WESTERN BASS STRAIT TRAWL FISHERY ASSESSMENT PROGRAM

Final Report to the Fisheries Research and Development Corporation
Project 86/39

David Smith, Dorothea Huber, Jodie Woolcock, Anne Withell and Steve Williams

December 1995

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

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SUMMARY

The Western Bass Strait Trawl Fishery Assessment Program was the first extensive study of the demersal trawl fishery in western Bass Strait. The study provided biological and fishery information on 11 commercially important species. All data presented here have been used extensively in the assessment of South East Fishery, primarily as reports to the Demersal and Pelagic Fisheries Research Group and Orange Roughy Workshops. This study has also provided the baseline data for subsequent assessment of the fishery through the South East Fishery Assessment Group (SEFAG).

The trawl fishery in western Bass Strait expanded rapidly during the 1980s mostly in response to the discovery of substantial orange roughy aggregations in 1986/87. Landings in main ports reached 10,000 tonnes by the late 1980s with over 3000 tonnes taken from the study area. Apart from orange roughy, blue grenadier was the major species. The catch of blue grenadier increased from about 400 tonnes (partial weight) in the mid 1980s to over 700 tonnes (partial weight) by the early 1990s. Blue and spotted warehou, were the other major species in terms of weight. The annual catches of king dory and ling increased between 1986 and 1993, whereas those of gemfish and jackass morwong declined. The catch of ocean perch, and silver and mirror dory was low, less than 20 tonnes in all years.

The study combined a stratified random trawl survey in depths from 100 to 1200 m with extensive sampling of commercial landings. The trawl survey of western Bass Strait was conducted between 1987 and 1989 was undertaken on generally smooth trawlable ground. Orange roughy, blue grenadier and warty oreo were consistently the dominant species. Biomass estimates for ling, ocean perch and gemfish were low in all surveys. Spotted warehou abundance was distinctly seasonal being relatively high only during winter. Survey catches of blue warehou were particularly low and the biomass estimates for this species were unreliable. Biomass estimates for king dory and spiky oreo varied between surveys but they were moderately abundant. The study species contributed substantially to the total demersal fish biomass in western Bass Strait.

No orange roughy aggregations were encountered during the survey and catch rates reflected this. Seasonal biomass indices ranged from 3111 to 7642 tonnes. The length frequency distributions of orange roughy taken during surveys were bimodal with a dominant mode (of juveniles) between 15-30cm SL and a mode of adult fish between 30-40 cm. For commercial landings, distributions were unimodal (30-40 cm SL) comprising adult fish. Females were relatively more abundant in the larger size classes. GSIs peaked during winter and there was evidence of spawning in the study area. Orange roughy are extremely long-lived with a maximum age in excess of 100 years.

Blue grenadier contributed the largest mean component of the commercially exploited resource in western Bass Strait. For the main depth strata, biomass indices were significantly lower during winter (3830 tonnes) than the other seasons (10847-11623

tonnes). Blue grenadier in both survey and commercial catches from western Bass Strait were distinctly different from those reported for spawning fish. Most fish were between 40 and 90 cm SL with few fish greater than 100 cm. During winter surveys there was a lower number of large, old fish and this together with the reduced winter biomass is consistent with a movement of these fish out of the area to spawn. Growth was described by the von Bertalanffy growth curve with females growing faster and to a larger size than males. Z, the instantaneous coefficient of total mortality was 0.42-0.46 for commercial catches and 0.36 for survey catches. There were indications of variable year-class strength. While fishing mortality was relatively low at 0.08, the fishery is based on 4-5 age classes of juveniles and sub-adults. which indicates the fishery is susceptible to population fluctuations.

Biomass indices for gemfish were low in all seasons. During autumn, female gonads showed some development but there were no indications of spawning gemfish in western Bass Strait. Very small gemfish (around 10 cm LCF) were caught off South Australia and the growth of juveniles was similar to that of east coast fish but appeared to be six months out of phase. Results indicate that gemfish in this area are a separate stock (now called western gemfish). This has been confirmed by electrophoretic analyses. Fishing mortality was equivalent to natural mortality (0.2) and results indicated that, during the study period, the fishery was at sustainable levels.

The trawl fishery for blue and spotted warehou is distinctly seasonal taking spawning fish during winter and early spring. The size at maturity for both species was about 40 cm LCF. Assigned ages for adults have yet to be validated but both species are short lived with relatively high natural mortalities. Trawl surveys of the type conducted here are not appropriate for blue warehou as biomass estimates were low in all surveys; less or equivalent to commercial landings.

Jackass morwong was not a major species in depths surveyed and commercial landings were relatively low. Size distributions were generally similar to those reported for the east coast but samples from jackass morwong landed at Beachport comprised more large fish. Spawning occurs during summer, earlier than that reported for east coast (late summer to autumn). Growth was similar to that reported for NSW and Victoria.

Ling are widely distributed in western Bass Strait and occur over a wide depth range (100-900 m depth strata). The abundance of ling was low with biomass indices ranging from 848 tonnes in autumn to 1229 in summer. Ling spawn during winter/spring. There was a weak size depth relationship for ling with smaller fish more abundant in the shallower depths. Commercial catches were low (from 50-70 tonnes per annum during the survey period). Ling is primarily a by-catch species in western Bass Strait.

Ocean perch taken in western Bass Strait were similar to the deepwater form described for waters off NSW. They were widely distributed over similar depth range to ling but were less abundant. Biomass indices ranged from 513 tonnes in winter to 972 tonnes in summer. There was a distinct depth size relationship with smaller fish more abundant in the shallower depth strata. Commercial catches were low averaging about 10 tonnes.

King dory were taken in depths from 270 to 945 m but was most abundant in the 400 to 700 m depth strata. It was the most abundant of the commercial dory species. Biomass indices ranged from 567 tonnes in winter to 2869 and 2778 tonnes in summer and autumn, respectively. The latter coincide with the spawning period which is protracted from January to May. The length at maturity for females occurred between 35-40 cm TL Small fish were more abundant in depths less than 500 m. Landings were about 30 tonnes per annum suggesting exploitation rates were low.

Two oreo species were common in the study area, warty and spiky oreo. Warty oreo was the next most abundant species after blue grenadier and orange roughy. It occurred over a similar depth range to orange roughy (800-1200 m). Spiky oreo were most abundant at intermediate depths (600-800 m). Warty oreo size distributions were typically bimodal, with distinct juvenile/subadult and adult modes. A similar pattern was evident for spiky oreo, though in the case of females the mode of large individuals included sub-adult and adult fish. In both species females attained larger sizes than males. Warty oreo is a late autumn/early winter spawner, spawning in May/June whereas spiky oreo spawn during late winter/early spring, in August - October. The size at which 50% of females were mature was estimated at 28 and 35 cm total length for warty and spiky oreo, respectively. There was some evidence of size structuring with depth for warty oreo, with adults becoming more abundant with increasing depth. Commercial catches of both species were low, ranging from 1 - 134 tonnes per annum between 1986 and 1993.

Overall, the study demonstrated that the demersal trawl resource in western Bass Strait is limited. There was potential for a small increase in the catch of blue grenadier (which was realised by an almost 80% increase in catch by the early 1990s). However, apart from blue grenadier, orange roughy and possibly spotted warehou, large increases in total catch could not be expected.

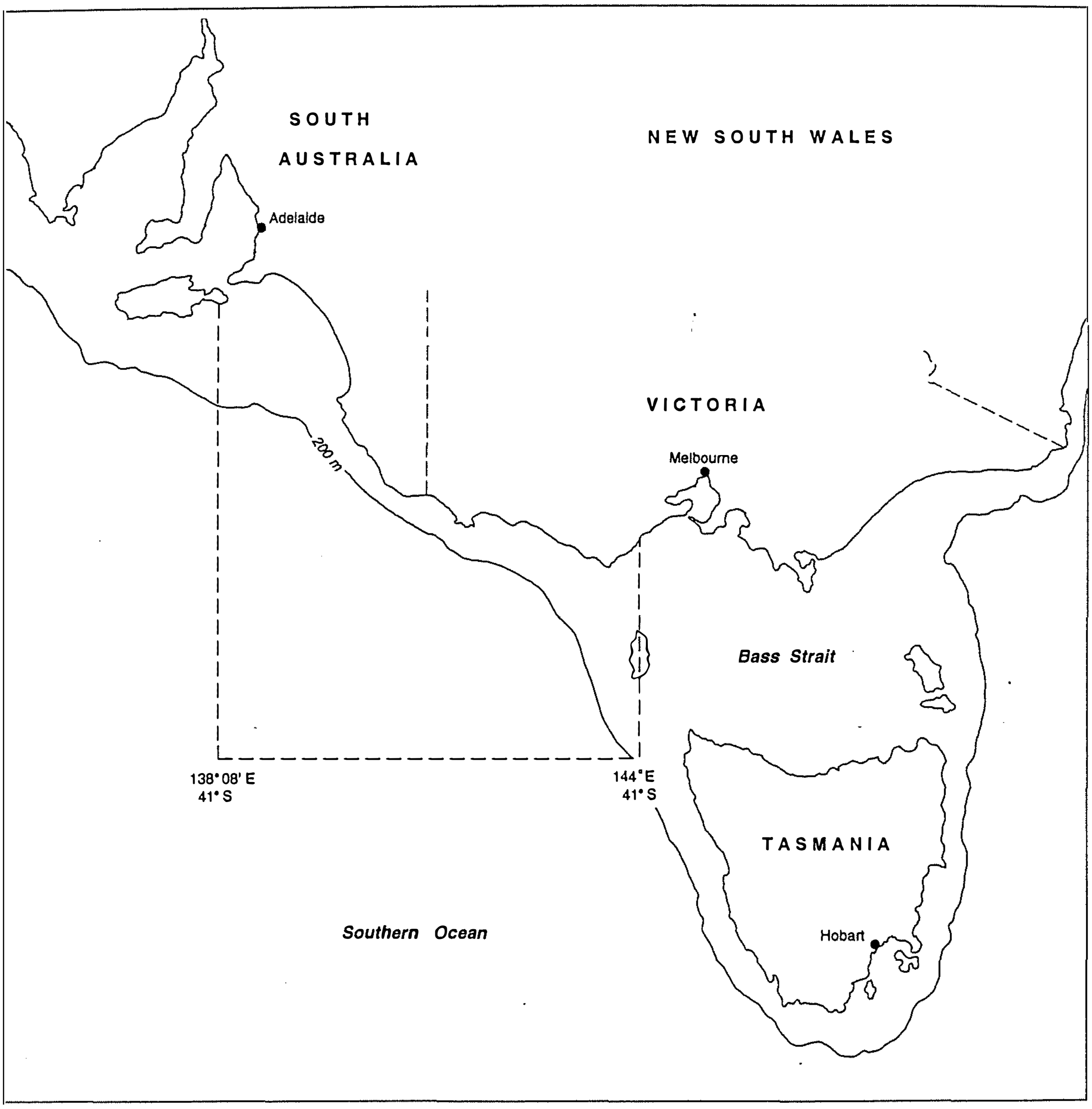


Figure 1.1 The western Bass Strait study area.

1 INTRODUCTION

1.1 Background

At the commencement of the Western Bass Strait Trawl Fishery Assessment Program in November 1986, western Bass Strait supported a rapidly-developing trawl fishery. Total trawl fish production from western Bass Strait and the west coast of Tasmania, in 1986/87, exceeded 10,000 tonnes. Before 1985, annual landings at Portland (the major port of landing in the area) were less than 2000 tonnes. Little was known, however, and in some cases nothing, regarding the stocks, biology and population dynamics of the species exploited. Also little was known about the scope and extent of the fishery itself.

Prior to 1976, there was no trawling of any form west of Cape Otway and limited trawling, predominantly Danish seining, around Tasmania in inshore waters. In 1976, the South Eastern Fisheries Committee initiated a trawl survey of the South East to extend existing trawl grounds to deeper water, define new trawl grounds and assess the commercial potential of these areas (Anon 1977).

Acoustic surveys and exploratory fishing by the Victorian Fisheries Division research vessel FRV "Sarda" identified trawlable grounds off western Victoria (Gresik 1977). A complementary federally funded survey, using the "Zeehan" extended this westward to South Australian (Anon 1977). These surveys were in depths of about 200 to 500 m. There are only limited trawlable grounds on the continental shelf (< 200 m) in western Bass Strait.

In 1978, a second survey was conducted by the "Zeehan" and the depth extended to 800 (Anon 1979). The survey was also extended eastward to north-western Tasmania to complement surveys of Tasmania waters by the "Craigmin" (Anon 1977, 1979). The major species taken during these surveys were gemfish *(Rexea solandri)*, blue grenadier (*Macruronus novaezelandiae*), king dory (*Cyttus traversi*), jackass morwong (*Nemadactylus macropterus)* and, to a lesser extent, deepwater flathead (*Neoplatycephalus conatus*).

Further ground surveys of southern Australia, including western Bass Strait, at depths from 400 to 1200 m, were conducted by the Tasmanian Department of Sea Fisheries (Wilson *et al* 1984).

Commercial trawlers first began working from Portland during 1977. Between 1979 and 1983 several vessels also fished from NSW ports, particularly Eden, during the winter to exploit gemfish (Smith 1989a). Trawlers also worked from Port Fairy, Geelong and Melbourne and, from 1986, Beachport (South Australia). Vessels from these ports exploited trawl grounds in western Bass Strait and around Tasmania.

Blue grenadier was initially the dominant species with annual catches reaching almost 2000 tonnes by the mid 1980s. However, in 1986, orange roughy *(Hoplostethus* *atlanticus)* aggregations were first exploited with about 7000 tonnes being landed during 1986/87. This species quickly became the most important species in the SET and this resulted in a complete restructuring of the South East Trawl fishery with considerable fishing effort moving from the traditional area on the east coast to fish waters adjacent to western Bass Strait and Tasmania.

The only prior study of western Bass Strait was by Wilson (1984) as part of an assessment of the trawl fish resources of what was then called the Developing Zone.

1.2 The Western Bass Strait Study

The aim of the study was to provide information essential for the management of the trawl fishery in western Bass Strait. It was the first systematic study of the fishery in this area. Specific objectives were:

1. To assess the distribution and resource size of commercially-important demersal fish species in western Bass Strait between 200 and 1200m depth.

2. To investigate the biology and determine population parameters (including age and growth, survival, recruitment and reproductive biology) of these species.

3. To estimate potential sustainable yields for these species.

4. To determine the consequences of various harvesting strategies on the resource of commercially-important fish species in western Bass Strait.

The objectives referred to:

a) The continental slope of western Bass Strait between 200 and 1200 m depth, between longitudes 138^{O} 08' and 144^{O}E to latitude 41^{O}S (that is from the eastern tip of Kangaroo I, South Australia, through to west of Cape Grim, Tasmania) (Figure 1.1). Note: the western boundary of the study area (originally 139^{O}E) was extended to the western limit of the SET.

b) The following species:

Orange roughy *(Hoplostethus atlanticus)*
Blue grenadier (*Macruronus novaezelandiae*)
Gemfish *(Rexea solandri)*
Warehous (*Seriolella brama* and *S. punctata*)
Jackass morwong (*Nemadactylus macropterus*)
Ling (*Genypterus blacodes*)
Ocean perch (*Helicolenus percoides*)
Deep-water dories and oreos.

The program was funded by FIRTA and the Victorian Department of Conservation Forests and Lands (now the Department of Conservation and Natural Resources).

The orange roughy component of the Program was part of a cooperative research effort initiated in 1987 by the Bureau of Rural Resources (BRR) and formalised following the first Demersal and Pelagic Fish Research Group (DPFRG) Orange Roughy Workshop held at Queenscliff 22-23 October 1987. The aim of this workshop was to coordinate, and to avoid duplication of, research (Williams 1987). At this Workshop it was agreed that the Western Bass Strait Trawl Fishery Assessment Program would undertake the main responsibility for ageing orange roughy using conventional methods. Other research programs engaged in orange roughy research provided regular samples of otoliths.

As a result of recommendations at this workshop and to ensure consistency with other projects, a number of changes were made to the program regarding research strategy and emphasis. They are discussed in the appropriate sections below. In addition, greater emphasis was given to orange roughy than was envisaged in the original application.

All data presented here have been used extensively in the assessment of South East Fishery. Initially as reports to the Demersal and Pelagic Fisheries Research Group and Orange Roughy Workshops, and latterly as reports to the South East Fishery Assessment Group. All reports and papers derived from this work, and all those for which the results of this study were a major component are listed at the end of the report.

2 METHODS

2.1 Survey fishing of the continental slope

Eight three-monthly (seasonal) surveys were planned using a chartered otter trawler equipped with commercial fishing gear but with a 40mm cod-end liner. Three surveys, during 1987, were completed using the F.V. "Wilsons Pride". This vessel was subsequently sold and there was a delay while new tenders were called. The remaining five surveys were completed, from May 1988 to April 1989 using the F.V. "Barameda".

"Wilsons Pride" Surveys

Sampling sites (randomly chosen) for the these surveys were grouped into four broad transects comprising 6 depth strata from 200 (100-300m) to 1200 (1100-1300m), with additional sites between each transect.

The "Wilsons Pride" was not equipped with a netsonde so the bottom time of two hours was estimated by the skipper of the vessel. In some cases, tows were aborted due to bottom topography or gear damage. Tows of less than 60 minutes duration or those with substantial gear damage or failure were not included in biomass estimation. The following data were recorded for each shot: start and finish position, time and depth, and trawl speed.

Data on catch composition was recorded. Length-frequency distributions and biological information were collected for each species at each site. The entire catch of the study species was measured or, if catches were large, a random sub-sample taken. Biological information and including length (mm), weight (g), sex, gonad weight (0.1 g) and sagittal otoliths for ageing were taken from fish sent to the laboratory. In some cases this represented the entire catch or, if the catch was large, a length-stratified sub-sample. For sub-sampled size distributions, the number of fish in a particular size class were multiplied by the total weight of the catch divided by the sample weight. For ageing purposes (see below) length-stratified samples were adjusted using an age-length key.

"Barameda" Surveys

The sampling design was changed for the 'Barameda' surveys to a stratified random survey following discussions at the first Orange Roughy Workshop described above. This design was consistent with the CSIRO survey of the south east (Bulman et al 1991) and that conducted by the Tasmanian Department of Sea Fisheries (FIRTA 87/65). The southern boundary of the study area (41^{o}S) was also the northern boundary of the Tasmanian research area.

Stratified random trawl surveys are widely used in the estimation of the biomass and abundance of demersal fish populations (Doubleday and Rivard 1981; Francis 1981; Sissenwine et al 1983; Robertson et al 1984). They are regarded as more useful than fixed site or transect surveys (Sissenwine et al 1983). The estimates from non-random surveys may sometimes be more precise but they are often inconsistent and the precision of the sample mean cannot be estimated without assumptions about the distribution of fish being sampled (Sissenwine et al 1983).

Random latitudes and longitudes were computer generated for each survey. With the help of the skipper of the `Barameda', Mr G Blackman, at least 10 sites in each depth stratum were allocated as far as possible on trawlable ground. During the survey, if no trawlable bottom was found within three nautical miles of the site then the next site on the list was chosen.

There is little trawlable ground between 100-200m in the study area and this reduced the number of sites surveyed in the 200m (100-299m) depth stratum. In some cases, sites in this depth stratum were repeated although these were not used in subsequent biomass analyses.

Trawl duration was reduced from two hours to one hour for these surveys to be consistent with the other research surveys. This also allowed more sampling sites (trawl shots) per survey.

The "Barameda" was equipped with a netsonde which was used primarily to indicate actual bottom time. During the few times there was equipment malfunction, bottom time was estimated by the skipper. As with the "Wilsons Pride", starting and finishing location, time and depth were recorded. In addition, headline height and bottom temperature as indicated by the netsonde were also recorded. Aborted tows were recorded but not used in subsequent analyses.

The sampling procedure was similar to that employed on the "Wilsons Pride" accept that approximately 100 fish per species were randomly selected from each shot and sent to the laboratory for processing. The remaining catch of each species was sexed and measured on board the vessel or if the catch was large a sub-sample taken. For sub-sampled size distributions, length data were worked-up by multiplying the number of fish in a particular size class by the total weight of the catch divided by the sample weight.

The catch of other commercial species was recorded and the catch of discarded species estimated.

Commercial landings of blue grenadier and gemfish are headed and gutted (see "Sampling of Commercial Landings"). The relationship between whole weight and headed and gutted weight for these species was determined.

As part of the regional studies of orange roughy, gonads were collected for reproductive and fecundity studies at the NSW Fisheries Research Institute (FIRTA 87/131, Bell et al 1992), and whole fish for electrophoretic population studies at the University of New South Wales (Black and Dixon 1989).

2.2 Biomass estimation

The demersal biomass was estimated for each species using the area swept method. The area within each depth stratum was calculated, by planimeter, using charts prepared by the Department of Sea Fisheries, Tasmania (Wilson *et al*, 1984).

Calculation of biomass and standard errors of biomass were based on Francis (1981).

A number of assumptions were made in these analyses:

a) all fish in the path of the net were caught.
b) no fish were above the headline.
c) there was no migration or emigration from the study area during each Survey.

There is, therefore, considerable uncertainty in these estimates and thus the values should be regarded as indices of abundance.

Analysis of variance, in the form of regression, was undertaken on log transformed data (catch rate+1) to test for annual, seasonal and depth effects (in the preferred depth strata).

2.3 Sampling of commercial landings

Commercial landings were sampled at Portland, Beachport and Geelong (also at Port of Melbourne and Port Fairy as available) to provide representative length-frequency distributions. Samples were taken six-weekly during 1987, then monthly for the remainder of the program.

Random samples were taken from the catch of a number of vessels during each sampling period. Length-frequency distributions were aggregated across vessels after first scaling for catch.

Gemfish and blue grenadier are headed and gutted at sea. Lengths of these species, therefore, were based on modified measurements:

a) blue grenadier - from the last caudal vertebrae to the first dorsal spine; termed dorsal standard length

b) gemfish - from the fork of the caudal fin to the junction of the upper and lower lateral lines; termed J-Fork length

The relationships between partial lengths and "whole" lengths were determined to allow later conversion.

In addition, biological information, including length, weight, sex, gonad weight and sagittal otoliths, were also taken from the major species. Where possible, samples were taken at monthly intervals. Seasonality and targeting on orange roughy, however, effected the availability of other species during the study period.

For blue grenadier and gemfish, arrangements were made with several fishers to land a portion of their catch of these species whole (i.e. without fish being headed or gutted).

2.4 Catch statistics.

There are no comprehensive catch statistics for western Bass Strait and the South West Sector prior to the introduction of the South East Trawl logbook in 1986. Some data before 1986, are available from records of fishermen' returns collected by Victorian Fisheries and from a voluntary logbook run by the Department of Sea Fisheries, Tasmania, between 1977 and 1984. SET logbook data were examined for the period 1986 to 1993.

In addition, as an independent source from which the accuracy and coverage of the SET logbook could be assessed, catch data were extracted from the records of fish agents, processors and cooperatives. This work was funded by the Australian Fisheries Service. Summaries of trawl fish landings are given by Andrews and Smith (1988a,b) and Carter and Smith (1989).

2.5 Age determination

Species Priorities

Rapid changes occurred in the fishery during the study period and greater emphasis was given to orange roughy than was envisaged in the original project. Also preliminary examination of catch statistics indicted that several species were taken in only small quantities. Consequently, extensive ageing studies were limited to the most important WBS species or to provide comparison with those species also important on the east coast; orange roughy, blue grenadier, gemfish, blue and spotted warehou and jackass morwong.

Ageing Methods - General

Otoliths were "read" using a semi-automatic system to record relevant details and measurements. Otoliths were immersed in water against a black background and examined under low power using reflected light. Under these conditions translucent zones appear dark whereas opaque zones appear white. Some otoliths from larger fish, depending on the species, required brief soaking in water to clarify the inner zones, but prolonged soaking reduced clarity at the edge.

Measurements for each otolith were taken using a 22 x 28 cm digitising pad (Kurta bitpad) and a LED cursor linked to a Olivetti microcomputer using custom software. A dissecting stereo-microscope and camera-lucida were used to superimpose the LED image on the microscope field of view. The focus was digitised first and the translucent zones were measured along the anterior/posterior axis.

Otoliths from some species required sectioning (see below). Otoliths were embedded in a polyester resin and sections, 0.2-0.4 mm thick, were cut with a Gemmaster cutting saw with a 10 cm x 0.2 mm blade. The sections were first washed in water, to remove resin and otolith particles, and then in 100% ethanol. Sections were mounted on slides (DPX mountant) and protected with a cover slip.

As far as possible each otolith was read "blind"; that is with no reference to the size of the fish. The appearance of the edge, whether translucent or opaque was also recorded. These data were written automatically to two files; one containing summary information including "age" and the second all data.

Ageing Methods - Species

a) Orange Roughy

Orange roughy have proven very difficult to age by conventional methods although their otoliths exhibit distinct translucent (hyaline) and opaque zones. Interpretation of these zones, however, led to considerably different estimates of growth rates and longevity (Kotylar 1980; van den Broek 1983; Gauldie *et al* 1989, Mace et al 1990).

Greatest emphasis was given initially to ageing juveniles. A range of hard parts were closely examined but otoliths were chosen as the most suitable material for ageing orange roughy. A detailed description of methods is given by Smith and Robertson (1991) and Smith et al (1995).

b) Blue Grenadier

Following Kenchington and Augustine (1987), blue grenadier were aged from whole otoliths for fish up to 70 cm standard length (about 7-8 years old). Zones on the otoliths from larger fish were revealed by transverse cross-section. As noted by Kenchington and Augustine (1987), this preparation reveals translucent and opaque zones on the proximal face of the otolith.

c) Gemfish

Gemfish were aged using the method of Rowling (1990). Otolith samples were exchanged with Kevin Rowling at the Fisheries Research Institute, NSW, initially to calibrate readers and subsequently to ensure consistency of interpretation.

d) Blue and Spotted Warehou

Spotted warehou from New Zealand waters were aged from scales and otoliths by Gavrilov (1974). Although ages were not explicitly validated, data presented did indicate that the zones counted were annual. No ageing studies have been undertaken on spotted warehou in Australia and there was no published data on the age and growth of blue warehou. From preliminary examination of material we chose to use whole otoliths for both species. They were examined whole with reflected light against a black background.

e) Jackass Morwong

The method used to age jackass morwong is described by Smith (1982).

2.6 Growth and Mortalities

Length and age data were fitted to the Von Bertalanffy growth curve by non-linear least square using the SAS statistical package. The relationship between length and weight was calculated by regressing the natural logarithm of weight on that of length.

Catch curves were constructed by plotting the natural logarithm of the number in each age group against age. Z, the coefficient of total mortality was estimated from the slope of the linear regression fitted to points on the right-limb representing fully recruited age classes.

Fishing mortality, F, was estimated (where appropriate) from the ratio of catch to estimated biomass and natural mortality, M, from Z-F..

3 RESULTS

3.1 General

Survey fishing

During the eight surveys a total of 291 shots were attempted. 284 of these were valid shots and used in subsequent analyses. The remainder were either aborted shots or repeated shots in shallow water. Totals of 78 and 206 valid shots were completed using the "Wilsons Pride" and "Barameda" respectively. These are summarised for each survey by 200 m depth strata in Table 3.1.1.

During the eight surveys, fish were grouped into the following three categories:

a) Western Bass Strait study species
b) Other commercial species
c) Discarded species

During surveys 4-8, the study species made up from 35 to 56% of the total catch (Table 3.1.2). Overall, of the total catch of over 95 tonnes, the breakdown was 44, 7 and 49% for the study species, other commercial species, and discards, respectively.

The proportion of other commercial species was highest at shallower depths (100-300m). Deepwater flathead (*Platycephalus conatus*), barracouta (*Thrysites atun*) and latchet (*Pterygotrigla polyommata*) were most common species. Tiger flathead (*Platycephalus richardsoni*) and redfish (*Centroberyx affinis*) were rarely taken. Small quantities of school shark (*Galeorhinus galeus*) and gummy shark (*Mustelus antarcticus*) (164 and 19 kg, respectively) were taken at depths between 168 and 597 m.

In the deeper shots, ribaldo (*Mora mora*) and the ghost sharks (Chimaeridae) were the most common other commercial species. Deepwater sharks (Squalidae), slickheads (Alepocephalidae) and whiptails (Macrouridae) were the dominant discarded species.

Biomass indices - General

The surveys were undertaken over three years including two summer, three autumn, two winter and one spring survey. Details for each species are given in the relevant sections below. There was no significant year effect for any species. Preliminary analysis showed that 200 m depth strata (ie 100-300) were too broad and the survey area was *post hoc* stratified into 100 m depth strata (i.e. 100-199, 200-299 m etc). During the spring survey there were no shots in the 600 m depth stratum, so for all species, catch rates in the 500-599 m depth stratum were applied to the 600 m depth stratum.

The 100 m depth stratum covered a considerably larger area than the other depth strata but because of the limited trawl ground the number of sites was relatively low. Because of this, there was the potential for significant bias in biomass estimates at this depth. Most of the study species were continental slope species (> 200 m), and thus the 100 m depth stratum had little input into biomass estimation. However, jackass morwong is predominantly a continental shelf species (Smith 1989a) and the highest

Table 3.1.1 The area (km2) of each 200 m depth stratum and the distribution of shots for each survey.

Note: duration of shots in Surveys 1-3 was 2 hours and in Surveys 4-8 1· hour.

Depth Stratum	Area (km2)	Survey 1 Feb-87	2 May-87	3 Aug-87	4 May-88	5 Aug-88	6 Nov-88	7 Jan-89	8 Apr-89
200 m	9605	3	4	3	6	4	5	6	4
400 m	2615	5	8	8	6	6	5	6	5
600 m	2775	6	5	9	11	7	5	9	10
800 m	1726	3	3	4	10	6	6	9	7
1000 m	1799	2	5	5	8	7	6	9	9
1200 m	2440	0	4	2	4	7	6	9	7
Total	20960	19	29	31	45	37	33	48	42

Table 3.1.2 Total catch (kg) and percentage breakdown of survey catches into:
A WBS Program study species; B other commercial species; and
C Discarded species.

Survey	Total Catch (kg)	Percentage catch A	B	C
4	23706	39.0	6.6	54.4
5	17018	56.1	9.9	34.0
6	10774	48.1	7.5	44.4
7	24775	35.1	6.0	58.9
8	19165	50.9	6.2	42.9
Overall	95438	44.4	7.0	48.5

catch rates for this species were at the shallowest depths. Consequently, biomass was not calculated for this species. The estimated biomass for each species by survey are shown in Table 3.1.3. Orange roughy, blue grenadier and warty oreo were consistently the dominant species. Biomass estimates for blue warehou, ling and ocean perch were low in all surveys.

Commercial fishery

The number of vessels based at Portland increased from 8 vessels in 1979 to 15 in 1985. The number of vessels based in western Victorian ports and Beachport reached a maximum of 26 in 1990. The average size of vessels also gradually increased. These vessels also fished the west coast of Tasmania.

The discovery of orange roughy aggregations saw the fleet become more dynamic. Vessels fished from Victorian or Tasmanian ports depending on the proximity of orange roughy aggregations. For example, during early 1988 about 30 vessels fished from Portland.

The total catches of fish in the study area in 1986, 1987 and 1988 were 2,747, 3,868 and 6,041 tonnes respectively (Table 3.1 4). However, blue grenadier and gemfish are headed at gutted at sea and hence the total catch is slightly higher than the quoted figures. Orange roughy was the most important species with annual catches increasing from just over 300 tonnes in 1986 to 4,060 tonnes in 1988. The high catch in 1988 was due to fishing on a aggregation off Beachport during early 1988. Blue grenadier was the next most important species followed by warehous (species combined) and gemfish. Annual catches of the other species were mostly less than 100 tonnes.

In Table 3.1.5, landings for WBS, west Tasmania (WTas) and total SET catches are compared for the period 1986 to 1993. Figures are given for West Tasmania because the fleet in western Bass Strait ports fishes this area and fish populations are continuous. In Table 3.1.5, WBS is based on Neil Klaers's SET partition (Tilzey 1994) which is smaller than the study area (40°S rather than 41°S) and catches are slightly lower but trends in catches are similar (cf 1986-1988 with Table 3.1.4).

Catches of orange roughy from WBS peaked in 1988 and subsequently declined following discovery of the spawning area off the Tasmanian east coast and summer aggregations off southern Tasmania. Apart from 1988, orange roughy catches were higher from WTas than WBS. The blue grenadier catch from WBS was relatively stable at around 400 tonnes from 1986-90, after in which it increased. On average, catches from WTas were about double WBS catches but the catch from both areas contributed between 65% and 77% of the annual blue grenadier catch recorded in the SET logbook (mean 71%) during this period. Between 1986 and 1993, blue warehou and spotted warehou from WBS made up an average 36% and 29% of total logbook

Table 3.1.3 Biomass indices (tonnes) for the study species by survey. The lower figure represents one standard error.

Species	Survey Feb-87	2 May-87	3 Aug-87	4 May-88	5 Aug-88	6 Nov-88	7 Jan-89	8 Apr-89
Orange roughy	*	6436	2751	5326	12988	4533	3023	10123
	*	1286	771	1435	4002	690	762	2661
Blue grenadier	10664	11035	2195	4938	5773	11201	9602	1113
	3098	5408	1102	1550	2733	3183	2640	3036
Gemfish	2148	1123	1767	609	186	978	1651	1816
	799	714	784	434	78	352	907	324
Blue warehou	0	791	304	38	674	0	51	0
	0	321	129	38	610	0	51	0
Spotted warehou	35	70	12048	312	4039	68	340	1039
	25	50	4473	207	2421	68	280	964
Ling	1525	745	668	700	1459	976	1017	955
	515	163	115	132	346	293	166	207
Ocean perch	875	383	343	603	669	729	994	909
	243	73	95	81	214	173	178	141
King dory	2784	1208	439	2237	613	913	3083	3670
	1653	599	134	730	178	227	1021	1513
Warty oreo	*	6378	3874	7575	5524	5393	7927	5718
	*	1967	2166	3583	1434	1188	2724	1647
Spiky oreo	*	271	1350	3264	4930	1064	2229	1892
	*	157	646	1301	368	503	911	817

* not calculated full depth range in Survey 1 not covered.

Table 3.1.4 Catch (tonnes) of major species, WBS study area, 1986-1988.
Note: catches are unadjusted.

Species	1986	Year 1987	1988
Orange roughy	310	1818	4060
Blue grenadier	520	585	591
Gemfish	286	235	196
Warehous	656	533	712
Jackass morwong	152	46	51
Ling	71	70	50
Ocean Perch	12	13	6
Dories	43	54	42
Oreos	0	7	72
Others	697	507	261
Total	2747	3868	6041

Table 3.1.5 SEF catch of study species (tonnes), 1986-1991, by zone WBS, West Tasmania (WTas) and total SEF. Note catches are unadjusted.

Species	Zone	1986	1987	1988	1989	1990	1991	1992	1993
Orange roughy	West	207	1797	4013	1102	365	403	184	610
	WTas	4367	3652	1219	5296	15862	3761	3426	2878
	Total	4636	5897	7224	27673	43922	22431	17121	10466
Blue grenadier	West	409	441	390	451	428	764	823	621
	WTas	677	1102	863	786	1012	1851	1091	1250
	Total	1460	2249	1828	1895	2287	3668	2471	2471
Gemfish	West	281	234	194	115	131	263	92	90
	WTas	28	17	36	42	5	10	<1	13
	Total W	309	251	230	157	136	273	92	103
	Total E	3328	4408	3281	1686	1062	303	386	212
Blue warehou	West	63	211	171	17	292	711	447	318
	WTas	9	7	27	79	14	17	38	49
	Total	212	406	544	776	881	1296	934	829
Spotted warehou	West	583	314	536	207	181	566	86	369
	WTas	68	190	165	367	120	110	124	402
	Total	1157	782	1650	939	1350	1448	733	1816
Jackass morwong	West	152	46	51	34	68	33	41	21
	WTas	0.5	14	17	51	15	14	27	4
	Total	968	1076	1442	1617	956	1106	713	968
Ling	West	63	56	43	46	49	107	71	118
	WTas	52	160	54	139	101	133	48	130
	Total	679	765	567	672	668	735	567	883
Ocean perch	West	11	10	5	6	8	19	8	10
	WTas	9	32	5	7	6	12	9	12
	Total	264	199	187	207	101	224	170	248
King dory	West	31	38	29	40	27	70	48	56
	WTas	14	18	9	41	25	53	49	60
	Total	56	68	58	99	67	141	112	149
Mirror dory	West	0.5	5	2	1	2	4	6	6
	WTas	8	37	15	10	8	11	3	12
	Total	415	477	346	591	296	246	167	299
Siver Dory	West	3	9	8	2	1	1	0.5	0.5
	WTas	6	3	1	21	12	8	15	3
	Total	66	53	46	68	62	26	33	14
Oreos	West	0.5	6	69	22	70	16	28	134
	WTas	20	63	20	294	1150	613	1025	383
	Total	21	73	94	537	2076	1983	3193	1030

Table 3.1.6 Total SEF trawl landings for Victoria and Beachport, SA, 1988-1990. Data were obtained from the records of fish processors, cooperatives and agents.

Year	Area	Orange roughy	Blue grenadier	Gemfish	Warehous	Ling	Ocean Perch	Morwong	Flatheads	Oreos	King dory	Mirror dory	Silver dory	School whiting	ephalpod	B'couta	Others	Total
1988	Eastern Victoria	304	200	554	282	78	28	391	1479	0	16	20	17	1161	114	7	136	4787
1988	Southern Victoria	4801	911	209	769	88	20	87	121	56	25	36	16	163	104	37	70	7513
1988	Beachport SA	866	119	92	24	24	6	39	15	30	22	2	12	0	11	0	42	1304
1988	Total	5971	1230	855	1075	190	54	517	1615	86	63	58	45	1324	229	44	248	13604
1989	Eastern Victoria	1834	294	111	247	61	17	584	1671	5	13	32	21	1078	49	11	314	6342
1989	Southern Victoria	7424	912	115	633	185	35	58	42	157	75	38	12.3	1	68	6.7	148	9910
1989	Beachport SA	918	138	52	48	23	5	30	9	20	24	2	0.7	0	6	0.3	41	1317
1989	Total	10176	1344	278	928	269	57	672	1722	182	112	72	34	1079	123	18	503	17569
1990	Eastern Victoria	1706	57	56	409	78	34	317	1034	53	9	22	18	2048	152	6	337	6336
1990	Southern Victoria	4736	696	62	387	115	21	88	30	128	46	12	4	0	83	8	196	6612
1990	Beachport SA	240	116	90	102	21	2	31	14	10	10	2	1	0	19	0	62	720
1990	Total	6682	869	208	898	214	57	436	1078	191	65	36	23	2048	254	14	595	13668

records, respectively (40% and 46% of total records for WBS and WTas combined). Jackass morwong, ocean perch, mirror dory and silver dory caught in WBS made-up, on average during this period, less than 10% of total SET landings. The ling catch from WBS and the areas combined ranged from 7-15% and 17-33% of the total SET catch, respectively. King dory was more important with a mean catch of 47% and 80% of the SET catch recorded in logbook records for WBS, and WBS and WTas combined, respectively. Oreos were only caught in quantity after 1988 following the shift to orange roughy. Catches in WBS were a small proportion of the total between 1989 and 1993 (< 5%). A greater proportion was taken in WTas, about 40%.

In Table 3.1.5, gemfish are recorded differently than other species with a breakdown between WBS, WTas and the east. This is because gemfish caught in WBS and WTas are different stock, western gemfish (see below) of which 90% are caught in WBS.

Total Victorian and Beachport landings, derived from processor records, were 13604, 17569 and 13668 tonnes in 1988, 1989 and 1990 respectively (Table 3.1.6). Landings at ports in southern Victoria (mostly Portland, Melbourne and Geelong) and Beachport made-up 65, 64 and 5% of these respectively. Orange roughy was the most important species followed by blue grenadier and the warehous. Comparison of these data (for combined species) with catches recorded in the logbook indicate that logbook data are reasonably accurate, in aggregate being 2 to 6% less than landings records (Andrews and Smith 1988a, b; Carter and Smith 1989).

3.2 Orange roughy

Distribution and abundance

Orange roughy were caught in depths from 630 to 1300m, but were most common in the 800 to 1100 m depth strata, occurring in 103 out of 105 shots in these depths (excluding Survey 1 because the full depth range was not covered). No aggregations were fished during the surveys and catch rates reflected this. The highest catch rate was 1020 kg/hr and was over 500 kg/hr in only 6 shots. Over 60% of shots had catch rates of less than 100 kg/hr.

Generally, mean standardised catch rates (catch rates standardised as fish per area swept, kg/km^2) were highest in the 800 to 1100 m depth strata (Table 3.2.1) particularly the 900 and 1000 m depths except during the autumn surveys when the highest catch rates were in the 800 and 900 m depth strata. Coefficients of variation were variable ranging from 23 to 71%. Although orange roughy biomass estimates for each survey were variable (Table 3.1.3), there were no significant year or season effects but there was a significant depth effect and season depth interaction for both the main depth strata (800-1100 m) and all depths (600-1200 m) (Table 3.2.2).

Seasonal biomass indices for orange roughy were lowest in summer at 3111 tonnes and highest in winter at 7642 tonnes (Table 3.2.3). CVs were relatively low ranging from 15 to 34%. Overall, ignoring season, the biomass index was 5947 tonnes.

Survey length frequency distributions and sex ratios

Orange roughy ranged in length from 5 to 46 cm SL but most fish were between 15 and 40 cm. Survey length frequency distributions were variable (Figure 3.2.1) and most were bi-modal (except Survey 1 February 1987 in which the full depth range was not covered). The dominant mode in all distributions was between 15 and 30 cm SL with a lesser mode between 30 and 40 cm. The main differences between surveys was in the relative height of the two modes with the larger fish better represented in Surveys 2 and 8 (May 1987 and April 1989).

Females were relatively more abundant in the larger size classes (Figure 3.3.2). Males ranged in length from 9 to 44 cm and females 10 to 46 cm SL. Females were particularly dominant in size classes greater than 35 cm.

There were no obvious trend of size with depth strata. (Figure 3.2.3). However, a considerably higher proportion of orange roughy were caught in the 800 m depth stratum in April 1989 than during the preceding three surveys.

Overall, significantly more females were caught than males (Table 3.2.4). Sex ratios varied from 0.9:1 to 1.2:1 females to males. The difference was significant for Surveys 5 and 8 (Table 3.2.4). The overall sex ratio was 1.1:1 females to males.

Commercial length frequency distributions

Orange roughy sampled from commercial landings at Portland, Geelong and Beachport ranged in length from 19 to 49 cm but most were between 30 and 40 cm SL (Figure 3.2.4). Samples from some catches contained relatively more small fish showing a similar bimodal pattern to survey catches. Distributions overall, however, were strongly unimodal with the mode at 35-38 cm.

There were no major difference in distributions between ports of landing. Given the dynamics of the orange roughy fleet this is not surprising. Many of the vessels sampled fished from more than one port during the study period and vessels from different ports fished similar grounds.

Reproduction

The results of this section have, in part, been published in Bell et al (1992).

Examination of the relationship between gonosomatic index (GSI, gonad weight/fish weight*100) and length for male and female orange roughy indicated that the length at 50 % maturity were about 30-31 cm and 32 cm, respectively (Figure 3.2.5). This is consistent with the results of macroscopic gonad staging reported by Bell et al (1992).

Mean GSIs for mature fish (males >29cm and females >31cm) caught during each survey are shown in Table 3.2.5. They indicate a seasonal cycle of reproduction with the highest mean value for both sexes occurring during the late autumn surveys (May) followed by low values in August. The maximum individual values were 7.63% and 9.50% for males and females, respectively.

Mean GSIs for female orange roughy (> 31cm) sampled from commercial landings showed a similar pattern. The mean GSI peaked during July followed by a rapid decline (Smith et al 1988).

Age and growth

Orange roughy proved extremely difficult to age using conventional methods. Considerable time was given to determining an appropriate otolith preparation and consistent method of interpretation. Age and growth studies of orange roughy undertaken during this program were published by Smith and Robertson (1992) and Smith et al (1995). These are summarised below.

The distal face of orange roughy otoliths exhibit distinct alternating translucent and opaque zones. Otoliths from 672 orange roughy ranging in length from 7 to 43 cm SL were used in analyses once repeatable methods were established. Zone counts on whole otoliths ranged from 2 (for 7.2 cm fish) to 38 (for a 39.1 cm fish). However, whole otoliths were of little use for ageing mature fish because of the relatively thicker otoliths of larger fish. Consequently otoliths from larger orange roughy were sectioned.

Preliminary results indicated that sections of otoliths along the anterior-posterior axis were the clearest and most useful. Incremental structure was revealed by transverse section but it was not possible to relate them to those seen on whole otoliths. Ages estimated from sectioned otoliths ranged from 8 (for a 24 cm fish) to 125 years (for a 41.3 cm fish). Ages determined using both methods were similar up to maturity but diverged rapidly thereafter.

Estimates ages for juveniles were consistent with those reported by New Zealand workers (Mace et al 1990), who showed that the first three translucent zones on very small orange roughy (<10 cm) were annual. Ages estimated for adults were broadly consistent with the radiometric ages of Fenton et al (1991). Ages estimated from zone

Table 3.2.1 Seasonal abundance (kg/km2) of orange roughy in western Bass Strait, 1987-89. by 100 m depth strata. N is the number of shots, SE is the standard error.

	Depth (m)						
	600	**700**	**800**	**900**	**1000**	**1100**	**1200**
Summer							
Mean	0.0	11.8	281.8	388.2	1484.1	478.3	496.0
SE	0.0	11.8	121.5	139.4	1065.7	223.1	283.0
N	6	5	7	8	3	6	3
Autumn							
Mean	2.7	134.6	2842.9	1862.4	1051.5	577.7	222.6
SE	2.3	126.0	718.9	485.0	403.3	308.7	116.9
N	11	5	16	14	8	8	6
Winter							
Mean	3.1	211.2	446.6	3956.5	1063.1	1877.3	241.2
SE	2.1	211.2	261.9	1528.8	372.8	1044.2	119.3
N	6	5	5	8	3	7	3
Spring							
Mean	*0*	230.3	51.2	2184.9	1432.0	535.4	307.1
SE	*0*	146.6	35.0	602.3	402.3	126.2	78.6
N	*0*	3	3	2	4	3	3
Overall							
Mean	2.0	162.9	1607.1	2147.5	1210.1	926.6	297.9
SE	1.2	82.1	436.0	503.9	251.7	334.3	74.8
N	23	18	31	32	18	24	15

Table 3.2.2. Analysis of variance of log(catch rate+1) for orange roughy, 800 to 1100 m depth strata.

Source	**DF**	**SS**	**MS**	**F Value**	**P**
Year	2	0.98	0.49	0.21	0.8111
Season	3	13.97	4.66	1.98	0.1235
Depth	3	40.71	13.57	5.79	0.0013
Year*Season	1	2.80	2.80	1.20	0.2777
Year*Depth	6	3.95	0.66	0.28	0.9445
Season*Depth	9	56.72	6.30	2.69	0.0092
Year*Season*Depth	3	1.51	0.50	0.21	0.8857
Residual	75	175.92	2.35		

Table 3.2.3. Biomass indices (tonnes) for orange roughy by season 1987-1989, 600 to 1200 m depth strata. N is the number of tows, SE is the standard error.

Season	N	Biomass	SE
Summer	46	3111	1069
Autumn	68	5965	905
Winter	37	7642	1928
Spring	18	4533	690
Overall	192	5947	746

Table 3.2.4 Proportion of female orange roughy by survey, western Bass Strait 1988/89. N is the sample size, Prop F the proportion of females. P is the probability of sex ratios varying from 1:1(based on Chi-square tests).

Survey	N	Prop F	*P*
4	3231	0.52	$0.05<p<0.10$
5	4791	0.53	$0.001<p<0.005$
6	1811	0.51	$0.25<p<0.50$
7	1740	0.47	$0.05<p<0.10$
8	4787	0.54	$p<0.001$
Overall	16360	0.52	$p<0.001$

Table 3.2.5 Mean gonosomatic indices (GSI) for orange roughy by survey. Males > 29 cm, females > 31 cm SL. N is the sample size, SD the standard deviation.

	Male				Female			
Survey	N	Mean	SD	Range	N	Mean	SD	Range
1 (Feb 87)	-	-	-	-	35	1.76	0.73	0.35-3.31
2 (May 87)	-	-	-	-	259	3.60	1.70	0.22-7.62
3 (Aug 87)	-	-	-	-	119	1.85	0.47	0.96-3.35
4 (May 88)	186	2.28	2.08	0.10-7.63	184	3.92	1.74	0.53-7.52
5 (Aug 88)	173	0.32	0.32	0.03-2.84	279	1.90	0.75	0.38-9.50
6 (Nov 88)	138	0.91	0.56	0.05-2.72	122	2.12	0.58	0.86-4.45
7 (Jan 89)	135	1.28	1.74	0.01-4.18	88	2.36	0.92	0.33-4.79
8 (Apr 89)	210	1.77	1.69	0.01-6.78	298	3.34	1.32	0.10-6.37

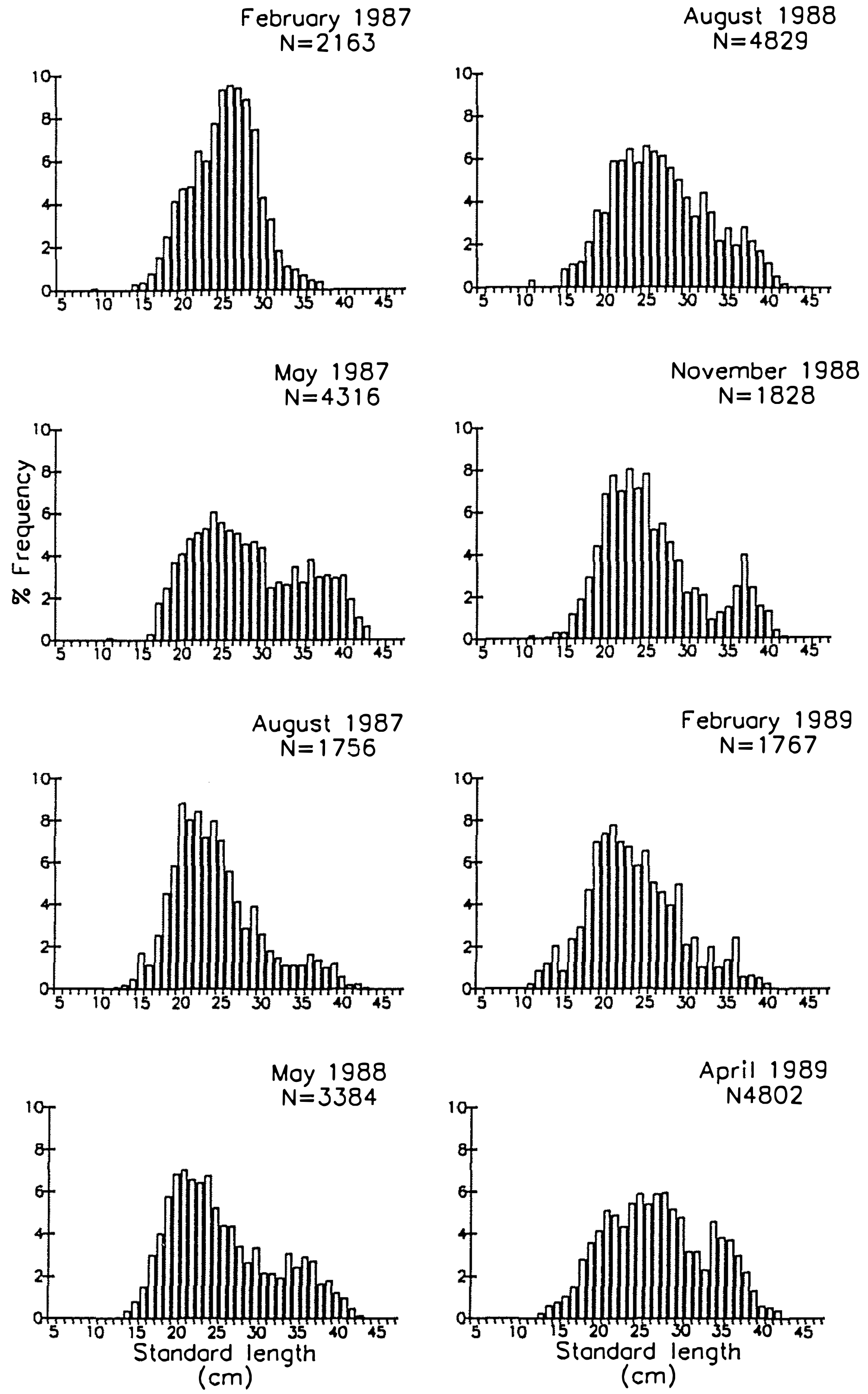


Figure 3.2.1 Percentage length frequency distributions for orange roughy by survey, western Bass Strait.

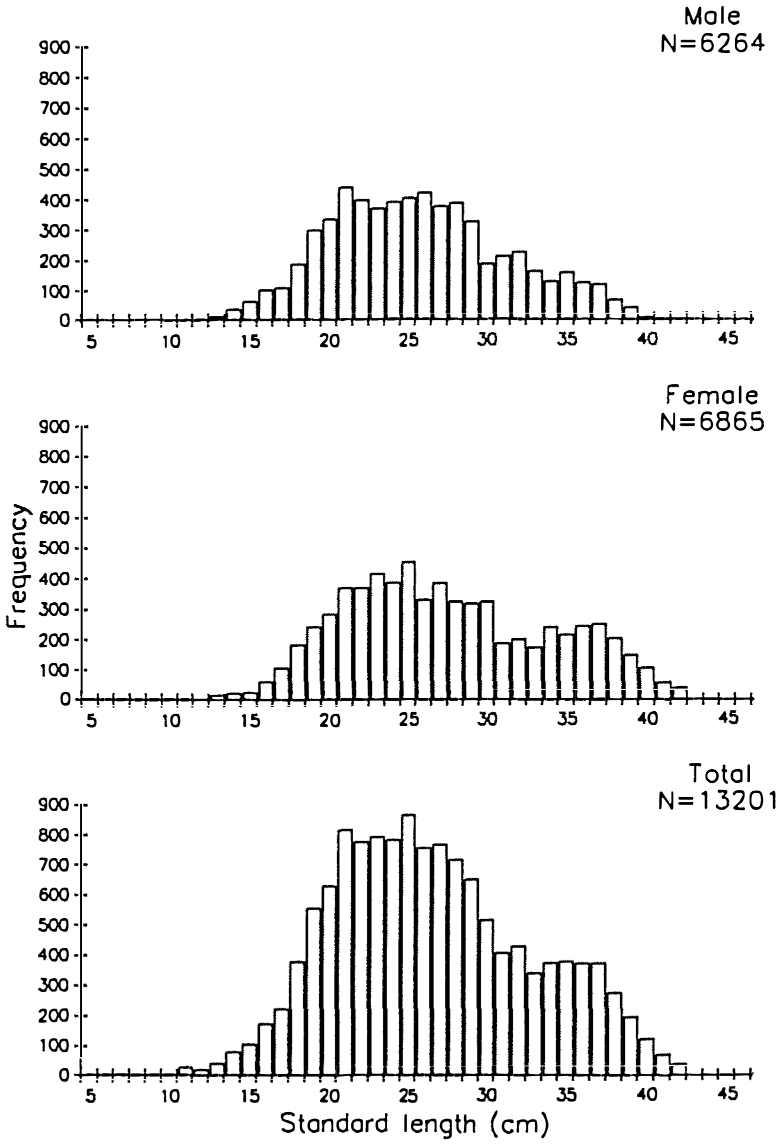


Figure 3.2.2 Length frequency distributions for orange roughy by sex.
Surveys 4-8 combined.

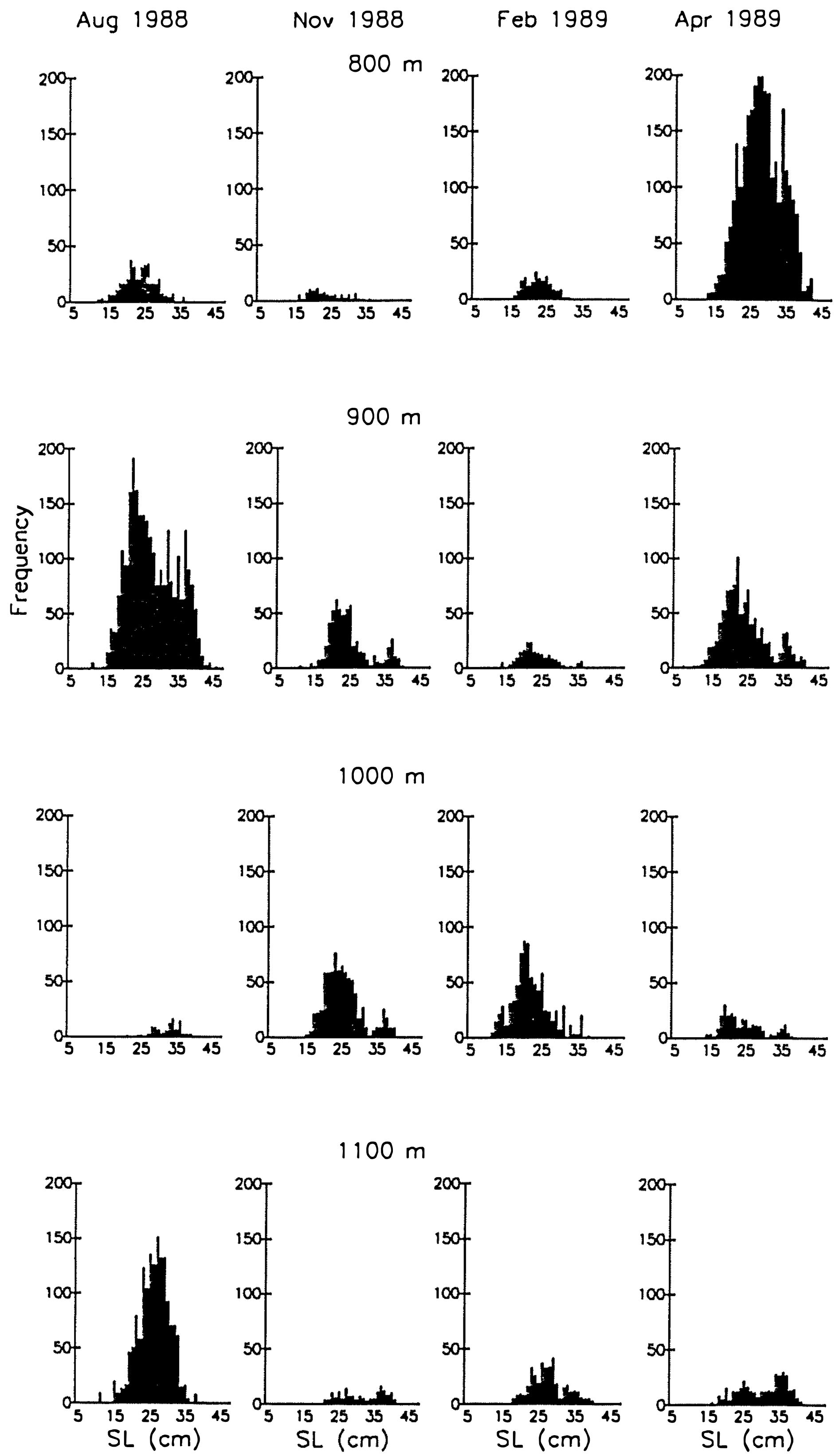


Figure 3.2.3 Length frequency distributions for orange roughy by depth, western Bass Strait 1988/89.

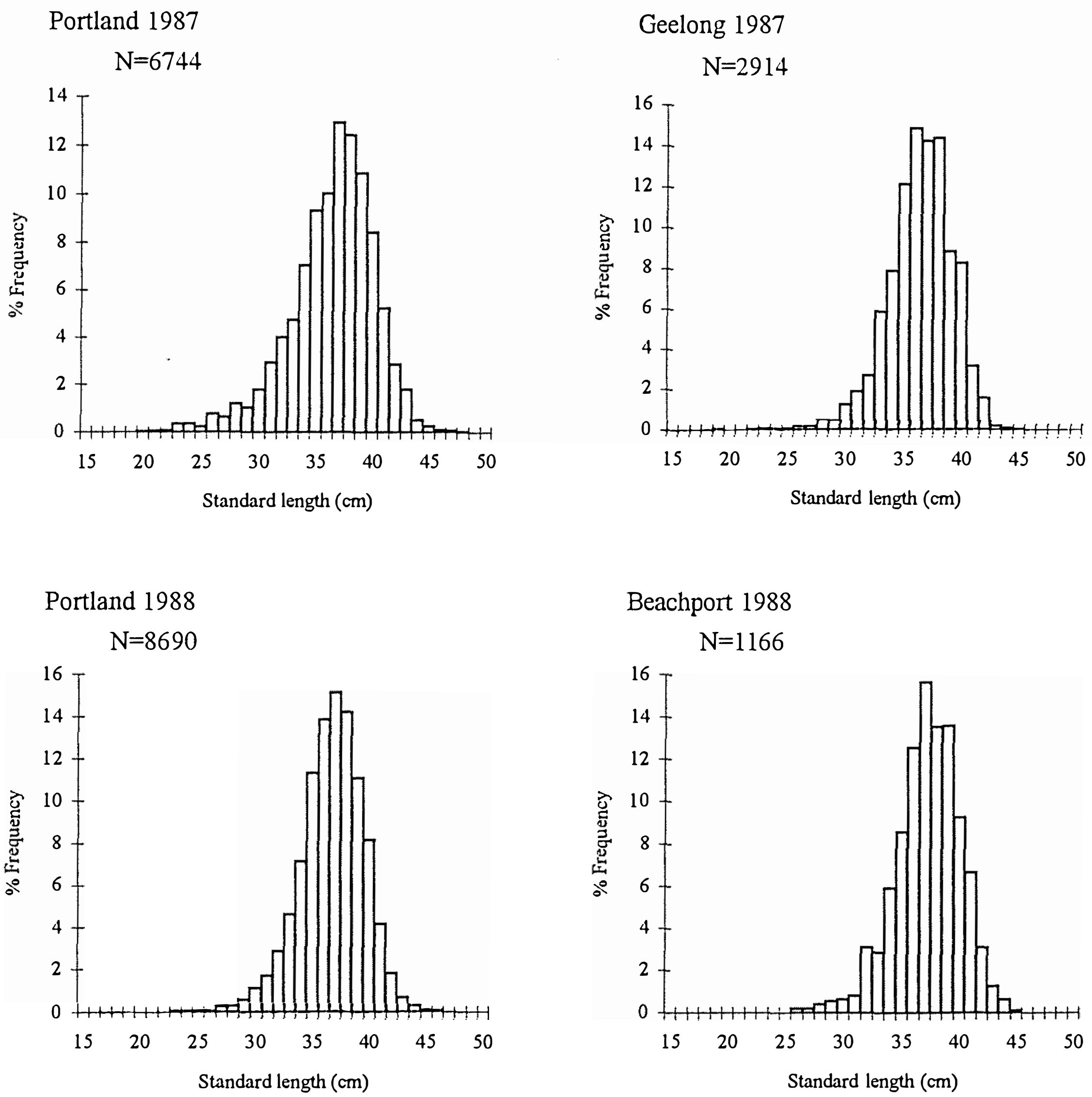
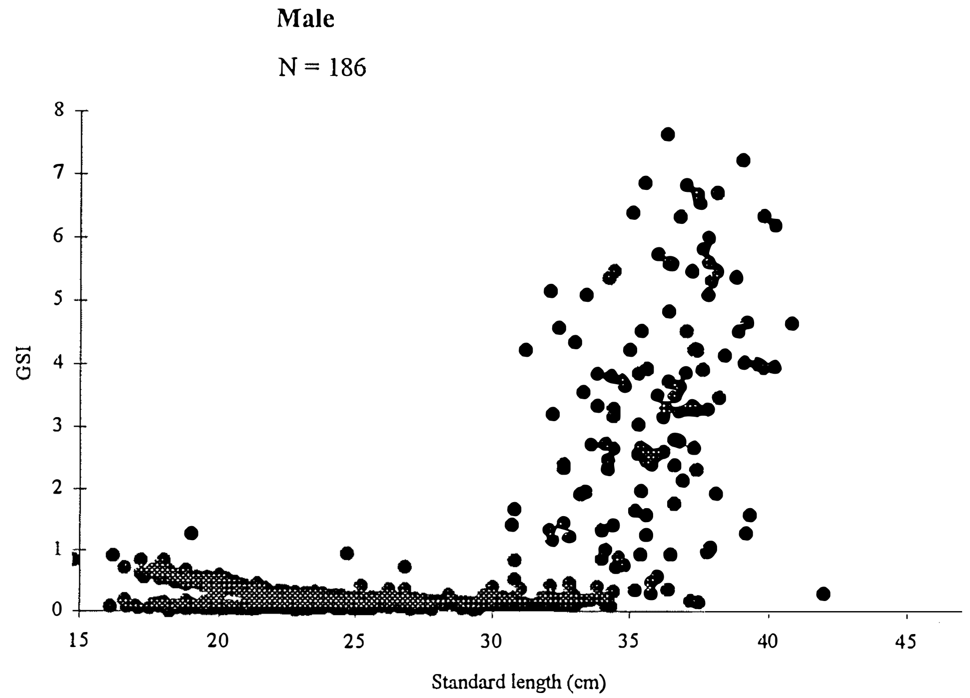


Figure 3.2.4 Percentage length frequency distributions for orange roughy landed at Portland, Geelong and Beachport, 1987-88.



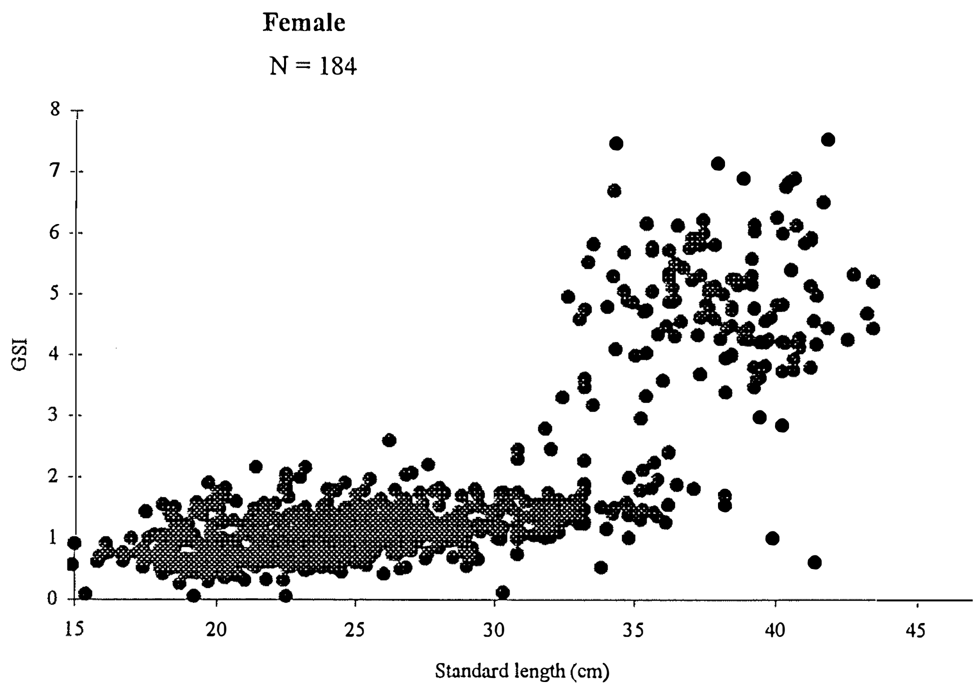


Figure 3.2.5 Relationship between gonosomatic index and length for male and female orange roughy.

counts and radiometric ageing converged when radiometric ages were recalculated using otolith mass growth data derived from the zone count data (Smith et al 1995).

The parameters of the von Bertalanffy growth curves were as follows:

	L_{inf}	K	t_o
Zone counts	39.06	0.06	-3.18
Radiometric	41.36	0.04	-4.90

The length-weight relationships for combined sexes was:

$$W = 5.84E\text{-}02\ L^{2.81} \quad N = 653,\ r^2 = 0.97$$

where W is the weight (g) and L the standard length (cm).

3.3 Blue grenadier.

Distribution and abundance

During the eight surveys, blue grenadier were caught in depths from 199 to 1170 metres. Blue grenadier were taken in 150 of the 195 shots (77%) in these depth strata. Catch rates were highest in the 300 to 600 metre depth strata and blue grenadier were taken in 94% of shots in these depths. The maximum catch rate was 1128 kg/hr. In the 300 to 600 metre depth strata, catch rates of greater than 100 kg/hr were recorded in 30% of shots. Catch rates were generally lower during the two winter surveys when only 14% of shots in 300 to 600 metre depth strata exceeded 100 kg/hr.

Standardised catch rates (kg/km^2) for each depth stratum and season are shown in Table 3.3.1. Standardised catch rates were highest in the 400 and 500 m depth strata and, overall were lower during the winter surveys. Coefficients of variation (CVs) were variable ranging from 25 to 58% in the main depth strata.

For the 300 to 700 m depth strata, analysis of variance gave no significant year or season effect but there was a significant depth effect (Table 3.3.2). However, for the preferred depth strata (400 to 600m) there was also a significant season effect ($p=0.0379$).

The biomass index for the winter surveys was considerably lower, 3830 tonnes, compared to the other seasons which were between 10847 and 11623 tonnes (Table 3.3.3). Because of this, the significant season effect for the main depth strata, and the size and age differences in the winter samples (see below), biomass indices were calculated for all seasons combined and also excluding winter (Table 3.3.3). CVs for the three seasons excluding winter varied between 21 and 28% and was 33% for winter.

Overall, ignoring season the estimated biomass for blue grenadier in the study area was 8965 tonnes and, with the winter surveys excluded, 10888 tonnes.

Survey length frequency distributions and sex ratios

Percentage length frequency distributions (catch adjusted) for each survey are shown in Figure 3.3.1. Fish ranged in size from 20 to 123 cm standard length. Distributions are characterised by distinct modes and but the position and height of these varied. Survey 2 (May 1987) was made up almost exclusively of fish in the 70-90 cm range. The size distribution of blue grenadier caught during Survey 6 (November 1988) was dominated by fish in the 40-50 cm range. Despite these differences a broad pattern is evident. A dominant mode, between 40 to 50 cm standard length occurred in six out of the eight surveys and a second peak occurred at 70 cm in five surveys. A third peak about 80 to 90 cm occurred in six but the proportion of fish greater 80 cm was low in the remaining two surveys which were both during winter.

Blue grenadier less than 30 cm in length were uncommon in all surveys, except Survey 3 (May 1987). In this survey there was a striking mode at 25-30 cm SL (Figure 3.3.1). Although fish of this length were taken in a number of shots the bulk were from one shot.

There was no apparent size depth relationship for blue grenadier (by 100m depth strata) although there is some suggestion in these data that the relative proportion of mature fish was highest in depths from 400-499m (Figure 3.3.2).

Blue grenadier greater than 90 cm SL were predominantly female (Figure 3.3.3). Relative proportions at other size classes, however, were less clear.

Overall, more females were caught than males. Sex ratios varied from 1.1:1 to 1.2:1 females to males. The difference was significant for Surveys 6-8 (Table 3.3.4). Sex ratios for small blue grenadier (<40 cm SL) did not differ from 1:1. Females were more abundant in the size classes between 40-60 and greater than 90 cm, whereas males were more abundant between 81-90. Between 61-80, the pattern was less clear. In some surveys males were more abundant for others the converse was true. For combined surveys males were either more abundant in these size classes or the sex ratios were equal.

Commercial length frequency distributions

The relationship between standard length (SL) and the modified measurement dorsal standard (DSL) is given by:

$$SL = 1.28\ DSL - 0.15 \qquad r = 0.99 \quad N=300$$

Using this relationship to convert from DSL to SL when DSL is expressed in cm increments, produces missing length classes in the SL distribution. To overcome this, a 5-point moving average (L_{i-2} - L_{i+2}) was used to smooth aggregate distributions.

Percentage length frequency distributions for blue grenadier landed at Beachport, Portland and Geelong are shown in Figure 3.3.4. Fish caught in WBS ranged in length from 38 to 114 cm SL, with most fish between 50 and 90 cm SL. There are indications that a strong year-class entered the fishery in 1987 (mode 55 cm), which can be seen in 1988 (mode 65 cm). There were differences in the relative proportion that this year class contributed to the catch dependent on the area fished.

Vessels from ports in WBS also target spawning blue grenadier off the west coast of Tasmania during winter. Thus for the above, winter months were examined separately and included only if not representative of spawning fish. For example, the distribution for Portland, winter 1988 (Figure 3.3.4) was from spawning fish. These fish ranged in length from 52 to 129 cm SL. There was a far greater proportion of very large fish (>100 cm), when compared to the WBS length frequencies, with a mode at 105 cm SL

Reproduction

The relationship between GSI and length for female blue grenadier by survey are shown in Figure 3.3.5. These data suggest a size at maturity of between 70 and 80 cm standard length. Maximum GSI values were approximately 10% and 13% for males and females respectively. Generally, higher values were recorded during the autumn and winter surveys.

Length at maturity of 70 and 75 cm for males and females respectively were used to calculate mean GSIs for mature fish for each survey (Table 3.3.5). These values were derived from the results of this project and from Blaber et al (1985) and Gunn et al (1989). Maxima were 1.5% (Survey 4, May 1988) and 1.9% (Survey 2, May 1987) for males and females respectively.

Age and growth

Ages for blue grenadier have recently been validated by bomb-radio carbon ageing (John Kalish pers comm). Incremental structure, at least for adults, is reasonably unambiguous and consistent between studies. The maximum ages were 16 and 24 for males and females respectively.

Growth in length was adequately described by the von Bertalanffy growth curve. Females grew faster and to a larger size than males.

Parameters of the curve and sample sizes (N) are given below:

	L_{inf}	K	t_o	N
Males	95.5	0.20	0.86	441
Females	101.0	0.18	0.58	457
Combined	100.1	0.17	0.38	949

Growth curves and observed length at age are shown in Figure 3.3.6

The length-weight relationships are given by:

males	$W = 4.84E\text{-}3\ L^{2.89}$	$N=1576,\ r^2 = 0.98$
females	$W = 3.93E\text{-}3\ L^{2.95}$	$N=1398,\ r^2 = 0.99$

Age composition and mortalities

The instantaneous rate of total mortality (Z) was estimated using data from both research and commercial age and length data. For research cruises, Z was considerable higher during winter (Survey 5) than for the other surveys: 0.78 and 0.31-0.49 (age groups 6-14), respectively. Consequently only Surveys 6-8 were used in subsequent analyses.

Age composition and the resultant catch curve for research (Surveys 6-8) are compared with that for commercial data (1988 and 1989) in Figure 3.3.7. The research catch was dominated by 3 and 4 year old blue grenadier whereas for commercial catches it was age groups 5-8. In each case, there were few fish older than 14 in samples.

Z was higher for commercial samples (0.42 and 0.46) than research samples (0.36).

Blue grenadier were fully recruited to research samples by age group 4 or 5 depending on the survey. Overall it was by age group 4. There was no apparent difference between the sexes. Full recruitment to the commercial fishery occurred by age groups 5-8. There are indications in all data sets of variable recruitment.

Table 3.3.1 Seasonal abundance (kg/km2) of blue grenadier in western Bass Strait, 1987-89. by 100 m depth strata. N is the number of shots, SE is the standard error.

	Depth (m)							
	200	300	400	500	600	700	800	900
Summer								
Mean	0	829.3	2668.1	2882.2	1195.4	242.8	52.3	3
SE	0	315.5	1136.5	867.0	673.4	133.4	25.8	3
N	3	7	4	9	6	5	7	8
Autumn								
Mean	12.9	706.4	3643.6	2131.4	516.0	49.6	78.5	3.7
SE	12.9	437.4	1733.1	550.3	143.3	24.3	36.6	2.8
N	4	8	11	15	11	5	16	14
Winter								
Mean	8.7	72.0	1754.1	374.1	169.8	182.3	1.5	21.2
SE	7.2	40.3	779.7	177.8	70.7	61.9	1.5	1.5
N	5	5	9	10	6	5	5	8
Spring								
Mean	11.8	685	677.1	3265.8	*3265.8*	72.8	350.4	0
SE	11.8	685	390.9	1485.3	*1485.3*	42.0	202.3	0
N	2	2	3	5	*0*	3	3	2
Overall								
Mean	9.1	599.4	2539.6	1999.5	602.9	144.0	86.5	7.6
SE	4.6	225.5	773.3	393.5	195.4	33.9	27.4	3.3
N	14	22	27	39	23	18	31	32
Overall excluding winter		*(see text for details)*						
Mean	9.4	754.5	2932.4	2560.0	755.8	129.3	102.8	3.1
SE	6.7	282.2	608.5	485.2	254.8	55.8	31.8	1.9
N	9	17	18	29	17	13	26	24

Table 3.3.2. Analysis of variance of log(catch rate+1) for blue grenadier, 300 to 700 m depth strata.

Source	DF	SS	MS	F Value	P
Year	2	2.73	1.37	0.35	0.7045
Season	3	23.50	7.83	2.02	0.1168
Depth	4	122.26	30.57	7.87	0.0001
Year*Season	2	7.76	3.88	1.00	0.3722
Year*Depth	8	32.83	4.10	1.06	0.4002
Season*Depth	11	75.70	6.88	1.77	0.0701
Year*Season*Depth	5	20.43	4.09	1.05	0.3922
Residual	93	361.16	3.88		

Table 3.3.3. Biomass indices (tonnes) for blue grenadier by season 1987-1989. N is the number of tows, SE is the standard error.

Season	**N**	**Biomass**	**SE**
Summer	49	11623	2465
Autumn	84	10847	2902
Winter	53	3830	1253
Spring	20	11201	3183
Overall	206	8965	1424
Overall (exl winter)	153	10888	1342

Table 3.3.4 Proportion of female blue grenadier by survey, western Bass Strait 1988/89. N is the sample size, Prop F the proportion of females. P is the probability of sex ratios varying from 1:1 (based on Chi-square tests).

Survey	N	Prop F	*P*
4	1073	0.59	0.25<p<0.50
5	1062	0.52	0.50<p<0.75
6	3185	0.55	0.50<p<0.75
7	2105	0.52	0.001<p<0.005
8	2684	0.53	0.01<p<0.025
Overall	10109	0.54	p<0.001

Table 3.3.5 Mean gonosomatic indices (GSI) for blue grenadier by survey. Males > 70 cm, females > 75 cm TL. N is the sample size, SD the standard deviation.

	Male				Female			
Survey	N	Mean	SD	Range	N	Mean	SD	Range
1 (Feb 87)	-	-	-	-	155	0.75	0.28	0.29-3.31
2 (May 87)	-	-	-	-	126	1.89	1.32	0.26-6.77
3 (Aug 87)	-	-	-	-	72	0.95	0.97	0.01-7.80
4 (May 88)	113	1.48	1.81	0.05-9.70	90	1.38	0.87	0.34-4.36
5 (Aug 88)	45	0.25	0.42	0.02-2.26	44	1.58	2.46	0.01-12.22
6 (Nov 88)	112	0.31	0.17	0.01-0.99	33	0.53	0.22	0.02-0.93
7 (Jan 89)	196	0.24	0.16	0.01-0.85	118	0.66	0.23	0.03-1.26
8 (Apr 89)	179	0.32	0.36	0.01-2.03	126	0.62	0.34	0.01-2.80

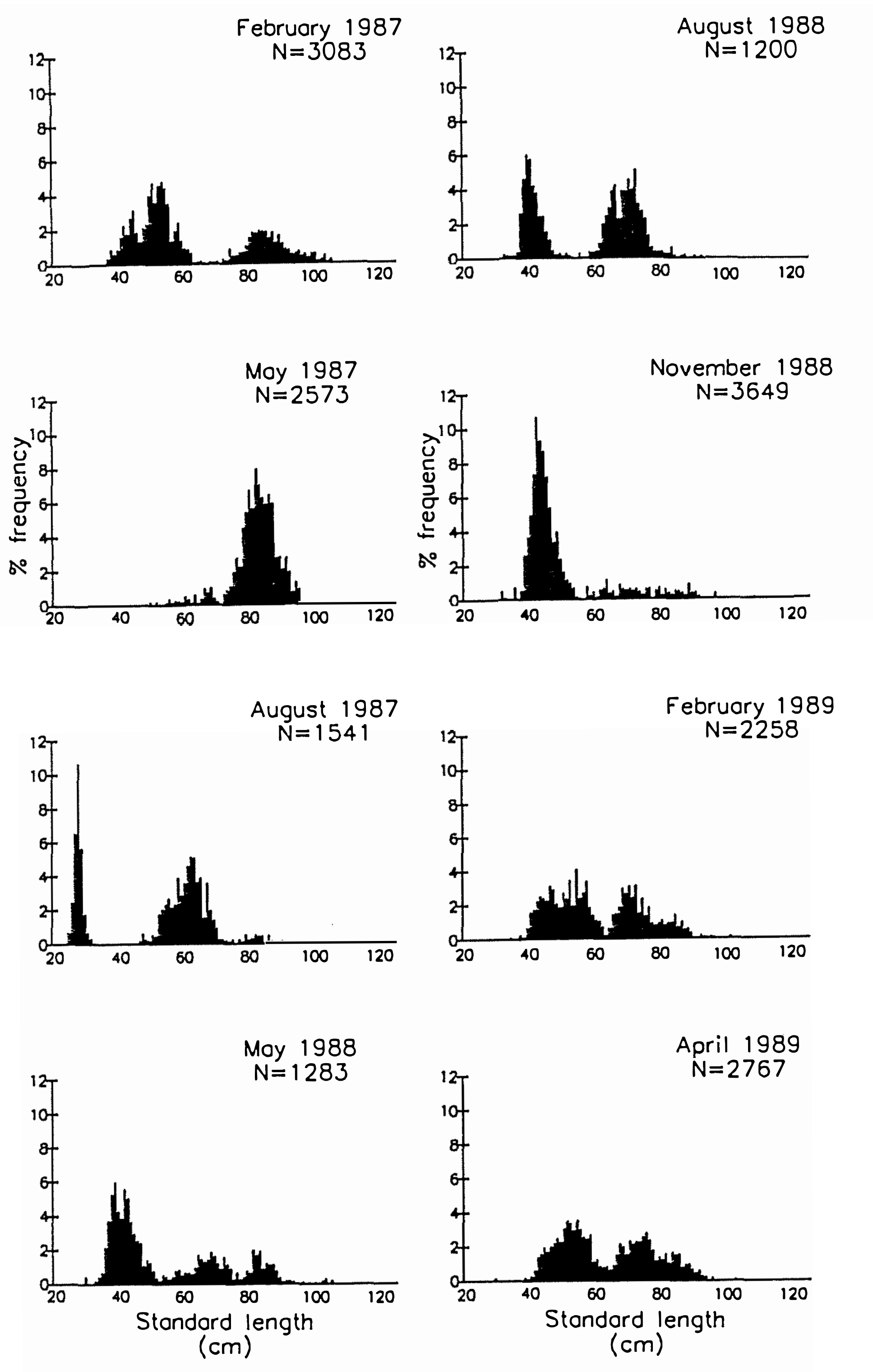


Figure 3.3.1 Percentage length frequency distributions for blue grenadier by survey, western Bass Strait.

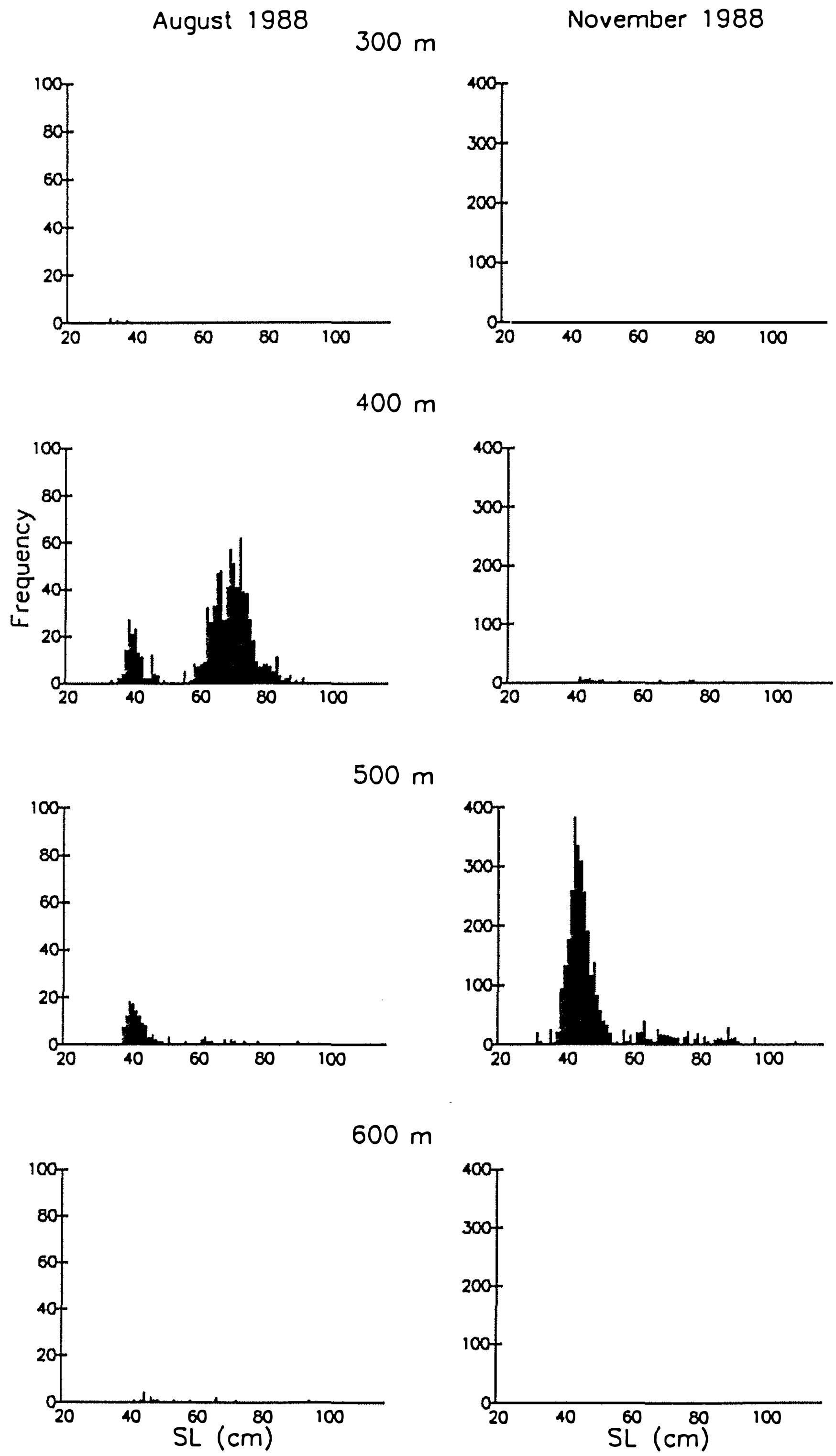


Figure 3.3.2 Length frequency distributions for blue grenadier by depth, western Bass Strait 1988/89.

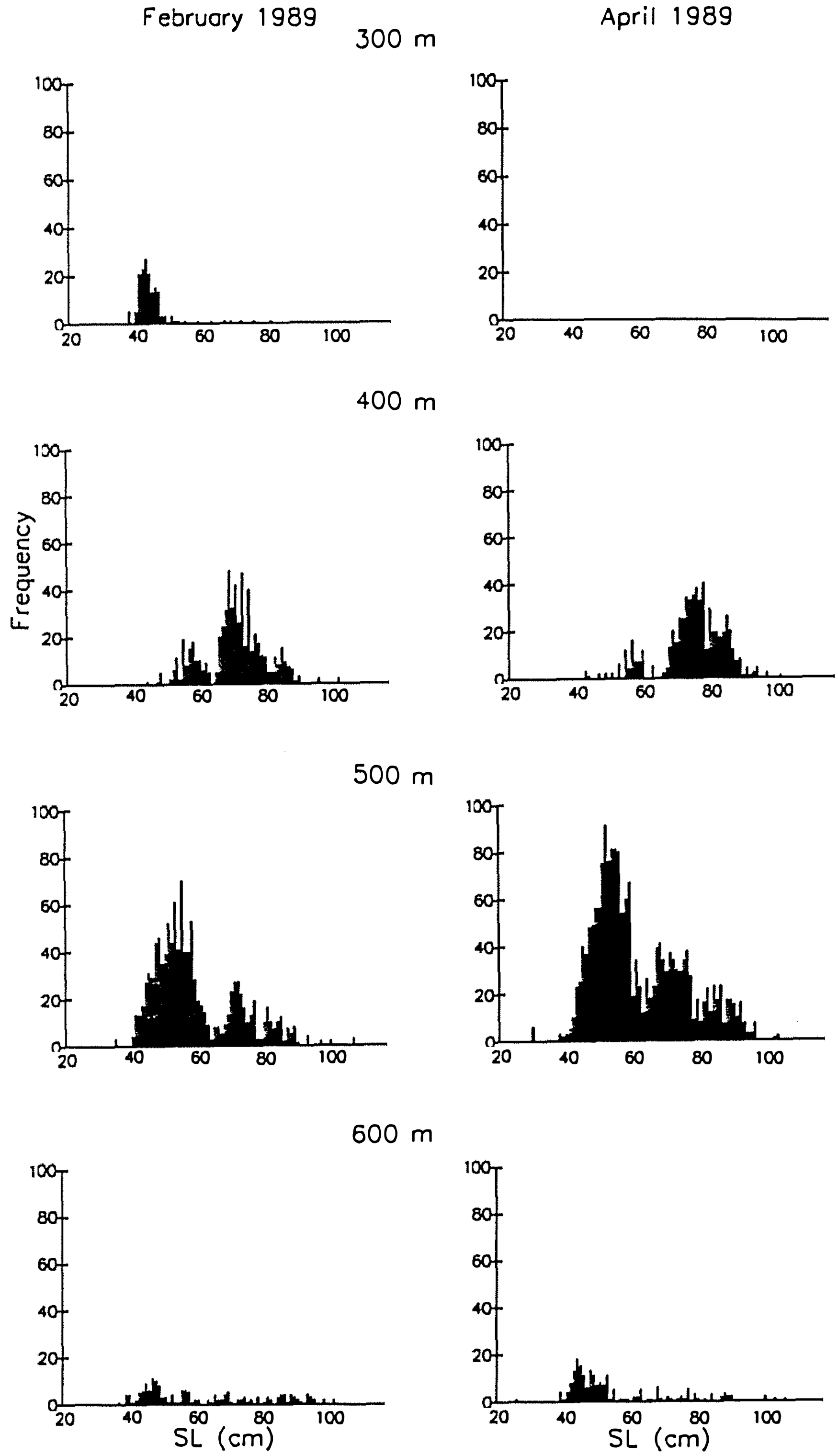


Figure 3.3.2 Length frequency distributions for blue grenadier by depth, western Bass Strait 1988/89 (Contd).

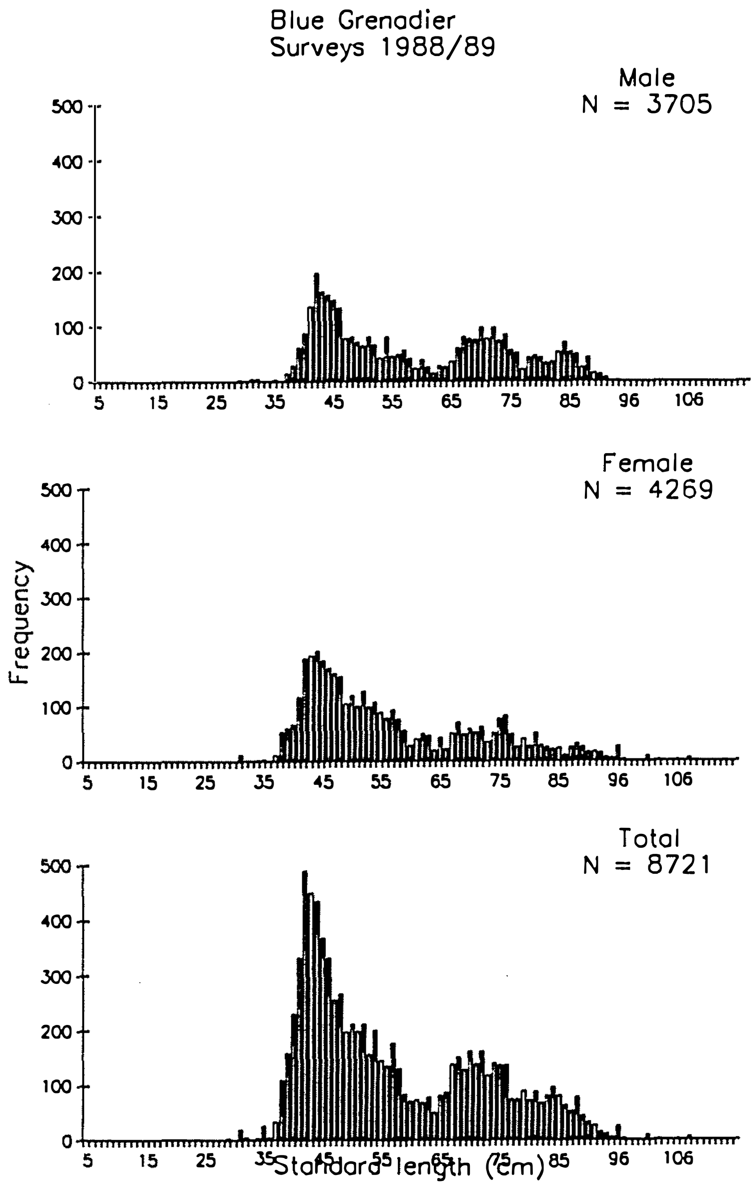


Figure 3.3.3 Length frequency distributions for blue grenadier by sex, western Bass Strait 1988/89.

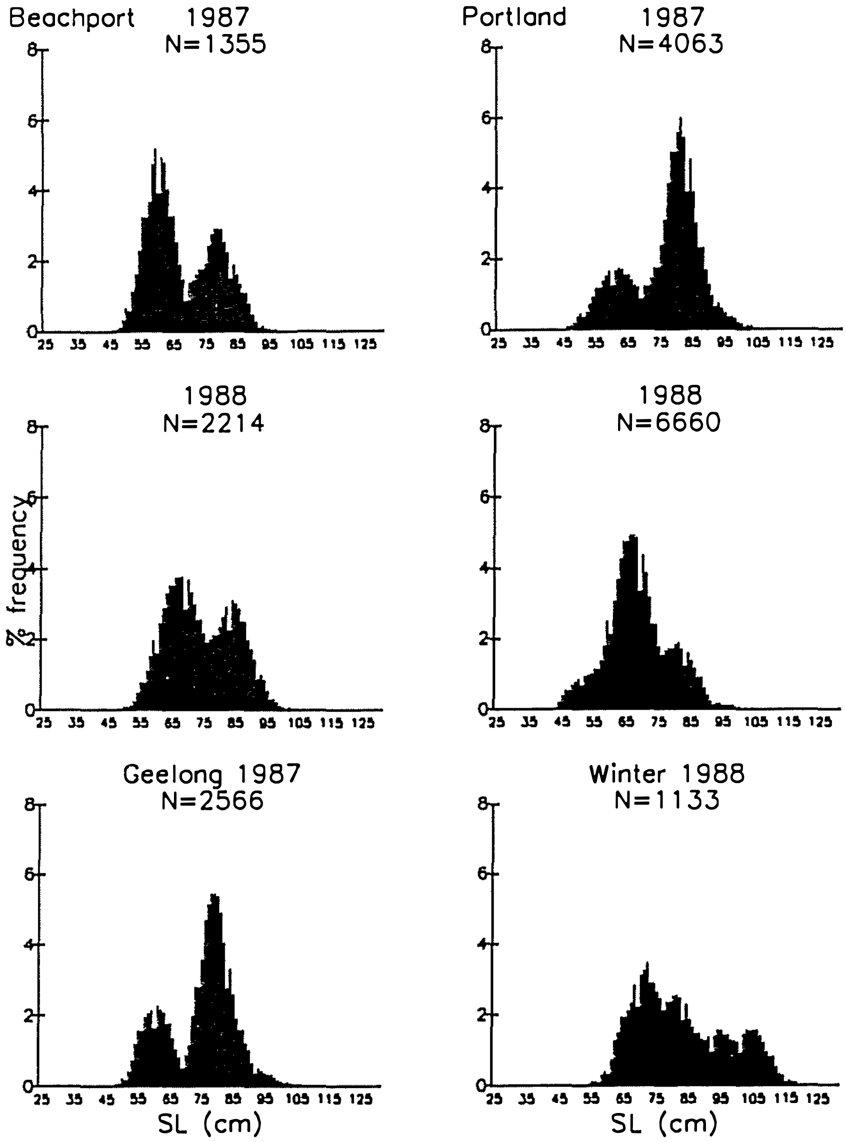


Figure 3.3.4 Percentage length frequency distributions for blue grenadier by port of landing. Note Portland winter 1988 from west coast Tasmania.

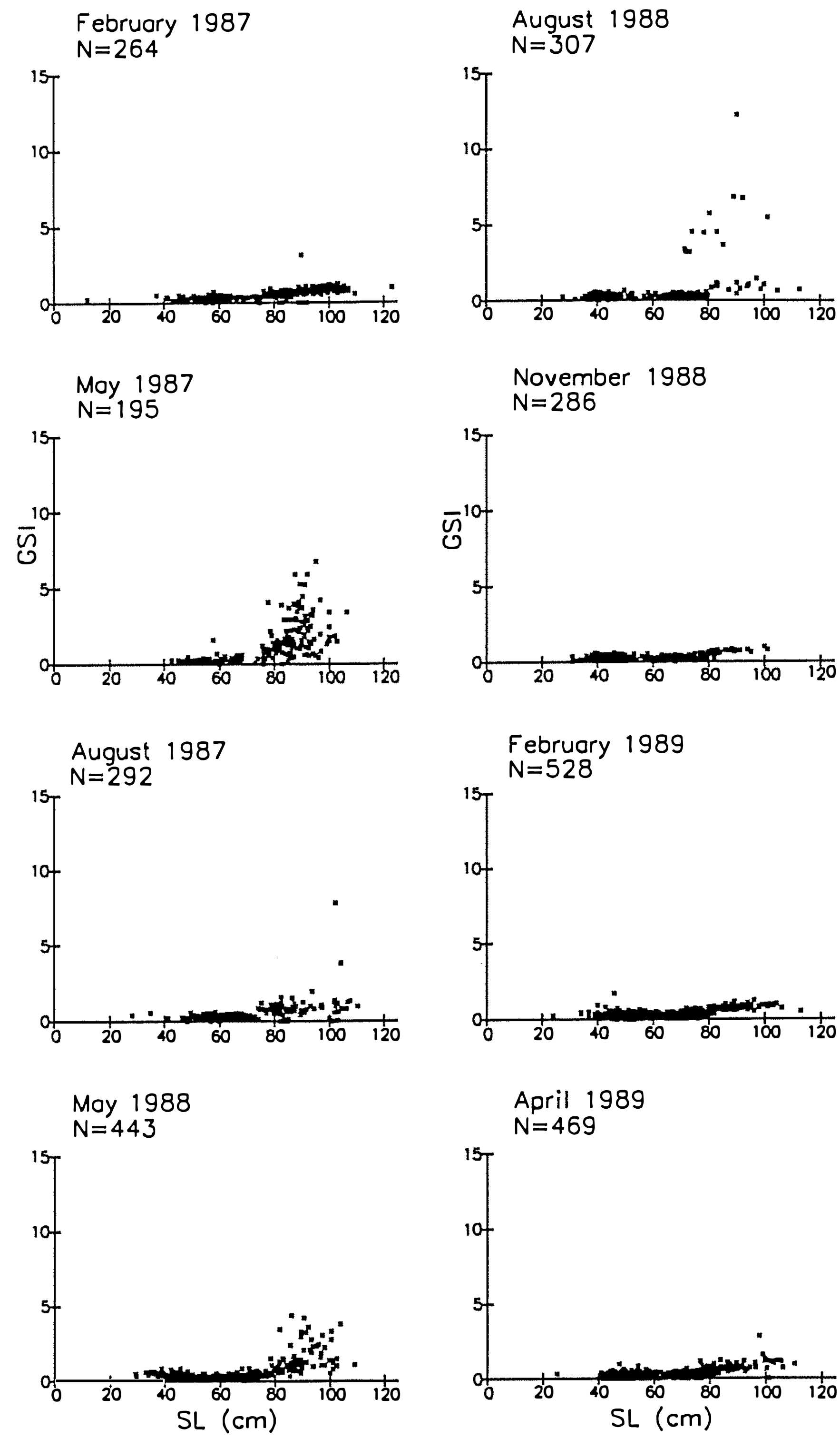


Figure 3.3.5 The relationship between gonosomatic index and length for female blue grenadier.

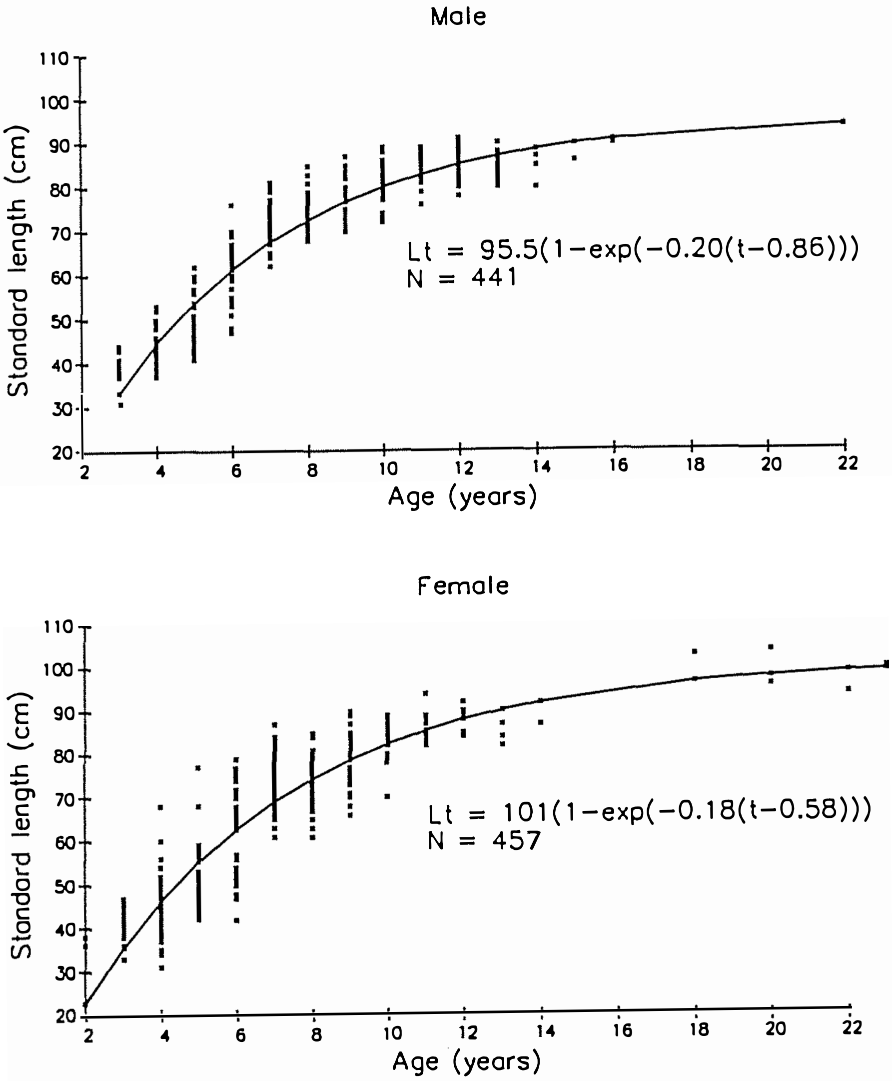


Figure 3.3.6 Von Bertalanffy growth curves for male and female blue grenadier.

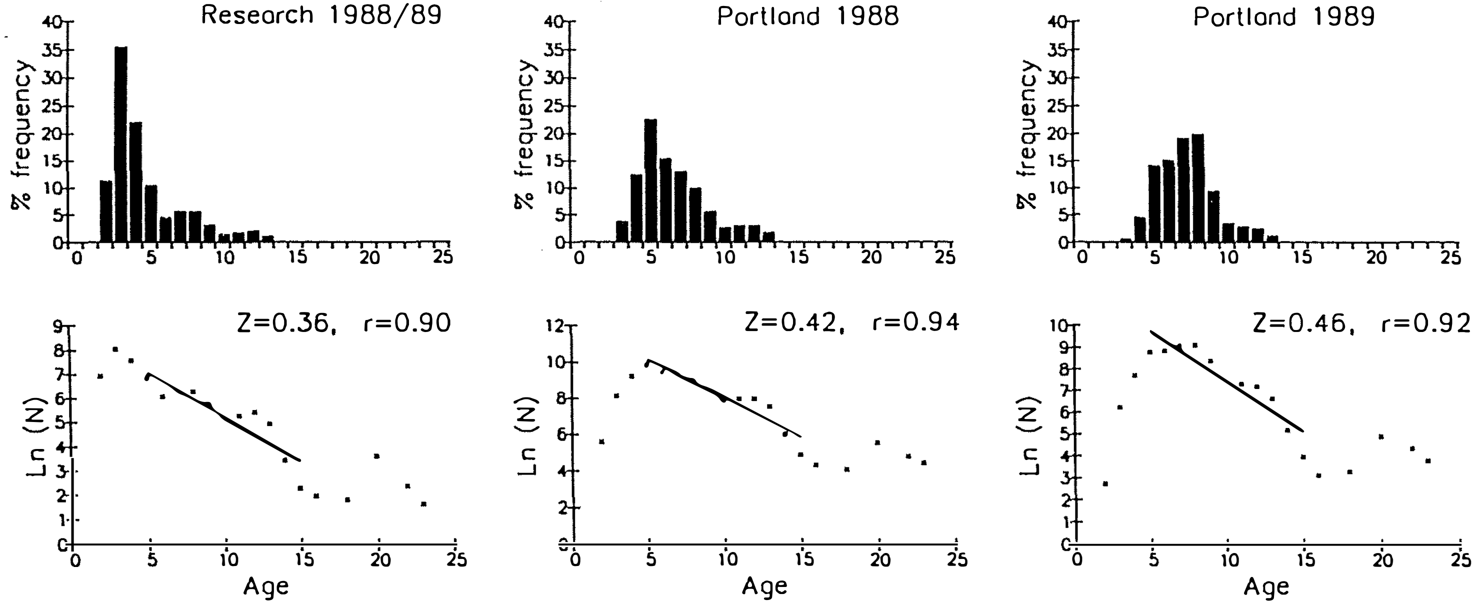


Figure 3.3.7 Age composition and catch curves for blue grenadier, Surveys 1988 - 89 and Portland 1988 - 89.

Fishing mortality was calculated from the ratio of average catch to biomass. The annual catch was adjusted to take into account partial weights (blue grenadier are headed and gutted at sea) by multiplying by 1.4 (see Chesson and Staples 1995), giving a mean annual catch of 791 tonnes (1987-1989). This provides an estimate of F of 0.08. However, because of the difference in age composition between surveys and commercial landings, and in the difference between Zs, it is likely that this estimate is low for the exploited age groups. A considerable component of the estimated biomass in WBS was made-up of younger fish poorly represented in commercial samples. Whether this reflected targeted fishing and differences in gear selectivity rather than discarding is not known.

Using the estimate of Z from survey results as the best representation of the overall population and F=0.08 gives M=0.28 which is not inconsistent with that derived from other studies (eg Evans 1985, Annala 1992).

3.4 Gemfish

Distribution and abundance

Gemfish were caught in depths from 100 to 900 m but were most abundant from 200 to 399 m. Gemfish were taken in 41% of shots in the former but 75% of the latter. Catch rates were relatively low. The highest catch rate was 279 kg/hr and all other were less then 250 kg/hr. In the dominant depth strata, only 37% of shots had catch rates greater than 50 kg/hr. Catches during Surveys 4 & 5 were particularly low when compared to similar seasons in other years.

Standardised catch rates (kg/km^2) for each depth stratum and season are shown in Table 3.4.1. Standardised catch rates were highest in the 200 and 300 m depth strata. Catch rates were variable but overall were lower during the spring survey. Mean standardised catch rates were highest in the 300 m depth stratum in all seasons but spring when catch rates were highest in the 200 m depth stratum. Coefficients of variation (CVs) were generally greater than 50% in the main depth strata.

For the 200 to 500 m depth strata, analysis of variance gave no significant year or season effect but there was a significant depth effect (Table 3.3.2). There were also significant year season, year depth, and season depth interactions.

The estimated biomass for each season (years combined) and for all data are shown in Table 3.4.3. It ranged between 583 (spring) and 1747 tonnes (summer). Ignoring season, the estimated biomass of gemfish in western Bass Strait was 1481. CVs were relatively high for each season (from 32 to 45%) but 21% overall.

Survey length frequency distributions

Gemfish length frequency distributions varied between surveys particularly in the proportion of juveniles caught. Gemfish ranged in length from 10 to 105 cm (LCF) (Figure 3.4.1) (Note: Surveys 4 & 5 are not shown because of low sample sizes). Fish greater than 90 cm were uncommon in all surveys. As with samples from commercial landings (see below), no length frequency distributions, from individual shots or in aggregate, were similar to those of spawning-run gemfish from the east coast. Distributions from western Bass Strait surveys resemble "summer" east coast length frequencies.

The distribution for Survey 1 was notable because of the distinct modes representing age groups 1-3. One shot, however, contributed the bulk of these. Although the number of gemfish caught during Survey 7 was small a similar pattern is evident. The proportion of juveniles taken during other surveys was variable. Several very small gemfish (less than 15 cm) were caught during Surveys 3 and 8.

Commercial length frequency distributions

The relationship between the modified length measurement (J-fork), used for commercial landings, and LCF is given by:

$$LCF = 1.46 \text{ J-fork} + 2.18$$

$$r = 0.99, \quad N = 177$$

Using this relationship to convert from J-fork to LCF when J-fork is expressed in cm increments, produces missing length classes in the LCF distribution. To overcome this, a 5-point moving average (L_{i-2} - L_{i+2}) was used to smooth aggregate distributions.

Gemfish ranged in length between 36 and 105 cm LCF. The majority of fish were in the 50 to 75 cm (LCF) length classes (Figure 3.4.2). Length distributions for fish sampled from landings at Portland and Beachport were similar with a dominant mode at 65 cm. In 1988. there were relatively more large fish in the sampled catch and the mode was higher at about 70 cm LCF. In both 1987 and 1988 there were indications of a smaller mode between 45 and 50 cm, equivalent to three-year old gemfish.

Length frequency distributions by month are shown in Figure 3.4.3. Although variable there were not the distinct differences between winter and summer distributions seen in catches from the east coast. Fish greater than 85cm (LCF) comprised only a small proportion of all distributions.

Reproduction

Gonosomatic indices were generally low for males and females during all surveys (Figure 3.4.4). Survey 2 (May 1987) was the only survey in which there was any trend in the relationship of GSI to fish length indicating mature or maturing fish. In all others, individual values were below 2% except for several individual females (January and April 1989).

Males and females greater than 60 and 69 cm LCF, respectively where used when calculating mean GSIs for each survey (Table 3.4.4). The highest individual and mean values for females occurred in May 1987, at 5.43% and 1.72% respectively. Mean values for females for winter surveys (August 1987 and 1988) were low, 0.74% in both cases. By comparison, GSIs of 10-20% are common for spawning fish on the east coast (K. Rowling pers comm).

Age and growth

Generally otoliths from gemfish sampled from western Bass Strait were more difficult to read than those from the east coast. Otoliths were more translucent and increments harder to interpret.

Validation of age determination for adults was not possible due to small and irregular samples. For juveniles, however, the polymodal length frequency distribution from Survey 1 provided the basis for validation of assigned ages. From the sample taken from shot 8, 100 otoliths were randomly selected from fish less than 60 cm and read with no reference to length. Of these, 95 could be confidently aged. The frequency distribution of estimated ages were compared to the original size distribution (Figure 3.4.5). These results indicate that the interpretation of gemfish otoliths for juveniles was correct.

Figure 3.4.6 shows a comparison of the juvenile length frequency distribution from Survey 1 (February 1987) with similar sized fish from NSW (K Rowling unpublished data). The WBS distribution is closer to NSW fish sampled in August rather than February.

The von Bertalanffy growth curve was fitted to length and age observations for the sexes combined because of the preponderance of young fish and the relatively small sample sizes. The curve adequately described growth over the entire dataset (Figure 3.4.7). Parameters were:

K	L_{inf}	t_0
0.19	98.12	-1.00

Table 3.4.1 Seasonal abundance (kg/km2) of gemfish in western Bass Strait, 1987-1989. by 100 m depth strata. N is the number of shots, SE is the standard error.

	Depth (m)							
	100	200	300	400	500	600	700	800
Summer								
Mean	51.2	208.6	976.4	68.9	89.3	8.6	7.3	0
SE	32.5	208.6	458.4	30.7	39.5	7.7	4.8	0
N	6	3	7	4	9	6	5	7
Autumn								
Mean	33.1	753.1	378.9	90.0	25.2	6.4	0	2.2
SE	28.0	449.0	315.5	35.0	11.6	1.9	0	2.2
N	10	4	8	11	15	11	5	16
Winter								
Mean	0	34.6	1026.8	64.1	10.9	4.3	0	7.7
SE	0	29.9	598.9	23.2	7.4	4.3	0	7.7
N	2	5	5	9	10	6	5	5
Spring								
Mean	0	147.6	212.6	35.5	31.1	*31.1*	0	78.7
SE	0	5.9	165.3	29.7	10.2	*10.2*	0	78.7
N	3	2	2	3	5	*0*	3	3
Overall								
Mean	30.4	404.7	701.1	72.2	37.1	7.7	2.0	10.0
SE	16.2	169.3	227.9	16.8	11.1	3.2	1.5	7.7
N	21	14	22	27	39	23	18	31

Table 3.4.2. Analysis of variance of log(catch rate+1) for gemfish, 200 to 500 m depth strata.

Source	DF	SS	MS	F Value	P
Year	2	27.37	13.69	3.02	0.0552
Season	3	25.42	8.47	1.87	0.1427
Depth	3	99.36	33.12	7.30	0.0002
Year*Season	2	31.67	15.83	3.49	0.0357
Year*Depth	6	92.98	15.49	3.41	0.0050
Season*Depth	9	98.33	10.93	2.41	0.0189
Year*Season*Depth	3	7.29	2.43	0.54	0.6596
Residual	73	331.34	4.54		

Table 3.4.3. Biomass indices (tonnes) for gemfish by season 1987-1989. N is the number of tows, SE is the standard error.

Season	N	Biomass	SE
Summer	47	1747	556
Autumn	80	1504	585
Winter	47	1580	710
Spring	21	583	195
Overall	195	1481	308

Table 3.4.4 Mean gonosomatic indices (GSI) for gemfish by survey. Males all, females > 70 cm LCF. N is the sample size, SD the standard deviation.

	Male				Female			
Survey	N	Mean	SD	Range	N	Mean	SD	Range
1 (Feb 87)	-	-	-	-	88	0.86	0.25	0.29-1.39
2 (May 87)	-	-	-	-	57	1.72	1.13	0.56-5.43
3 (Aug 87)	-	-	-	-	59	0.74	0.18	0.31-1.35
4 (May 88)	4	2.79	1.52	0.96-4.35	7	1.34	0.29	0.92-1.72
5 (Aug 88)	1	0.48	-	-	5	0.74	0.22	0.51-1.01
6 (Nov 88)	4	0.62	0.30	0.37-1.05	12	0.81	0.15	0.64-1.18
7 (Jan 89)	0	-	-	-	30	0.82	0.61	0.39-3.87
8 (Apr 89)	6	1.59	0.99	0.47-3.03	50	0.94	0.38	0.42-3.09

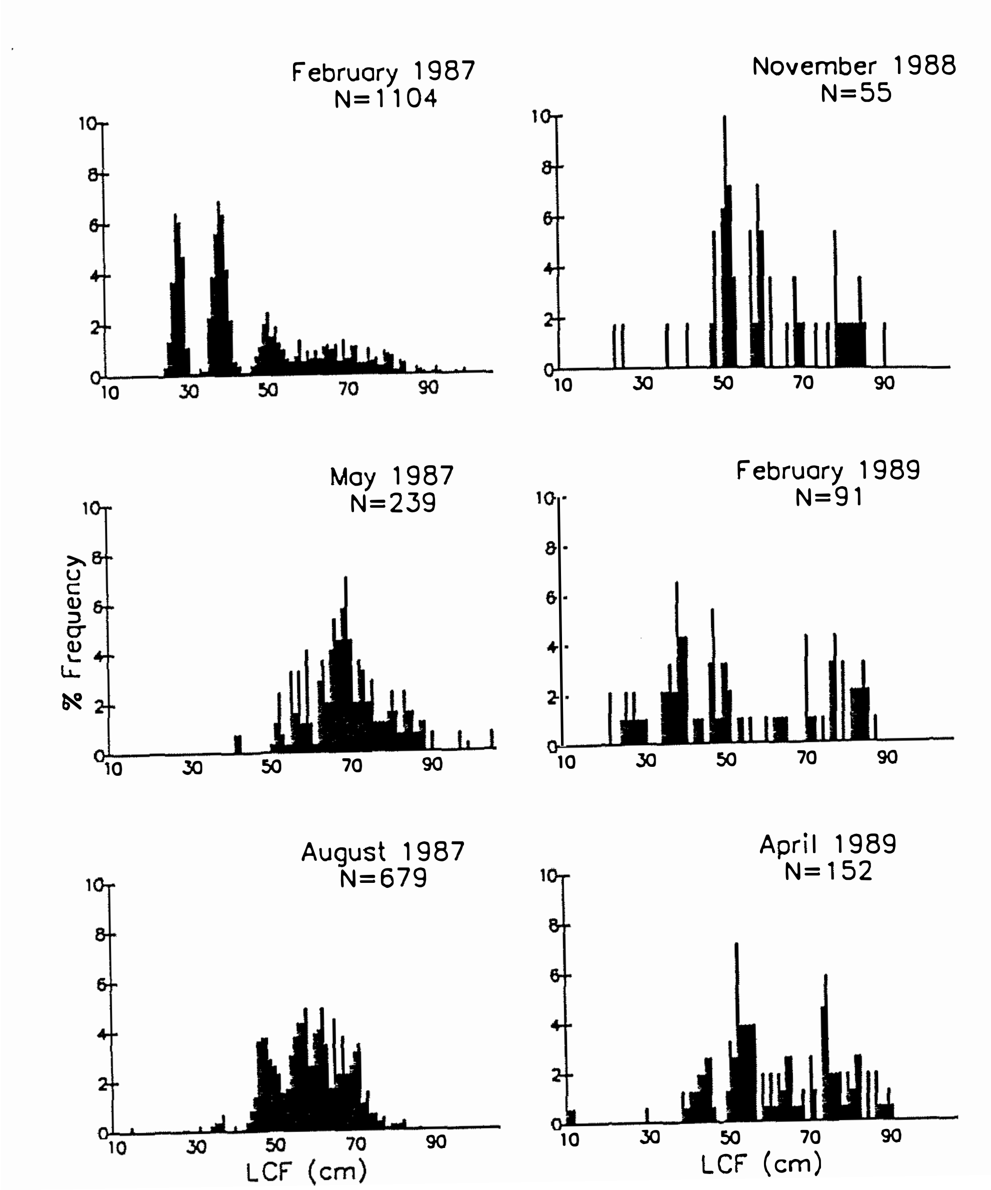


Figure 3.4.1 Percentage length frequency distributions for gemfish by survey, western Bass Strait.

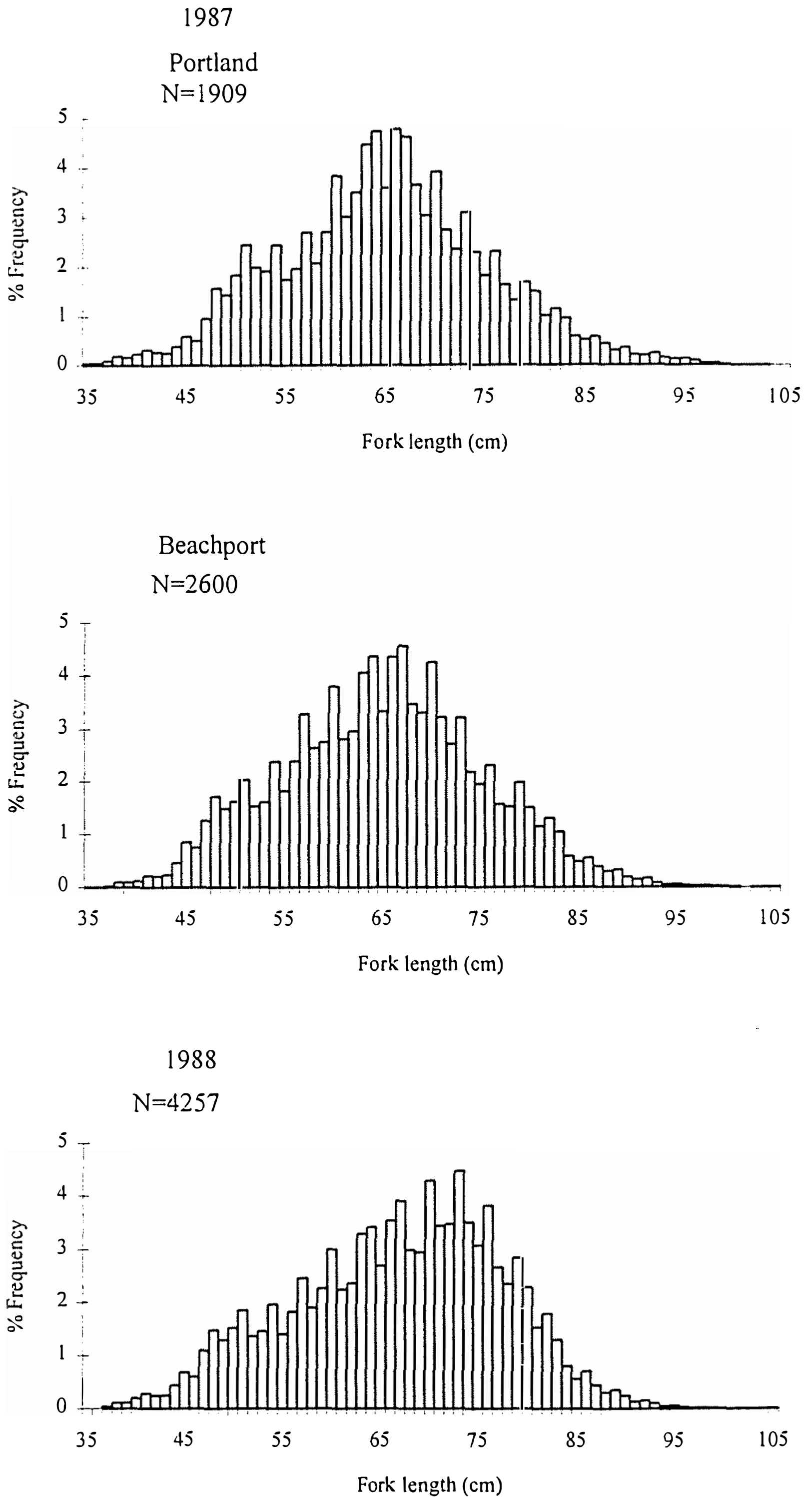


Figure 3.4.2 Percentage length frequency distributions for gemfish landed at Portland and Beachport 1987, and for combined ports 1988.

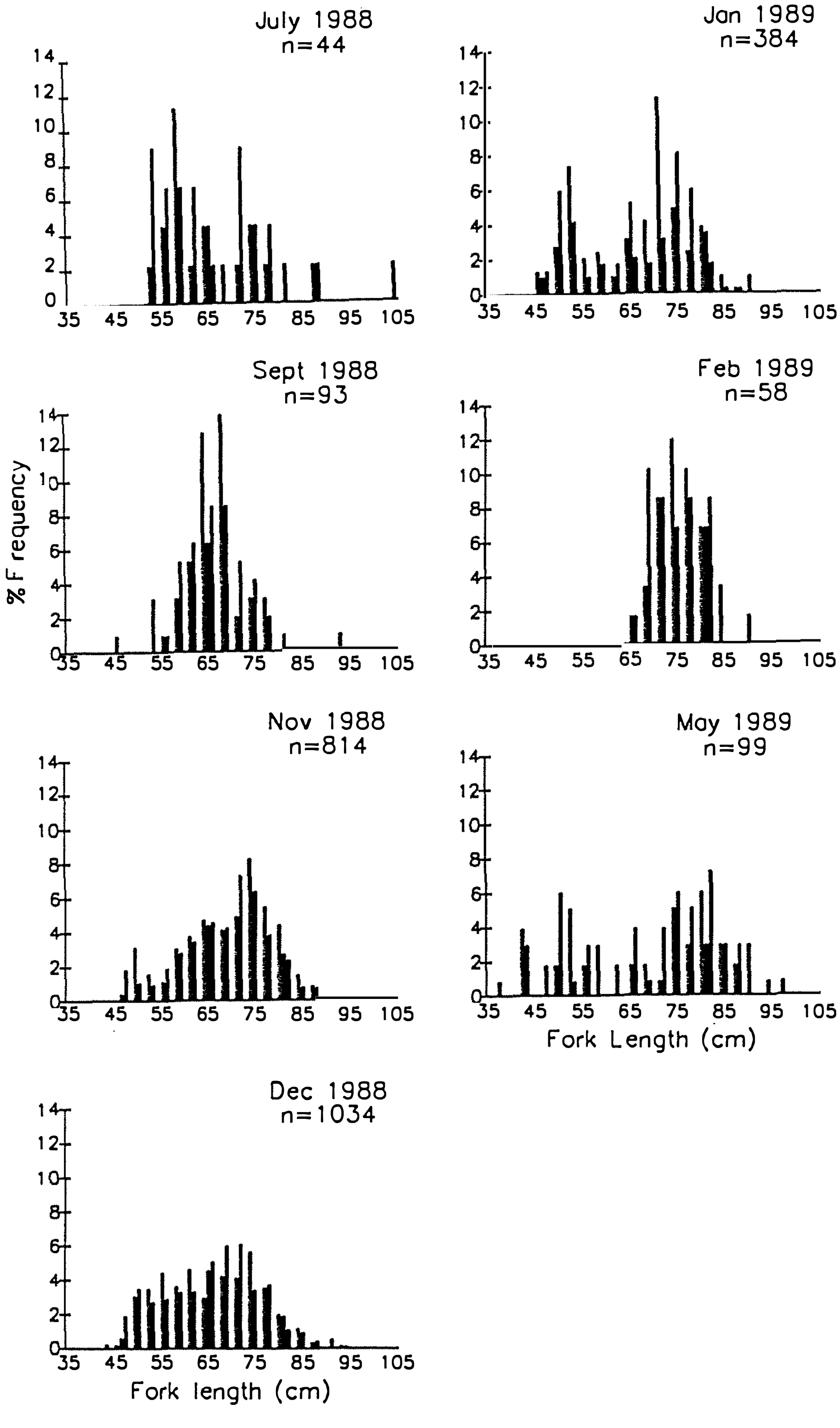


Figure 3.4.3 Percentage length frequency distributions for gemfish landed at Portland, by month 1988/89.

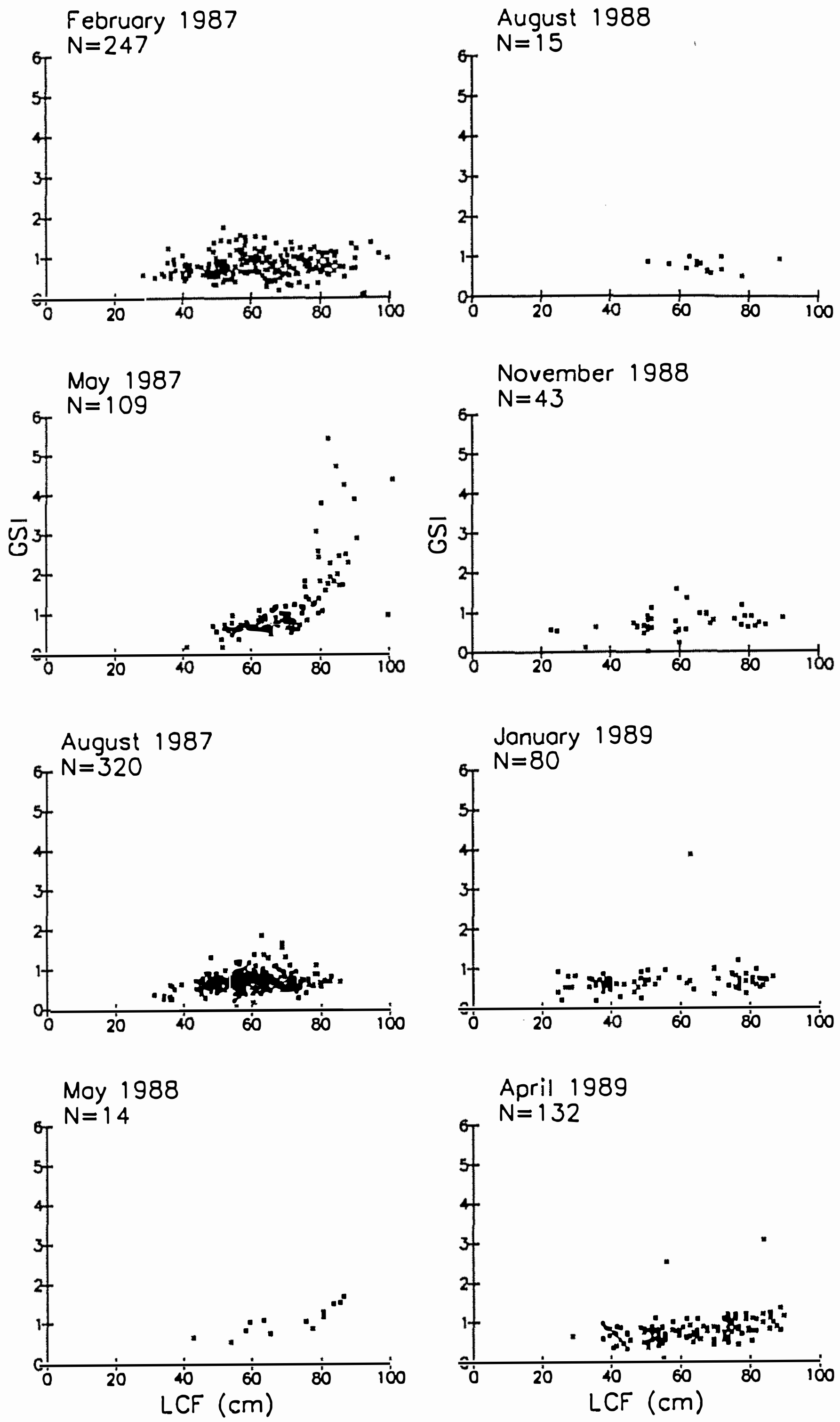
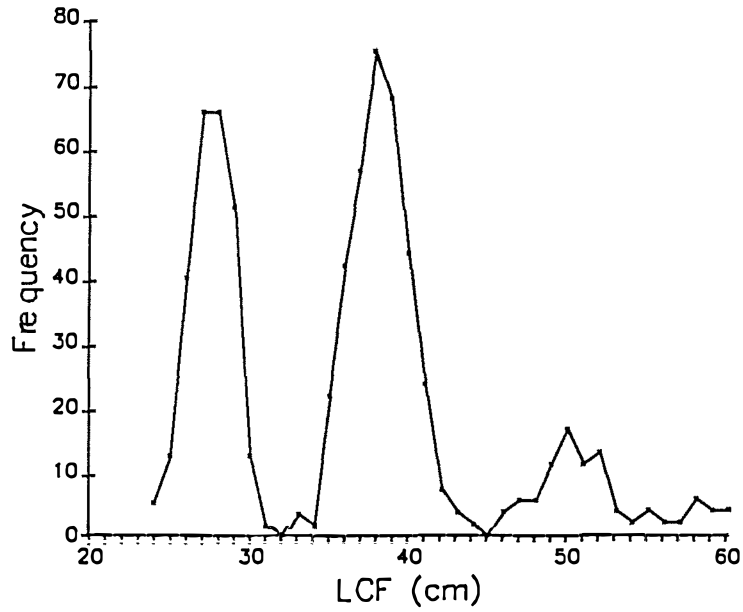


Figure 3.3.4 Relationship between gonosomatic index and length for female gemfish.



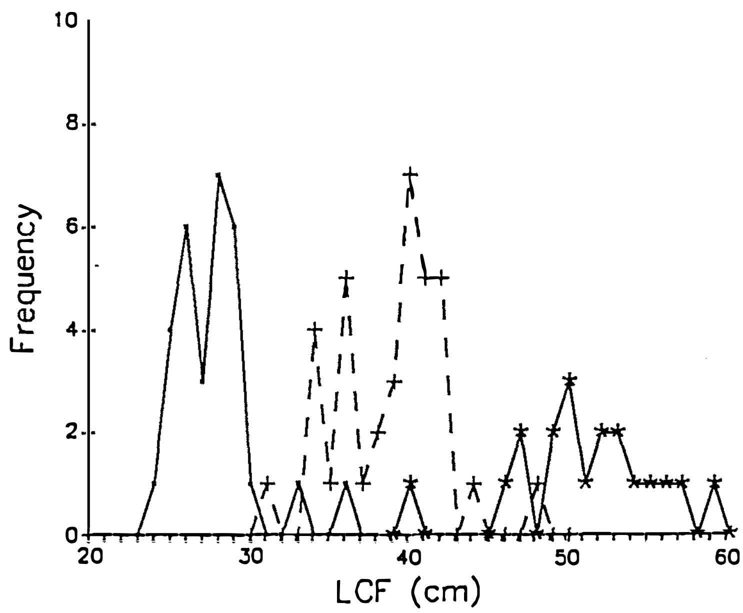


Figure 3.4.5 Comparison of juvenile length frequency distribution (upper) and assigned ages (lower) for the first 3 age groups. (solid line 1s, broken line 2s, solid and * 3s)

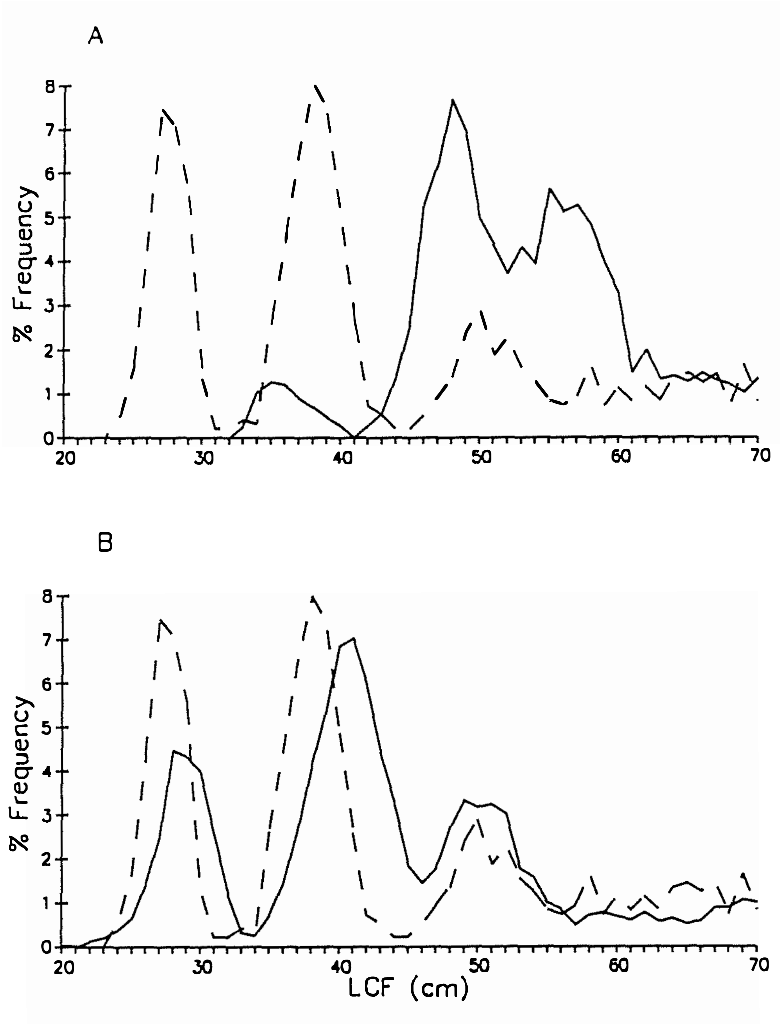


Figure 3.4.6 Comparison of juvenile length frequency distributions, WBS February 1987, (broken line) with NSW fish (solid line) A February and B August. NSW data from K Rowling, NSW FRI.

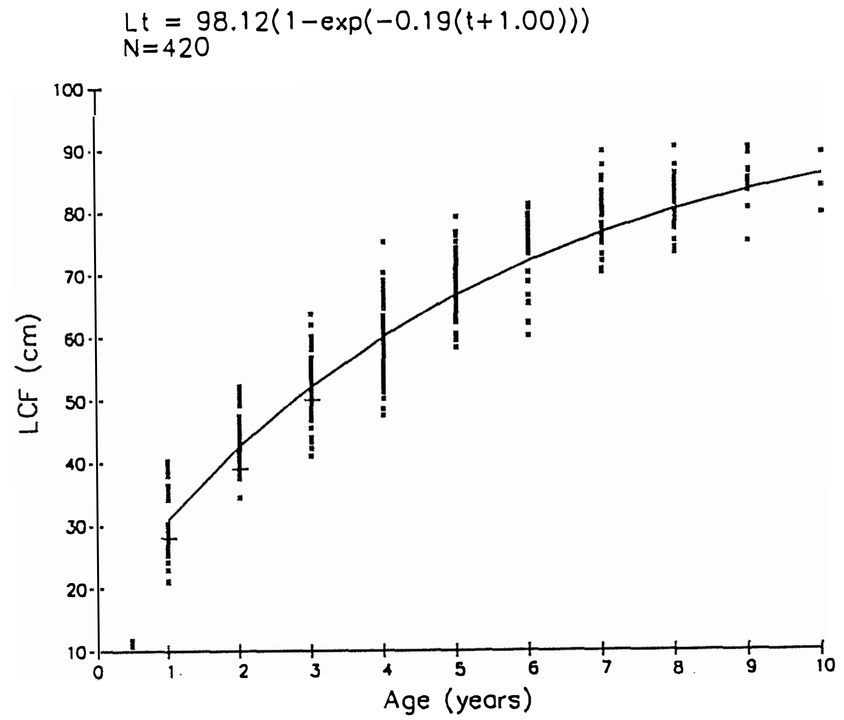


Figure 3.4.7 Von Bertalanffy growth curve for gemfish. - represents mean lengths derived from juvenile length frequency distribution, February 1987.

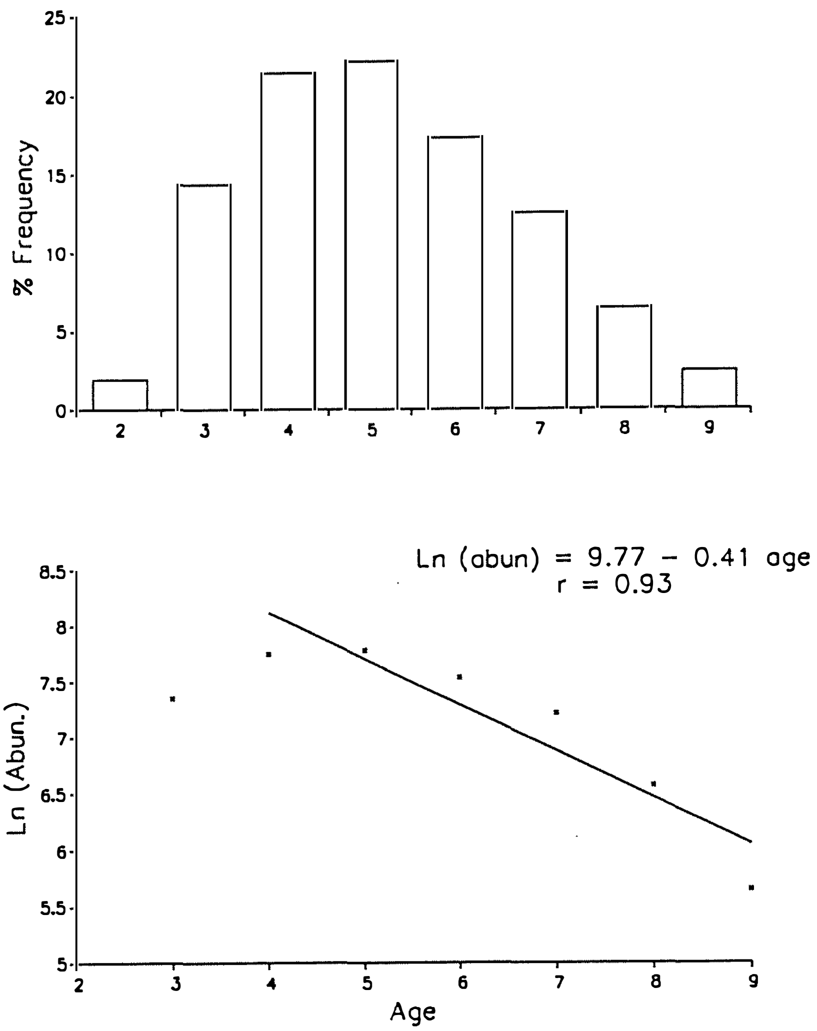


Figure 3.4.8 Percentage age composition and catch curve for gemfish landed at Portland 1988.

The mean length for ages 1-3 derived from the length frequency distribution, described above, are also plotted on this curve giving further confirmation that otolith interpretation was correct.

Length-weight relationships for gemfish were as follows:

Male	$W=8.9E\text{-}3\ L^{2.95}$	$N=272,\ r^2 = 0.94$
Female	$W=9.1E\text{-}3\ L^{2.95}$	$N=725,\ r^2 = 0.95$
Total	$W=7.2E\text{-}3\ L^{3.00}$	$N=1107,\ r^2 = 0.97$

where W is the weight (g) and L is fork length (cm).

Age composition and mortalities

Commercial catches in 1988 were mostly 3 to 8 year old fish (Figure 3.4.8). The instantaneous coefficient of total mortality, Z, estimated from these data was 0.41 (Figure 3.4.8).

F was derived from the ratio of catch to biomass for the period 1987-89. The mean catch (headed and gutted fish), converted to total weight by a factor of 1.30, was 311 tonnes. The mean F (311/1481) was 0.21 and thus M (=Z-F) is of the order of 0.2.

3.5 Blue warehou

Distribution and abundance

Blue warehou, as represented by catches, were not abundant during any survey. Catch rates were low in all surveys and blue warehou were not caught at all in Surveys 6 and 8. They were taken in 20 shots (out of 88 shots) in depths ranging from 153 to 560 m but catches were highest in the 100 to 300 m depth strata. The maximum catch rate was 31 kg/hr in Survey 3 (winter 1987); 5 shots had catch rates from 10 to 20 kg/hr and the remaining were under 10 kg/hr.

Standardised catch rates (kg/km^2) are shown in Table 3.5.1. Blue warehou were relatively more abundant during the winter surveys. Standard errors were large in all cases. Biomass indices (Table 3.5.2) were low with a maximum of 813 (+/- 613) tonnes in winter.

Survey length frequency distributions

Blue warehou ranged in length from 21 to 56 cm LCF and were evenly distributed over this size range (Figure 3.5.1). However, because samples sizes were small it is difficult to draw firm conclusions.

Distinct modes were evident in the size distributions for Surveys 2 and 3 (Figure 3.5.2). In Survey 2 the modes were at 22-25 cm and 28-31 cm. The mode of smaller fish was missing in Survey 3 but there was a clear mode at 31-35 cm LCF.

Commercial length frequency distributions

Size distributions of blue warehou landed at Portland varied considerably between years. In 1987, fish ranged in length from 25 to 56 cm LCF (Figure 3.5.3). The distribution was bi-modal with modes at 33-35 cm and 43-47 cm LCF. A significant proportion of the catch was immature fish. In 1988, fish ranged in length from 25 to 54 cm LCF but the distribution was unimodal with the majority of fish in 40 to 50 cm size classes.

Reproduction

Blue warehou taken during the winter surveys were in spawning condition with individual GSIs of up to 14% recorded. Examination of the relationship between GSI and length for females taken in Surveys 3 and 5, and from commercial samples, indicated that the size at maturity occurs between 40 to 45 cm (Figure 3.5.4).

As a result of only small numbers being taken during surveys, blue warehou were also sampled from commercial landings during 1998 to provide additional information. Mean GSI values for female blue warehou (>40 cm LCF) for the period June to November 1988 are shown in Table 3.5.3. The highest individual values were 12.8% and 13.5% in June and July, respectively. The mean value was highest in July (3.9%), declining through August and September, and lowest in November (0.7%).

These data suggest that blue warehou spawn during winter.

Age and growth

Blue warehou otoliths are ovoid and characterised by a large central opaque centre after which increments are narrowly paced. Ages were assigned by counting assumed annual increments. These were complete translucent zones compared to those increments which were discontinuous, split or irregularly spaced.

Table 3.5.1 Mean catch rates (kg/km2) of blue warehou in western Bass Strait, 1987-1989, by season and 100 m depth strata.
N is the number of shots, SE is the standard error.

	Depth (m)					
	100	**200**	**300**	**400**	**500**	**600**
Summer						
Mean	3.9	0	0	0	0	0
SE	2.5	0	0	0	0	0
N	6	3	7	4	9	6
Autumn						
Mean	19.4	25.8	0	2.3	0	0
SE	12.5	15.1	0	2.3	0	0
N	10	4	8	11	15	11
Winter						
Mean	70.9	136.8	51.8	3.9	1.9	0
SE	70.9	60.5	42.1	3.9	1.9	0
N	2	5	5	9	10	6
Spring						
Mean	0	0	0	0	0	0
SE	0	0	0	0	0	0
N	3	2	2	3	5	*0*

Table 3.5.2. Biomass indices (tonnes) for blue warehou by season 1987-1989.
N is the number of tows, SE is the standard error.

Season	**N**	**Biomass**	**SE**
Summer	29	34	21
Autumn	42	196	108
Winter	31	813	613
Spring	15	0	0

Table 3.5.3 Mean gonosomatic indices (GSI) for female blue warehou (>40cm LCF) sampled from commercial landings. N is the sample size, SD the standard deviation.

		GSI		
Survey	N	Mean	SD	Range
June 88	28	2.63	2.54	0.79-12.79
July 88	40	3.85	2.93	0.52-13.47
August 88	41	3.30	2.70	0.25-10.33
September 88	26	1.74	1.40	0.07-5.56
November 88	10	0.65	0.20	0.40-0.95

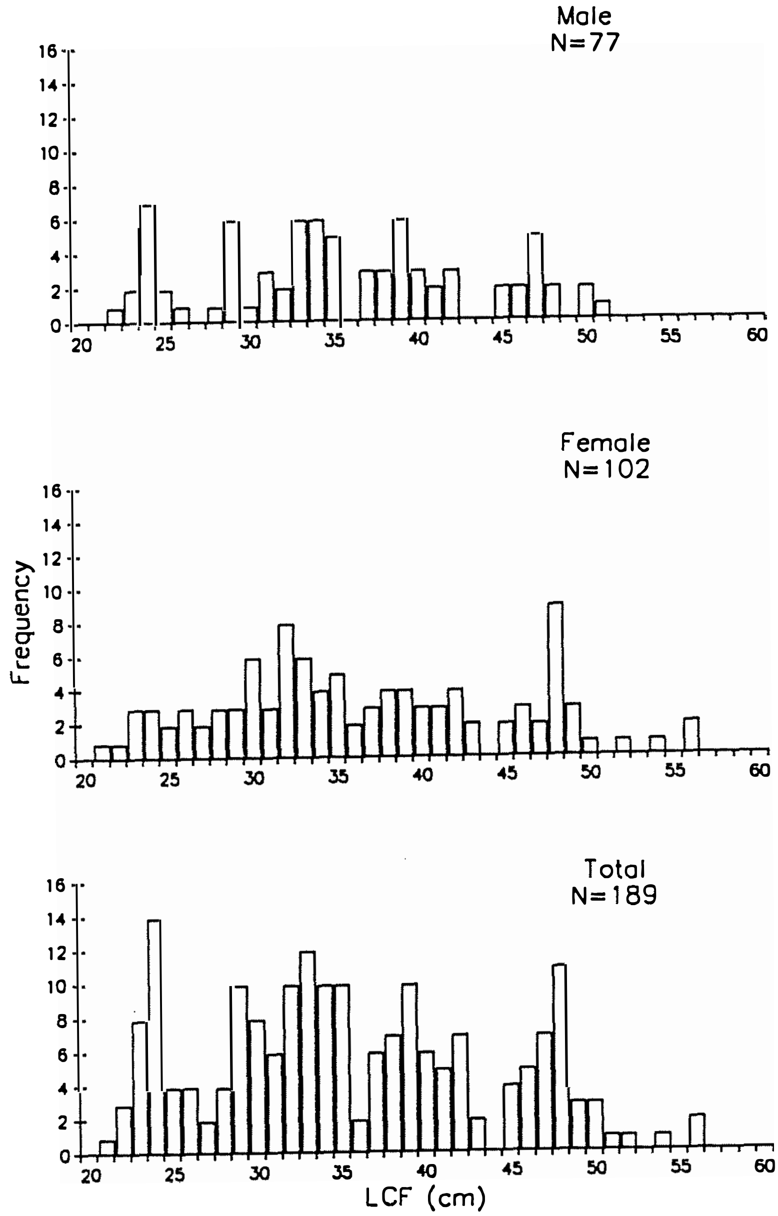


Figure 3.5.1. Length frequency distributions for blue warehou by sex. Surveys 4–8 combined.

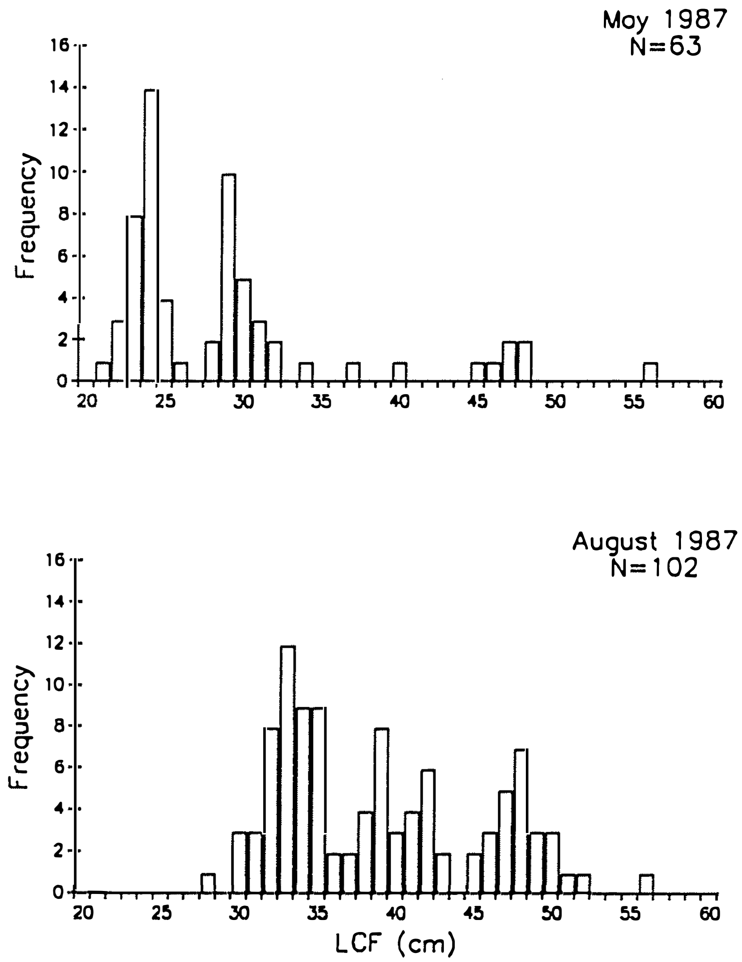


Figure 3.5.2. Length frequency distributions for blue worehou Moy and August 1987 surveys.

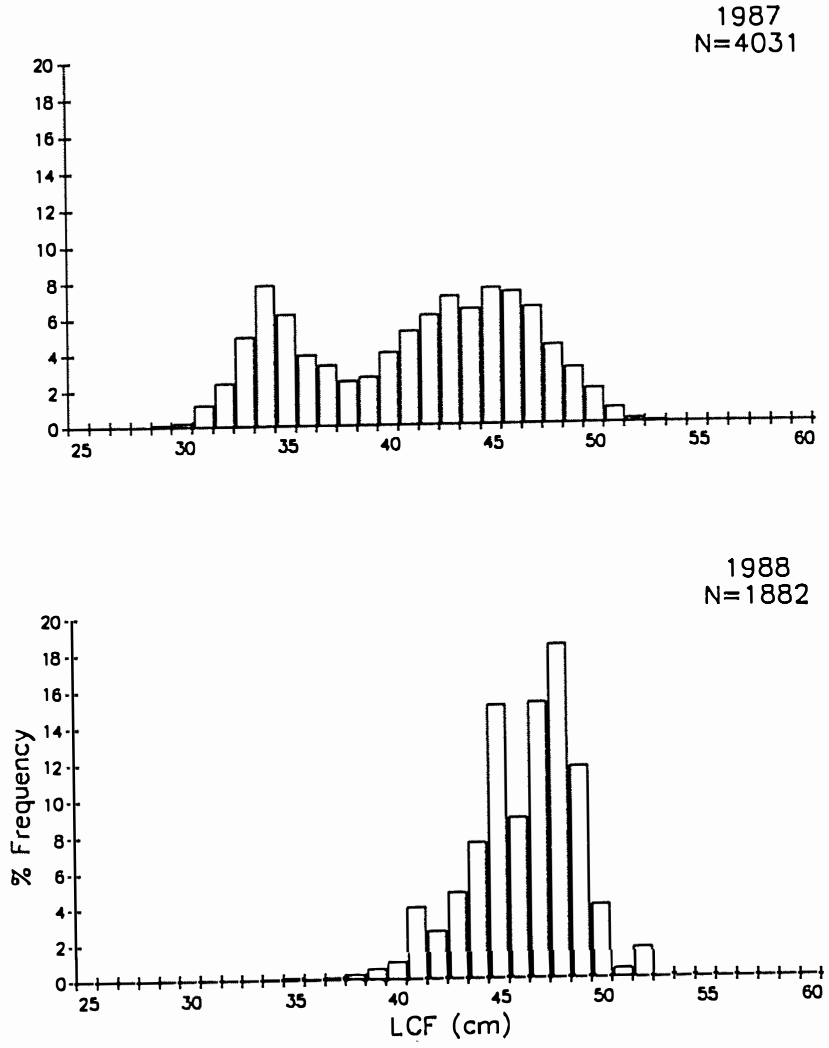


Figure 3.5.3 Percentage length frequency distributions for blue warehou landed at Portland 1987–88.

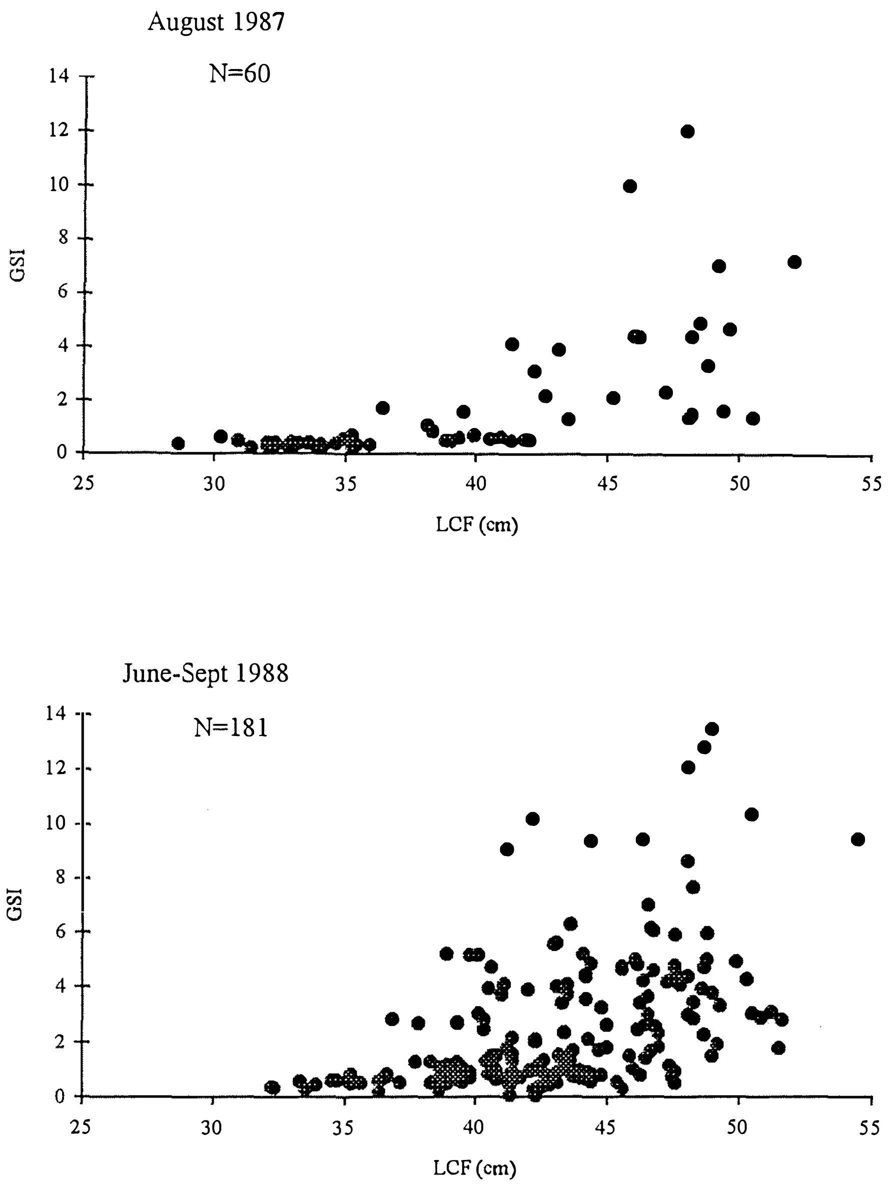


Figure 3.5.4 Relationship between gonosomatic index and length for female blue warehou.

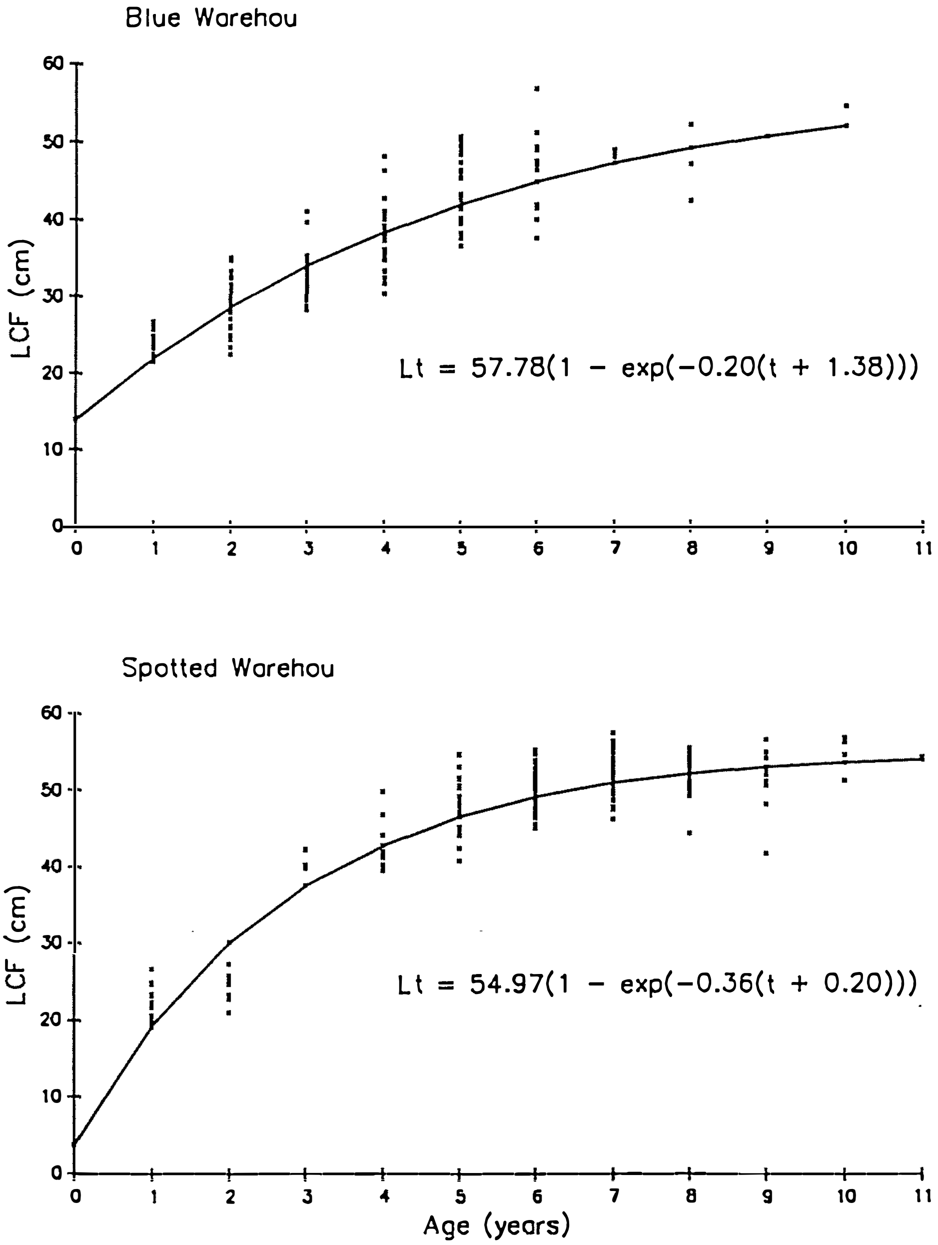


Figure 3.5.3 Von Bertalanffy growth curves for blue and spotted warehou.

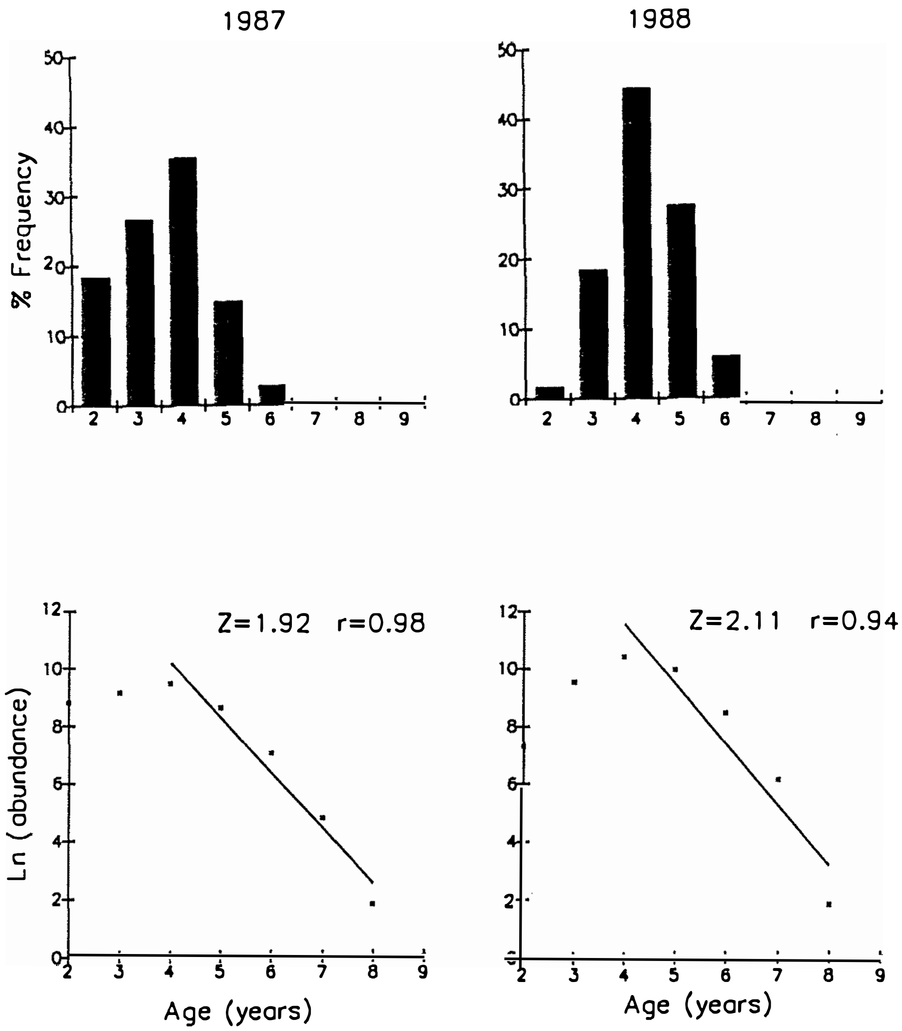


Figure 3.5.6 Age composition and catch curves for blue warehou landed at Portland, 1987–88.

Because of the seasonal nature of catches it was not possible to validate ages for adults using methods such as marginal increment analysis. However, assigned ages were consistent with juvenile modes seen in size distributions. Fish in the 22-25 cm were about one year of age, whereas those in the 28-31 cm size classes were two years.

Growth was rapid with a maximum age of 10 years for blue warehou. There were few fish older than 7 years in samples (Figure 3.5.5).

Parameters of the von Bertalanffy growth curve (Figure 3.5.5) were:

K	L_{inf}	t_o
0.20	57.78	-1.38

The length-weight relationship is given by:

$W = 0.03\ L^{2.89}$ $\qquad$ $N=282,\ r^2 = 0.99$

where L is the length in centimetres and W the weight in grams.

Age composition and mortalities

The age composition of blue warehou landed at Portland in 1987 and 1988 are shown in Figure 3.5.6. (Note: the sample size of blue warehou taken during surveys was small) In 1987, catches were dominated by age groups 2-5, and in 1988 by 3-5s.

Blue warehou were fully recruited at age group 4. The instantaneous coefficient of total mortality, Z, estimated from catch curve analysis for age groups 4-8, was 1.9 and 2.1 respectively (Figure 3.5.6).

3.6 Spotted warehou.

Distribution and abundance

Spotted warehou abundance was distinctly seasonal with catches and catch rates considerably higher during the winter surveys, particularly Survey 3. In these surveys, spotted warehou were taken in depths from 195 to 761 m but catches were highest in the 200 to 300 m depth strata. Spotted warehou were represented in all but one shot in the 200 to 400 m strata. The maximum catch rate was 1750.5 kg/hr but in 50 % of shots catch rates were less than 20 kg/hr.

In all other surveys catches were low. Of the 27 shots in which spotted warehou were taken, catch rates of between 10 to 20 kg/hr occurred four times but the remaining were less than 7 kg/hr. Spotted warehou were caught in only one shot in the spring survey.

Mean standardised catch rates were highest in winter and very low in the other seasons (Table 3.6.1). Reflecting catches, spotted warehou were most abundant in the 200 m and 300 m depth strata and to a lesser extent the 400 m depth strata. CVs were high in all seasons and depth strata (for example, 68 to 100% during winter).

Analysis of variance was not undertaken for spotted warehou because of the distinct seasonality. Survey data were pooled by season. The estimated biomass was 11,628 tonnes in winter and less than 250 tonnes in the other surveys (Table 3.6.2). CVs were high in all surveys (67%, 54%, and 47% for summer, autumn and winter respectively). The biomass index for spring is based on too few data to be reliable.

Survey length frequency distributions and sex ratios

Spotted warehou ranged in length from 22 to 64 cm LCF. During Surveys 3 (August 1987) and 5 (August 1988), most fish were in the 45 to 55 cm size classes (Figure 3.6.1). The numbers of each sex caught was variable between surveys. In Survey 5, almost 3 females were caught for every male. During this survey, females were relatively more abundant in the larger size classes.

In Surveys 4 to 8, a mode of juvenile fish was evident (Figure 3.6.2). There was a distinct modal progression with fish ranging in size from 18-23 cm in autumn 1988, increasing to 28-35 cm in autumn 1989.

In Survey 3, there was a weak relationship between depth and size, with larger fish being relatively more abundant at depth (Figure 3.6.3).

Commercial length frequency distributions

Spotted warehou sampled from commercial landings at Portland varied in length from 31 to 58 cm. Distributions were uni-modal and most fish were between 45 and 55 cm LCF in 1987 and 40 and 50 cm in 1988 (Figure 3.6.4)

Reproduction

GSIs for spotted warehou were high during the winter surveys with individual values of over 20% for females and 16% for males. The relationship between GSI and length indicates that sexual maturity occurs at about 40 cm for females and males (Figure 3.6.5).

Mean GSI values (+/- 1 s.d) for females over 40 cm were 10.61% (+/- 5.54) and 9.80% (+/- 2.81) for Surveys 3 and 5, respectively. The mean GSI for males over 40 cm (Survey 5) was 10.56% (+/-4.3).

Age and growth

Spotted warehou otoliths were similar to those of blue warehou with a large opaque centre followed by narrow increments. Interpretation of the spotted warehou otoliths was more difficult than those for blue warehou due to the fine increments at the edge of the otolith.

The otoliths from fish sampled from the juvenile mode at 23-27 cm (Survey 5) were characterised by a translucent edge with no evidence of other increments. The otoliths of juvenile spotted warehou (of a similar size) sampled from the Gulf of St Vincent, South Australia also showed this pattern. These results indicate that spotted warehou of this size were about one year of age. The modal progression described above also indicates that fish are about 30-34 cm LCF at two years of age. Otoliths from fish of this size had one completed translucent increment and a translucent edge.

Similarly to blue warehou, growth of spotted warehou was rapid. The maximum age recorded was 11 years. Parameters of the von Bertalanffy growth curve (Figure 3.5.5) were :

K	L_{inf}	t_o
0.36	54.97	-0.20

The length/weight relationship is given by:

$$W = 0.004\ L^{3.40} \qquad N=272,\ r^2 = 0.99$$

where L is the length in centimetres and W the weight in grams.

Age composition and mortalities

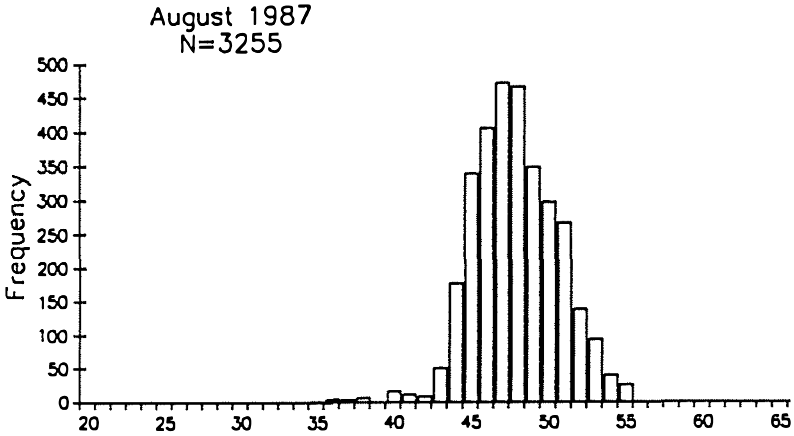
The age composition of August 1987 survey catch (used because of the greater number of spotted warehou caught during Survey 3 compared to the others) and the commercial catch were similar (Figure 3.6.6). In both, the dominant age groups were 6 and 7.

Table 3.6.1 Mean catch rates (kg/km2) of spotted warehou in western Bass Strait, 1987-1989. by season and 100 m depth strata. N is the number of shots, SE is the standard erro

	Depth (m)							
	100	200	300	400	500	600	700	800
Summer								
Mean	26.7	0	5.5	0	2.6	0	0	0
SE	18.6	0	5.5	0	2.6	0	0	0
N	6	3	7	4	9	6	5	7
Autumn								
Mean	37.8	6.4	6.8	15.4	14.5	4.0	0	0
SE	24.3	4.6	3.5	8.3	11.3	1.2	0	0
N	10	4	8	11	15	11	5	16
Winter								
Mean	135.8	2533.6	6121.7	679.1	112.9	72.3	4.7	0
SE	135.8	2428.8	4185.6	545.4	85.6	54.4	4.7	0
N	2	5	5	9	10	6	5	5
Spring								
Mean	7.9	0	0	0	0	0	0	0
SE	7.9	0	0	0	0	0	0	0
N	3	2	2	3	5	0	3	3

Table 3.6.2. Biomass indices (tonnes) for spotted warehou by season 1987-1989. N is the number of tows, SE is the standard error.

Season	**N**	**Biomass**	**SE**
Summer	40	239	160
Autumn	64	392	210
Winter	40	11628	5315
Spring	18	68	68



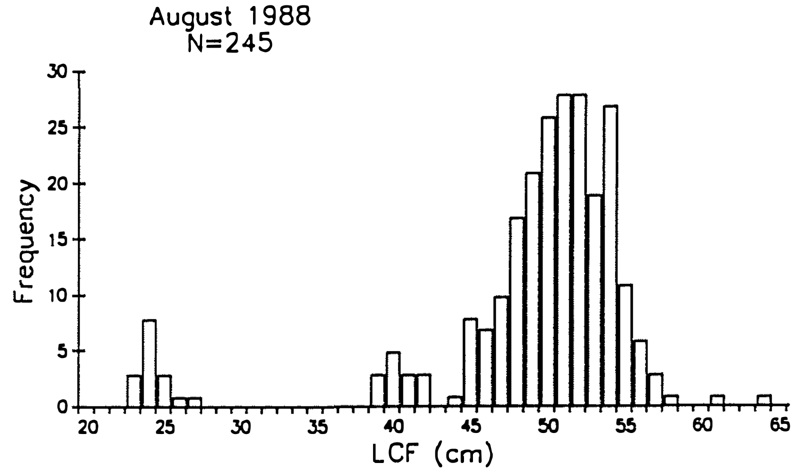


Figure 3.6.1 Length frequency distributions for spotted warehou by survey, western Bass Strait.

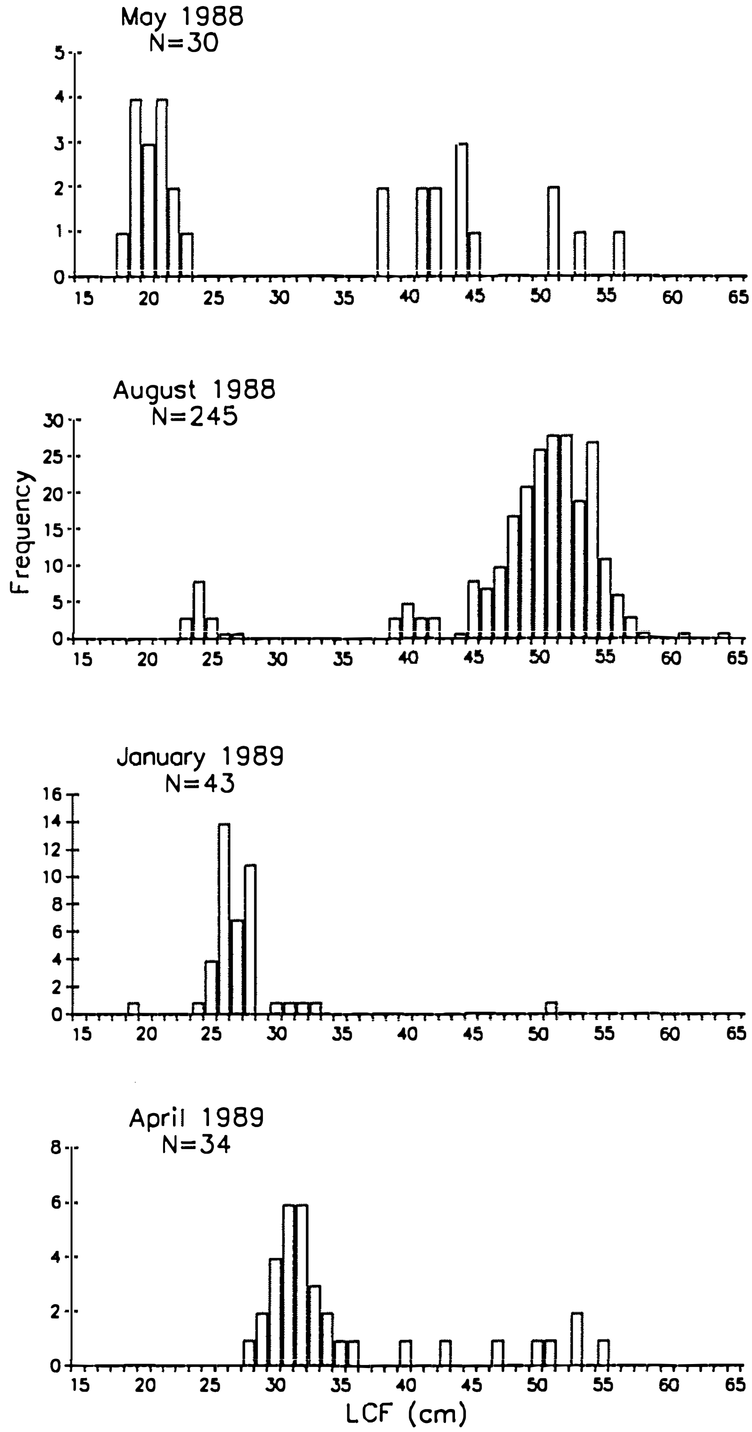


Figure 3.6.2 Length frequency distributions for spotted warehou by survey, western Bass Strait 1988/89.

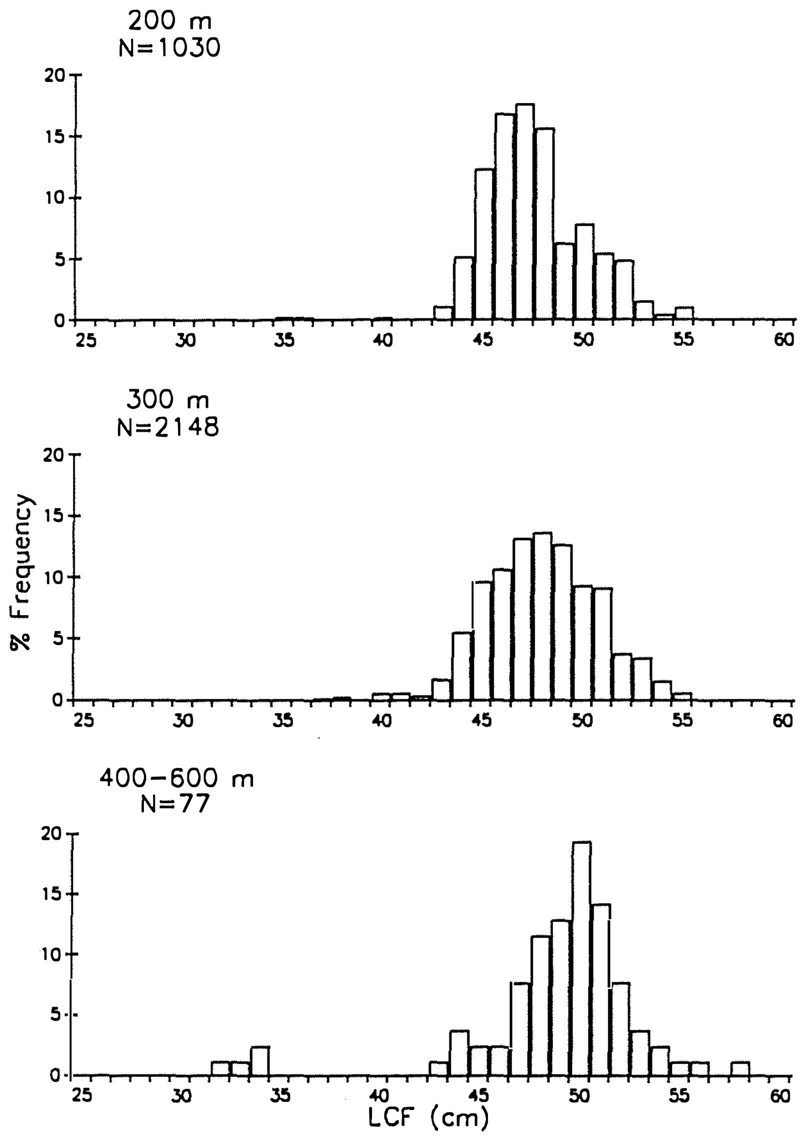


Figure 3.6.3 Percentage length frequency distributions for spotted warehou by depth, Survey 3 August 1987.

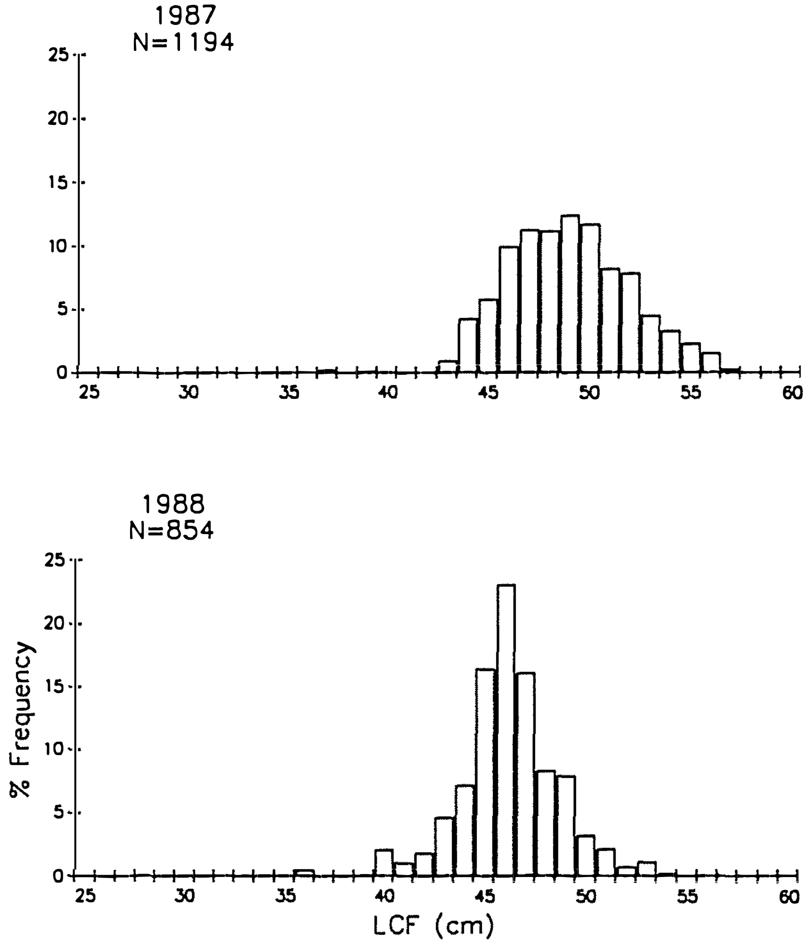
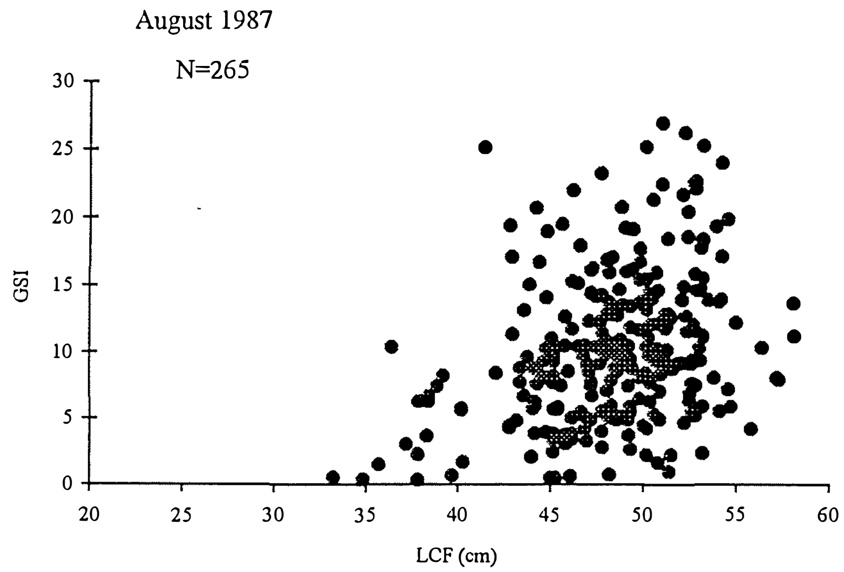


Figure 3.6.4 Percentage length frequency distributions for spotted warehou landed at Portland 1987–88.



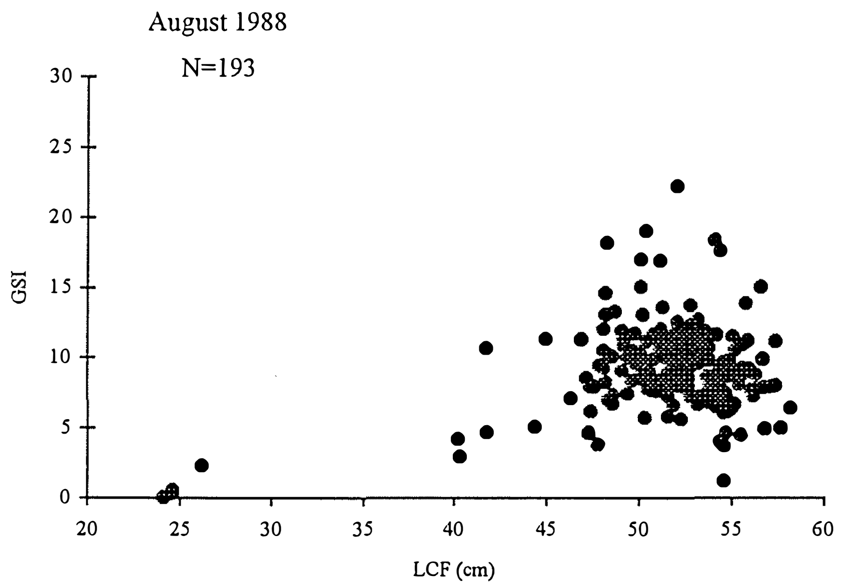


Figure 3.6.5 Relationship between gonosomatic index and length for female spotted warehou.

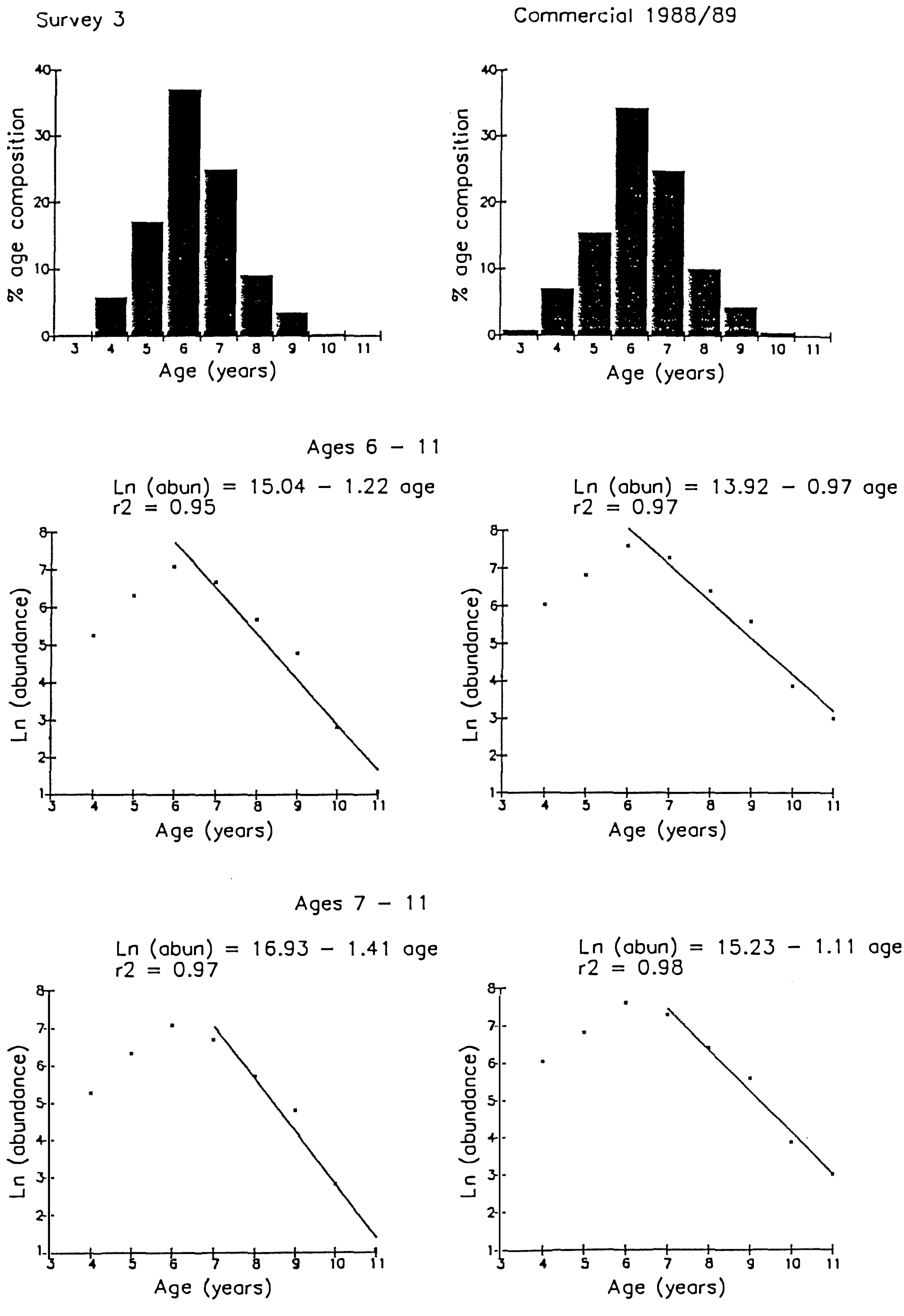


Figure 3.6.6. Age composition and catch curves for spotted warehou sampled from Survey 3 and commercial landings 1988/89

The instantaneous coefficient of total mortality, Z, estimated from catch curves (Figure 3.6.6), however, was higher for Survey 3 compared to the commercial sample. This was the case regardless of the age groups used in the analysis. Spotted warehou were fully recruited at age 6. Using age groups 6-11, Z was estimated to be 1.22 and 0.97 for survey and commercial samples, respectively. For age groups 7-11, Z was higher at 1.41 and 1.11.

Although considerable uncertainty surrounds the estimated biomass of spotted warehou in western Bass Strait, the relatively low catch of spotted warehou (about 200 tonnes per annum during the study period) indicates that the fishing mortality is probably low.

These results suggest that natural mortality for this species is high.

3.7 Jackass morwong

Distribution and abundance

Jackass morwong were taken in depths ranging from 121 to 381 m and were present in 28 of the 57 shots in these depths. They were caught in 22 of 35 shots in the 100-200 m depth strata. The highest catch rate was 165 kg/hr in 180 m during Survey 7 (summer 1988/89). Generally, catches were highest in the shallower shots except for Survey 2 (autumn 1987) when the highest catch rate (95 kg/hr) was in 318 m.

Standardised catch rates (kg/km^2) are shown in Table 3.7.1 for each depth stratum and season. Due to the absence of shots in some depth/season cells, analysis of variance was not undertaken. However, the results indicate that the abundance was greatest during spring and summer in the 100-199m depth strata. They also suggest a seasonal depth relationship with jackass morwong being relatively more abundant in deeper water during autumn and winter. Coefficients of variation (CVs) were relatively high ranging from 25 to 64% in the 100 m depth stratum.

Jackass morwong is predominantly a continental shelf species. The 100m depth stratum covered a considerably larger area than other depth strata but because of the limited trawl ground the number of sites was relatively low. Because of the potential bias due to this biomass indices were not calculated.

Survey length frequency distributions and sex ratios

Percentage length frequency distributions (catch adjusted) for each survey (excluding Survey 8 during which few jackass morwong were taken) are shown in Figure 3.7.1. Fish ranged in size from 21 to 46 cm LCF. Generally, distributions were uni-modal with most fish between 30 and 40 cm LCF. The mode occurred between 33 and 35 cm except Survey 1, (February 1987) and Survey 3 (August 1987) where it was 36-37 cm

LCF. However, the sample size for the latter was small. Fish less than 25 cm LCF were uncommon in all surveys.

Female jackass morwong were relatively more abundant than males in the larger size classes. Females ranged in length from 25-46 and males from 21-43 cm LCF (Figure 3.7.2). More males were caught than females. Sex ratios varied from 1.4:1 to 0.31:1 females to males and was 0.44:1 overall. The difference was significant for Surveys 6 and 7 where there were over three times as many males as females (Table 3.7.2).

Commercial length frequency distributions

Percentage length frequency distributions for jackass morwong landed at Beachport, Portland and Geelong are shown in Figure 3.7.3. Fish caught in WBS ranged in length from 20 to 47 cm LCF, with the majority in the 30-40 cm size classes. There were relatively few fish less than 25 cm LCF in all samples. Fish landed at Beachport were on average slightly bigger (mode 35-38 cm) than those landed at Portland and Geelong (mode 32-35 cm). Also, fish sampled at Beachport and Portland were generally larger in 1988, compared to 1987, with relatively more greater than 40 cm LCF.

Reproduction

Gonosomatic indices for female jackass morwong were highest during the summer surveys, with individual GSIs up to 12% recorded (Figure 3.7.4). GSIs were lowest during late autumn and winter. The relationship between GSI and length indicates that all fish above 25 cm LCF were mature (Figure 3.7.4). For the summer surveys, the mean GSIs for females were 4.56% and 4.99% for 1987 and 1988, respectively (Table 3.7.3). GSIs during the winter and May surveys were low, with mean values less than 1%. Females appeared to be maturing during late spring (mean GSI 1.9%).

GSIs for males tracked those of females with individual GSIs up to 8.5% recorded during summer 1989. Mean values were less than 0.5% in the autumn and winter surveys.

Age and Growth

Jackass morwong otoliths were similar to those examined from the east coast. Fish ranged in age from 3 to 16. Parameters of the von Bertalanffy growth curve (Figure 3.7.5) for combined sexes, due to the preponderance of males in samples, were:

K	L_{inf}	t_0
0.12	46.90	-3.98

Table 3.7.1 Mean catch rates (kg/km2) of jackass morwong in western Bass Strait, 1987-1989, by season and 100 m depth strata. N is the number of shots, SE is the standard error.

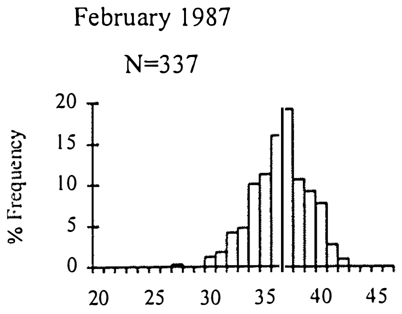
	Depth (m)		
	100	**200**	**300**
Summer			
Mean	1013.9	6.4	0
SE	253.2	6.6	0
N	6	3	7
Autumn			
Mean	188.5	13.7	134.2
SE	121.4	8.6	127.1
N	10	4	8
Winter			
Mean	0	141.5	15.5
SE	0	67.1	10.3
N	2	5	5
Spring			
Mean	653.4	5.9	0
SE	262.3	5.9	0
N	3	2	2
Overall			
Mean	472.8	56.7	52.3
SE	127.0	28.5	46.3
N	21	14	22

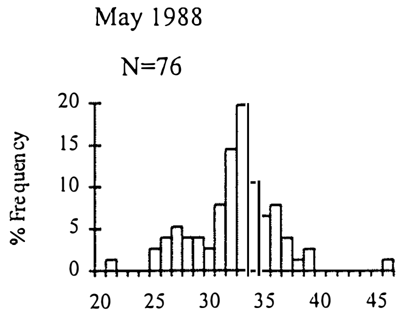
Table 3.7.2 Proportion of female jackass morwong by survey, western Bass Strait 1988/89. N is the sample size, Prop F the proportion of females. P is the probability of sex ratios varying from 1:1 (based on Chi-square tests).

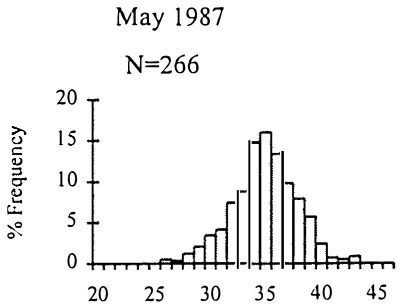
Survey	N	Prop F	*P*
4	71	0.57	$0.25<p<0.50$
5	78	0.53	$0.50<p<0.75$
6	205	0.24	$p<0.001$
7	393	0.24	$p<0.001$
Overall	755	0.30	$p<0.001$

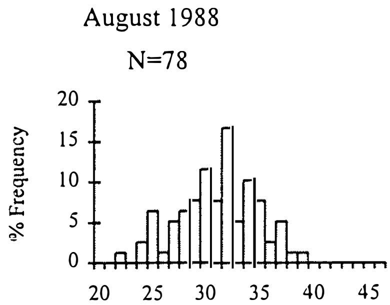
Table 3.7.3 Mean gonosomatic indices (GSI) for jackass morwong by survey. N is the sample size, SD the standard deviation.

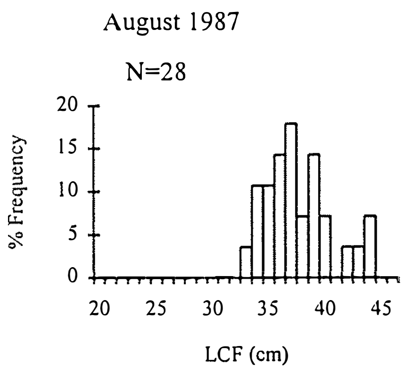
	Male				Female			
Survev	**N**	**Mean**	**SD**	**Range**	**N**	**Mean**	**SD**	**Range**
1 (Feb 87)					17	4.56	1.29	2.46-8.67
2 (May 87)					55	0.65	0.28	0.19-2.00
3 (Aug 87)					16	0.84	0.30	0.12-1.28
4 (May 88)	30	0.36	0.19	0.05-1.00	41	0.84	0.22	0.51-1.72
5 (Aug 88)	37	0.20	0.21	0.02-1.16	41	0.68	0.22	0.22-1.15
6 (Nov 88)	156	0.63	0.30	0.03-2.01	48	1.88	0.92	0.07-4.41
7 (Jan 89)	247	1.94	1.21	0.07-8.52	53	4.99	1.82	1.03-12.08
8 (Apr 89)	2	0.37	-	0.17-0.58	6	1.32	0.94	0.28-3.03











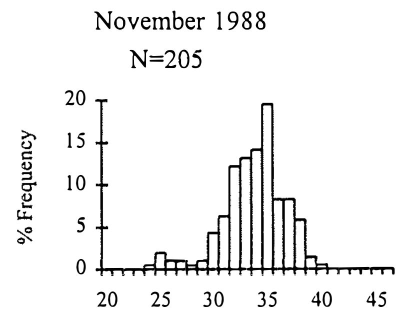
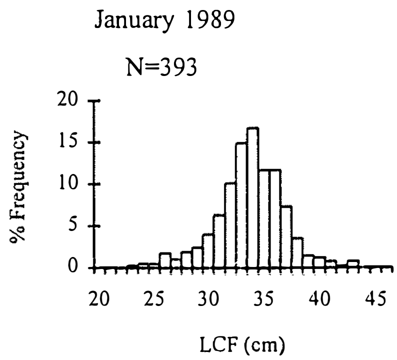


Figure 3.7.1 Percentage length frequency distributions for jackass morwong by survey, westerm Bass Strait.



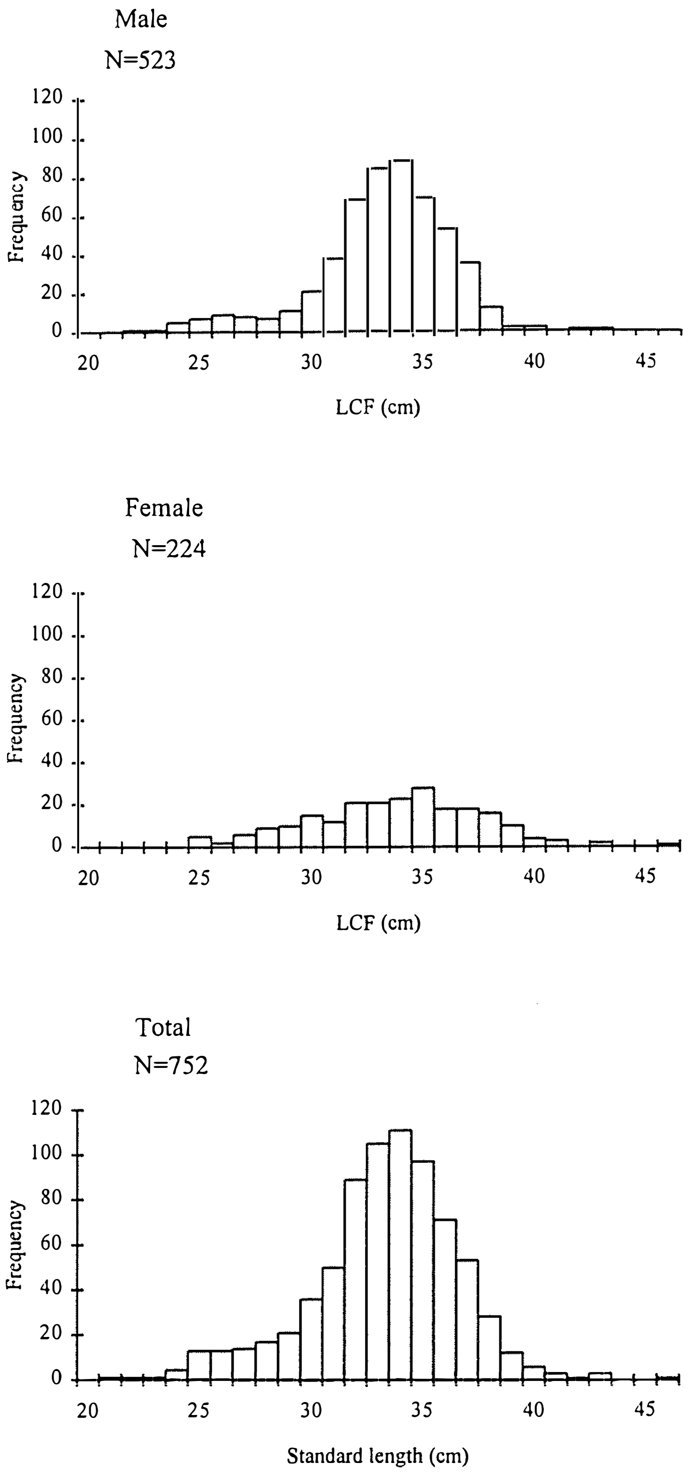


Figure 3.7.2 Length frequency distributions by sex for jackass morwong, western Bass Strait, Surveys 4-8.

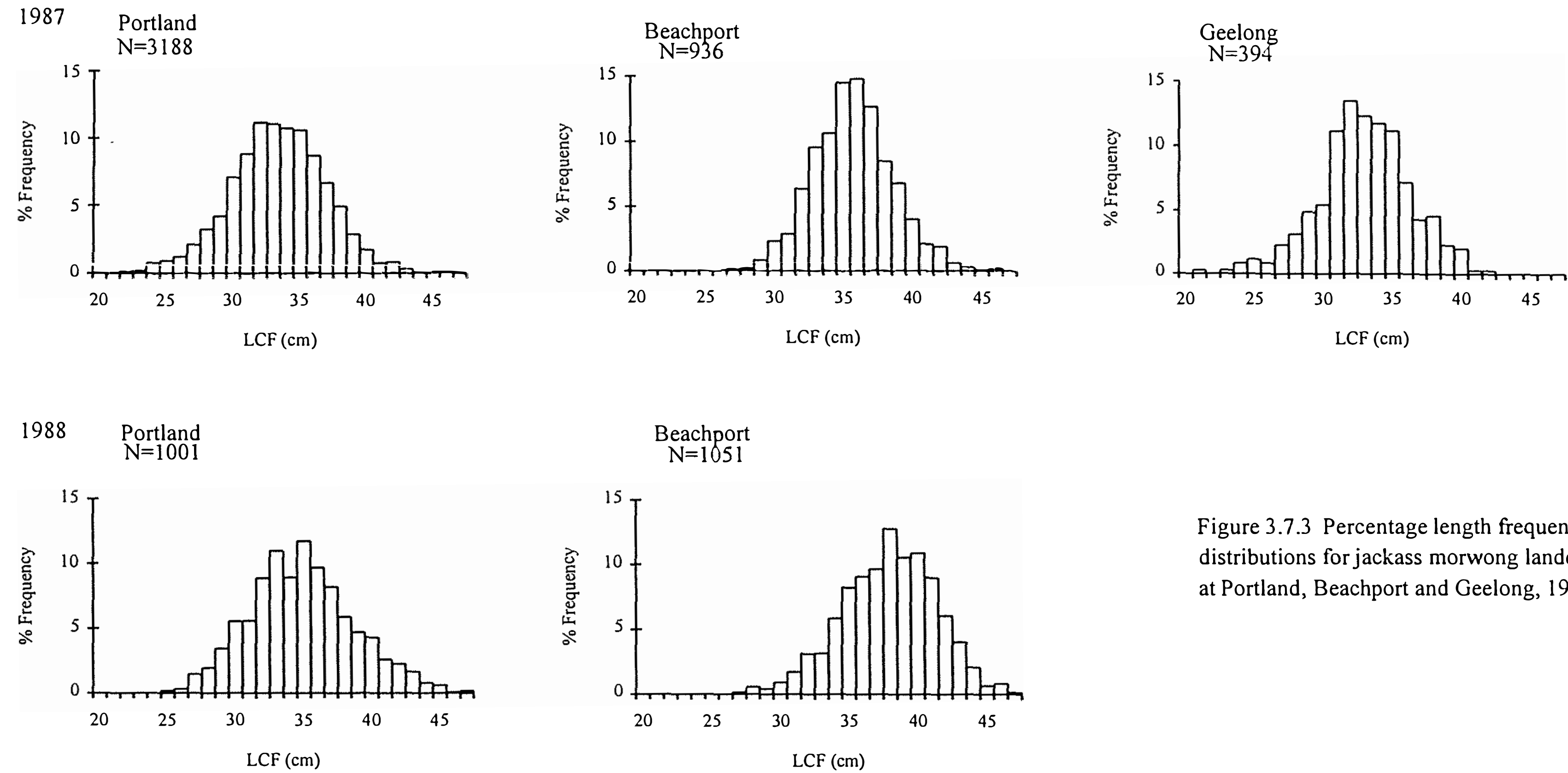


Figure 3.7.3 Percentage length frequency distributions for jackass morwong landed at Portland, Beachport and Geelong, 1987-88.

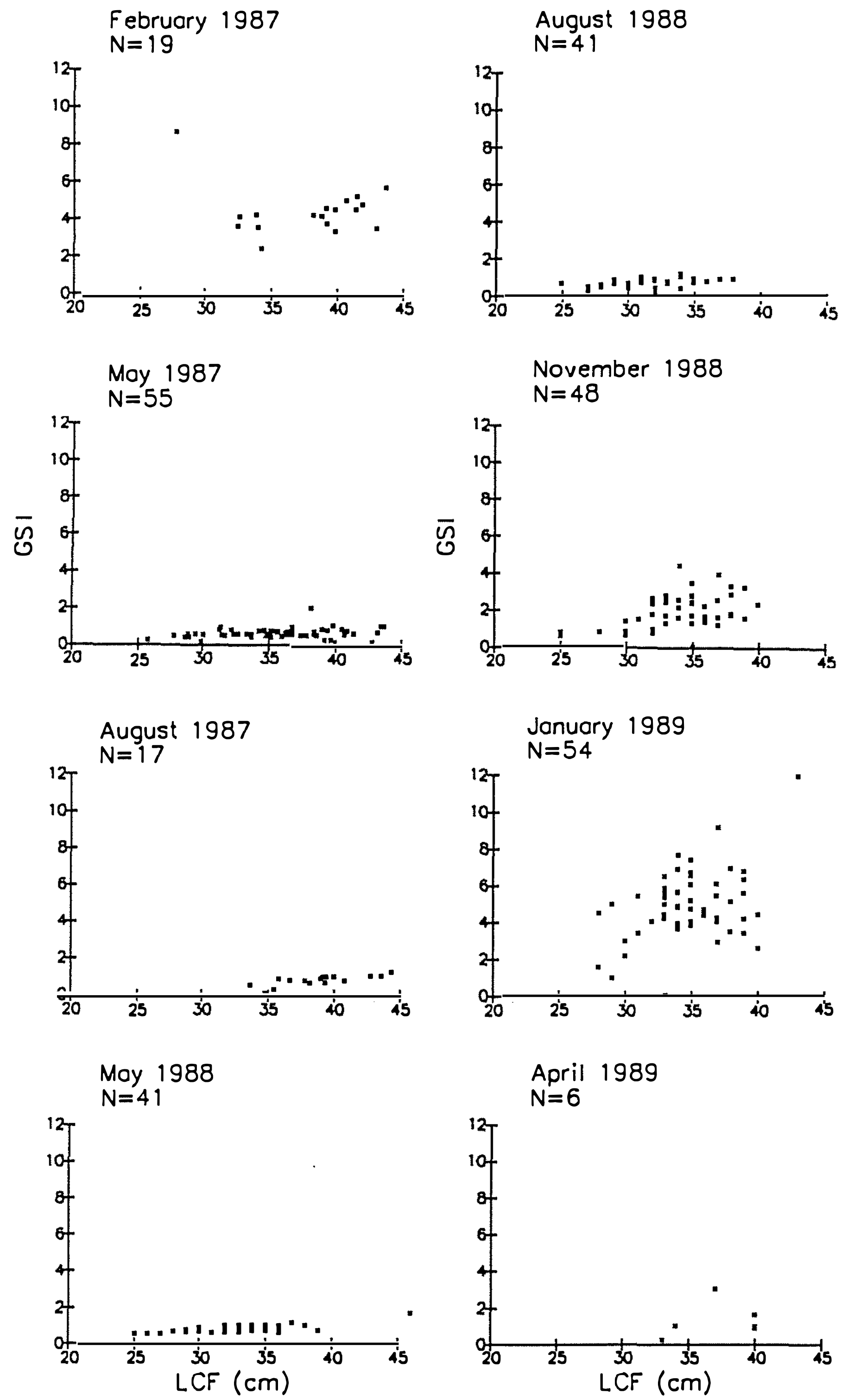


Figure 3.7.4 Relationship between gonosomatic index and length for female jackass morwong.

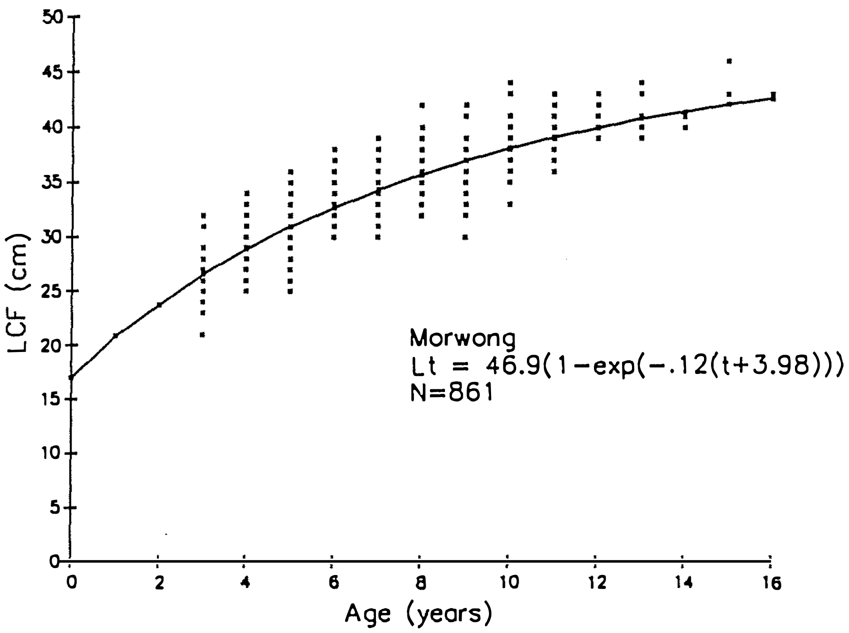


Figure 3.7.5 Von Bertalanffy growth curve for jackass morwong, sampled from western Bass Strait, 1987–89.

The length-weight relationships are given by:

male	$W = 0.064\ L^{2.67}$	N=624, $r^2 = 0.91$
female	$W = 0.041\ L^{2.79}$	N=272, $r^2 = 0.95$
total	$W = 0.049\ L^{2.75}$	N=904, $r^2 = 0.93$

3.8 Ling

Distribution and abundance

Ling were very widely distributed and occurred over broad depth range, from 132 to 915 m. They were present in 150 of the 227 shots in the 100 to 900 m depth strata but were most common in the 300-700 m depth strata (117 out of 129 shots). Unstandardised catch rates were relatively low with 84% less than 20 kg/hr. The highest catch rate was 120.4 kg/hr.

Generally, mean standardised catch rates (kg/km^2) were highest in the 400 to 600 m depth strata (Table 3.8.1), except in summer (500 to 700 m). Catch rates were also highest during summer surveys. CVs were lower during the autumn and winter surveys ranging from 19 to 31% in the main depth strata, compared to 24 to 58% in spring and summer. There were no significant year or season effects but there was a significant depth effect in the 300 to 700 m depth strata (Table 3.8.2). There was a significant year season depth interaction.

Seasonal biomass indices for ling ranged from 848 tonnes in autumn to 1129 tonnes in summer (Table 3.8.3). CVs varied considerably between seasons from 12% in autumn to 30% in spring. Overall, ignoring season, the biomass index was 1055 tonnes.

Survey length frequency distributions and sex ratios

Ling ranged in length from 16 to 118 cm TL but most were in the 55 to 95 cm length classes (Figure 3.8.1). Sample sizes in each survey were relatively small and it was, therefore, difficult to determine whether there were seasonal differences. However, although fish less than 50 cm were poorly represented in all surveys, there was an indistinct mode between 15 and 35 cm TL during the autumn and winter surveys. Most of these fish were caught in the shallower depths (Figure 3.8.2). Females were relatively more abundant in the larger size classes (>90 cm TL) but sample sizes were small (Figure 3.8.3).

Table 3.8.1 Seasonal abundance (kg/km2) of ling in western Bass Strait, 1987-1989. by 100 m depth strata. N is the number of shots, SE is the standard error.

	Depth (m)								
	100	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**
Summer									
Mean	14.4	27.6	18.1	65.0	271.2	408.2	159.9	55.7	0
SE	8.7	21.9	6.7	34.3	66.3	231.3	52.3	27.4	0
N	6	3	7	4	9	6	5	7	8
Autumn									
Mean	9.6	7.8	54.1	215.0	155.3	108.6	49.6	20.8	1.8
SE	2.4	3.0	17.3	48.0	28.9	32.8	19.2	10.6	1.8
N	10	4	8	11	15	11	5	16	14
Winter									
Mean	56.5	6.2	100.6	220.2	192.7	101.8	64.2	3.1	3.2
SE	44.7	2.8	46.9	44.0	60.6	24.5	10.0	3.1	1.1
N	2	5	5	9	10	6	5	5	8
Spring									
Mean	0	5.9	23.6	98.4	257.0	*257.0*	74.8	11.8	0
SE	0	5.9	23.6	56.8	99.3	*99.3*	43.2	6.8	0
N	3	2	2	3	5	*0*	3	3	2
Overall									
Mean	14.1	11.2	50.4	181.6	204.7	185.0	88.5	24.9	1.6
SE	5.2	4.8	13.6	27.1	27.4	66.0	21.0	8.6	1.1
N	21	14	22	27	39	23	18	31	32

Table 3.8.2. Analysis of variance of log(catch rate+1) for ling, 300 to 700 m depth strata.

Source	**DF**	**SS**	**MS**	**F Value**	**P**
Year	2	9.95	4.98	2.19	0.1174
Season	3	17.61	5.87	2.59	0.0578
Depth	4	70.93	17.73	7.81	0.0001
Year*Season	2	0.13	0.06	0.03	0.9718
Year*Depth	8	13.35	1.67	0.74	0.6601
Season*Depth	11	37.62	3.42	1.51	0.1423
Year*Season*Depth	5	32.86	5.57	2.9	0.0179
Residual	93	211.09	2.27		

Table 3.8.3. Biomass indices (tonnes) for ling by season 1987-1989.
N is the number of tows, SE is the standard error.

Season	**N**	**Biomass**	**SE**
Summer	55	1229	269
Autumn	94	848	100
Winter	55	964	140
Spring	23	976	293
Overall	227	1055	97

Table 3.8.4 Proportion of female ling by survey, western Bass Strait 1988/89.
N is the sample size, Prop F the proportion of females. P is the probability of sex ratios varying from 1:1(based on Chi-square tests).

Survey	N	Prop F	*P*
4	99	0.53	$0.50<p<0.75$
5	129	0.43	$0.10<p<0.25$
6	80	0.54	$0.50<p<0.75$
7	104	0.50	ns
8	93	0.63	$0.05<p<0.10$
Overall	505	0.52	$0.50<p<0.75$

Table 3.8.5 Mean gonosomatic indices (GSI) for ling by survey. Males and females >60 cm TL. N is the sample size, SD the standard deviation.

	Male GSI				Female GSI			
Survey	N	Mean	SD	Range	N	Mean	SD	Range
1 (Feb 87)	-	-	-	-	87	0.49	0.28	0.04-2.27
2 (May 87)	-	-	-	-	57	0.42	0.30	0.04-1.28
3 (Aug 87)	-	-	-	-	69	1.23	1.47	0.01-4.54
4 (May 88)	27	0.13	0.14	0.03-0.74	37	0.40	0.28	0.04-1.05
5 (Aug 88)	55	0.14	0.09	0.03-0.68	39	0.99	1.06	0.03-4.87
6 (Nov 88)	37	0.08	0.03	0.01-0.16	42	0.56	0.63	0.05-3.88
7 (Jan 89)	44	0.07	0.05	0.01-0.24	42	0.50	0.22	0.01-0.95
8 (Apr 89)	24	0.08	0.05	0.01-0.17	41	0.51	0.25	0.04-1.93

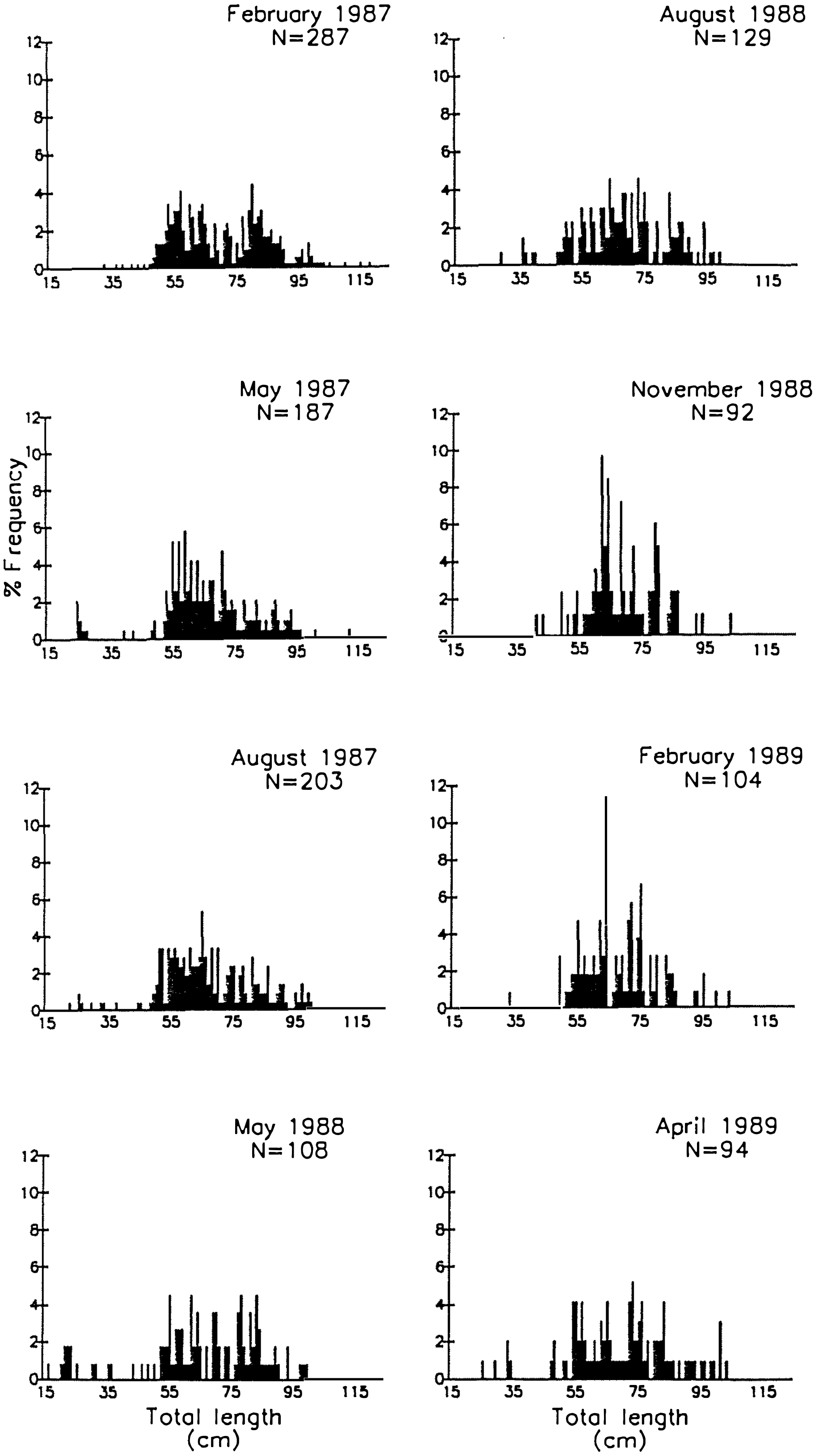


Figure 3.8.1 Percentage length frequency distributions for ling by survey, western Bass Strait.

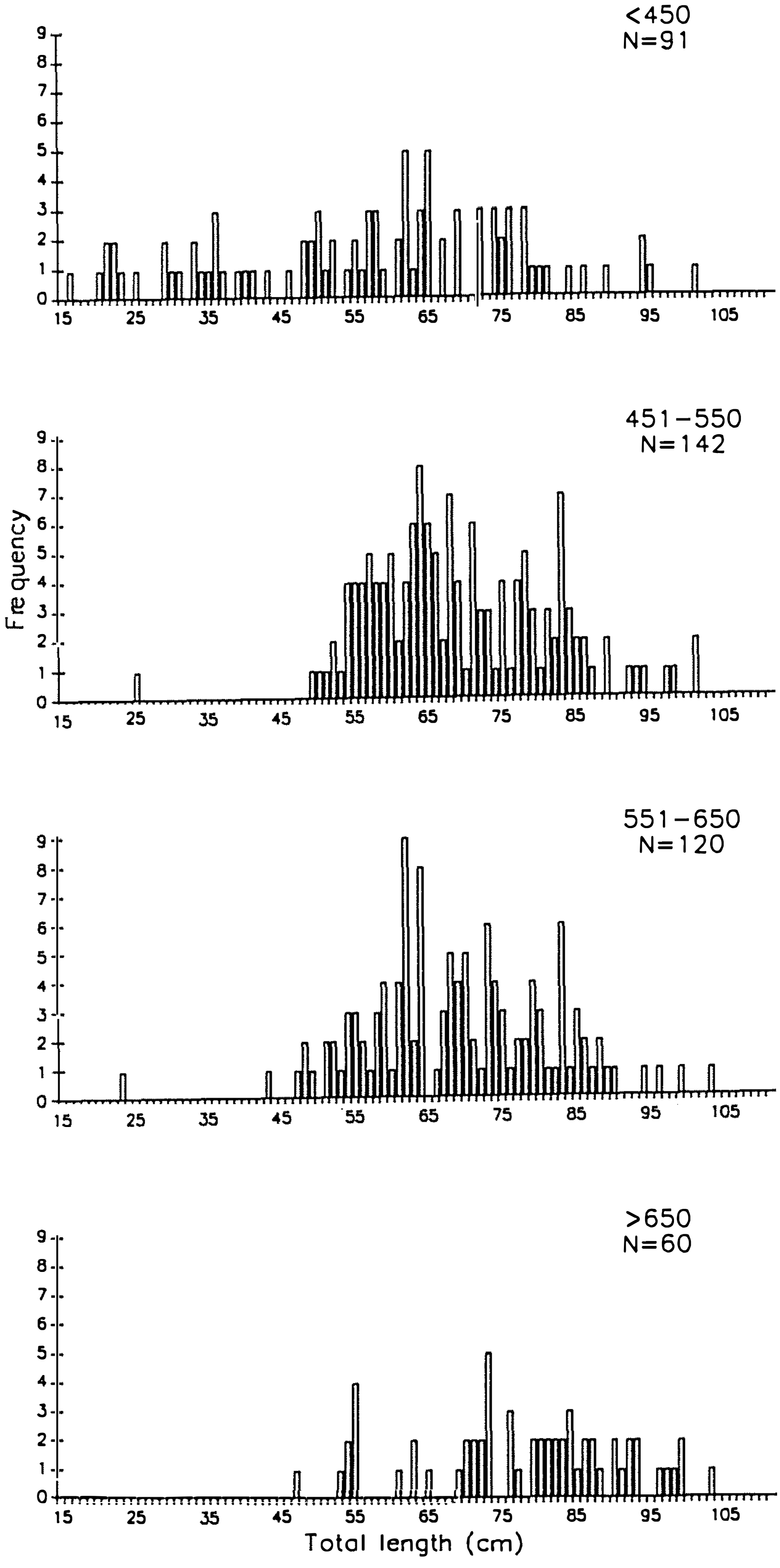


Figure 3.8.2 Length frequency distributions for ling by depth, western Bass Strait.

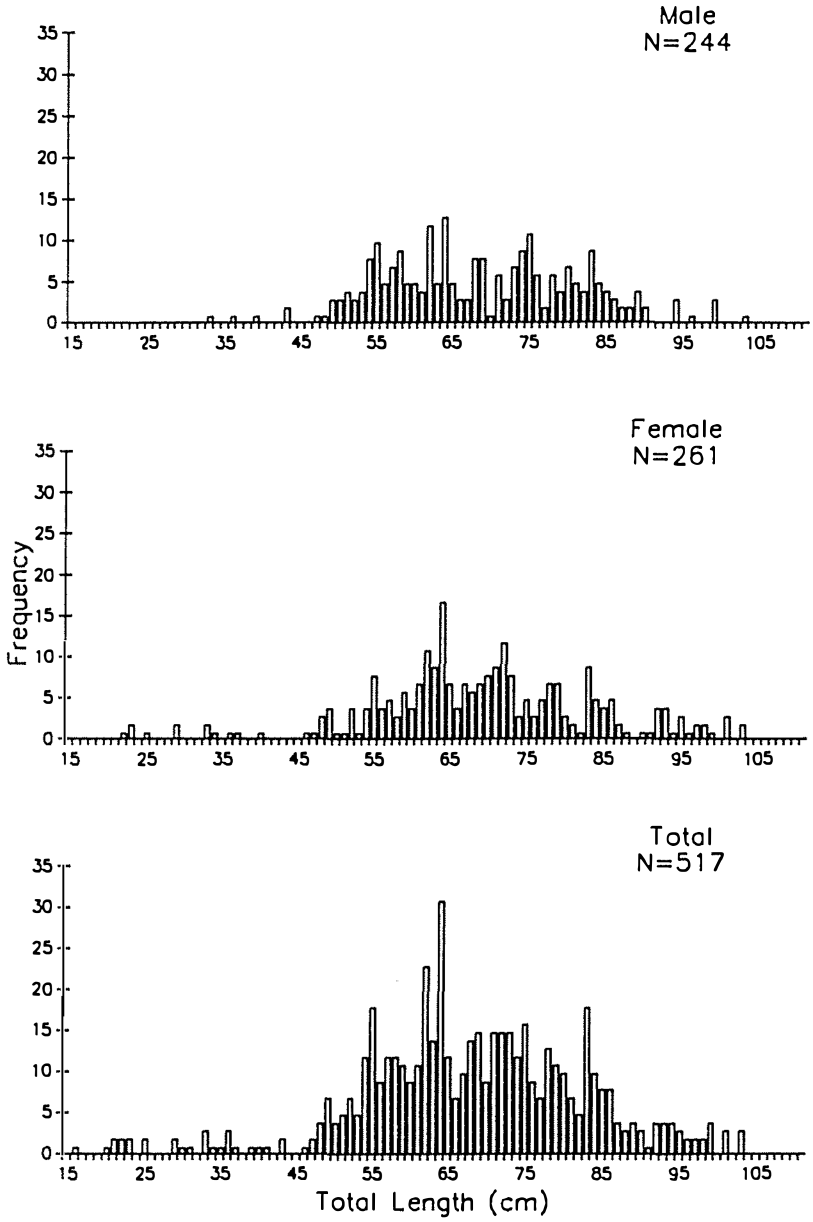


Figure 3.8.3 Length frequency distributions for ling by sex, western Bass Strait. Survey 4-8 combined.

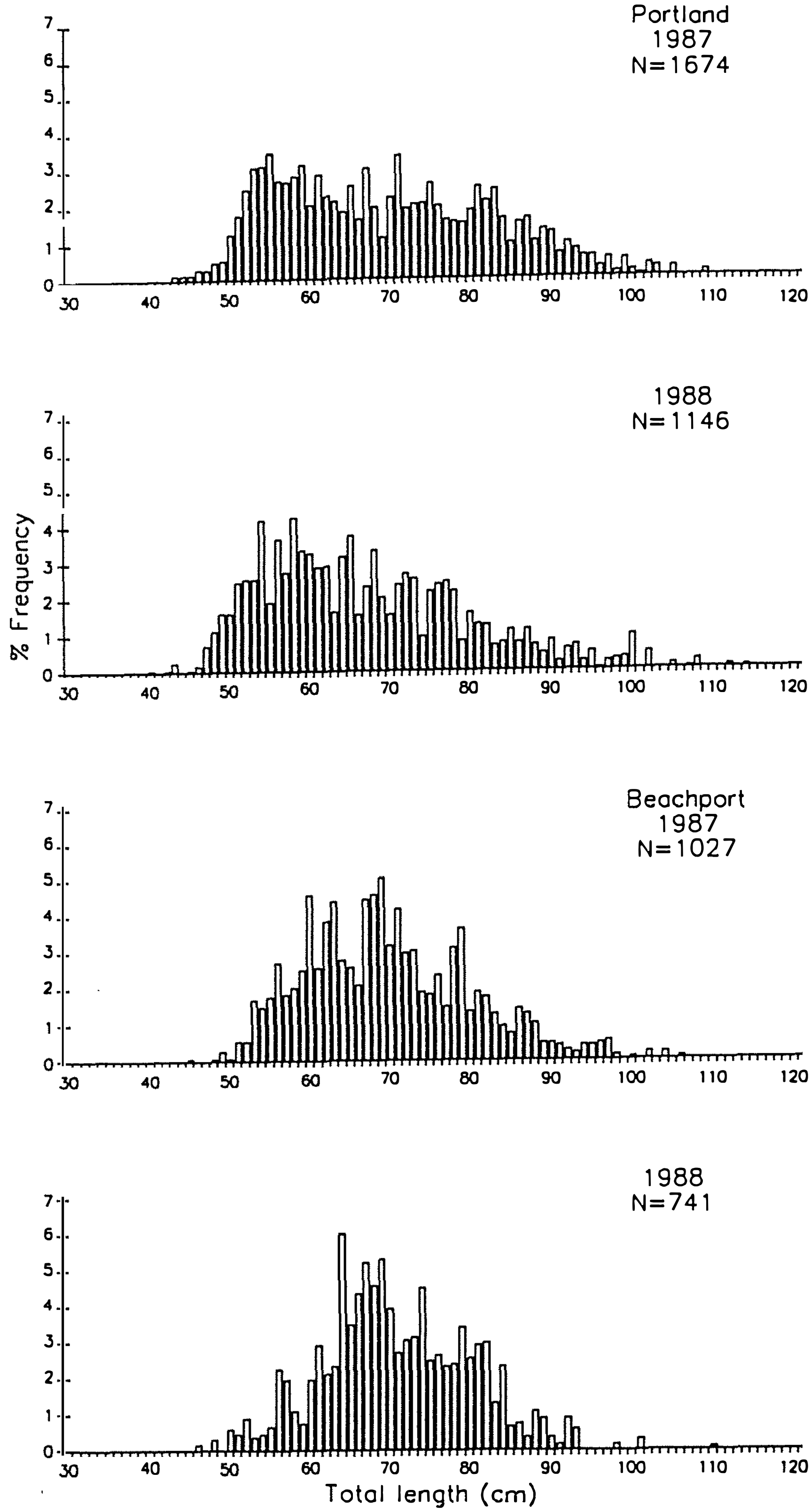


Figure 3.8.4 Percentage length frequency distributions for ling landed at Portland and, Beachport, 1987-88.

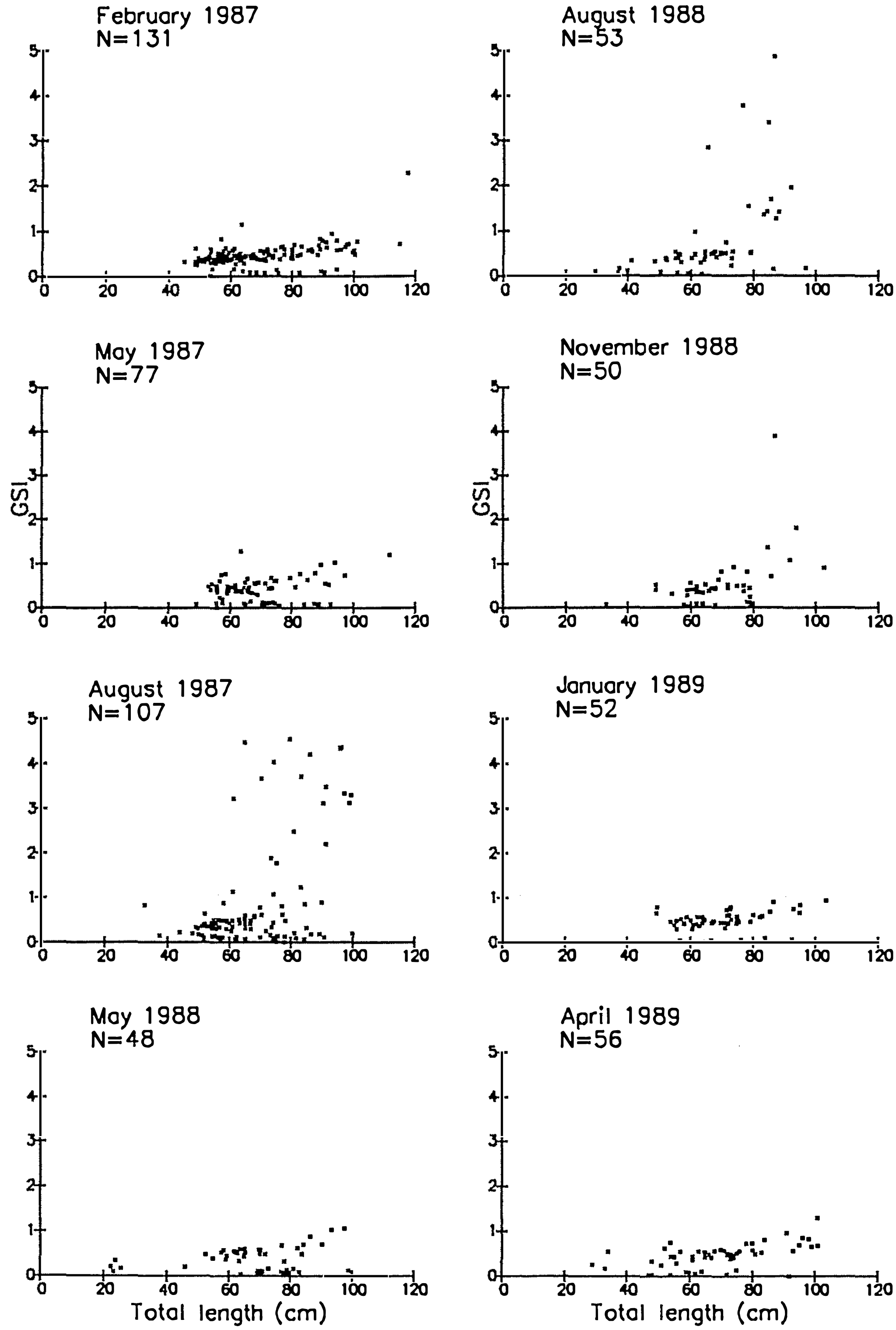


Figure 3.8.5 Relationship between gonosomatic index and length for female ling.

Overall, more females were caught than males. However, this was not significantly different from 1:1, either overall or for individual surveys.

Commercial length frequency distributions

Percentage length frequency distributions for ling landed at Portland and Beachport are shown in Figure 3.8.4. Fish landed at Portland ranged in length from 32 to 117 cm TL but most were 50 to 100 cm. There were relatively fewer large fish (> 80cm) in 1988 samples.

Ling landed at Beachport, in 1987 and 1988, ranged in length from 46 to 110 cm TL. The distributions were different from ling sampled at Portland being composed predominantly of fish in the middle size classes (55-90 cm). There were relatively fewer small fish (<60cm) and large fish (>80cm).

Reproduction

Examination of the relationship between GSI and length for female ling indicates that fish mature at about 60 cm TL (Figure 3.8.5). For males it was not clear with little variation in GSI for all size classes.

GSIs for female ling were highest in the winter surveys with individual GSIs up to 5% Table 3.8.5). There were also relatively high individual values for ling caught during the spring survey. This suggests that in WBS the main spawning period for ling is winter/spring. For males, however, there was little variation between surveys. The highest individual GSI was 0.74%.

Length-weight relationships

The relationship between length (cm) and weight (g) for all fish sampled was:

$$W = 0.0028 \times L^{3.15} \qquad n = 1167, r^2 = 0.98$$

Length-weight relationships for each sex were:

males

$$W = 0.0028 \times L^{3.15} \qquad n = 500, r^2 = 0.97$$

females

$$W = 0.0032 \times L^{3.12} \qquad n = 574, r^2 = 0.96$$

3.9 Ocean perch

Distribution and abundance

Ocean perch catches were low but they were widely distributed, occurring over broad depth range, from 180 to 970 m. They were present in 140 of the 227 shots in the 100 to 900 m depth strata but were most common in the 300-700 m depth strata (114 out of 129 shots). Unstandardised catch rates were low with 90% less than 20 kg/hr. The highest catch rate was 49.3 kg/hr.

Generally, mean standardised catch rates (kg/km^2) were highest in the 500 to 700 m depth strata (Table 3.9.1). Apart from the 700 m depth stratum, catch rates were lowest during the winter surveys. In the main depth strata, CVs were variable, lowest during the autumn surveys ranging from 13 to 26% compared to 25 to 60% during the other seasons. There was no significant year effect but there were significant depth and season effects in the 300 to 800 m depth strata (Table 3.9.2). There were no significant interactions.

Seasonal biomass indices for ocean perch ranged from 513 (tonnes) in winter to 972 tonnes in summer (Table 3.9.3). CVs were relatively low ranging from 13% in autumn to 21% in spring. Overall, ignoring season, the biomass index was 720 tonnes.

Survey length frequency distributions and sex ratios

Ocean perch ranged in length from 7 to 48 cm TL. Each distribution comprised several modes but the relative height and position varied (Figure 3.9.1). Apart from spring samples, all distributions had a mode between 35 and 45 cm TL. Small fish were relatively more abundant in the summer surveys. In Surveys 1-3, there is an indication of a modal progression of small fish (<15 cm TL). These results suggest that recruitment of ocean perch probably occurs during summer.

There was a distinct size depth relationship with smaller fish more abundant in the shallower depths (Figure 3.9.2).

Commercial length frequency distributions

Percentage length frequency distributions for ocean perch landed at Portland, Beachport and Geelong are shown in Figure 3.9.3. Fish ranged in length from 14 to 46 cm TL.

In 1987, the distributions of fish sampled from landings at Portland and Beachport (combined) and Geelong were broad and flat with most fish between 20 and 40 cm. There were relatively more small fish in the Geelong samples.

Table 3.9.1 Seasonal abundance (kg/km2) of ocean perch in western Bass Strait, 1987-1989. by 100 m depth strata. N is the number of shots, SE is the standard error.

	Depth (m)								
	100	200	300	400	500	600	700	800	900
Summer									
Mean	5.9	35.4	21.3	72.8	170.4	291.3	173.5	21.9	6.4
SE	5.9	29.7	5.2	23.9	52.9	72.9	63.9	18.1	6.4
N	6	3	7	4	9	6	5	7	8
Autumn									
Mean	1.2	11.8	9.0	57.9	181.5	135.0	111.2	46.4	0
SE	1.2	6.8	4.2	10.0	46.9	18.0	20.8	13.2	0
N	10	4	8	11	15	11	5	16	14
Winter									
Mean	0	2.4	5.6	40.6	54.9	260.5	78.4	0	15.3
SE	0	2.4	5.6	12.5	19.9	65.5	38.6	0	15.3
N	2	5	5	9	10	6	5	5	8
Spring									
Mean	7.9	5.9	11.8	31.5	200.6	*200.6*	39.4	15.7	0
SE	3.9	5.9	0	18.2	68.0	*68.0*	22.7	9.1	0
N	3	2	2	3	5	*0*	3	3	2
Overall									
Mean	3.4	12.7	12.4	51.4	148.9	208.5	107.4	30.4	5.4
SE	1.8	6.7	2.8	7.1	22.3	29.5	23.1	8.5	4.1
N	21	14	22	27	39	23	18	31	32

Table 3.9.2. Analysis of variance of log(catch rate+1) for ocean perch 300 to 800 m depth strata.

Source	**DF**	**SS**	**MS**	**F Value**	**P**
Year	2	4.46	2.23	1.20	0.3034
Season	3	31.49	10.50	5.67	0.0012
Depth	5	197.44	39.49	21.32	0.0001
Year*Season	2	6.02	3.01	1.62	0.2014
Year*Depth	10	15.95	1.59	0.86	0.5716
Season*Depth	14	41.17	2.94	1.59	0.0925
Year*Season*Depth	6	5.25	0.87	0.47	0.8279
Residual	117	216.72	1.85		

Table 3.9.3. Biomass indices (tonnes) for ocean perch by season 1987-1989. N is the number of tows, SE is the standard error.

Season	N	**Biomass**	SE
Summer	55	972	144
Autumn	94	714	90
Winter	55	513	86
Spring	23	792	173
Overall	227	720	56

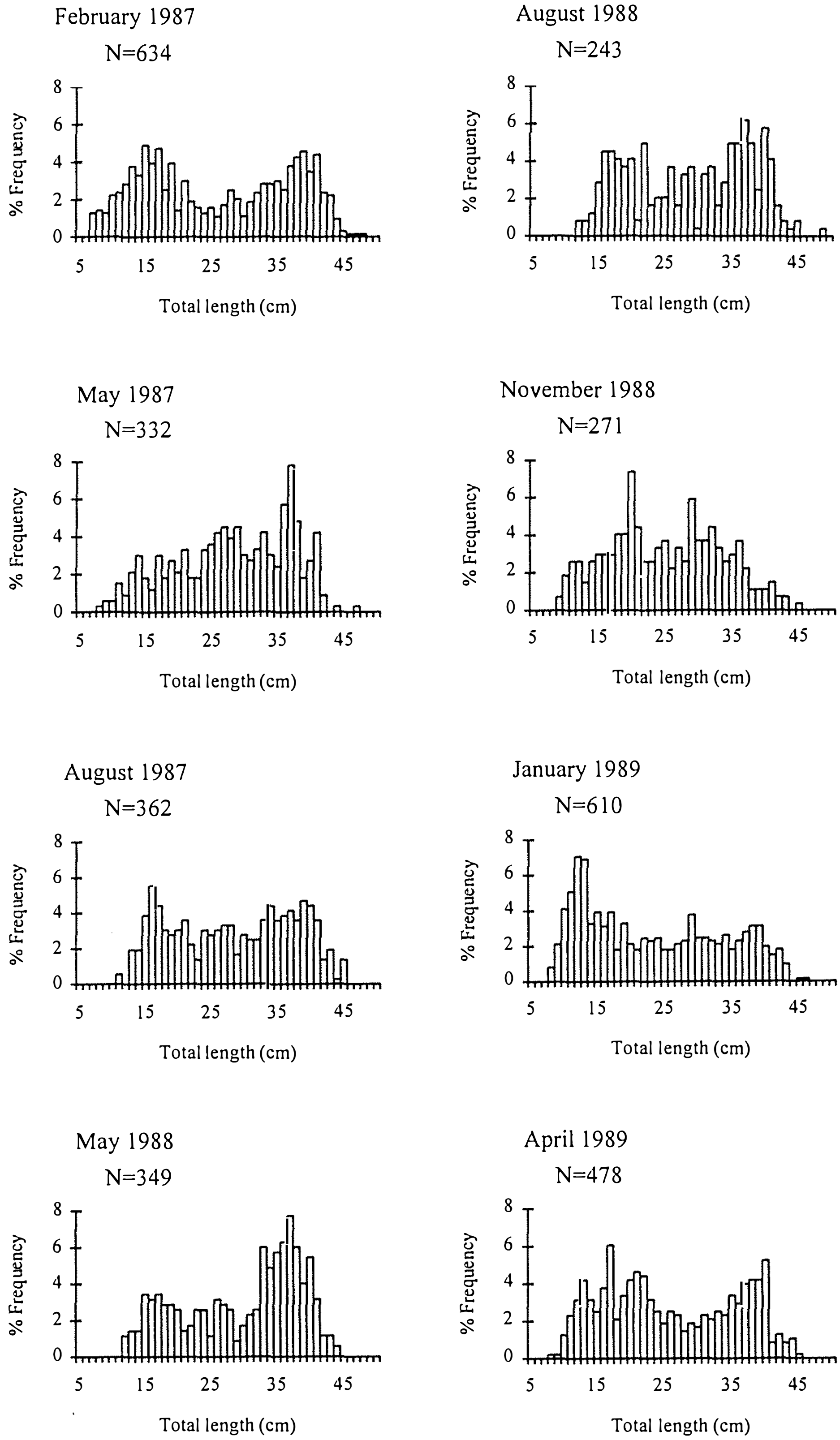


Figure 3.9.1 Percentage length frequency distributions for ocean perch, by survey western Bass Strait

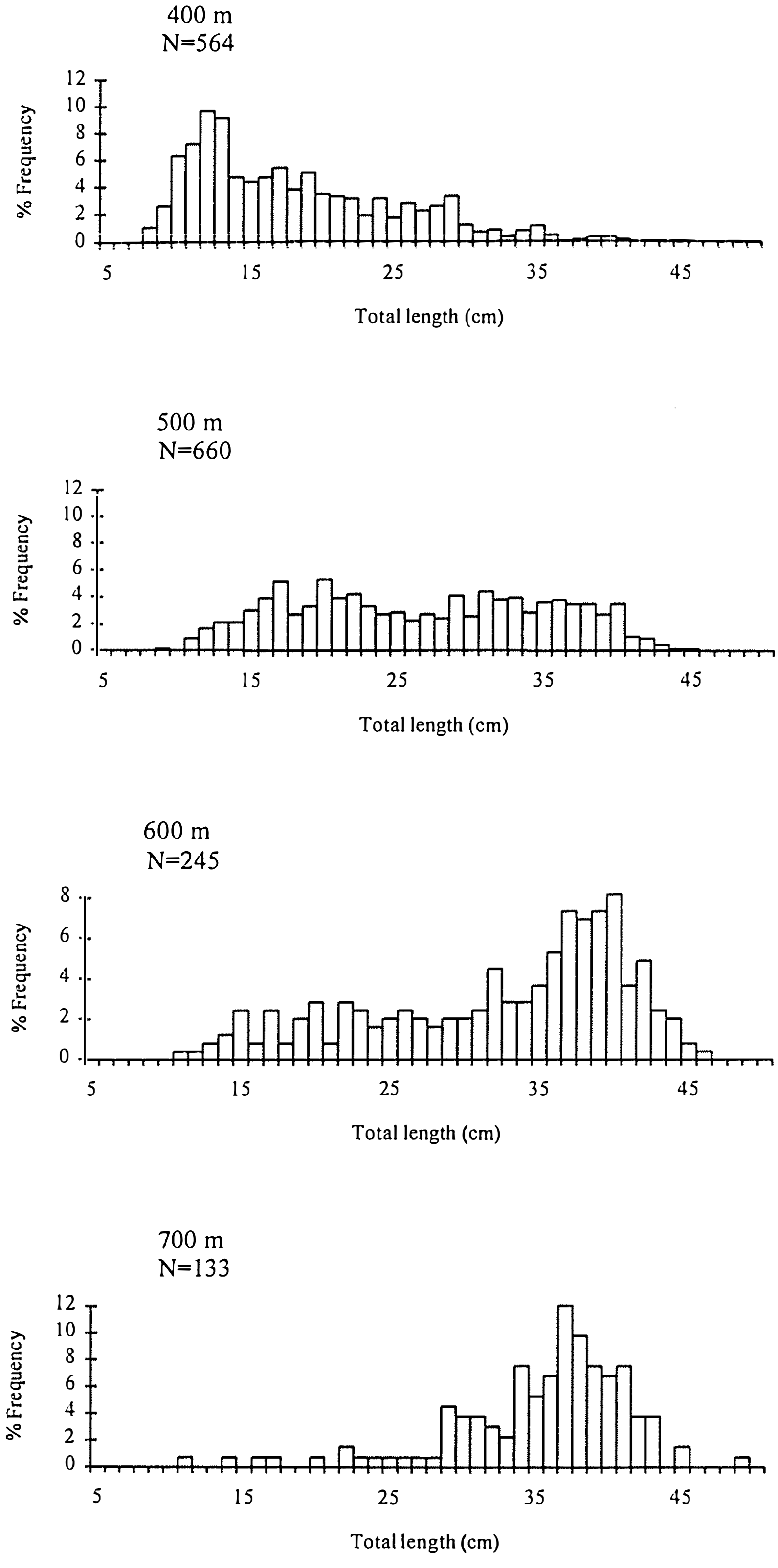


Figure 3.9.2 Percentage length frequency distributions for ocean perch by depth, western Bass Strait. Note 400 m also includes all depths up to 400 m and 700 m includes all depth greater than 700 m

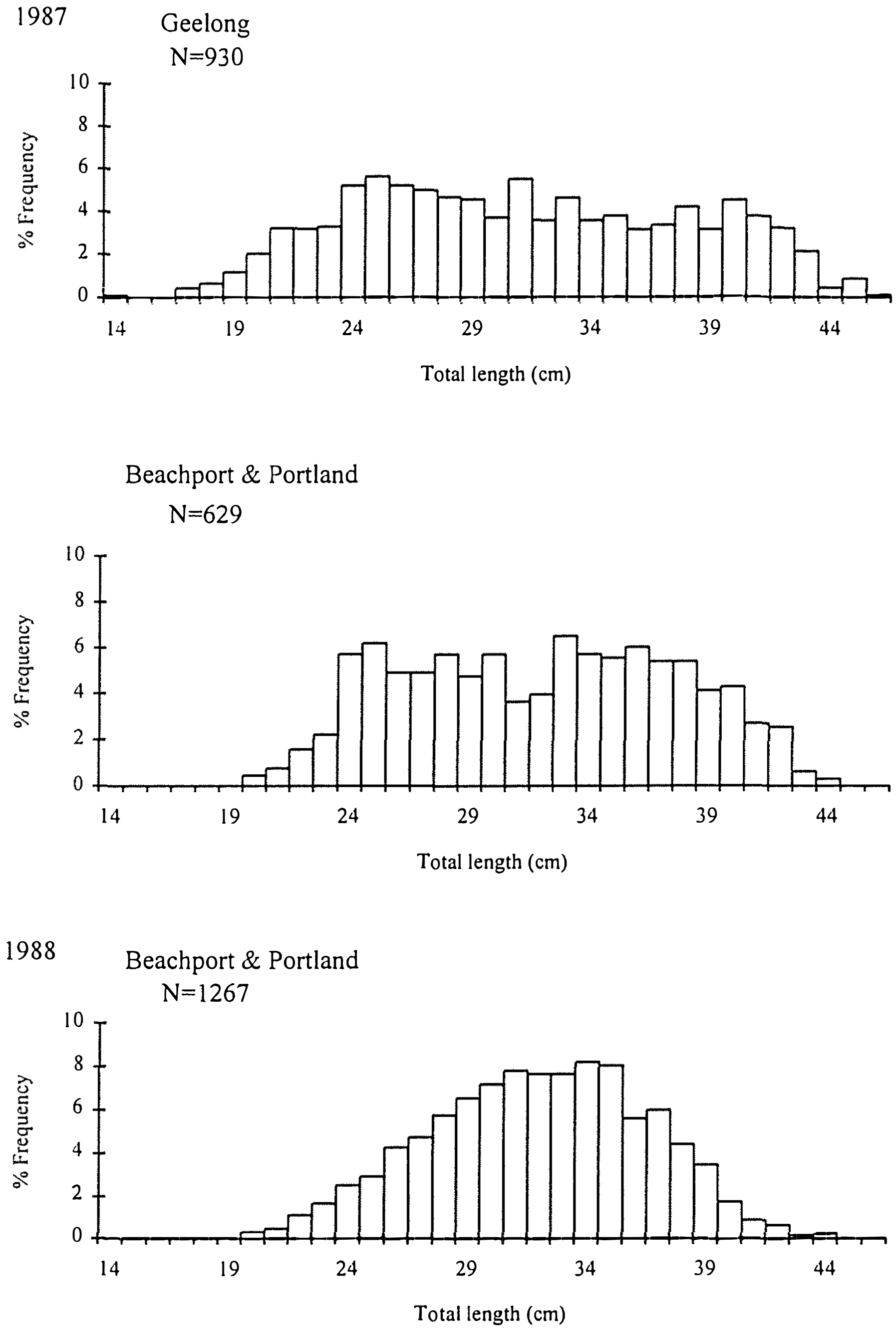


Figure 3.9.3 Percentage length frequency distributions for ocean perch landed at Geelong, and Portland and Beachport, 1987-88.

The 1988 distribution of ocean perch sampled at Portland and Beachport was quite different: peaked with most fish between 24 and 39 cm TL.

Length-weight relationships

The relationship between length (cm) and weight (g) was:

$$W = 0.011 \times L^{3.14} \qquad N=938,\ r^2= 0.99$$

3.10 King Dory

Distribution and abundance

King dory were taken in depths from 270 to 945 m. However, they were most abundant in the 400 to 700 m depth strata. King dory were caught in 85% of shots in these depths. The species was taken in only two shots less than 400m and in 8 greater than 800 m.

The highest unstandardised catch rate was 351 kg/hr but 82% of shots were under 50 kg/hr. There were no catch rates >50 kg/hr during the winter and spring surveys.

Mean standardised catch rates (kg/km2) were highest in the 500 and 600 m depth strata in all seasons. They were highest in summer and autumn and lowest in winter and spring (Table 3.10.1). CVs in the major depth strata were mostly between 25 and 35%. There were no significant year and season effects but there was a significant depth effect in the 400 to 700 m depth strata (Table 3.10.2). There was also a significant depth season interaction.

Seasonal biomass indices for king dory ranged between 567 (winter) to 2869 (summer) (Table 3.10.3). CVs were between 21 and 29%

Survey length frequency distributions and sex ratios

King dory ranged in length from 10 to 63 cm TL. Length frequency distributions in the summer and autumn surveys were dominated by a mode between 30 and 55 cm TL (Figure 3.10.2). In these surveys, there were also a mode between 10 and 20 cm TL. In the winter and spring surveys (Figure 3.10.1) there were relatively fewer large fish (>30 cm) in the length frequency distributions.

Females were generally larger (40-55) than males (30-45) and reached a greater maximum size, 63 cm compared to 51 cm (Figure 3.10.2).

Small fish were generally more abundant in the shallower depths particularly depths less than 500 m (Figure 3.10.3).

Overall, more males were caught than females. Sex ratios varied from 0.6:1 to 1.1:1 females to males. The difference from 1:1 was significant for Surveys 7 and 8 and overall (Table 3.10.4).

Commercial length frequency distributions

King dory in commercial catches ranged from 15 to 63 cm TL, but most were between 30 and 55 cm (Figure 3.10.4). There was some variation in length frequency distributions between years particularly in the relative number of larger fish but sample sizes particularly in 1989 were relatively small.

Reproduction

The relationship between gonosomatic index and length suggests that the length at first maturity for females occurs between 35 and 40 cm (TL) (Figure 3.10.5). Gonosomatic indices for female king dory were highest in the summer and autumn, with individual GSIs in excess of 20% recorded (Figure 3.10.5). For these seasons, the mean GSI for females > 39 cm was 6% to 11% (Table 3.10.4). GSIs during the winter and spring surveys were low, with mean values between 1.5% and 3.4%.

GSIs for males were low averaging less than 0.5% in all seasons sampled.

Length-weight relationships

Length-weight relationships for king dory were as follows:

Male	$W=0.024\ L^{2.98}$	$N=717,\ r^2 = 0.98$
Female	$W=0.025\ L^{2.97}$	$N=591,\ r^2 = 0.99$
Total	$W=0.024\ L^{2.98}$	$N=1500,\ r^2 = 0.99$

where W is the weight (g) and L is total length (cm).

Table 3.10.1 Seasonal abundance (kg/km2) of king dory in western Bass Strait, 1987-1989. by 100 m depth strata. N is the number of shots, SE is the standard error.

	Depth (m)						
	300	400	500	600	700	800	900
Summer							
Mean	0	54.1	533.0	1753.3	100.9	3.4	7.3
SE	0	41.0	268.8	692.2	58.1	2.2	6.5
N	7	4	9	6	5	7	8
Autumn							
Mean	0	20.8	1224.9	535.8	25.3	4.0	0
SE	0	7.8	417.9	117.7	20.0	2.7	0
N	8	11	15	11	5	16	14
Winter							
Mean	1.4	59.3	187.0	105.6	31.3	7.5	0
SE	1.4	24.9	60.7	26.5	16.8	6.0	0
N	5	9	10	6	5	5	8
Spring							
Mean	0	1.7	315.4	*315.4*	23.6	3.9	0
SE	0	1.7	110.5	*110.5*	18	3.9	0
N	2	3	5	*0*	3	3	2
Overall							
Mean	0.3	37.1	682.5	741.2	47.7	4.4	2.3
SE	0.3	10.9	184	222.1	11.2	1.1	1.9
N	22	27	39	23	18	31	32

Table 3.10.2. Analysis of variance of log(catch rate+1) for king dory, 400 to 700 m depth strata.

Source	DF	SS	MS	F Value	P
Year	2	1.02	0.51	0.16	0.8515
Season	3	11.03	3.68	1.17	0.3285
Depth	3	172.71	57.57	18.24	0.0001
Year*Season	2	13.96	6.98	2.21	0.1164
Year*Depth	6	30.15	5.03	1.59	0.1606
Season*Depth	8	59.41	7.43	2.35	0.0254
Year*Season*Depth	4	16.61	4.15	1.32	0.2717
Residual	78	246.19	3.16		

Table 3.10.3. Biomass indices (tonnes) for king dory by season 1987-1989. N is the number of tows, SE is the standard error.

Season	**N**	**Biomass**	**SE**
Summer	46	2869	839
Autumn	80	2778	757
Winter	48	567	119
Spring	18	913	227
Overall	192	2370	411

Table 3.10.4 Proportion of female king dory by survey, western Bass Strait 1988/89. N is the sample size, Prop F the proportion of females. P is the probability of sex ratios varying from 1:1(based on Chi-square tests).

Survey	N	Prop F	*P*
4	407	0.47	$0.25<p<0.50$
5	126	0.52	$0.50<p<0.75$
6	148	0.48	$0.50<p<0.75$
7	426	0.39	$0.001<p<0.005$
8	473	0.42	$0.01<p<0.025$
Overall	1580	0.44	$p<0.001$

Table 3.10.5 Mean gonosomatic indices (GSI) for king dory by survey. Males > 29cm, females >39 cm TL. N is the sample size, SD the standard deviation.

	Male GSI				Female GSI			
Survey	N	Mean	SD	Range	N	Mean	SD	Range
1 (Feb 87)	-	-	-	-	62	11.02	4.88	0.86-20.69
2 (May 87)	-	-	-	-	52	5.59	5.28	0.21-17.36
3 (Aug 87)	-	-	-	-	42	1.92	1.33	0.28-8.88
4 (May 88)	173	0.19	0.08	0.06-0.50	152	5.99	6.28	0.16-33.02
5 (Aug 88)	31	0.15	0.05	0.05-0.30	25	1.50	0.28	1.03-1.86
6 (Nov 88)	34	0.13	0.05	0.04-0.25	24	3.40	1.53	0.16-7.14
7 (Jan 89)	212	0.22	0.17	0.01-2.24	121	8.73	3.61	0.98-18.79
8 (Apr 89)	235	0.17	0.08	0.02-0.46	142	7.11	5.41	1.03-20.19

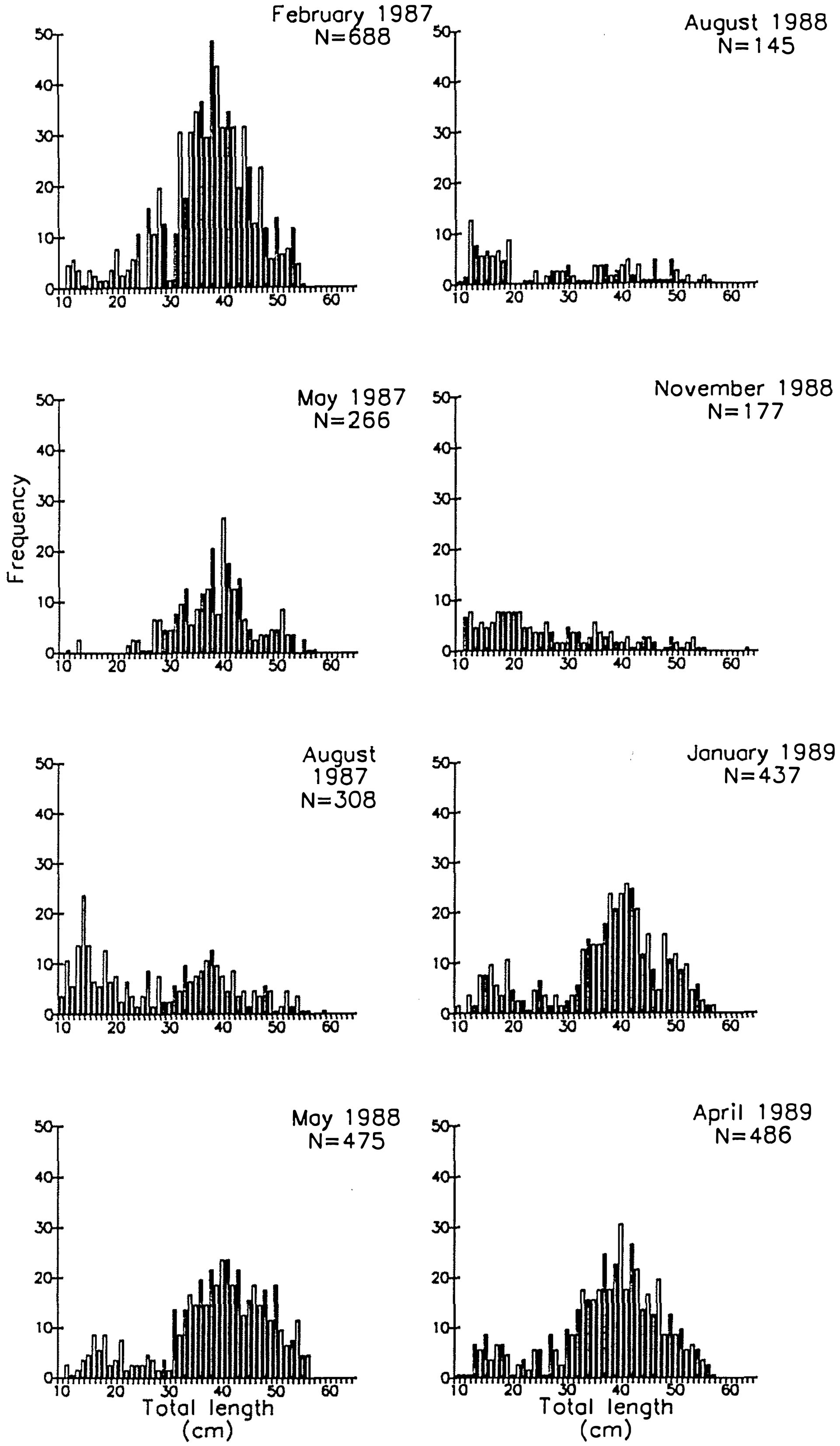


Figure 3.10.1 Length frequency distributions for king dory by survey, western Bass Strait.

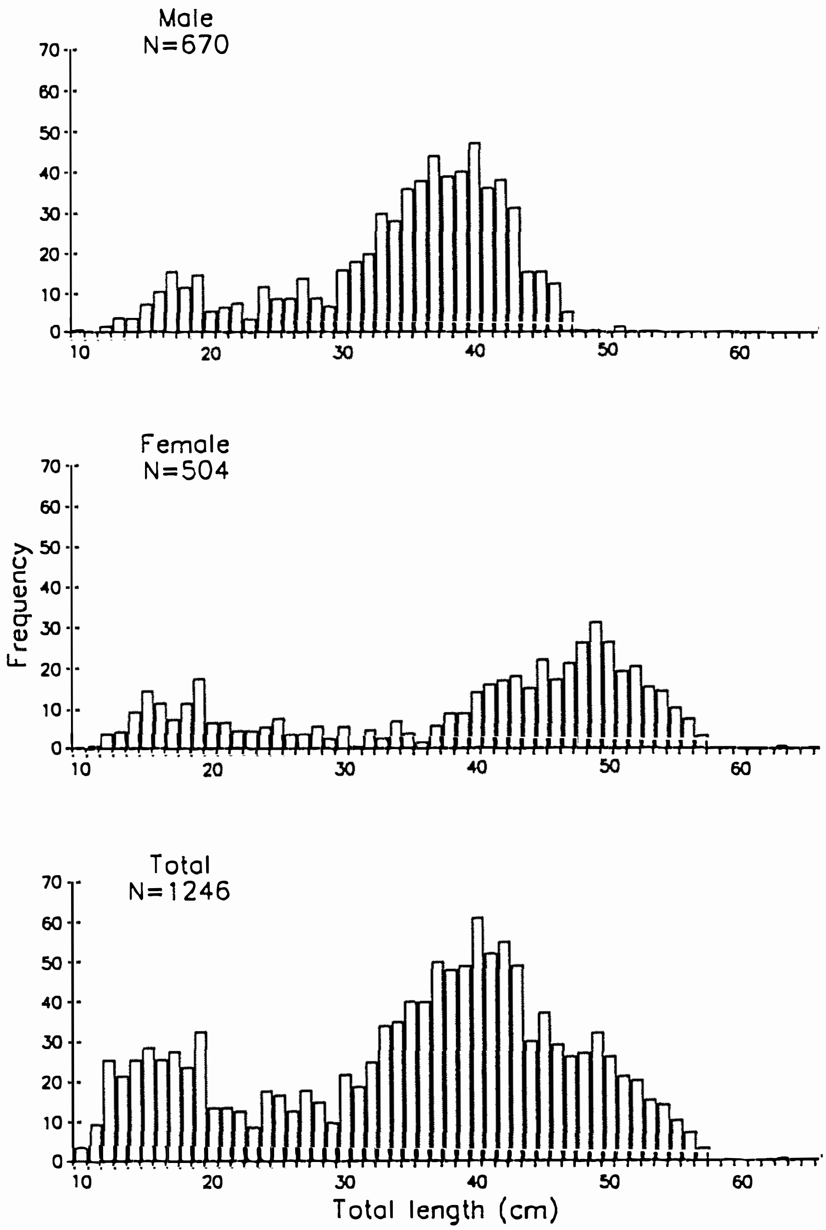
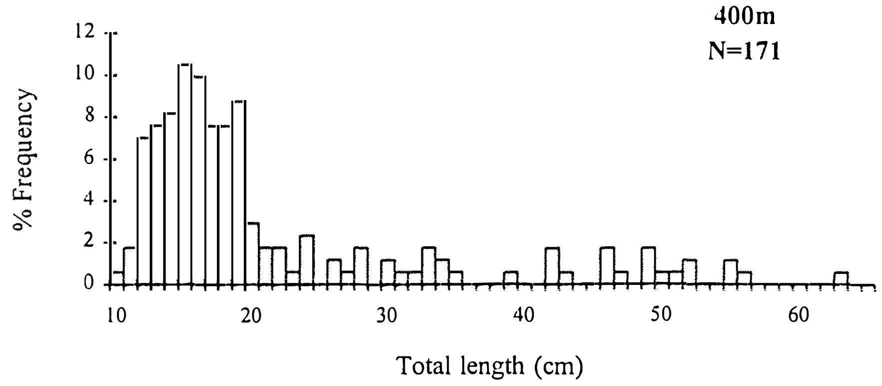
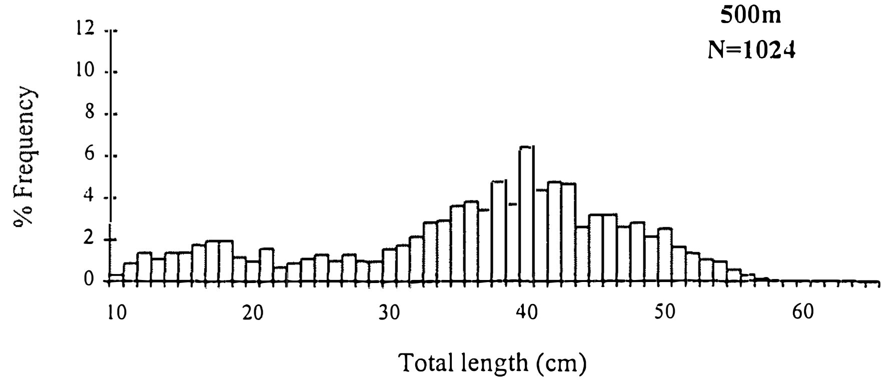
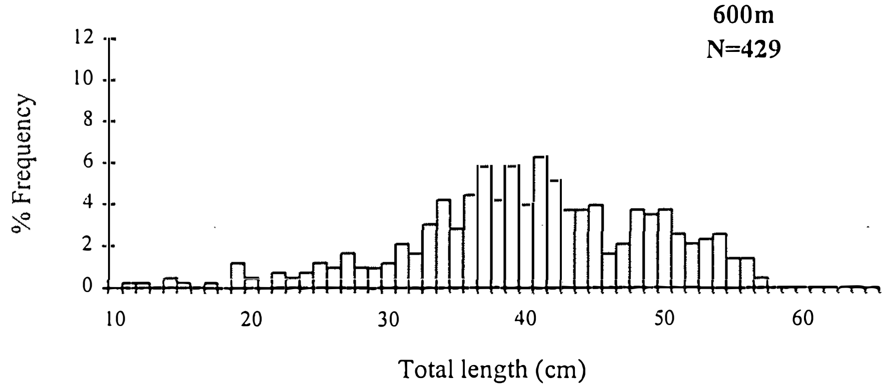


Figure 3.10.2 Length frequency distributions for king dory by sex, western Bass Strait.
Survey 4-8 combined.







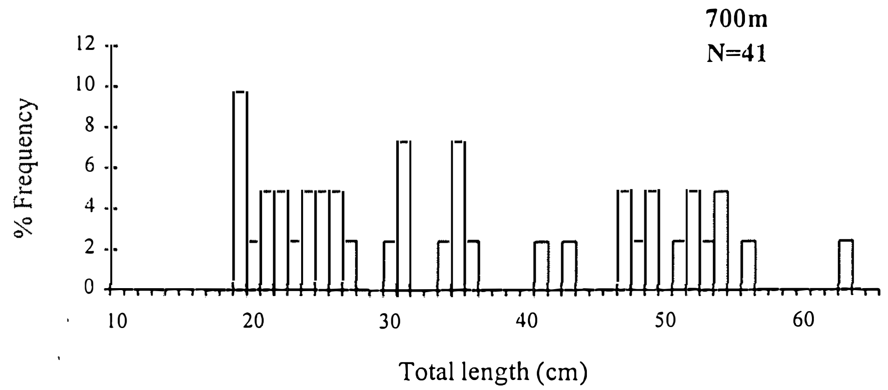


Figure 3.10.3 Percentage length frequency distributions for king dory by depth, western Bass Strait 1988/89.

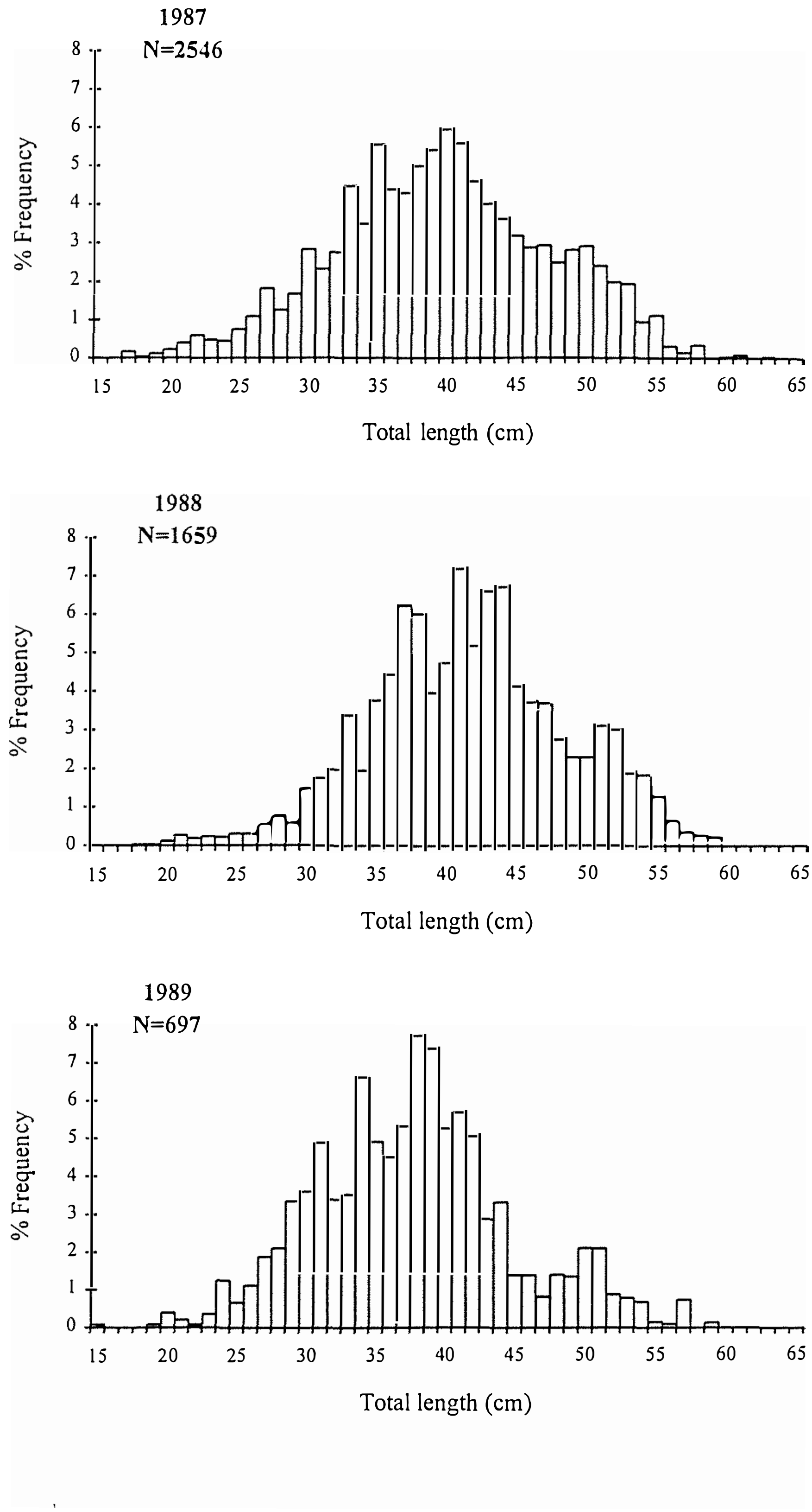


Figure 3.10.4 Percentage length frequency distributions for king dory, sampled from commercial landings, Portland and Beachport.

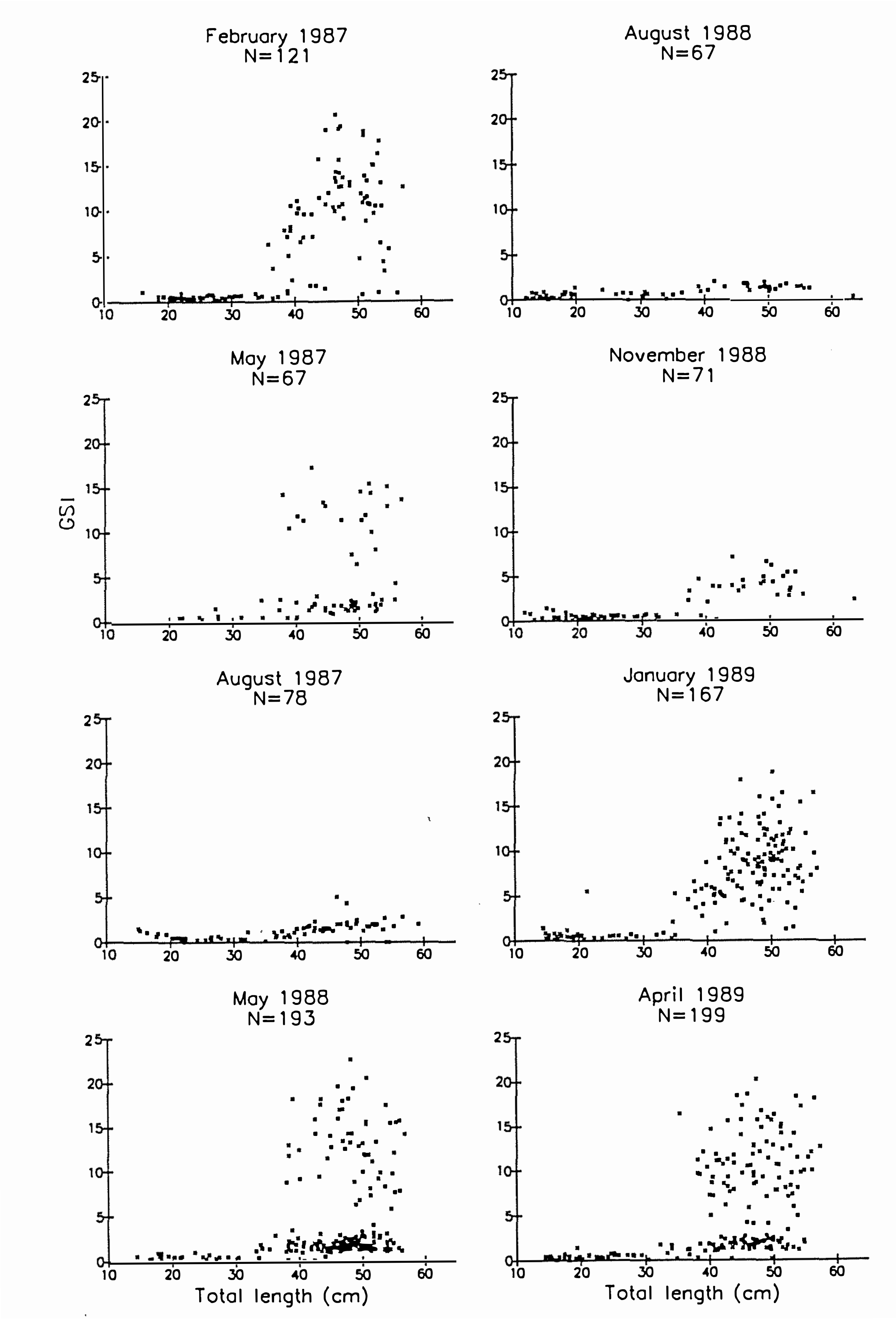


Figure 3.8.5 Relationship between gonosomatic index and length for female king dory.

3.11 Oreos

Two oreo species were common in WBS, the warty oreo and spiky oreo. The other species were only rarely taken (eg oxeye oreo) or not at all (black oreo). The abundance and basic biology of warty oreo and spiky are described by Lyle and Smith (submitted). The abstract is given below and the paper appended.

Lyle, J.M and Smith, D.C. The abundance and biology of warty oreo Allocyttus verrucosus (Gilchrist) and spiky oreo Neocyttus rhomboidalis (Gilchrist) (Oreosomatidae) off south-eastern Australia. Submitted to Marine Biology

The distribution, abundance, size structure, reproductive biology and diet of warty and spiky oreo from the continental slope region (400 - 1200 m) of south-eastern Australia are described. The depth distributions of the two species overlap, warty oreo were recorded over a depth range of 655 - 1308 m and spiky oreo between 424 - 1263 m. Spiky oreo were more abundant at intermediate depths (600 - 800 m) whereas greatest abundance of warty oreo occurred in the 900 - 1200 m depth range. Both species appear to be at low densities, though probably do form aggregations at times. Warty oreo size distributions were typically bimodal, with distinct juvenile/subadult and adult modes. A similar pattern was evident for spiky oreo, though in the case of females the mode of large individuals included sub-adult and adult fish. In both species females attained larger sizes than males. There was some evidence of size structuring with depth for warty oreo, with adults becoming more abundant with increasing depth. The size at which 50% of females were mature was estimated at 28 and 35 cm total length for warty and spiky oreo, respectively. Male maturity was attained at slightly smaller sizes in each case. Warty oreo is a late autumn/early winter spawner, spawning in May/June whereas spiky oreo spawn during late winter/early spring, in August - October. Macroscopic examination of ovaries suggests that ovarian development is synchronous, with a single batch of oocytes produced each year. Segregation of the sexes by depth in wary oreo just prior to the spawning season was observed, with males dominant in shallower depths and females becoming more dominant with increasing depth. Both species are benthopelagic feeders, consuming a range of prey items including crustaceans, fish and squid. Salps were also an important component of the diet of spiky oreo.

4 DISCUSSION

4.1 General

The Western Bass Strait Trawl Fishery Assessment Program was the first extensive study of the demersal trawl fishery in western Bass Strait. The study provided biological and fishery information on 11 commercially important species. All data presented here have been used extensively in the assessment of South East Fishery, primarily as reports to the Demersal and Pelagic Fisheries Research Group and Orange

Roughy Workshops. This study has also provided the baseline data for subsequent assessment of the fishery through the South East Fishery Assessment Group (SEFAG).

Orange roughy, blue grenadier and warty oreo were consistently the dominant species. Biomass estimates for ling, ocean perch and gemfish were low in all surveys. Spotted warehou abundance was distinctly seasonal being relatively high only during winter. Survey catches of blue warehou were particularly low and the biomass estimates for this species were unreliable. Biomass estimates for king dory and spiky oreo varied between surveys but they were moderately abundant. Of the species studied, jackass morwong was the only predominantly continental shelf species and the highest catch rates for this species were at the shallowest depths. Biomass was not estimated for this species.

The study species contributed substantially to the total demersal fish biomass in western Bass Strait. However, biomass estimates derived from trawl surveys such as this one must be treated cautiously. A number of assumptions have to be made which may over or underestimate the actual biomass. The nature of the survey was such that sampling was only undertaken on relatively smooth and trawlable bottom. Results were extrapolated to the entire area although there were large areas in the study area, particularly in the shallower depths, of rough bottom. By contrast, the assumptions about the behaviour of fish in relation to the gear (i.e. all fish in the path of the net were caught and no fish were above the headline) are probably conservative although there are also potential herding effects of the gear (Kenchington 1989).

The question of migration or emigration from the study area during each survey is difficult because, apart from gemfish, the fish in western Bass Strait are clearly part of larger stocks. In the case of blue grenadier and the warehous there appears to be movement into and out of the area. Therefore, biomass indices for western Bass Strait should not be viewed in isolation.

Notwithstanding the above, biomass indices conform with landings and logbook data in terms of major and minor species except for blue warehou and orange roughy. Clearly, trawl surveys, or at least broad, non-targeted surveys similar to the one undertaken here, are not the appropriate method of estimating the abundance of these two species. Possible reasons are discussed below.

Biomass estimates were surprisingly consistent for some species such as blue grenadier, ling and ocean perch. This indicates the change of survey design, from 120 to 60 minute shots and the change of vessel did not have a major effect on these estimates. Analysis of variance gave no significant year effect for any species.

The results presented here are generally consistent with biomass estimates reported by Wilson (1984) based on trawl surveys and commercial logbook data. The exception is gemfish where the biomass estimated by Wilson was much higher than reported here.

The trawl fishery in western Bass Strait expanded rapidly during the 1980s mostly in response to the discovery of substantial orange roughy aggregations in 1986/87. Landings in main ports reached 10,000 tonnes by the late 1980s with over 3000 tonnes taken from the study area. Apart from orange roughy, blue grenadier was the major species. The catch of blue grenadier increased from about 400 tonnes (partial weight) in the mid 1980s to over 700 tonnes (partial weight) by the early 1990s. Blue and spotted warehou, were the other major species in terms of weight. The annual catches of king dory and ling increased between 1986 and 1993, whereas those of gemfish and jackass morwong declined. The catch of ocean perch, and silver and mirror dory was low, less than 20 tonnes in all years.

Overall, the study demonstrated that the demersal trawl resource in western Bass Strait is limited. There was potential for a small increase in the catch of blue grenadier (which increased by almost 80% by the early 1990s). However, apart from blue grenadier, orange roughy and possibly spotted warehou, large increases in total catch could not be expected.

4.2 Orange roughy

Biomass estimates for orange roughy in western Bass Strait were generally consistent with studies conducted by the Sea Fisheries Division, Department of Primary Industry around Tasmania (Lyle et al 1991), and from a CSIRO survey between Kangaroo Island and Gabo Island (Bulman et al 1991). All indicated a relatively small stock.

During the study period, large aggregations of orange roughy were found off Tasmania. First of the west coast followed by sustained catches from a spawning aggregation off the east coast and "summer" aggregations to the south of Tasmania. In addition about 3000 tonnes were taken from an aggregation off Beachport during 1988. Catches reached of over 40,000 tonnes were reported in 1990. Clearly, the trawl surveys seriously underestimated the true size of the stock. Orange roughy aggregations are generally over rough bottom which was not included in trawl surveys.

The coefficients of variation for orange roughy caught during survey trawling in western Bass Strait were relatively low (25-30% of the biomass estimate). This is perhaps surprising given the aggregating behaviour of this species. However, the surveys were on smooth bottom and there was no attempt at "target fishing" for orange roughy. Also survey catches were dominated by juveniles whereas those in aggregations are almost exclusively adults. These results indicate fairly uniform distribution on the grounds surveyed. It is not known if those fish on smooth bottom are constant proportion of the overall biomass and thus whether standard trawl surveys provide a useful index of abundance for adult orange roughy has yet to be assessed. Trawl surveys, however, do provide a useful means of monitoring recruitment of juveniles.

Lyle et al (1991) reported a weak depth size relationship for surveys off north west Tasmania with mean lengths tending to increase with depth and larger fish predominating in the deepest stratum. No such relationship was apparent in western Bass Strait. A significant depth season interaction was found for standardised catch rates. This was due to the considerably higher catch rates in the 1100 m depth stratum during winter. It is not known whether this is reflects changes in fish behaviour associated with spawning or is due to sampling bias.

The only known major spawning site for orange roughy is off the east coast of Tasmania, (Bell et al 1992, Lyle 1994). The results of this study indicate that there is some spawning in western Bass Strait. Subsequent industry surveys have confirmed this but no single large aggregation has been located (Smith et al 1995). Spawning has also been reported from NSW (Graham and Bell 1989) and in the Great Australian Bight (Newton et al 1990).

Orange roughy are extremely long-lived with a maximum age in excess of 100 years and an age at maturity around 30 years. This may explain the characteristic bimodal size distributions of orange roughy from trawl surveys with the mode of large fish representing an accumulation of a large number of age classes. Length-based models developed to explain these size distributions also produce similar growth curves (K Sainsbury unpublished data).

The longevity of orange roughy have important implications for stock productivity and hence optimum harvest rates. It indicates that natural mortality is extremely low. Recent Australian assessments use M=0.04.

4.3 Blue grenadier

Blue grenadier contributed the largest mean component of the commercially exploited resource in western Bass Strait. This is consistent with May and Blaber (1989) who reported that blue grenadier was one of most abundant species off the east coast of Tasmania.

The species is found throughout southern Australia from mid New South Wales to southern Western Australia. The stock structure of blue grenadier has been assessed by several methods, including electrophoresis (Milton and Shaklee 1987), morphometrics and meristics (Kenchington 1989), parasite loads (Lester et al 1988) and egg and larval surveys (Gunn et al. 1989; Thresher et al. 1989). These studies indicate that blue grenadier are a single stock.

The only known spawning area for blue grenadier is located off the west coast of Tasmania, with spawning occurring during winter (Wilson 1981, 1982; Gunn et al. 1989; Thresher et al. 1989). No other major spawning area has been identified in Australian coastal waters. Blue grenadier show similar behaviour in New Zealand with the largest spawning aggregation on the west coast of the South Island (Patchell 1982; Kuo & Tanaka 1984a).

Size distributions of spawning blue grenadier are distinctly different when compared to the non-spawning fishery (Smith 1995). The former are characterised by a greater proportion of large fish (> 100 cm SL). Such distributions were not evident in western Bass Strait either from the trawl surveys or from commercial landings.

Only maturing fish were caught in western Bass Strait. Mean GSIs peaked during autumn and winter surveys and the maximum individual values recorded were 12.2% and 9.7% for females and males, respectively. However, these are low when compared to the results of Blaber et al (1985) who found mean GSIs of 12% (females) and 8% (males), with individual female GSIs in excess of 20%.

These results together with the significantly lower winter biomass and the relatively lower number of large and old blue grenadier in winter samples are all consistent with a migration of spawning fish out of western Bass Strait.

Industry have reported running ripe female blue grenadier in western Bass Strait but none were observed during the study period. These reports could indicate some intermittent spawning but also are not inconsistent with fish being caught while migrating to the single known major spawning area.

In this study, females were found to mature between 70-80 cm SL. This is similar to that reported for Tasmanian coastal waters (Gunn et al 1989). Blue grenadier appear to reach sexual maturity at a slightly smaller size in New Zealand (Kuo & Tanaka 1984b) and current New Zealand estimates of age at maturity (and recruitment to the fishery) are 4 years for males and 5 years for females (Sullivan and Cordue 1990).

There was close agreement between estimated growth parameters from this study and previous Australian work (Kenchington and Augustine 1987) indicating that ageing methods, at least for adults, are consistent. There are concerns, however, regarding the interpretation of otoliths from juvenile fish and this may require further work.

While fishing mortality appeared to be low during the study period the fishery in western Bass Strait concentrates principally on 4-5 age classes of juveniles and sub-adults. There are indications of variable year class strength which means the fishery is susceptible to natural population fluctuations. Further, the impact of exploitation of these young fish on the spawning biomass is unknown.

4.4 Gemfish

The main gemfish fishery in the SEF occurs on the east coast when spawning fish are targeted as they move north to spawn (Rowling 1990). Despite extensive sampling during the study period, there was no indication of a spawning run of gemfish similar to this in western Bass Strait. Research and commercial size distributions were more similar to the east coast "summer" fishery. During the autumn surveys, female gonads showed some development but GSIs were low compared to those for spawning gemfish on the east coast (Rowling pers comm).

Very small gemfish (around 10 cm) were taken infrequently during the survey. However, fish of this size (assumed to be about 6 months of age) were occasionally caught in quite large numbers off South Australia by trawlers operating in this area. It seems unlikely that such fish could be derived from spawning grounds off northern New South Wales. In addition, while the growth rate of juveniles in western Bass Strait was similar to that given by Rowling (1990) modes in the length frequency distribution were about six months out of phase. A recent genetic study (Paxton and Colgan 1993) has confirmed that gemfish in WBS, called western gemfish, are a separate stock with a boundary at the western end of WBS.

Trends in gonosomatic indices for female gemfish are unclear with the highest mean values found in May 1987 but they were low in both winter surveys when they are known to spawn off NSW. Lyle and Ford (1993) report the highest individual values in November. The spawning location is unknown but running ripe gemfish have been caught of Cape Leuwin, WA, and it has been suggested that spawning could occur in this area during summer (Tilzey 1995). Certainly biomass estimates in WBS were lowest during spring which could indicate the movement of fish from this area. However, gemfish catch rates were extremely variable and this may have been a statistical artefact. The gemfish in western Bass Strait are therefore at the eastern extremity of their range and as such it would be expected that the resource would fluctuate considerably depending on recruitment to the area.

Allen (1989) derived an estimate of natural mortality of 0.2. This is a similar estimate to that estimated here from total mortality less fishing mortality. The results of the present study indicate that, during the study period, fishing mortality was equivalent to natural mortality. It is concluded that, during the study period, the fishery was at sustainable levels.

4.5 Blue and spotted warehou

These species have become increasingly important to the trawl fishery in western Bass Strait. These species were initially lumped and there is a potential problem with catch data when catches are not sorted or are incorrectly identified. Smith et al (1994) concluded that logbook data were likely to be the most accurate. During the study period a major gillnet fishery for blue warehou commenced in eastern Bass Strait (Smith 1989).

The trawl fisheries for both species are distinctly seasonal with peak landings during winter and spring (Smith 1989, Smith et al 1994). It is likely that this increased vulnerability to trawl gear is associated with spawning behaviour as GSIs were high during this period, particularly for spotted warehou. In New Zealand waters, blue warehou were found to spawn during spring/summer (Gavrilov 1976) suggesting that spawning may occur earlier in Australian waters. Spotted warehou in New Zealand waters were found to spawn from winter to summer depending on the area (Gavrilov 1976, Grimes and Robertson 1981, McKoy 1988). Both warehou species are reported to undertake major migrations and aggregate to spawn or feed (Gavrilov and Markina 1979, Annala 1992).

Gonosomatic indices indicates a size of first maturity for both species of about 40 cm LCF equivalent to three to four years of age. This is similar to that reported by Gavrilov (1976) for spotted warehou in New Zealand waters.

Assigned ages for adults have yet to be validated thus there is uncertainty about growth and mortality estimates. However, both appear to be short lived with relatively high natural mortalities which indicates they may be fairly productive stocks.

Blue warehou biomass estimates were low. The results of trawl surveys in eastern Bass Strait (Wankowski and Moulton 1986) gave similar results. Generally these estimates were less than commercial landings. For this species, trawl surveys of this type are obviously not appropriate. If a trawl survey was to be successful it would have to be more targeted than was possible here.

Recent trends in the fishery, extending the results reported here, were described by Smith et al (1994).

4.6 Jackass morwong

Jackass morwong are distributed around the southern half of Australia (including Tasmania), New Zealand and off south-eastern South America (Gomon et al 1994) and southern Africa. The stock structure of jackass morwong in Australian waters is uncertain and evidence is conflicting. Electrophoretic analyses (Richardson 1982) and more recently, more extensive, genetic studies (Elliot and Ward 1994) confirmed that there was no evidence of separate stocks in Australian waters, but indicated that New Zealand and Australian stocks are distinct. However, analysis of the microstructure of otoliths indicates that jackass morwong from southern Tasmania may be a separate stock from those off NSW and Victoria (Thresher et al in press). The pelagic post-larvae of jackass morwong (6-30mm) have been found off-shore (up to 120nm) associated with oceanographic fronts (Barry Bruce, CSIRO, pers comm). These are not found in waters on the continental shelf. Transport mechanisms are unknown. The relationship of jackass morwong in western Bass Strait to other areas is therefore unknown.

Jackass morwong in the depths surveyed was not a major species in western Bass Strait. For example the highest catch rate was 165 kg/hr compared to 1128 kg/hr for blue grenadier. Commercial catches confirm this. Apart from high landings during 1986 (reported as unusually good by industry) catches of jackass morwong in western Bass Strait remained stable and low.

Survey and commercial length frequency distributions were generally similar to those previously reported for the east coast (Smith 1989) composed primarily of fish from 30 to 40 cm LCF. The size distributions for jackass morwong taken by trawls off Tasmania are given by Lyle and Ford (1993). Although the sample size was small there was a greater proportion of large fish with the mode of the distribution at about 40 cm LCF.

There was a pronounced depth size relationship in Tasmanian samples. Juveniles were taken in depths less than 100 m and the distribution of fish taken in depths greater than 200 m comprised mostly large fish. In western Bass Strait, this relationship was not evident in survey samples but the depth range covered for this species was narrow.

There were difference in commercial landings between ports; Beachport fish being larger than Portland fish overall particularly in 1988 when the size distribution approached those taken from deepwater off Tasmania. Whether this reflects spatial structuring in the population or simply the depth fished is unknown.

The pattern of GSIs indicated that spawning in western Bass Strait occurred during summer. This appears earlier than previously reported for jackass morwong on the east coast where spawning takes place during late-summer to autumn (Han 1964, Hobday and Wankoswki 1987, Lyle and Ford 1993). The variability in sex ratios reported here is consistent with previous studies (Smith 1983).

The growth of jackass morwong determined from whole otoliths was similar to that reported for NSW and Victoria (Smith 1982, Wankowski and Jolley 1985). Recent work at the Central Ageing Facility suggests that using whole otoliths (rather than otolith sections) may underestimate the age of this species. Given the general similarity of otoliths (clarity and morphology) from these areas it is not expected, however, that this would reveal difference between areas.

4.7 Ling

Ling occur throughout southern Australian shelf and upper slope waters from southern WA across to NSW. Prior to this study little was known of their biology. GSI data imply that spawning probably occurs in winter/spring with females maturing at about 60 cm TL. For males it was not clear with little variation in GSI for all size classes. Lyle and Ford (1993) recorded the highest GSI values in September and noted that changes in GSI with length suggested that females mature at about 72 cm (TL), larger than that reported here. In New Zealand waters spawning occurs between August and October (Paul 1986).

Survey and commercial size distributions suggest there is some structuring within the population. There was a weak size depth relationship with small ling confined mostly to the shallower depths. There were also differences in the size distributions of ling landed at Beachport and Portland. The significance of this is unknown.

Ling are widely distributed in western Bass Strait, occurring over a wide depth range but abundance as measured by catch rates was low. During summer, the peak abundance of ling was deeper than during the other seasons. This may, in part, explain the significant year depth season interaction. Tilzey (1994) reported that CPUE data indicated ling move into deeper waters during winter and spring but these data were mostly from the eastern Bass Strait and New South Wales.

The results of this study indicate that the resource of ling in western Bass Strait is limited and that the species will remain primarily a by-catch.

4.8 Ocean perch

Assessment of ocean perch is complicated by confusion regarding the taxonomy of the species. Park (1993) has identified two morphs from waters off NSW (an inshore and offshore form) and argues that ocean perches of the genus Helicolenus in Australian waters may form a species complex. This is supported by the electrophoretic analyses of Paxton and Colgan (1993).

Ocean perch taken in western Bass Strait, were as far we could ascertain, similar to the deepwater form described by Park (1993).

Similarly to ling, ocean perch were widely distributed over a broad depth range but the abundance was low. The estimated biomass was lowest during the winter. This may reflect reproductive behaviour as the offshore fish are reported to mate (the species is viviparous) during July/August off NSW (Park 1994).

In western Bass Strait, ocean perch are a by-catch species with low commercial catches.

4.9 King dory

No previous studies of king dory have been undertaken. Of the commercially exploited dories, king dory are found in the deepest water. They occur on the upper slope from depth of 270 to 1000 m but are most common from 500 to 700 m. Mirror dory and silver dory are taken in western Bass Strait but landings are low. Survey catch rates were also much lower than king dory.

Gonosomatic indices (GSIs) of female king dory suggest a protracted spawning season. For fish sampled in western Bass Strait GSIs were highest from January to May and for Tasmanian waters from March to June (Lyle and Ford 1993). Length at first maturity for females occurs at about 40 cm TL.

Small fish (10-20 cm TL) were more abundant in the shallower depths particularly depths less than 500 m (Figure 3). They were taken during all surveys and there was no clear indication of a peak period of recruitment. Lyle and Ford (1993) found that in Tasmanian waters, fish less than 20 cm TL only present in depths greater than 500 m.

Biomass indices were considerably lower during winter and to a lesser extent spring. This was associated with a reduction in the proportion of large fish in survey samples. Lyle and Ford (1993) also found that large adults were poorly represented in winter samples. The estimated biomass was highest during summer and autumn which coincided with peak reproductive condition. The results suggest that large fish may aggregate for spawning during these seasons and are thus more vulnerable to trawling.

The commercial catch during the study period was low compared to the overall biomass. There are inconsistencies between the indicated exploitation rate (catch/biomass) and trends in catch rates which are stable but low (Smith 1995). King dory are relatively long-lived, up to 40 years (Smith and Stewart 1994) and because of this the stock is unlikely to be productive.

4.10 Oreos

The biology and distribution of warty and spiky oreos in south-eastern Australia, including western Bass Strait, is described by Lyle and Smith (submitted, copy appended).

These species share some characteristics with orange roughy. They are long-lived (~ 100 years) (Smith and Stewart 1994, Stewart et al 1995) and show the same bimodal size distributions.

Despite a relatively large biomass of oreos in WBS catches have remained low. This is probably due to the low market appeal as both species are small (compared to blacks and smooth oreo). However, given their biology, a considerably larger resource than found here would be required to sustain a substantially larger fishery.

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Appendix

The abundance and biology of warty oreo *Allocyttus verrucosus* (Gilchrist) and spiky oreo *Neocyttus rhomboidalis* (Gilchrist) (Oreosomatidae) off south-eastern Australia

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Abstract

The distribution, abundance, size structure, reproductive biology and diet of warty and spiky oreo from the continental slope region (400 - 1200 m) of south-eastern Australia are described. The depth distributions of the two species overlap, warty oreo were recorded over a depth range of 655 - 1308 m and spiky oreo between 424 -1263 m. Spiky oreo were more abundant at intermediate depths (600 - 800 m) whereas greatest abundance of warty oreo occurred in the 900 - 1200 m depth range. Both species appear to be distributed at low densities, though probably do form aggregations at times. Warty oreo size distributions were typically bimodal, with distinct juvenile/subadult and adult modes. A similar pattern was evident for spiky oreo, though in the case of females the mode of large individuals included sub-adult and adult fish. In both species females attained larger sizes than males. There was some evidence of size structuring with depth for warty oreo, with adults becoming more abundant with increasing depth. The size at which 50% of females were mature was estimated at 28 and 35 cm total length for warty and spiky oreo, respectively. Male maturity was attained at slightly smaller sizes in each case. Warty oreo is a late autumn/early winter spawner, spawning in May/June whereas spiky oreo spawn during late winter/early spring, in August - October. Macroscopic examination of ovaries suggests that ovarian development is synchronous, with a single batch of oocytes produced each year. Segregation of the sexes by depth in warty oreo just prior to the spawning season was observed, with males dominant in shallower depths and females becoming more dominant with increasing depth. Both species are benthopelagic feeders, consuming a range of prey items including crustaceans, fish and squid. Salps were also an important component of the diet of spiky oreo.

Introduction

Six species of oreo are known from the continental slope waters of southern Australia, they are the smooth oreo (Pseudocyttus maculatus Gilchrist), black oreo (Allocyttus niger James, Inada and Nakamura), warty oreo (Allocyttus verrucosus (Gilchrist)), spiky oreo (Neocyttus rhomboidalis (Gilchrist)), oxeye oreo (Oreosoma atlanticum Cuvier) and rough oreo (Neocyttus sp.). Apart from black oreo, which appear to be restricted to waters adjacent to New Zealand and Tasmania, and rough oreo, which have only recently been identified from southern Australian waters (Yearsley in press), the species are widely distributed throughout the southern hemisphere (James et al. 1988).

Commercial fisheries for oreos developed in New Zealand in the late 1970s and more recently in Australian waters. Recent annual landings are around 21 000 tonnes for New Zealand (McMillan and Hart 1993) and 2 000 tonnes for Australia (Lyle et al. 1992). Oreos are usually taken in conjunction with orange roughy (Hoplostethus atlanticus Collett) but some targeting occurs and large catches (over 50 tonnes per haul) have been taken. Smooth and black oreos comprise the bulk of the commercial catch, warty and spiky oreo are also taken but in smaller quantities. Oxeye and rough oreo are rarely caught and, because of their small size, have no commercial significance.

Oreos are slow growing and very long-lived with maximum ages around 100 years (Smith and Stewart 1994; Stewart et al. 1995). The reproductive biology and feeding of smooth and black oreo has been studied in some detail in New Zealand (Pankhurst et al. 1987; Clark et al. 1989; Conroy and Pankhurst 1989). However, apart from growth, virtually nothing is known of the biology of warty and spiky oreo. The only study available is of feeding in warty oreo from South African waters (Mel'nikov 1980).

This paper provides information about the distribution, abundance, size structure and reproductive biology of warty and spiky oreo from the continental slope region of southern Australia.

Materials and Methods

Survey design

Between 1987 and 1989 the Tasmanian Department of Primary Industry and Fisheries and the Victorian Department of Conservation and Natural Resources conducted demersal trawl surveys of the continental slope between Kangaroo Island and western Tasmania

(Fig. 1). The area of western Bass Strait (WBS) between 400 - 1200 m was stratified into 200 m depth intervals and western Tasmania (WTas) into 100 m depth intervals between 800 - 1200 m (i.e. 4 depth strata in each area). Trawl stations were then randomly assigned within these strata, the number of stations allocated to each stratum being weighted for the relative area of the particular stratum. Trawls were restricted to areas of trawlable bottom (mud/sand substrate, generally flat or undulating topography).

The areas of bottom represented between the 400 - 800 m and 800 - 1200 m depth contours for WBS are 3191 and 3799 km^2, respectively. In WTas the 800 - 1200 m contours encompass an area of 1026 km^2. Average sampling densities of one station per 130 km^2 and one per 54 km^2 were achieved for WBS and WTas, respectively. To allow comparison between areas, the WBS survey area was post hoc stratified into eight 100 m depth strata.

Tows were aimed to be of 60 minutes duration (bottom time) and catch rates have been standardised per km^2 swept area. Swept area was based on wing spread (55% of the headline length) multiplied by distance travelled. It was assumed that all fish in the path of the net were caught (i.e. no escapement or avoidance) and that there was no concentrating or herding effect by the sweeps and trawl doors (i.e. wing spread was the effective sampling width). Calculation of biomass and standard errors of biomass were based on Francis (1981).

Additional tows were attempted off south western Tasmania (around 43°30'S) and north-eastern Tasmania (between 41°25' and 41°50'S). Catches from these areas have not been incorporated in the calculations of abundance or analysis of size structure but are included in the biological analyses.

Abundance estimates and length frequencies are based on seasonal samples collected between August 1988 (winter) and May 1989 (autumn), the period during which the two sampling programs overlapped. Catch weights were calculated by weighing the fish directly or using size composition data and known length-weight relationships. Since trawl catch rates are generally distributed according to a lognormal distribution (Francis 1981), examination of the effects of area, season and depth on catch rates was performed by analysis of variance (via regression) on $\log_e$(catch rate + 1).

Biological observations

At each station the entire catch or a randomly selected sub-sample of at least 200 fish of each species was sexed and measured for total length (TL) to the nearest centimetre rounded down. Size distributions from sub-samples were scaled-up by the ratio of the total catch to the sample weight. More detailed biological examination was carried out on a sub-sample of the catch, length was measured to the nearest millimetre and total body weight and gonad weight were measured to the nearest gram. Length-weight relationships were calculated by regressing the natural logarithm of weight on that of length. Length-weight relationships were compared using the 'extra sum of squares' principle (Draper and Smith 1981).

Gonad condition was noted for fish collected off Tasmania using macroscopic staging criteria developed for the closely related smooth and black oreos (Pankhurst *et al.* 1987). Developing oocytes are readily distinguishable macroscopically, an observation confirmed histologically for a small number of ovaries from adults of both species collected in May 1992. Exogenous vitellogenic oocytes (appearance of yolk granules) were clearly larger (diameters of 0.8 - 1.45 mm in warty oreo and 0.5 - 1.25 mm in spiky oreo) than the previtellogenic and endogenous vitellogenic oocytes (accumulation of yolk globules in cytoplasm) (diameters ranging between 0.05 - 0.55 mm in warty oreo and 0.05 - 0.4 mm in spiky oreo).

Presence of food in the stomach and principal prey categories (fish, cephalopod, crustacea) was recorded in Tasmanian samples. Easily recognisable prey were identified to family or genus level.

Additional samples, collected during exploratory trawl surveys of the study area in 1983 (Wilson and Evans 1983), have been included in the analysis of reproductive cycles.

Results

Distribution and Abundance

The depth distributions of the two species overlap; warty oreo were recorded in depths of 655 - 1308 m and spiky oreo between 424 - 1263 m. Spiky oreo were, however, more abundant at shallower depths, mainly between 600 - 800 m, whereas warty oreo increased in abundance below 800 m, peaking between 1000 - 1200 m (Fig. 2).

Warty oreo was a common species throughout the survey area, occurring in 146 out of 162 tows undertaken in the 800 - 1200 m depth range. Abundance was highest in the 1000 m depth stratum in all seasons and in both areas except for summer in WBS, where it was slightly higher in the 1100 m stratum (Table 1). For WBS, mean abundances in the 1000 m stratum varied from 1835 (winter) to 3256 kg/km^2 (summer) and the coefficient of variation (CV) on the mean was similar for winter, spring and autumn (36 - 39%) but was considerably higher in summer (57%). For WTas, means varied from 132 (spring) to 5924 kg/km^2 (summer) in the 1000 m stratum, with CVs being more variable, ranging from 25% in autumn to 63% in summer. Analysis of variance showed that there were significant area, season and depth effects on catch rates for warty oreo (Table 2). There was also a significant depth-season interaction.

In WBS, estimated warty oreo biomass was generally consistent at about 5500 tonnes in winter, spring and autumn but peaked at almost 8000 tonnes during summer (Table 3). For WTas, biomass was low (under 300 tonnes) in all seasons except for summer when the estimate was almost 1500 tonnes. CVs were mostly between 20 and 30% except for summer when they were 34 and 61% for WBS and WTas, respectively. The particularly high summer estimate for WTas is heavily influenced by two large catches (1984 and 1234 kg/tow) which, when excluded from the analysis, reduced the biomass to only 95 tonnes, with a CV of 19%.

Catches of spiky oreo were generally more variable and lower than for warty oreo. In WBS, the species was caught in 64 out of 91 tows completed in the 500-1100 m depth range and 52 out of 65 tows undertaken off WTas between 800 - 1100 m. Comparisons between areas are limited because the highest abundances were in the 600 and 700 m depth strata (Fig. 2), shallower than the WTas surveys. However, in the 800 to 1000 m depth strata abundances were generally higher for WTas (Table 4).

In WBS abundance spiky oreo abundance was highest in either the 600 or 700 m strata in all seasons apart from autumn when the peak abundance occurred in the 500 m stratum. The 600 m stratum was not sampled in spring and, since it is unreasonable to assume that there would have been no fish at this depth, the abundance estimate for the 700 m stratum was assigned to the 600 m stratum when examining season and depth interactions and estimating biomass. Analysis of variance showed that there were significant depth and depth-season interactions for spiky oreo in WBS (Table 5). Although catch rates varied considerably between seasons the differences were not significant.

Seasonal biomass estimates for WBS were lowest during spring (around 1100 tonnes) and peaked during winter at almost 5000 tonnes (Table 6). The CVs were also variable, from 7% in winter to 63 % in spring.

Size composition

Warty oreo length frequency distributions for WBS and WTas were similar, being bimodal with a dominant mode at 28 - 35 cm for females and 27 - 32 cm for males and a secondary mode between 16 - 24 cm for both sexes (Fig. 3). Females were on average 1 - 2 cm larger than males and attained larger maximum sizes, the largest female examined being 39 cm, 2 cm larger than the biggest male. The smallest individuals examined were 9 cm.

Seasonally there was little variation in size composition of warty oreo catches for WBS, distributions being characterised by a dominant mode between 26 - 34 cm and a second, less obvious mode, between 16 - 24 cm (Figure 4). In contrast, small fish (< 25 cm) dominated the WTas catches in all but the summer sample which was comprised largely of fish between 26 - 35 cm.

The mean size of warty oreos size increased with depth in WBS, due largely to changes in the relative heights of the two modes (Fig. 5). Small fish predominated in the 800 m stratum whereas large fish became progressively more abundant with increasing depth. This trend was not evident in WTas where the greatest abundance of small fish occurred in the 900 and 1100 m strata (Fig. 5). Interestingly, large fish evident in the 800 m stratum in both areas were only present in the autumn samples.

Spiky oreo ranged in size from 9 - 44 cm, the largest male and female being 43 cm and 44 cm, respectively. Length frequency distributions for both areas were dominated by 30 - 40 cm fish, with females generally larger (mode at 33-36 cm) than males (mode at 31-33 cm) (Fig. 6).

In WBS small fish (< 25 cm) were poorly represented in all seasons apart from spring, when 15-23 cm fish comprised the dominant mode (Fig. 7). Although small fish were most common in the 700 and 800 m depth strata, there did not appear to be an obvious size/depth trend (Fig. 8).

Sex ratios

The proportion of female warty oreo caught in catches varied from 0.43 to 0.54 in WBS and 0.49 to 0.55 in WTas (Table 7). Chi-square tests indicated that these were significantly different from 1:1 in all seasons except for spring in WTas. Overall, there were slightly more females in WTas.

During autumn there was a marked and consistent increase in the proportion of female warty oreo with depth, from 0.11 to 0.57 in WBS and from 0.2 to 0.67 in WTas (Table 7). This trend is accentuated to some extent by considering fish ≥ 24 cm, that is mainly adults. In other seasons, sex ratios either varied little or showed no obvious trend with depth.

Apart from winter, when male spiky oreo were numerically dominant, sex ratios in the seasonal samples for WBS did not differ significantly from 1:1 (Table 8). In the combined WBS sample, however, there were slightly (but significantly) more males than females. There were no consistent or obvious trends in sex ratio with depth for either the complete sample or the mature component (characterised as ≥ 29 cm) of the catch (Table 8).

Length-weight relationships

Length-weight parameters, based on the standard relationship $W = aL^b$, were determined to be:

		a	b	
Warty oreo	Male	1.48×10^{-2}	3.139	(N = 1469, r^2= 0.97)
	Female	1.29×10^{-2}	3.191	(N = 1708, r^2= 0.98)
Spiky oreo:	Males	2.52×10^{-2}	2.946	(N = 622, r^2= 0.99)
	Females	2.29×10^{-2}	2.980	(N = 798, r^2= 0.99)

where L is total length (cm), W is body weight (g), N is sample size and r^2 is the coefficient of determination. All relationships are highly significant ($P < 0.001$)

In each case the exponents (b) differed significantly between the sexes indicating a significant sex effect on the length weight relationships (warty oreo: $F = 7.81$; d.f. 1, 3173: $0.005<P<0.01$; and spiky oreo: $F = 4.12$; d.f. 1, 1416: $0.025<P<0.05$).

Size at maturity

Length at maturity was assessed using macroscopic gonad staging criteria. Females that had developed to Stage 3 (ovary opaque white, maturing oocytes conspicuous) or beyond and males of Stage 2 (enlarged testes, grey to cream in colour) or greater were considered to be mature.

The smallest mature male and female warty oreo were 18 and 23 cm, respectively. By comparing the proportion of mature fish in each centimetre length class, the size at which over 50% of individuals were mature was 25 cm in males and 28 cm in females (Fig. 9). At 29 cm or greater, virtually all males were mature while almost all females larger 32 cm were sexually mature. Gonadosomatic index (GSI - gonad weight expressed as a percentage of body weight) values for immature fish (Stage 1 male and Stages 1 and 2 for females) were generally between 0.02 - 0.35 for males and 0.02 - 2.0 for females. Mature fish tended to have GSIs of greater than 0.2 in males and 1.2 in females, with maximum values of over 5.0 and 10.0 respectively.

Maturity is attained at larger sizes in spiky oreo, with 50% maturity at 29 cm in males and 35 cm in females and first maturity at 28 cm and 29 cm, respectively (Fig. 9). Almost all males over 35 cm and females of greater than 40 cm were mature. The range of GSIs for immature and mature fish were similar to those for warty oreo, with the exception that the upper limits for mature fish rarely exceeded 1.0 in males and 5.0 in males.

Reproductive cycle

Mean monthly GSI values for adult females of both species indicate discrete annual cycles of reproduction. Males, on the other hand, showed little variation in GSI throughout the year.

GSIs for female warty oreo (≥ 28 cm) peaked with mean values of greater than 6 in April 1988 and in May 1989, before declining to about 3.5 in August/September (Fig. 10). Although peak GSIs were out of phase by a month between 1988 and 1989, individual GSIs of over 14 and up to 19 were recorded in April and May of both of these years. Of the mature females examined in May 1989, 40% were Stage 4 (final oocyte maturation, hyaline oocytes present) and a single spent fish was found. No running ripe fish were recorded. Macroscopic examination of ovaries suggested that ovarian development is synchronous with a single batch of oocytes being matured during the reproductive cycle.

Data from 1983 for warty oreo, which included samples collected between April and August as well as October, are presented in Fig. 10 for comparison with the more recent data. A similar pattern of gonad development is apparent with GSIs peaking in April and then falling rapidly by June.

Monthly GSI values for mature warty oreo males (i.e. ≥ 25 cm) did not show such a pronounced seasonal cycle with mean values fluctuating between 0.6 and 1.0 throughout the year (Fig. 10). Gonad staging revealed the presence of some spent fish in August and September, supporting an early winter spawning season.

GSIs for mature female spiky oreo (i.e. ≥ 35 cm) peaked in August and September and had declined sharply by November (Fig. 11). Mean values of between 3.2 - 4.6 were recorded in August and September, with individual GSIs of up to 8.2. Of the females examined in August 1988, 48% were at Stage 4 and a further 12% were running ripe or spent. In August/September 1989, 19% of sampled fish were running ripe or spent. Spent fish accounted for 22 and 58% of the November 1988 and 1989 samples, respectively. The remaining mature fish were either recovering or in a resting condition at this time. Macroscopic examination of ovaries again suggested that females spawn a single batch of eggs.

Collections of spiky oreo from 1983 included June, July and October samples, the latter with a mean GSI of 7.0, substantially higher than the maximum of 4.6 recorded in September 1989 (Fig. 11).

Although monthly GSI values for mature males (i.e. ≥ 29 cm) do not show a clear trend (Fig. 11), analysis of reproductive condition indicated the first occurrence of spent males in August and by November 1989, over two-thirds of mature males were in a spent condition. These data suggest that spiky oreos spawn in late winter to early spring, with spawning completed by November.

Diet

Out of a total 3173 warty oreo examined for stomach contents, 55.7% were everted. Around 90% of the non-everted stomachs contained food items, with crustaceans found in 71%, fish in 33% and cephalopods in 26% of those stomachs with food. Crustaceans were mainly represented by cariid prawns, with amphipods (family Gammaridae) and copepods (mostly in small fish) also present. Although fish prey were usually at an advanced stage of digestion, members of the families Myctophidae, Macrouridae (*Coryphaenoides* sp.), Neoscopelidae, Gonostomatidae and Nemichthyidae were identified. Cephalopods were represented by squid and in many instances only beaks remained.

Dietary analysis for spiky oreo was limited since nearly 94% of the 1427 stomachs examined were everted. Of the 55 stomachs that contained food, fish and crustaceans were each present in 24%, cephalopods were found in 18% and other prey taxa (almost exclusively salps) occurred in 49% of the stomachs.

Discussion

Oreos are an important component of the deepwater demersal fish community off southern Australia. In terms of biomass, oreos along with orange roughy, are among the dominate species groups in the mid-slope region. At depths between 600-1200 m in WBS, Smith (1995) found that warty and spiky oreo together comprised about 15% of the demersal fish biomass, while in the 800-1200 m range the oreos accounted for 25% of the biomass which compared with 22% for orange roughy. Similarly, Koslow et al. (1994) found that oreos (principally warty and spiky oreo) contributed about 22% of the overall demersal fish biomass in the mid-slope region (800-1200 m) off south-eastern Australia, with orange roughy and squalid sharks comprising 23 and 20% of the biomass, respectively. By contrast, on the north Chatham Rise (Robertson et al. 1984) and Challenger Plateau (Tracey et al. 1990) off New Zealand, oreos account for 1% or less of the demersal fish biomass, with orange roughy by far the dominant species, accounting for 90 and 67% of the total biomass, respectively.

Although depth distributions overlap, our data show that spiky oreo are more abundant at intermediate depths (600 - 800 m) and are replaced by warty oreo at greater depths (900 - 1200 m). Off south-eastern Australia, Koslow et al. (1994) distinguished three distinct species assemblages of demersal fish in the 800-1200 m depth range, with spiky oreo characterising the 'shallow' and warty oreo a dominant indicator species in the 'intermediate' and 'deep' assemblages.

Smooth and black oreo, which also occur over a similar depth range to warty and spiky oreo (James et al. 1988), were rarely caught in our surveys and most individuals were juveniles. By contrast, commercial trawl catches of oreos from southern Tasmania (south of about 44° S), an area not surveyed in this study, are dominated by smooth and black oreo (Lyle et al. 1992). Commercial fishing is targeted over areas of hard bottom, in particular pinnacles and drop-offs, where aggregations of smooth and black oreo occur, along with orange roughy. Warty and spiky oreo represent a very minor by-catch in this area, inferring that smooth and black oreo prefer areas of rough bottom whereas warty and spiky oreo are more associated with soft bottom habitats.

Warty and spiky oreo are typically distributed at low densities as indicated by generally low catch rates. The small number of large catches do, however, suggest that at times both species form aggregations. This patchiness is reflected in very high CVs in some seasons, in particular the summer abundances of warty oreo. Our data demonstrate significant area, season and depth effects and a significant depth-season interaction on abundances for warty oreo. Highest abundances were recorded in summer, with generally higher abundances in WBS. While there were significant depth and depth-season interactions for spiky oreo, the effect of season on catch rates was not significant.

Oreosomatids typically undergo a transition from a juvenile pelagic form to a demersal adult phase. In warty and spiky oreos metamorphosis and settlement occurs at length of around 8 - 9 cm (James et al. 1988), possibly at an age of 4-5 years in warty oreo (Stewart et al. 1995). Although pelagic juveniles were not taken in our study, probably because of their small size and pelagic habit, the smallest individuals of both species were close to the size at settlement.

In both species females tended to be larger than males and size distributions were comprised of a discrete mode of large fish and a broader mode, or series of modes, of smaller fish. Warty oreo size distributions were characteristically bimodal, separated by a trough which was close to the size at maturity. A similar pattern was evident for male spiky oreo, where adults formed a distinct mode. By contrast, the upper mode for females comprised a mix of subadult and adult fish (the length class at 50% maturity being close to the modal peak). Bimodality in size structure is also known for orange roughy, with distinct juvenile/subadult and adult modes (Lyle et al. 1991; Bulman et al. 1994). Orange roughy and warty oreo are extremely long-lived and slow growing, with maturity occurring at around 30 years and maximum ages of over 100 years (Smith et al. 1995, Stewart et al. 1995). Although growth is extremely slow, growth rate slows substantially after maturity and this may account for the bimodality with the adult mode representing the accumulation of a very large number year classes. Unvalidated ageing data for spiky oreo also suggest that it is a very long-lived and slow growing species (Smith and Stewart 1994).

Our data suggest that warty oreo is an late spring/early winter spawner, with ovaries ripening in April and May and spawning completed by August. Although no samples were available in June/July, data from earlier years (1983) suggest that spawning occurs over a relatively short period and is probably is completed by June. Peak female GSIs occurred in April in 1988 (and 1983) and in May in 1989, suggesting that there may be slight variation in the timing of the spawning event between years. Spiky oreo spawn during spring, with some evidence of spawning as early as August but most fish probably spawning between September and October. Smooth and black oreo, by contrast, are summer spawners off southern Australia and New Zealand (Pankhurst et al. 1987; Lyle et al. 1992). The timing of spawning in each of the species presumably corresponds in some way to the cycles in primary productivity. Blooms in phytoplankton production occur off south-eastern Tasmania in spring, summer and autumn, and it is likely that larvae spawned around these times would be able to capitalise on the production generated by these blooms (Harris et al. 1987, 1991).

In WBS, there was evidence of structuring within the warty oreo population, the proportion of juvenile and adult fish in the catches changed with depth, with adults becoming progressively more abundant as depth increased. By contrast in WTas juveniles were more abundant in the intermediate and deepest depth strata suggesting a different pattern of structuring. In WBS and WTas, however, all of the adults caught in the 800 m stratum were only present in the autumn sample. At this time there was also strong evidence for segregation of the sexes with depth, with males clearly dominant in the shallower depths and females becoming progressively more abundant with increasing depth. The presence of adult males in the 800 m stratum and segregation of the sexes with depth just prior to spawning suggests that this behaviour may be in some way related to spawning. Schooling by sex and depth during spawning has been reported in other deep water species, including orange roughy (Robertson et al. 1984; Pankhurst 1988). There was less evidence for structuring within the spiky oreo population although juveniles were relatively more abundant in intermediate depths.

The occurrence of small aggregations of warty oreo during summer, several months prior to the spawning season, suggests that they are not directly related to spawning, despite the predominance of adult fish in the catches (> 85% by number). In the absence of surveys conducted during the peak spawning period for both species, it is not possible to determine whether they form aggregations to spawn. Smooth and black oreos are known to form aggregations, a behaviour that appears to be related to spawning as well as feeding. In these species spawning occurs over a wide area and takes place in small aggregations (Lyle et al. 1992; McMillan and Hart 1993).

Dietary analysis was influenced by the high proportion of everted stomach, a consequence of a gas filled swim bladder. Both species of oreo are benthopelagic feeders. The main prey groups taken by warty oreo were bentho- and mesopelagic crustacea (shrimps, amphipods and copepods), fish and squid, a finding that is consistent an earlier study from South African waters (Mel'nikov 1980). As warty oreo grow in size, Mel'nikov (1980) observed a general shift in diet from crustaceans to fish. Although only a small sample of spiky oreo contained food, crustacea, fish and squid also featured in the diet of spiky oreo along with salps. Salps are also an important component of the diet of smooth and black oreo (Clark et al. 1989). A number of other deep water species also feed heavily on salps, including the slickhead (Alepocephalus australis Barnard) and rattail (Macrourus carinatus Gunther) (Clark et al. 1989). With the exception of salps, the oreo diets are similar to that for orange roughy, which is considered to be an opportunistic feeder (Bulman and Koslow 1992).

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Table 1 Allocyttus verrucosus. Seasonal abundance (kg/km^2) in WBS and WTas by 100 m depth strata. N is the number of tows, SE is the standard error.

	WBS Depth stratum (m)				WTAS Depth stratum (m)			
	800	900	1000	1100	800	900	1000	1100
Winter								
Mean	15.75	799.15	1834.92	1669.16	0.43	61.78	486.70	157.53
SE	10.43	246.94	667.54	659.01	0.43	23.17	168.05	58.93
N	3	6	4	6	4	5	5	3
Spring								
Mean	7.87	501.93	2539.17	1211.71	2.88	86.33	132.45	161.54
SE	7.87	479.74	946.74	297.45	1.43	41.50	60.00	55.60
N	3	2	4	5	5	7	6	5
Summer								
Mean	209.21	495.24	3255.65	3373.75	0.68	30.39	5294.20	230.62
SE	142.58	256.31	1879.65	1860.09	0.68	18.38	3386.33	47.75
N	7	6	3	6	5	7	6	5
Autumn								
Mean	474.85	821.98	2819.66	916.12	150.00	232.16	611.37	119.58
SE	170.16	434.58	1106.27	555.23	86.52	151.85	150.11	53.75
N	7	5	4	7	4	5	6	4

Table 2 Allocyttus verrucosus. Analysis of variance of $\log_e$ (catch rate (kg/km^2) + 1) by depth (800 - 1100 m depth strata), season and area. df is degrees of freedom; SS is sum of squares; MS mean sum of squares; and P is probability.

Source	df	SS	MS	F Value	P
Area	1	76.7040	76.7040	27.46	0.0001
Season	3	28.7899	9.5966	3.44	0.0191
Depth	3	386.4012	128.8004	46.12	0.0001
Area*Season	3	6.4537	2.1512	0.77	0.5128
Area*Depth	3	6.6820	2.2273	0.80	0.4976
Season*Depth	9	61.3065	6.8118	2.44	0.0138
Area*Season*Depth	9	23.3832	2.5981	0.93	0.5016

Table 3. Allocyttus verrucosus. 1988/89 seasonal biomass indices (tonnes) in WBS and WTas, based on 800 to 1100 m depth strata. N is number of tows, SE is standard error.

Season	WBS			WTAS		
	N	Biomass	SE	N	Biomass	SE
Winter	17	5524	1434	17	187	49
Spring	15	5393	1188	21	100	25
Summer	25	7927	2724	23	1497	917
Autumn	23	5718	1647	19	294	63

Table 4 Neocyttus rhomboidalis. Seasonal abundance (kg/km^2) in WBS and WTas by 100 m depth strata. N is the number of tows, SE is the standard error.

	Depth stratum (m)					
	500	600	700	800	900	1000
WBS						
Winter						
Mean	56.70	4623.60	1192.80	86.60	23.60	0.00
SE	53.80	4588.20	534.20	27.60	11.20	0.00
N	5	2	3	3	6	4
Spring						
Mean	7.10	-	521.60	11.80	29.50	8.90
SE	7.10	-	371.10	6.80	17.10	8.90
N	5	0	3	3	2	4
Summer						
Mean	0.00	236.20	3672.90	248.00	74.00	11.80
SE	0.00	178.60	992.00	93.70	31.90	11.80
N	4	5	2	7	6	3
Autumn						
Mean	613.40	338.60	165.00	174.10	47.20	32.50
SE	231.90	214.80	96.80	65.80	25.60	18.30
N	7	3	4	7	5	4
WTAS						
Winter						
Mean				203.93	50.50	11.16
SE				71.51	22.43	7.61
N				4	5	5
Spring						
Mean				180.96	100.63	8.83
SE				45.47	31.98	3.85
N				5	7	6
Summer						
Mean				484.98	202.93	12.37
SE				71.57	76.80	12.15
N				5	7	6
Autumn						
Mean				422.15	71.48	4.05
SE				341.63	41.16	2.58
N				4	5	6

Table 5 Neocyttus rhomboidalis. Analysis of variance of $\log_e$ (catch rate (kg/km^2) + 1) by depth (500 - 900 m depth strata) and season for WBS. Refer to Table 2 for explanation of terms.

Source	df	SS	MS	F Value	P
Season	3	9.6312	3.2104	0.75	0.5290
Depth	4	181.5748	45.3937	10.54	0.0001
Season*Depth	11	99.1125	9.0102	2.09	0.0338

Table 6. Neocyttus rhomboidalis. 1988/89 seasonal biomass indices (tonnes) for WBS, based on the 500 to 900 m depth strata. N is number of tows, SE is standard error.

Season	N	Biomass	SE
Winter	19	4930	368
Spring	13	1064	503
Summer	24	2229	911
Autumn	26	1892	817

Table 7 Allocyttus verrucosus. Sex ratios, based on proportion of females (all size groups and for fish ≥ 24 cm) by season, area and depth stratum.

Area/ season	Depth stratum (m) 800 All	800 >24	900 All	900 ≥24	1000 All	1000 ≥24	1100 All	1100 >24	All depths All
WBS									
Winter									
Prop. F	0.43	0.75	0.48	0.40	0.60	0.61	0.57	0.59	0.54
N	7	4	991	490	319	275	987	868	2390
Spring									
Prop F	0.63	1.00	0.45	0.52	0.38	0.35	0.53	0.54	0.43
N	8	1	238	61	1605	1080	401	391	2444
Summer									
Prop F	0.46	0.32	0.42	0.35	0.52	0.62	0.44	0.45	0.46
N	367	21	471	220	871	241	2415	2181	4242
Autumn									
Prop F	0.11	0.10	0.37	0.34	0.47	0.50	0.57	0.60	0.47
N	176	158	545	345	1412	1025	882	626	3061
WTAS									
Winter									
Prop F	0.33	-	0.52	0.64	0.55	0.54	0.57	0.47	0.55
N	3	0	124	14	624	355	128	43	879
Spring									
Prop F	0.30	-	0.42	0.39	0.53	0.44	0.50	0.50	0.49
N	10	0	225	56	282	59	248	56	765
Summer									
Prop F	0.50	-	0.51	0.67	0.52	0.52	0.49	0.55	0.52
N	4	0	100	12	4624	4312	464	102	5192
Autumn									
Prop F	0.20	0.22	0.46	0.49	0.60	0.69	0.67	0.79	0.54
N	91	83	316	129	795	398	129	29	1331

Table 8 Neocyttus rhomboidalis. Sex ratios, based on proportion of females (all size groups and fish ≥ 29 cm) by season and depth stratum for WBS.

Season	Depth stratum (m) 500 All	500 ≥29	600 All	600 ≥29	700 All	700 ≥29	800 All	800 ≥29	900 All	900 ≥29	All depths All
Winter											
Prop. F	0.52	0.64	0.38	0.40	0.54	0.56	0.54	0.49	0.45	0.45	0.44
N	31	25	946	801	424	301	26	23	11	11	1444
Spring											
Prop F	0.83	1.00	-	-	0.48	0.54	0.50	1.00	0.80	0.75	0.49
N	6	5	-	-	254	72	10	2	5	4	281
Summer											
Prop F	1.00	1.00	0.77	0.84	0.44	0.45	0.52	0.54	0.57	0.54	0.49
N	3	3	124	103	835	555	226	149	47	41	1242
Autumn											
Prop F	0.58	0.61	0.45	0.48	0.33	0.33	0.46	0.45	0.50	0.50	0.52
N	273	241	95	90	15	15	143	107	20	20	568

Figure Legends

Fig. 1 Map showing survey area and boundaries of Western Bass Strait (WBS) and Western Tasmania (WTas). Sites from which additional biological material was obtained are indicated by hatched areas.

Fig. 2 Mean standardised catch rates by 100 m depth strata for WBS, warty oreo Allocyttus verrucosus (top) and spiky oreo Neocyttus rhomboidalis (bottom). Clear bars represent one standard error.

Fig 3 Allocyttus verrucosus Length frequency distributions by sex for WBS (left) and WTas (right). N is sample size, L is mean length.

Fig. 4 Allocyttus verrucosus Length frequency distributions by season for WBS (left) and WTas (right). N is sample size, L is mean length.

Fig. 5 Allocyttus verrucosus Length frequency distributions by 100 m depth strata (800 m to 1100 m) for WBS (left) and WTas (right). N is sample size, L is mean length.

Fig. 6 Neocyttus rhomboidalis Length frequency distributions by sex for WBS (left) and WTas (right). N is sample size, L is mean length.

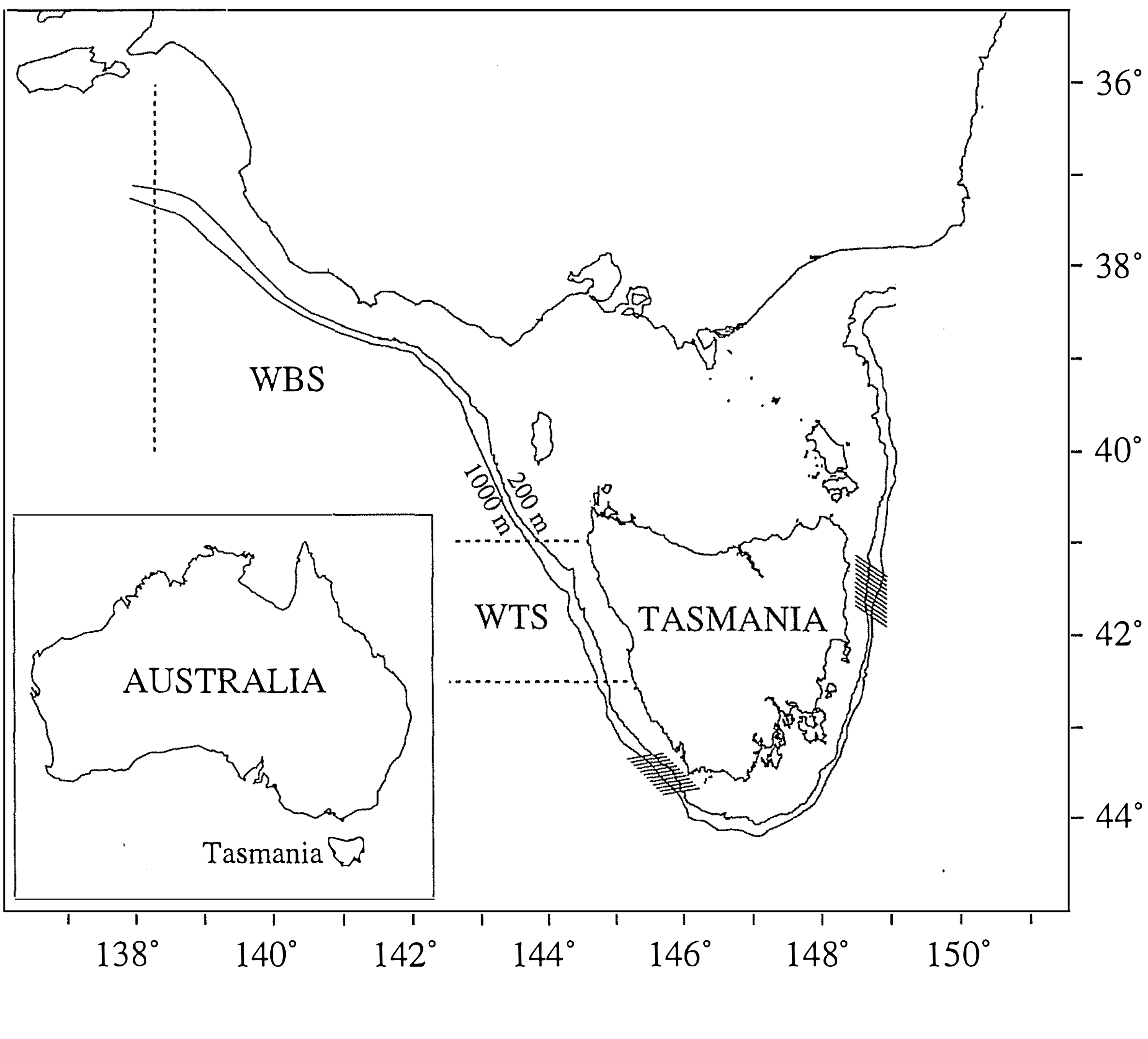
Fig. 7 Neocyttus rhomboidalis Length frequency distributions by season for WBS. N is sample size, L is mean length.

Fig. 8 Neocyttus rhomboidalis Length frequency distributions by 100 m depth strata (500 m to > 900 m) for WBS. N is sample size, L is mean length.

Fig. 9 Allocyttus verrucosus (top), Neocyttus rhomboidalis (bottom) Relative abundance of mature individuals by 1 cm size intervals. Black dots for males and white dots for females, N is sample size.

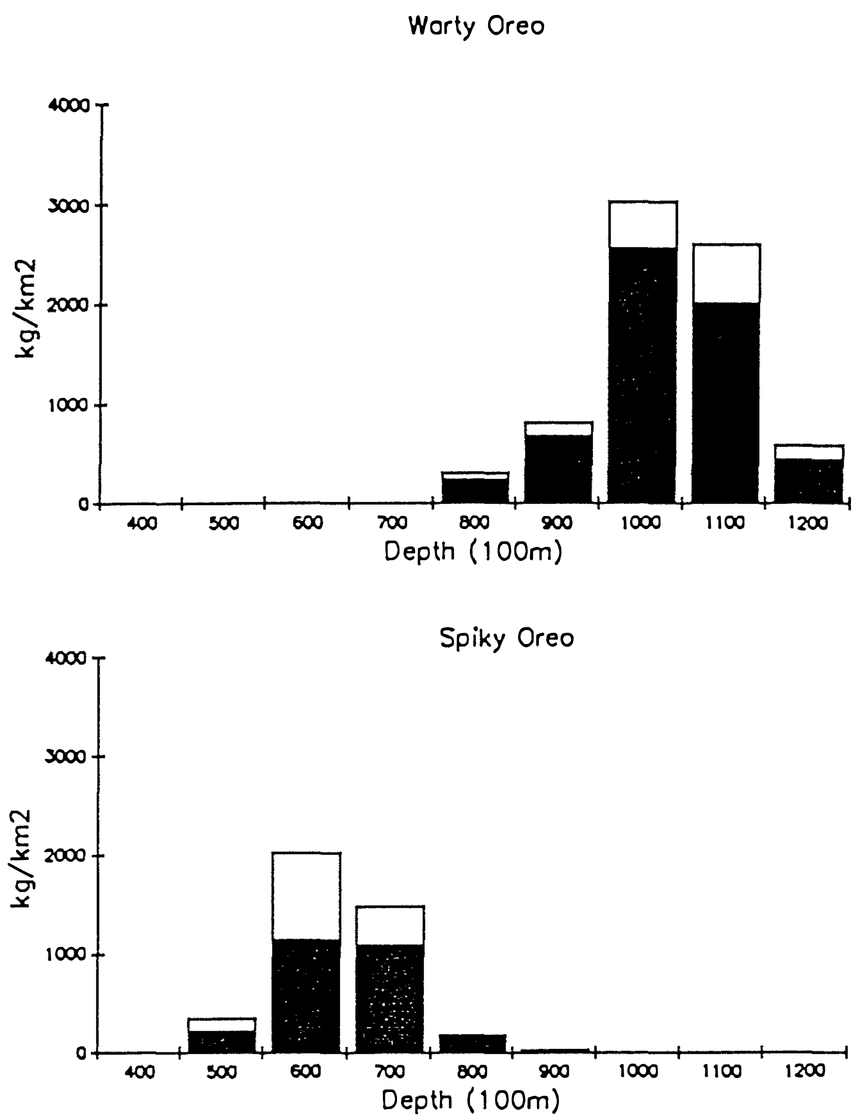
Fig. 10 Allocyttus verrucosus Mean monthly gonadosomatic index for females (top) and males (bottom). Error bars represent one standard deviation and numbers indicate sample size.

Fig. 11 Neocyttus rhomboidalis Mean monthly gonadosomatic index for females (top) and males (bottom). Error bars represent one standard deviation and numbers indicate sample size.



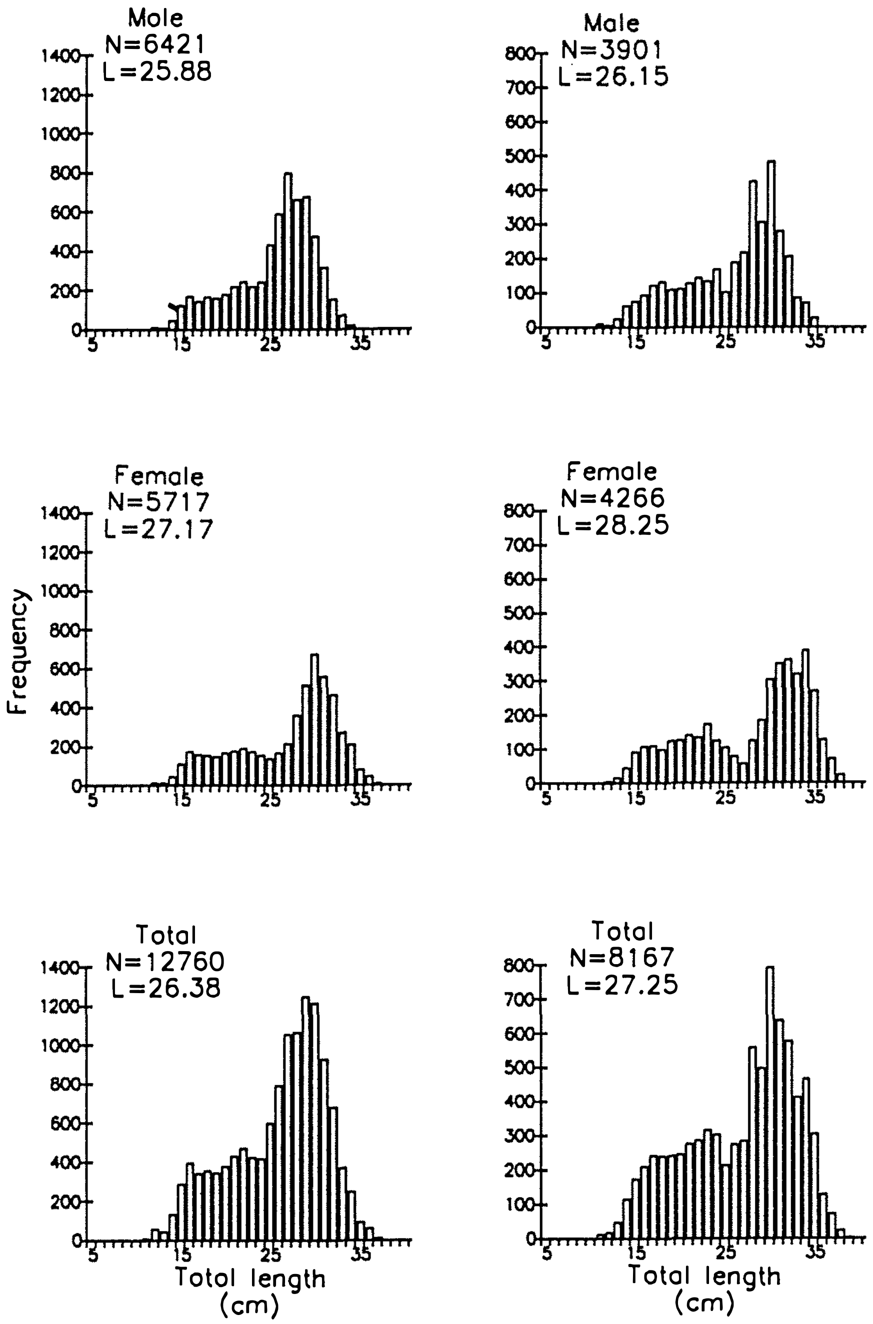
36°
38°
40°
42°
44°
WBS
WTS
TASMANIA
1000 m
200 m
AUSTRALIA
Tasmania
138°
140°
142°
144°
146°
148°
150°

Fig. 1



Warty Oreo
4000
3000
2000
1000
0
kg/km2
400
500
600
700
800
900
1000
1100
1200
Depth (100m)
Spiky Oreo
4000
3000
2000
1000
0
kg/km2
400
500
600
700
800
900
1000
1100
1200
Depth (100m)

Fig. 2



Male
N=6421
L=25.88
Male
N=3901
L=26.15
Female
N=5717
L=27.17
Female
N=4266
L=28.25
Total
N=12760
L=26.38
Total
N=8167
L=27.25
Frequency
Totol length (cm)
Total length (cm)

Fig. 3

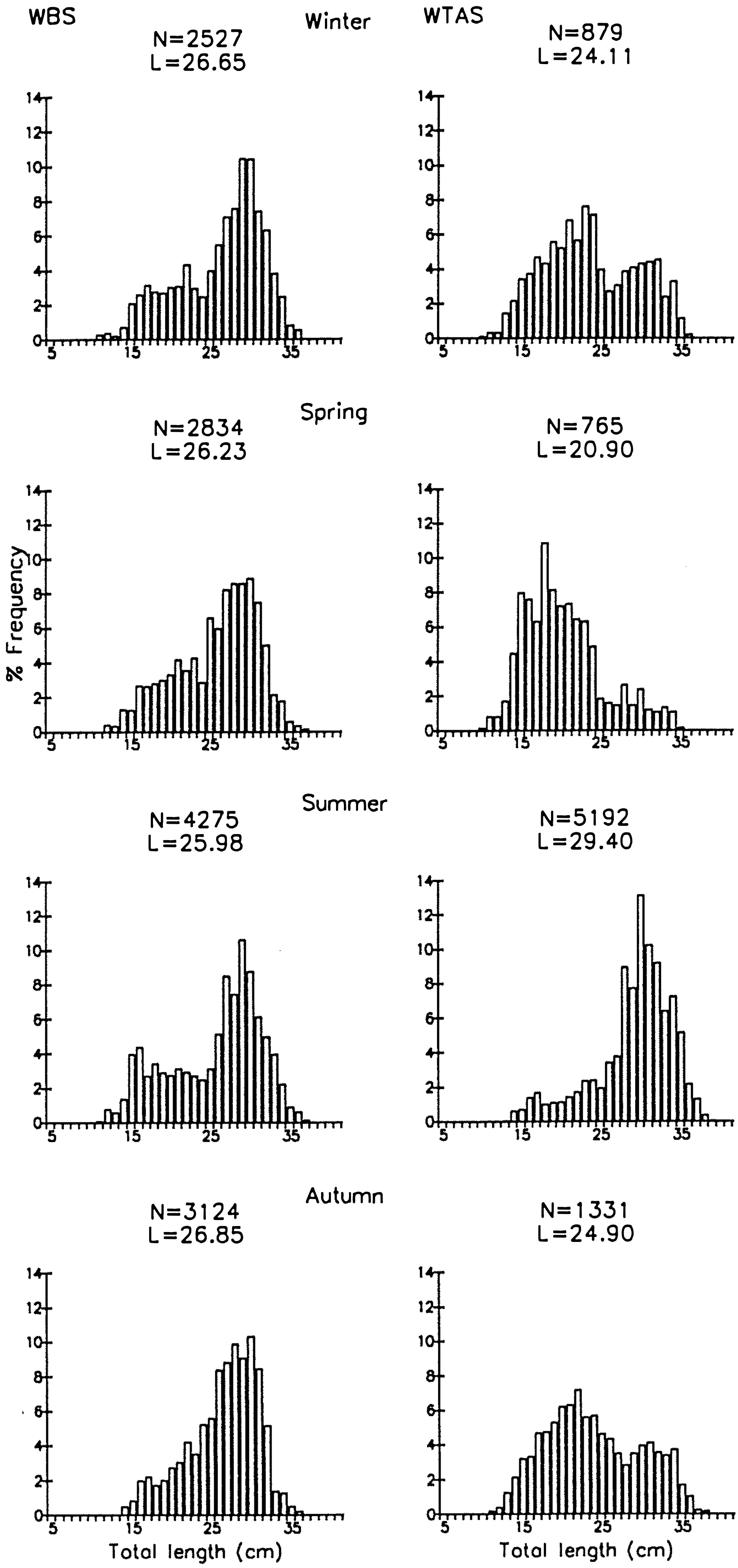

WBS
Winter
WTAS
N=2527
L=26.65
N=879
L=24.11
Spring
N=2834
L=26.23
N=765
L=20.90
% Frequency
Summer
N=4275
L=25.98
N=5192
L=29.40
Autumn
N=3124
L=26.85
N=1331
L=24.90
Total length (cm)
Total length (cm)

Fig. 4

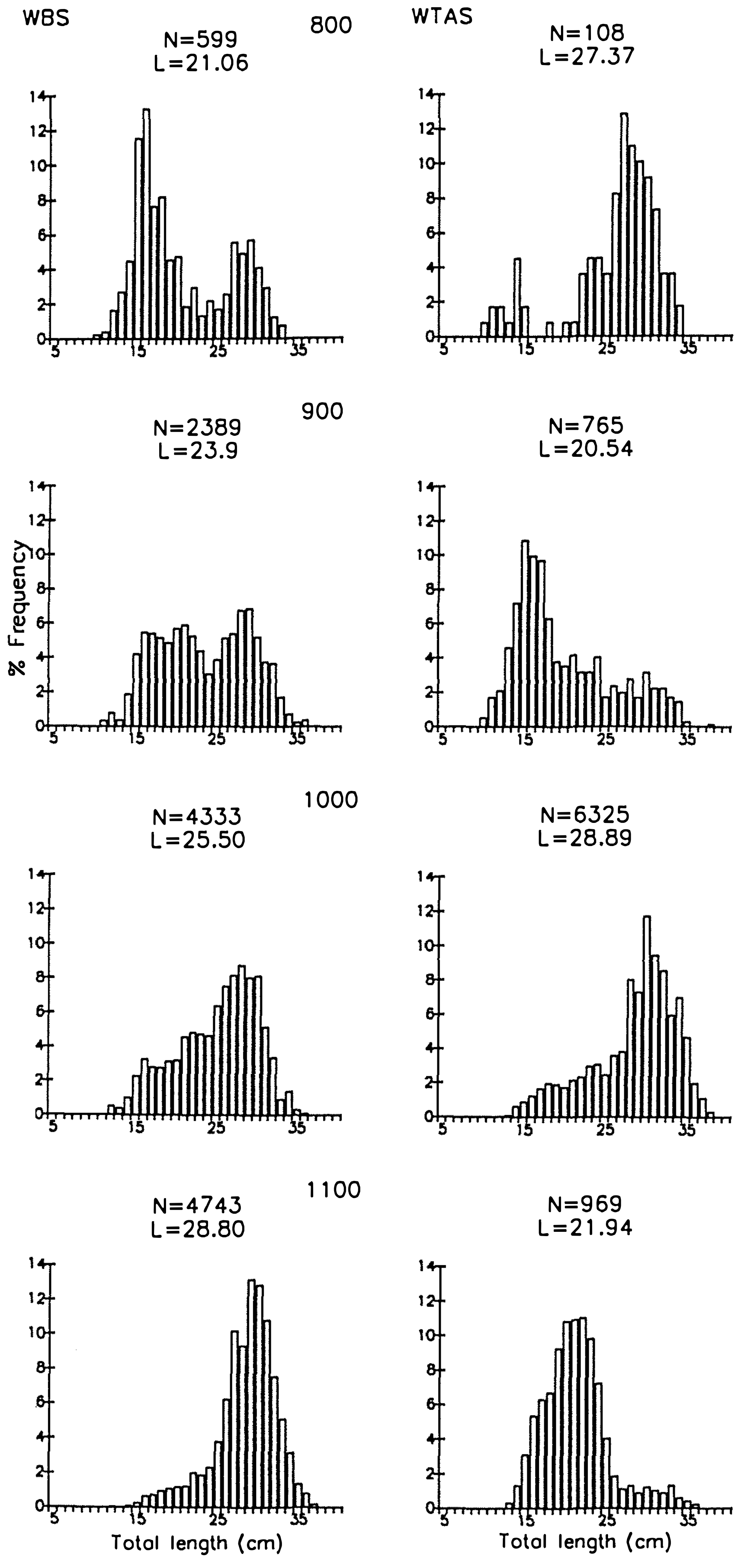
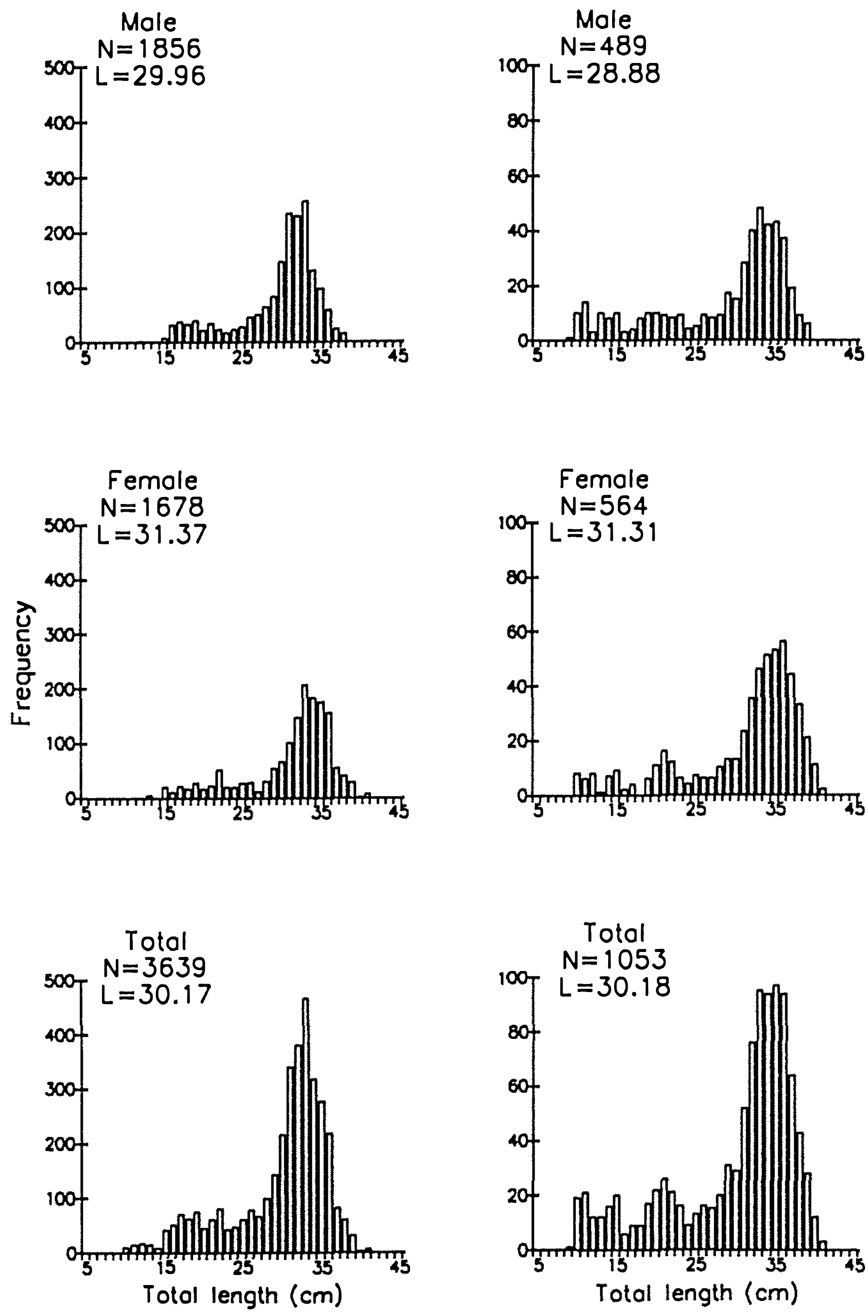

WBS
WTAS
800
900
1000
1100
N=599
L=21.06
N=108
L=27.37
N=2389
L=23.9
N=765
L=20.54
N=4333
L=25.50
N=6325
L=28.89
N=4743
L=28.80
N=969
L=21.94
% Frequency
Total length (cm)
Total length (cm)

Fig. 5



Male
N=1856
L=29.96
Male
N=489
L=28.88
Female
N=1678
L=31.37
Female
N=564
L=31.31
Total
N=3639
L=30.17
Total
N=1053
L=30.18
Frequency
Total length (cm)
Total length (cm)

Fig. 6

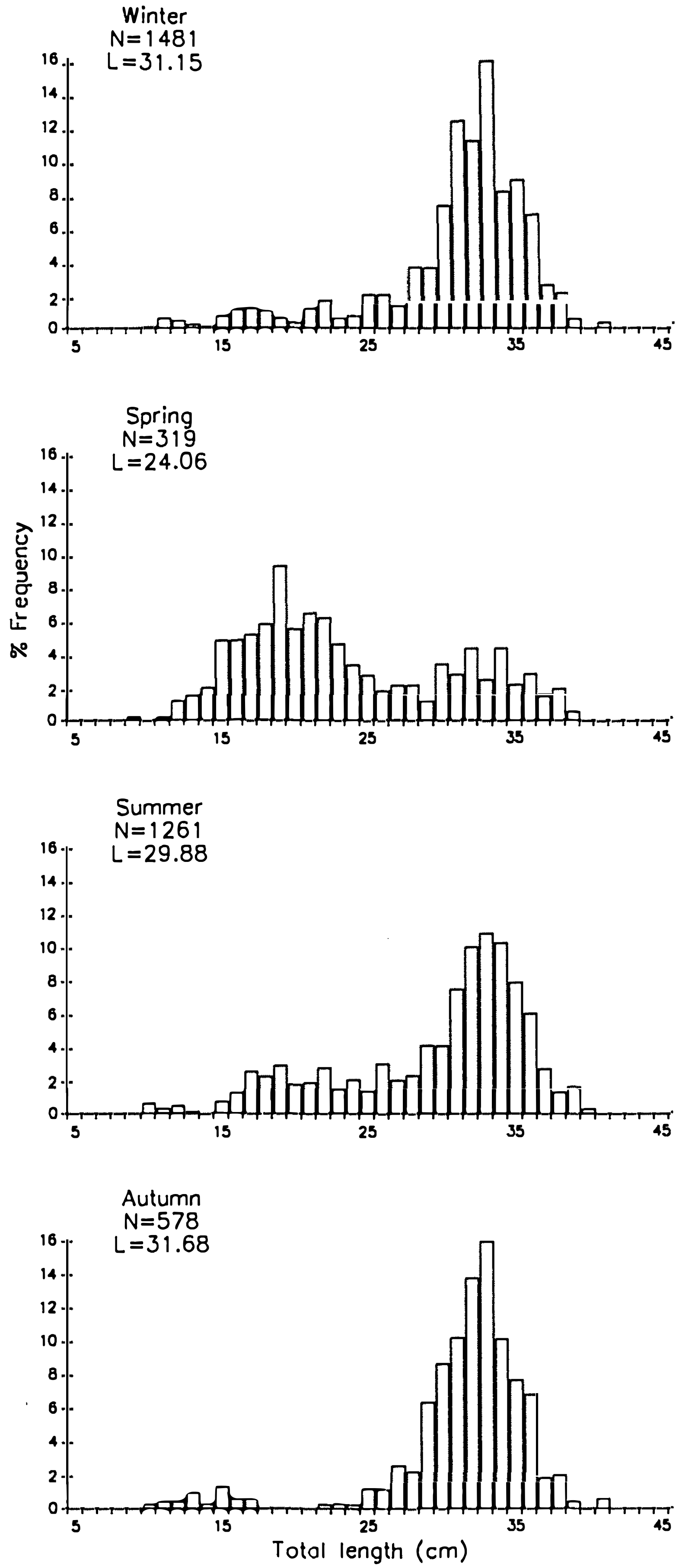

Winter
N=1481
L=31.15
Spring
N=319
L=24.06
Summer
N=1261
L=29.88
Autumn
N=578
L=31.68
% Frequency
Total length (cm)
0
2
4
6
8
10
12
14
16
5
15
25
35
45

Fig. 7

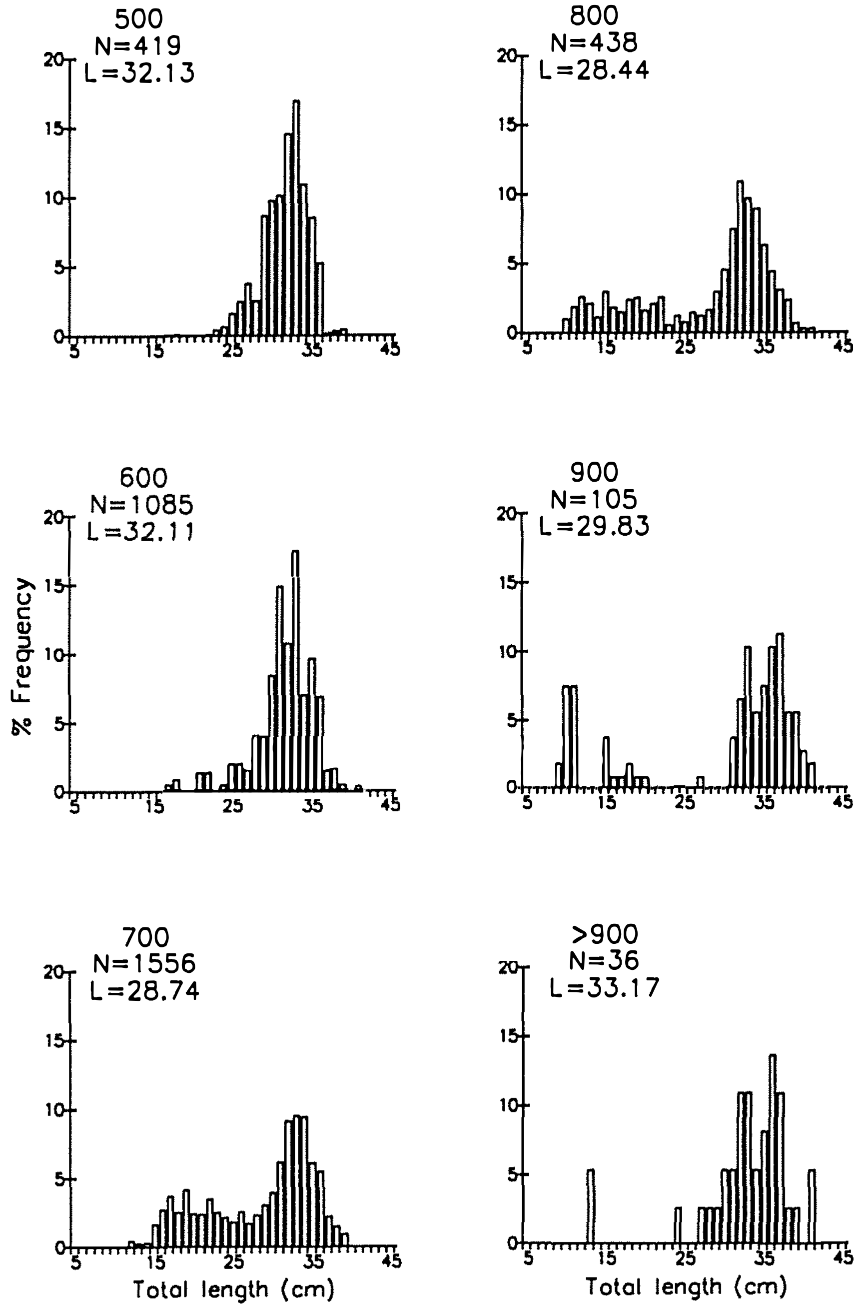

500
N=419
L=32.13
800
N=438
L=28.44
600
N=1085
L=32.11
900
N=105
L=29.83
700
N=1556
L=28.74
>900
N=36
L=33.17
% Frequency
Total length (cm)
Total length (cm)
0
5
10
15
20
5
15
25
35
45

Fig. 8

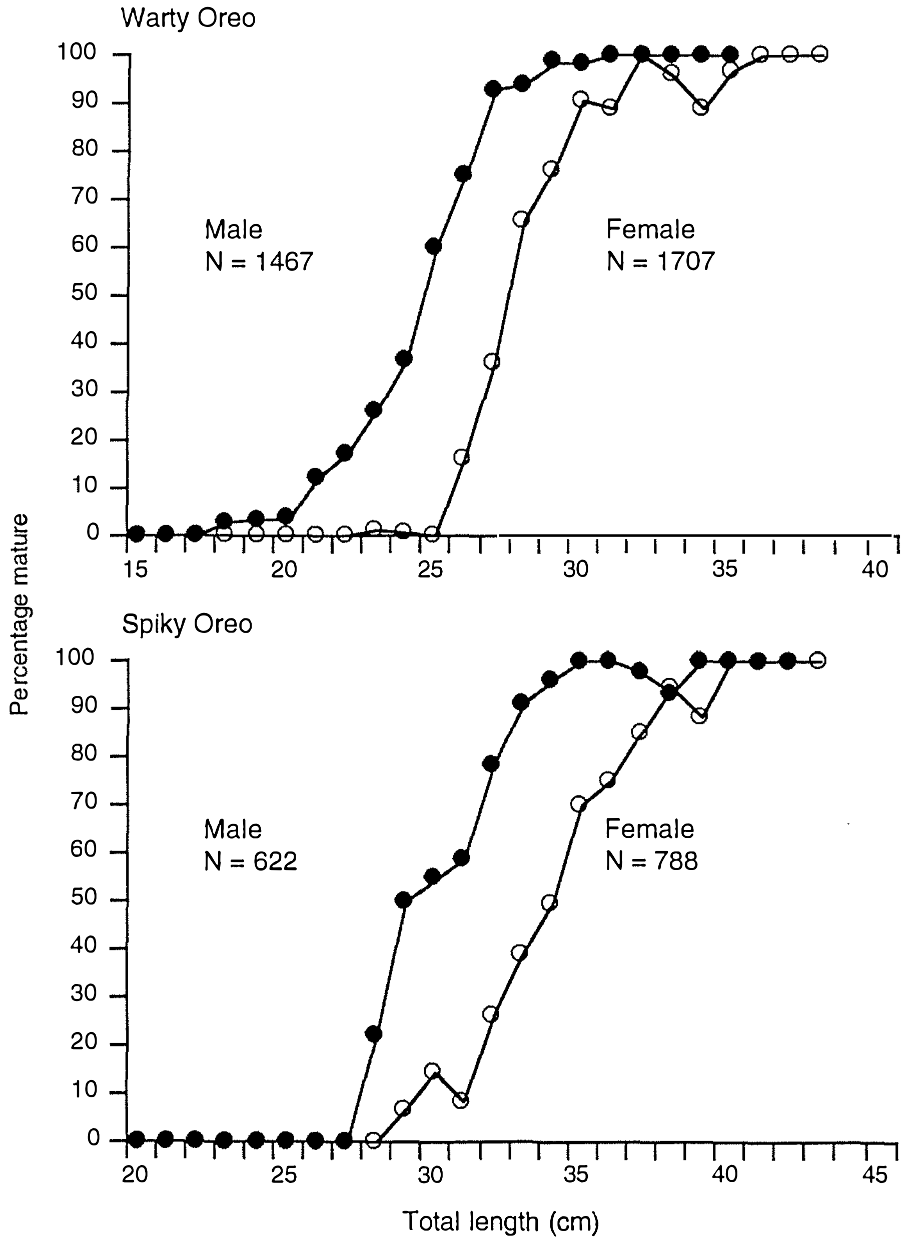

Warty Oreo
Male
N = 1467
Female
N = 1707
Spiky Oreo
Male
N = 622
Female
N = 788
Percentage mature
Total length (cm)
100
90
80
70
60
50
40
30
20
10
0
15
20
25
30
35
40
45

Fig. 9

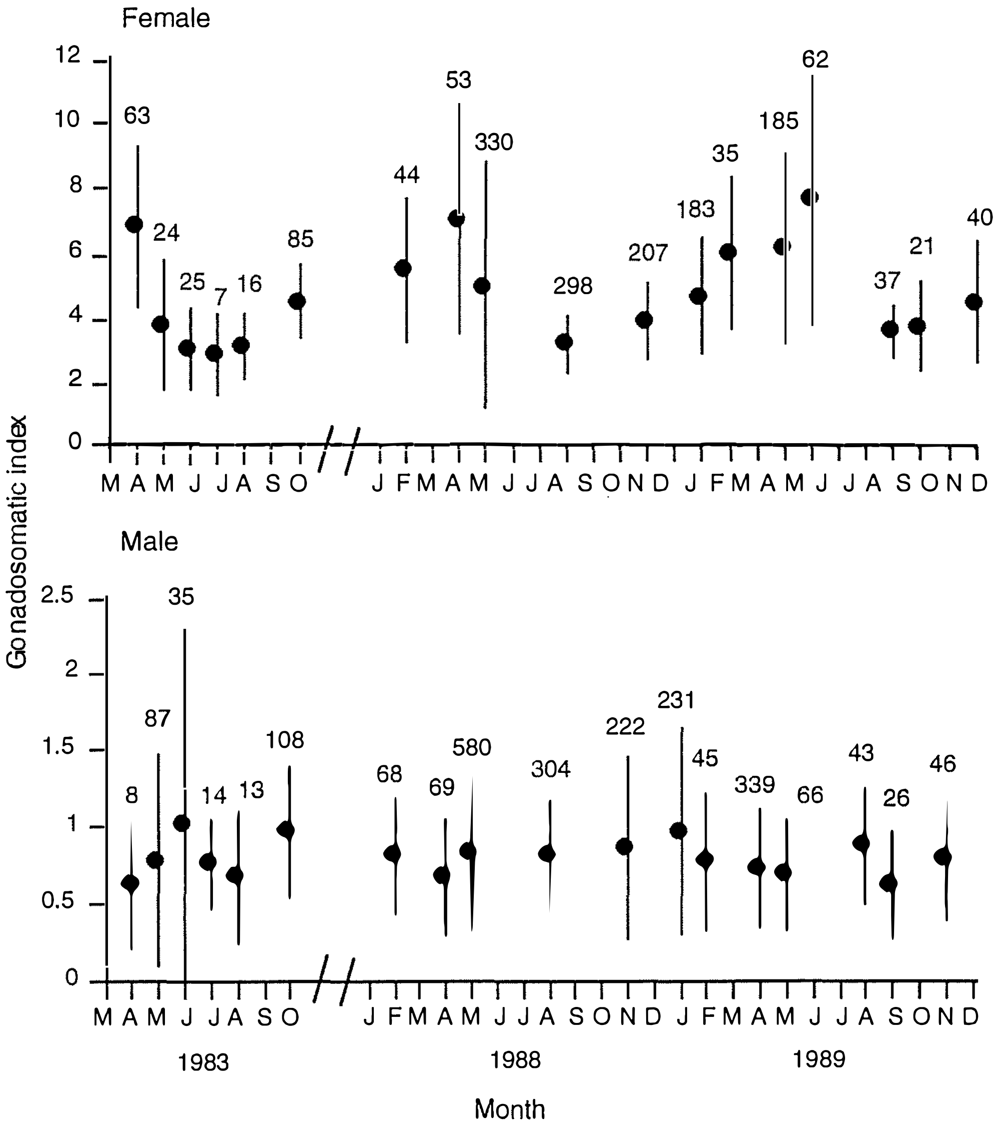

Female
Male
Gonadosomatic index
M A M J J A S O J F M A M J J A S O N D J F M A M J J A S O N D
1983
1988
1989
Month

Fig. 10

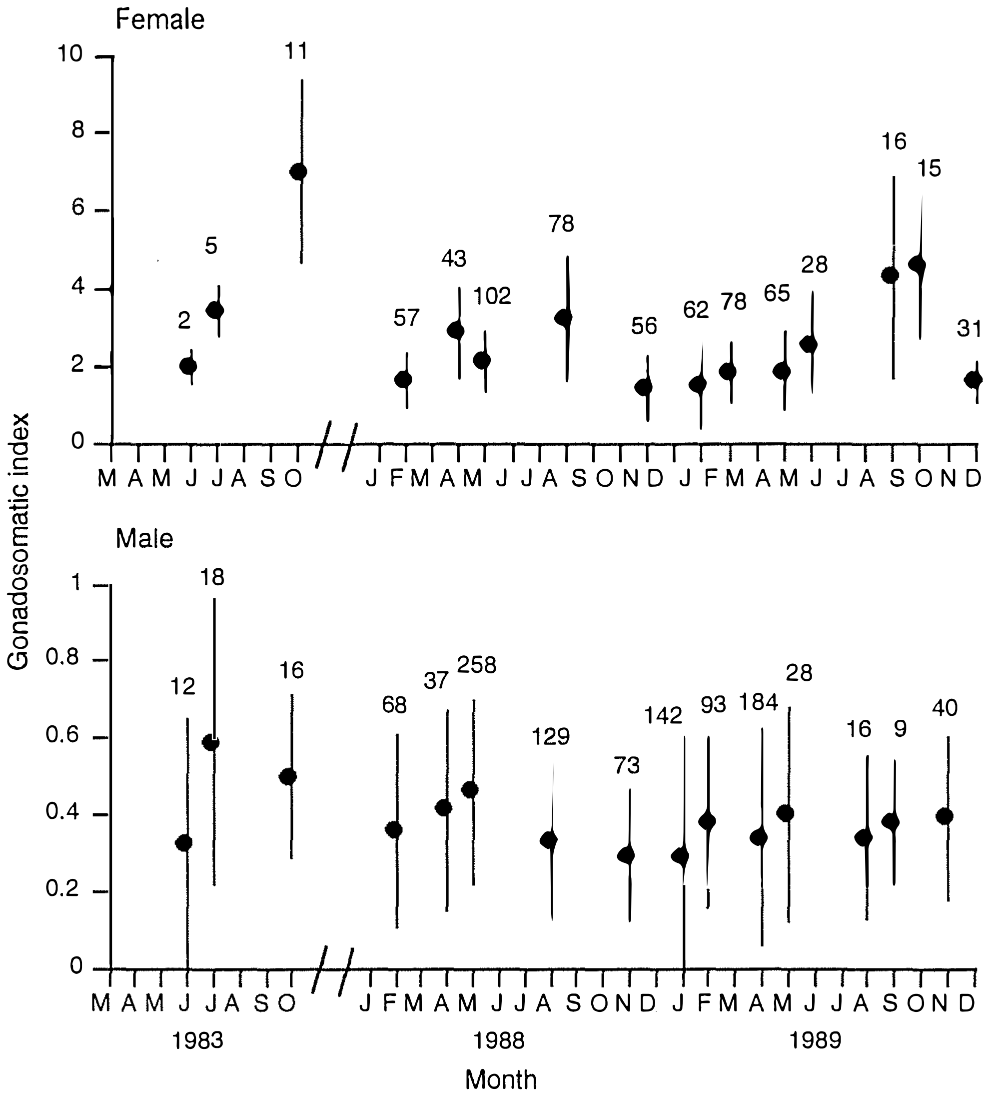

Female
Male
Gonadosomatic index
0
2
4
6
8
10
0.2
0.4
0.6
0.8
1
M A M J J A S O
J F M A M J J A S O N D
J F M A M J J A S O N D
1983
1988
1989
Month
2
5
11
57
43
102
78
56
62
78
65
28
16
15
31
12
18
16
68
37
258
129
73
142
93
184
28
16
9
40

Fig. 11