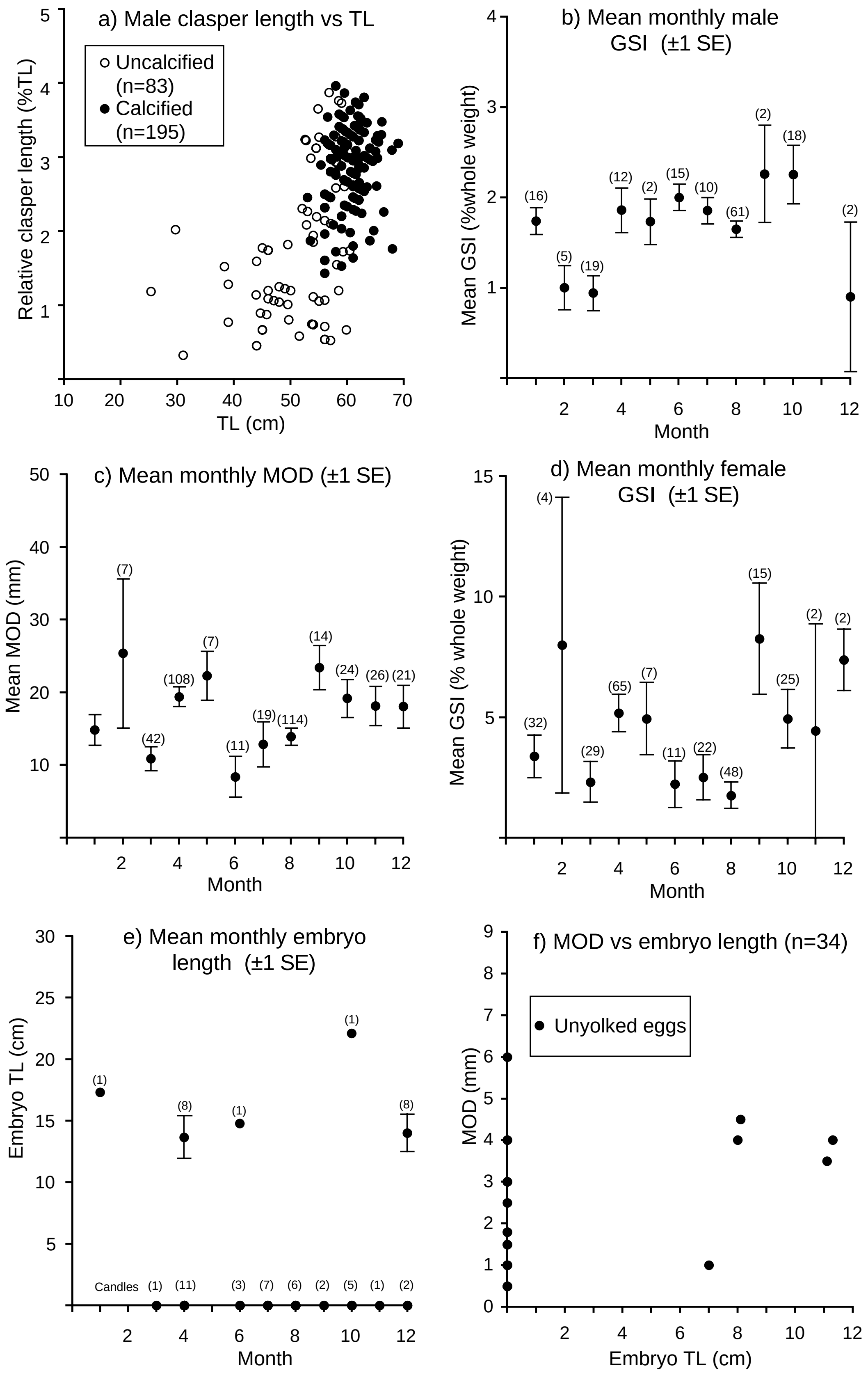
Ageing

Samples were collected from 47 females (31–79 cm) and 42 males (25–63 cm). Preliminary attempts to age specimens using x-radiography were unsuccessful.

Diet

Stomach contents of 276 females (19–85 cm) and 93 males (30–68 cm) were examined. Dietary items were found in 28% of stomachs; 11% were everted and 7% contained only unidentifiable material. Teleost fishes dominated the diet, with cephalopods also a significant component (Table 5.2). Most of the teleosts were large commercial species such as orange roughy and oreos (Oreosomatidae) caught with *E. granulosus*.

Figure 5.20: Reproductive parameters for *Etmopterus granulosus*



5.3.13 *Etmopterus* sp. B

Most data were from NSW mid-slope catches by FRV ‘Kapala’.

Distribution
Possibly endemic to southern Australia where it is found on the mid-slope (750–1380 m) from central NSW to Perth, WA, and on the southern seamounts including Pedra Branca, Cascade Plateau and South Tasman Rise (Last and Stevens, 1994). Off NSW, the species was caught from 750–1225 m, but was most abundant in depths greater than 1100 m.

Population structure
Data summary (* codend mesh 45 mm):

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
NSW	1988	800–1200	430	17–62	217	20–73	Female 0.51:1
NSW *	1989	800–1200	301	15–64	192	17–71	Female 0.67:1
Tas.	1985–87, 99	800–1200	20	41–62	25	53–79	Female 1.25:1

Catches off NSW comprised mainly mature males larger than 50 cm TL (Figure 5.21). Length data for the 1989 catch with smaller codend mesh were similar to other years, although with a slightly higher proportion of juveniles. The Tasmanian sample size was too small to show trends.

Length–weight relationships

Male	Weight (g) = 0.0014 TL (cm) $^{3.3}$	(n = 142)	$R^2 = 0.98$
Female	Weight (g) = 0.0017 TL (cm) $^{3.3}$	(n = 125)	$R^2 = 0.98$

Reproduction
Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	38	19–52	121	50–62		
Female	NSW	121	23–67	132	57–73	24	2–21, average=12

Male: The size at maturity for males was around 50 cm (Figure 5.22a). The largest male with uncalcified claspers was 52 cm and the smallest male with calcified claspers was 50 cm.

Female: Size at first maturity for females was about 60 cm but varied. The smallest pregnant female was 57 cm and the largest immature female was 67 cm.

Litter sizes ranged from 2–21 with an average of 12. The largest embryos were 18 cm and smallest neonates were 15 cm, indicating a birth-size of 15–18 cm. The MOD range was 9–38 mm. None of the pregnant females (including 34 with candled ova) contained ovaries with developing eggs, indicating a non-continuous breeding cycle.

There were insufficient data to determine seasonality, annual fecundity, or gestation period (Figures 5.22b–e).

Ageing
Samples were collected from one female (63 cm) and 10 males (54–60 cm), but they have not been assessed.

Diet

Stomach contents were examined from 140 females (27–69 cm) and 81 males (21–62 cm). Dietary items were found in 32% of stomachs (Table 5.2). Over 80% of stomachs with food contained small squids. The few teleosts found included a slickhead, a cardinal fish (*Howella* sp), and a deep-sea smelt (Bathylagidae).

Figure 5.21: Length frequency distributions for Etmopterus sp. B

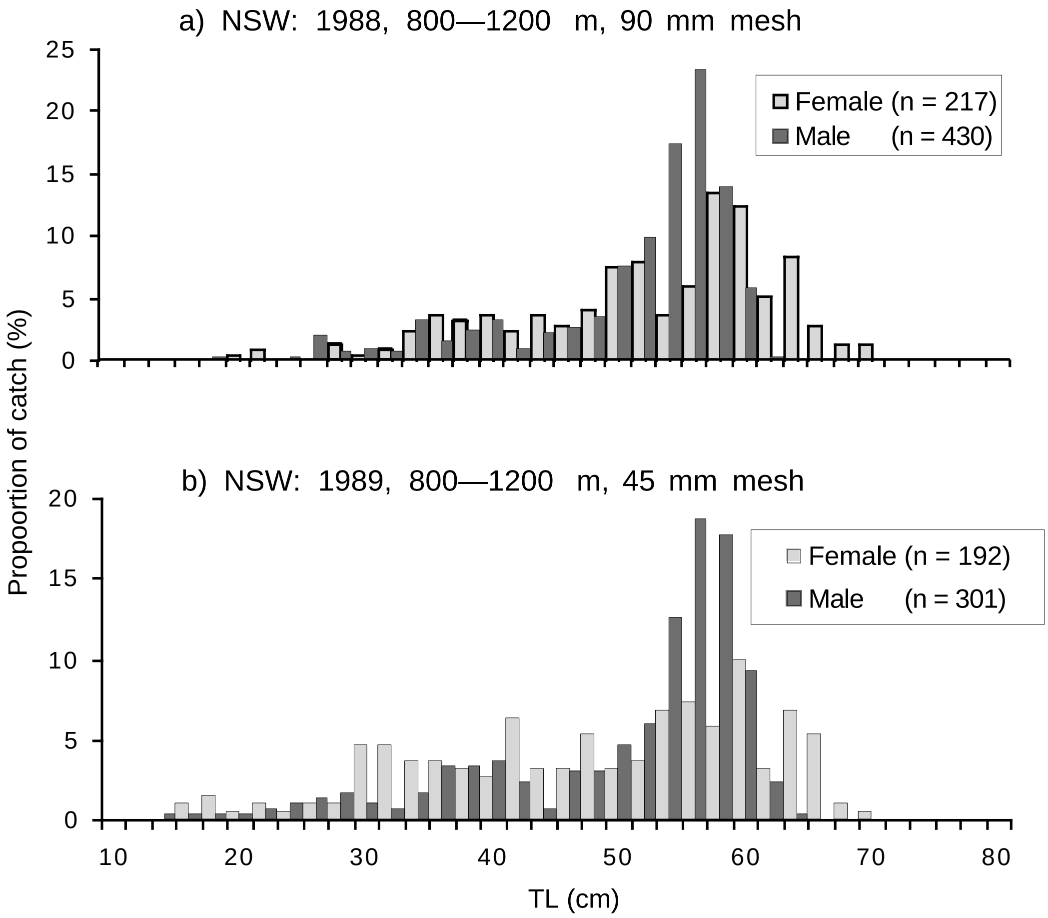
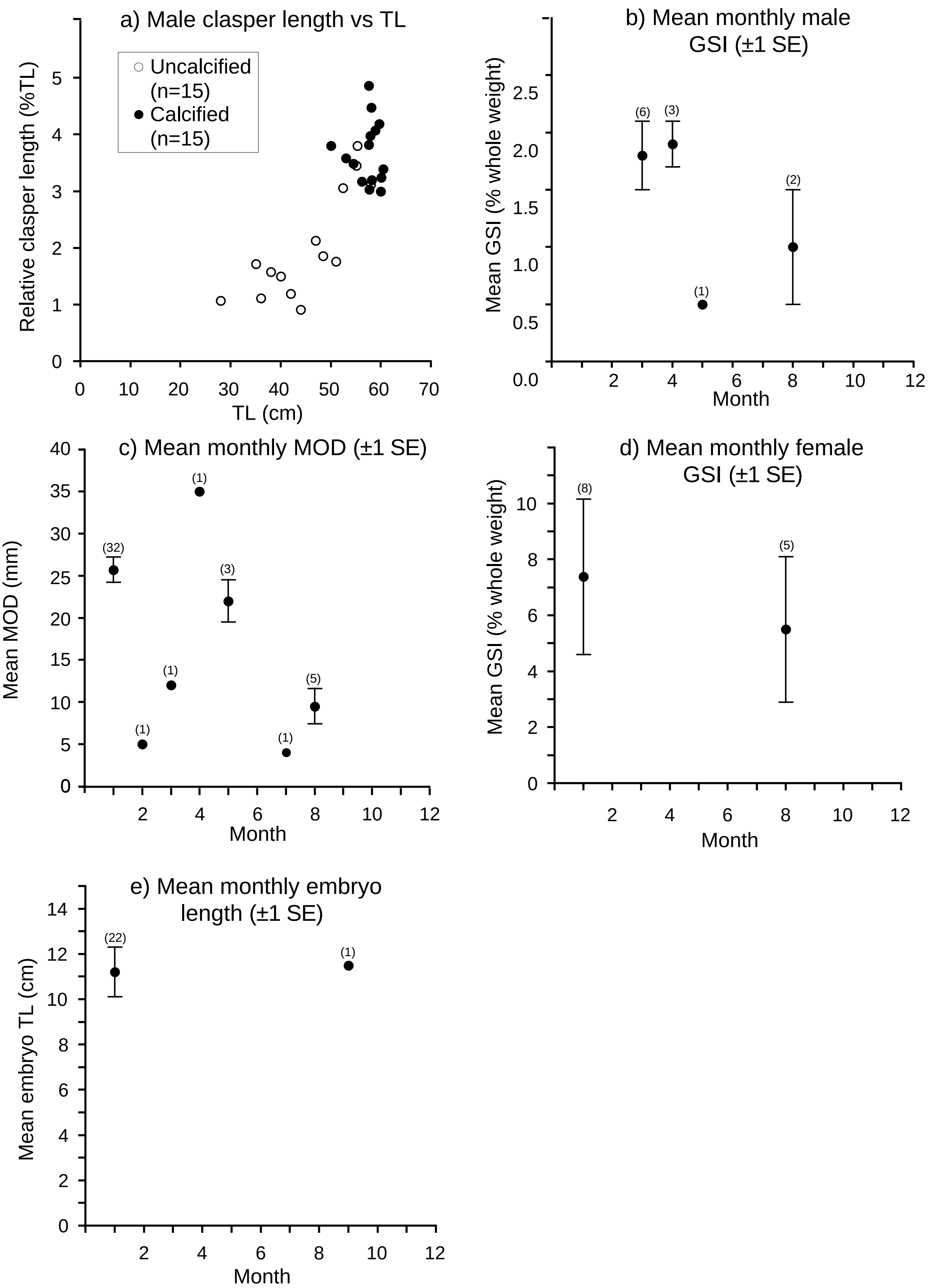


Figure 5.22: Reproductive parameters for *Etmopterus* sp. B



5.3.14. *Squalus mitsukurii*

Off NSW, the distributions of *S. mitsukurii* and the similar *Squalus* sp. F (Last and Stevens, 1994) overlap, and historical data for 'greeneye dogfish' was a mixture of both species. Data presented here for *Squalus mitsukurii* only are from NSW slope catches by FRV 'Kapala', and from recent experimental catches off Portland (FRDC Study 98/204).

Distribution

This species is thought to be widely distributed in temperate and subtropical oceans. However, the taxonomy of this species is not fully resolved. It seems likely that *Squalus mitsukurii* consists of more than one species and the Australian form is possibly endemic (P. Last, CSIRO Marine Research, personal communication). In Australia, the nominal *S. mitsukurii* occurs around southern Australia south of 20ºS in the depth range of 180–600 m (Last and Stevens, 1994). Data for this study were mainly from catches in 220–750 m off NSW, and in 350–550 m off Portland.

Population structure

Data summary:

			Male TL (cm)		Female TL (cm)		
Area	Period	Depth (m)	n	Range	n	Range	Sex ratio
W. Vic.	2000–01	350–550	79	58–81	49	55–88	Female 0.62:1

The Portland data reflect the present population structure off western Victoria. Males dominated the Portland catches, and most males and females were adult-sized (Figure 5.23). The maximum size of males was 81 cm and for females 93 cm.

Length–weight relationships

Male	Weight (g) = 0.0284 TL (cm) $^{2.6}$	(n = 54)	R^2 = 0.87
Female	Weight (g) = 0.0006 TL (cm) $^{3.5}$	(n = 74)	R^2 = 0.93

Reproduction

Data summary:

		Immature TL (cm)		Mature TL (cm)		Litter size	
	Area	n	Range	n	Range	n	Range
Male	NSW	6	55–67	18	70–78		
Male	W. Vic.	3	60–62	66	63–81		
Female	NSW	23	54–80	19	80–93	6	4–10, average=7
Female	W. Vic.	42	56–82	22	80–91	1	9

Male: The size at maturity for males was around 65cm (Figure 5.24). The largest male with uncalcified claspers was 67 cm and the smallest male with calcified claspers was 63 cm.

Female: Size at first maturity for females was about 80 cm. The smallest pregnant female was 80 cm and the largest immature female was 82 cm.

Litter sizes of seven females ranged from 4–10 pups with an average of seven. No neonates were caught, but the length of full-term embryos was about 25 cm.

The ovaries of pregnant females contained developing (yellow-yolked) ova. The MODs (15–45 mm) increased with embryo length (Figure 5.24d) indicating a continuous reproduction cycle. However, the data was insufficient to determine reproductive seasonality, annual fecundity or gestation period (Figures 5.24b–c).

Ageing

No ageing samples were collected.

Diet

Stomach contents were examined from 23 females (52–96 cm) and 12 males (25–96 cm). Food items were found in 63% of stomachs. The diet comprised a mixture of demersal teleosts, squids and crustaceans (Table 5.2).

Figure 5.23: Length frequency distribution for *Squalus mitsukurii*

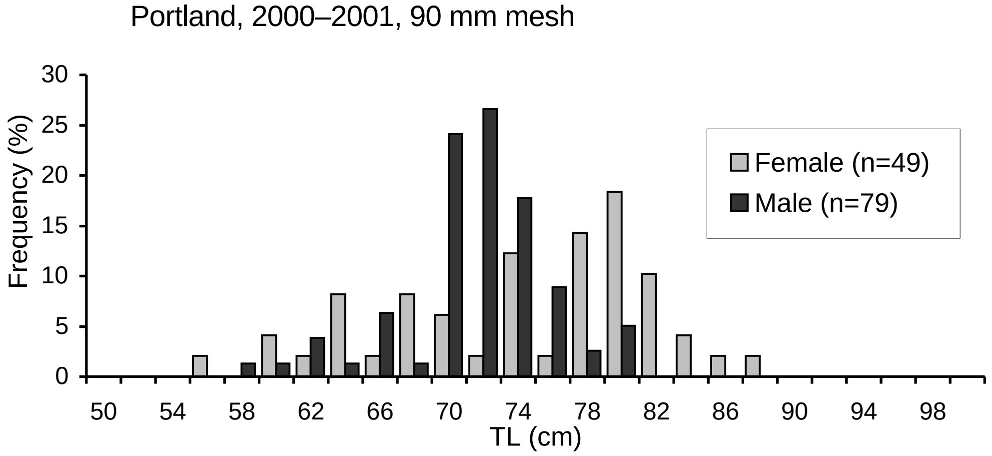
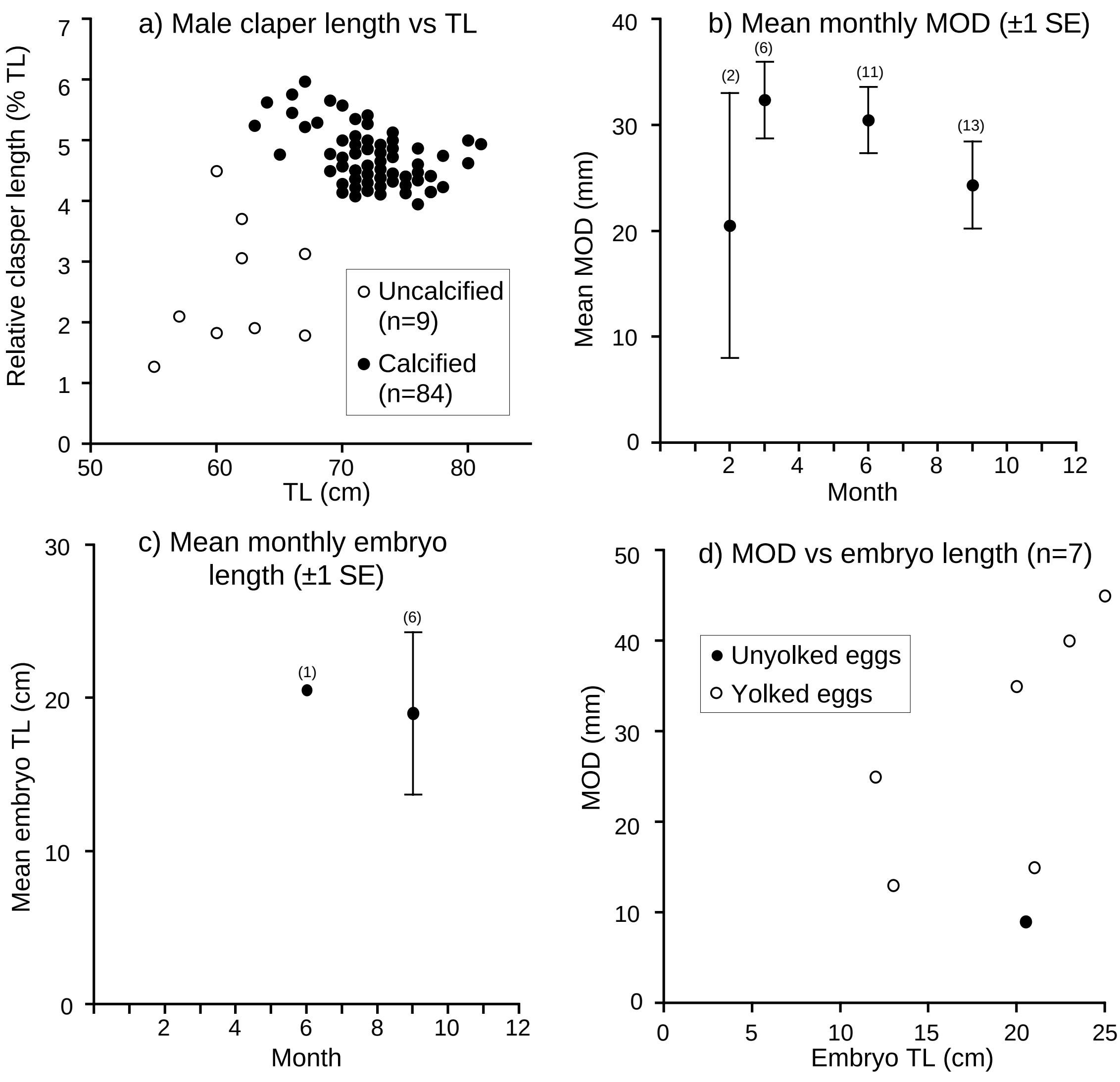


Figure 5.24: Reproductive parameters for *Squalus mitsukurii*



5.4 Discussion of deepwater dogfish biology

The taxonomy of many species of dogfish is uncertain, particularly within the genera *Squalus* and *Centrophorus*. It is possible that the distributions of several of the species discussed here are more restricted than reported in the literature and are in fact endemic to the region. Very limited distributions make them susceptible to over-exploitation. In particular, upper-slope dogfishes such as *Squalus* spp and *Centrophorus* spp are vulnerable as they are fished throughout their principal depth and geographic range. *Centrophorus harrissoni* stands out as especially vulnerable to fishing due to a combination of its limited geographic distribution and biology. This species is now recognised as endemic to SE Australia and is listed as Endangered by the Australian Society for Fish Biology (ASFB) (Hall, 2001). Similarly, *C. uyato* is currently listed as Vulnerable by the ASFB. Further study of Australian *Centrophorus* spp and *Squalus* spp is required to determine the precise taxonomic status of each species. Should *C. uyato* and *S. mitsukurii* also be found to comprise species complexes of which the local forms are endemic, there would be a strong case to review their listing.

The bathymetric distributions of mid-slope dogfishes may make some less vulnerable to fishing than the upper-slope species. Their depth distributions often extend deeper than current commercial fishing, so that deeper waters may provide a refuge. Within species, segregation by size, sex or reproductive state has been reported for several species of deepwater species. Examples are *Centroscymnus owstoni* (Yano and Tanaka, 1988), *C. coelolepis* (Girard and Dü Buit, 1999), and *Etmopterus granulosus* (Wetherbee, 2000). The most notable example shown by this study was *Deania calcea*, which is the principal mid-slope species targeted by trawlers. Despite the high abundance of mature females in catches, preovulatory or pregnant *Deania calcea* were almost totally absent suggesting spatial segregation of the breeding females. The segregation of pregnant *Deania calcea* simply by depth appears unlikely, as almost the full depth range of this species was well sampled.

Most length-frequency data used to describe the population structures were derived from historical sampling off NSW and Tasmania by NSW Fisheries and CSIRO. There is now strong evidence that the deepwater fisheries that have developed around southern Australia have substantially reduced a number of dogfish stocks (Sections 2–3). This is particularly so for upper-slope species off NSW (Andrew *et al*., 1997, Graham *et al*., 2001), and probably so for species in other areas around SE Australia. Length-frequency data collected by Kapala in the 1970s and 1980s represent the size structure of the NSW dogfish populations before there was any appreciable impact on the stocks by trawling (Graham *et al*., 1997). Similarly, data on mid-slope species around Tasmania collected by CSIRO in the 1980s were from lightly fished stocks. The importance of this base-line information is now being realized as stocks of several species, in particular *Centrophorus* spp, have become so depleted that comparable data cannot now be collected.

Several mid-slope species were sampled off both NSW and Tasmania, and the size data showed notable differences. Some of these differences reflect geographical or depth segregation of size classes. However, codend mesh size also had an influence. For example, the length data for *Deania calcea* (Figure 5.16a–b) shows a high proportion of juveniles in catches in codends with 45 mm mesh, a smaller proportion in the 90 mm mesh codends, and almost no juveniles in the catches taken around Tasmania with 110 mm mesh codends. This pattern for catches of juveniles is similar in the data for *Centroscymnus coelolepis*, *C. crepidater* and *C. owstoni*; although for these species few adults were caught off NSW (Figures 5.8, 5.10, 5.12). It is possible that adults were absent from the NSW grounds. Alternatively, it is possible that the large *Centroscymnus* avoided the relatively low-opening Kapala trawl nets, but were more readily captured in the high-opening trawl nets used around Tasmania. However, despite the apparent selection of small juveniles through the 110 mm codend mesh, sub-adult and adult sizes of all species were vulnerable to the trawls and were retained in codends of all mesh sizes. For some upper-slope species of *Centrophorus*, the large size at birth makes even neonates vulnerable to capture.

Geographic differences in the distributions of adults and juveniles of deepwater dogfishes have been highlighted off Ireland (Clarke *et al*., 2002b). It is likely that mid-slope dogfishes undertake migrations (Clarke, 2002b; Wetherbee, 2000; Clarke and King, 1989). It has been suggested that these migrations are extensive and are associated with reproduction (Clarke and King, 1989). In the present study, large aggregations of *Etmopterus* were taken over seamounts. Yano and Tanaka (1986) successfully tagged and acoustically tracked deepwater dogfishes; therefore mark and recapture studies to examine movements may be possible. However, tag return rates would probably be very low.

The life-history strategy of sharks with generally slow growth, late age at maturity, low fecundity and natural mortality predispose them to rapid stock depletion. The dogfishes appear to be at the lower end of the shark productivity spectrum. Radiometric analysis of *Centrophorus uyato* specimens 59–81 cm TL provided tentative age estimates from 25–46 years (Fenton, 2001). Unvalidated age estimates for *Deania calcea* range from 11 to 35 (Clarke *et al*., 2002b). Unvalidated estimates suggest *Centroscymnus crepidater* may grow to 54 years (Sarah Irvine CSIRO Marine Research, unpublished data). An *Etmopterus granulosus* female (62 cm) had 19 bands in the dorsal spine (Irvine, 2000). The deepwater dogfishes examined in this study reached maturity close to their maximum size and other studies have found that sexual maturity of deepwater dogfishes is not reached until growth ceases (Clarke *et al*., 2002b).

The upper-slope genera (*Centrophorus* and *Squalus*) exhibited a continuous reproductive cycle with parturition closely followed by fertilisation and pregnancy. However, litter numbers were only 1 or 2 for *Centrophorus*, and up to 10 in *Squalus*. Mid-slope genera (*Centroscyllium*, *Centroscymnus*, *Deania* and *Etmopterus*) have relatively large litters (up to 22 in *Centroscyllium kamoharai*) but their reproductive cycles are discontinuous with a resting period between pregnancies. It is likely that most, if not all, deepwater dogfishes have a breeding cycle longer than one year. For some species it may exceed 22 months (Clarke *et al.*, 2002b). Clarke and King (1989) suggested a resting period of 4 years in *Deania calcea*, limiting the **lifetime** fecundity of this species to 34 pups (Clarke *et al*., 2002b). There was no evidence that breeding is linked to the seasons and for some species pregnant females were collected in most months. Previous studies have found neither sex displays seasonal patterns associated with breeding in *Centroscymnus coelolepis* or *C. owstoni* (Yano and Tanaka, 1987).

Diets varied among the species but some groupings were apparent. *Centrophorus harrissoni*, *Deania calcea* and *D. quadrispinosa* fed almost exclusively on small mesopelagic animals, principally lanternfishes and lesser quantities of squids. Lanternfishes were also common in the diets of *C. moluccensis* and *C. uyato,* but demersal teleosts, cephalopods and crustaceans were more important. These species have relatively long snouts, which may assist in the location or mesopelagic prey. In contrast, *Centroscymnus coelolepis, C. plunketi*, *Dalatias licha*, *Etmopterus granulosus* and Squalus mitsukurii preyed mostly on larger demersal teleosts and cephalopods, while the diets of *Centroscymnus owstoni* and *Etmopterus* sp. B comprised mainly squids.

8. BENEFITS

Declines in upper-slope dogfish have been highlighted so that Environment Australia and AFMA can implement informed management responses to aid their recovery. Catches of mid-slope species are increasing and need to be carefully monitored. Improvements to commercial logbook data quality were achieved through the design and production of dogfish identification sheets.

9. FURTHER DEVELOPMENT

Findings were presented to managers and industry at Southern Shark Management Advisory Committee meeting (Melbourne**,** 13 June 2000), the SET Fishery Assessment Group meeting (Canberra, 20 June 2000) and the ISMP observer workshop (26 June 2002).

Results were discussed at The Australian Society for Fish Biology annual conference (Albury, August, 2000).

10. CONCLUSION

Fishery-based estimates of the retained dogfish catch are in the order of 1500 t live weight. This catch is higher than any single shark species in Australia except for gummy shark. The marketed catch at Melbourne and Sydney wholesale markets represents approximately 800 t (live weight). The value of the catch is estimated from market figures to be $1.5 million. The discarded proportion of the catch could not be calculated because there is almost no reporting of discards. Most discarded dogfish are dead when returned to the water from trawlers.

Dogfishes taken on the upper-slope (200–650 m) and mid-slope (650–1200 m) differ in their distribution, biology, vulnerability to capture and historic exploitation levels. These groups need to be managed separately.

Commercial fishery, market and research data suggest upper-slope dogfish, particularly *Centrophorus*, have declined off NSW, Victoria and South Australia. Catches in the SSF and SET fisheries in particular have fallen in recent years. Previous research surveys have documented declines of 99.5% in abundance of *Centrophorus* spp off southern NSW (Graham *et al*., 1997). Declines in catches are correlated with significant declines in sales of *Centrophorus* and *Squalus* spp at Sydney Wholesale Fish Markets. Wholesalers reported reduced availability of *Centrophorus* spp livers for processing. Although these sharks were targeted, much of the catch was wasted because of mercury regulations that prevented landing of carcasses in Victoria. Fishery management responses for these species are unlikely to be effective, as numbers are now too low to be fished commercially. Other measures such as endangered species listing and/or closed areas may be required. The introduction of such measures would require better understanding of taxonomy, critical habitat, biology and movements.

Fishery and market information suggests abundance of key commercial mid-slope dogfish, particularly *Deania* and *Ce*ntroscymnus spp, are currently stable. These sharks are caught primarily in the SET where catches and catch rates for dogfish are increasing in mid-slope waters. This increase is correlated with increased carcass sales at Melbourne Fish Market. The introduction of ITQs for key commercial species in the SET has resulted in increased targeting of non-quota species, including *Deania* and *Centroscymnus* spp. Commonwealth bycatch action plans require that emerging fisheries be managed as new markets develop. Annual dogfish catches exceed some quota species in the SET and management responses need to be considered by AFMA.

A number of factors suggest that depleted dogfish stocks will be slow to recover. *Centrophorus* appear to be the most vulnerable to over-fishing. These species have the lowest litter sizes of all dogfish and are fished throughout their vertical distribution. Some species appear to have localised distributions and heavy fishing in one area alone could result in extinction. Mid-slope species probably breed less than once per year although they have larger litter sizes and their deeper bathymetric distribution probably affords them some protection from fishing.

Commonwealth Guidelines for Ecologically Sustainable Development require that management regimes be capable of assessing, monitoring, avoiding, remedying or mitigating any adverse impacts. Bycatch Action Plans require reliable data for byproduct as well as bycatch species. Discarded dogfish catches were largely unreported. Data for retained catch was not reliably identified and there was confusion over the method of recording weight. Some improvements were achieved in data collection during the project through the development of a Field Guide to Australian Sharks and Rays and identification sheets targeted at specific fisheries.

Commonwealth managed fisheries are in the process of strategic assessment of ecological sustainability, a requirement under the Environment Protection and Biodiversity conservation (EPBC) Act. Guidelines for ecologically sustainable management of fisheries require compliance with threat abatement plans and recovery plans. If species of *Centrophorus* are listed under the EPBC Act, their recovery plans would list key threatening process, which would almost certainly include some fishing activities. The South East Trawl and the Southern Shark Fishery would need to comply with such plans.

11. ACKNOWLEDGEMENTS

Sarah Irvine (Deakin University) provided age estimates and helped with dissections. Rory McAuley and Colin Simpfendorfer (W.A. Marine Research Laboratories) also assisted with ageing. Nick Baxter dissected hundreds of specimens and provided reproductive and feeding data.Some catch data were provided by the Department of Primary Industry, Water and Energy (Tasmania). Mick Baron and Anthony de Frie provided AFMA observer data.

We thank the following staff from CSIRO Marine Research, Hobart, for technical advice and assistance: Cathy Bulman, Stephanie Davenport, Alastair Graham, Mark Green, Peter Nichols, Andre Punt, Spikey Riddoch, Janet Slater, Sally Wayte, Grant West and Alan Williams.

The following industry members assisted with specimen collection and industry surveys: Nick Albers, (FV 'Starfire'), Alan Bates (FV 'Petuna Explorer'), Jeremy Bearman (FV 'Corvina'), Tom Bibby (FV 'Megisti Star'), Gerard Bourke (FV 'Cape Hood), Tony Campisi (NSW Dropline Fishery), Brian Cooksley (FV 'Adriatic Pearl'), Andrew Hogg, (FV 'Moira Elizabeth'), Brendan Kelleher (FV 'Adriatic Pearl'), Bill Kyle (FV 'Saxon Progress'), Ben and Malcolm McLouglin (ConsolFish) and Zane Yusada (Deep Sea Oils Ltd.). Particular thanks go to Russel Bradshaw, Brian Cooksley, David Guillotte, Ashley Goodwin and the crews of the FV 'Empress Pearl' and FV 'Saxon Progress' for their help with sampling at sea.

We also thank the following people for their contributions and comments:
Nick Baxter (AMC), Stephanie Kalish (AFMA), Ian Knuckey (MAFRI), Jeremy Lyle (DPIWE), Paul McCoy (ISMP), Hamish Malcolm (CSIRO), Jeff Nemmick, (ISMP), Jeremy Prince (Buisisness name), Kevin Rowling (NSW Fisheries), Ken Smith (ISMP), Hein Sturmann, (AFMA), Bruce Taylor (MAFRI) and Raeleen Thomas (Underwater World, Mooloolabah).

Thanks to FRDC staff for their ongoing support, input and advice.

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APPENDIX A: INTELLECTUAL PROPERTY

There was no intellectual property of commercial value developed during the project.

APPENDIX B: STAFF

John Stevens,	CSIRO Marine Research
Ross Daley,	CSIRO Marine Research
Ken Graham,	NSW Fisheries
Terence Walker	MAFRI
Russell Hudson	MAFRI
Bruce Taylor	MAFRI
Colin Simpfendorfer	WA Fisheries

APPENDIX C: QUESTIONNAIRE FORM

DATE	
CONTACT	
SKIPPERS NAME	
VESSEL NAME	
ADDRESS	
PHONE	
HOME PORT	
FISHING AREAS	
DEPTH	
NUMBER OF BOATS FISHING IN THE AREA	
SEASON	
TARGET SPECIES	
GEAR	
TOW/SOAK TIME	
TYPES OF SHARKS CAUGHT	
TYPES OF SHARKS RETAINED	
SIZE OF SHARKS	
UTILISATION	
CHANGES IN UTILISATION AND REASONS	
CATCH SIZE	
CHANGES IN CATCH SIZE OVER TIME	
METHOD OF RECORDING CATCH WEIGHT	
CHANGES IN CATCH RECORDING PRACTICES	
CONTACTS	
REMARKS	

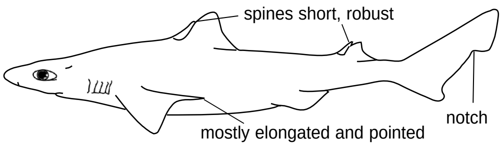
APPENDIX D: DOGFISH IDENTIFICATION SHEET

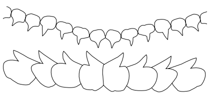
Common deepwater dogfish sharks of Australia

Endeavour dogfishes 37 020902

Centrophorus harrissoni, C. moluccensis, C. uyato

Other names: dumb shark, endeavour dogshark, gulper shark, Harrison's dogfish, southern dogfish, toughskin dogfish





upper teeth broad at bases but mostly with narrow pointed tips; lower teeth interlocking to form a slicing edge

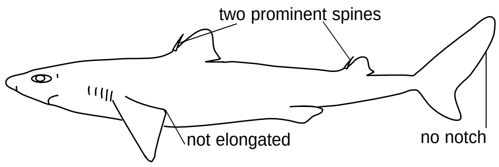
Size: up to 110 cm, typically 60–80 cm

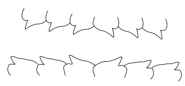
Distribution: eastern, southern and western Australia; 50–1400 m, mainly 300–650 m

Greeneye dogfishes 37 020901

Squalus spp

Other names: dogfish, dogshark, grey spiny dogfish, piked spurdog, spikey dogfish, spurdog





teeth overlapping to form sharp cutting edges, similar in both jaws

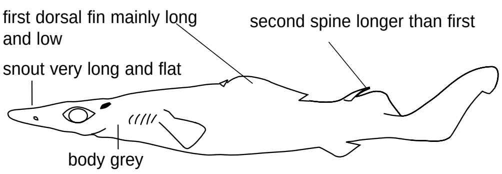
Size: up to 100 cm

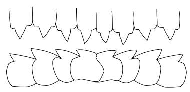
Distribution: most Australian waters; down to 600 m

Platypus sharks 37 020905

Deania calcea, D. quadrispinosa

Other names: birdbeak dogfish, brier dogshark, longsnout dogfish, pearl shark





upper teeth dagger shaped with single points; lower teeth mostly interlocking to form a slicing edge (pointed in some adult males)

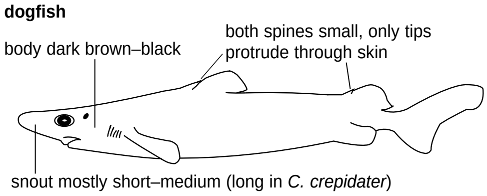
Size: up to 115 cm, typically 65–85 cm

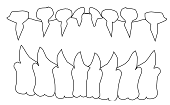
Distribution: eastern, southern and western Australia; 70–1450 m, mainly 400–900 m

Smallspine dogfishes 37 020906

Centroscymnus crepidater, C. plunketi, C. coelolepis, C. owstoni

Other names: black shark, golden dogfish, longnose velvet dogfish, Owston's dogfish, Plunket's dogfish, Portugese dogfish





upper teeth slender;
lower teeth forming a slicing edge

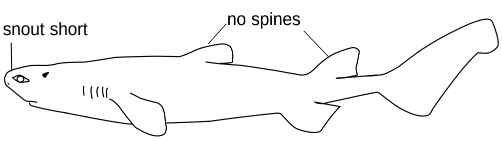
Size: up to 170 cm

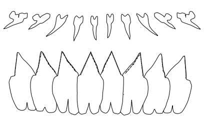
Distribution: eastern, southern and western Australia; 240–1550 m, mainly deeper than 600 m

Black shark 37 020002

Dalatias licha

Other names: kitefin shark, seal shark





upper teeth small, narrow and pointed, bases not touching; lower teeth larger, triangular, with fine serrations; lips fleshy

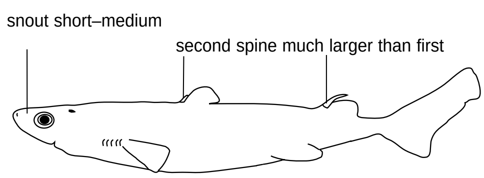
Size: up to 160 cm

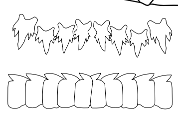
Distribution: eastern, southern and western Australia; 40–1800 m, mainly 450–850 m

Lantern sharks 37 020907

Etmopterus spp

Other names: black shark, lucifer shark, seal shark





upper teeth multi-pointed;
lower teeth interlocking to form a slicing edge

Size: up to 70 cm

Distribution: most Australian waters; 180–1800 m

APPENDIX E: CSIRO RESEARCH VESSEL DATA EXAMINED

Cruise	Vessels	Principal regions (Figure 3.1)	No. shots examined
Upper-slope			
1984 – 2	FRV 'Soela'	E. Tas.	7
1984 – 3	FRV 'Soela'	E. Tas.	9
1984 – 4	FRV 'Soela'	E. Tas.	7
1984 – 5	FRV 'Soela'	E. Tas.	7
1984 – 6	FRV 'Soela'	E. Tas.	7
1985 – 1	FRV 'Soela'	E. Tas.	8
1985 – 3	FRV 'Soela'	E. Tas.	9
1993 – 5	FRV 'Southern Surveyor'	E. Vic., E. Tas.	7
1994 – 5	FRV 'Southern Surveyor'	E. Tas.	5
			66
Mid-slope			
1986 – 3	FRV 'Soela'	W. Tas.	4
1986 – 4	FRV 'Soela'	E. Tas.	1
1988 – 1	FRV 'Soela'	W. Vic, SA	78
1988 – 2	FRV 'Soela'	E. Tas., W. Tas., W. Bass St., W. Vic.,	74
1988 – 3	FRV 'Soela'	NSW, E. Bass St., E. Vic.,	46
1988 – 4	FRV 'Soela'	E. Tas.	6
1989 – 1	FRV 'Soela'	SA	71
1989 – 2	FRV 'Soela'	W. Tas, W. Bass St., W. Vic., SA	84
1989 – 3	FRV 'Soela'	E. Bass St., E. Tas.	25
1990 – 1	Commercial vessel charter	E. Tas.	19
1990 – 2	FV 'Megisti Star'	E. Tas.	7
1991 – 2	FRV 'Southern Surveyor'	E. Bass St., E. Tas., Southern zone	18
1992 – 1	FRV 'Southern Surveyor' Commercial vessel charter	Southern zone	33
1992 – 2	FRV 'Southern Surveyor'	E. Tas.	4
1992 – 3	Commercial vessel charter	Southern zone	1
1992 – 4	Commercial vessel charter	Southern zone	1
1993 – 3	FRV 'Southern Surveyor'	Southern zone	8
1994 1	FRV 'Southern Surveyor' Commercial vessel charter	Southern zone	73
1996 – 4	Commercial vessel charter	E. Tas., Southern zone	44
			587