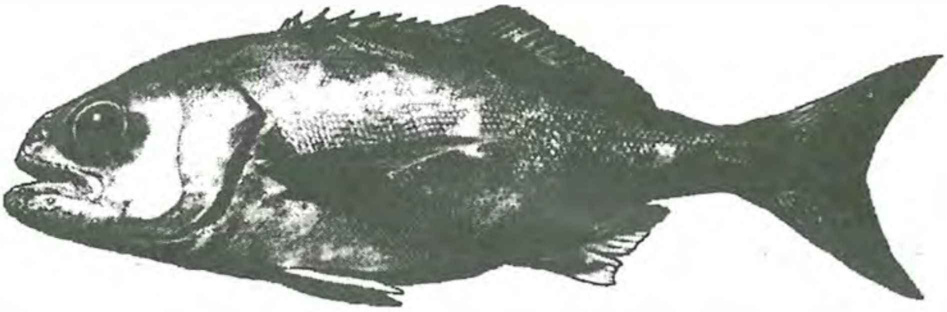
July 1995

FINAL REPORT TO THE FISHERIES RESEARCH AND DEVELOPMENT CORPORATION

ASSESSMENT OF THE BLUE-EYE TREVALLA FISHERY AND ANALYSIS OF MIDWATER TRAWLING

FRDC Grant 91/20



Department of Conservation and Natural Resources
Victoria

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Department of Primary Industry and Fisheries
TASMANIA

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ACKNOWLEDGEMENTS

Tasmania

Many thanks to Tasmanian drop-line fishers and fish processors whose generous and sustained assistance made this project possible. Thanks to Lisa Hick and Fiona Ewing for helping with the collection of data at sea and at the processing factories, to Andrew Brown for helping with the analysis of data, and to Simon Robertson for ageing the otoliths collected. Robert Kennedy provided assistance with yield-per-recruit analyses, while Bryce Graham and Ross Corkrey helped with statistical comparisons between fishing gears. Finally, thanks to Jeremy Lyle, Kevin Rowling and Grant West for reviewing parts of this report.

Victoria

Thanks are due to Ken Smith (V.F.R.I.) who assisted with field work, and the skippers and crew of the commercial vessels who assisted with various aspects of the project, in particular John Bolitho, John Guidera, Greg Keatley, Andrew Levings, Peter and Maree Price, David and Annette Sharp, and Bert and Margaret Tober. Graham Cottier and Jodie Peel obtained many of the length-frequency samples of the commercial catch. Corey Green assisted with the sectioning of otoliths and was the second reader, and Kylie Hall (both of the Central Ageing Facility, V.F.R.I.) weighed otoliths and entered biological data.

SUMMARY

The blue-eye trevalla fishery is traditionally a line fishery and plans to develop mid-water trawl fishing techniques to target this species have raised concern at the capacity of the stock to sustain high fishing pressure. As there was very limited information on the biology or size of the resource, a three-year FRDC research programme was established in 1991 to study the biology of, and fishery for blue-eye trevalla. Tender for mid-water trawl surveys failed to attract fishers' interest (see Appendix II), and, as a result, only limited data are available from the trawl sector of the fishery. In this report, the state of the stock is assessed by analysing the interactions between fish biology and behaviour and drop-line fishing practices. Data available from other fishing methods (bottom long-line, demersal trawl and mid-water trawl) are also analysed for comparison.

Problems associated with analysis of hook catch rate

The study showed that the scale used to aggregate catch and effort data changed the shape of the cpue frequency distribution, and that cpue calculated from data aggregated on the smallest spatial scale (individual drop-lines) better reflected the dynamics of the fishery and distribution patterns of the fish.

In addition, the proportionality between catch rate and abundance was shown to be biased by drop-line fishing practices, differences in fishers' skills, and fish behaviour. Catch does not increase proportionally with effort in number of hooks, and the fishing efficiency of the unit of fishing effort (the hook) is not constant; it varies during fishing operations and with the carrying capacity (total number of hooks) of the drop-lines.

Changes in fishing dynamics over time in the Tasmanian drop-line fishery

Trends in catch statistics from the Tasmanian drop-line fishery showed that, after an expected decrease in catch rates in the early years of the fishery (late 1960s), annual catch rate increased again from the late 1980s. However, there has been a dramatic decrease in the size of fish in commercial catches since the fishery began. Drop-line catches are currently dominated by small (below 55 cm fork-length), immature fish, while the average length of fish was 70-80 cm fork-length when at the beginning of

the fishery. Larger fish are now only caught during spring-summer feeding and spawning aggregations.

Detailed analysis of changes over time in the frequency distribution of catch rates and in the length of fish revealed that the late 1980s increase in catch rate was related to change in targeting practice rather than increase in fish abundance. The fishery first developed in relatively deep waters targeting large fish. The abundance/catchability of these fish rapidly declined, and the fishery moved to shallower depths targeting schools of small fish. These schools appear to inhabit more open waters, and their patchy distribution is reflected in the cpue frequency distribution, now dominated by low cpue values, with occasionally very high values. The identification and location of the schools is facilitated by colour-echo-sounders and GPS.

Catch rates were higher when smaller, and uniformly sized fish were caught. Thus, by targeting patchy, but dense fish schools, fishers have maintained, or even increased, annual catch rates. This, together with the exploitation of a new ground (i.e. temporarily more productive) explain the increase in annual cpue since the late 1980s.

The decrease in catch rate of large fish occurred shortly after their exploitation began, likely reflecting a decrease in catchability at lower density in relation to their non-schooling behaviour. The impact of the fishery on their true abundance is uncertain and needs to be elucidated. However, the fishery has entered a new phase, and catch rates are unlikely to reflect a decrease in fish abundance now that fishers target concentrations of schooling fish.

Reproduction and recruitment

The annual fecundity of blue-eye trevalla is high and increases with the length of females (to a maximum of about 11 million). Both sexes reach sexual maturity at large sizes, 71.3 and 61.6 cm for females and males, respectively. Preliminary age data indicate that corresponding ages at sexual maturity are about 11-12 years for females and 8-9 years for males.

One major spawning ground was identified off Tasmania, although there is evidence of widespread spawning activity across southern Australia. Blue-eye trevalla aggregate on the Tasmanian ground for several months (from October to May), with progressive arrivals of fish of different size and different stages of maturity. Smaller fish join the aggregation earlier and at earlier stages of gonad maturation than larger fish. Spawning then takes place during a 2-month period at the end of summer-autumn (early March to early May). The presence of pre-adult, non-spawning fish suggests that the aggregation is related to both spawning and feeding behaviours.

After spending their first few years in pelagic waters, blue-eye trevalla settle to the bottom in late spring-summer, at length between 45 to 52 cm FL. They are fully recruited to the fishery at an average length of 50 cm FL, showing that blue-eye trevalla become vulnerable to the fishery very shortly after settling to the bottom.

Growth, mortality, yield- and egg-per-recruit

Present results on growth, mortality, yield- and egg-per-recruit should be regarded as preliminary only as problems with age validation and suspected length/age specific changes in catchability hamper estimation of growth and mortality rates.

It seems that the drop-line fishery is currently at its optimum level of exploitation, with no scope to increase yield by increasing effort or changing the size at first capture.

The fishery for blue-eye trevalla in Victoria

The fishery for blue-eye trevalla in Victoria is a multi-method fishery which interacts with other components of the diversified fishery of southern Australia. The drop-line fishery is sporadic in nature, and only a minority of licensed vessels participate in any one year. Drop-lining contributed an estimated 45% of their total catch value for fishers who participated in the drop-line and other fisheries between 1992 and 1994. Blue-eye trevalla contributed an estimated 87% of this value. In contrast blue-eye trevalla contributes 6% to the value of the mesh net fishery.

The combined catch of blue-eye trevalla by all gears except otter trawl varied between 77 and 170 tonnes between 1987 and 1994. Drop-lines and mesh nets take approximately equal shares of the catch. The catch by otter trawl in the South East Fishery for the eastern and western zones combined is smaller than the combined catch from the other components of the fishery. Increased reporting of drop-line catches, in response to changed management arrangements, may be partly responsible for the increase landings in recent years.

Trawl caught fish are on average slightly smaller than drop-line caught fish from the same area, but the differences are smaller than those observed between areas. The mean size of fish caught in eastern Bass Strait is larger than that for western Bass Strait. Some size structuring in the populations of blue-eye across Bass Strait is indicated.

There is an indication of a decline in the mean length of fish caught by otter trawl in western Victoria since 1992.

Age determination

The age of blue-eye trevalla was estimated from thin sections of sagittal otoliths. Blue-eye trevalla are believed to live to over 40 years. On the basis of marginal increment analysis, otolith weight plots, and agreement with the estimates from bomb radiocarbon, it is believed that the assigned ages are accurate.

These are higher age estimates than previously reported for fish from New Zealand but the differences are not due to differences in methods of preparation or reading.

Growth, age composition and mortality estimates

Growth of blue-eye trevalla is relatively fast for the first three or four years (prior to recruitment to the fishery) and then slows. Commercial catches are composed mostly of young fish, less than 15 years old.

Over all areas, 3 and 4 year old fish predominated in the samples of both females and males from North East, South East and West Tasmania. Fish from the Cascade Plateau had a modal age of 15 years for females and 11 years for males. Western Bass Strait was intermediate between these areas.

Growth curves showed significant differences between the sexes. Females and males have similar mean lengths at up to about age 9 after which the mean lengths of females is higher. Fish from the Cascade Plateau are faster growing than those from other areas. Growth estimates for young fish are biased by the lack of small fish in the samples.

Estimates of total instantaneous mortality, obtained after age-length keys had been applied to port-sampled length frequency data, varied between 0.21 to 0.37.

Gear comparison

Trawl catch and effort data recorded in the South East Fishery logbooks indicate an average catch rate of about 5 t/hour for mid-water trawl fishing method. In comparison, Tasmanian drop-line fishers' returns indicate catch rates of about 1.5 t/month.

The length compositions of catches also varied significantly between the fishing gears, mid-water trawl catches being comprised mostly of pre-adult fish, compared with newly settled and immature fish in drop-line catches. This would require further investigation should fishing pressure from the trawl sector be increased.

Analysis of the impact of semi-pelagic trawling.

Blue-eye trevalla can be effectively targeted by semi-pelagic trawl gear in western Bass Strait . The likely extent of potential semi-pelagic trawl resources other than blue-eye trevalla is yet to be determined.

The level of by-catch from shots of semi-pelagic trawl gear was low with few non-target species recorded in any individual shot.

Large shot by shot variation in the quantity and size of fish in the catch precludes any useful estimation of likely catch rates for semi-pelagic trawl gear in western Bass Strait. Semi-pelagic trawl gear may generate higher returns to fishers for an equivalent weight of otter trawl caught fish even if catch rates are lower.

There is no evidence from the surveys that semi-pelagic trawl gear catches smaller fish than are currently taken by the drop-line fishery in the same area, and may catch proportionally fewer small fish than are currently taken by either drop-line or otter trawls. The variation in the size distribution of individual shots indicates the need for caution in interpreting these data.

Research needs

The suspected small size of the resource will probably never warrant expensive, and uncertain, acoustic and sampling surveys over hard bottom to estimate the biomass of the stock. Research effort should concentrate on better understanding the structure of the population, and on validating age estimates.

INTRODUCTION

Background to the project

Blue-eye trevalla (*Hyperoglyphe antarctica*, Centrolophidae) are semi-pelagic fish, widely distributed in the southern oceans, from New Zealand, to southern Australia, South Africa and the southern Indian Ocean (Haedrich, 1967; McDowall, 1982). In Australia, their distribution ranges from central New South Wales to southern Western Australia, including some offshore seamounts off Tasmania and New South Wales. The fishery has mostly developed off south-eastern Australia, and particularly off Tasmania. Fishing is traditionally done using drop-lines on hard bottom associated with the continental shelf break, at depths between 300 and 500 m. Commercial landings are relatively small (about 800 tonnes/year), but blue-eye trevalla are excellent table fish and fetch high prices on the domestic market. The annual value of landings is currently in excess of $3.5 million.

Since the early 1970s, blue-eye trevalla have been caught in small quantities by demersal trawling off south-eastern Australia as by-catch of blue grenadier (*Macruronus novaezelandiae*). In the late 1980s, a conflict began between traditional line fishers and trawl fishers who wanted to develop mid-water trawl fishing methods to target blue-eye trevalla among other semi-pelagic species, . Early fishing trials showed that mid-water trawling had the potential to catch large quantities of this species. As there was very limited information on the biology or size of the resource at that time, a 3-year FRDC research programme was established in 1991 to study the biology of, and fishery for blue-eye trevalla.

Objectives of the project

The initial objectives of the project were:

- to evaluate differences in the vulnerability of the population to exploitation by either line fishing or mid-water trawling,
- to collect basic biological data on:
  - catch composition, age, growth, mortality and reproductive biology
  - movement by tagging,
- to assess the impact of different gears on the fishery, individually and in combination.

The project was a collaborative project between the Tasmanian Marine Research Laboratories and the Victorian Fisheries Research Institute.

The Tasmanian Marine Research Laboratories was responsible for:

- field work conducted in waters off the west, south and east coasts of Tasmania,
- conducting tagging cruises from the FRV *Challenger*,
- assessment of maturity and reproduction, and
- population modelling and assessment of the impact of the different gears.

The Victorian Fisheries Research Institute was responsible for:

- field work conducted in Western Bass Strait,
- conducting tagging under charter off Victoria,
- ageing of historic samples and samples collected during this program, and
- analysis of growth.

This programme relied on participation from both the line and trawl sectors of the industry to provide information on catch composition and fishing practices. In particular, the industry was to take part in seasonal mid-water trawl surveys off Tasmania and Victoria. However, in early 1992, restrictive quotas were imposed on trawl catches to discourage targeting of blue-eye trevalla. As a result, all trawl fishers but one, already dissatisfied with some of the conditions in the survey protocol, withdrew from participating in the research project.

The implementation of restrictive quota on trawl catches has momentarily reduced the conflict between the two fishing sectors, but has not solved it. There is pressure from the trawl industry to increase the blue-eye trevalla quota to cover by-catches of this species in blue grenadier catches, and there is still interest in developing mid-water trawling to target semi-pelagic species.

To date, the hook fishery is un-regulated, while there are concerns about increasing catch and effort and localised depletions of the blue-eye trevalla stock. Tagging trials in New Zealand (Horn 1989) have suggested that blue-eye trevalla may be particularly vulnerable to fishing due to its sedentary habits. Recent Offshore Constitutional Settlement (OCS) agreements have given the Commonwealth the responsibility to manage the fishery off Tasmania and Victoria (negotiations in New South Wales have not been finalised yet). In this report, the status of the stock is assessed through detailed analysis of the Tasmanian drop-line fishery to help appropriate management of the resource.

Data currently available on blue-eye trevalla are limited and inappropriate for use with standard stock assessment methods based on historical catch statistics and catch composition. The state of the stock is assessed in this study by analysing the interactions between fish behaviour and drop-line fishing practices, and how they influence catch composition and catch rate. Data available from other fishing methods (bottom long-line, demersal trawl and mid-water trawl) are also analysed for comparison.

With most published studies on hook fishing referring to long-line (horizontal) fishing methods, this study also provides information specific to drop-line (vertical) fishing methods.

Transfer of the results to the industry

Some results of the study have already been transferred to the industry by means of various reports:

- individual and confidential reports summarising biological and fisheries data collected were sent to the Tasmanian drop-line fishers who participated in the project;
- an article on the discovery of juvenile blue-eye trevalla was published in *Australian Fisheries* (Last *et al.* 1993);
- an article on the New Zealand blue-eye trevalla fishery was published in Fishing Today (Baelde 1995);
- a report on the Tasmanian Demersal Hook Fishery was produced for the Marine Research Laboratories Internal Report series (Baelde 1994);
- two Stock Assessment Reports were produced as part of the stock assessment process set up by AFMA (Baelde 1994, 1995);
- an article summarising the major results shown in the present FRDC report is being prepared for publication in *Australian Fisheries*.

Benefits to other research projects

Tissue samples of blue-eye trevalla were collected for the CSIRO's genetic study on this species (see Bolch *et al.* 1993). Fish samples (gemfish and ocean perch) were also collected for taxonomic research undertaken by J. Paxton at the Australian Museum, Sydney.

PART 1

ANALYSIS OF THE BLUE-EYE TREVALLA FISHERY OFF TASMANIA

(P. Baelde)

CHAPTER 1: STRUCTURE AND DEVELOPMENT OF THE DROP-LINE FISHERY

Structure of the fishery and fishing practices

Most drop-line vessels range from 10 to 25 m in length with 50-250 HP main engines. There has been no major change in length or engine power since their construction in the 1960s, but a significant change in electronic equipment occurred in the late 1980s with the introduction of colour echo-sounders and Global Positioning System (GPS).

Drop-lines are anchored to the bottom with a weight and supported vertically by a series of buoys (Fig. 1). Most commonly used hooks are tuna circle hooks (12/0-16/0) with snoods and clips, which are baited with squid and set about 1 meter apart on the lines. The amount of gear (lines and hooks) carried onboard drop-line vessels has increased over the years from 3-4 lines and about 50 hooks per line when the fishery began (corresponding to about 500 to 1000 hooks set per day), to 8-15 lines and 80-120 hooks per line now (corresponding to 1000 to 2500 hooks set per day).

Lines are set in groups (or shots) over a particular spot and retrieved with a hydraulic line hauler 1 to 2 hours later. Fishers re-set the lines a number of times during a fishing operation, depending on catch rate. During the first shot, about 1500 hooks can be set in less than 30 minutes; the re-setting is slower because of the combination of retrieving the lines, un-hooking the fish and re-baiting the hooks. Knowledge of tides, currents and bottom topography are key elements in the success of drop-line fishing. Additional information on gear configuration and fishing practices can be found in Paulovics and Williams (1995).

Blue-eye trevalla feed mainly on the pelagic tunicate *Pyrosoma atlantica* which concentrates near the bottom during the day and disperses in the water column at night (Winstanley 1978). Fish are targeted before dawn, on their descent near the bottom when following concentrations of *Pyrosoma*, and fishing usually stops after mid-day when fish disperse in the water column.

Fishing grounds around Tasmania are 3 to 10 hours steaming from ports. Fishers usually have their own grounds which they fish consistently and they more or less co-operate by recognising each others areas. Until a few years ago, there was little searching time involved prior to fishing which was conducted on known grounds; black and white echo-

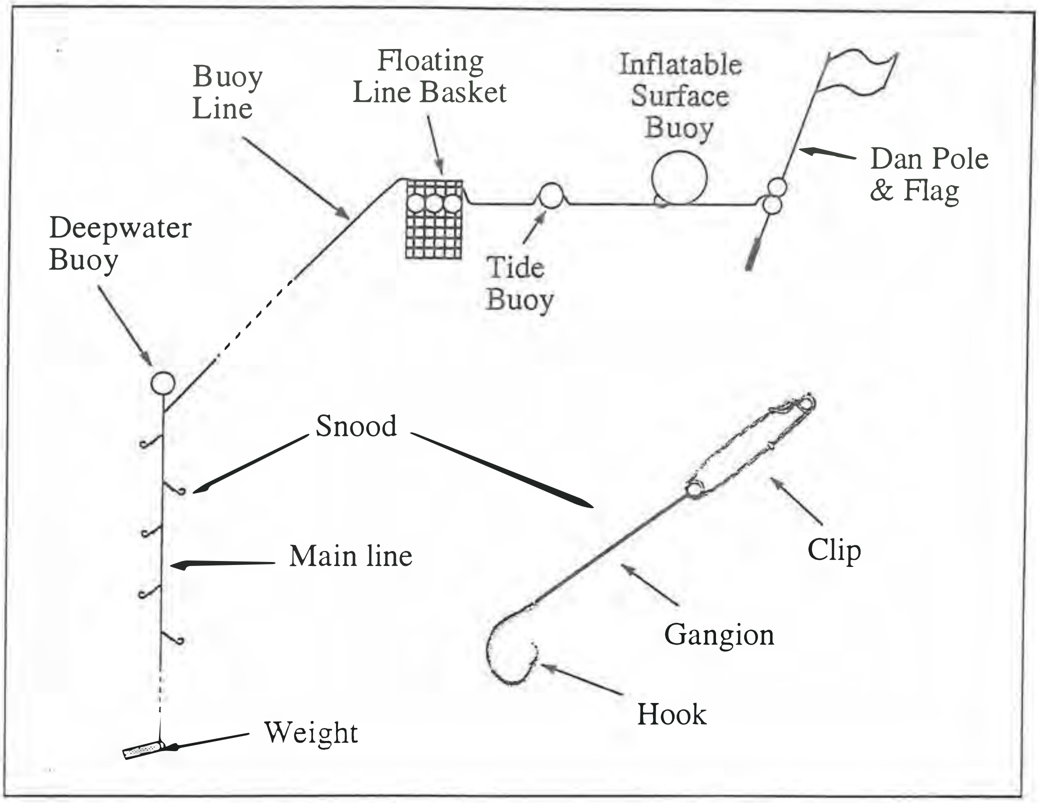


Fig. 1: Gear configuration of drop-lines used in Tasmania.

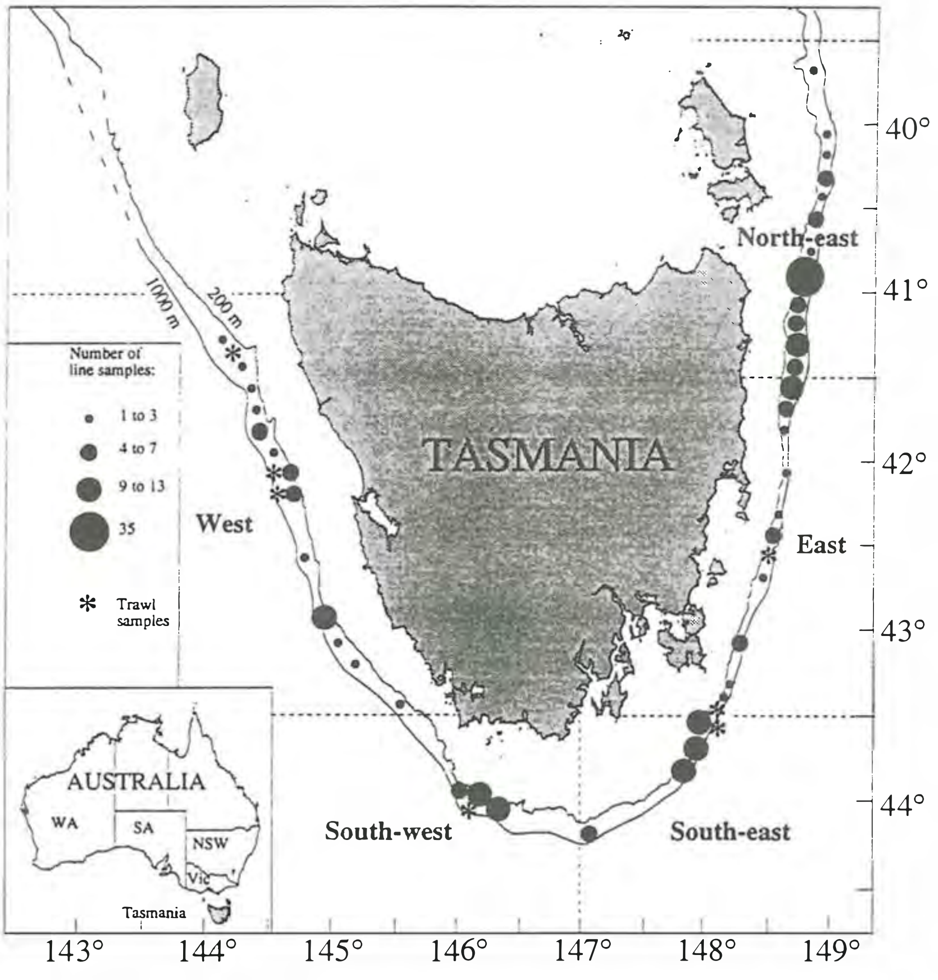


Fig. 2: Map of Tasmania showing the location of samples and the five fishing zones used in the study. WA= Western Australia, SA= South Australia, Vic= Victoria, NSW= New South Wales.

sounders being mainly used to locate suitable hard bottom. If fish were scarce, fishers moved to another known ground. A change in fishing practice is now occurring following the introduction of colour echo-sounders and GPS. Fishers tend to search for fish schools in more open waters using colour echo-sounders, while GPS increases fishing efficiency by allowing fishers to locate fishing spots more accurately.

Fishers' experience in searching for new grounds and some anecdotal information (Dix 1979, Winstanley 1979, Wankowski and Moulton 1986), indicate that the blue-eye trevalla resource off southern Australia is small due to the limited extent of suitable bottom on the continental slope.

Trends in catch statistics

Monthly catch by species have been recorded by drop-line fishers in the Tasmanian Monthly General Fishing Returns (Appendix I) since 1969. As no fishing effort data were recorded in these returns, boat-month was used as a rough measure of fishing effort in the analyses. Small catches (less than 200 kg a month, generally made by fishers not fully involved in the blue-eye trevalla fishery) were excluded from the analyses to avoid bias in estimation of catch rate. Also, it was not possible to standardise fishing effort as not enough data were available to account for the spatial and temporal distribution of the fishing fleet and for differences in fishers' skills.

When the Tasmanian fishery for blue-eye trevalla began in the late 1960s, effort was directed on an opportunistic basis by fishers primarily engaged in other fisheries, such as shark lining and cray fishing. The number of drop-liners increased from about 5 in the 1970s, to about 20 in the 1980s and to 60-70 in the 1990s. Less than 10 fishers are currently engaged full time in the blue-eye trevalla fishery, landing about half of the annual catch (Baelde, 1995).

Catch data were grouped within 5 fishing zones: north-east, east, South-east, south-west, and west (Fig. 2) to reflect the distribution of the fishing fleet. As the number of fishers increased and the fishery expanded to new grounds, annual landings increased from 50-100 tonnes in the 1970s to about 250-300 tonnes (Fig. 3) in the 1990s. The fishery developed first in the east zone in the late 1960s following the successful survey by Cowper and Downie (1957); it then expanded to the south-east zone (on the so-called 'Thirty Mile Patch') in the late 1970s. By that time, a significant decline in the size of fish and catch rate in the east zone prompted further exploratory fishing in the south-west and west zones (Dix 1979, Wilson 1981, 1982), where the fishery eventually expanded to in

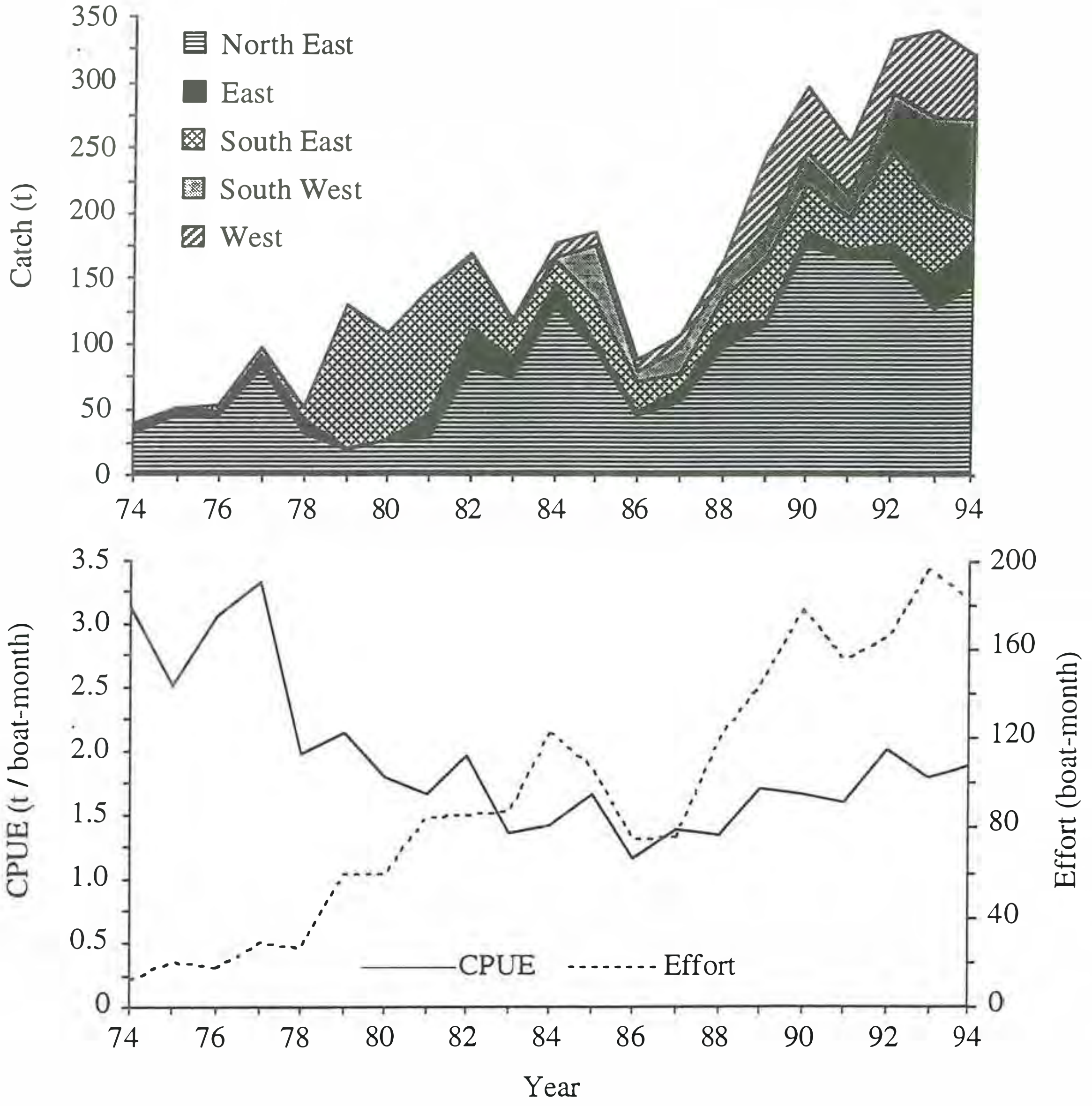


Fig. 3: Annual catch (t), fishing effort (boat-month) and cpue (t/boat-month) in the Tasmanian blue-eye trevalla fishery. Catches are shown distinguishing 5 fishing zones.

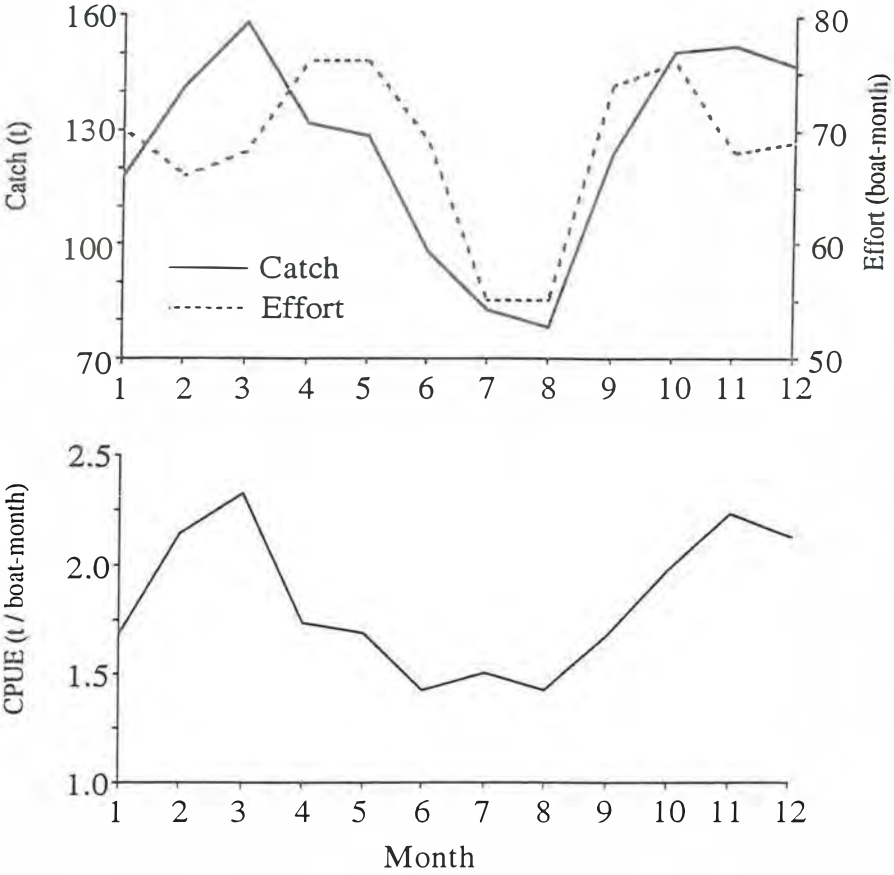


Fig. 4: Seasonal changes in catch (t), fishing effort (boat-month) and cpue (t/boat-month) in the Tasmanian blue-eye trevalla fishery (pooled logbook data 1990-1994).

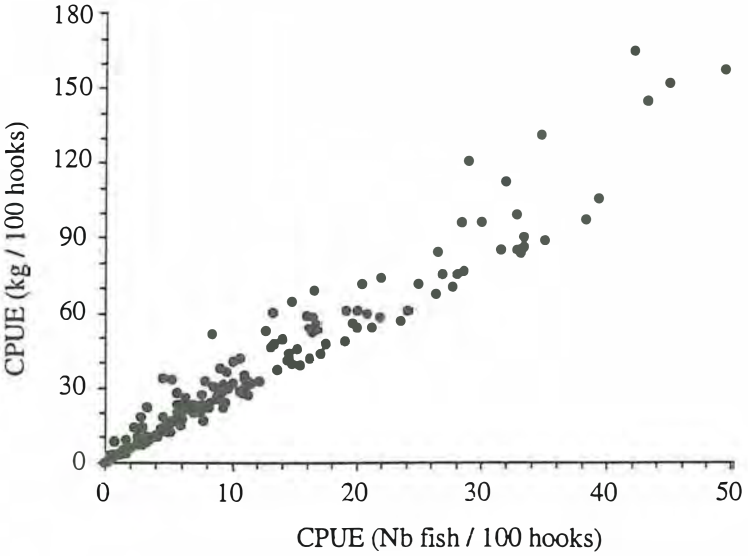


Fig. 5: Scatter plot showing the proportionality between cpue in number of fish/100 hooks and in weight of fish/100 hooks (cpue calculated using data aggregated by shot).

the mid-1980s. Generally bad weather conditions and limited suitable grounds have limited the development of the fishery in the west zone. Exploitation of the Thirty Mile Patch virtually came to a stop in the mid-1980s after catch rates declined severely, to resume in the early 1990s.

Catches in the north-east zone represented about 50% of the total 1990-93 Tasmanian catch, compared with about 15% for the south-east, south-west and west zones, respectively; catches in the east zone represented only 5%.

Catch rates at the beginning of the fishery were high, at about 3 t/boat-month (Fig. 3); by the end of the 1970s, it had decreased to about 1.5-2 t/boat-month and kept decreasing regularly thereafter, until the mid 1980s when it started to increase again.

The blue-eye trevalla fishery is seasonal, more in relation to weather conditions than to abundance of fish. Fishing slows down markedly in winter (July-August, Fig. 4) when weather conditions deteriorate, and starts again in spring (from September).

Some fishing also took place on an offshore seamount (Cascade Plateau) discovered in 1985 about 120 miles south east of Tasmania. Good catches of large fish were made (not documented); again, size of the fish and catch rate declined within a few months, and difficult weather conditions offshore limited exploitation of this seamount to very occasional fishing trips by the largest vessels.

CHAPTER 2: PROBLEMS SPECIFIC TO ANALYSIS OF HOOK CATCH RATE

The catching process in hook fishing is not well understood and less documented than other fishing methods. In this type of stationary fishery, changes in catch rate are closely related to fishers' skills and fish behaviour (feeding, competition) and distribution (Bannerot and Austin 1983, Lokkeborg and Bjordal 1992). The interactions between distribution pattern of the fish and fishing practices affect the relationship between catch and effort data, and thus the relationship between catch rate and abundance (Hilborn and Walters 1992). In this chapter, some of the problems associated with the definition of the unit of fishing effort and with aggregation of data are addressed.

Several studies on the effects of hook gear configuration (hook shape and size, hook spacing on the line, size and type of bait) on line catch rate and catch composition have failed to show clear trends (Skud 1978, Bertrand 1988, Matsuoka 1990, Ralston 1990, Lokkeborg and Bjordal 1992). Likewise, the few changes in drop-line configuration that have occurred in the Tasmanian drop-line fishery (hook shape and size mainly, Paulovics and Williams 1995) probably had little effect on fishing efficiency compared to differences in fishers' skills.

An intensive catch monitoring programme was undertaken off Tasmania between November 1991 and July 1993. Fisheries and biological data were collected from commercial catches either at sea during fishing operations or at processing factories. A total of 229 samples were collected, which represented catches made on most Tasmanian fishing grounds (a sample here refers to the total catch made on a given day and given fishing ground). The spatial and seasonal distribution of sampling effort more or less reflected the distribution of the fishing fleet (Fig. 2).

Detailed information on fishing practice was obtained during this sampling programme. Data were collected for individual line and included date and time of day, fishing location (using a 7.5 mile grid) and fishing depth (the range mid-point of maximum and minimum depths recorded was used), number of hooks set per line and number of fish caught. For samples collected at processing factories, drop-liners themselves provided information on fishing location and depth.

A linear relationship was obvious between catch rates calculated in terms of number of fish/100 hooks and catch rate calculated in terms of kg/100 hooks (Fig. 5). As data on

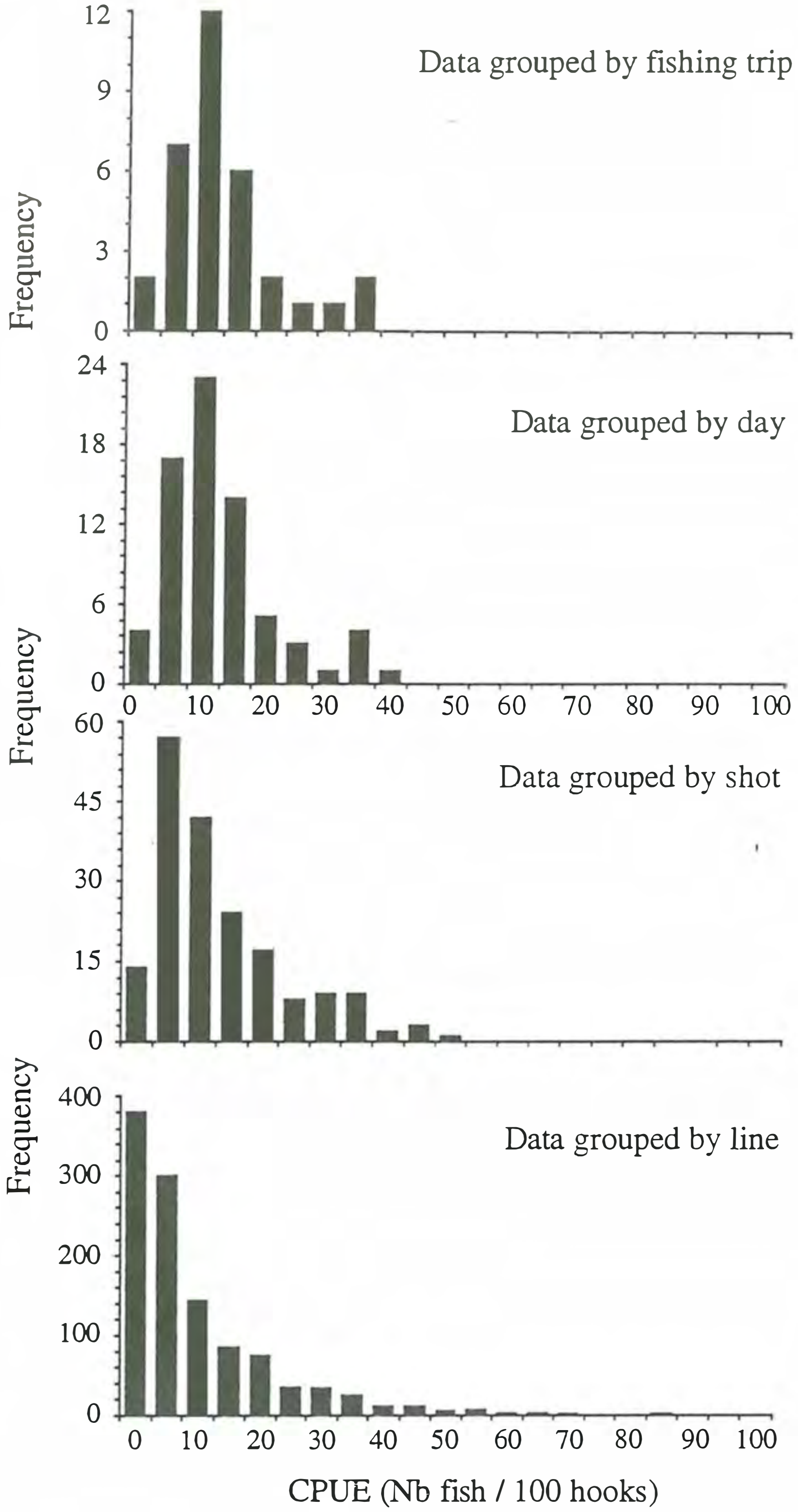


Fig. 6: Effect of aggregating catch (number of fish) and fishing effort (number of hooks) data on cpue frequency distribution.

number of fish caught were more accurately recorded than data on weight of fish, catch rates in number were used in all analyses.

Effect of data aggregation on catch rate

The shape of the frequency distribution of cpue contains important information on the dynamics of a fishery (Bannerot and Austin 1983). However, the spatial dimension at which catch and effort data are collected (or aggregated) can change the shape of this distribution and influence the interpretation of cpue. The effect of data aggregation on cpue was examined in the blue-eye trevalla fishery by calculating cpue (number of fish/100 hooks) at different levels of aggregation: whole fishing trips, fishing days within fishing trips, shots within fishing days and individual lines within shots. These levels generally corresponded to a decreasing spatial extent of the fishing operations.

There was little change in the shape of the cpue frequency distribution when catch and effort data where aggregated by fishing trip or by day (Fig. 6). However, at lower levels of data aggregation (by shot and by individual line), the frequency distribution became markedly skewed to the right. The frequency distribution of cpue calculated at the smallest spatial scale (individual line) better reflected the dynamics of fishing showing the predominance of low cpue values and occasionally very high values. Whenever data permitted, catch rates were calculated on a per line basis in this study.

Effect of gear configuration and fishing practices on catch rate

Relationship between catch and effort

The relationship between catch and effort was examined by plotting the number of successful hooks (i.e. having caught blue-eye trevalla) and empty hooks (i.e. not having caught blue-eye trevalla) against the total number of hooks set during a shot (i.e. group of lines set at the same time on the same fishing spot, Fig. 7). Empty hooks included hooks which were retrieved without blue-eye trevalla caught (with or without bait) or with by-catch of another species. There was no relationship between the number of fish caught and the total number of hooks set, but there was a clear linear relationship between the number of empty hooks and the total number set (Fig. 7).

The lack of relationship between catch and effort reflected some specific drop-line fishing practices and also variation in these fishing practices between fishers. Catch rates tend to be higher at the start of fishing, and to decrease during periods of sustained effort (possibly due to local area being fished out, feeding behaviour or increased gear

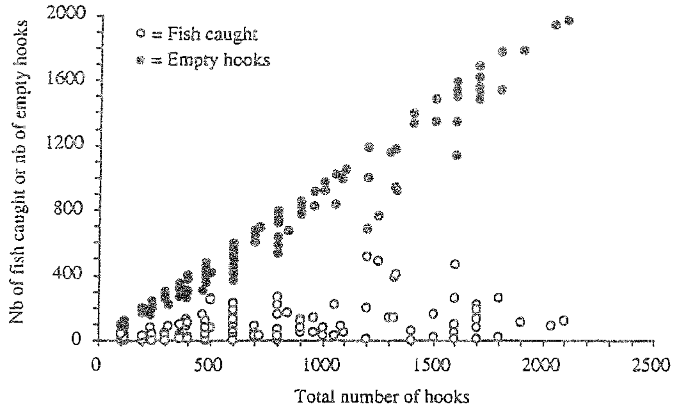


Fig. 7: Scatter plot showing the relationship, or lack of, between the total number of hooks used per shot and the number of empty hooks (i.e. unsuccessful hooks), or the number of fish caught (i.e. successful hooks). Data aggregated by shot, sample size=156 shots.

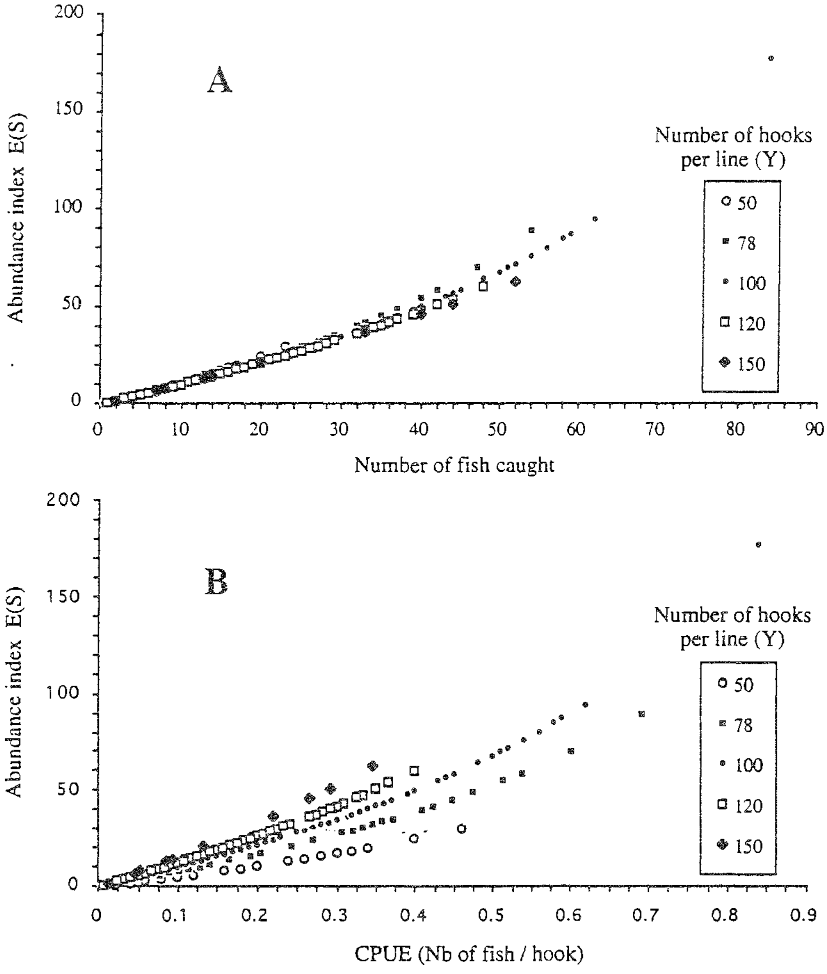


Fig. 8: Application of Rothschild's (1978) saturation model (see text) to show how gear carrying capacity (total number of hooks (Y) set per line) influence cpue and its interpretation as an index of abundance.

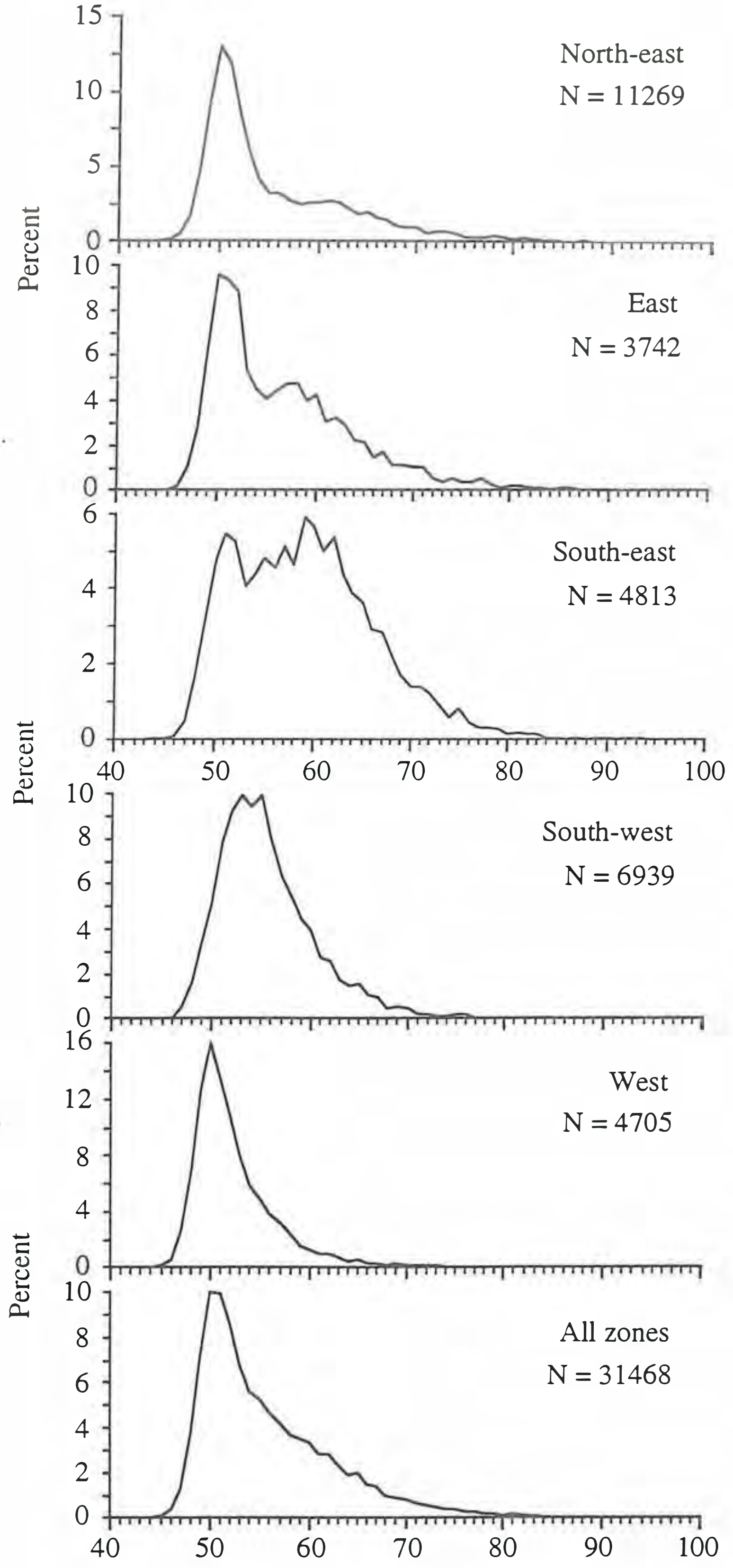


Fig. 9: Length frequency distribution of blue-eye trevalla by fishing zone and for all zones combined. N=number of fish.

avoidance, Dickson 1989), and fishers visit several fishing spots alternatively, rarely staying more than 2 consecutive days on the same spot. They always use a greater number of hooks at the start of the fishing on a spot, without prior information on fish abundance. This initial large number of hooks varies between fishers depending on the number of lines they carry onboard and the number of hooks they set per line. If catch rates are good, fishers further increase the number hooks used by quickly re-setting available lines. Thus, the increase in fishing effort as fishing goes on is not directly proportional to abundance but varies quantitatively with fishing capacity and fishing experience of individual fishers.

Also, some hooks are known to have less fishing efficiency; such as hooks set at the top and at the bottom of the lines, which usually (but not always) catch less fish than hooks set in the middle of the line. The number of hooks used at the top and bottom of the lines again varies between fishers, depending on their fishing experience and preferences. Fishers sometimes set additional hooks to finish off bait at the end of the day, with little hope of catching fish.

Competition - Gear saturation

Gear saturation is another potential problem characteristic of hook fisheries. When saturation occurs, the catch rate tends toward a maximum at high fish abundance which is set by the capacity of the gear (number of hooks), and does not reflect the abundance of fish. Saturation is usually seen as a function of time (Ricker 1975, Gulland1983, Matsuoka 1990), but in the case of drop-lining, soaking time is short and the rapid setting and retrieving of the lines reduces the effect of gear saturation.

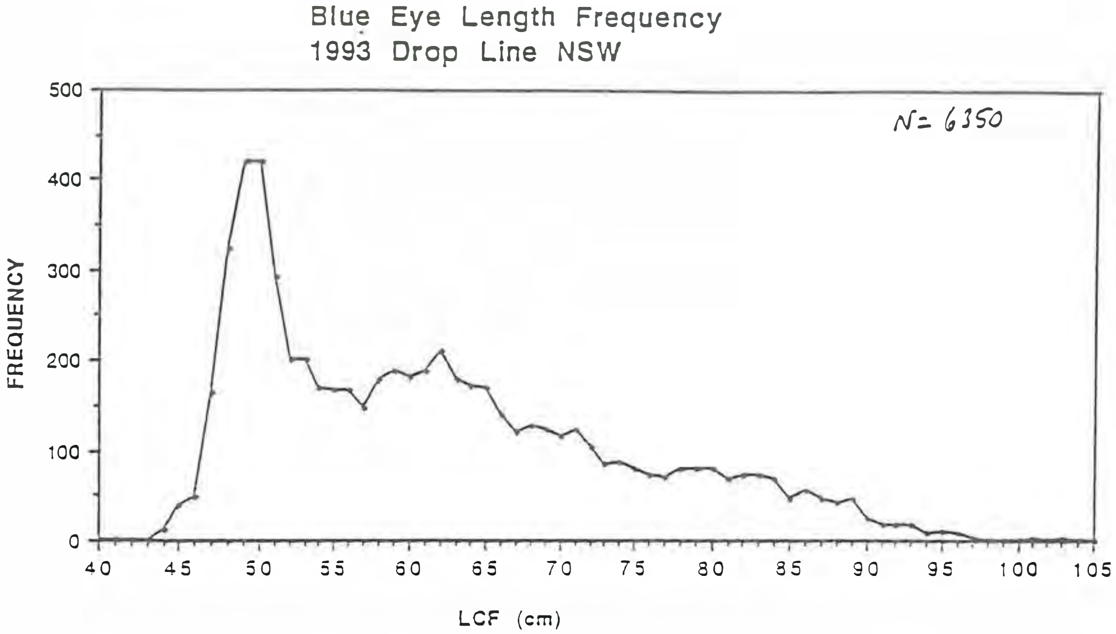
Gear saturation is usually considered when all the hooks on a line are occupied. It has happened sometimes during the study that nearly all hooks on a line were occupied by blue-eye trevalla. However, fish were more often caught in clumps of adjacent hooks. This suggested that saturation can occur on a portion of a line, depending on the depth distribution of the fish, their competitive feeding behaviour and ability to move up and down the line. Rothschild (1978) has proposed a 'probabilistic saturation model' to estimate the density of fish in the water at the time of fishing from the number of fish that are caught on a line. In the model, saturation is regarded as a competition for the same hook, and is a chance event which occurs when fish contact hooks with a fish caught already (equivalent to sampling without replacement in probability theory). The equation of the model is:

$$E(S) = Y \operatorname{Log} (N / N-r+1)$$

where E(S) is the expected number of fish that contact the hooks (i.e. represents an index of abundance), Y is the total number of hooks on the line, r is the number of fish caught, and N is the number of fish caught when all hooks are saturated (i.e. N=Y at complete saturation of the line).

This model was applied to the drop-line data (Fig. 8A), distinguishing lines with different carrying capacity (Y). Y had little influence on the relationship between the number of fish caught and the index of abundance E(S) within the range of data collected. However, when replacing the number of fish caught with the corresponding cpue (Fig. 8B), E(S) increased significantly for a given cpue value as Y increased. For example, a cpue value of 0.4 fish/hook corresponds to E(S) values of 24 and 49 for Y= 50 and Y=100 hooks, respectively. According to this model, the fishing power of a hook varied with fishing practices, i.e. the preferred carrying capacity of the lines.

In conclusion, although the hook is probably the best measure of unit of fishing effort, this study has highlighted some problems associated with its use in calculation of cpue. Catches do not increase proportionally with effort in number of hooks, and the proportionality between catch rates and fish abundance is biased by some fishing practices specific to drop-lining and by differences between fishers' skills. The catching power of the hook as a unit of fishing effort decreases with time during a fishing operation and varies with fishers' working preferences. It would be very difficult to quantify these factors and standardize the unit of fishing effort amongst fishers. During the present study, the majority of fishers from whom data were collected used a standard 100 hooks per line, and the effect on the cpue of occasional change from it was not considered further.



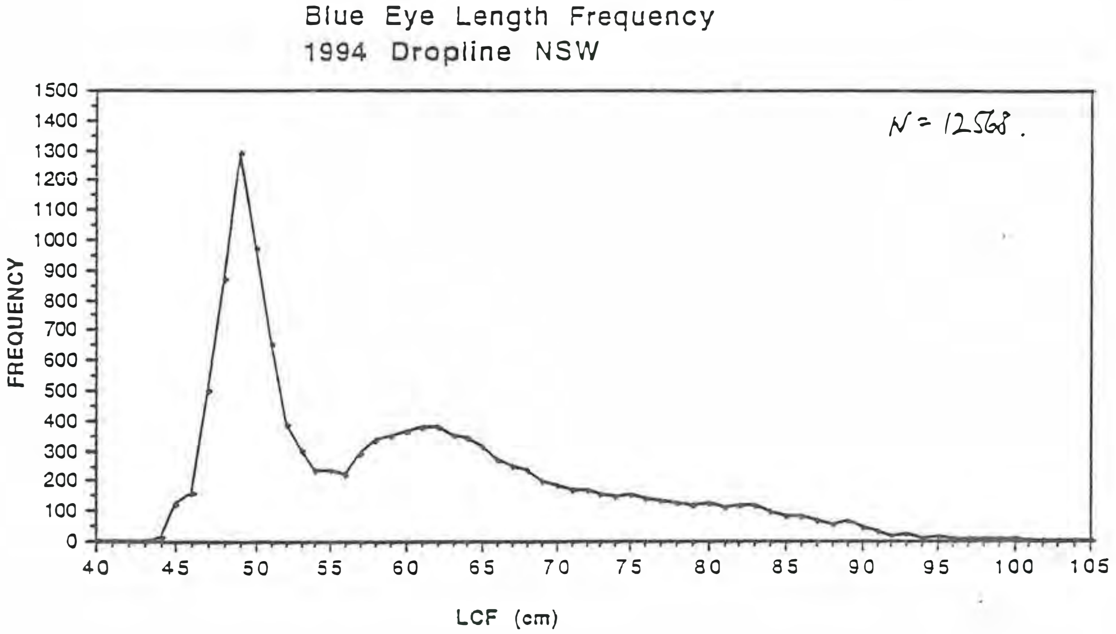


Fig. 10. Length frequency distributions of blue-eye trevalla caught by drop-lining off New South Wales (data from K. Rowling).

CHAPTER 3: CATCH COMPOSITION AND CATCH RATE

Information on catch composition was collected during the sampling programme (November 1991-July 1993) described in the previous chapter. Whole catches (or the majority of them) were examined, ranging from about 50 to 500 fish. When data were collected at sea, samples were processed distinguishing individual lines. Fish were sexed (when ungutted), measured (fork length rounded down to the nearest cm below), and some of them were weighed (whole or gutted weight) when feasible. Subsamples of otoliths were collected to approximately reflect the length frequency distribution of the fish. Data on the reproductive status were also collected (see details in chapter 6).

Sectioning of otoliths (N=2613), age determination and estimation of the von Bertalanffy growth equation were made at the Central Ageing Facility, Victoria. Ages were determined by counting all rings present. This technique has not yet been validated, as there are few appropriate techniques to validate ageing of otoliths from deep-sea fish (tagging was attempted during the present study but proved difficult). Thus, all results referring to age determination and growth rate are only preliminary.

The age-length keys obtained for each sex were used to estimate the age composition of blue-eye trevalla in commercial catches. From the subsample of aged fish, the proportions of fish by age were calculated for each length interval; these proportions were then applied to the length frequency distributions.

Composition of current drop-line catches

Commercial catches were dominated by small immature (FL ≤ 55cm) fish (Fig. 9). Fish under 55 cm FL represented 59% (332t) of the 562 tonnes of fish caught by the commercial drop-line fishery during the period of this study. Similar length compositions were observed in New South Wales (Fig. 10).

The major change in length composition was a seasonal increase in the abundance of fish above 55 cm FL in spring-summer when fish formed feeding and spawning aggregations (see chapter 6). Difference in the season of fishing accounted for most of the differences in catch composition between fishing zones (Fig. 9).

Ages estimated from otoliths sections varied widely within length (Fig. 11), recalling that age data must be interpreted with caution. They also differed significantly from previous

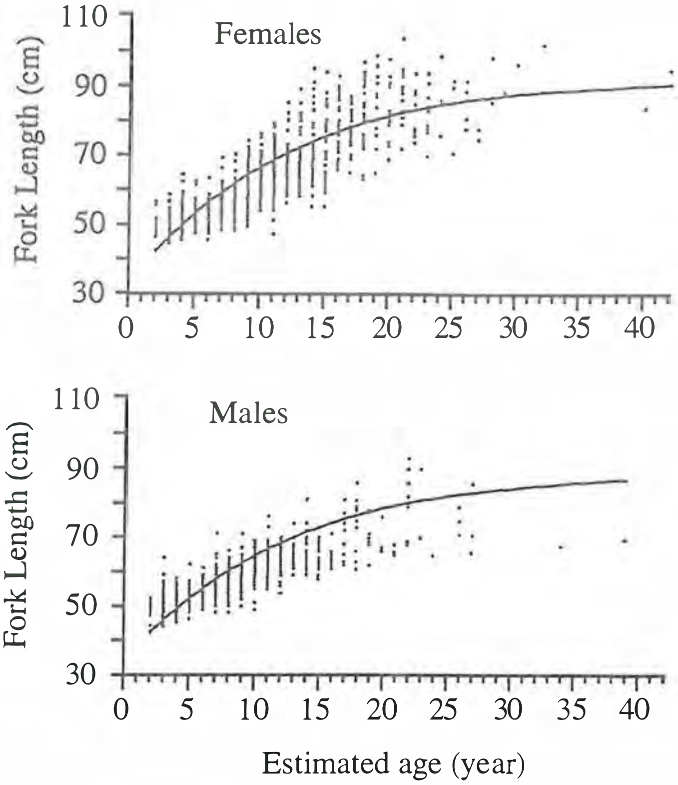


Fig. 11: Estimated age (year) from sectioned otoliths and fitted von Bertalanffy growth equations (estimated parameters shown in text). Data from the Central Ageing Facility, Victoria.

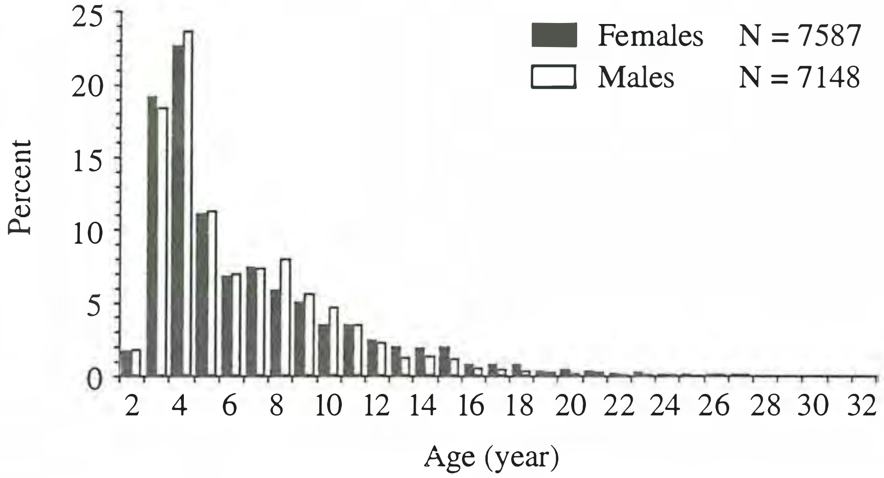


Fig. 12: Age composition by sex of blue-eye trevalla in drop-line commercial catches (November 1991-July 1993) using the age-length key established by the Central Ageing Facility, Victoria.

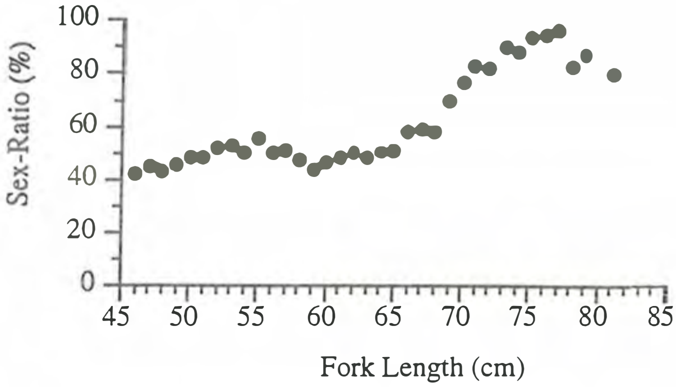


Fig. 13: Change in sex-ratio (percent females) with length of blue-eye trevalla (only size classes with at least 20 individuals were considered).

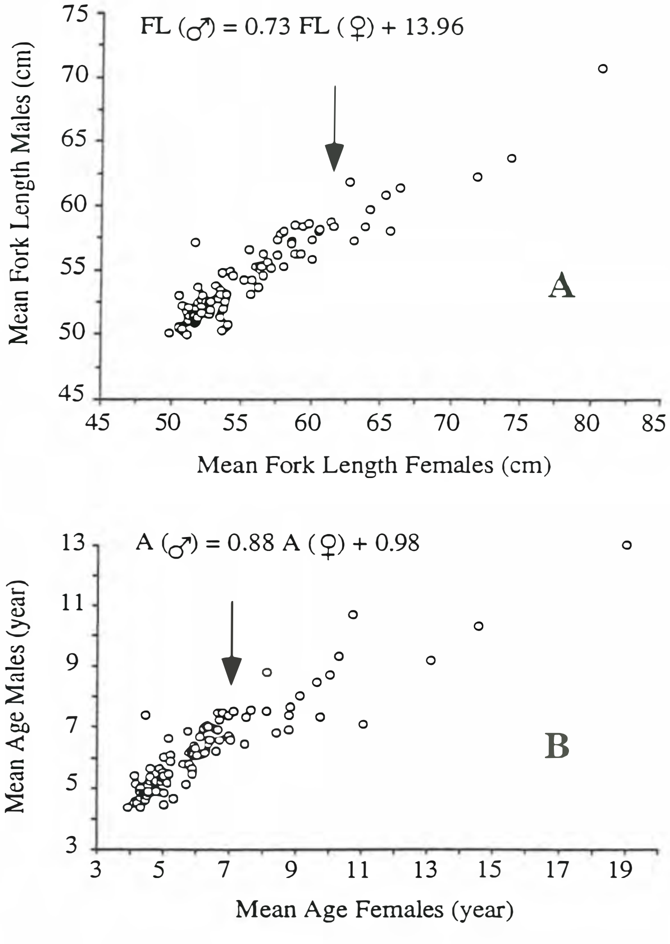


Fig. 14: Scatter graphs showing the relationships between A: mean length of females and mean length of males, and B: mean age of females and mean age of males. Regression equations calculated up to arrows (up to size and age for females of 62 cm FL and 7 years old, respectively).

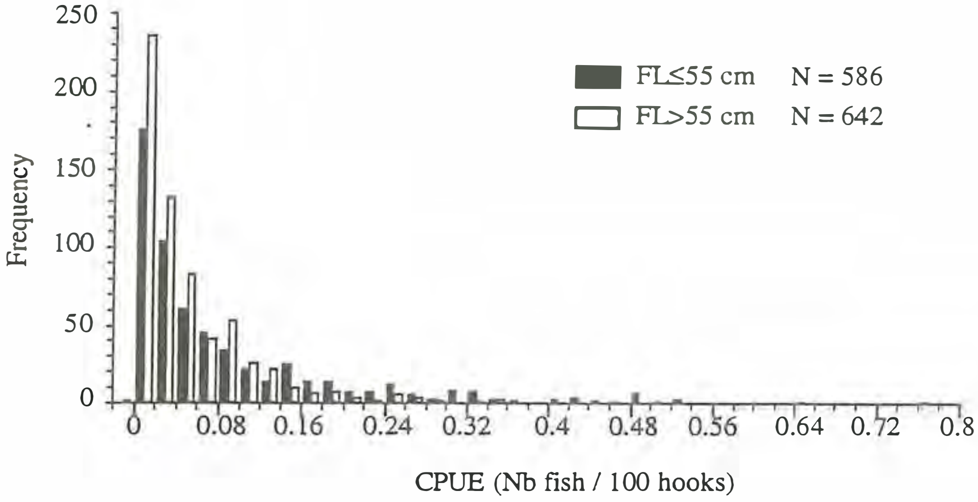


Fig. 15: Comparison of cpue frequency distributions between two size categories of fish. Cpue calculated for individual lines, N=number of lines.

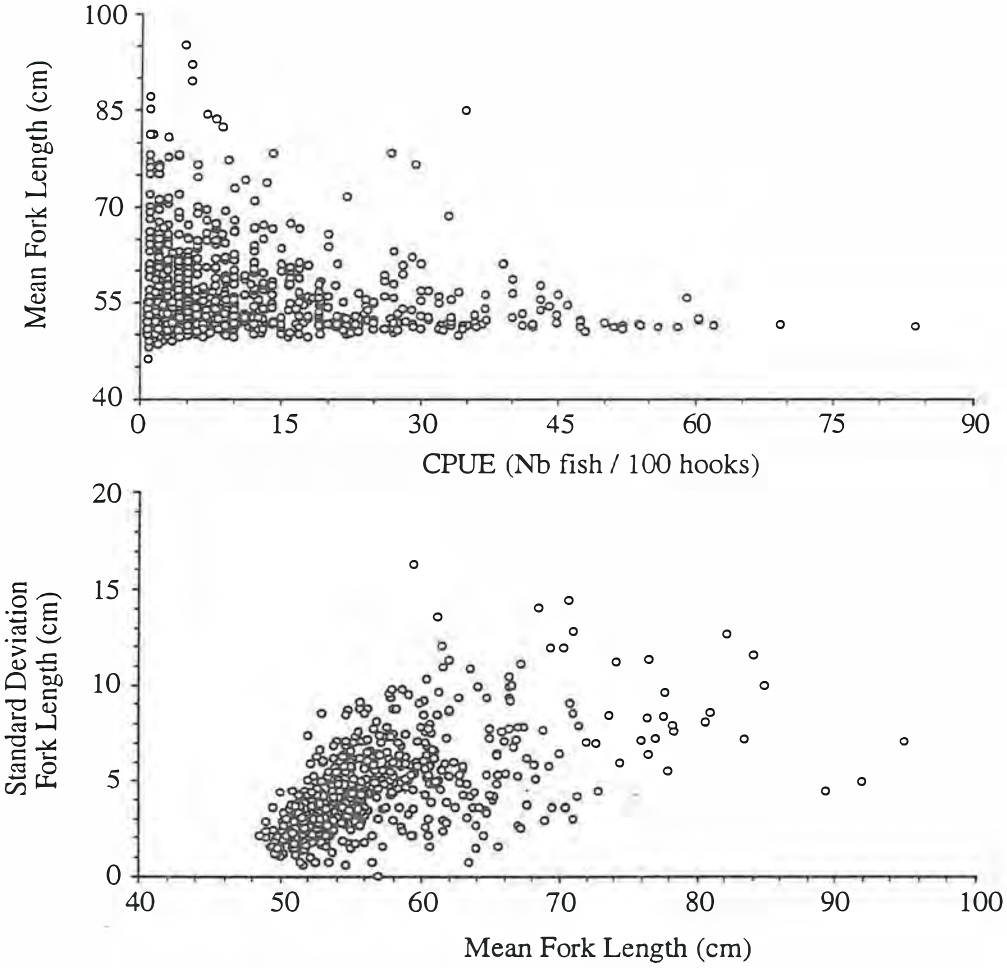


Fig. 16: Scatter plots showing the trend for cpue to increase when smaller and more uniformly sized fish are caught. Cpue, mean length and standard deviation calculated for individual lines.

studies (Webb 1977, Horn 1988). Note however, that one otolith aged at 30 years from sections was later aged at 33 years using a newly described radio-carbon method (Kalish 1993). Age compositions of drop-line catches are shown in Fig. 12 for each sex. The bulk of catches were made of 3 to 5 year old fish. The maximum age estimated were 42 years for females and 39 years for males (not represented in Fig. 12 because of the small sample size).

The global sex-ratio (percent females) in pooled commercial catches was 50.9% (the mean sex-ratio in daily samples was 51.2 ± 17.2). Sex-ratio varied significantly with the length of fish (Fig. 13). Males dominated small size classes up to 51 cm FL (sex-ratio ranging from 42.1 to 48.8%); the sex-ratio was then stable at about 50% between 51 and 65 cm FL, and increased markedly afterward with females dominating large size classes.

There was a linear relationship between the mean length of females and the mean length of males in daily samples (Fig. 14A). This relationship was stronger for small fish, up to the female length of about 62 cm FL. There was also a strong relationship between the mean ages estimated for each the sex (Fig. 14B). Comparison of the slopes and origins between the two regressions estimated for mean lengths and mean ages suggested that females and males schooled by age rather than by size (at least up to about 7 years old).

Effect of fish length and distribution patterns on catch rate

The relationship between length of fish and catch rate was examined by comparing the frequency distributions of cpue (per line) constructed for two size categories of fish ($FL<55$ and $FL\geq55$ cm, Fig. 15). The Kolmogorov-Smirnov test showed that the cpue for fish above 55 cm FL was significantly lower than the cpue for smaller fish ($p<0.0001$).

The relationship between cpue, mean fish length and standard deviation of the mean (Fig. 16) also showed a trend for cpue to increase as fish were smaller and of more uniform length. The increase in standard deviation with the mean length indicated that large fish were caught with small fish in the same area. Larger individuals became more vulnerable during spring-summer feeding and spawning periods (see chapter 6); they were usually caught in small numbers at the bottom of the lines, while small fish were caught in greater numbers and further up on the lines, i.e. in more open waters. These results confirm the general perception that, after settling to the bottom, small fish form dense schools in mid-water while larger fish tend to be more solitary and associated with the bottom (Horn and Massey 1989, Karp and Walter 1994). In New Zealand too, where fishers use bottom long-lines, catch rates of small fish were significantly increased by setting the lines in more open waters, up to 80-100 m off the bottom (Baelde 1995).

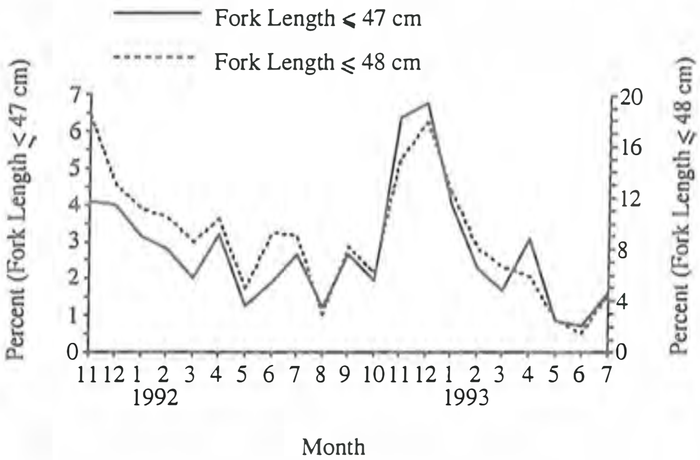


Fig. 17: Changes in monthly proportion of the smallest fish in drop-line catches. Proportions calculated using two size criteria (FL≤47 and FL≤48 cm) within fish below 55 cm FL.

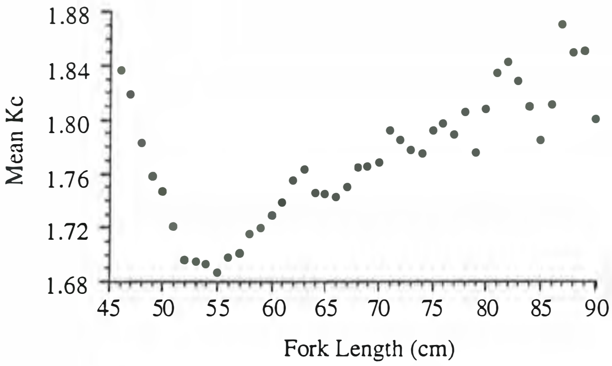


Fig. 18: Change in mean coefficient of condition (Kc) with length of fish (sexes combined). Only size classes with at least 15 fish were considered.

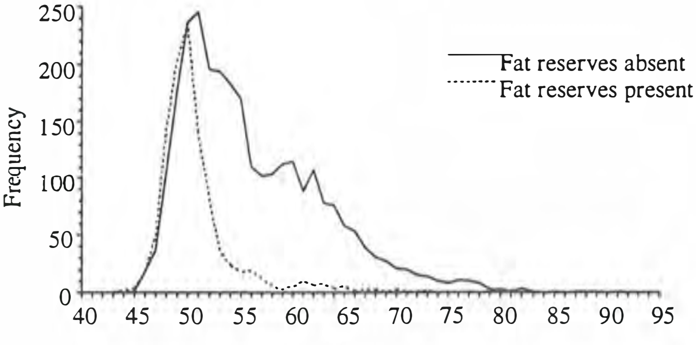


Fig. 19: Comparison of length frequency distributions between fish with and without reserves of fat present in visceral cavity.

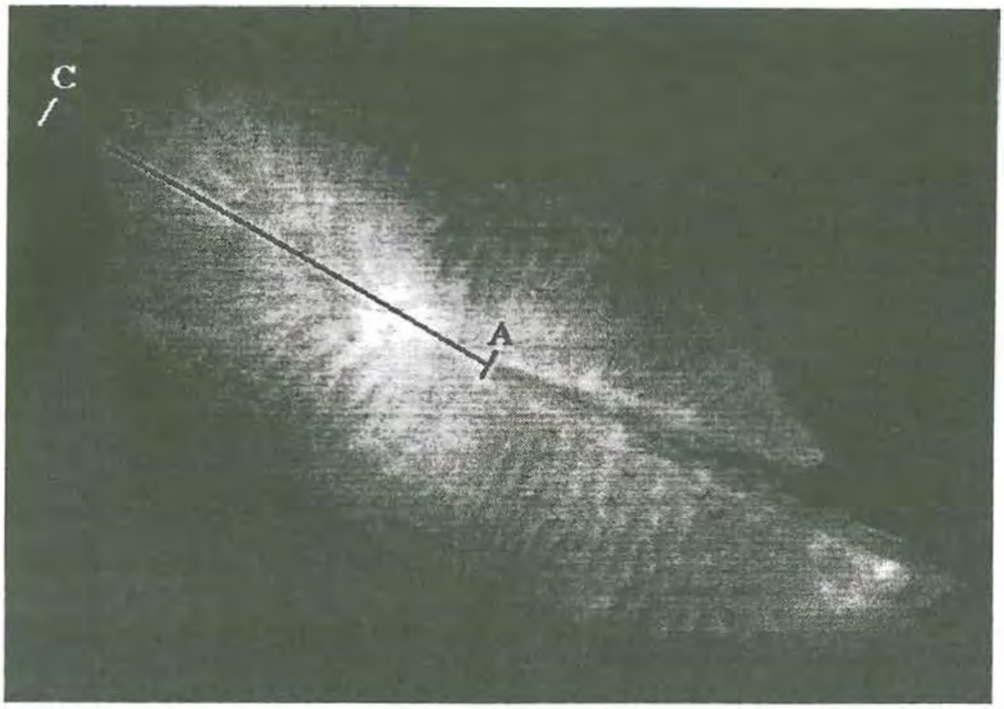


Fig.20. Otolith of blue-eye trevalla showing the dense centre zone (A-B) and the clear outer zone (B-C).

Recruitment

Blue-eye trevalla are pelagic for the first few years of their life, and then settle over hard bottom in depths of 200-900 m (Webb 1979, Horn 1988, Jones 1988). The processes of recruitment to the bottom and of recruitment to the fishery was analysed through examination of 1/ occurrence of smallest fish in catches, 2/ condition of fish, and 3/ change in otolith structure.

The proportion of the smallest fish in catches increased markedly in spring (November-December, Fig. 17) suggesting that blue-eye trevalla settled to the bottom at that time of the year. These small ($FL \leq 48$ cm), newly recruited fish occurred in all fishing zones, representing between 2.4 and 11.8% of the total fish measured in each zone. They were the least abundant in the south-west zone.

The coefficient of condition Kc ($Kc=Wg/FL^3 * 100$, where Wg is the gutted weight of the fish) decreased markedly with the length of fish between 46 and 52-55 cm FL, and increased afterward (Fig. 18). A significant number of fish presented large amounts of fat reserves (visceral fat), and their occurrence in catches was recorded from December 1992 to July 1993. It was essentially the small fish that had such reserves of fat (Fig. 19), and the decrease in their Kc most likely resulted from the utilisation of reserves stored prior to settling to the bottom.

These fish were first recorded in small numbers in November 1992; in December 1992 and January 1993, their proportion (within fish below 55 cm FL) increased to about 50%, and then decreased to about 20% in July 1993 when data were last recorded. They were well represented in all fishing zones, except in the south-west zone where they were uncommon.

Finally, examination of the otoliths provided further information on the settlement process. The otoliths of blue-eye trevalla showed a distinct density change between the centre and the outer regions (Fig. 20), and electron microprobe analysis made on one otolith showed that this was due to a major change in chemical composition (C. Proctor, CSIRO, Division of Fisheries, personal communication). It can be assumed that this chemical change in otoliths reflected the change of habitat when fish settle to the bottom . If this is true, then the marginal increment (total radius of otoliths - radius of the centre zone) should be very small at the time of settlement and increase afterward. To check this, and to see whether the end of the dense centre zone could be used as a marker of settlement, the marginal increment was calculated monthly for small fish ($FL \leq 50$ cm FL,

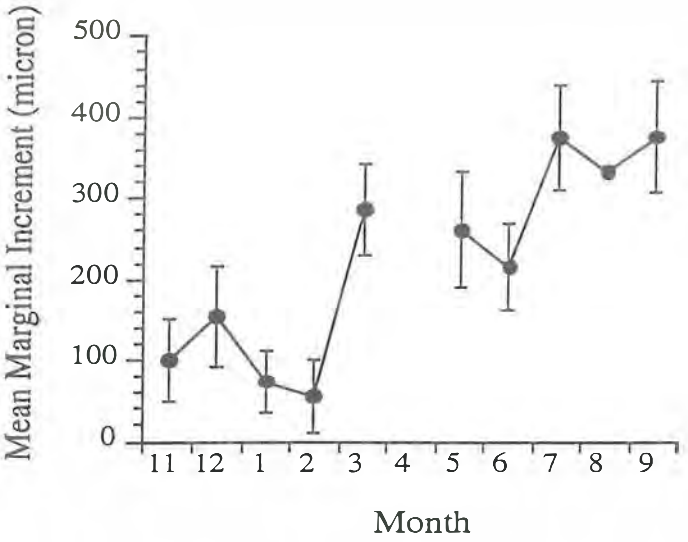


Fig. 21: Change in monthly mean marginal increment (radius otolith - radius centre zone) for newly recuited fish (FL≤ 50 cm, sexes combined). 1991-93 cumulated data; bars represent 25% standard deviation.

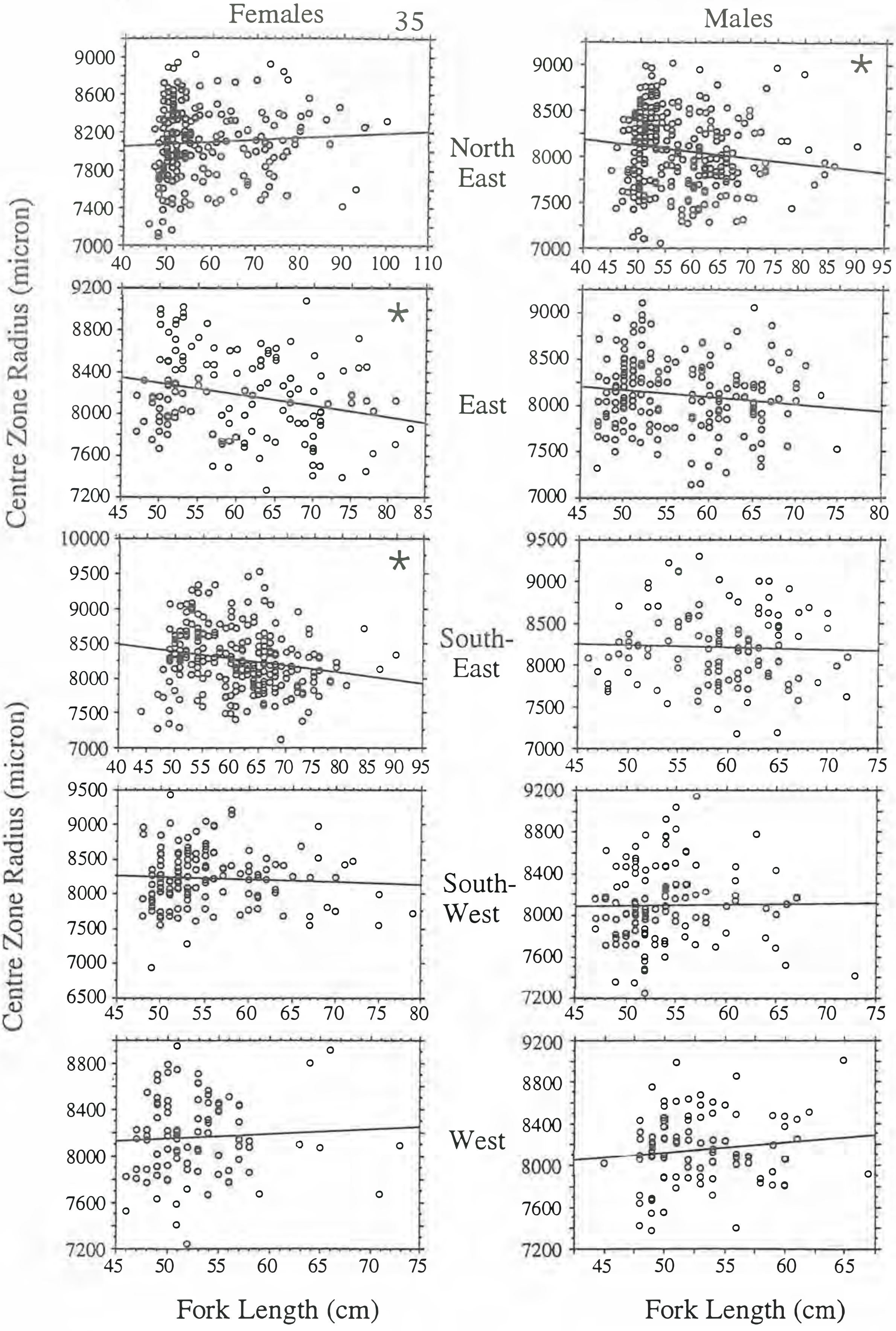


Fig. 22: Regressions between length of the fish and radius of the centre zone of the otoliths, by sex and fishing zone. *=regression significant (see results in Table 1).

N=208, Fig. 21). It was indeed lowest from November to February and increased thereafter (Fig. 21).

In conclusion, change in fish condition suggests that fish settle to the bottom in late spring-summer, at length between about 45 to 52 cm FL, and, according to the length composition of catches, they are fully recruited to the fishery at an average length of 50 cm FL. This indicates that blue-eye trevalla become vulnerable to the fishery very shortly after settling to the bottom. This was supported by the fact that a large proportion of small fish were caught with fat reserves still present in the visceral cavity (reserves of fat are usually utilised within a few weeks to a few months, A. Goodsell, personal communication). The presence in catches of small fish with a very narrow marginal increment also supports the view of a close timing between settlement to the bottom and recruitment to the fishery.

Selective catch of fast growing fish

It is generally believed that hook fishing selectively removes fast growing fish (because of size selectivity and/or competitive behaviour), particularly amongst young fish (Miranda *et al.* 1987, Ferreira,and Russ 1994). If this is true, and assuming (as suggested above) that the end of the centre zone more or less coincides with the recruitment to the fishery, small fish (fast growing) in catches should have a larger centre zone than larger fish (i.e. older fish that were growing slowly when younger). After verifying that the size of otoliths was proportional to the size of fish (data not included), the radius of the centre zone of otoliths was measured for about 1200 fish within a wide range of fork-lengths.

The regressions estimated between fish length and radius of the centre zone are shown in Fig. 22 and Table 1 for each sex and each fishing zone. Three of these regressions were significant, all three with a negative slope, and all in the zones which have been exploited for the longest time (note that the regression for males was close to the significant level in the east zone, Table 1). The regressions were not significant in the most recently exploited zones (south-west and west).
Although these analyses are only preliminary, they suggest that, over time, the fishery may selectively remove fast growing fish. This would be worth investigating further as it would have important implications for the estimation of growth rate (growth rate being overestimated for younger fish and underestimated for older fish).

Table 1: Regression between the radius of the central zone of the otoliths (micron) and the fork length of the fish (cm), by sex and fishing zone. *=significant at 0.05%.

Sex	Fishing zone	Slope	DF	F	P
Female	North-east	2.309	215	0.981	0.3230
	East	-10.961	136	9.258	0.0028*
	South-east	-10.444	244	9.750	0.0020*
	South-west	-3.750	136	0.485	0.4875
	West	3.898	93	0.288	0.5928
Male	North-east	-6.648	275	5.281	0.0223*
	East	-7.618	178	3.210	0.0749
	South-east	-2.781	114	0.174	0.6774
	South-west	0.788	115	0.012	0.9127
	West	9.552	90	1.381	0.2430

CHAPTER 4: CHANGES IN CATCH COMPOSITION AND CATCH RATE UNDER FISHING PRESSURE

Cowper and Downie (1957) carried out a drop-line exploratory fishing survey in the mid 1950s during which they collected detailed data on catch composition, location and depth of fishing. Additional length data were collected between the early and mid 1980s by the Tasmanian Fisheries Development Authority. Detailed catch and effort data (catch by species, and number of lines and hooks used per fishing day) were obtained for major Tasmanian fishers from their personal logbooks or from information recorded in voluntary logbooks between 1969 and 1991, missing 1978-79 and 1987 (data were successively collected by Webb (1977), and by M. Wilson and K. Paulovics, unpublished data). Fishing depth was also recorded in voluntary logbooks between 1981-86. Combined with data collected during the present study, these historical data provided an invaluable opportunity to analyse changes in the fishery as it developed. Anecdotal information on localised depletions is first summarised below.

Evidence of localised stock depletions

A rapid reduction in size and catch rate of fish was first observed by the industry as early as the 1970s off the east coast; then off the south-east coast, on the Thirty Mile Patch (Dix, 1979). Similar observations were made on offshore seamounts off Tasmania and New South Wales (K. Rowling, personal communication). All known localised depletions have occurred in the same manner: fish were usually large and abundant on newly exploited grounds, but their size and catch rate decreased rapidly to non-economical levels and fishers left the grounds. Localised depletions were related to the size of the fish; they always referred to large (average length between 70 and 80 cm FL) fish on deep grounds. Large fish have a more dispersed distribution on the bottom and seem to become less vulnerable to fishing as their abundance declines. The fact that fishing recommenced on the Thirty Mile Patch in 1992, with good catch rates, suggested that the abundance of large fish has increased since the late 1970s depletion.

Changes in catch composition

There has been a dramatic decrease in the length of blue-eye trevalla since the fishery started, which was concurrent to a general decrease in fishing depth (Fig. 23). The relationship between the mean length of fish and fishing depth has also changed (Fig. 24,

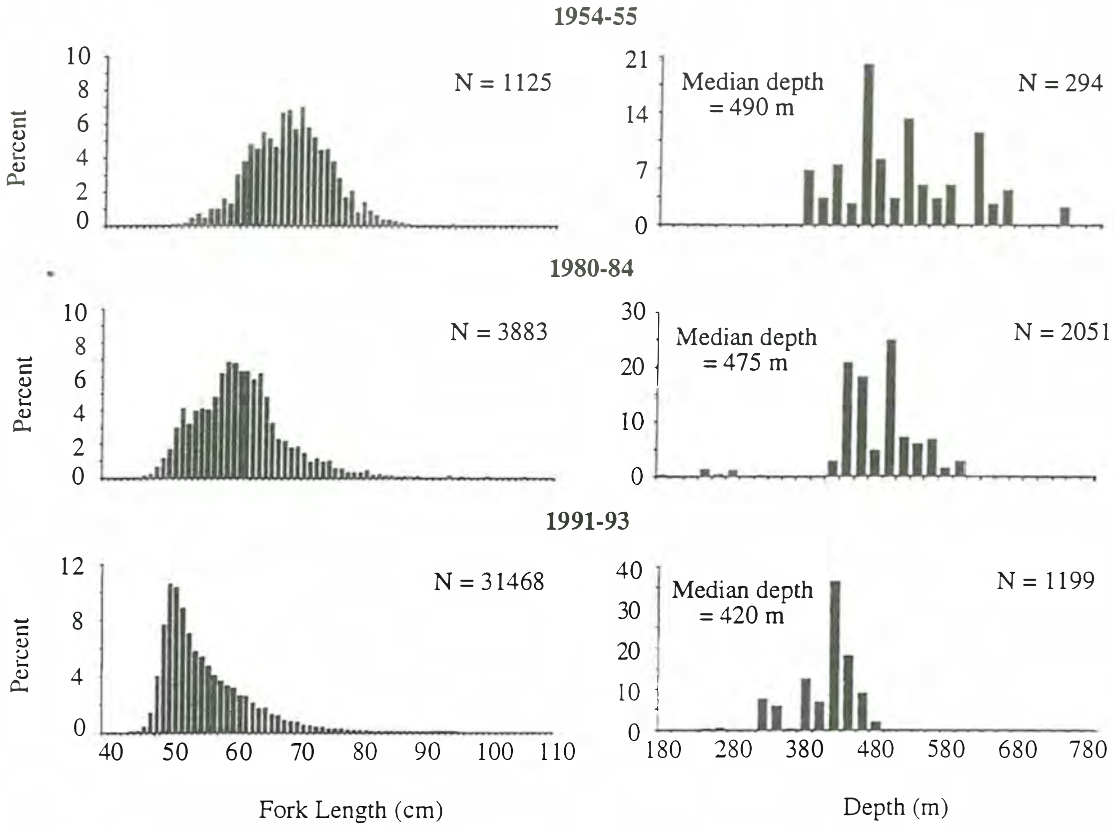


Fig. 23: Changes in length of fish and fishing depth over time in the blue-eye trevalla fishery. N= number of fish or number of lines.

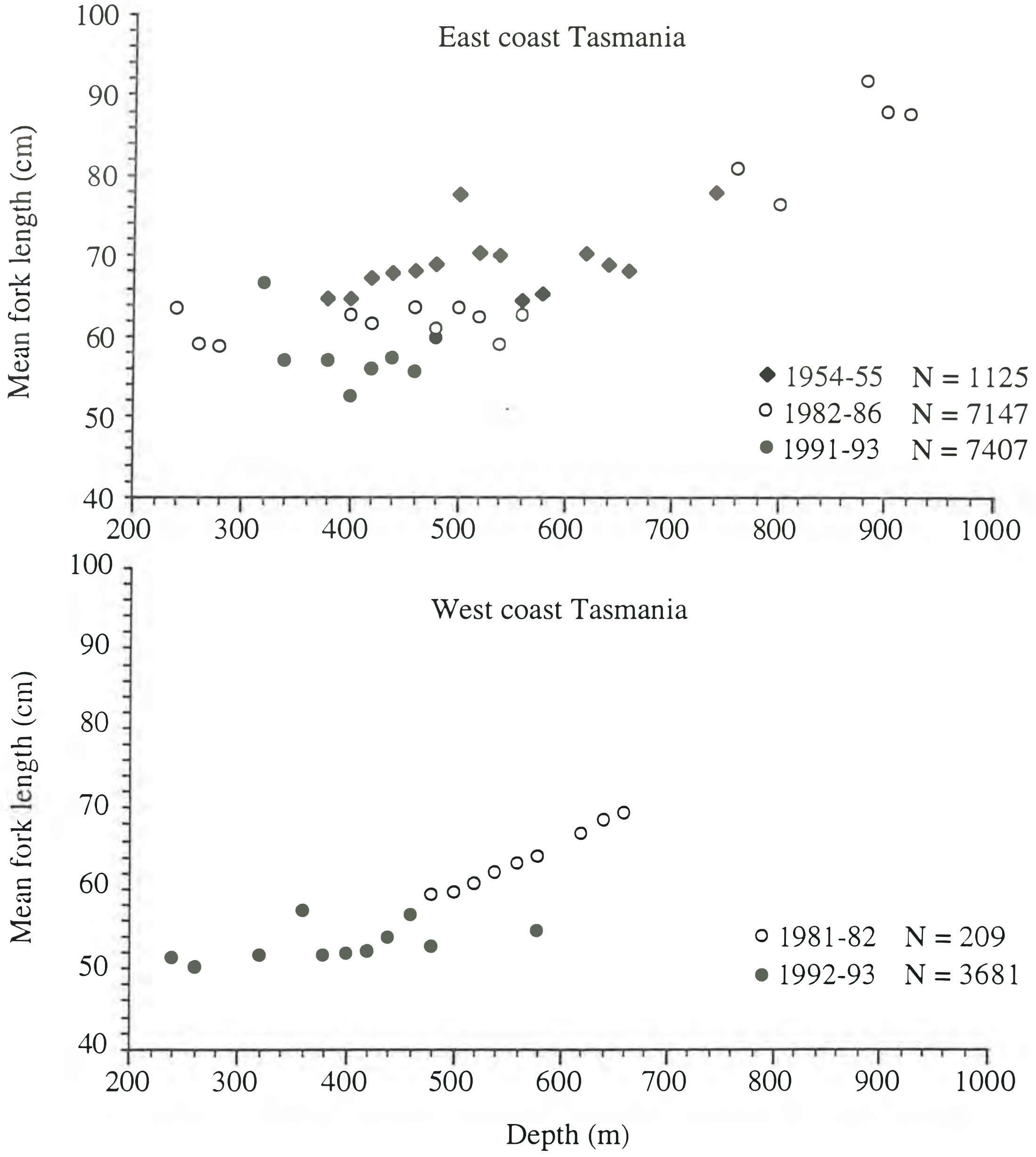


Fig. 24: Graph showing, for the east and west Tasmanian coast, the general increase in length of fish with depth, and the decrease in length of fish at given depth over time (sample sizes and standard deviations for each length shown in Table 2). N=total number of fish.

Table 2: Mean fork-length (FL, cm) of blue-eye trevalla and standard deviation (Std) by depth and periods, for the east and west coasts of Tasmania. Data used to draw Fig. 27. N=sample size. For the 1980-86 period, mean length was estimated from catch weight and catch number.

	East Tasmania								West Tasmania					
Period	1954-55			1980-86		1991-93			1981-82			1991-93		
Depth (m)	Mean FL,cm	Std	N	Mean FL,cm	N	Mean FL,cm	Std	N	Mean FL,cm	Std	N	Mean FL,cm	Std	N
180				57.6	15									
200														
220				57.7	162									
240				63.4	209							51.2	3.8	5
260				58.9	17							50.1	2.2	54
280				58.5	96									
300														
320						66.4	9.7	356				51.4	3.5	178
340						56.8	8.2	301						
360												57.0	3.9	23
380	64.5	4.0	43			56.8	8.0	804				51.4	3.0	132
400	64.4	4.9	47	62.4	75	52.3	3.3	1150				51.7	2.5	168
420	66.9	6.4	78	61.3	185	55.7	6.1	1046				51.9	4.0	2491
440	67.5	6.3	23	61.8	268	57.2	6.5	1736				53.8	5.2	575
460	67.9	6.7	383	62.1	1687	55.4	4.8	1706				56.4	3.9	7
480	68.8	7.3	65	60.7	1057	59.6	8.3	44	59.2	5.1	66	52.7	3.3	45
500	77.5	0.0	1	62.7	919				59.5	2.6	4			
520	70.1	5.0	124	60.4	1111				60.5	8.4	13			
540	69.8	3.8	57	61.8	325				61.8	8.8	6			
560	64.2	6.9	6	62.4	552				63.0	5.5	79			
580	65.0	5.6	52	52.3	39				64.0	18.6	12	54.7	0.6	3
600				47.1	2									
620	70.2	5.1	153	74.2	127				66.8	6.5	8			
640	68.8	7.9	8						68.5	5.7	8			
660	67.9	6.2	80						69.2	5.9	13			
680														
700				56.5	80									
720														
740	77.8	6.8	5											
760				80.8	205									
780														
800				76.2	484									
820														
840														
860														
880				91.9	253									
900				87.8	1293									
920				87.6	275									

standard deviations of the means and samples sizes shown in Table 2). Apart from an expected general increase in the length of fish with depth, Fig. 24 shows that not only there has been a decrease in the depth of fishing (i.e. towards catching smaller fish), but also that fish are now smaller at given depth (particularly visible on the east coast of Tasmania).

During the present study, higher catch rates were obtained in the south-west and south-east fishing zones (newly exploited and newly re-exploited zones, respectively), compared with the other zones (Fig. 25, fishing zones with similar cpue distributions and which were geographically close were combined, i.e. north-east and east zones, and south-east and south-west zones, respectively). Note that the newly exploited west zone is not regarded as a productive ground, mostly due to the limited extent of suitable bottom. On the two currently most productive grounds, fishers tend to fish in slightly deeper waters and to catch slightly larger fish (see Fig. 9, although these fish were still well below the average 70-80 cm FL that was reported in the early years of the fishery). According to fishers, catch rates in the south-west zone have declined in the last two years, and if this trend continues, it could be the case of another localised depletion, this time affecting younger fish compared with situations described in the 1970-1980s. Fishing in shallower waters is currently attempted in this zone (recall that small and newly recruited fish were uncommon in catches from this zone).

The range of fishing depth currently exploited by the fishery is narrow (Fig. 26), most effort being spent between the depths of 400-440 m. For both sexes, analysis of variance showed that fish were significantly smaller in this main range of fishing depth than on either sides of it ('shallow' less than 400 m, and 'deep' 440-500 m, Table 3). Shelf-break features (such as thermal front generated by currents) constitute environmental heterogeneity where biological patchiness often occurs (Barange 1994). This author also found that the density of fish aggregations was higher on the shelf-break than on the shelf above.

The fishery tends to catch a greater proportion of males amongst small fish. Difference in growth pattern between sexes probably accounts for this (Parma and Deriso 1990), and males could be under increasing fishing pressure. The sex-ratio calculated from data collected in the 1950s was 68.2% of females, compared with the present ratio of 51%. Females, which grow larger and live longer than males, were under greater fishing pressure in the early years of the fishery, when larger fish were targeted in deeper waters.

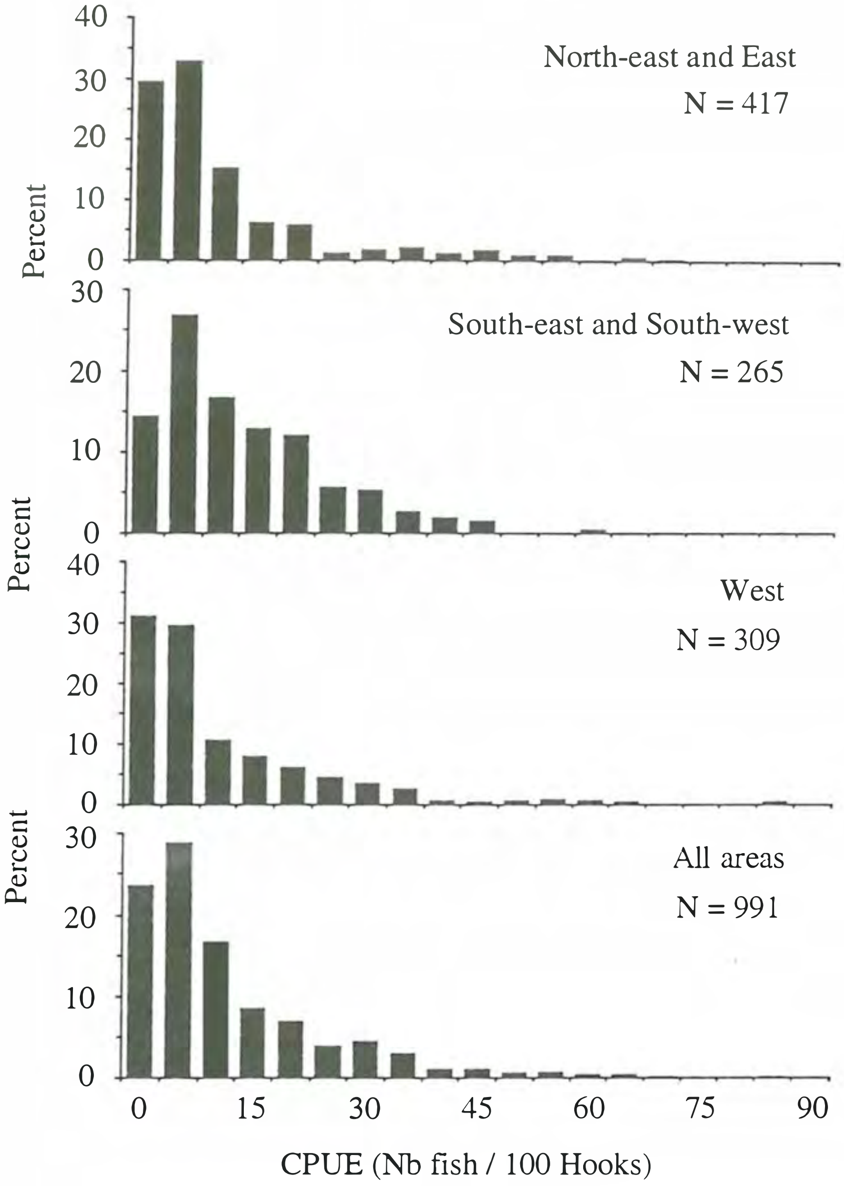


Fig. 25: Frequency distribution of cpue by fishing zone and for all zones combined (fishing zones with similar cpue frequency distributions were combined). Cpue calculated for individual lines.

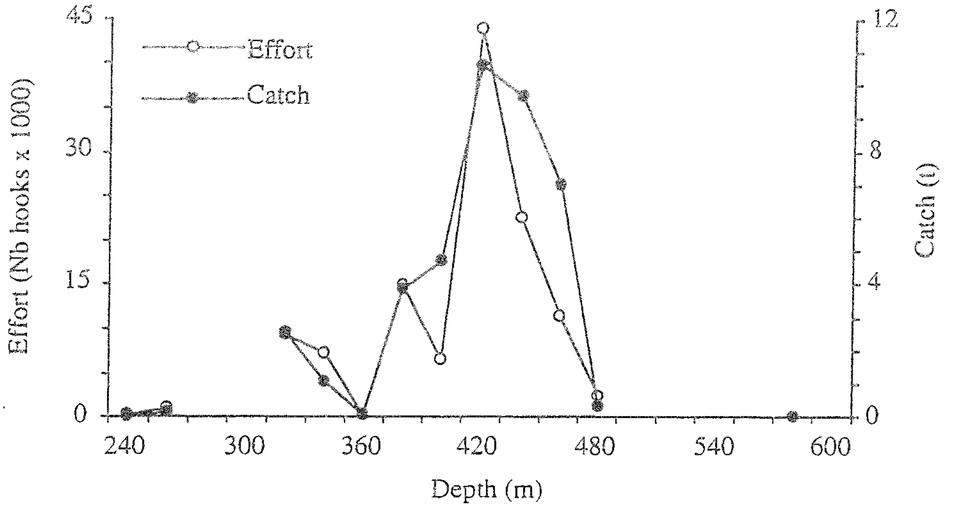


Fig. 26: Depth distribution of catch (t) and fishing effort (number of hooks) in the Tasmanian blue-eye trevalla fishery. Data from catch monitoring programme November 1991-July 1993.

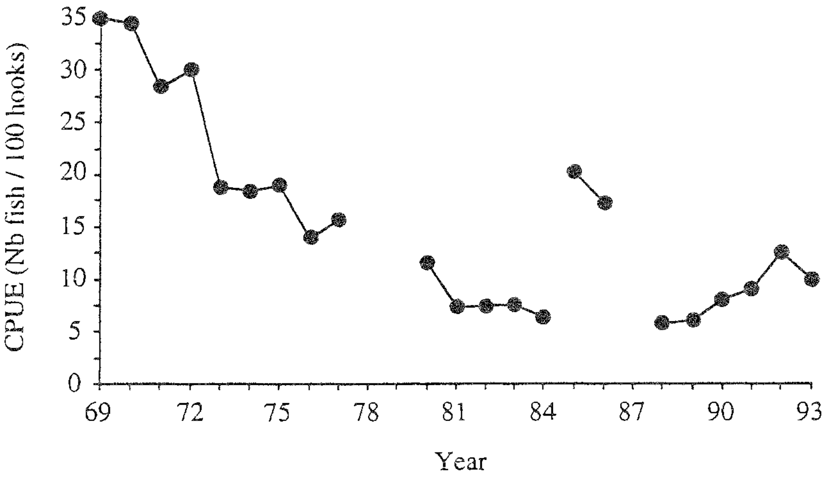


Fig. 27: Annual cpue in number of fish/100 hooks estimated from major Tasmanian drop-liners' personal or voluntary logbooks. High values in 1985-86 corresponded to a one off fishing trial in unusual deeper waters (see text).

Table 3: Results of ANOVA comparing the mean length of fish between three depth ranges (shallow, medium and deep) by sex. 'Spawning' (January to April) and 'non-spawning' (May to December) periods were distinguished to account for aggregation of large fish during spawning.

					Least squares mean FL (cm)		
Sex	Period	DF	F	P	Shallow (<400m)	Medium (400-440m)	Deep (440-500m)
Female	Spawning	2-3725	294.29	0.000	61.3	53.4	57.3
	Non-spawning	2-1911	53.90	0.000	56.2	52.7	55.6
Male	Spawning	2-3259	251.22	0.000	57.5	52.4	55.2
	Non-spawning	2-1902	48.92	0.000	54.5	52.4	54.6

In conclusion, blue-eye trevalla were larger at greater depths, as usually observed for demersal fish populations (Macpherson and Duarte 1991, Lehodey *et al.* 1994, Sinclair 1992). As the abundance of larger fish in deeper waters declined, the fishery moved to shallower waters, where drop-liners now target small and schooling fish.

Change in the frequency distribution of catch rate

Annual cpue in number of fish/100 hooks (Fig. 27) showed similar trends as annual catch rate calculated as boat-month (Fig. 3). Cpue was high at the beginning of the fishery, and then declined markedly within a few years, to increase again from the late-1980s. The two high catch rate values in 1985 and 1986 were obtained by some fishers who attempted fishing in deeper water on the Thirty Mile Patch; catch rate were good but dropped quickly and fishing was abandoned.

While annual catch rate increased from the late-1980s, the frequency distribution of cpue (as number of fish/100 hooks calculated per day) has become more skewed to the right over the years (Fig. 28). Cpue was high during 1969-73, at the start of the fishery, with a more or less normal frequency distribution. Exploitation of the Thirty Mile Patch (south-east zone) accounted for the still high cpue during 1974-77. However, by the early 1980s, this fishing ground was depleted and low values dominated the cpue distribution. In the early 1990s, the introduction of colour echo-sounders and GPS, and the start of fishing in the south-west zone, produced some high cpue values (at about 35 fish/100 hooks, Fig. 28). These high cpue values were responsible for the increase in annual cpue shown in Fig. 3 and 27.

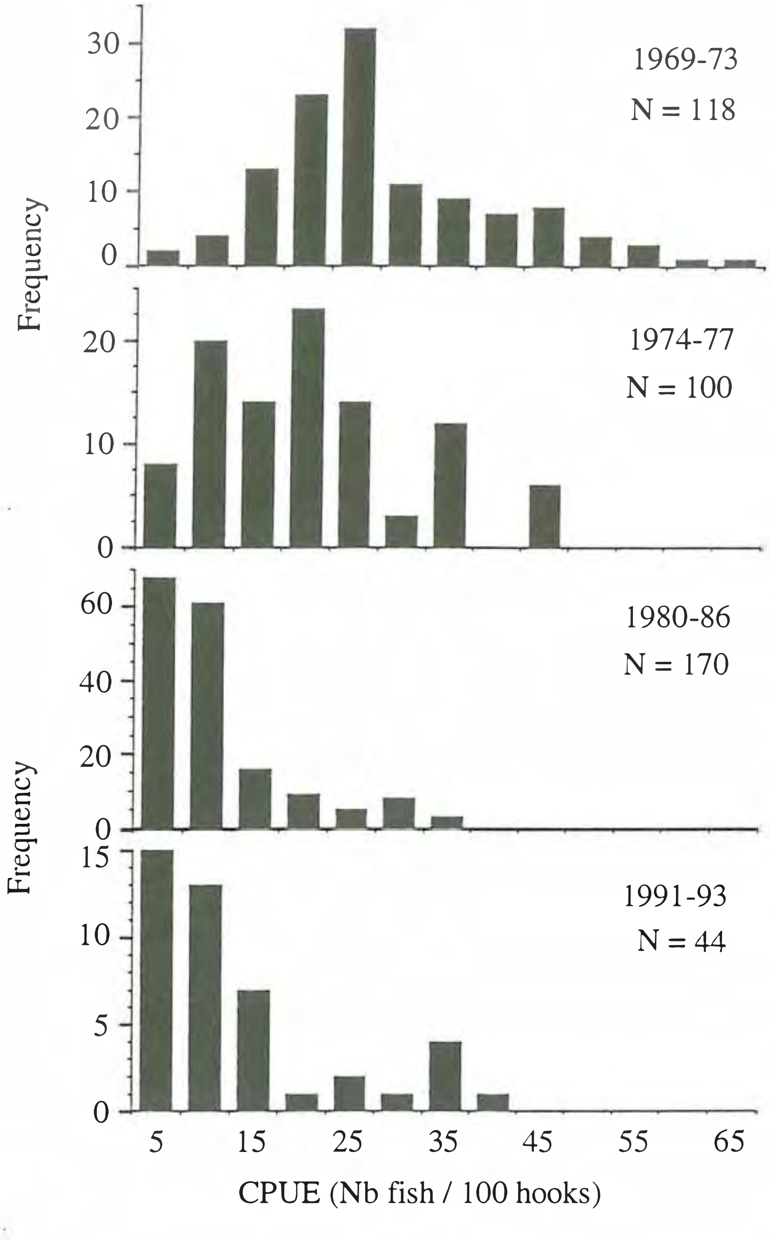


Fig. 28: Change in cpue frequency distribution over the years (cpue calculated for catch and fishing effort data aggregated by day). N= number of days.

This increase in annual cpue thus reflected changes in fishing practice rather than greater abundance of fish. These changes were a combination of technological improvements and exploitation of new (i.e. temporarily more productive) grounds. Colour echo-sounders and GPS now allow fishers to better localise and target schools of small fish in mid-waters. Changes in the shape of the cpue frequency distribution usually reflect changes in fish distribution, and high occurrence of unsuccessful fishing indicates a patchy distribution of the fish and great differences in fishers' skills (Palaheimo and Dickie 1964, Bannerot and Austin 1983, Au 1986). The cpue frequency distribution becoming skewed to the right over the years for blue-eye trevalla could reflect the greater patchiness of the schools of small fish that are now targeted by the fishery.

There are two mechanisms at play here: the change in fishing practice towards targeting smaller fish, and the more patchy distribution of schools of small fish. Thus, as the abundance of large fish has declined, fishers have maintained, and even increased, catch rates by targeting patchy but dense schools of small fish. However, spatial patchiness can result in cpue remaining high even when stock size reduces because the fishery directs effort on concentrations of fish (Paloheimo and Dickie 1964, Bannerot and Austin 1983, Rose and Leggett 1990).

CHAPTER 5: GEAR COMPARISON

Using available data, catch rates and catch compositions were compared between the four fishing gears involved in the blue-eye trevalla fishery: drop-line, bottom long-line, mid-water and demersal trawls. Drop-line and mid-water trawl gears are both used to target blue-eye trevalla, while this species is mainly caught as a by-catch of blue grenadier in demersal trawl catches, and of pink ling in bottom long-line catches. Species composition of catches are shown in Table 4 for drop-line, bottom long-line, mid-water trawl and demersal trawl.

Table 4: Species composition associated with blue-eye trevalla catches in mid-water and demersal trawl catches (pooled South East Fishery logbook data 1986-94, including only trawl shots of at least 1 tonne of blue-eye trevalla) and in Tasmanian drop-line and bottom long-line catches.

	Mid-water trawl		Demersal trawl	
Main species	Catch (t)	%	Catch (t)	%
Deep-sea trevalla	103.9	95.9	92.6	36.9
Blue grenadier	1	0.9	102.8	41.0
Spotted trevalla	0	0	35.9	14.3
Gemfish	3.4	3.2	2.6	1.1
Pink ling	~0	~0	4.3	1.7
All species	108.3		250.7	

Main species	Drop-line %	Long-line %
Deep-sea trevalla	97.2	12.4
Pink ling		79.1
Others (shark,cod)	2.8	8.5

Trawl catch and catch rate

Catch statistics from the trawl fishery have been recorded in the South East Fishery logbooks since 1986. Detailed information on fishing effort (hour trawled), catch by species, fishing location and depth are recorded by trawl shot. About 50 to 100 t of blue-eye trevalla have been recorded in trawl catches each year between 1988 and 1993. By-catches of this species in demersal trawl catches were usually less than 200kg per shot.

Recorded catches then dropped markedly to 50-60 tonnes after implementation of quotas in 1992.

Data are generally recorded in logbooks without distinction between mid-water and demersal trawl fishing methods, and without distinction between targeted catches and by-catches. In an attempt to distinguish catches between the two trawl fishing methods, trawl shots producing at least one tonne of blue-eye trevalla were first selected to eliminate small by-catches; then, amongst these shots, mid-water and demersal trawl shots were arbitrarily distinguished on the basis of their duration in hours (Fig. 29), the duration of mid-water trawl shots being much shorter (usually less than 1 hour) than the duration of demersal trawl shots. A significant number of shots, assumed to be demersal non-targeted trawl shots, yielded more than one tonne of blue-eye trevalla (Fig. 29). In fact, when considering only shots of more than one tonne of this species, catch sizes were similar between the two trawl gears (Fig. 30), with, of course, very different catch rates (about 0.7 t/hour for demersal trawl catches compared with 4.9 t/hour for mid-water trawl catches, Table 5). This shows the need to distinguish trawl fishing in logbooks if cpue is to be of any use. For comparison, the average catch rate of a drop-liner fully involved in the blue-eye trevalla fishery is currently about 1.5t/month.

Table 5: Comparison of fishing effort and cpue between mid-water and demersal trawl shots (pooled 1986-94 logbook data). Only trawl shots of at least 1 tonne of blue-eye trevalla were included.

	Mid-water trawl	Demersal trawl	Combined
Effort (hours)	23	155	178
Effort (Nb shots)	40	43	83
Mean cpue blue-eye (t/hour/shot)	4.9 ± 3.4	0.7 ± 0.5	2.7 ± 3.2

Targeting of blue-eye trevalla using mid-water trawl gear occurred mainly off south-east and west Tasmania, and Victoria (Fig. 31), and during spring-early summer (October-December, Fig. 32).

Comparison of catch length composition between fishing gears

Length data were occasionally collected from trawl and bottom long-line blue-eye trevalla catches in the early 1990s during various catch monitoring programmes and during the present study. The length frequency distributions of blue-eye trevalla caught by drop-line, bottom long-line, mid-water and demersal trawls are shown in Fig. 33

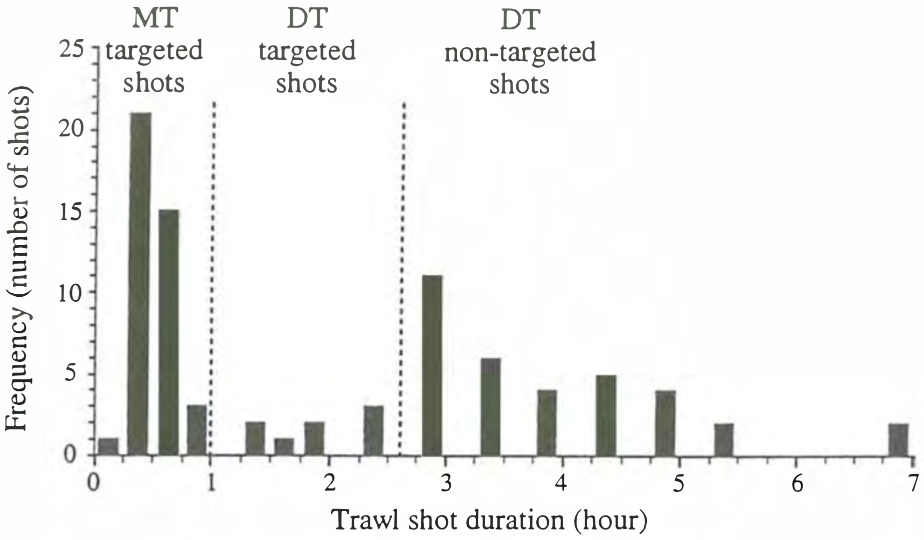


Fig. 29: Frequency distribution of trawl duration (hours) for all trawl shots yielding more than 1 tonne of blue-eye trevalla (pooled logbook data 1986-1994). Shots of less than 1 hour duration were regarded as mid-water (MT) trawl shots. DT=demersal trawl.

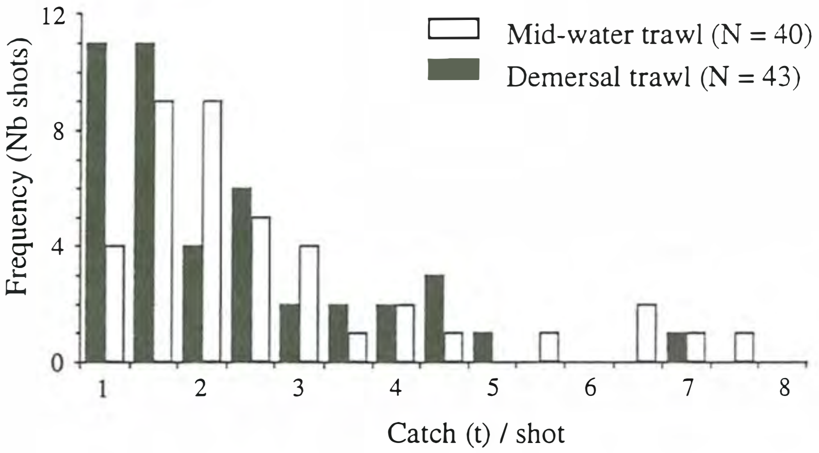


Fig 30: Comparison of the frequency distributions of catch by shot between mid-water (MT) and demersal (DT) trawls (pooled logbook data 1986-1994). N= number of shots.

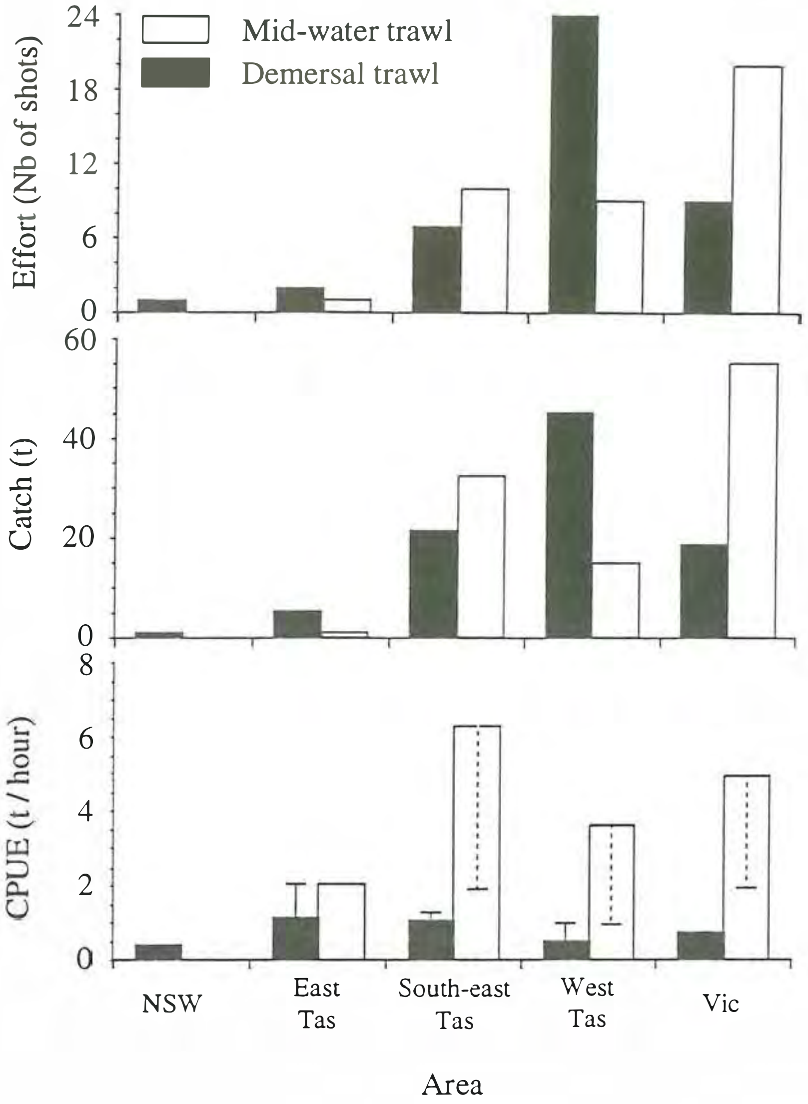


Fig. 31: Catch, effort and cpue by area within southern Australia for mid-water (MT) and demersal (DT) trawls (pooled logbook data 1986-1994).

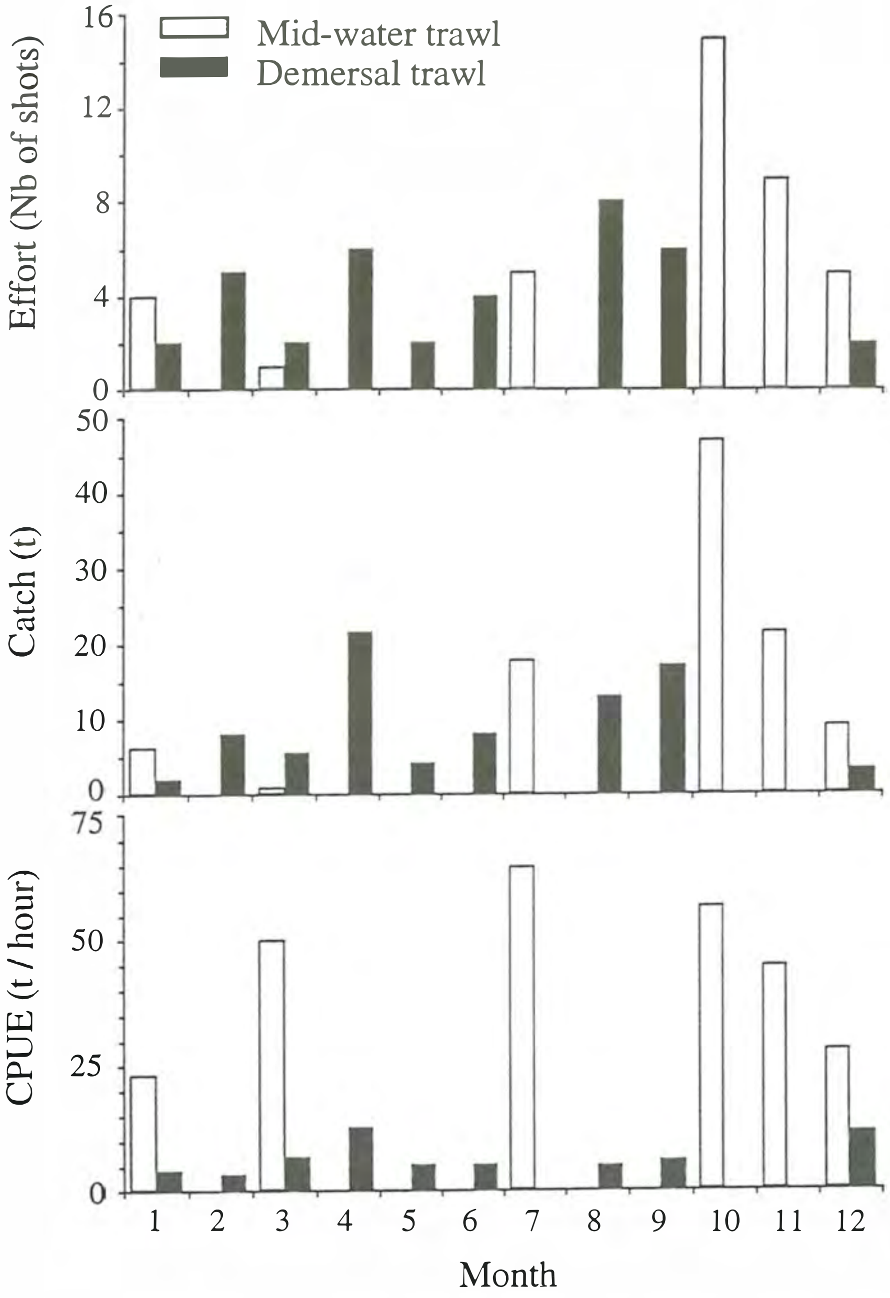


Fig. 32: Monthly catch, effort and cpue for mid-water (MT) and demersal (DT) trawls (pooled logbook data 1986-1994).

(fishing depths and fishing periods at which data were collected were comparable). Logistic curves fitted to the ascending and descending limbs of these length frequency distributions (Fig. 34 and Table 6) illustrated well the differences in catch composition between the gears.

Table 6: Parameters of the logistic equation $p = e^{(a + bFL)}/(1 + e^{(a + bFL)})$ fitted to the ascending and descending limbs of the length frequency distributions shown in Fig. 35. p = proportion of fish by size class relative to the maximum number of fish at the top of the ogive; $FL_{0.5}$= fork length (cm) at which the number of fish is half this maximum.

	a	b	$FL_{0.5}$ (cm)	95% conf. limits
Ascending limb				
Drop-line	-55.22	1.14	48.41	48.38 - 48.45
Bottom long-line	-21.09	0.41	51.37	50.90 - 51.83
Mid-water trawl	-20.18	0.40	50.36	49.94 - 50.77
Demersal trawl	-56.58	1.17	48.47	48.35 - 48.59
Descending limb				
Drop-line	11.64	-0.20	57.64	57.53 - 57.75
Bottom long-line	16.88	-0.27	61.84	61.09 - 62.51
Mid-water trawl	22.12	-0.34	64.44	63.95 - 64.91
Demersal trawl	33.25	-0.60	55.15	54.96 - 55.33

The Kolmogorov-Smirnov test showed that the shapes and locations of the length frequency distributions on the length axis were significantly different (Table 7). The relative locations of the distributions could be summarised as follow, from left to right:

demersal trawl <<< drop-line << mid-water-trawl<bottom long-line

The differences between mid-water trawl and long-line were very small (the test statistics were the lowest: 2.0 for the comparison of shapes, and 0.87 for the comparison of location, Table 7).

To examine size-specific vulnerability of blue-eye trevalla to the different gears in more detail, the chi-square test was applied to compare the proportions in catches of fish arranged in 5 size groups of 5 cm interval (below 55, 55-60, 61-65, 66-70, and over 70 cm FL). These size groups related to some trends in distribution patterns, from small, newly recruited fish forming dense schools, to large and more dispersed fish. Results are shown in Table 8. Small fish ($FL \leq 55$ cm) were mostly caught by drop-line and demersal trawl, catches of the latter gear comprising the smallest fish of that group. Mid-water trawl and long-line catches were not significantly different, they were mostly

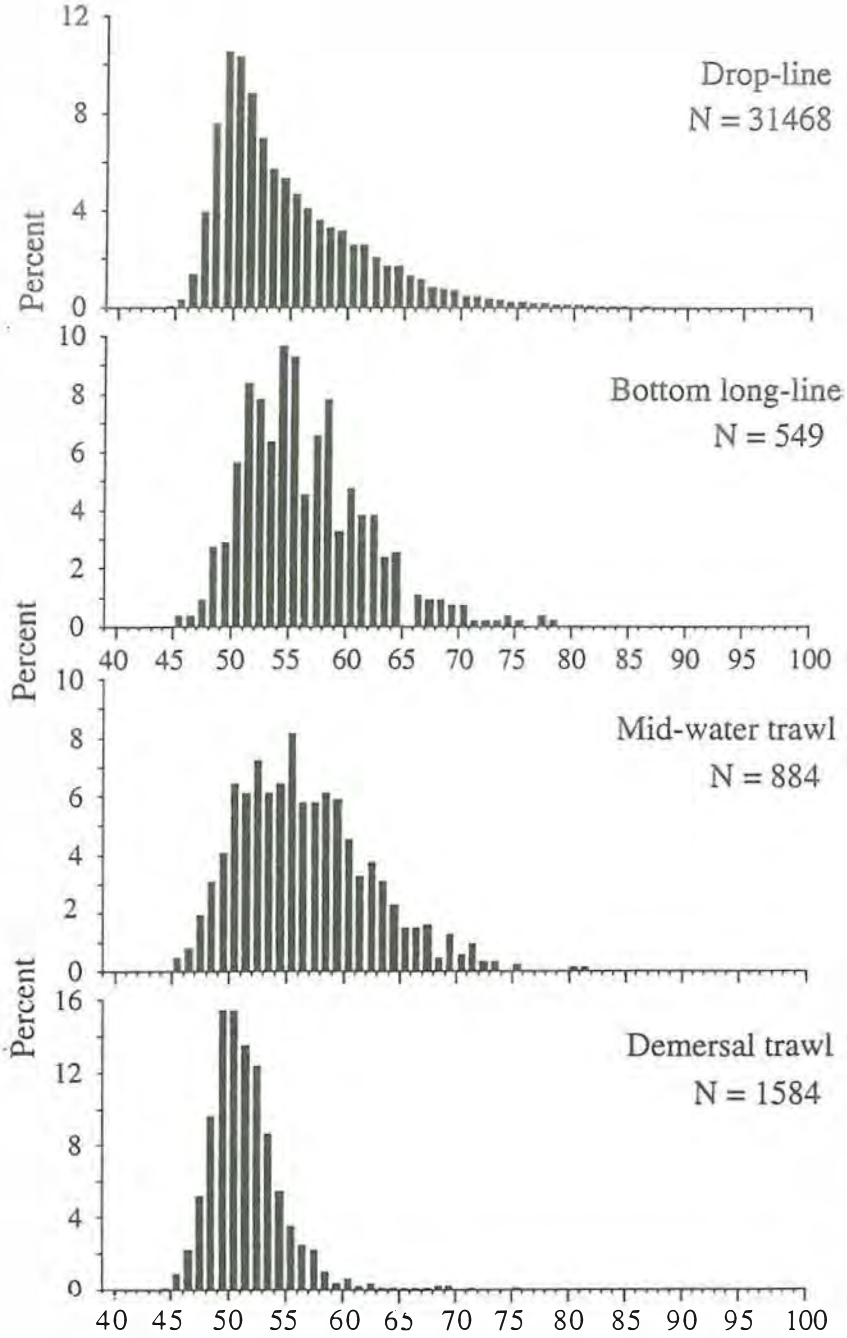


Fig. 33: Comparison of length compositions of blue-eye trevalla caught by different line and trawl fishing gears. N=number of fish.

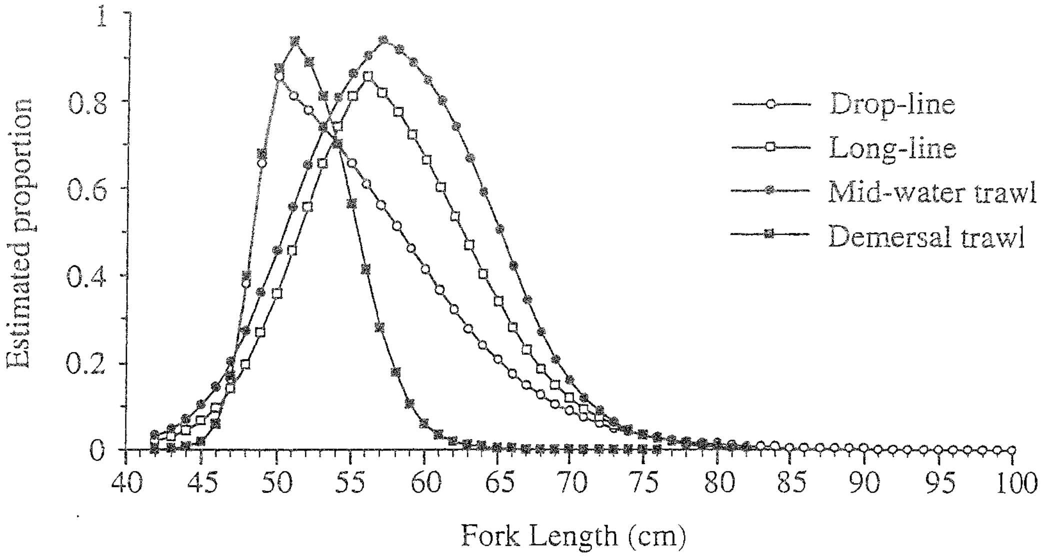


Fig. 34: Logistic curves fitted, for each fishing gear, to the ascendant and descendant limbs of the length frequency distributions shown in Fig. 33 (logistic equations shown in Table 6).

comprised of pre-adults (see chapter 6). Drop-line gear catches less pre-adults (55<FL≤65 cm) than these two gears, but as many adults (FL>65).

Table 7: Paired comparisons of shape and relative location of fish length frequency distributions between fishing gears. Numbers refer to large sample statistics of the Kolmogorov-Smirnov test, probabilities are shown in brackets (* = significant at 0.05%). DL=drop-line, LL=bottom long-line, MT=mid-water trawl, DT=demersal trawl.

Comparison	Shape	Left location	Right location
DL vs LL	5.1 (0.00)*	1.03 (0.11)	5.1 (0.00)*
DL vs MT	6.0 (0.00)*	0.61 (0.44)	6.0 (0.00)*
DL vs DT	12.6 (0.00)*	12.6 (0.00)*	0.03 (1.00)
LL vs MT	2.0 (0.00)*	0.87 (0.00)*	2.01 (0.19)
LL vs DT	10.6 (0.00)*	10.6 (0.00)*	0.05 (1.00)
MT vs DT	12.6 (0.00)*	12.6 (0.00)*	0.00 (1.00)

Table 8: Two-by-two chi-square test comparing the proportions of 5 size groups of blue-eye trevalla between fishing gears. Probabilities are shown in brackets, *=significant at 0.05%, with sign + or - indicating whether the proportion is higher or lower (example: proportion of fish below 55 cm is significantly greater in drop-line catches than in long-line catches. DL=drop-line, LL=bottom long-line, MT=mid-water trawl, DT=demersal trawl.

	Comparisons						Summary	
Size group (FL, cm)	DL vs LL	DL vs MT	DL vs DT	LL vs MT	LL vs DT	MT vs DT	DL vs DT	DL vs (LL,MT)
<55	92.76 (<0.001)* +	138.00 (<0.001)* +	444.90 (<0.001)* -	0.07 (0.794)	444.85 (<0.001)* -	556.19 (<0.001)* -	-	+
55 - 60	82.50 (<0.001)* -	87.99 (<0.001)* -	72.38 (<0.001)* +	1.32 (0.251)	164.72 (<0.001)* +	170.51 (<0.001)* +	+	-
61 - 65	23.36 (<0.001)* -	32.09 (<0.001)* -	146.00 (<0.001)* +	0.05 (0.826)	202.41 (<0.001)* +	213.34 (<0.001)* +	+	-
66 - 70	1.83 (0.176)	3.20 (0.074)	63.24 (<0.001)* +	4.54 (0.033)	28.74 (<0.001)* +	71.79 (<0.001)* +	+	
>70	3.24 (0.072)	3.67 (0.055) +	59.21 (<0.001)* +	0.08 (0.783)	29.34 (<0.001)* +	34.68 (<0.001)* +	+	

In conclusion, there are fundamental differences between line and trawl fishing gears regarding gear saturation, catching capacity and operational tactics (Bjordal 1985). Several studies have shown that long-line fishing methods are more efficient at low fish density and when fish are scattered, and usually catch larger/older fish than trawl fishing methods (O'Boyle *et al.* 1991, Hovgard and Riget 1992, Lokkeborg and Bjordal 1992, Sinclair 1992, Punt and Japp 1994). Although data are too limited to draw conclusions with certainty, it appears that the differences in blue-eye trevalla catch composition between fishing methods reflect the targeting of mid-water schools of small fish by drop-lining, and the catch, or by-catch, of larger, more dispersed and demersal fish by mid-water trawling and bottom long-lining.

CHAPTER 6: BIOLOGY AND DYNAMICS OF THE REPRODUCTION OF BLUE-EYE TREVALLA

Little and fragmented information on the reproduction of blue-eye trevalla is available from Webb (1979), Jones (1988) and Horn and Massey (1989), and no fecundity study has been undertaken. A detailed study of the reproductive biology (gonad maturation, size at maturity, spawning frequency and fecundity) and composition and dynamics of spawning aggregations is presented here.

Materials and methods

Sampling

At least one sample was obtained each month from most fishing grounds around Tasmania (Fig. 35). Females and males were staged macroscopically using maturity stages described in Table 9 (adapted from Hunter and Macewicz, 1985 a and b; Schaefer, 1987 and West, 1990). To calculate the gonado-somatic index (GSI), ovaries and testes were collected to be weighed in the laboratory to the nearest 0.1 g. For later histological examination and measurement of whole oocytes, ovaries at various stages of maturity were preserved in Davidson's solution immediately after the catch. Nearly all mature ovaries (stages 4 to 6, Table 9) were preserved.

Histological staging of ovaries

A total of 447 ovaries were examined histologically to check macroscopic staging and to note the presence of atretic oocytes and post-ovulatory follicles (see description in Table 9, Fig. 36 and Fig. 37A and 37B). Ovary sections were stained in haematoxylin and eosin and ovaries were staged by the most advanced type of oocytes present, regardless of their abundance (West, 1990).

Size at maturity

The average size at maturity ($FL_{0.5}$) was the size at which 50% of fish caught during the breeding season were mature (i.e. stages 4 to 6 for females, and stages 3 and 4 for males). For each sex, the proportion (p) of mature individuals by 1 cm fork length intervals was fitted to the logistic function:

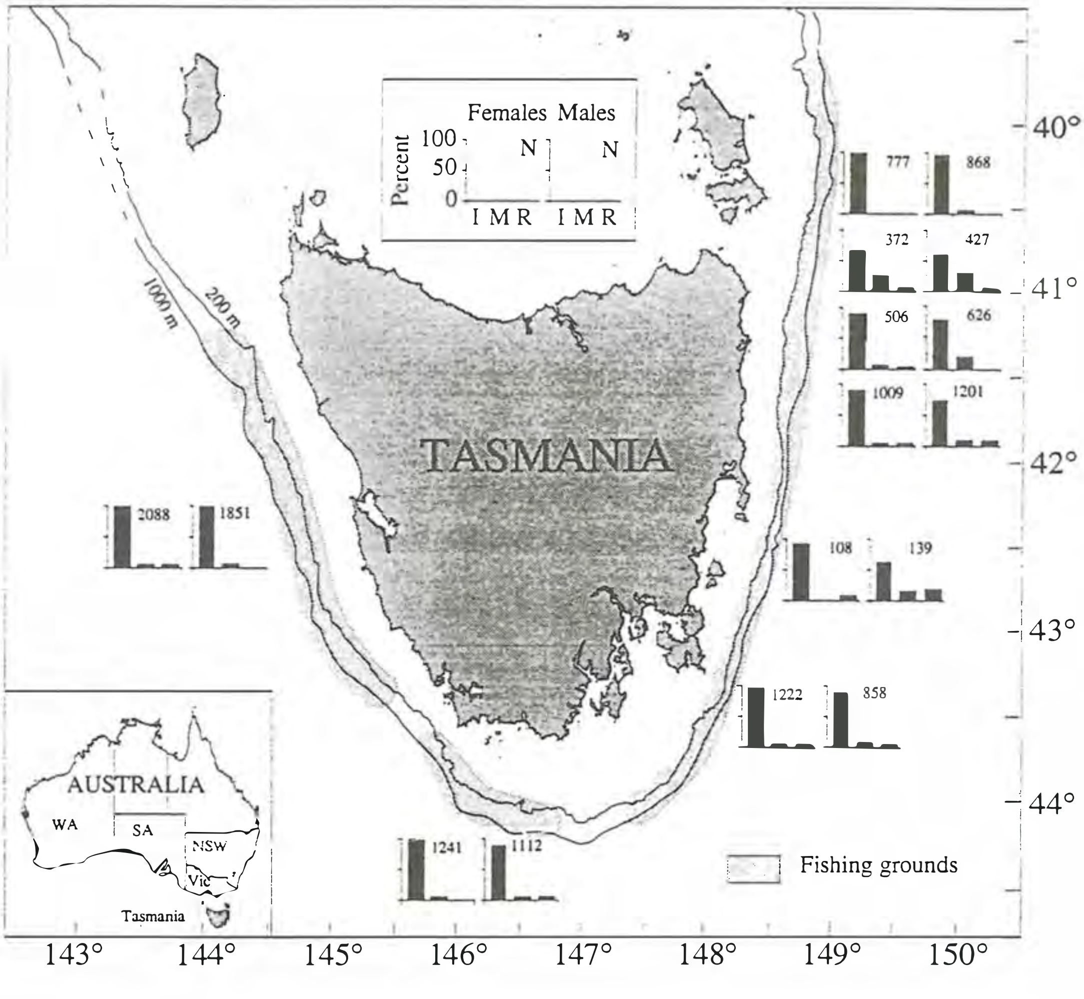


Fig. 35. Proportions by sex of immature (I), mature (M) and resting (R) fish in samples collected from major fishing grounds around Tasmania. I= stages 1 to 3 for females, 1 to 2 for males; M= stages 4 to 6 for females, 3 to 4 for males; R= stages 7 and 8 for females, stage 5 for males. N= sample size. WA= Western Australia, SA= South Australia, Vic Victoria, NSW= New South Wales.

Table 9. Female and male maturity stages. Adapted from Hunter and Macewicz 1985 a and b, Schaefer 1987, West 1990, Hunter et al. 1992, Davis and West 1993.

FEMALES

Stage	Macroscopic	Histological	Whole preserved ooyctes
1 - Immature	Small thread-like ovaries, pink and translucent;	Chromatin nucleolar stage: very small oocytes, nucleus surrounded by thin layer of dark blue stained cytoplasm;	
2 - Early developing	Oocytes not visible, ovaries pink and translucent; *First-time developing females*: ovaries up to 10cm long, 1cm across, ovary wall thin and transparent; *Re-developing females*: ovaries up to 20cm long, 5cm across, flaccid, ovary wall thick, whitish and opaque;	Perinucleolar stage: oocyte size increases slightly as dark blue stained cytoplasm thickens, nucleoli appear at the periphery of nucleus;	Cytoplasm homogeneous, brownish and transparent, comparatively large dark nucleus;
3 - Developing	Small oocytes becoming visible, still translucent, ovaries occupy less than 20% of body cavity;	Cortical alveoli stage: appearance of cortical alveoli in pale blue stained cytoplasm, pink stained zona radiata distinguishable, oil vesicles appearing, lampbrush chromosomes often visible in the nucleus;	Oocytes more or less spherical, cytoplasm thickened, darker, granular, but still translucent, nucleus still visible;
4 - Late developing (yolked)	Small opaque oocytes clearly visible, marked increase in ovary size (20% to 100% of body cavity) and change from pink to yellow-orange color, ovary wall thin and transparent;	Yolk stage: marked increase in oocyte size, cytoplasm filled with pink stained yolk granules, cortical alveoli and oil vesicles increase in size and number; degenerating post-ovulatory follicles visible if spawning has started;	Oocytes dark, completly opaque, size increasing with development, nucleus occluded; degenerating post-ovulatory follicles visible if spawning has started;
5 - Ripe	Ovary size as in previous stage, large transparent (hydrating) oocytes visible amongst smaller opaque oocytes;	Nuclear migration stage: migration of nucleus to periphery of oocyte, fusion of yolk granules into yolk plates; fusion of oil vesicles into the oil droplet; degenerating post-ovulatory follicles visible if spawning has started;	Occurence of partly translucent oocytes (hydrating), yolk plates visible; degenerating post-ovulatory follicles visible if spawning has started;
6 - Running-ripe	Ovary size as in previous stage, hydrated oocytes larger, easily expressed from ovaries;	Hydratation stage: further increase in size of oocytes, all yolk granules fused into a few plates;	Occurence of very large, almost totally translucent oocytes, oil droplet visible;
7 - Spent	Ovaries flaccid, occupy about 20% of body cavity, greyish ovary wall thickened and wrinkled, some residual oocytes visible within translucent material;	Post-ovulatory follicles clearly visible, no yolked oocytes left except for a few undergoing atresia; structure of ovaries generally loose, hydrated oocytes may be present in lumen;	Post ovulatory follicles visible, remaining yolked oocytes at early stage of atresia;
8 - Resting	Aspect of ovaries as in previous stage, not accurately distinguishable.	Oocytes at stages 2 and 3 predominate, no trace of post-ovulatory follicles left, advanced atresia of remaining yolked oocytes, hydrated oocytes sometimes still present in lumen.	Very small oocytes (stages 2 and 3) predominate, advanced atresia of remaining yolked oocytes.

MALES

Stage	Macroscopic
1 - Immature	Testes very small, flat and threadlike;
2 - Early developing	Testes increase in size, rounder in shape;
3 - Developing	Size of testes increases further, lobes in formation and marked grove in the middle of each teste visible, creamy/white, milt sometimes present;
4 - Late developing to running-ripe	Testes very large and multilobed, white/pinkish, sometimes bloodshot, free-flowing milt;
5 - Spent and resting	Testes much smaller, very bloodshot, milt sometimes present, become thinner, brownish and rubbery as they regress to resting stage.

$$p = e^{(a + bFL)} / (1 + e^{(a + bFL)})$$

using generalised linear models (Genstat 5 Reference Manual). The average size at maturity was also estimated for length and maturity data collected during the 1950s (Cowper and Downie, unpublished data).

Spawning frequency and fecundity

Hunter *et al.*. (1992) have identified three main factors which can affect fecundity estimates: 1/ the rate of atresia in reducing the number of oocytes spawned, 2/ the occurrence of previous spawnings (as shown by the presence of post-ovulatory follicles), and 3/ the accurate identification of which oocytes to include when estimating fecundity. These three factors were examined as shown below.

1-Rate of atresia

The proportion of atretic oocytes was determined in ovaries at various stages of maturity using samples preserved in Davidson's solution. Only early stages of atresia (stages alpha and beta as described by Hunter and Macewicz, 1985b) were considered (Fig. 37B, C, D); oocytes at later stages of atresia are too difficult to identify with commonly used histological techniques.

2-Occurrence of post-ovulatory follicles

The presence of post-ovulatory follicles in ovaries was used to identify females which had begun to spawn. Also, examination of morphological changes in post-ovulatory follicles after ovulation (as described by Hunter and Macewicz, 1985b; Schaefer, 1987; Macewicz and Hunter, 1993) provided information on spawning frequency. Post-ovulatory follicles were classified in 3 types according to the degree of resorption visible in histological sections. Type 1 post-ovulatory follicles were the most recent presenting a very fine, stretched and collapsed zona radiata; type 2 post-ovulatory follicles (Fig. 37A) were much reduced in size but still presented an involuted shape with numerous folds and an open cavity; the granulosa cells were still aligned within a thickening zona radiata; type 3 post-ovulatory follicles were small with fewer involutions and much reduced follicular cavity; at that stage the zona radiata is very thick and the granulosa cells are disorganised. When present in ovaries, 50 post-ovulatory follicles were randomly measured (perimeter) using NIH Image analysis software.

3-Staging and measurement of whole oocytes

Staging and measurement of whole oocytes was used to assess whether the fecundity of blue-eye trevalla is determinate or indeterminate, that is whether yolk formation is completed before spawning starts or continues after (Hunter *et al.* 1985). This information is needed to know whether the annual fecundity can be estimated from a standing stock of yolked oocytes present in ovaries. Subsamples of ovaries preserved in Davidson's solution were mixed in small jars with water and 3mm glass beads and manually shaken to dissociate the oocytes. Oocytes were examined under a microscope and staged (see description in Table 9 and Fig 37C and 37D, adapted from West, 1990; Hunter *et al.*,. 1992; Davis and West, 1993). Fifty oocytes were measured (along the maximum diameter) for 135 females at various stages of maturity. Figure 37D also shows whole preserved post-ovulatory follicles of types 1 and 2 (type 3 were too small to be properly dissected and photographed).

4-Fecundity estimation

Only ovaries that showed no sign of previous spawnings (absence of post-ovulatory follicles), no sign of major atresia, and in which oocytes were fully yolked (as indicated by their diameter, see below) were used to estimate the annual fecundity. Before estimating fecundity, a check was made that the oocytes were uniformly distributed within the ovaries. Using 5 fish, the number of oocytes per gramme was compared between subsamples taken across the ovaries (near the periphery and near the centre) and along the ovaries (within the anterior, median and posterior regions). ANOVA showed no differences between subsamples across the ovaries (F=0.68, df 1,4, p=0.42), or between subsamples along the ovaries (F=0.74, df 2,8, p=0.49). Oocytes were then routinely dissociated and counted from three weighed subsamples taken randomly within the ovaries.

Batch fecundity was estimated for 8 ripe females by estimating the number of hydrated oocytes; only ovaries which hydrated oocytes formed a well defined mode were used. Also, the numbers of yolked oocytes remaining in partially spent ovaries were determined for 24 females.

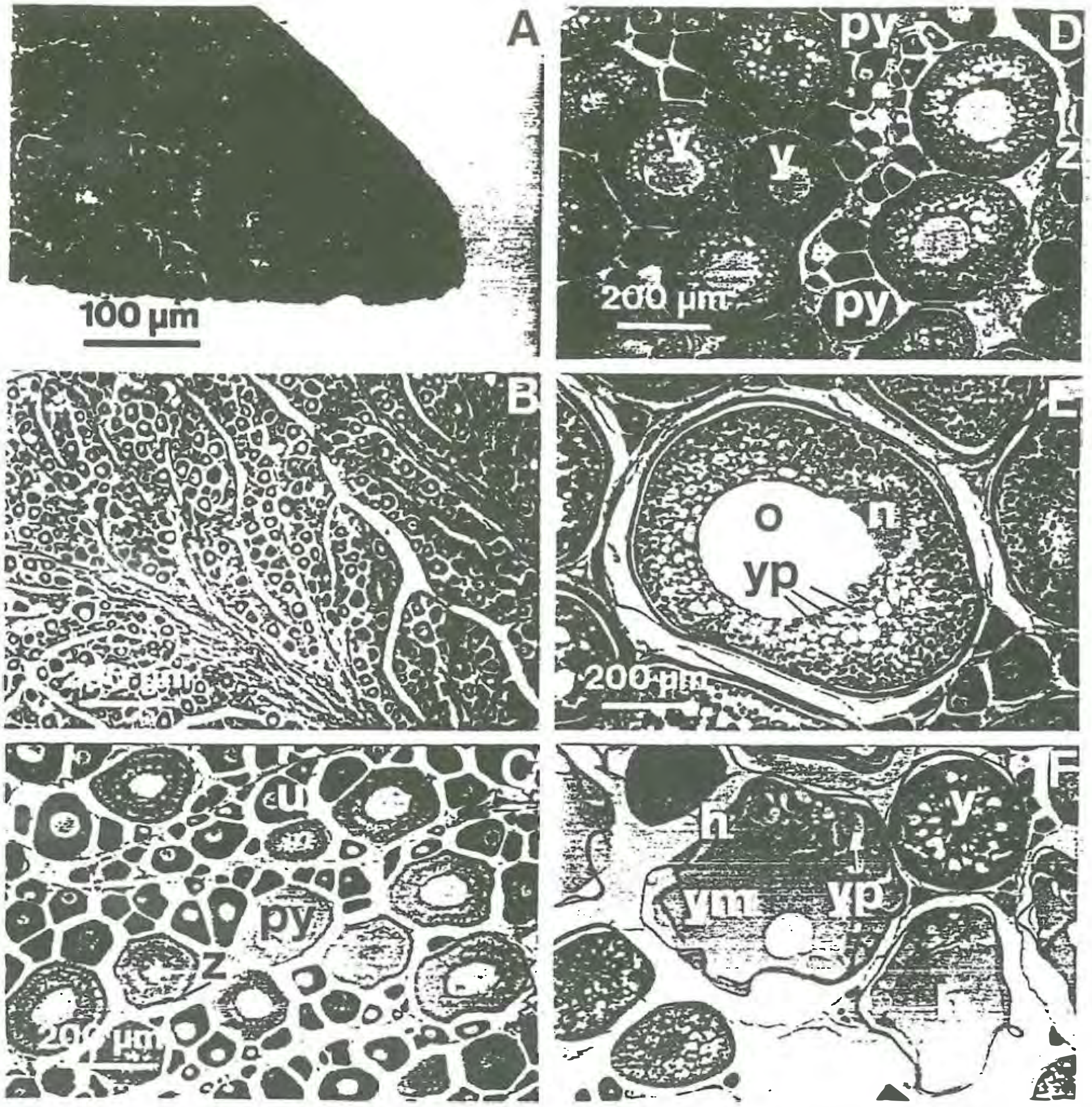


Fig.36. Histological sections showing ovary maturation stages. Photos A to F represent stages 1 to 6 successively. Photo D shows a 'stage early 4' characterised by the non-uniform size of yolked (y) oocytes. h = hydrating oocyte (irregular shape due to loss of fluid during histological processing), n = nucleus, o = oil droplet, py = partially yolked oocyte, u = unyolked oocyte, y = yolked oocyte, ym = yolk mass (fusion of yolk plates, yp = yolk plate, z = zona radiata).

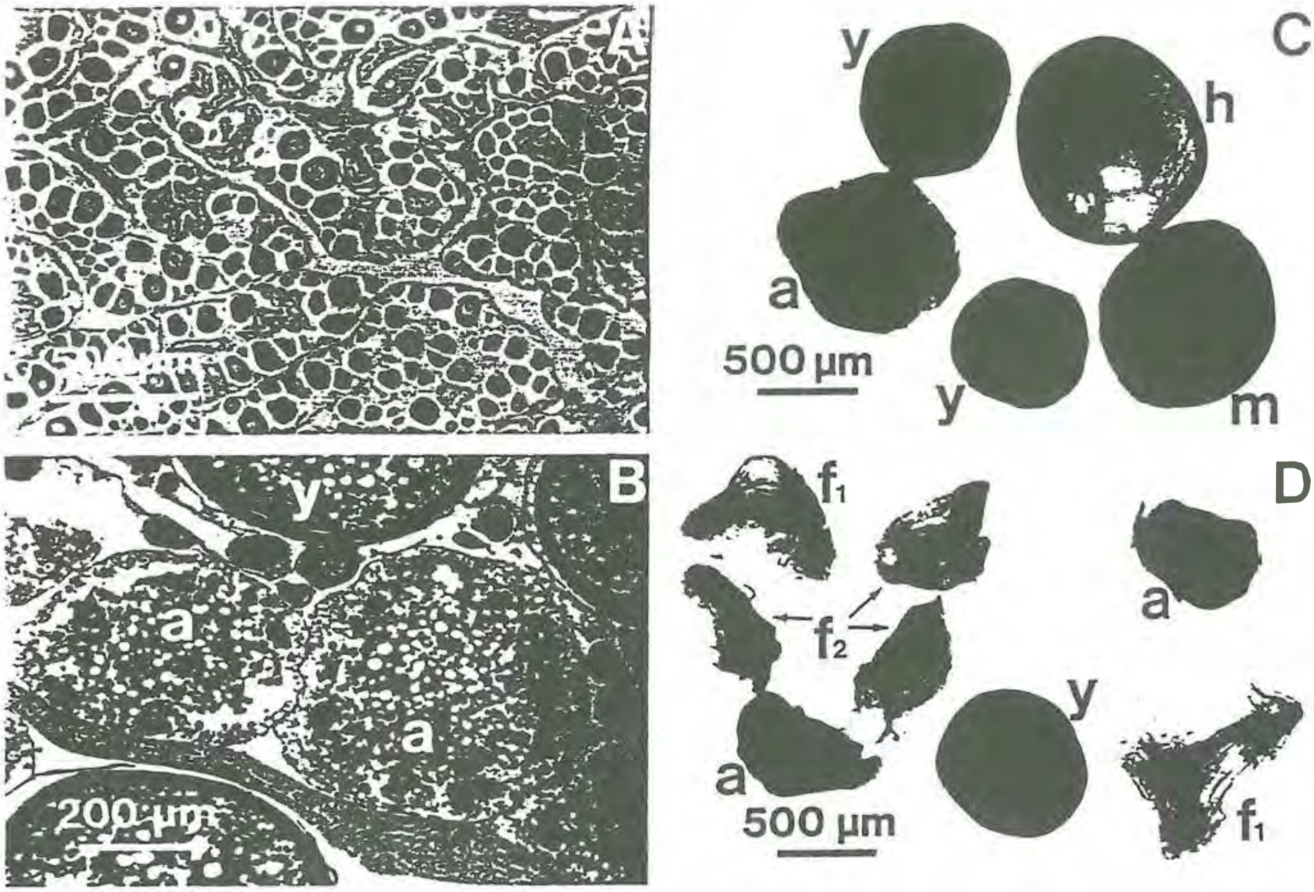


Fig.37 A: histological section of ovary at stage 7 showing type 2 post-ovulatory follicles. B: histological section showing two yolked oocytes at early stage (alpha) of atresia (a), y = healthy yolked oocyte. C and D are composed photos of whole preserved oocytes showing: stage 4 yolked oocyte (y), stage 5 oocyte (m) (yolked plates only faintly visible on this photo), hydrating oocyte (h) with oil droplet, post-ovulatory follicles of type 1 and 2 (f1 and f2) and yolked oocytes at early stage of atresia (a).

Results

Gonad maturation

Ovaries at stages 1 and 2 could not be accurately distinguished macroscopically and were grouped together in the analyses, as were stages 7 and 8. GSI values varied greatly within the maturity stages (Table 10) and could not be used to assess the development of ovaries. Macroscopic staging of the testes was more difficult than for the ovaries (Table 9). The main criterion used to assess male maturity development, based on presence/absence of milt, was not consistent. Milt was sometimes present in small, developing testes but absent in large testes.

Table 10. Range and median value of female gonado-somatic index (GSI) by stage of maturity. * indicates partially spent ovaries (presence of post-ovulatory follicles), N= sample size.

	Gonado-Somatic Index		
Stage	**Range**	**Median**	**N**
1+2	0.2 - 1.1	0.4	58
3	0.3 - 2.0	0.8	203
Early 4	1.6 - 12.0	4.7	19
4	3.3 - 19.5	10.3	92
4*	3.3 - 15.9	8.7	18
5	8.9 - 19.4	15.7	5
5*	5.1 - 14.8	9.8	6
6	20.6	-	1
7	1.6 - 3.8	2.5	8
8	0.7 - 2.5	1.4	66
Atretic	0.7 - 8.1	1.1	21

Histological examination of stage 4 ovaries led to the distinction within this stage of ovaries at early stage of yolk formation. These ovaries were characterised by a great variation in the size of oocytes (Fig. 36D) compared with the uniform size of fully yolked oocytes. They will be referred to as 'early stage 4' in the text. Also, partially spent ovaries (i.e. stage 4 or 5 ovaries containing post-ovulatory follicles and which were not identifiable macroscopically) will be referred to as stages 4* and 5*.

Spawning location and season

Mature fish of both sexes (stages 4 to 6 for females and stages 3 and 4 for males) were caught mostly off the north-east coast of Tasmania, at about 41^{O} S (Fig. 35), but a few were also occasionally caught in other areas. Off north-east Tasmania, and over the 20 month sampling period, mature fish were first caught in small numbers between October and December; then their abundance increased markedly between January and March (Fig. 38). Stage 4 females caught from October to December 1992 were at early stage of yolk formation (early stage 4) with a low GSI ranging from 1.6 to 2.3. GSI values then increased to a mean of 5.6 (with a standard deviation of ± 2.3) in January, 8.0 (± 2.9) in February, and 9.4 (± 2.7) in March, 1993. In both 1992 and 1993, ripe (stage 5) and partially spent (stages 4* and 5*) females were caught from early March to early May; females in post-spawning condition (stages 7 and 8) were caught from mid-March, their abundance being maximum in May and June (66.3% of the total 445 post-spawning females examined). Thus, maturation of ovaries spanned over several months, from October to February, followed by a two-month spawning period from early March to early May.

Size at maturity

The smallest mature fish observed during the present study were a 59 cm female and a 52 cm male. The estimated average sizes at maturity were 71.3 and 61.6 cm for females and males, respectively (Table 11 and Fig. 39). These sizes were very similar to those estimated from data collected in the mid 1950s (Table 11).

Table 11. Average size at maturity ($FL_{0.5}$) by sex, and 95% confidence limits. Data were fit to the logistic equation $p = e^{(a + bFL)} / (1 + e^{(a + bFL)})$. Results are shown for data collected during the current study and for data collected in the mid 1950s before the fishery developed (from Cowper and Downie's unpublished data).

	N	a	b	FL0.5	95% Conf. limits
Current data					
Females	1803	-29.86	0.419	71.3	70.7 - 71.9
Males	1613	-21.06	0.342	61.6	61.2 - 62.1
Cowper & Downie's data					
Females	813	-23.79	0.341	69.8	69.2 - 70.3
Males	498	-24.05	0.397	60.6	59.6 - 61.4

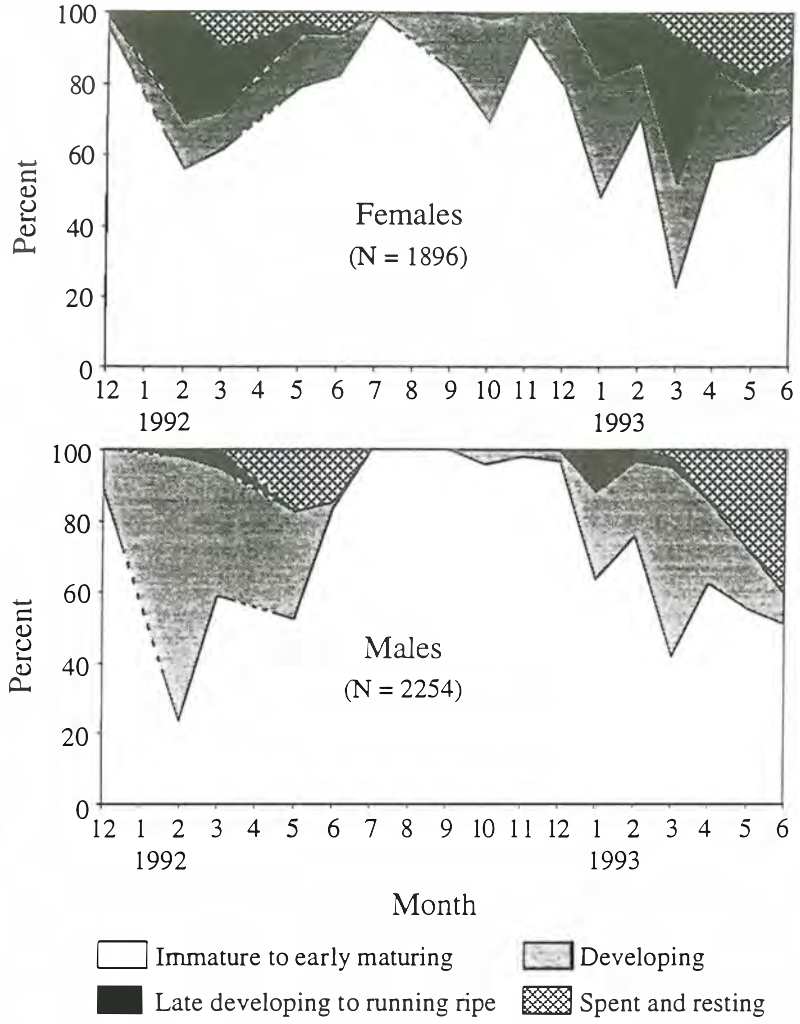


Fig. 38. Monthly proportions of maturity stages by sex. N= sample size.

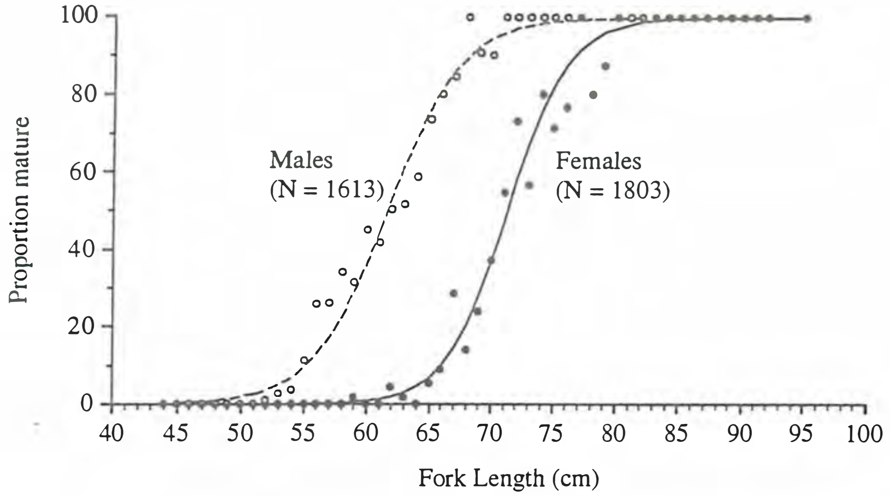


Fig. 39. Relative abundance of mature individuals (stages 4 to 6 for females, stages 3 and 4 for males) by 1 cm size intervals. Data were fit to the logistic equation p = e (a + bFL) / (1 + e (a + bFL)). Black dots for females, white dots for males, N= sample size.

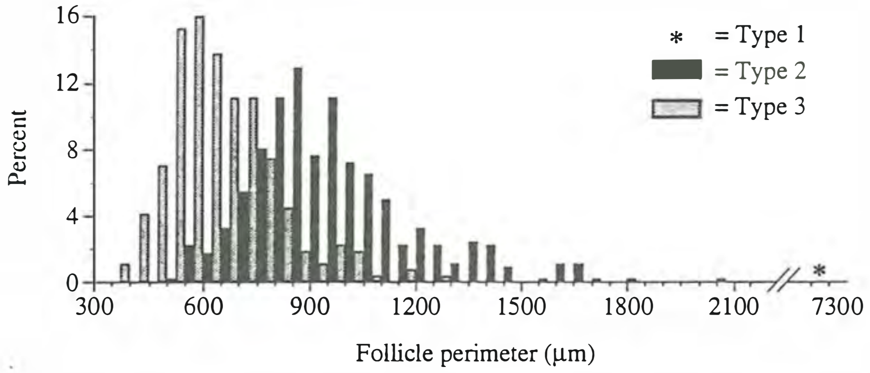


Fig. 40. Frequency distributions of the perimeter (microns) of types 2 and 3 post-ovulatory follicles (pooling of measurements from 16 ovaries). Only one post-ovulatory follicles of type 1 was measured (shown by asterisk).

Rate of Atresia

The rate of atresia for both unyolked and yolked oocytes was generally low (atretic oocytes represented between 1 and 10% of all oocytes when present). However, a few ovaries presented high level of atresia (about 90%) of their yolked oocytes. These atretic ovaries were of two types. The first type consisted of small ovaries with abundant white oocytes visible macroscopically within a translucent, pinkish mass of unyolked oocytes. Histological examination later revealed that the white oocytes were oocytes at an early stage of yolk formation which were undergoing atresia. This type of ovary was observed in May and June 1992 and 1993, and represented 64% of all yolked ovaries examined during these periods. It was always observed in pre-adult females at size below the average size at maturity (mean FL = 63.6 ± 3.2 cm).

Only two females presented the second type atretic ovaries; they had large ovaries (GSI of 6.9 and 8.1) with nearly all fully yolked oocytes at early stage of atresia. These atretic oocytes could not be detected macroscopically, but they were recognisable microscopically in preserved samples (Fig. 37C and 37D). The two females were caught during the spawning period in March 1993; they represented only 1.2% of all mature ovaries examined histologically.

Occurrence of post-ovulatory follicles

Post-ovulatory follicles occurred in 16.8% of all mature ovaries examined (N=167). They were never found in ovaries at early stage of yolk formation. Post-ovulatory follicles of type 1 were observed in 6 partially spent (stage 4*) ovaries during fecundity work, but only one could be found in histological sections and measured; it was much bigger than post-ovulatory follicles of types 2 and 3 (Fig. 40). Two types of post-ovulatory follicles were usually present in stage 4*, while only small and old post-ovulatory follicles (type 3) were found in hydrating ovaries (stage 5*).

Measurement of whole oocytes

As maturation progressed, a clear gap appeared between unyolked and yolked oocytes (Fig. 41a-d), showing that the fecundity of blue-eye trevalla is determinate. The recruitment of oocytes from the reserve of unyolked oocytes was completed when the average diameter of yolked oocytes reached about 650 µm (Fig. 41e). Unyolked oocytes present in these ovaries were at stage 2 with a diameter of less than 100 µm. The diameter of yolked oocytes then increased slightly to about 700 µm (Fig. 41g) before migration of the nucleus and hydration began (Fig. 41h-i). After a batch was spawned,

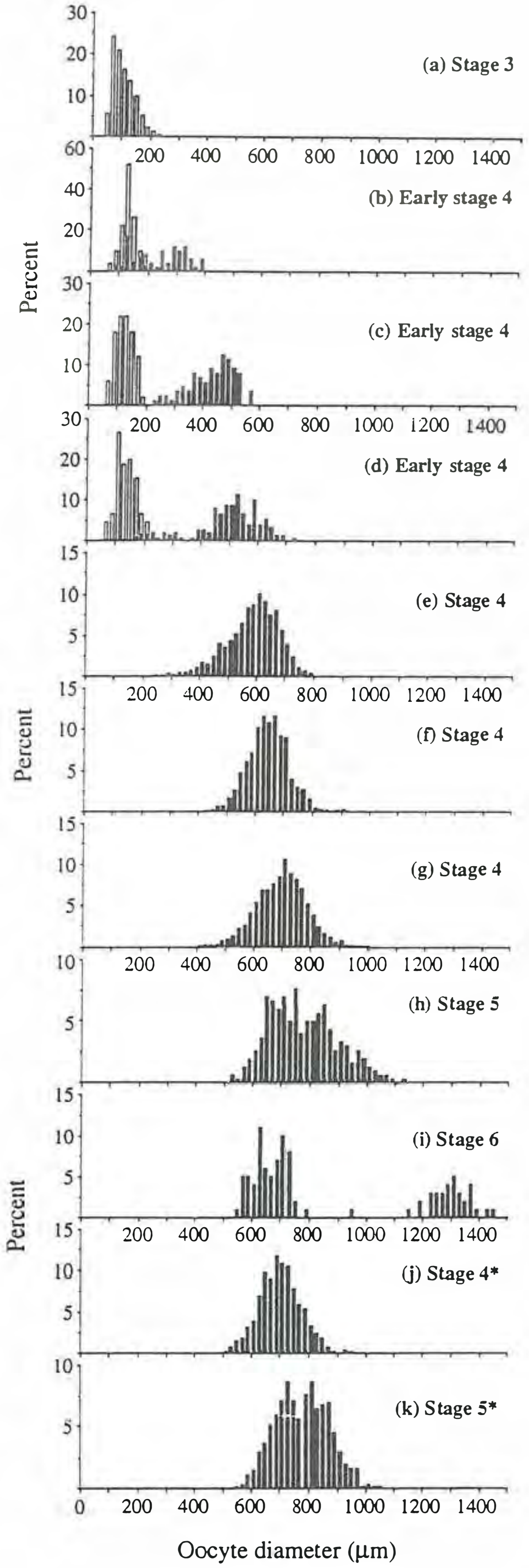


Fig. 41. Frequency distribution of oocyte diameter by stage of maturity (measurements from several ovaries pooled in each graph). White and black bars represent independent measurements of unyolked and yolked oocytes, respectively (unyolked oocytes were not measured in stage 4 ovaries from graph e). *= partially spent ovaries.

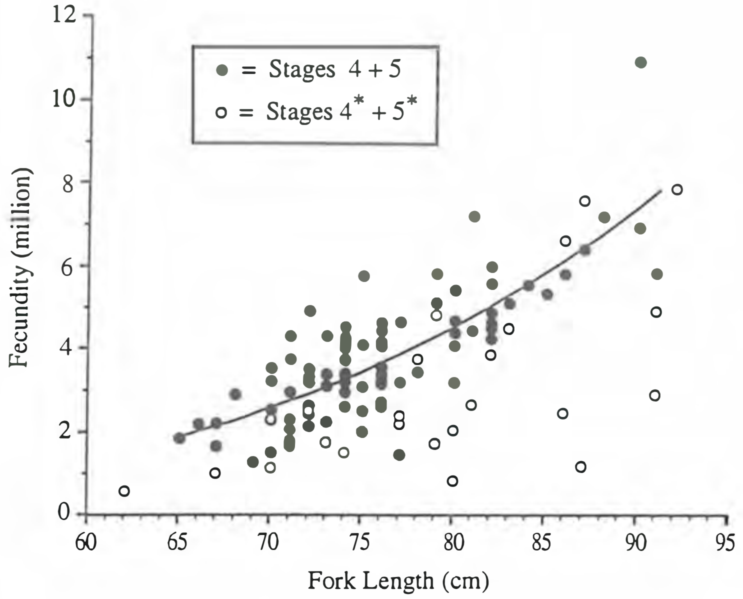


Fig. 42. Annual fecundity estimates (black dots) and power relationship between annual fecundity and size of females (line drawn from equation F = 0.42 x 10-7 x FL4.22). Fecundity estimated for partially spent ovaries are also shown (white dots), but were not included in regression analysis.

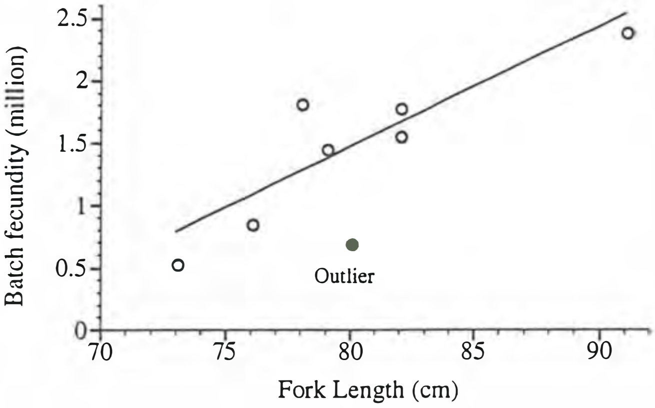


Fig. 43. Linear relationship between batch fecundity and size of females. Line drawn from the equation: Batch Fec.= 0.097 * FL - 6.28 (F=20.18, df=5, p<0.001, R2=0.80, R2 increased from 0.65 to 0.80 when outlier was excluded from regression).

formation of a new batch began from the remaining pool of yolked oocytes with migration of nucleus and hydration (Fig. 41j-k). The mean oocyte diameter of the stage 4 ovaries used to construct graphs e to g ranged from 500 to 770 μm (with an overall mean of 640 ± 60 μm, N=81). Hydrating oocytes observed during the present study were about 1.3 mm (Fig. 41i). The large size of the post-ovulatory follicle type 1 (Fig. 40) suggests that fully hydrated oocytes are even bigger at the time of spawning.

Fecundity

As the fecundity was found to be determinate, annual fecundity was estimated from the standing stock of yolked oocytes in stages 4 and 5 ovaries (Fig. 41e-h). Fecundity (F) ranged from 1.3 to 11.0 million and, although varying considerably at given length (Fig. 42), it showed a significant exponential increase with the length (FL) of females, following the equation:

$$F = 0.42 \times 10^{-7} \times FL^{4.22}$$

The linear regression between log-transformed data was statistically significant: F=110.59; df = 82; p<0.001, R^2 =0.57. Multiple regression analysis showed that the variation in average diameter of yolked oocytes between mature females (as illustrated in Fig. 41e-h) did not affect fecundity estimates (Table 12).

Batch fecundity estimated for ripe females ranged from 0.5 to 2.4 million (N=8), and also increased with length (Fig. 43). The number of yolked oocytes left in partially spent ovaries ranged from 0.6 to 7.9 million (Fig. 42), with a median value at 2.4 million (N=24).

Table 12. Multiple regression between log-transformed annual fecundity, fork-length (FL, cm) and mean oocyte diameter (micron). Sample size = 84.

Source	**Coefficient**	**Std Error**	**Std Coeff**	**t**	**p(2 tail)**
Constant	-3.942	2.263	0.000	-1.742	0.086
Log (FL)	4.059	0.437	0.736	9.291	0.000
Log (Oocyte diam.)	0.228	0.302	0.060	0.757	0.451

Spawning aggregation

The bulk of the commercial catch consisted of small (FL<55 cm), immature fish year round, the proportion of larger fish increasing during the breeding season (Fig. 44). The proportion of fish (both sexes) above 55 cm FL increased in catches from 31.1% during

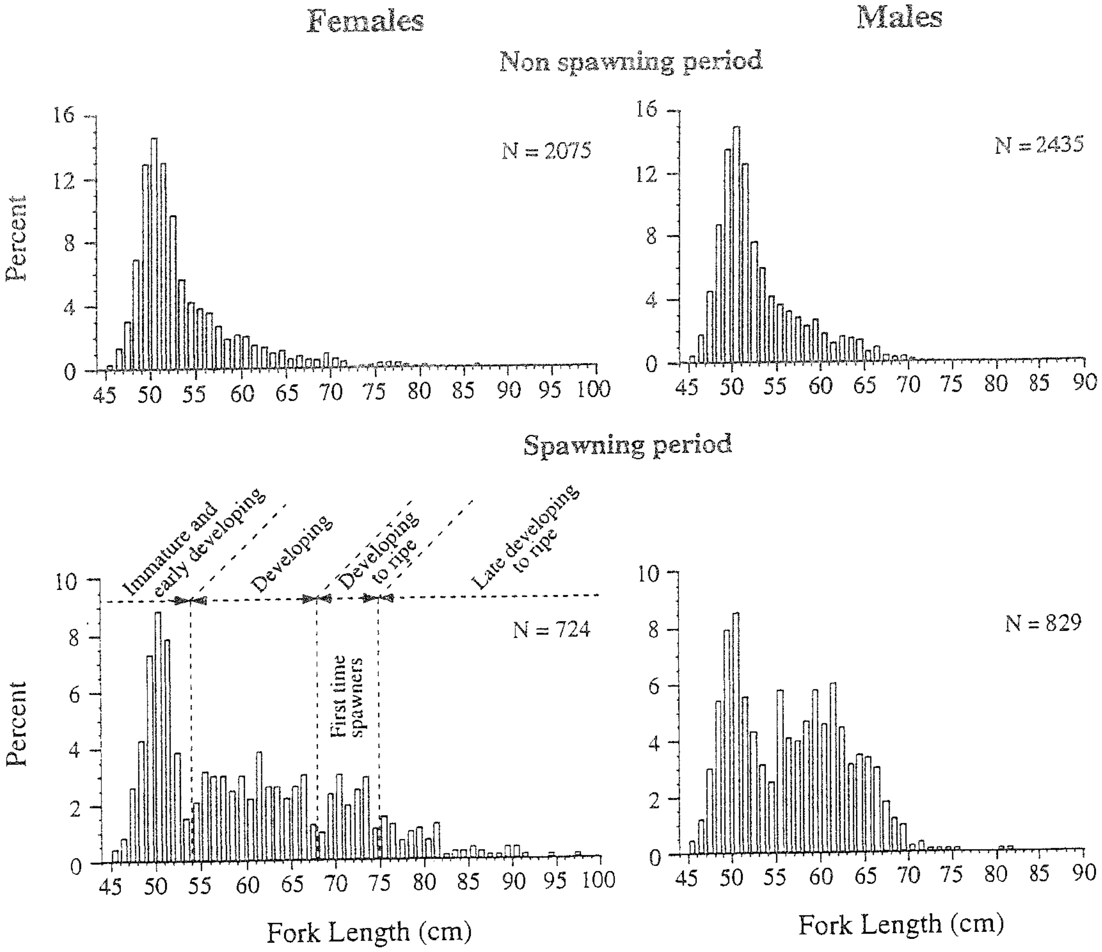


Fig. 44. Comparison by sex of frequency distributions between 'non spawning' (May to December) and 'spawning' (January to April) periods (years combined). For females, most common maturity status are indicated for different size groups (see text). N= sample size.

the 'non-spawning period' (May to December) to 61.3% during the 'spawning period' (January to April).

Analysis of size composition and sexual maturity data for females showed that, in addition to the group of immature individuals (FL<55 cm), three groups of fish could be broadly distinguished in commercial catches during the breeding season (Fig. 44): 1/ pre-adult females at size below the average size at maturity (55≤FL<69 cm), which were developing but unlikely to spawn during the current spawning period, 2/ females just reaching the size at maturity (69≤FL<75 cm) which would spawn for the first time during the current spawning period and which ranged from developing to ripe stages of maturity, and 3/ large females (FL≥75 cm) with already fully developed ovaries. Females in the first group were caught from November to May; females in the second group were more abundant between January and April, while large females in the third group occurred during the brief early March-early May spawning period and quickly disappeared from catches afterward (very few were caught in post-spawning condition). Females in group 1 were caught on all fishing grounds around Tasmania, while females in groups 2 and 3 were mainly caught off north-east Tasmania.
For males, several groups could also be distinguished (Fig. 44), although not as clearly as for females because of their generally more compact length frequency distributions.

Pre-adult females (55≤FL<69 cm) represented as much as 45.6% of all three groups defined above. Similarly, 31.5% of males above 55 cm FL had not reached the average size of sexual maturity. Also, first time spawners (i.e mature females at FL ≤ 75 cm and mature males at FL ≤ 65 cm) represented as much as 56.7 and 75.9% of all mature females and males, respectively.

Discussion

Ovary maturation, spawning frequency and fecundity

Maturation of ovaries appears to be synchronous for blue-eye trevalla, spanning from spring to summer (October-February), and followed by a brief spawning period in late summer-autumn (early March-early May). As observed for other fish species (Hunter and Macewicz, 1985b), the occurrence of atretic ovaries marks the end of spawning. The timing of spawning coincides well with the discovery in June 1991 and May 1993 of a few juvenile blue-eye trevalla amongst floating seaweed off the Tasmanian east coast (Last *et al.*, 1993). These juveniles ranged in size from about 30 to 60 mm standard length, and were estimated to be about 2.5 to 3 months old based on count of daily rings from otoliths (C. Proctor, CSIRO, Division of Fisheries, personal communication).

Blue-eye trevalla reach sexual maturity at a large size, and according to -yet unvalidated- age data (Central Ageing Facility Victoria, unpublished data), females are about 11-12 years old, and males about 8-9 years old, when reaching sexual maturity. The bulk of immature fish in commercial catches are about 3 to 4 years old. Analysis of data collected in the 1950s showed no changes in the size at maturity of blue-eye trevalla since the fishery began.

The fecundity of blue-eye trevalla is clearly determinate, with several batches of ripe oocytes being formed successively from a standing stock of yolked oocytes. Post-ovulatory follicles usually persist in fish ovaries for between 24 and 48 hours (Macewicz and Hunter, 1993; Oda *et al.*, 1993), and type 1 post-ovulatory follicles observed in the present study were probably no more than a few hours old. The co-occurrence in some ovaries of post-ovulatory follicles and ripe oocytes indicates that hydration and ovulation of successive batches is rapid, possibly taking place every 1 or 2 days. Also, comparison of annual and batch fecundities, combined with examination of post-ovulatory follicles, suggests that females spawn all their oocytes within a few days, in 3 or 4 large batches . These results support the view that fish at high latitude have a short breeding season and determinate fecundity with few but large batches (e.g. Langley, 1993), contrasting with protracted spawning seasons and numerous batches for species at lower latitude (e.g. Hunter and Golberg, 1980; Schaefer, 1987; Davis and West, 1993).

Annual fecundity of blue-eye trevalla is high and increases markedly with the size of females (to a maximum of 11 million). The rate of atresia in ovaries appears to be negligible and, in the present study, it did not affect fecundity estimates (although this would not necessarily be true for all spawning seasons). The fact that female blue-eye trevalla are partial spawners constitutes more of a problem when estimating fecundity, even more so since spawning batches are large. Partially spent females can not be identified macroscopically, and to avoid underestimating annual fecundity it is necessary to check microscopically for the presence of post-ovulatory follicles in every female before estimating the number of oocytes.

Composition and dynamics of the spawning aggregation

Fish in spawning condition were mostly caught off the north-east coast of Tasmania, suggesting that a major spawning ground lies near this area. However, the occasional occurrence of mature blue-eye trevalla on nearly all other Tasmanian fishing grounds, including an offshore seamount 120 miles south of Tasmania (data not included), and the presence of spawning aggregations off New South Wales (K. Rowling, personal communication) and South Australia (Jones, 1985), indicates that spawning takes place on several grounds within southern Australia. The fact that no genetic difference was found between blue-eye trevalla collected off New South Wales, Tasmania and South Australia (Bolch *et al.*, 1993) further supports the view of a widely distributed spawning activity. Horn and Massey (1989) also believed that blue-eye trevalla spawned on many grounds in New Zealand.

During his work on hoki spawning aggregations, Langley (1993) identified several spawning groups successively arriving and leaving the spawning ground. The situation is different for blue-eye trevalla, where the three groups identified for females within the summer aggregation correspond to progressive arrivals of different size (or age) groups, and not to commuting spawning groups. All spawners will spawn during a brief 2-month period at the end of summer. Older females join the aggregation just before spawning and leave shortly after; younger (first time spawners) females aggregate earlier and stay on the grounds for some time after spawning.

The presence of "non-spawning" fish (pre-adult at size below the average size at maturity) in the aggregation suggests that this summer aggregation off north-east Tasmania are related to both feeding and spawning behaviours. Blue-eye trevalla feed mainly on the pelagic tunicate *Pyrosoma atlanticum* (Winstanley, 1978), and Cowper (1960) noted a maximum incidence of *Pyrosoma* in the stomachs of blue-eye trevalla in summer. As observed for atlantic cod (Swain, 1993), it is possible that blue-eye trevalla off north-east Tasmania migrate between deeper wintering grounds and shallower feeding and spawning summer grounds. The occurrence of pre-adult fish on other Tasmanian fishing grounds during spring and summer indicates that feeding aggregations are not restricted to the north-east coast of Tasmanian. Winstanley (1979) also noted that blue-eye trevalla off Victoria probably move from deeper to shallower depths in spring.

The spawning population observed in catches was young, comprising a majority of first time spawners. It is not known whether the low proportion of older spawners (the third group identified in Fig. 10) reflects a lower vulnerability to fishing (due to age or size specific change in distribution and aggregating behaviour), or reflects a significant decline in abundance due to fishing. The fact that the major spawning aggregation off north-east Tasmania is well localised and has been fished regularly for more than two decades , along with the fact that the size of fish has decreased dramatically since the fishery began in the 1960s (see chapter 4), are cause for concern.

It is believed that there is one stock of blue-eye trevalla in southern Australia, and, as shown for other fish species with a wide geographic distribution (Schaefer, 1987; Bell *et al.*, 1992; Rijnsdorp, 1993; Clark *et al.*, 1994), size at maturity, spawning season and fecundity could vary significantly between areas. Differences in the time of spawning and size of spawners have already been observed between New South Wales and Tasmania (K. Rowling, personal communication). This study shows that before the spawning biomass of the stock can be estimated, research effort need to concentrate on determining the abundance of spawners; this implies localisation of spawning aggregations in southern Australia and better understanding of their structure in relation to migrations of fish between grounds.

CHAPTER 7: GROWTH, MORTALITY, YIELD- AND EGG-PER-RECRUIT

The parameters of the von Bertalanffy growth equations were:

Females:
$K = 0.07999 \pm 0.00029$ $L_\infty = 95.97 \pm 2.78$ $t_0 = -5.25 \pm 11.0$ $N = 1348$
Males:
$K = 0.07999 \pm 0.00046$ $L_\infty = 89.91 \pm 3.46$ $t_0 = -5.86 \pm 17.5$ $N = 1246$

There was no difference in the length-weight relationships between females and males and data were combined. The global length-weight relationship was estimated using log transformed whole (Wt) and gutted weight (Wg) data:

whole weight: $\mathrm{Log}(Wt) = 3.016 * \mathrm{Log}(FL) - 4.014$
(F=20231.7, df=851, $p<0.0001$, R2=96.0%)

gutted weight: $\mathrm{Log}(Wg) = 3.081 * \mathrm{Log}(FL) - 4.385$
(F=33353.6, df=1550, $p<0.0001$, R2=95.5%)

where FL is the fork-length in cm and weights are in grammes, df=degrees of freedom.

Yield-per-recruit (YPR) was expressed as a percentage of the maximum biomass (Bmax) attained by a cohort and calculated using parameters of the von Bertalanffy growth equation and of the length-weight relationship. The biomass of a cohort at age t (year) was:

$$B_t = N_t * W_t \qquad (1)$$

where the number of fish at age t (Nt) was calculated as:

$$N_t = N_{t-1} * e^{-(F*q_{t-1} + M)} \qquad (2)$$

Bmax was determined as the maximum value of B_t. Then, the YPR was calculated as

$$YPR = 1 / Bmax * 100 * \sum_{t_r}^{t_y} (F * q_t / F * q_t + M) * N_t * W_t * (1 - e^{-(F*qt+M)}) \qquad (3)$$

where tr was the age at recruitment to the fishery, ty was the longevity, F and M were fishing and natural mortality rates, respectively, Wt was the gutted weight at age t. The size-specific selection coefficient (q) was calculated as the proportion (p) of each length class that was recruited to the fishery using a selection ogive fitted to the ascendant limb of the length frequency distribution:

$$p = e^{(a+bx)} / (1 + e^{(a+bx)}) \qquad (4)$$

where x is the length class, and where parameters a and b were estimated at a= -55.22 and b=1.14 (see Table 6, sexes were combined because there was very little difference in these parameters between sexes).

The egg-per-recruit (EPR) analysis was made to examine the proportion of the egg production that remained after fishing, relative to that of the unfished stock (i. e. when fishing mortality F=0). The additional parameters needed for EPR analysis were the parameters a and b of the length-fecundity power relationship ($Fec=a\ FL^{b}$), and the parameters a and b of the length-maturation logistic regression (these parameters were estimated in chapter 6).

To obtain a rough estimate of natural mortality M, age-length keys obtained from otoliths were applied to length data collected prior to the start of the fishery, in the mid-1950s. Estimates of mortality rates are shown in Fig. 45 (note the differences in age ranges between the data sets). Little confidence should be given to these estimates because applying current growth parameters to historical data is not recommended (Kimura 1977), and also because of the suspected size/age specific changes in vulnerability to fishing.

Yield and egg-per-recruit analyses were run for increasing values of fishing mortality F and size at first capture, and for 5 pre-set values of natural mortality M (Fig. 46). Assuming a natural mortality of about 0.2 $year^{-1}$, and even though fishing mortality F is very much uncertain, it seems that the maximum yield is currently obtained from the stock with a size at first capture at about 50 cm FL. There is little scope for increasing yield by increasing fishing mortality or changing the size at first capture. Further, the egg-per-recruit appears to be very low, between 10 and 20% for a fishing mortality around 0.2 $year^{-1}$. This is probably a result of the large gap between the size at first capture and the average size at maturity (72 and 62 cm FL for females and males, respectively, see Chapter 6).

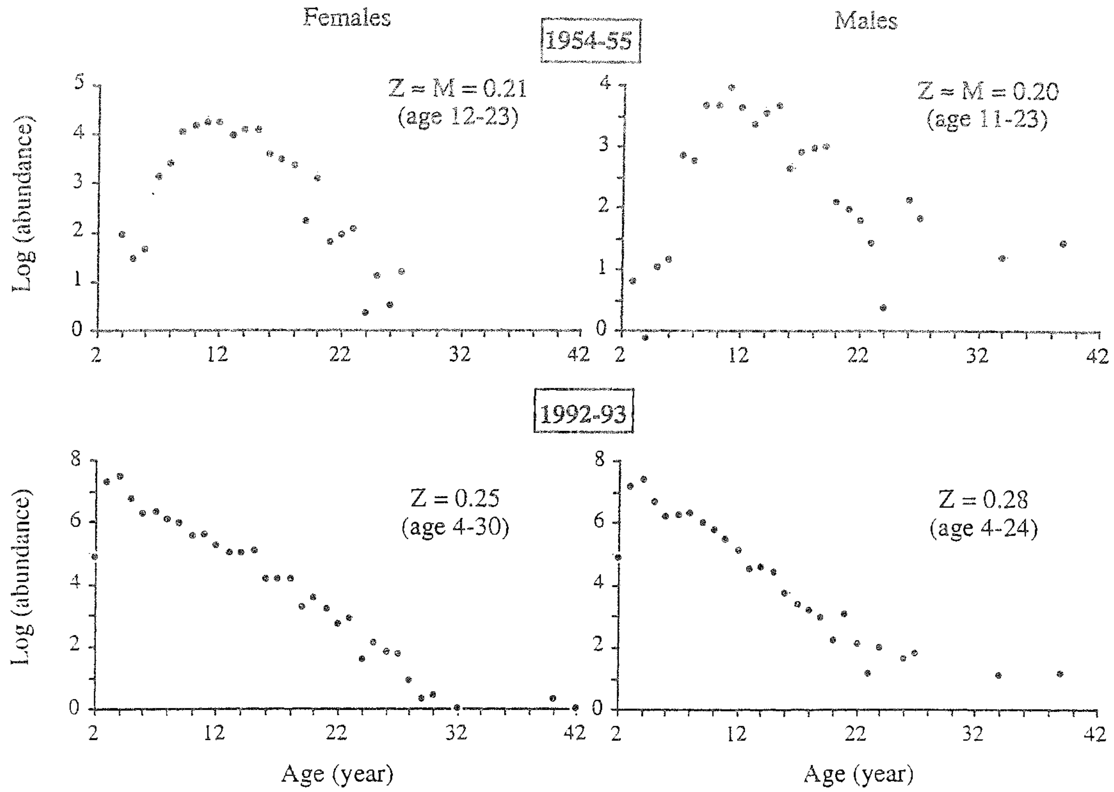


Fig. 45: Estimates of mortality rates applying the age-length key established by the Central Ageing Facility, Victoria, to historical (1954-55) and current (1992-93) length frequency distributions (note: age 19 years for females in 1954-55 data set not included in estimation of mortality because of low sample size).

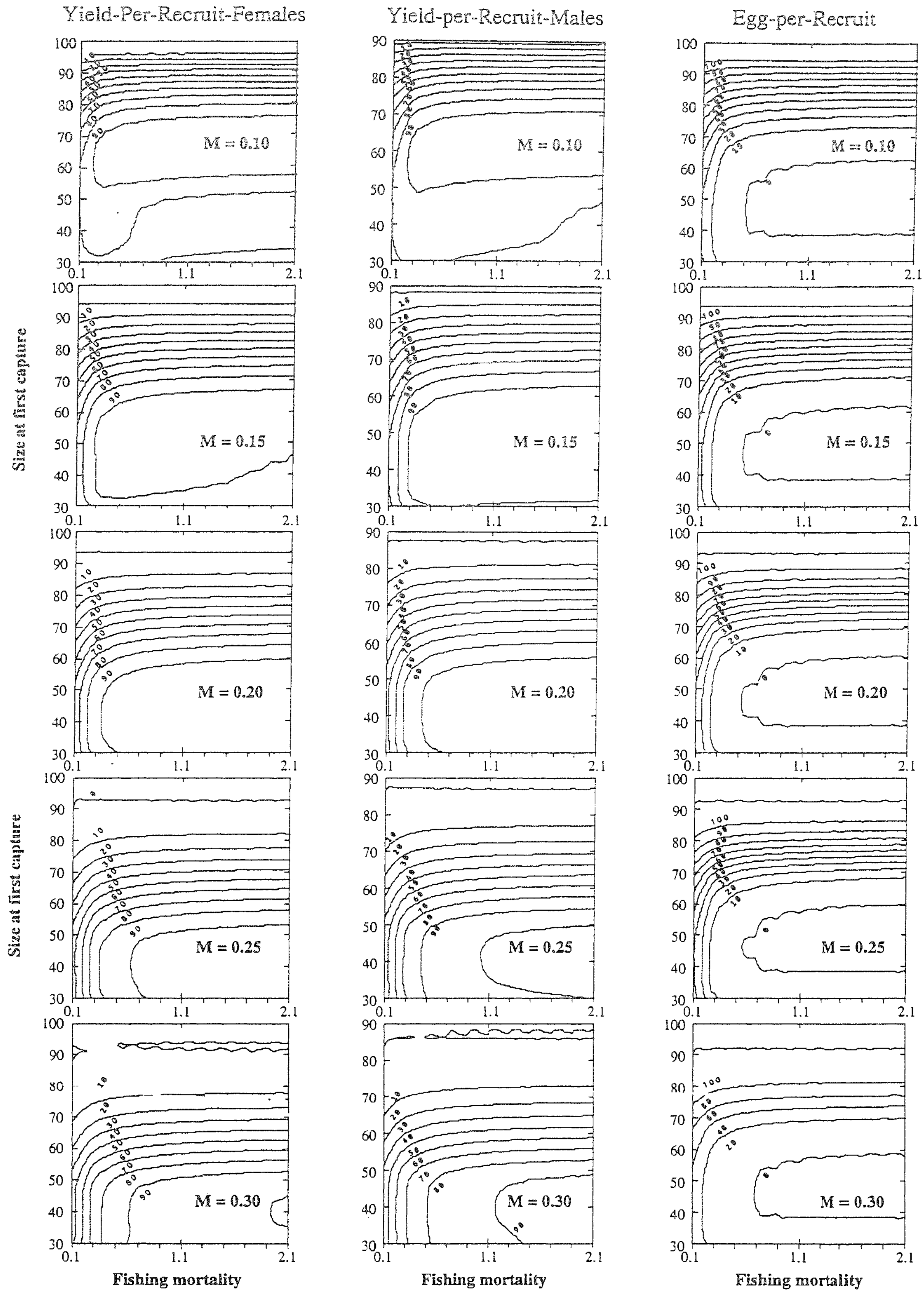


Fig. 46: Results of yield- and egg-per-recruit analyses run for 5 different value of natural mortality M. F= fishing mortality.

CHAPTER 8: CONCLUSIONS AND RESEARCH NEEDS

To date, the drop-line fishery is still unregulated, and catch and effort have regularly increased over time as more fishers have entered the fishery and exploited new grounds. As is usually the case during the development of a fishery, annual catch rates were high when the fishery first started, and then decreased significantly. However, at the same time as the annual cpue decreased, the frequency distribution of cpue became skewed to the right and the size of the fish declined markedly. This was related to changes in fishing practices over the years, as a response to change in fish abundance and/or vulnerability to fishing.

After the abundance /vulnerability of large fish initially targeted in deep waters declined, fishers began targeting dense schools of small fish in more open waters (and at shallower depths). This was facilitated by the introduction of colour echo-sounders and GPS. By targeting patchy, but dense schools, fishers have globally maintained, or even increased, catch rates, as illustrated by the increase in annual cpue observed since the late-1980s (also due to exploitation of new grounds off south-west Tasmania). The blue-eye trevalla drop-line fishery is a good example of how an increase in annual cpue reflects changes in fishing practices rather than increase in fish abundance.

The localised depletions of large fish that have occurred in the early years of the fishery, were always observed very shortly after exploitation started on new grounds. This probably related to the more dispersed distribution and lower vulnerability to fishing of larger fish, especially as their abundance declined. Such localised depletions have not been recorded since the fishery began targeting small fish. As fishers become more able to locate and target concentrations of fish, global cpue is unlikely to reflect changes in abundance of these smaller fish because of their schooling behaviour. Similar situations have been described in other fisheries (Crecco and Overholtz 1990, Rose and Leggett 1990, Swain and Wade 1993).

Acoustic surveys of blue-eye schools have proved difficult in New Zealand (Horn and Massey 1989) as is often the case for (semi)-demersal species (Karp and Walters 1994). Also, previous attempts made to relate catch rate of lines to that of trawls for other species (Hovgard and Riget 1990, 1992) have not been very convincing. The suspected small size of the resource off southern Australia will probably never warrant expensive and difficult echo-sounding and sampling surveys over hard bottom to estimate the biomass of the stock.

To apply stock assessment techniques based on abundance indices and catch composition, it is first necessary to better understand the structure of the population. The dramatic decrease in the size of blue-eye trevalla since the fishery began is of great concern for the sustainability of the stock. It appears that the drop-line fishery has already had a significant impact on the stock. With hook fishing, fishers' interest is in catching large fish on each hook, and the reasons (economical and/or biological?) for the disappearance of large adults in catches need to be elucidated.

Fishery independent analysis of the population structure is required to better understand size/age specific distribution patterns (including analysis of migrations, or lack of) in southern Australia, identify spawning areas and estimate the size of the spawning population. Also, age estimates need to be validated, perhaps using the pre- and post-bomb radiocarbon method developed by Kalish (1993).

This study showed that in-depth analysis of the interactions between biological and fisheries data, and particularly analysis of cpue frequency distributions and fishing practices, were key elements in assessing the status of the blue-eye trevalla stock.

PART 2

THE FISHERY FOR BLUE-EYE TREVALLA IN VICTORIA, 1987-1994

(S. Morison, D. Carter)

Introduction

Off Victoria, blue-eye trevalla are currently caught by three different methods: line, mesh, and trawl. Production of blue-eye off Victoria ranged between 0 and 6.7 tonnes between 1964/65 and 1973/74 using a variety of methods including mesh nets and Danish seine (Winstanley 1979). Exploratory drop-lining, which was undertaken in the early 70's in response to restrictions imposed in August 1972 on the sale of school shark, identified blue-eye trevalla as a potential new resource for operators in the existing Victorian rock lobster and shark fisheries (Winstanley 1979). The commercial catch rose to approximately 100 tonnes by 1984/85 and has become a significant component in these diversified fisheries. Williams (1993) provides a recent overview of the blue-eye trevalla fishery across southern Australia, concentrating on the catches by demersal otter trawl.

This report collates the available information for the Victorian fishery for blue-eye trevalla for the period seven year period 1987-1994. It concentrates on the drop-line fishery, which is the main method by which blue-eye trevalla are caught, but also presents catch data for all methods. To place the blue-eye trevalla fishery in a local context, a profile is provided of the fishing activities of blue-eye trevalla fishers over the period 1990-1992. The relative effort for, and catch and value from, each fishing method they used is detailed.

Methods

Data were obtained from the Victorian catch and effort system detailing the monthly catch by species for all drop-line caught fish and the number of days spent drop lining each month by fishers participating in the fishery. These data were extracted for the seven year period 1987-1993 and summarised by month. This database included fishers using line methods in inshore waters to target snapper, and such shots were excluded from the analysis. Careful scrutiny of individual catch returns was also required to calculate total effort, as multiple methods were often employed on the one day. At the time of this analysis, there were some fishing returns outstanding and annual totals for the detailed analysis are incomplete. Data were also collected detailing all Victorian landings of blue-eye trevalla by all methods other than trawl. These analyses, based on total annual catches, were completed later and include all returns.

A number of fishers who target and catch blue-eye trevalla by drop-line or mesh net were chosen and their fishing practices were examined in detail over a three year period (1990-1992). This allowed the estimation of the relative importance of both the drop-line and mesh net fisheries for blue-eye trevalla, to fishers who participate in more than one fishery. Time allocated to different fishing methods was totalled and the relative value of the catch obtained was calculated using average market prices for each species in each year. These prices were obtained from the Melbourne Fish Market. The prices per kilogram for each species which were used in the calculation of these values are detailed in Table 1.

Length frequency data were collected from commercial drop-line, trawl and mesh net catches of blue-eye trevalla from January 1992 to June 1994 at both Portland and Lakes Entrance. These length frequencies were adjusted by the ratio of the weight of total catch to the weight of the sample measured, and summed across vessels. Mean lengths were calculated from the weighted frequencies.

Results

Fishing practices

Blue-eye trevalla in Victoria are predominantly caught by either drop-line or mesh nets. Drop-lines employed by Victorian fishermen are essentially the same as those employed in Tasmania, as described elsewhere in this report, except that floating line baskets are not frequently used. Tuna circle hooks are used and are baited with squid. Mesh nets used to catch blue-eye trevalla are of a variety of mesh sizes and construction, They may be either the typical 150 mm mesh nets employed in the shark fishery, or more recently, nets modified to be used at deeper depths and specifically target blue-eye trevalla. There are no purpose built drop-liners operating in Victoria. Vessels are usually less than 20m in length. Lines are retrieved by hydraulic line haulers which are also used as pot haulers on vessels which also operate in the rock lobster fisheries.

In Victoria, fishers who use droplines are usually licensed to be engaged in other fisheries, particularly, the rock lobster and southern shark fisheries. The fishery began as a by-catch to hook fishing for shark. In 1994 there was only one fisher in Victoria who exclusively targeted blue-eye trevalla and the fishery is therefore of a sporadic nature. Drop-liners may switch to rock lobster fishing completely when the season is open or they may continue to operate both gear types, even on the same day. Mesh netters will vary the target species depending on availability and price of different species: warehous, ling or sharks may be targeted at different times. Mussel diving, tuna long-lining, scallop dredging, trolling and hand-lining, have all been used by fishers who have also caught significant quantities of blue-eye trevalla.

Catch statistics

The combined catch of blue-eye trevalla by all gears except otter trawl has varied between 77 and 170 tonnes during the period 1987 to 1994 (Table 2, Figure 1). Data for mesh nets includes Tasmanian returns (after 1990) because these vessels usually operated out of Lakes Entrance. Overall, drop-lines and mesh nets take approximately equal shares of the catch and only a small proportion are caught by long-line. The catch by otter trawl in the South East Fishery for the Eastern B (east Bass Strait) and Western (west Bass Strait) Zones combined (Figure 2) is smaller than the combined catch from the other components of the fishery, and fluctuated between 23 and 35 tonnes following a peak of 72 tonnes in 1988.

The drop-line fishery for blue-eye trevalla

The drop-line fishery operates around the Victorian coast with fishers primarily based in Lakes Entrance in the east, and Portland and Port Fairy in the west.

There are 43 vessels with endorsements to drop-line, but only between eight and fifteen of these participated in the fishery in any one year (Table 3). Together, these vessels applied an average of 169 days of fishing effort per year (range 103 to 208 days) each year between 1987 and 1993. (Table 3). Over the three year period between 1990 and 1992 the most consistent drop-line fishers spent an average of 26 days per year drop-lining each (range 2 to 46 days) out of an average of 102 days spent fishing (range 14 to 195 days) by all methods.

Blue-eye trevalla is the primary target species, making up an average of 85% of total landings (by weight) for the fishery (Table 4). Other species targeted include hapuka and ling which are caught mainly off Lakes Entrance during spring. Table 4. shows the total drop-line landings by species for 1987-1993 (species included had a total greater than 500 kg for at least one of the years examined). The quantities of some other species caught varied substantially from year to year (Figure 5). The catch of hapuka remained relatively constant, but a large increase in the catch of ling in 1992 especially, reflects increased targeting. Catches of oilfish and tuna have declined.

Annual total catch has increased since 1987, and annual average catch rate has increased since 1988 (but has stabilised recently); but total effort has not risen since 1988 (Figure 3).

Monthly catch and effort between 1987 and 1993 were variable within and between years (Figure 4), although, overall, they were highest between September and January and lowest in winter (July to August). There is a significant positive correlation between the average monthly catch and the effort applied in that month ($R=0.80$, $P<0.01$), whereas monthly catch rates show no annual trend, indicating that the higher catches in some months are associated with increased effort.

Although fishers only spent approximately 25% of fishing time drop-lining, the average value of the drop line catch was approximately 45% of the total catch value from all methods combined (Figure 6). Drop-line fishing consistently returned a higher yield for the proportion of effort expended over the period 1990-92 for the fishers examined (Figure 6). Blue-eye trevalla accounted for an average of 87% (range 76% - 92%) of the value of all drop-line caught fish.

The mesh net fishery

The mesh net fishery is primarily based at Lakes entrance. Blue-eye trevalla is not the major target species but, in recent years, more heavily weighted nets which are fished deeper, have been used to target them. Catches of 11 tonnes in a month have been reported using this method. Despite this, the catch of blue-eye trevalla by mesh nets was lower in the early 90s than in the late 80s (Table 2).

In most years about four fishers regularly catch blue-eye trevalla with mesh nets of a range of types. Unlike fishers in the drop-line fishery, these fishers were almost exclusively engaged in netting operations. Between 1990 and 1992, they spent an average of 93% of their time (range 89% to 95%) engaged in mesh netting operations (Figure 7). This effort returned an average of 98% of the value of their catch (range 95% to 99%) by all methods (Figure 7). However, blue-eye trevalla contributed an average of only 6% to this total (range 3% to 10%).

Size composition of the catch

Blue-eye trevalla measured in Victorian ports between 1991 and 1994 ranged from 43 cm to 111 cm caudal fork length (LCF). The mean sizes of fish landed in eastern Victoria by any method were bigger than those landed in western Victoria, due to a greater representation of fish in the 60-70 cm size range (Figure 8). In both eastern and western Victoria the mean size of fish caught by drop-line was slightly bigger than those caught by otter trawl (Figure 8). The mean size of mesh net caught fish in eastern Victoria was similar to drop-line and trawl caught fish. The length-frequency distributions for all three methods in eastern Victoria are very similar, showing two distinct modes at about 50 cm and 60 cm. Likewise, the catches by drop-line and otter trawl in western Victoria are more similar to each other than to the catches by the same gear in eastern Victoria.

The mean size and distribution of the drop-line catch from eastern Victoria varied between 1992 and 1994 (Figure 9) although sample sizes are not large in each year. There is a greater proportion of fish over 55 cm LCF than in western Victorian drop-line catch, particularly in 1993 and 1994. The drop-line catch from western Victoria (1992-94) was predominantly of fish between 45 cm and 70 cm (Figure 9), and showed a decline in mean length over this period.

Fish measured from the otter trawl catch in western Victoria between 1991 and 1993 were mostly less than 55 cm, but in 1994 the mean size and size distribution of fish landed (Figure 10) were similar to those from the drop-line fishery in that year (Figure 9).

To investigate seasonal trends in the size distribution within areas, the samples were pooled across years and capture methods (Figure 11). In eastern Victoria, there is seldom one mode in the distribution, but there is a greater proportion of fish less than 60 cm LCF, and the mean is lowest, in the July to September period. Fish over 75 cm LCF were only caught between January and June, and the mean length was highest in the April-June period. By contrast, in western Victoria, the mean size is lowest in the April-June period. Fish over 75 cm were caught throughout the year, but there is a greater proportion of fish over 60 cm between October and March than between April and September.

Discussion

The fishery for blue-eye trevalla in Victoria is a multi-method fishery which interacts with other components of the diversified fishery off southern Australia. The fishery provides a significant proportion of the income of some fishers, particularly those using drop-lines. For such fishers it provides an income which complements that obtained from other seasonal fisheries such as the rock lobster and shark line fisheries. For mesh-netters it is of less significance, but may become more important if catches of other target species such as the warehous or sharks decline. Efforts to develop techniques to specifically target blue-eye trevalla with mesh-nets have taken place and a much larger effort could be directed at blue-eye trevalla with this gear in the future.

Catch statistics suggest a rising interest in the drop-line fishery which can land a product of high value. However, increased reporting of drop-line catches, in response to changed management arrangements, may be partly responsible for the increased landings recorded. Involvement in the fishery has fluctuated with few fishers participating on a long-term basis. Effort may change rapidly depending on developments in other fisheries.

Trawl caught fish are on average slightly smaller than drop-line caught fish from the same area, but the differences are smaller than those observed between areas. The similarity in the size distributions of fish caught by different gear types in the one area, suggests that gear selectivity is less important than other factors in determining the shapes of these distributions. Furthermore, the consistent differences in the size of fish caught in eastern and western Victoria indicate some size structuring in the populations of blue-eye trevalla across Bass Strait.

There is an indication of a decline in the mean length of fish caught by otter trawl in western Victoria since 1992, but no similar indication in eastern Victoria. Also, the size distributions of fish landed in both eastern and western Victoria show a greater proportion of smaller fish than that reported by Jones (1985) from a drop-line survey in South Australian waters in 1983 and 1984. Webb (1979) has previously reported a similar decline in the size of fish caught by drop-line off Tasmania.

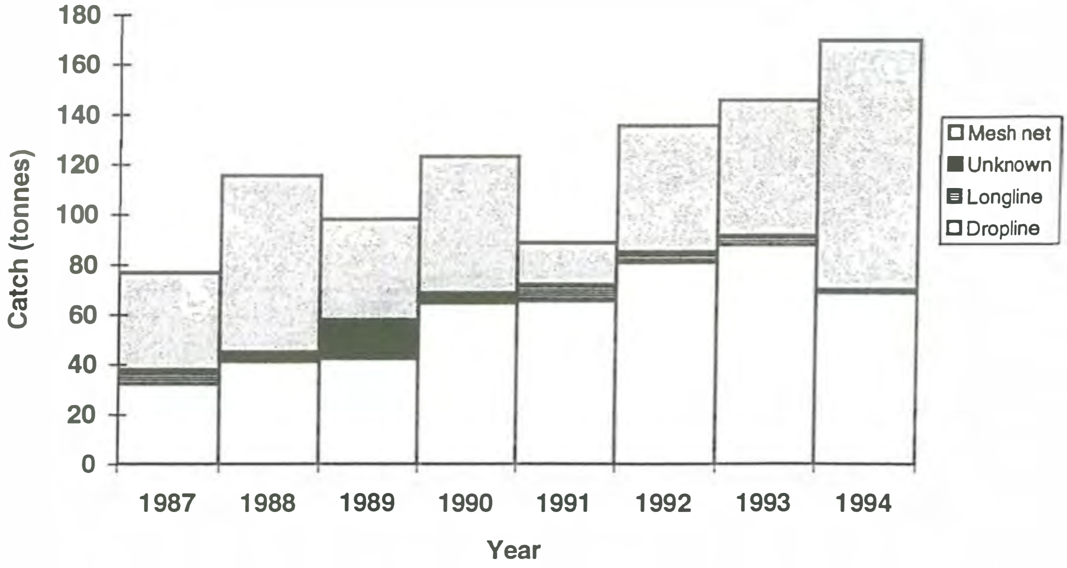


Figure 1. Annual catch of blue-eye trevalla by commercial fishers operating out of Victorian ports, by gear (otter trawl excluded) 1987-94. Mesh net data includes Victorian (1987-94) and Tasmanian (1990-94) returns.

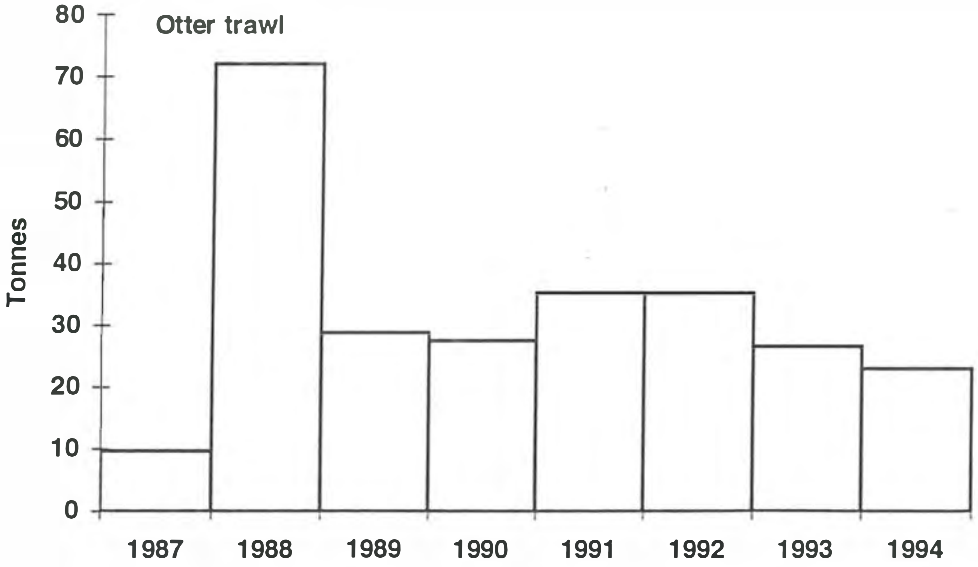


Figure 2. Annual total catches of blue-eye trevalla, by otter trawl in the South East Fishery Eastern Bass Strait and Western Bass Strait (zones 20 and 50) combined. 1987-94.

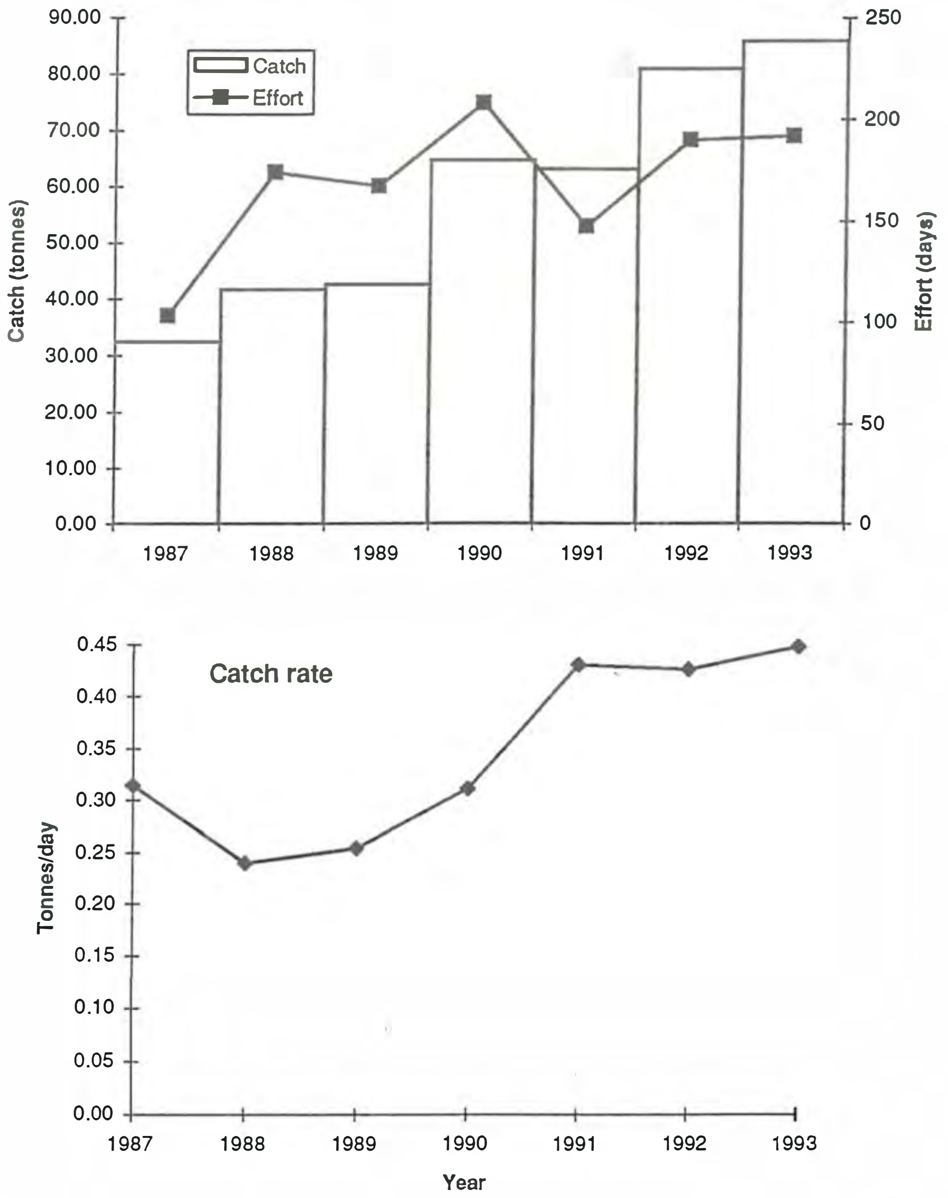


Fig 3. Catch (tonnes), effort (days fished) and catch rate (tonnes per day) for blue-eye trevalla caught by drop line in Victoria, 1987-93.

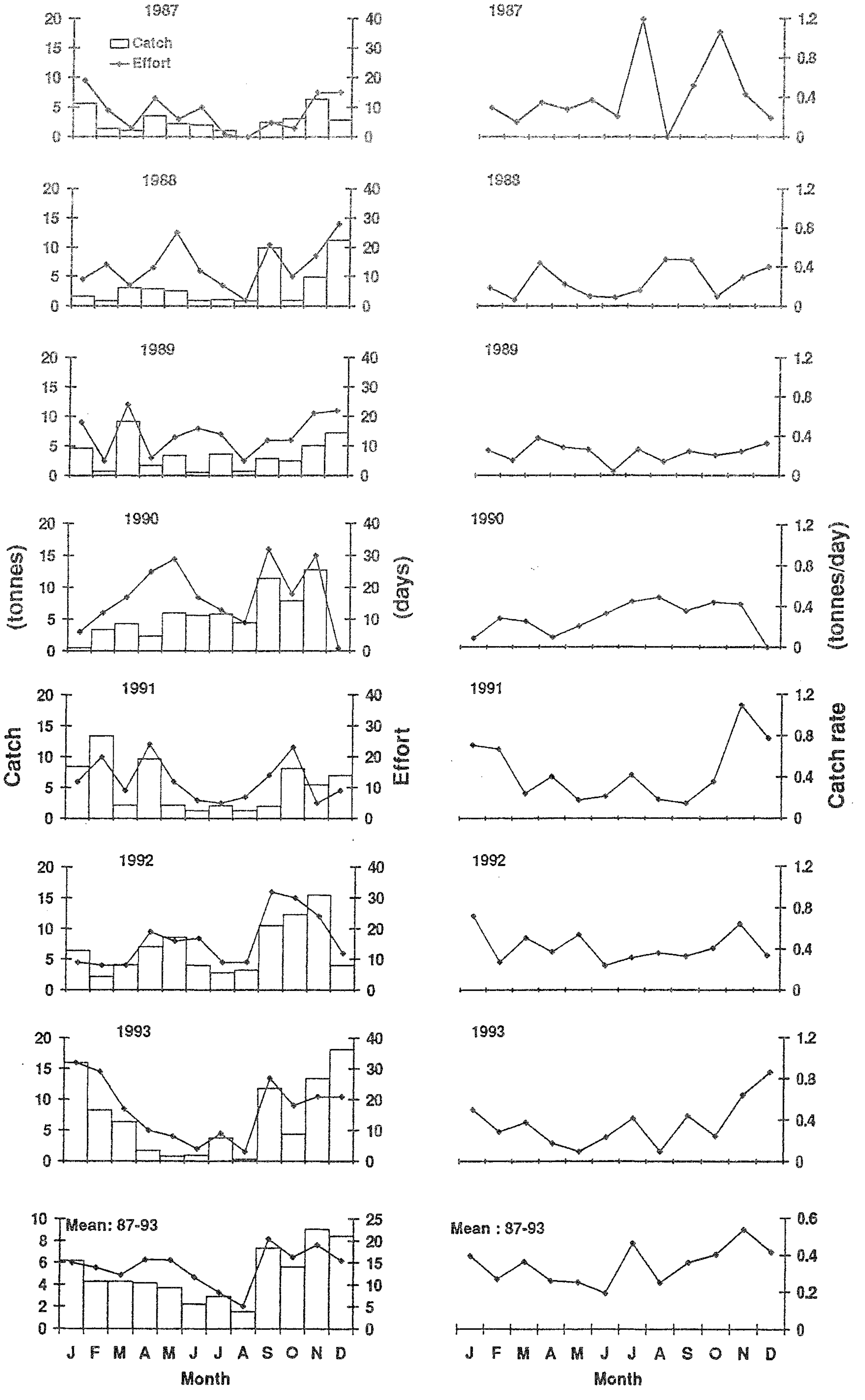


Figure 4. Catch (tonnes), effort (days) and catch rate (tonnes per day, line) by month for Victorian landings of blue eye trevalla caught by dropline, and monthly mean (1987-1993).

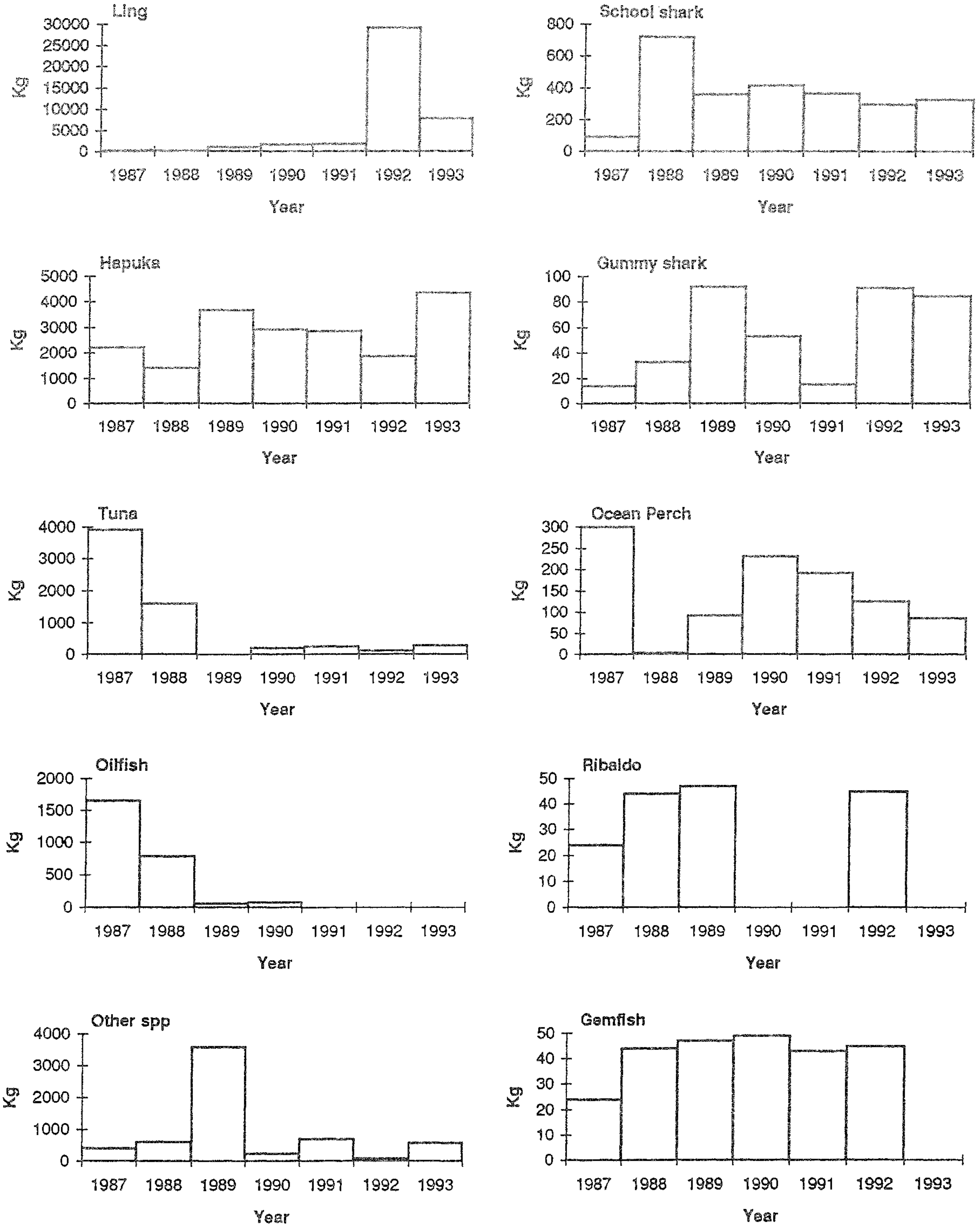


Figure 5. Catch by dropline of species other than blue eye trevalla, 1987-93. Note differences in scales between species.

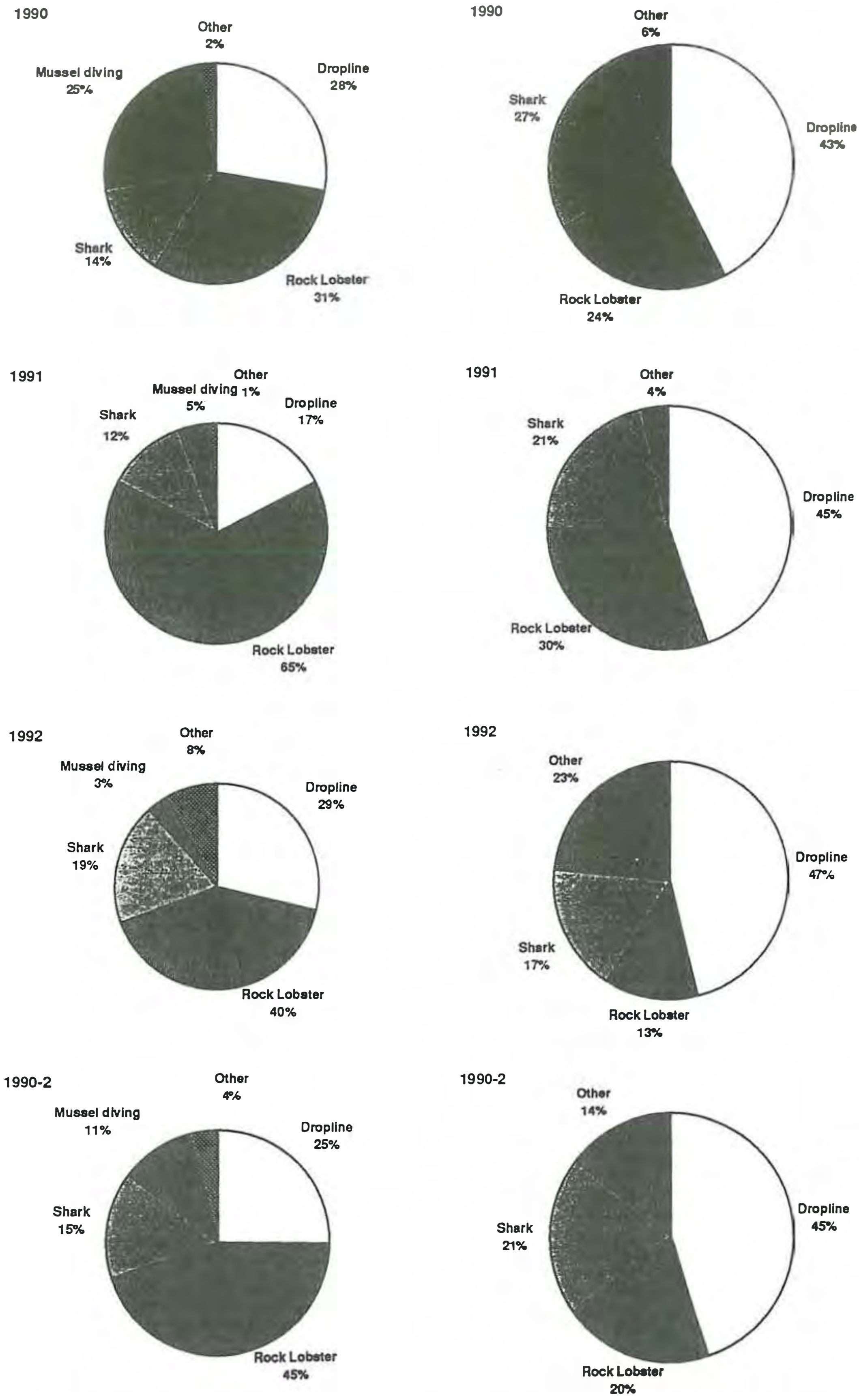


Figure 6. Relative effort (% of days spent fishing) and relative value (% of the value of the catch), by fishery and year, for fishers who targeted blue-eye trevalla by drop-line, 1990-92.

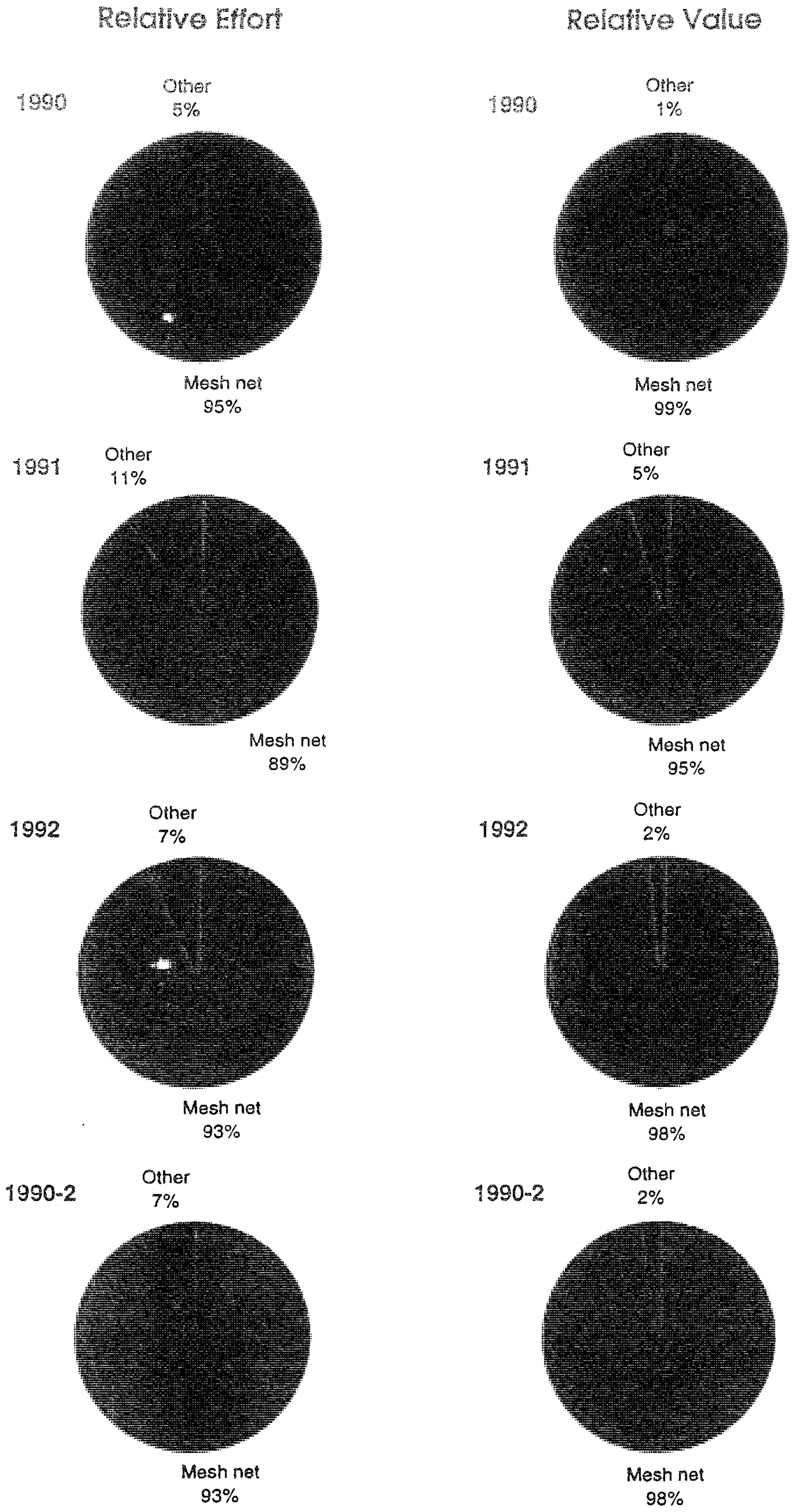


Figure 7. Relative effort (% of days spent fishing) and relative value (% of value of catch), by fishing method and year, for fishers who caught blue-eye trevalla by mesh nets, 1990 to 1992.

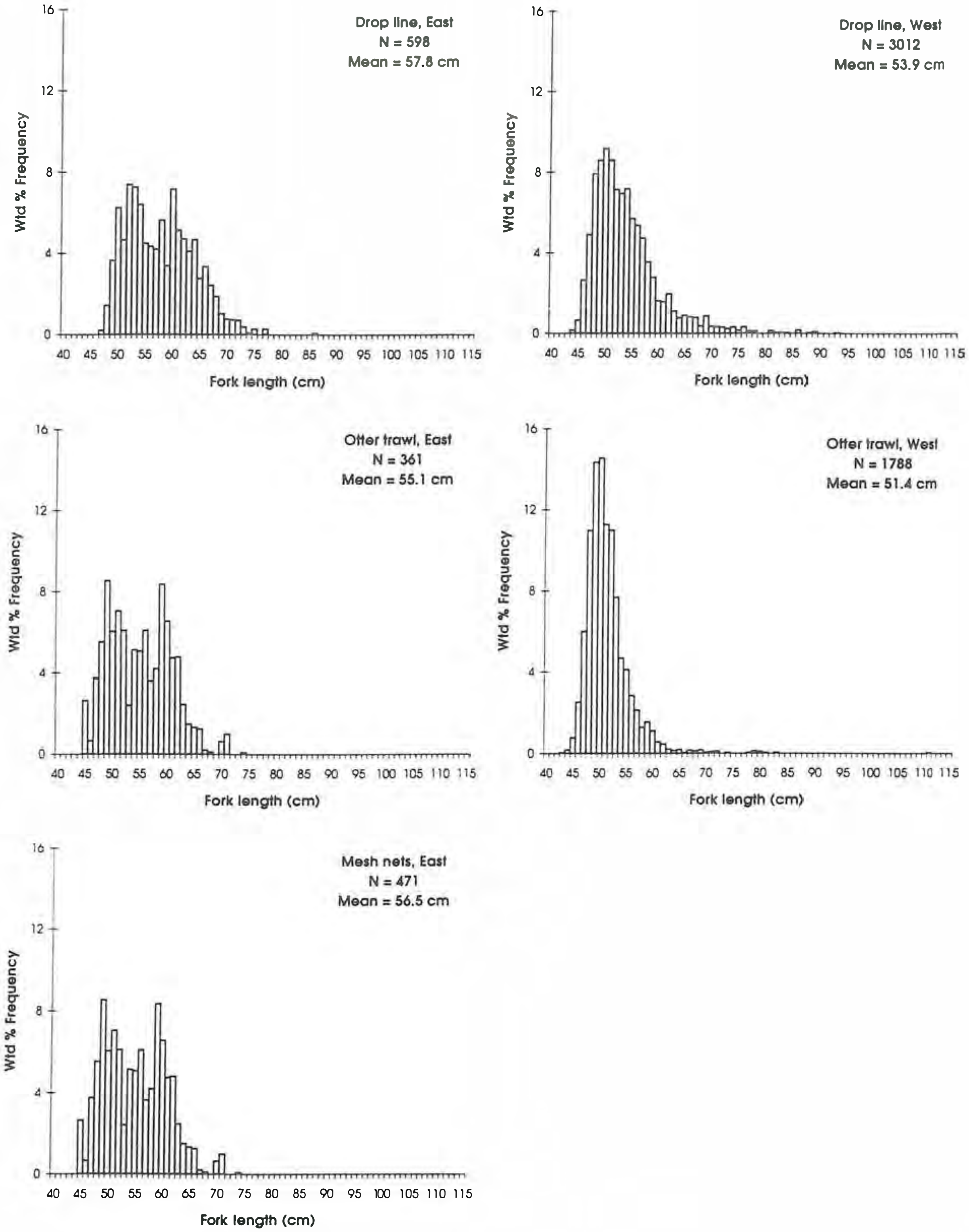


Figure 8. Length-weighted % frequency of blue-eye trevalla caught by drop line, otter trawl and and mesh nets and landed in eastern and western Victoria, 1991-94 combined.

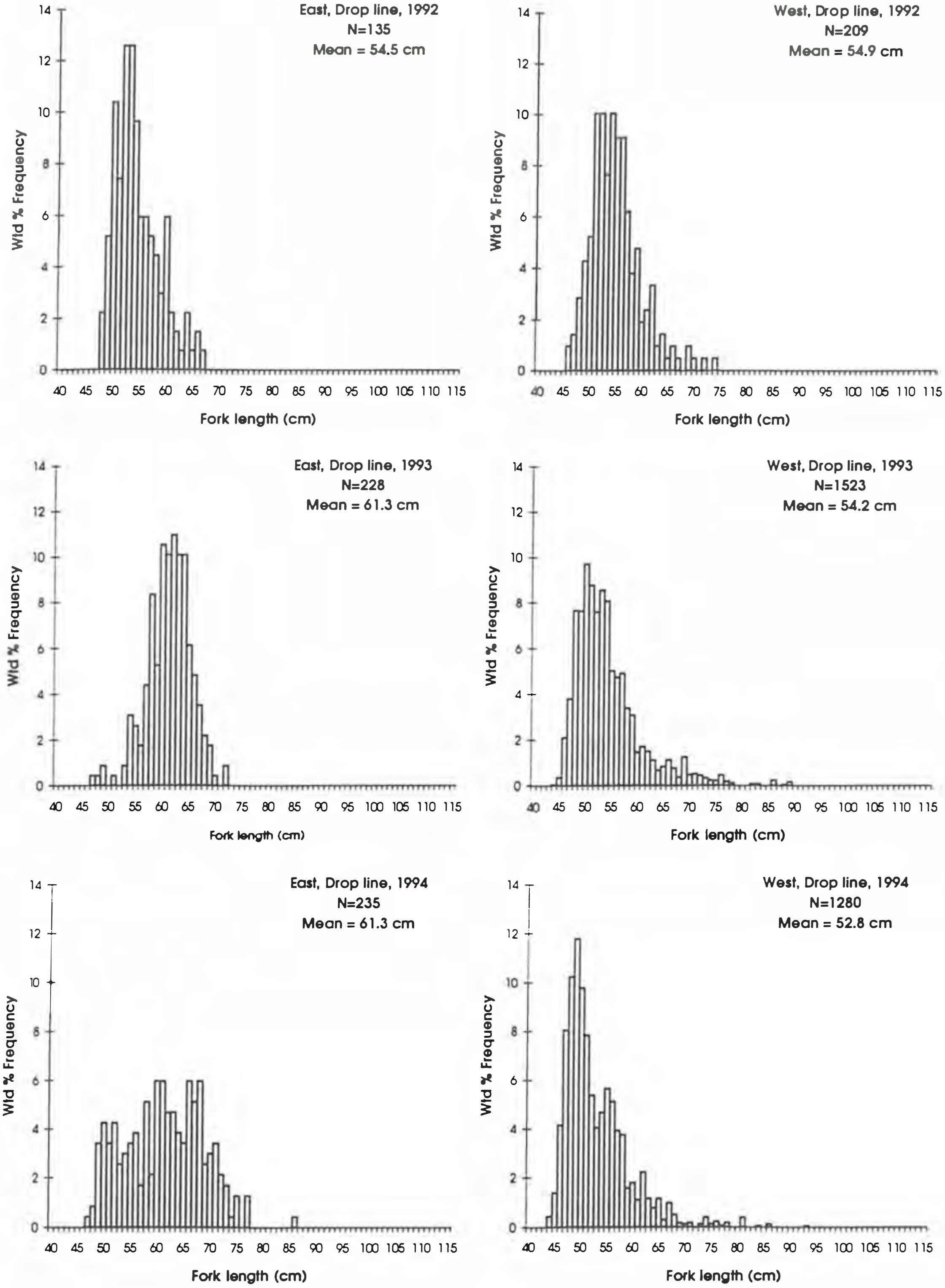
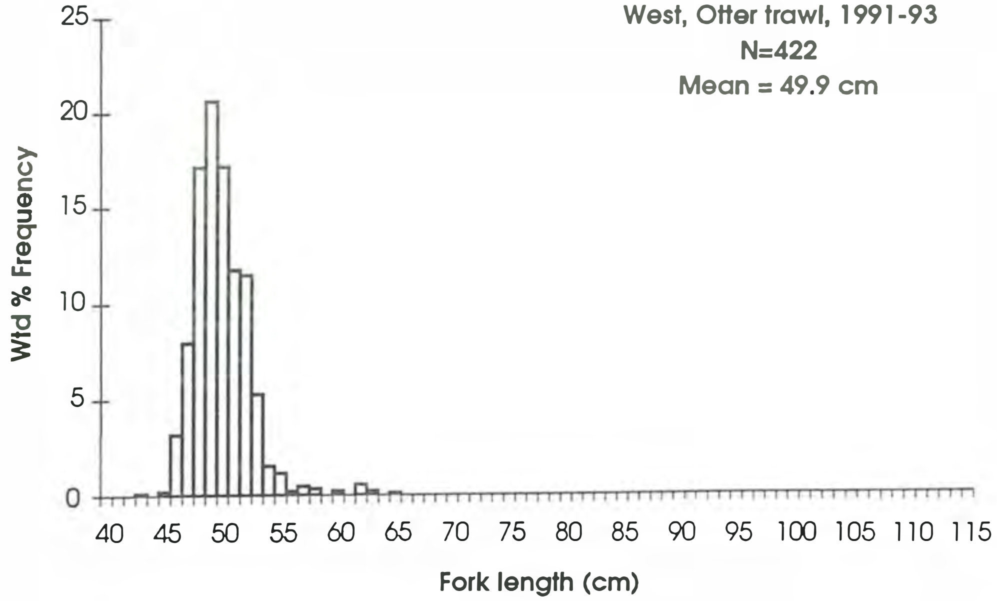


Figure 9. Length-weighted % frequency of blue-eye trevalla caught by drop line by year and landed in eastern and western Victoria.



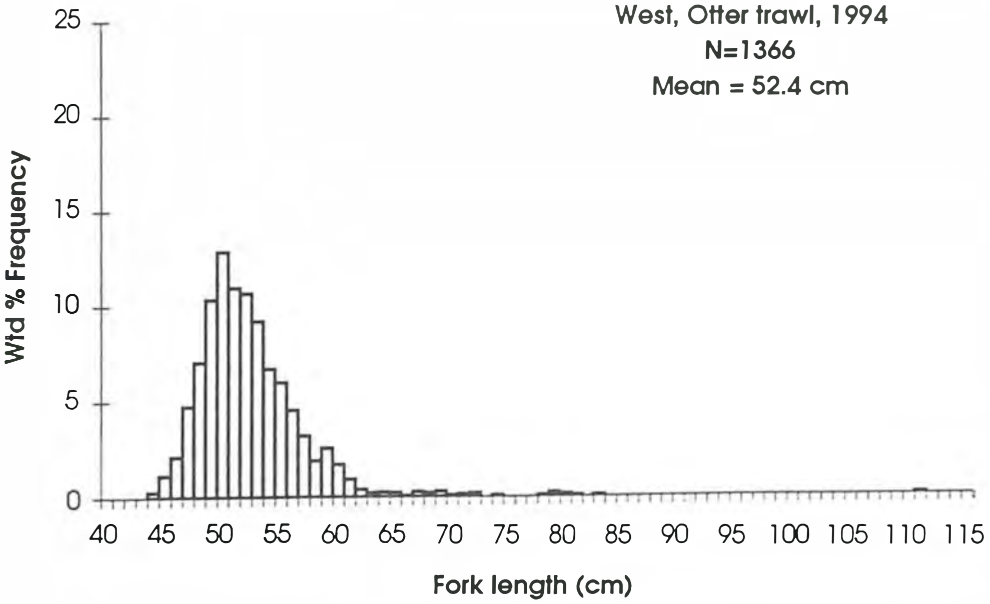


Figure 10. Length-weighted % frequency of blue-eye trevalla caught by otter trawl, and landed in Western Victoria, 1991-93 combined and 1994.

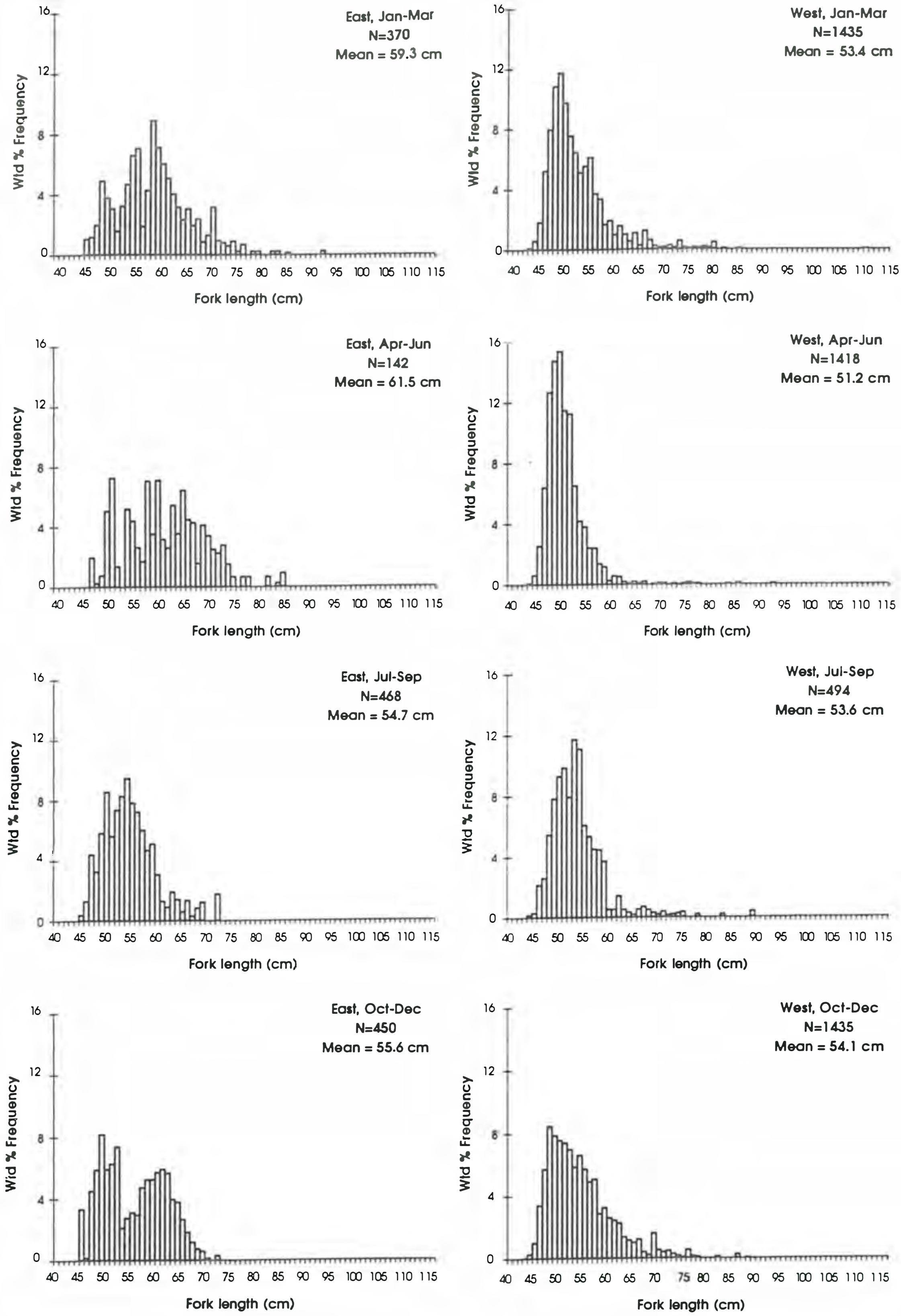


Figure 11. Length-weighted % frequency of blue-eye trevalla landed in eastern and western Victoria, all gears and years combined by quarter.

Table 1. Market prices of different species caught by blue-eye trevalla fishers, used to estimate the relative value of the blue-eye trevalla component of the fishery.

Species	Year		
	1990	1991	1992
Blue-eye trevalla	$4.10	$4.16	$4.56
Crabs	$6.72	$3.59	$3.73
Gemfish	$3.69	$3.10	$3.95
Hapuka	$4.66	$4.80	$4.95
Ling	$3.10	$3.09	$3.69
Jackass morwong	$1.81	$1.81	$1.94
Mussels	$2.08	$2.69	$2.08
Other	$2.00	$2.00	$2.00
Rock lobster	$23.25	$21.74	$21.03
Scallops	$12.00	$12.00	$12.00
Shark (other)	$2.09	$2.48	$2.57
Shark - gummy	$4.95	$5.60	$5.29
Silver trevally	$1.15	$1.21	$1.41
Snapper	$6.15	$6.35	$6.97
Trumpeter	$2.69	$2.65	$3.38
Tuna	$4.09	$3.85	$3.22
Warehou (blue & spotted)	$1.65	$1.43	$2.08

Table 2. Catch (tonnes) of blue-eye trevalla by method for the Victorian fishery, 1987-94, excluding otter trawl. Mesh net includes a variety of mesh sizes and net types. Mesh net data includes Victorian (1987-1984) and Tasmanian (1990-94) returns.

Method	Year							
	1987	1988	1989	1990	1991	1992	1993	1994
Drop line	32.36	41.38	42.46	64.70	65.66	80.98	88.06	68.95
Long line	4.73	0.31	1.77	1.91	6.31	3.36	3.67	1.06
Mesh net	38.85	70.69	40.28	54.61	16.75	50.61	54.38	100.12
Unknown	0.91	3.37	13.84	2.15	0.16	0.92		
Total	76.85	115.76	98.35	123.36	88.88	135.80	146.05	170.12

Table 3. Number of fishers participating, the total fishing effort (number of days fished), and average effort per fisher, by year for the Victorian dropline fishery (1987-1993), and average values for the 7 year period.

	Year							Average
	1987	1988	1989	1990	1991	1992	1993	
No. fishers	8	15	15	15	15	10	11	13
No. days fished	103	174	167	208	147	190	192	169
Av. days/fisher	13	12	11	14	10	19	17	13

Table 4. Catch (tonnes) by species by drop-line, excluding fishing effort directed at the inshore snapper and shark fisheries, and % by weight of the catch which is blue-eye trevalla.

Species	Year						
	1987	1988	1989	1990	1991	1992	1993
Blue eye trevalla	32.36	41.38	42.46	64.70	65.66	80.98	85.91
Gummy shark	0.01	0.03	0.09	0.05	0.02	0.09	0.09
School shark	0.09	0.73	0.36	0.42	0.36	0.30	0.33
Hapuka	2.22	1.42	3.69	2.93	2.86	1.87	4.38
Ling	0.30	0.17	0.99	1.59	1.80	29.31	7.80
Gemfish	0.02	0.04	0.05	0.05	0.04	0.05	0.00
Oilfish	1.65	0.79	0.06	0.07	0.00	0.00	0.00
Tuna	3.92	1.60	0.00	0.20	0.25	0.11	0.28
Ribaldo	0.02	0.04	0.05	0.00	0.00	0.05	0.00
Ocean Perch	0.30	0.00	0.09	0.23	0.19	0.13	0.09
Other spp	0.41	0.60	3.60	0.24	0.69	0.08	0.58
Total	41.32	46.81	51.43	70.47	69.42	112.94	99.45
% Blue-eye trevalla	78.33	88.38	82.55	91.80	91.06	71.69	86.39

PART 3

AGE, GROWTH AND MORTALITY OF BLUE-EYE TREVALLA

CHAPTER 1: AGE DETERMINATION (S. Morison, S. Robertson)

Introduction

An understanding of age and growth in aquatic animals is crucial to an understanding of the dynamics of their populations and the impacts of exploitation (Smith 1992) and providing an estimate of the age composition of blue-eye trevalla in Australian waters was considered an important part of the present study.

The only significant previous description of the age and growth of blue-eye trevalla is that of Horn (1988) for fish from east coast of the North Island of New Zealand. He estimated their age using sections of broken and burnt sagittal otoliths. Females were found to grow faster and live longer (maximum estimated age 12 years) than males (maximum age 10 years). Whole otoliths were found to be unsuitable for fish older than about 3 years, as the otoliths tended to increase in thickness rather than width after this age. Earlier work by Webb (1979) was based on a very small sample size (89) and gives an inadequate description of the method of preparation employed. He examined both whole and broken and burnt, but only one set of results was presented; it is not clear whether the age estimates of the two methods of preparation agreed or whether one method was favoured over the other. The maximum estimated age for his sample was 9 years. Jones (1985) used scales to age 76 blue-eye trevalla and produced a maximum age of 13 years for females and 10 years for males. Scales have been frequently shown to underestimate the age of fish species which live for many years after approaching their maximum size and age estimates made only from scales must therefore be interpreted with caution. Similarly, age estimates made from whole otoliths have also been found to frequently underestimate maximum ages because increments laid down on the proximal face of the otolith are not discernible by examining the distal face (the normal method of examining whole otoliths).

Methods

Otolith collections

For the present study sagittal otoliths were collected from commercial catches of blue eye trevalla by dropliners, demersal otter trawlers and from catches made during trials of semi-pelagic trawl nets, between January 1992 and October 1993. Otoliths were stored dry in envelopes marked with collection and fish details.

Samples examined came from the major fishing areas off Tasmania and Victoria, and included samples collected during the current project and collections made in the 1980s.

Description and preparation of the otolith

Blue-eye trevalla otoliths are comparatively large (up to 40 mm long - anterior to posterior margins, 17 mm wide - dorsal to ventral margins, and up to 1.9 g in the sample examined) ovoid, and laterally compressed (Figure 1). They have a pronounced rostrum at the anterior end.

Sagittae were examined both whole and after preparation of thin sections. When viewed whole from the distal surface they show a relatively large central area which is predominantly opaque, but with between one and three translucent bands. There is then an abrupt change to a region of alternating translucent and opaque zones. On larger otoliths there is also an outer region of narrower and more clearly defined alternating opaque and translucent zones.

When viewed in transverse section under transmitted light, the sagittae also show the relatively large central opaque area with a variable number of translucent zones (Figure 2). Outside this central zone, alternating opaque and translucent zones are present of more or less equal thickness. These zones are most clearly delineated at the margins of the largest otoliths, and, in most otoliths, are most clearly distinguished on either side of the sulcul groove. To standardize the process, counts were routinely made down the side of the sulcul groove.

Sagittal otoliths were embedded in rows of 4-5 in blocks of polyester resin and three or four sections approximately 0.3 mm thick were cut through their centres with a modified gem-cutting saw, using a blade 0.25 mm thick. Sections were mounted on microscope slides under coverslips with further polyester resin. Sections were then viewed with transmitted light at 6 to 10 times magnification. All sections of each row of otoliths were inspected and the section closest to the primordium used for subsequent ageing. One reader, who was experienced in interpreting structure in sectioned otoliths, examined all sections and estimated ages.

Counts and measurements

A customized image analysis system was used to view the sections, count marked increments, and measure their positions. A frame grabber in a personal computer captured an image from a video camera mounted on the dissecting microscope, and displayed it on the computer monitor. Using the screen cursor, a transect was drawn on the otolith image from the primordium to the edge of the section. The positions of increments along this transect, and of the otolith edge, were then marked with the cursor. The customized image analysis system then recorded the number of increments marked, and the distances from the primordium to each increment and to the edge of the otolith.

The marginal increment was calculated as the distance between the edge of the otolith section and the outermost increment. This was calculated for fish aged up to 10 years. After this age, increments are generally become very narrow so that measurement errors preclude the detection of any annual pattern in increment widths. Mean monthly marginal increments (± 1 standard error) were calculated for separate age classes, or pairs of age classes where sample sizes were low, combining sexes and areas, and pooling data for the same months in different years.

All counts were made without knowledge of fish size, sex, or location or date of capture, to avoid the potential for biasing age estimates or marginal increment measurements.

Once age estimates were completed, the ageing data were combined with information on fish length and sex, location and date of capture, and otolith weight, for subsequent analysis.

Otolith weights

Otolith weight is a useful diagnostic tool in assessing potential errors in age estimates and for examining patterns of otolith growth. Otoliths tend to grow linearly in length and width with increasing fish size, and to grow linearly in thickness and weight with increasing fish age. In long-lived species, plots of otolith weight of against estimated age will therefore show an increasing slope at older ages if the ages have been underestimated. Such underestimation has often occurred for species when scales or whole otoliths have been used, when it was necessary to section otoliths to reveal all the annual increments. Also a large variation abut the relationship is indicative of a lack of precision in the estimates.

All otoliths were weighed to the nearest 0.01 g on an electronic balance.

Precision of the age estimates

Repeated readings of the same otoliths provide a measure of intra-reader or inter-reader variability. They do not validate the assigned ages but provide an indication of size of the error to be expected with a set of age estimates, due to variation in interpretation of an otolith. Beamish and Fournier (1987) have developed an index of average percent error (APE), which has become a common mean of quantifying this variation. The APE is calculated as:

$$APE = \frac{100}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{|X_{ij}-X_j|}{X_j}\right]$$

where N is the number of fish aged, R is the number of times fish are aged, Xij is the ith determination for the jth fish, and Xj is the average estimated age of the jth fish. The index has the property that differences in age estimates for younger fish will contribute more to the final value than will the same absolute error for older fish (Anderson et al. 1992).

A subsample of 100 otoliths were read a second time by the main reader and an APE calculated. In addition, 200 otoliths were read by a second reader who was experienced in interpreting with sectioned otoliths (although not specifically with blue-eye trevalla) and the APE for the two readings calculated. The distributions of the differences between repeat readings were also inspected as another indicator of ageing errors, and of any bias between readings.

Validation

The marginal increment was calculated from the measurements recorded as the distance between the outermost increment counted and the otolith edge. The marginal increment ratio was similarly calculated as the ratio of the marginal increment to the distance between the last two completed increments. Plots of the mean marginal increment against month of capture, for each of the youngest 10 age classes identified, were examined to determine if there was an annual cycle in the timing of increment formation.

Dr John Kalish of the Australian National University has developed a new method of direct age estimation for fish otoliths using precise measurements of the levels of radioactive carbon present in otolith cores (Kalish 1993). He analysed the carbon in a single blue-eye trevalla otolith for which the sister otolithhad been aged from a sagittal section. Close correspondence between the ages assigned by both methods would give confidence that the ages estimated from sections are accurate. The otoliths chosen for this comparison were close to the largest available (otolith weight 1.3 g). Establishing accuracy in the maximum assigned age for even one fish is useful because the oldest age estimates cannot be accurate unless the increment counts for the inner parts of the otolith, and hence age estimates for younger fish, are also accurate.

Results

Age determination

Initially, age estimates were made using whole otoliths immersed in water, viewing the lateral surface with reflected light. The age was estimated as the number of complete translucent zones visible on the otolith. The changing pattern of zonation within the otolith made any consistent interpretation difficult, within and between readers. Also, on the larger otoliths, it was apparent that their increasing thickness was masking increments, which were clearly visible when sections of the same otoliths were examined.

At an early stage in the project a workshop was held to consider and agree on the best means of preparation and interpretation of blue-eye trevalla otoliths, with workers from Victoria, New South Wales and Tasmania participating (see Appendix IV). The outcome of this workshop was agreement that the whole otoliths were believed to be suitable for ageing young blue-eye trevalla, but that sections needed to be cut for the larger otoliths. The pattern of a central opaque area with few presumed annual increments, through a transition zone of often confusing increments, to an outer zone of narrow and more clearly defined increments, was identified and described.

After examination of a greater number of sectioned otoliths, it was clear, however, that the transverse sections offered a more easily interpretable pattern for small as well as large otoliths. This was particularly the case for the intermediate or transition zone in which the number of increments could frequently not be clearly distinguished. Sectioning all otoliths also obviated both the need to determine a size of fish or otolith at which to change from one method of preparation to the other, and also the need to demonstrate equivalence between counts obtained by the two methods.

Transverse sectioning of the sagittae was therefore adopted as the method of preparation and all age estimates were made by counting the number of complete opaque zones visible in such sections.

For females, age estimates ranged from 2 years for a 47 cm fish, to 42 years for 97 cm fish (both from N.E. Tasmania). The largest female (a 105 cm fish from the Cascade Plateau) was aged at 21 years. For males, age estimates ranged from 2 years for a 44 cm fish, to 39 years for a 70 cm fish (also both from N.E. Tasmania). The largest male (a 93 cm fish from the Cascade Plateau) was aged at 22 years. Over all areas, 3 and 4 year old fish predominated in the samples, comprising over 35% of the entire samples examined.

Validation

The mean monthly marginal increment was examined for ages 3 to 10 separately (there were insufficient 2 year olds for analysis) and for combinations of ages 5 &6, 7 & 8 and 9 & 10 (Figures 3-5). For each of these plots the marginal increment is at a minimum in July or August, and generally also at a maximum between April and June. There is clearly only one cycle over a year. A plot of the mean monthly marginal increment for ages 1-10 combined (Figure 5), shows this cycle most strongly and has the largest fluctuations around the cyclical trend immediately prior to the formation of the new increment. These results are consistent with increments which were counted being forming on an annual basis and provides support for the validity of the age estimates up to 10 years.

Beyond, the age of 10 years there is no change in the pattern of banding in the otolith sections, upon which the increment counts are based. If the increments are formed annually for the first 10 years, it is logical to suggest that they are also formed annually beyond this age, and that the older estimated ages are equally valid.

The age estimate provided by Dr John Kalish for the single otolith analysed was 33 years, ± 6 months (J. Kalish, personal communication). This fish which had been estimated to be 30 years old from an initial reading of the otolith section. The level of agreement between these estimates adds strong support to the validity of the ages estimated from the otolith sections. It also supports the indication from this study that blue-eye trevalla from southern Australian waters live much longer than had been previously thought and longer than populations in New Zealand. Once the radiocarbon age of this specimen had been determined, it was used as a reference sample to assist in providing a consistent interpretation of other sections.

Otolith weight

Plots of otolith weight against estimated age show a linear relationship for both females and males (Figure 6). There is no indication, as often occurs in longer-lived species, of a two-stage relationship. However, the absence of data for smaller fish may be giving a biased estimate of this relationship. The increasing variation about the trend line with increasing age is frequently observed in such plots. Regression lines fitted to the relationships had R^2 values of 0.86 for females and 0.82 for males.

Plots of fork length against otolith weight (Figure 7) show relationships which are linear over the range of fish length in the sample and up to otolith weights of about 1.0g, for both males and females. Above this weight (of which all but 5 are females) the slope of the relationship decreases substantially, indicating that the growth in fish length has slowed compared with the growth in otolith weight. For smaller fish and lighter otoliths, the relationship would be expected to pass close to the origin. However, for the regression lines fitted to the data (otolith weights up to 1.0 g), the intercepts are close to 40 cm for both females and males (R2 values 0.93 and 0.89 respectively). Therefore, the growth of otoliths in young fish must be much faster than over the range of fish and otolith sizes examined.

Precision of the age estimates

The index of APE calculated for repeat readings by the primary reader was 5.01% and for repeat readings by the second reader was 5.75%. The distribution of differences for the primary reader (Figure 8) had a mode a 0 although the distribution was skewed to the right so that on average the primary reader assigned slightly higher ages on the second reading (average difference was 0.57 years). The distribution of differences between readers (Figure 8) showed a mode at -1 years (indicating a higher age by the second reader), but the distribution is also skewed to the right so that on average the second reader assigned slightly higher ages (average difference was 0.26 years).

Discussion

We experienced similar difficulties in using whole otoliths to those reported by Horn (1988). Both studies indicate the need to adopt some method of sectioning to be able to view and count all the increments which are present on otoliths of all but the youngest fish.

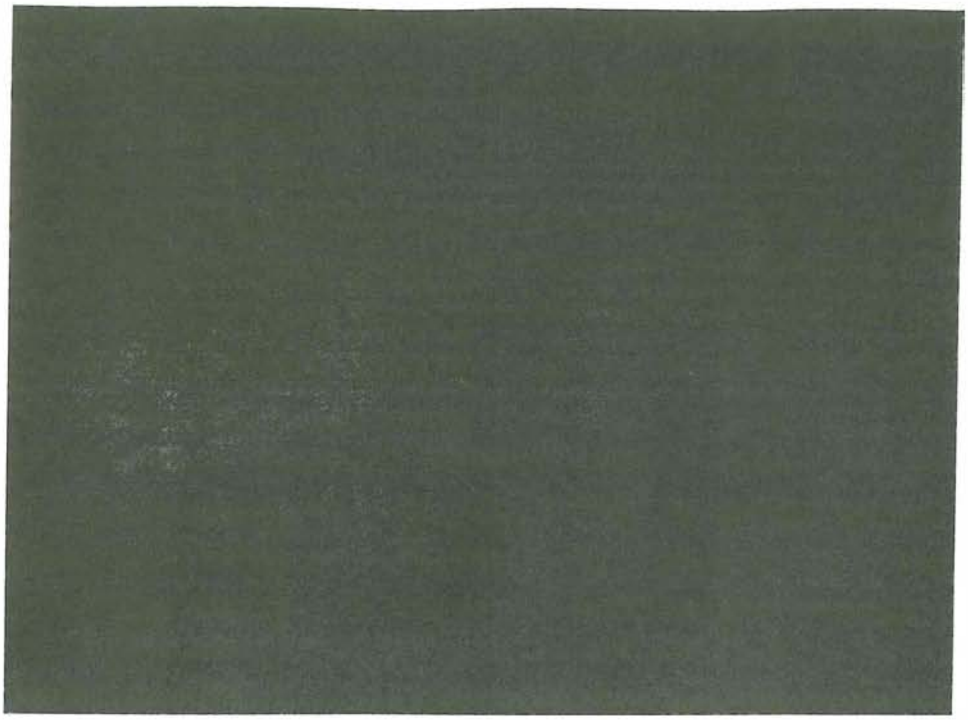
The combination of the marginal increment analysis, the otolith weight plots, and the agreement with the estimates from bomb radiocarbon, together provide strong evidence that the assigned ages are accurate.

The marginal increment analysis suggests a time of formation of increments of July or August, which is earlier than the November time found for blue-eye trevalla in New Zealand (Horn 1988). However, there are differences between the studies in the plane of measurement of the increments and the index calculated. Hornís measurements were made on the dorsal half of the otolith (rather than near the sulcus) and increments may become visible in this part of the otolith later than near the sulcus. Horn also expressed marginal growth as a proportion of the width of the most recently completed increment. This ratio was also calculated for the data from the present study but the results showed a weaker trend than that observed when using the raw increment measurements. Slight differences between readers in the criteria for recognising when a new increment has been completed could also account for the difference.

The intra- and inter-reader comparisons of assigned ages indicates that the otoliths of blue-eye trevalla are moderately difficult to interpret. The readers achieve APE indices of less than 4% on other species of similar longevity. New readers would probably require extensive training with blue-eye trevalla otoliths before accurate and consistent interpretations could be expected .The difficulty comes in part from the large change in the growth of the otolith after recruitment, which necessitates a different interpretation of the otoliths structure in its inner and outer regions. This unusual change in appearance was recognised early in the study (see report on workshop in the Appendix).

The maximum estimated age indicates that blue-eye trevalla from waters off southern Australia are a moderately long-lived. The maximum ages estimated are significantly greater than those estimated for fish from New Zealand. Dr Peter Horn, who undertook the study of New Zealand blue-eye trevalla, has viewed several sections of otoliths of Australian fish, which had been estimated to be older than the maximum age assigned to New Zealand fish. He concurred with the interpretation and agreed that the higher age estimates were not due to a differences in preparation or reading (personal communication). Further inter-laboratory comparisons are planned.

Further validation work is desirable to confirm the longevity of blue-eye trevalla. The use of tagged fish, which have been injected with a fluorochrome marker, and the radiocarbon analysis of a greater number of otoliths, are the most likely means of achieving this.



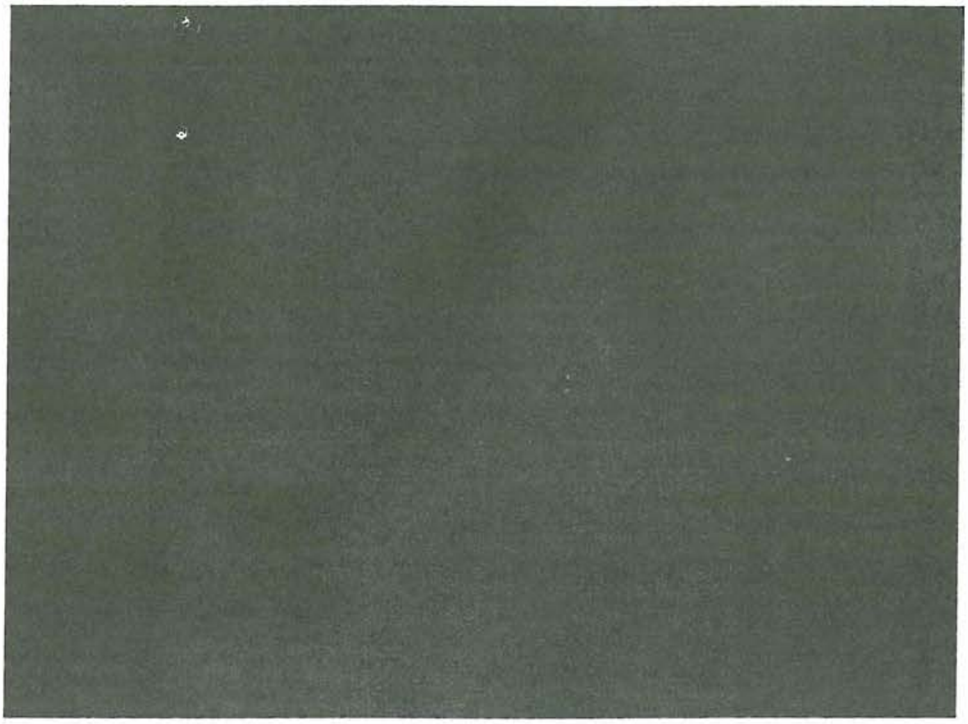


Figure 1. *Top* -Whole sagittal otolith of a 47 cm female blue-eye trevalla from West Tasmania. Estimated age 4 years. Otolith is 15 mm long,. *Bottom* - Anterior half of sagittal otolith of 79 cm fish used for radiocarbon estimate of age, 16 annual increments visible (first 12 only marked). Distance from primordium to rostrum is 14.3 mm. X's indicate approximate positions of annual increments, crosses indicate primordium. Otoliths viewed with reflected light against black background.

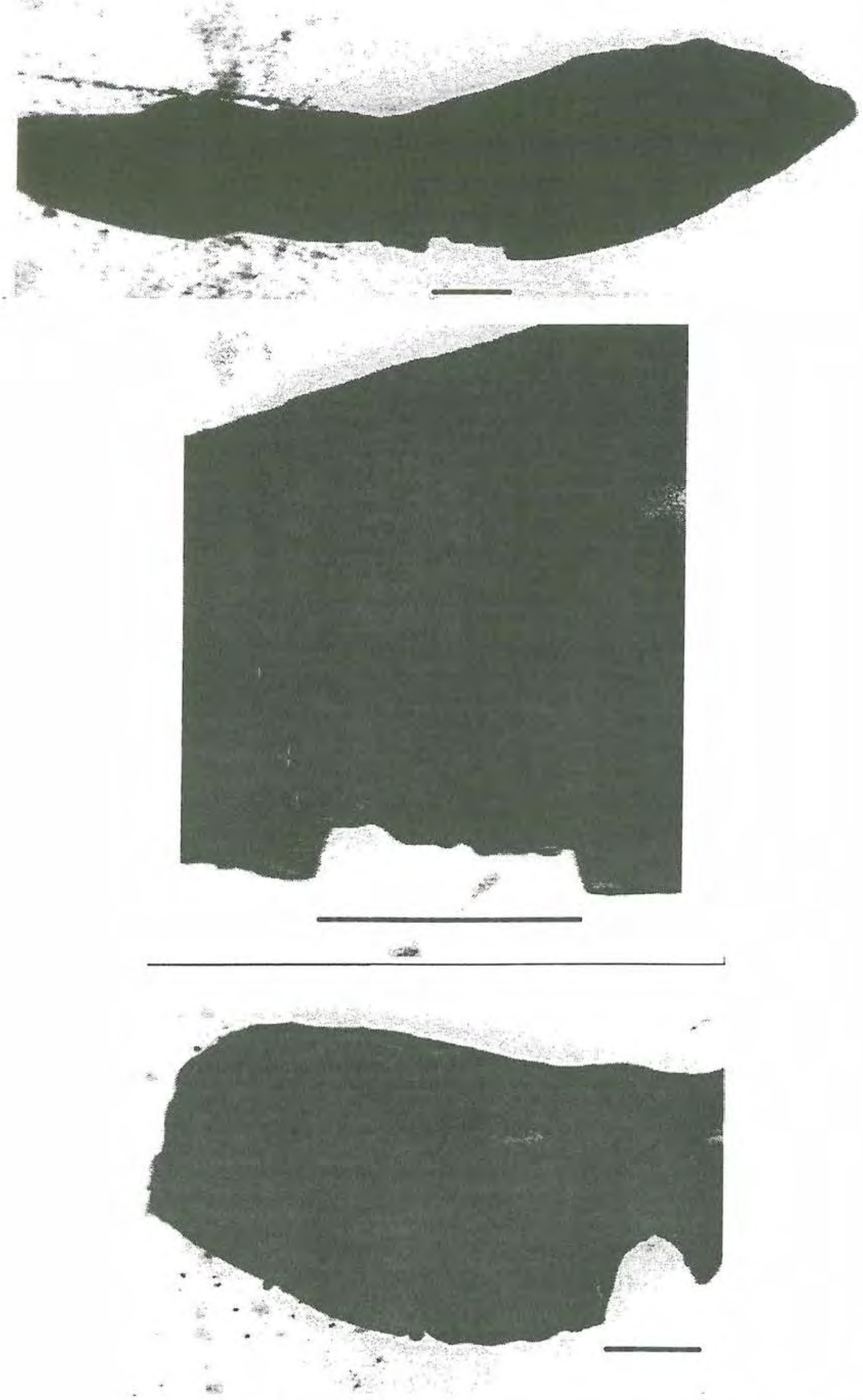
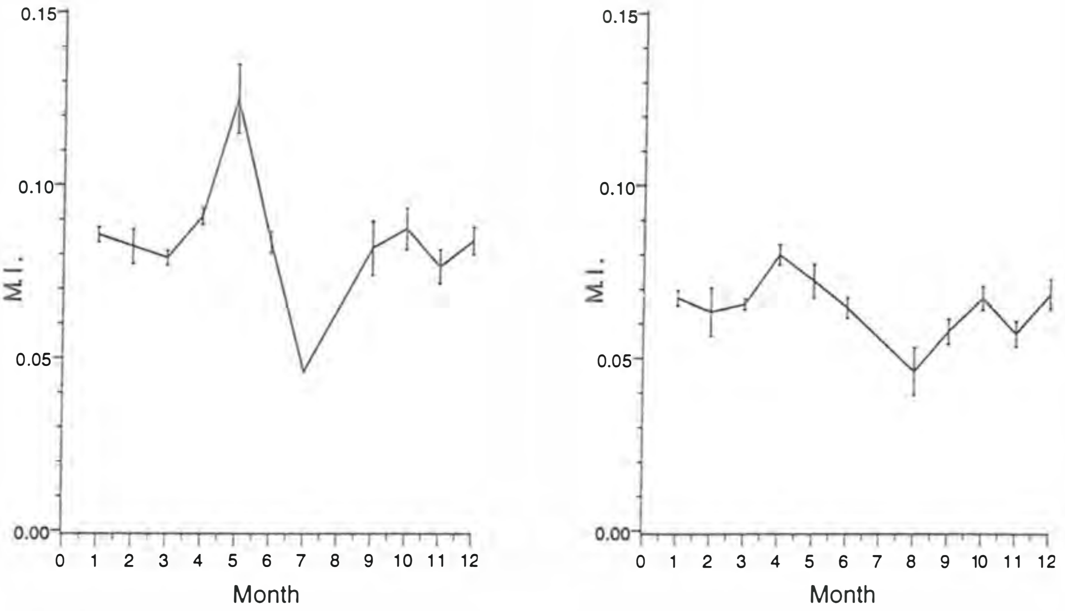


Figure 2. *Top*. Transverse section of sagittal otolith of 79 cm female blue-eye trevalla, from the Cascade Plateau, aged at 22 years, complete section. *Middle*. Enlargement of sulcul area of same otolith. White crosses indicate every 5th increment counted. *Bottom*. Ventral half of transverse section of sagittal otolith used for radiocarbon age estimate (33 years). Scale bar 1.0 mm. Sections viewed with transmitted light.

Age 3. N = 436

Age 4. N = 502



Age 5. N = 243

Age 6. N = 140

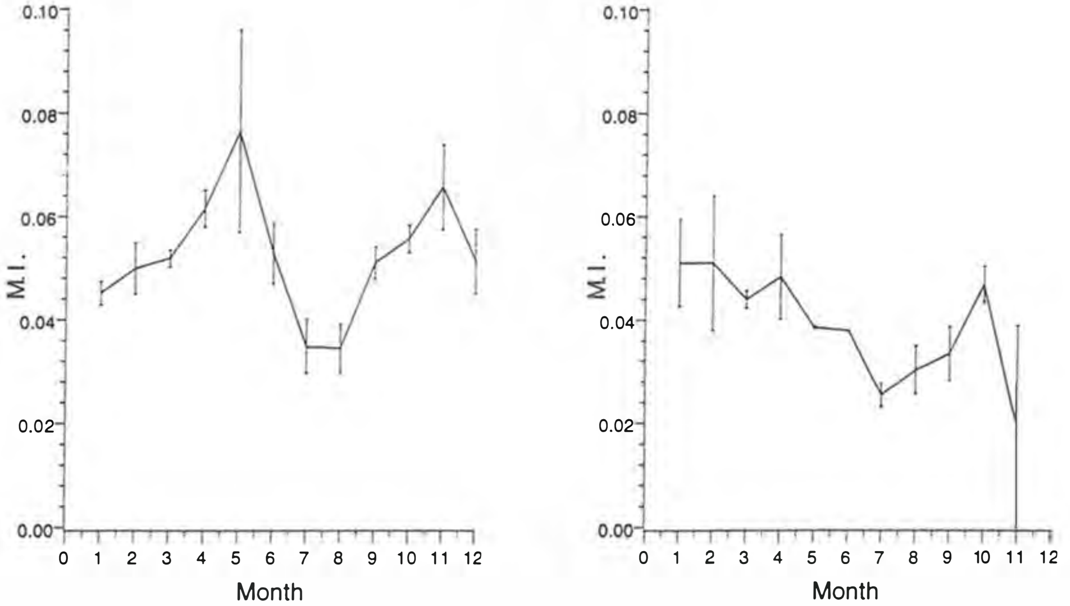
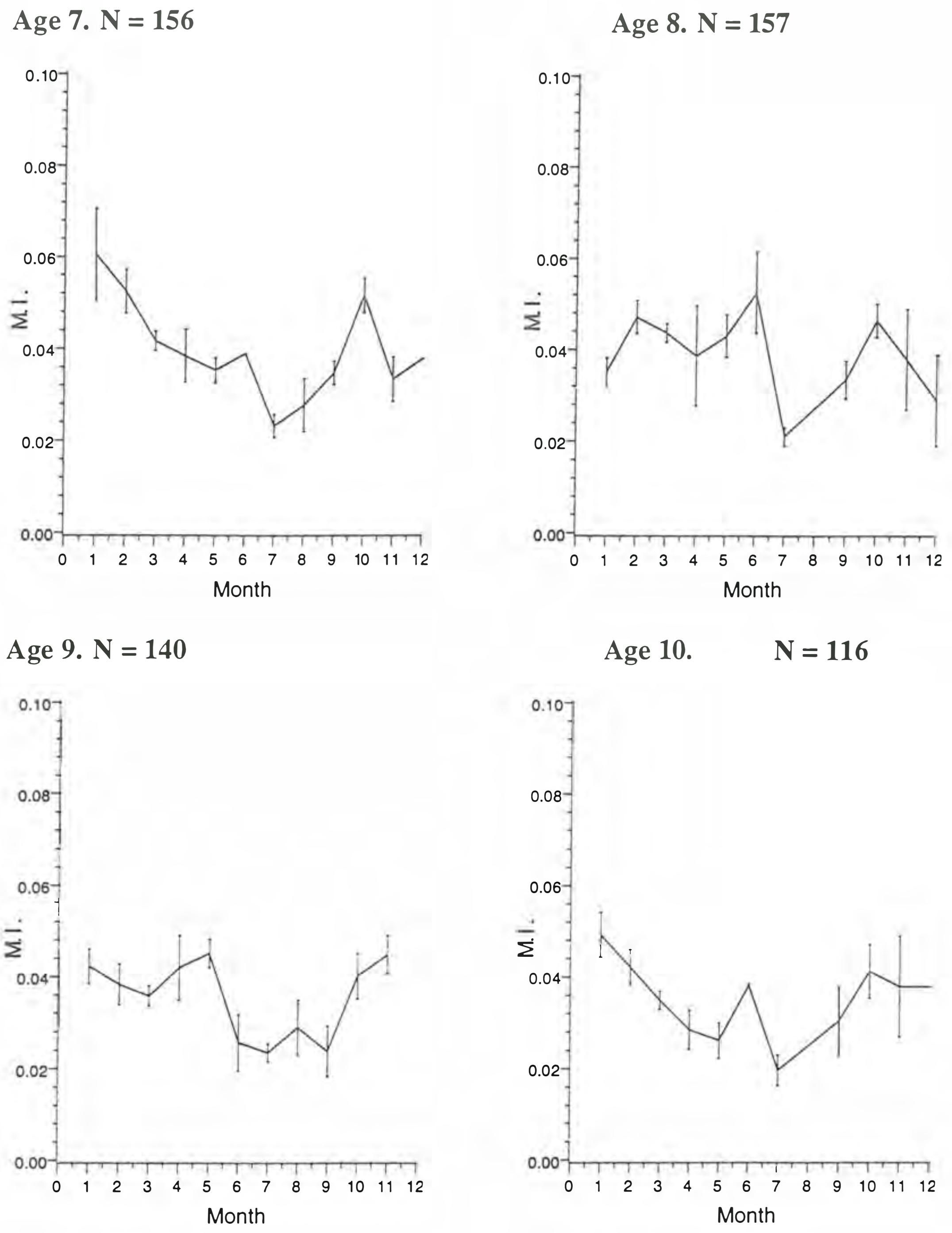


Figure 3. Blue eye trevalla: Mean marginal increment (in mm ±1 S.E.), by month, (data for Jan 92-Sep 93 combined), Ages 3-6.



Age 7. N = 156

Age 8. N = 157

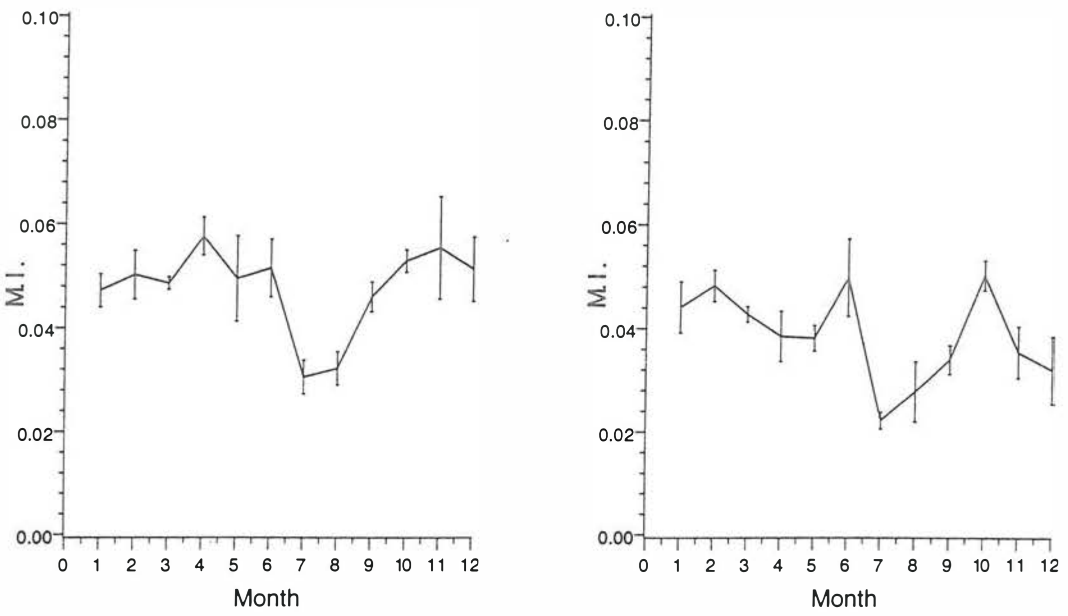
Age 9. N = 140

Age 10. N = 116

Figure 4. Blue eye trevalla: Mean marginal increment (in mm ±1 S.E.), by month, (data for Jan 92-Sep 93 combined), age 7-10.

Ages 5 & 6 combined. N = 383

Ages 7 & 8 combined. N = 313



Ages 9 & 10 combined. N = 256

Ages 1-10 combined. N = 1937

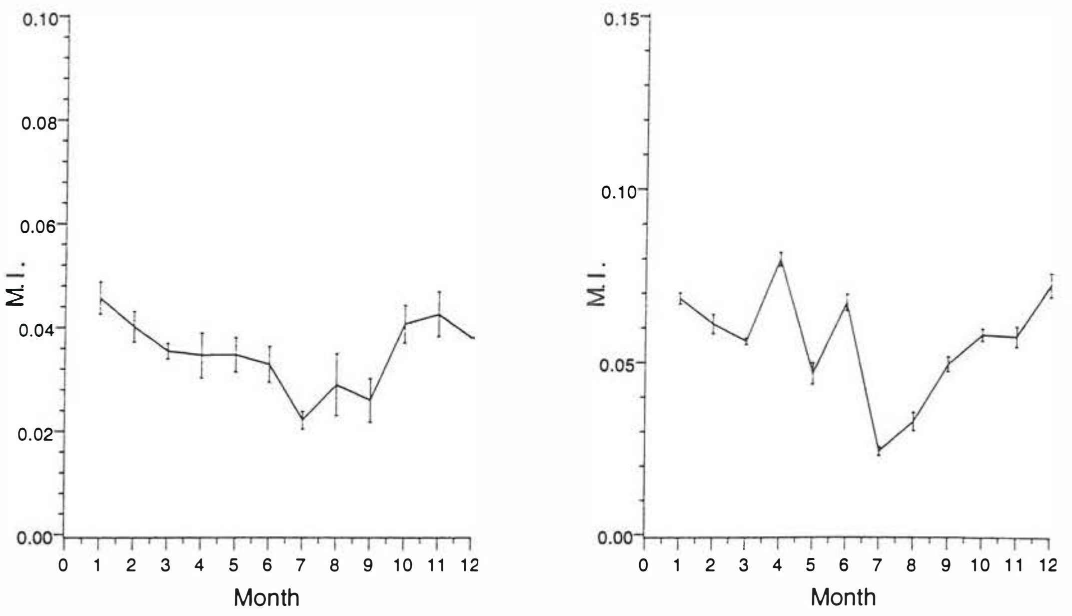


Figure 5. Blue eye trevalla: Mean marginal increment (in mm ±1 S.E.), by month, (data for Jan 92-Sep 93 combined), ages 5&6 combined, 7&8 combined, 9 & 10 combined, and ages 1-10 combined.

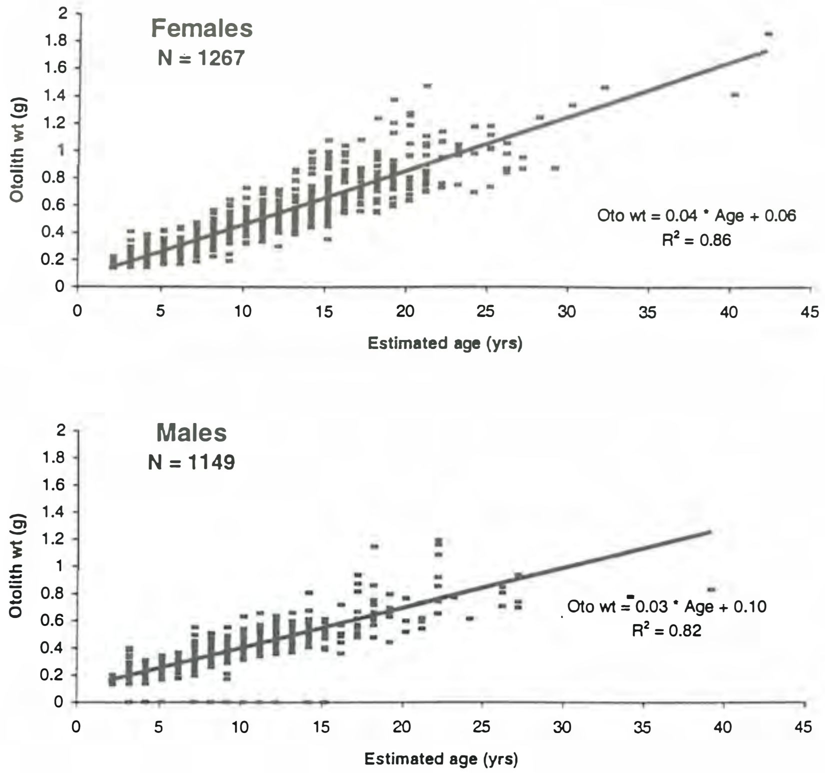


Figure 6. Otolith weight versus age estimated from sectioned otoliths for blue-eye trevalla for females and males, areas combined.

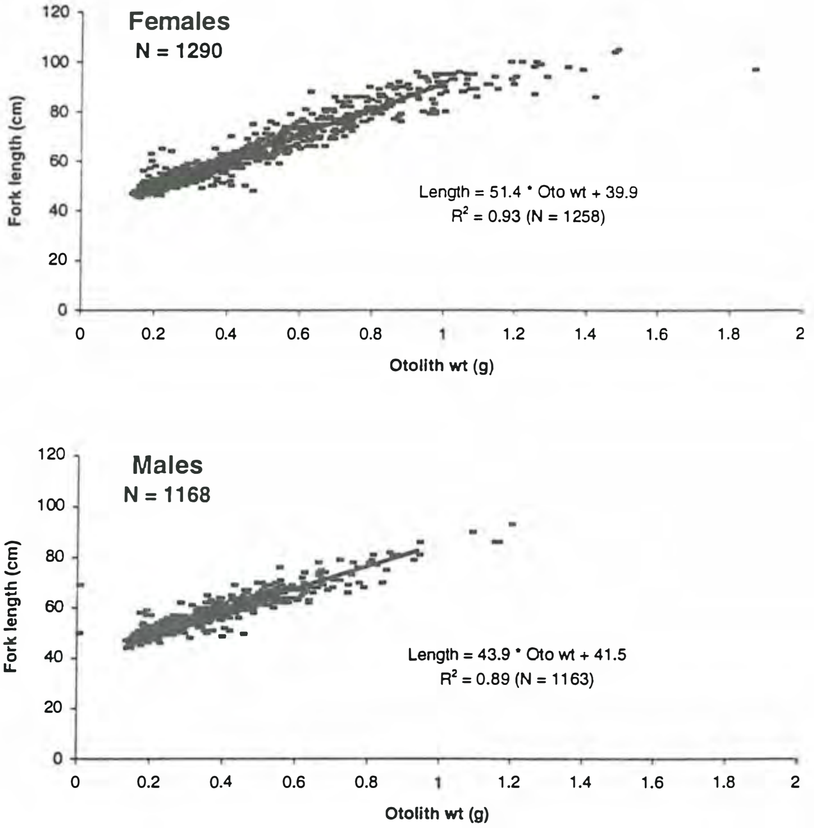


Figure 7. Fork length versus otolith wt for blue-eye trevalla, for females and males, areas combined. Regression lines fitted for otolith wts up to 1.0 g.

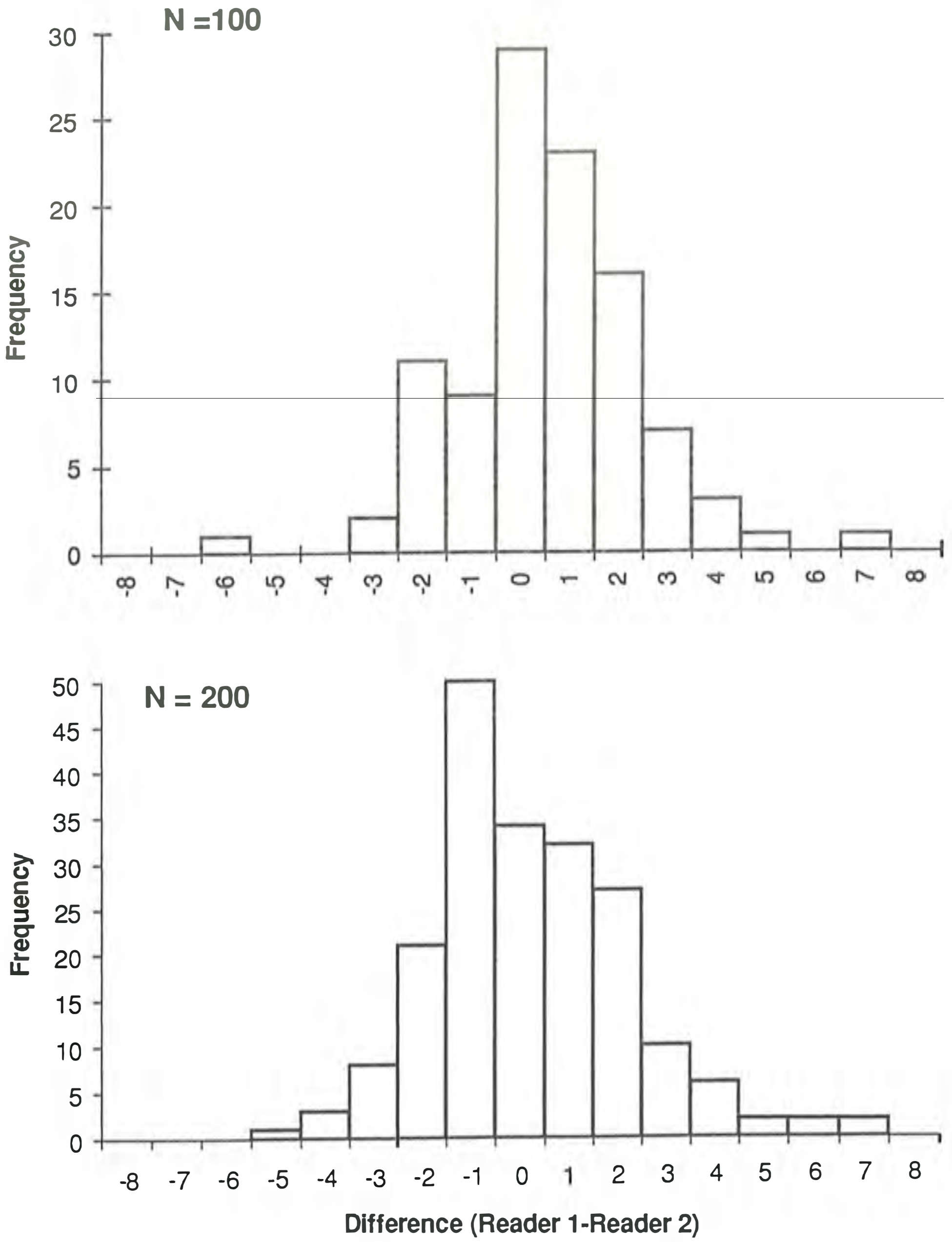


Figure 8. Distribution of differences in estimated ages for repeat readings by the same reader (top) and by a second reader (bottom).

CHAPTER 2: GROWTH, AGE COMPOSITION AND MORTALITY ESTIMATES

(S. Morison)

Introduction

The information provided by estimating the age of fish is of particular value when used to estimate growth and mortality of populations. The growth of blue-eye trevalla has previously been estimated for fish from New Zealand (Horn 1988) based on age estimates from sectioned otoliths. Webb (1979) and Jones (1985) provided preliminary estimates for the growth of blue-eye trevalla from southern Australian waters but their sample sizes were small and ageing methods unreliable. Horn and Massey (1989) provided estimates of natural mortality for blue-eye trevalla from two New Zealand fishing grounds, but believed that these were overestimates due to biases in the catch age structure.

Methods

Ageing methods and results are described elsewhere in this report. Using the estimated ages, mean lengths-at-age were calculated for males and females separately for each area, for all areas combined, and for all areas except Cascade Plateau. The Cascade Plateau sample has an obviously different age structure and was treated separately

Age estimates represent the number of completed annual increments. Partly because fish may grow a substantial amount during a 12 month period, particularly when young, fish of the same nominal age may vary greatly in length. Blue-eye trevalla are believed to spawn between March and May (work by Baelde, this study). To give a more accurate representation of chronological age, age estimates were converted to a 'decimal' age where the decimal portion represents the proportion of the year between an assumed average date of spawning (1 April) and the date of capture.

Non-linear growth curves were fitted to the length and age data obtained from the ageing component of the present study. A least squares procedure using the Marquardt method of minimization was applied in the NLIN procedure of the SAS® statistical package. Curves were fitted to data for each sex separately and for the sexes combined. Curves were also fitted to the data for females and males from each of the main areas separately, and from all areas combined. Differences between the sexes, and between Cascade Plateau and the other areas, were tested using an F test on the ratio of the error mean square for the combined fit and the sum of the error mean square for each sex or area when fitted separately.

Length frequency data were obtained from samples of the commercial catch of drop liners, otter trawlers and mesh netters landed in Victorian ports between 1991 and 1994. The age composition of these catches was then estimated by applying the age length key from the combined sample to these length data in the following manner:

A_t = $(\Sigma_x(L_x\ P_{tx})$ where
A_t = the estimated number of fish of age t in the length-frequency sample,
L_x = the number of fish of length x in the length-frequency sample, and
P_{tx} = the proportion of aged fish of length x which were age t.

The slope of $\ln(A_t)$) plotted against age, over the age range 4 to 20 years, was used to estimate the total instantaneous mortality (Z). The age-length key used for these analyses are given in the section on age determination, and the length-frequencies to which the age-length key was applied are given in the section profiling the Victorian blue-eye trevalla fishery.

Results

Age composition

Over all areas, 3 and 4 year old fish predominated in the samples of both females and males (Figure 1), comprising over 35% of the entire samples examined.

The age composition of the samples from the North East, South East and West Tasmania were very similar to each other, comprising predominantly 3 and 4 year old fish, but they were substantially different from the Cascade plateau sample, where the modal age was 15 years for females and 11 years for males (Figures 2 and 3). Western Bass Strait was intermediate between these areas, but only small numbers of otoliths were examined from this area.

There is some evidence of variable recruitment in the age composition second mode at around 8 years in the Tasmanian samples not from the Cascade Plateau. This is most evident in the combined age composition for males.

Growth

Mean lengths at each age by sex and area, and for the areas combined are presented in Tables 1 and 2. In general females and males have similar mean lengths at up to about age 9 after which the mean lengths of females is higher. The mean lengths of the younger age classes (less than about 5 years) are undoubtedly biased by the lack of small fish in the samples. The mean lengths-at-age for both female and male blue-eye trevalla from the Cascade Plateau are greater than for fish from other areas. Thus not only is the sample of blue-eye trevalla from this area comprised of a greater proportion of older fish, they are also faster growing than in other areas.

Growth curves fitted to the data from the combined areas showed significant differences between the sexes, (F=1.186, P<0.001), and growth data are therefore presented separately for each sex. Growth curves were also calculated separately for each area, and the von Bertalanffy parameters for each of these curves are listed in Table 3, together with their confidence intervals. The curves for females and males from the Cascade Plateau and other areas combined are shown in Figure 4. Growth curves for males from all areas except Cascade Plateau, and all areas combined, are shown in Figure 5. A comparison of the growth curves for females from the Cascade Plateau with females from the other areas combined showed a significant difference (F=1.476, P<0.001). However, for males no significant difference was detected (F=0.806, P>0.05), probably because of the small sample size of males from the Cascade Plateau (N = 48).

The fitted curves all have a t_0 which is substantially less then zero, as a result of the lack of small fish in the samples. The length-frequency distributions of the samples aged (Figure 6) clearly show this lack of small fish in the samples.

Mortality estimates

The estimated age composition of the catch by dropline, otter trawl and mesh net in Eastern Victoria, and by drop line and otter trawl in Western Victoria all show a predominance by three and four year old fish (Figures 7 and 8). The differences between the areas are greater than the differences between gear types within areas, reflecting the similar trend found in the underlying length-frequency distributions. This difference has translated to a greater abundance of seven and eight year old fish in samples landed in Eastern Victoria compared to Western Victoria.

Estimates of total instantaneous mortality for samples collected varied between 0.21 for the combined 1991-94 samples of mesh net caught fish, to 0.37 for the 1994 sample of fish caught by otter trawl in Western Victoria (Figures 9 and 10). The dropline samples from Eastern and Western Victorian waters for 1993 and 1994, and the combined Eastern Victorian otter trawl sample for 1991-94, all produced estimates between 0.26 and 0.29.

Discussion

Growth of blue-eye trevalla is relatively fast for the first three or four years (prior to recruitment to the fishery) and then slows. Blue-eye trevalla in southern Australian waters are potentially long-lived, but commercial catches are composed mostly of young fish, less than 15 years old. There is strong evidence that fish from the Cascade Plateau are faster growing than those from elsewhere around Tasmania or Victorian waters.

The growth of blue eye trevalla which is indicated from these analyses is slow relative to that reported for blue-eye trevalla from New Zealand waters (Horn 1988), and that previously estimated by Webb (1987) and Jones (1985). The latter two workers undertook only very preliminary analyses of small samples and their growth estimates are likely to be in error. Jones (1985) used scales to estimate age and this method has been frequently been shown to underestimate ages. Webb (1987) used otoliths, but whether he obtained his age estimates from whole or sectioned otoliths is not clear. Age estimates from whole otoliths are frequently subject to the same errors as scales, because as fish approach their asymptotic length growth increments are only laid down on the medial surface of the otolith, and sectioning is needed to view and count them. The work of Horn (1988) is based on similar methods to the present analysis, but even the faster growing population from the Cascade Plateau grow slower and reach older ages than he reported. This is believed to reflect a real difference between the populations, as comparisons between laboratories in the two countries indicate no difference in interpretation of otolith structure.

The growth curves calculated from the samples aged are not representative of the growth of young fish, which is apparently much faster. The samples contained few fish less than three years old, and all age classes less than about eight years old are likely to be biased towards the faster growing fish. This has produced large negative estimates for t0 which are unrealistic and have wide confidence intervals. Horn (1988) faced a similar problem and used back-calculated sizes at age for fish up to 3 years. This was not attempted in the present study. Inclusion of small fish in the sample would be likely to increase estimates of K and t_0 and lower the estimates of L_∞.

The relationship between fish length and otolith weight supports the contention that the growth of pre-recruits is much faster than that of older fish. This relationship (see section on age determination) has no subjective measure, such as age, which may introduce errors, yet also shows that otolith growth in small fish is much faster than after recruitment.

The total mortality estimates derived in the present study are lower than the high estimates of natural mortality derived by Horn and Massey (1989) for grounds in New Zealand of 0.5 and 0.8. However, these authors hypothesised that their catch age structure was biased by size-specific variation in vulnerability to trawl gear and age-specific migration, which tended to overestimate M. They concluded that an M exceeding 0.3 would be unlikely. The estimates of total mortality derived from the present study agree with this conclusion.

The data from this study suggest that blue-eye trevalla in southern Australian waters is a relatively long-lived species, and that their populations could not sustain a high level of exploitation without significantly reducing their biomass. Localised depletion has been reported to have occurred in some areas (Williams 1993).

Table 1. Mean lengths at age for Female blue-eye trevalla by area, for all areas combined and for all areas except Cascade Plateau combined.

	N.E. Tas			S.E. Tas			West Tas			Western Bass Strait			All Non-Cascade			Cascade Plateau			All Areas		
Age	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d
2	8	50.88	3.64	3	49.33	2.31	11	49.45	1.81				22	49.95	2.65	1	57.00		23	50.26	2.97
3	125	50.08	1.86	54	50.54	2.00	65	49.55	1.81				244	50.04	1.90				244	50.04	1.90
4	139	51.20	2.84	46	51.65	2.40	73	51.11	2.00				258	51.26	2.55	1	63.00		259	51.30	2.64
5	56	51.55	1.73	26	52.88	2.69	44	52.61	2.27	1	56.00		127	52.23	2.23	1	63.00		128	52.31	2.41
6	28	52.21	3.51	18	53.94	2.36	22	54.14	2.53	2	58.50	0.71	70	53.44	3.12				70	53.44	3.12
7	25	56.48	4.51	22	57.27	2.99	20	55.35	2.48	6	57.50	2.95	73	56.49	3.50				73	56.49	3.50
8	27	58.41	4.49	17	57.47	3.30	12	57.92	4.66	5	57.00	2.00	61	57.93	4.02	2	71.00	0.00	63	58.35	4.58
9	30	59.27	5.39	18	59.50	2.83	1	55.00		3	61.00	2.00	52	59.37	4.46	13	67.38	4.29	65	60.97	5.46
10	16	63.00	5.24	17	63.94	2.73	5	59.80	2.95	1	59.00		39	62.90	4.13	10	69.90	5.26	49	64.33	5.18
11	25	63.52	7.56	14	62.64	3.77	3	61.67	4.93	1	61.00		43	63.05	6.22	9	73.56	3.43	52	64.87	7.06
12	15	68.80	7.75	14	63.00	3.28				1	66.00		30	65.63	4.63	12	73.17	6.87	42	67.79	6.30
13	15	68.80	7.75	8	64.88	3.27	1	63.00		1	63.00		25	67.08	6.56	11	76.27	8.32	36	69.89	8.23
14	13	68.92	4.42	8	63.13	3.72	1	66.00					22	66.68	4.87	18	79.94	9.40	40	72.65	9.79
15	14	66.29	5.82	6	64.50	4.18	2	66.00	0.00				22	65.77	5.08	20	80.45	8.23	42	72.76	9.98
16	8	73.63	3.54				1	68.00					9	73.00	3.81	17	82.65	7.76	26	79.31	8.07
17	3	81.67	5.03	3	67.33	2.31							6	74.50	8.60	19	80.68	5.07	25	79.20	6.47
18	8	74.00	6.37	2	68.50	6.36							10	72.90	6.44	16	86.63	7.02	26	81.35	9.53
19	4	75.25	6.24				1	73.00					5	74.80	5.50	9	88.78	8.09	14	83.79	9.89
20	6	76.00	5.06										6	76.00	5.06	10	88.30	7.54	16	83.69	8.97
21	4	81.25	6.99										4	81.25	6.99	12	91.00	5.89	16	88.56	7.37
22	4	84.25	9.36				1	77.00					5	82.80	8.73	4	86.00	4.97	9	84.22	7.08
23	3	81.00	2.65	2	74.50	4.95							5	78.40	4.72	4	92.00	3.32	9	84.67	8.40
24	2	93.50	9.19										2	93.50	9.19	1	77.00		3	88.00	11.53
25	1	72.00											1	72.00		4	92.50	1.00	5	88.40	9.21
26	3	87.33	7.37										3	87.33	7.37	1	82.00		4	86.00	6.58
27	1	79.00											1	79.00		1	76.00		2	77.50	2.12
28				1	87.00								1	87.00		1	100.00		2	93.50	9.19
29																1	90.00		1	90.00	
30																1	98.00		1	98.00	
32																1	104.00		1	104.00	
40	1	86.00											1	86.00					1	86.00	
42	1	97.00											1	97.00					1	97.00	

Table 2. Mean lengths at age for male blue-eye trevalla by area, for all areas combined and for all areas except Cascade Plateau combined.

	N.E. Tas			S.E. Tas			West Tas			Western Bass Strait			All Non-Cascade			Cascade Plateau			All Areas		
Age	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d	n	Mean	s.d
2	8	49.25	2.66	8	49.63	0.74	4	48.75	1.71				20	49.30	1.84				20	49.30	1.84
3	116	49.43	2.47	37	50.38	2.03	56	49.79	1.87				209	49.69	2.26	1	64.00		210	49.76	2.47
4	139	50.29	2.13	45	50.16	1.88	62	50.69	2.21	1	51.00		247	50.37	2.11				247	50.37	2.11
5	70	51.70	2.49	19	52.58	2.48	27	52.81	2.73				116	52.10	2.57				116	52.10	2.57
6	30	53.33	2.12	17	53.76	2.66	21	54.67	2.29	2	54.00	1.41	70	53.86	2.32	1	58.00		71	53.92	2.36
7	43	55.05	3.29	18	55.56	2.91	17	56.71	2.42	7	56.86	2.79	85	55.64	3.06	3	67.00	3.46	88	56.02	3.69
8	50	56.64	3.08	30	56.53	3.15	13	55.62	1.85	3	56.00	1.00	96	56.45	2.91	3	62.33	3.51	99	56.63	3.08
9	40	59.68	3.65	18	58.50	3.03	15	56.73	3.28	2	59.00	4.24	75	58.79	3.57	5	63.60	1.14	80	59.09	3.66
10	39	60.23	3.86	14	59.79	1.67	8	58.13	2.10	7	61.86	3.76	68	60.06	3.39	3	64.00	1.00	71	60.23	3.42
11	29	61.83	3.39	16	60.31	2.24	4	58.25	3.30				49	61.04	3.19	8	66.25	4.83	57	61.77	3.87
12	27	62.15	4.25	9	61.00	1.87							36	61.86	3.80	1	67.00		37	62.00	3.84
13	14	64.14	3.30	3	62.67	1.53	2	61.00	2.83				19	63.58	3.11	3	66.67	6.43	22	64.00	3.66
14	17	63.53	3.20	4	62.00	2.94							21	63.24	3.14	4	72.00	8.29	25	64.64	5.25
15	18	64.44	3.76	2	66.00	4.24							20	64.60	3.72	1	68.00		21	64.76	3.70
16	7	63.57	1.40	2	63.00	2.83							9	63.44	1.59	1	71.00		10	64.20	2.82
17	5	67.80	6.46	1	68.00								6	67.83	5.78	3	78.67	4.04	9	71.44	7.37
18	6	67.83	7.70	1	75.00								7	68.86	7.54	4	80.25	3.86	11	73.00	8.46
19	5	67.80	3.42	1	70.00								6	68.17	3.19	1	78.00		7	69.57	4.72
20	3	69.67	5.51										3	69.67	5.51				3	69.67	5.51
21	4	66.25	1.26										4	66.25	1.26				4	66.25	1.26
22	3	73.00	7.81										3	73.00	7.81	4	87.00	6.06	7	81.00	9.73
23	1	70.00											1	70.00		1	90.00		2	80.00	14.14
24	1	65.00											1	65.00					1	65.00	
26	2	73.00	2.83										2	73.00	2.83	1	79.00		3	75.00	4.00
27	3	74.33	10.41										3	74.33	10.41				3	74.33	10.41
34	1	68.00											1	68.00					1	68.00	
39	1	70.00											1	70.00					1	70.00	

Table 3. Parameters of the von Bertalanffy growth curve (with 95% confidence intervals) as fitted to the data for for each area.

Area	Sex	N	L inf	95% Conf. Int	K	95% Conf. Int	To	95% Conf. Int
North East Tas	F	585	95.0	86.0 to 104	0.050	0.049 to 0.051	-10.9	-61.5 to 39.7
	M	682	80.0	73.0 to 87	0.060	0.059 to 0.061	-12.1	-51.9 to 27.6
South East Tas	F	279	95.0	81.9 to 108.1	0.040	0.039 to 0.041	-14.8	-113.4 to 83.9
	M	245	79.9	68.2 to 91.5	0.060	0.058 to 0.062	-12.0	-82.0 to 58
West Tas	F	263	84.7	72.5 to 96.9	0.050	0.049 to 0.051	-14.0	-105.2 to 77.1
	M	229	69.1	58.3 to 79.8	0.080	0.078 to 0.082	-12.4	-85.8 to 60.9
Non-Cascade (combined)	F	1148	119.9	112.2 to 127.7	0.030	0.029 to 0.031	-13.8	-77.0 to 49.4
	M	1178	75.0	69.9 to 80.1	0.070	0.069 to 0.071	-11.7	-39.1 to 15.8
Cascade Plat.	F	200	120.0	100.8 to 139.2	0.040	0.039 to 0.041	-11.7	-286.7 to 263.3
	M	48	Not estimated					
All	F	1348	130.0	122.1 to 137.9	0.030	0.023 to 0.03	-12.0	-68.7 to 44.6
	M	1226	85.0	79.3 to 90.7	0.050	0.049 to 0.051	-14.0	-55.6 to 27.6

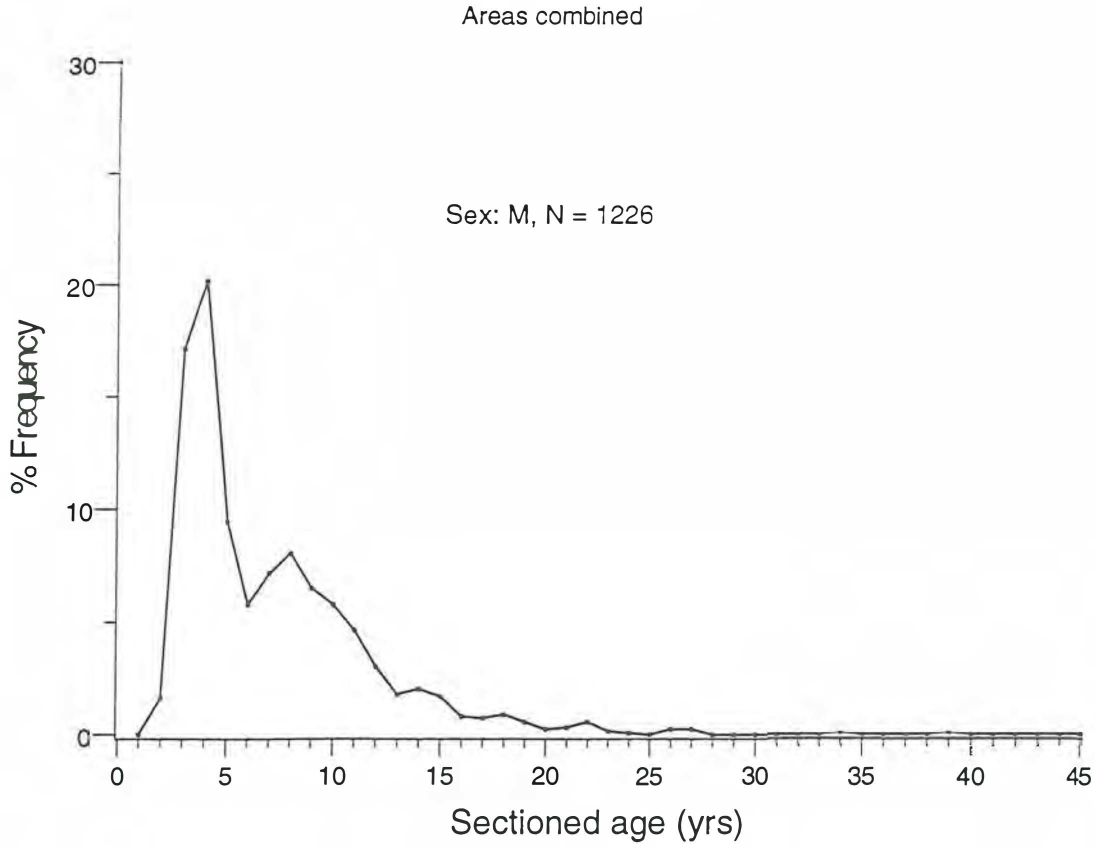


Figure 1. Age composition of aged sample of blue-eye trevalla by sex, all areas combined.

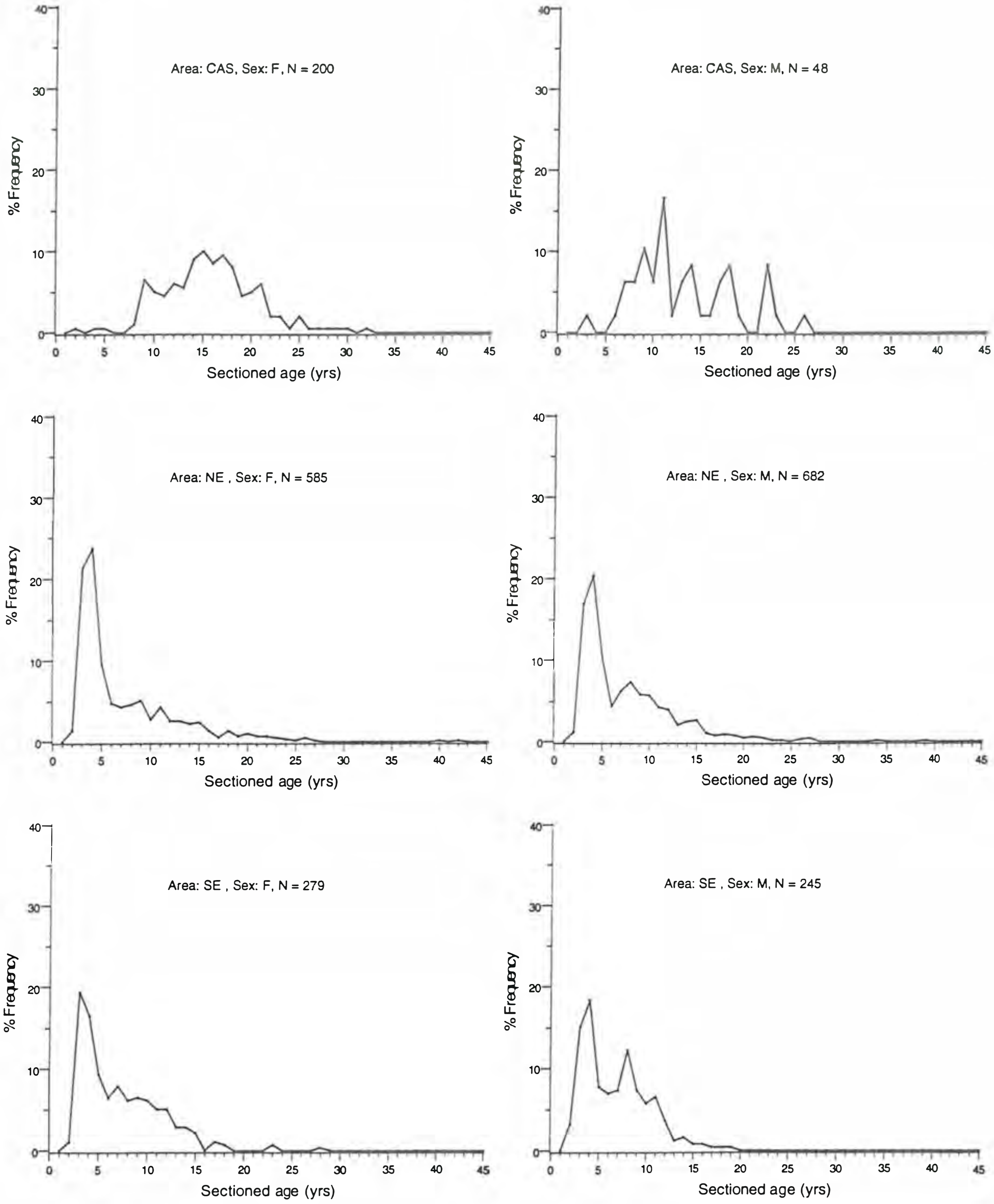


Figure 2. Age composition by sex for Cascade Plateau, North East Tasmania, and South East Tasmania.

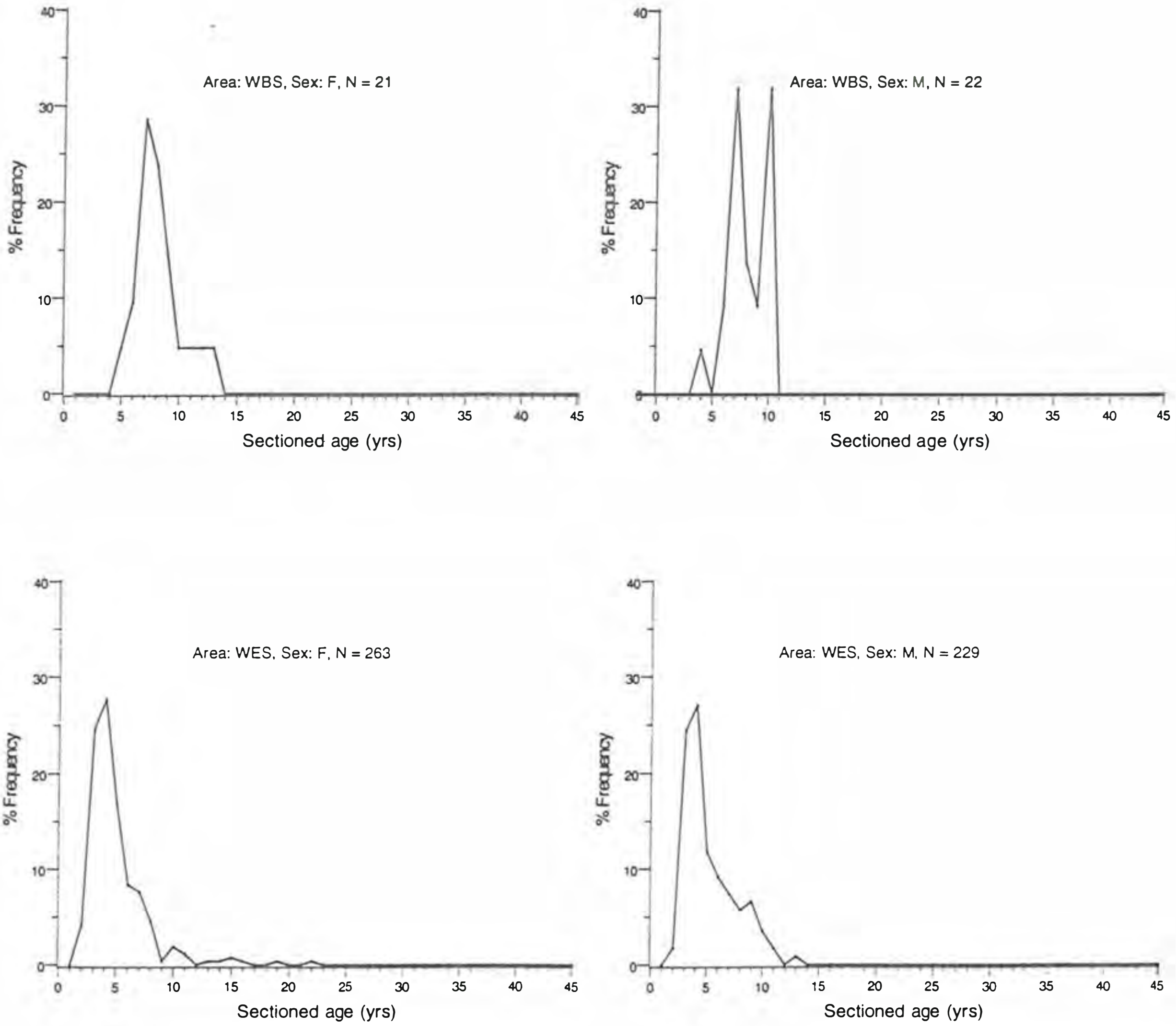
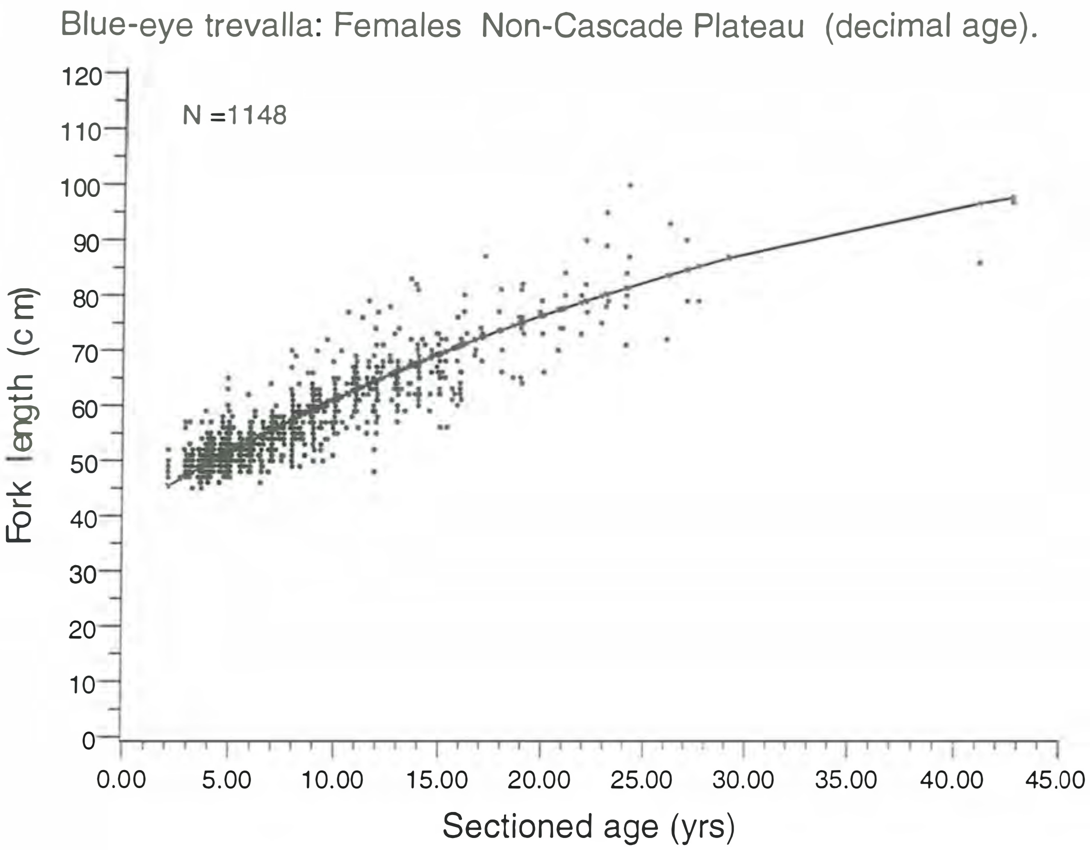


Figure 3. Age composition by sex for Western Bass Strait, Western Tasmania.



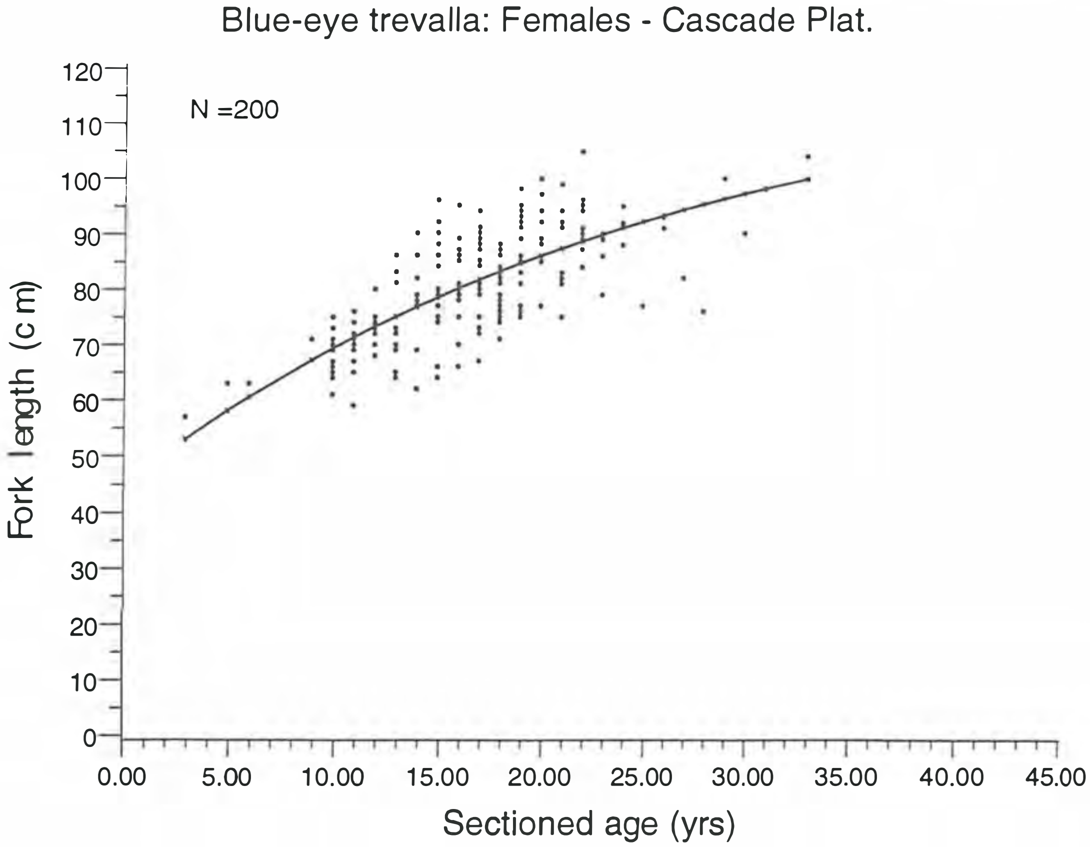


Figure 4. Growth curves for female blue-eye trevalla from the Cascade Plateau and other areas combined. Parameters of the growth curves are given in Table 3.

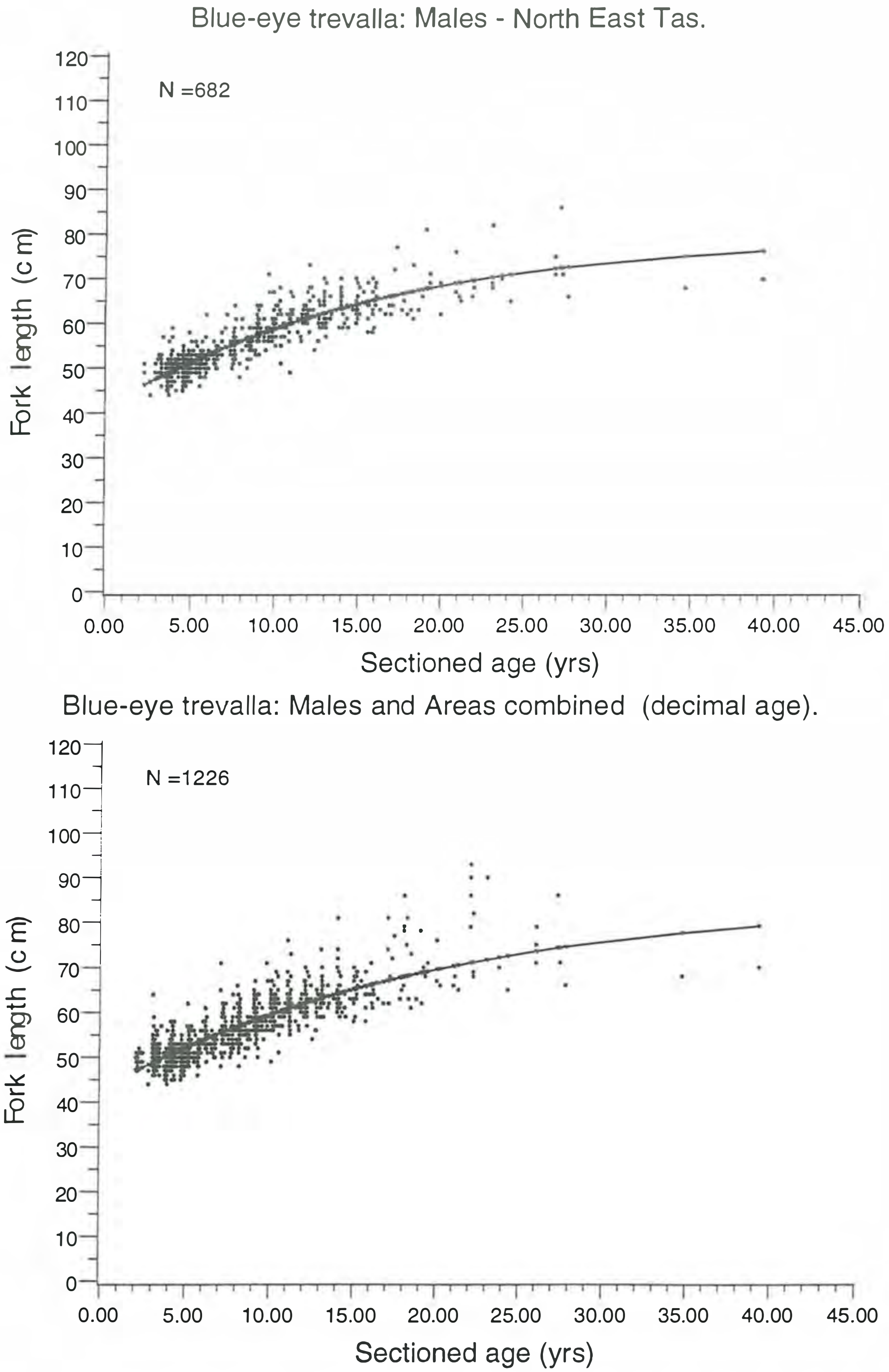


Figure 5. Growth curves for males blue-eye trevalla from North East Tasmania and for all areas combined. Parameters of the growth curves are given in Table 3.

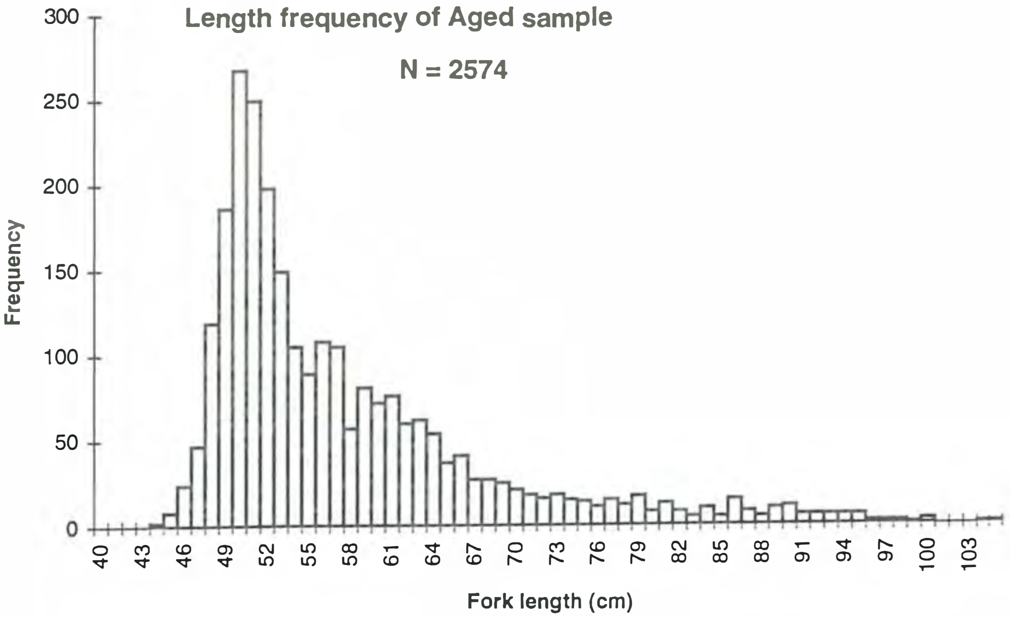


Figure 6. Length frequency of aged sample blue-eye trevalla - areas and sexes combined.

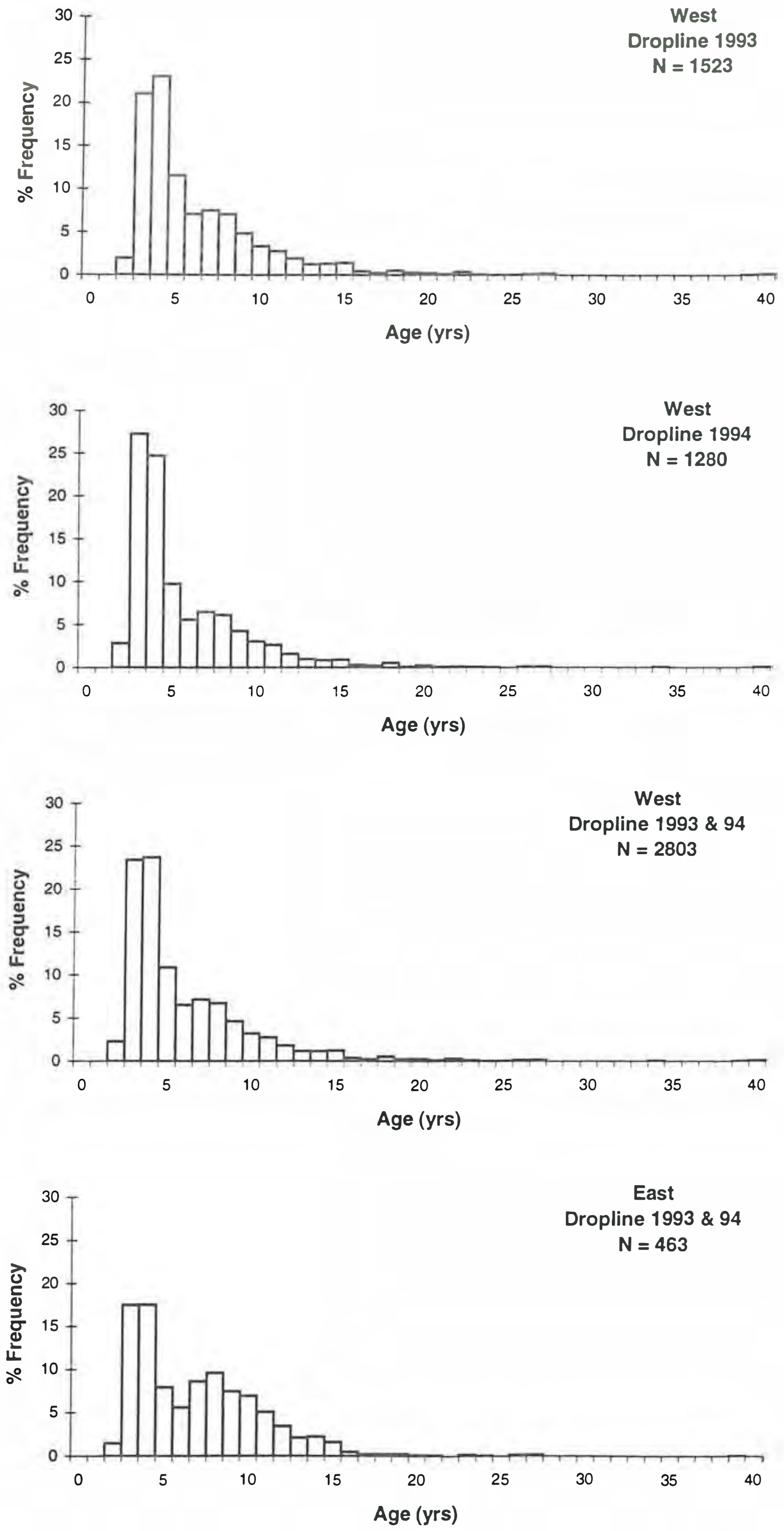
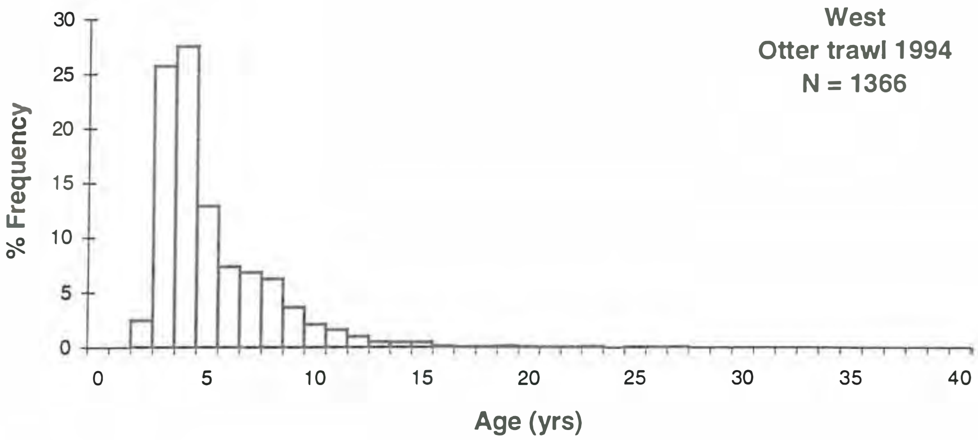
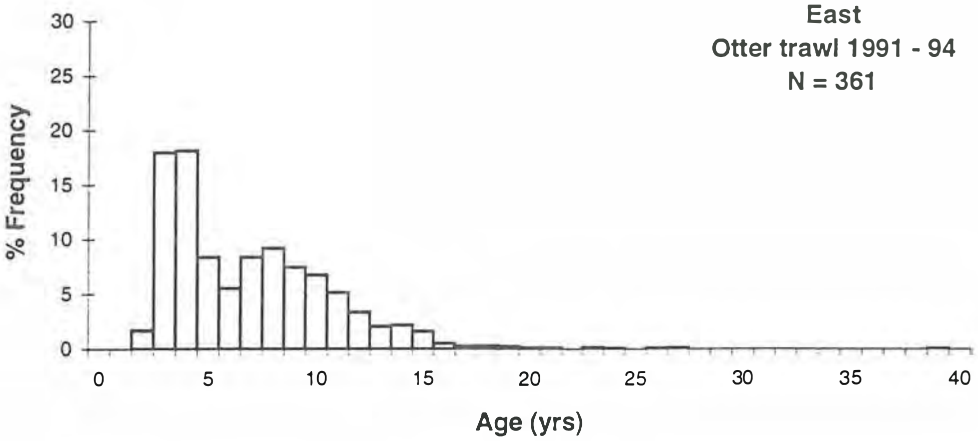


Figure 7. Calculated age composition of the catch of blue-eye trevalla by drop liners landed in West and East Victoria in 1993 & 94.





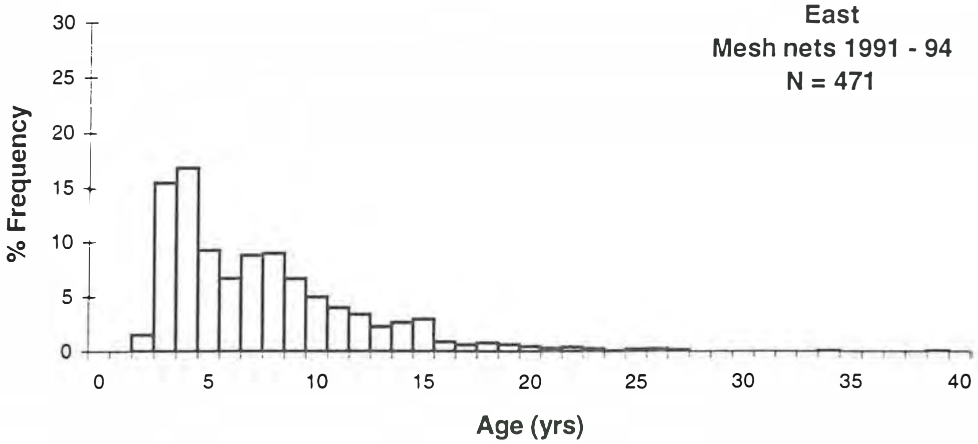


Figure 8. Calculated age composition of the catch of blue-eye trevalla by otter trawl and mesh net, and landed in West and East Victoria in 1991 to 1994.

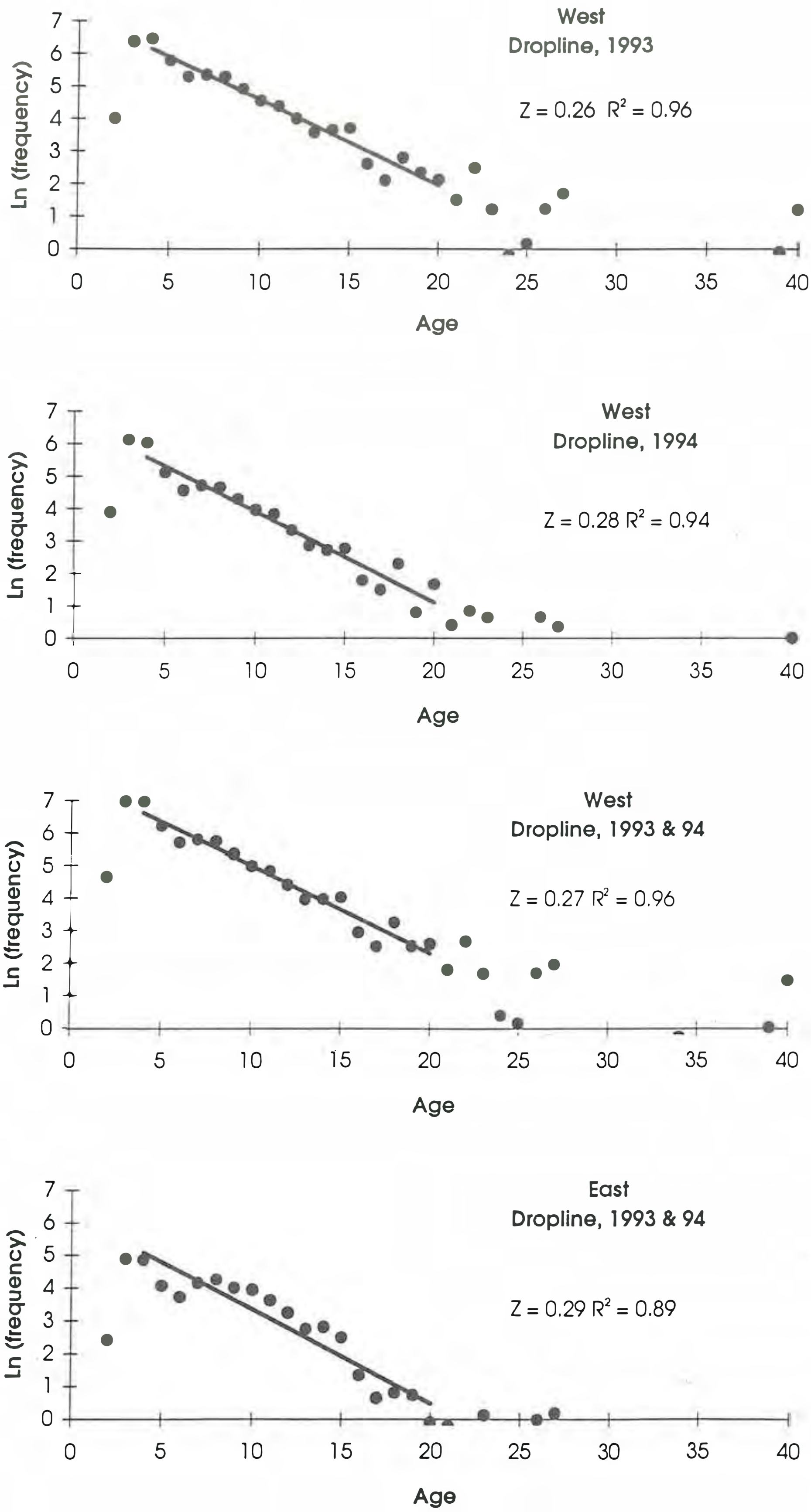
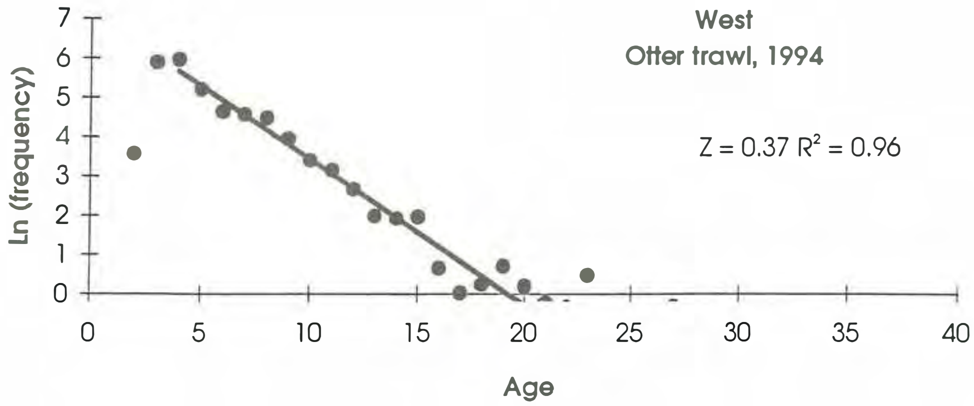


Figure 9. Mortalities estimated from catch curves for blue-eye trevalla caught by dropliners and landed in West and East Victoria, 1993 and 94.



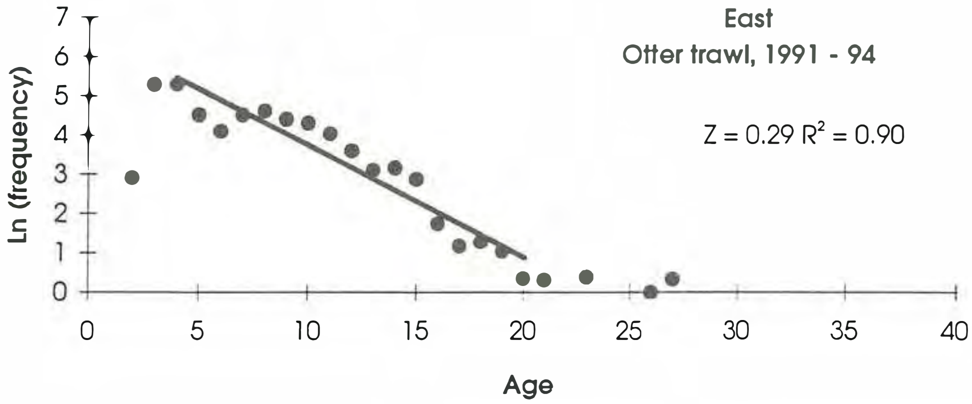


Figure 10. Mortalities estimated from catch curves for blue-eye trevalla caught by otter trawl and mesh nets and landed in West and East Victoria, 1993 and 94.

PART 4

TAGGING EXPERIMENTS

(H. Williams, P., D. Carter)

Materials and methods

Similar break-away hooks were used in this project to tag blue-eye trevalla as those previously used in New Zealand (Horn 1989). Baited hooks with vinyl yellow tubing were attached to lines with light breaking strain snood. In theory, when a fish caught on the hook struggles to escape, the snood breaks and the fish escapes with the tagged hook set in its mouth. Stainless steel circle hooks (Mustad Beak size 7), and nylon coated stainless steel fishing trace were used. Fishing trace of 10 kg breaking strength was used to ensure that the hook was set firmly in the mouth of the fish. Break-away hooks were set alternatively with normal hooks (every second hook) as a control of the composition of the fish population at the time of tagging.
In Tasmania, 7 tagging cruises were undertaken, 4 by the FRV *Challenger* , one by a chartered vessel, and 2 during commercial fishing operations with professional fishers who generously offered to set a few break-away hooks on their drop-lines. Two cruises were also undertaken in Victoria onboard chartered vessels.

Results

The list of break-away tags released are shown in Appendix II. A total of 582 tags were lost, 489 off Tasmania and 93 off Victoria (about 17% of all tags released off Tasmania were released during commercial fishing). The number of tags lost represented more than 3 times the number of blue-eye trevalla caught on adjacent normal hooks. For example, in Tasmania, during the 5 non-commercial tagging cruises, 127 blue-eye trevalla were caught and 403 tags were lost, most of them near the bottom. No tags have been returned as yet.

Discussion

There were problems with the use of break-away hooks that seriously limited the usefulness of this tagging method. Apart from problems associated with fishing operations (bad weather conditions, poor catch rate), there were important problems more specifically related to the method itself. It seems that more tags were lost by brushing of the gear against the bottom and by tagging other species (sharks mainly) than by tagging blue-eye trevalla. In New Zealand, of 2122 tags lost (of which about 2000 were assumed to have tagged blue-eye trevalla, Horn 1989), 2.2% (47) were recovered, as soon as one week after tagging, but no later than 231 days after tagging (Horn, personal communication). Horn concluded from his study that blue-eye trevalla were fairly sedentary in the short term.

PART 5

SEMI-PELAGIC (MID-WATER) TRAWL SURVEYS

(S. Morison, D. Carter)

Introduction

With the recent interest in midwater trawling in the South East Fishery, there was potential for catches of blue-eye trevalla to increase, either from direct targeting or as a by-catch from targeting other species such as blue grenadier (*Macruronus novaezelandiae*) or alfonsino (*Beryx splendens*) (Williams, 1993).

Following the introduction of these methods in New Zealand during the early 1980's, trawling replaced line fishing as the main method of fishing for blue-eye trevalla in some areas. As the contribution of trawl catches to total landings in New Zealand increased there was a concomitant rise in the proportion of juvenile fish landed. At present up to two thirds of the New Zealand trawl catch of blue-eye trevalla (by weight) is comprised of juvenile fish (Horn, 1987).

The trawl technique referred to is better termed *semi-pelagic trawling* as the nets are towed only a few metres above the bottom, and not in the middle of the water column as the term midwater implies.

Concerns at the potential changes that semi-pelagic trawling may have on the blue-eye trevalla resource in waters off southern Australia, and its interaction with the established line fishery, caused considerable controversy between the different sectors of the fishing industry. Concerns developed around several issues, including:

- the unknown status of the resource and thus the unknown capacity for it to sustain increased effort and catches,
- the effect of increased landings and different product quality on markets,
- the effect of cost differentials between semi-pelagic trawling and line fishing on the ultimate viability of the line fishing fleet,
- the desirability of developing semi-pelagic trawling techniques for otherwise lightly exploited species such as alfonsino, blue grenadier, cardinal fish (*Epigonus telescopus*) and squid.

In order to address some of these concerns, a series of semi-pelagic trawl surveys were planned in three areas:

- western Bass Strait,
- southwestern and southern Tasmania, and
- eastern Bass Strait and eastern Tasmania.

The objectives of these surveys were to:

- explore the potential for semi-pelagic trawl resources other than blue-eye trevalla,
- determine the level of by-catch and catch rates off blue-eye trevalla from semi-pelagic trawling,
- evaluate the vulnerability and selectivity of the blue-eye trevalla populations to semi-pelagic trawling, and
- collect basis biological data for all species caught.

Methods:

A survey protocol was developed in consultation with industry, and commercial fishers invited to express interest in fishing in one of three areas. Each area was to be surveyed once every three months over a two year period, by a different vessel in each year. Full details of the survey protocol are listed in Appendix III. Briefly, vessels were to search for fishable marks within a chosen area and fish selected marks. Trip limits otherwise in force for trawl caught blue-eye trevalla (500 kg per trip) were relaxed and catches of up to 10 tonnes per trip were allowed during the survey. Any excess was to be forfeited, and the proceeds from its sale placed into a trust account to support research on the blue-eye trevalla fishery. Scientific observers were to be present on all trawl surveys.

Only one vessel agreed to participate in a semi-pelagic trawl survey, in western Bass Strait area off western Victoria. Three surveys were undertaken by this vessel: in September 1992, January 1993, and May 1993. Low catches led to the winter 1993 survey being abandoned. Individual cruise reports have been prepared (Appendix III). The area searched extended over the complete designated survey zone, from the South Australian border to south King Island.

The size distribution of the catch during the semi-pelagic trawl surveys was compared with those of blue-eye trevalla caught by otter trawl and drop-line over a two year period from April 1992 to March 1994.

Results:

A total of 22 shots were made over the three surveys (Table 1) over bottom depths of 274-512 m, except for one shot at 750 m (Figure 1). A total of 13 species were caught during the surveys, eight of these being commercial species, however, the most species were caught in any one shot was four.

Catch rates were variable. A total of 4,898 kg of blue-eye trevalla were caught, however, 4214 kg (98%) of this catch came from one shot on the third survey. Blue warehou was the only other species caught in significant quantities (2666 kg), but all but 11kg of this catch resulted from a single shot. No alfonsino or cardinal fish were caught and only small quantities of blue grenadier and squid. Small quantities of frost fish (*Lepidopus caudatus*) were taken in five of the shots.

The blue-eye trevalla caught ranged in size from 47 cm to 97 cm fork length, with a mode at 56 cm (Figure 2). The size distribution of fish caught varied between shots. For example, all the fish over 65 cm from survey 1 came from one shot which included no smaller fish. The overall size distribution of the catch by semi-pelagic trawl has a larger mode than the catches of either drop-line or otter trawl (Figure 3), and contains fewer fish less than 50 cm.

Discussion

Blue-eye trevalla can be effectively targeted by semi-pelagic trawl gear in western Bass Strait. However, data from the surveys are insufficient to indicate the effectiveness of semi-pelagic trawling for species other than blue-eye trevalla.

The level of by-catch from shots of semi-pelagic trawl gear was low with few non-target species recorded in any individual shot. Semi-pelagic trawl nets have been previously found to catch fewer unwanted species and to have less impact on the substrate than demersal (otter) trawl nets (Ramm *et al.* 1993).

Individual catches of blue-eye trevalla were quite high, however, there was large shot by shot variation in the quantity and size of fish in the catch. This prevents any useful estimation of likely catch rates for semi-pelagic trawl gear in western Bass Strait waters. The relative quality, and hence value, of the product caught by different gear types also needs to be considered. Drop-lines are known to produce fish in good condition, and semi-pelagic trawl nets have been found to produce higher quality product than a demersal trawl net (Ramm *et al.* 1993). Semi-pelagic trawl gear may generate higher returns to fishers for an equivalent weight of otter trawl caught fish even if catch rates are lower.

There is no evidence from the surveys that semi-pelagic trawl gear would catch smaller fish than are currently taken by the drop-line fishery in the same area; indeed, semi-pelagic trawling may catch proportionally fewer small fish than are currently taken by either drop-line or otter trawls. However, the variation in the size distribution of individual shots indicates the need for caution in interpreting these data.

Finally, experience from these surveys indicates that if future surveys of this type are to more successful, they would need to be fully funded and not be dependent on the goodwill of industry.

Table 1. Results of semi-pelagic trawl surveys for blue-eye trevalla.

Survey	Shot	Start_time	Depth	Species	Number	Kg	Comments
1	1	2200	296	Blue warehou	7	11	Shot through middle of mark
7-9/9/92				Porcupine fish	2		
	2	230	512	Blue eye trevalla	33	98	Tow 5-10m off bottom
				Blue grenadier	3	3	
	3	1030	750	Deep sea Squid	8		Tow 100m off bottom
	4	1745	322	Barracouta	7	7	Tow 20m off bottom
				Sunfish	1		
	5	1845	322	Blue warehou		2655	Repeat last shot
	6	2230	499	Nil			Missed mark
	7		499	Blue eye trevalla	23	254	Repeat, snagged on bottom
2	1	1904	457	Blue eye trevalla	54	155	
4-7/1/93	2	702	502	Frost fish	11	20	Missed mark
	3	1430	457	Blue eye trevalla	60	166	
3	1	1910	393	Blue eye trevalla	1	3.5	
11-18/5/93	2	220	400	Blue eye trevalla	1	2.5	Longer tow through feed mark
				Frost fish	2	2	
				Squid	8		
	3	815	274	Frost fish	1		Long tow / very rough
				Squid	8		
	4	1900	448	Squid	6		
	5	350	393	Squid	12		Towed through two marks
	6	850	347	Frost fish	12		Long tow towards bank
	7	1800	362	Blue eye trevalla	2	5	Missed mark
				Jack mackerel	1		
				Squid	6		
	8	2025	356	Squid	3		Repeat of last shot
				King crab	1		
	9	740	400	Blue grenadier	2		
				Frost fish	20		
				NZ dory	4		
				Whiptail	8		
	10	1730	460	Blue eye trevalla		4214	
	11	2225	411				Towed through two marks
	12	235	466	Squid	1		

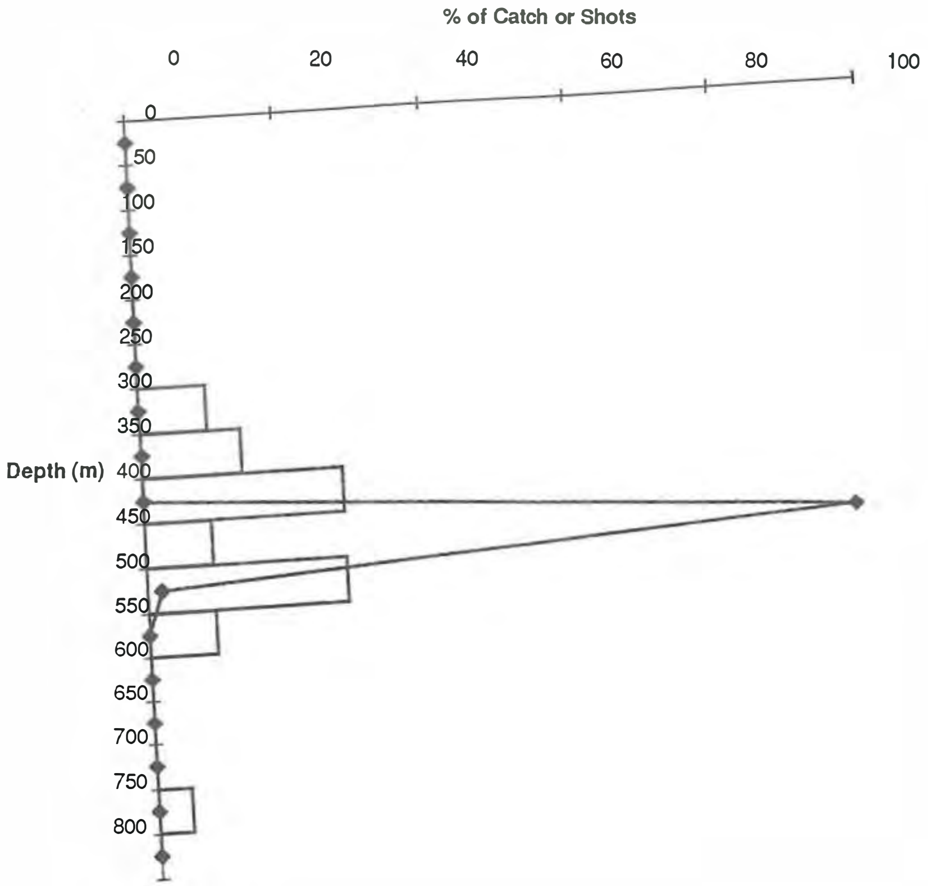


Figure 1. Depth distribution of shots (bars) and catch of blue-eye trevalla by weight (line). Results of three semi-pelagic trawl surveys combined.

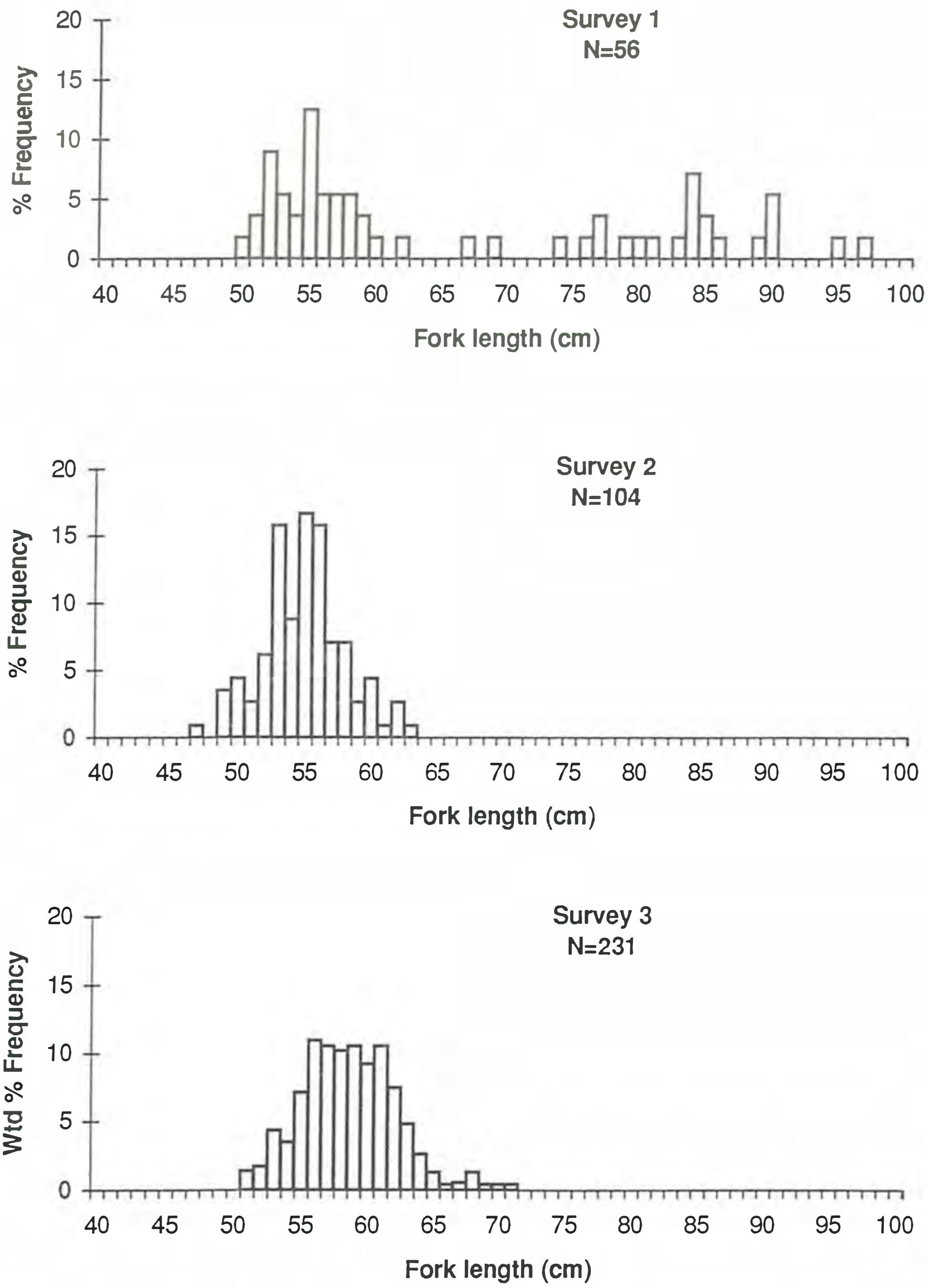


Figure 2. Length frequency distributions of blue-eye trevalla caught by semi-pelagic trawls, Sep 92-May93. Sample from one large shot in survey 3 weighted by total shot catch before combining with other data.

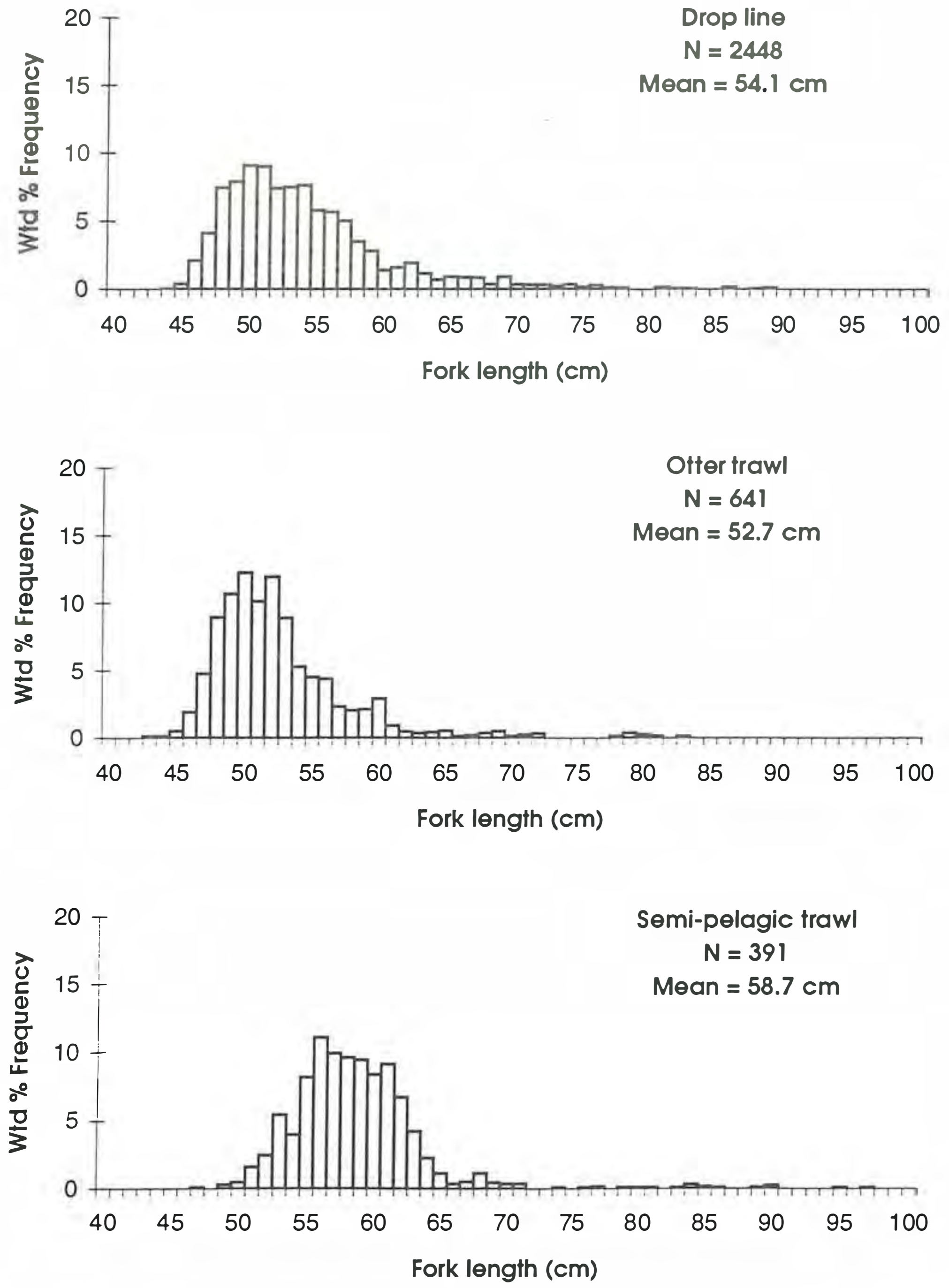


Figure 3. Length frequency distributions of blue-eye trevalla caught by drop-lines, otter (demersal) trawls, and semi-pelagic trawls. Drop-line and otter trawl data for Apr 92-Mar 94 combined.

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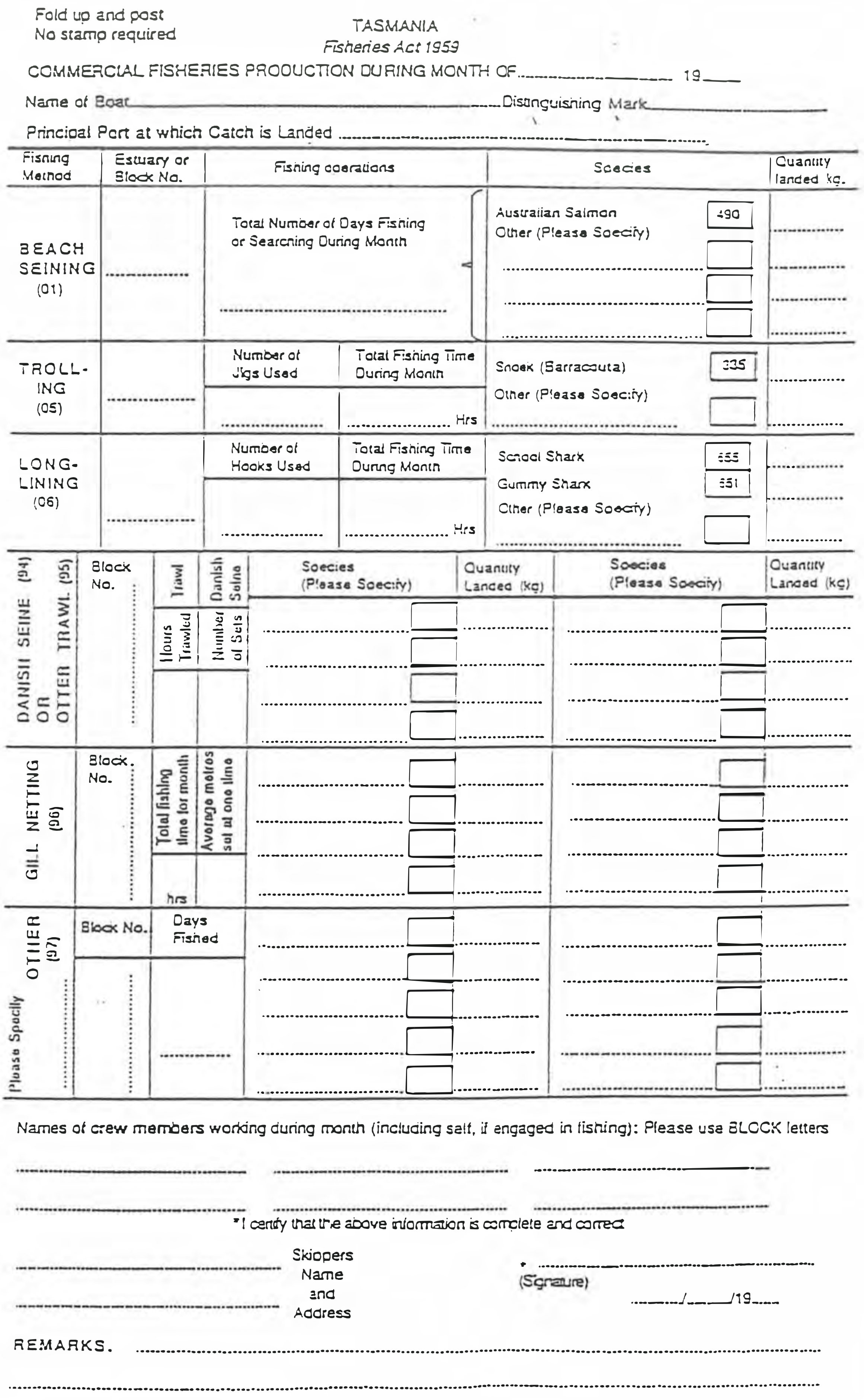
Appendices

Appendix I: Tasmanian Monthly General Fishing Return.



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No stamp required

TASMANIA
Fisheries Act 1959

COMMERCIAL FISHERIES PRODUCTION DURING MONTH OF.................... 19.....

Name of Boat .... Distinguishing Mark ....

Principal Port at which Catch is Landed ....

Fishing Method	Estuary or Block No.	Fishing operations		Species		Quantity landed kg.
BEACH SEINING (01)	....	Total Number of Days Fishing or Searching During Month		Australian Salmon	490	....
				Other (Please Specify)	☐	....
		....		....	☐	....
				....	☐	....
TROLL-ING (05)	....	Number of Jigs Used	Total Fishing Time During Month	Snoek (Barracouta)	335	....
		....	.... Hrs	Other (Please Specify)	☐	....
LONG-LINING (06)	....	Number of Hooks Used	Total Fishing Time During Month	School Shark	655	....
				Gummy Shark	651	....
		....	.... Hrs	Other (Please Specify)	☐	....

	Block No.			Species (Please Specify)		Quantity Landed (kg)	Species (Please Specify)		Quantity Landed (kg)
DANISH SEINE (94) OR OTTER TRAWL (95)	....	Trawl	Danish Seine	....	☐	....	....	☐	....
		Hours Trawled	Number of Sets	....	☐	....	....	☐	....
				....	☐	....	....	☐	....
				....	☐	....	....	☐	....
GILL NETTING (96)	Block No.	Total fishing time for month	Average metres set at one time	....	☐	....	....	☐	....
				....	☐	....	....	☐	....
				....	☐	....	....	☐	....
		hrs		....	☐	....	....	☐	....
OTHER (97) Please Specify	Block No.	Days Fished		....	☐	....	....	☐	....
....	....			....	☐	....	....	☐	....
				....	☐	....	....	☐	....
		....		....	☐	....	....	☐	....
				....	☐	....	....	☐	....

Names of crew members working during month (including self, if engaged in fishing): Please use BLOCK letters

....

....

*I certify that the above information is complete and correct

.... Skippers Name and Address * ....

.... (Signature) ..../......./19.....

REMARKS. ....

....

Appendix II

List of released tags off Tasmania and Victoria

Tagging of blue-eye trevalla off Tasmania
List of break-away tags released

Note: *=duplicate TAG No

TAG No	Date	Lat	Long	Area	Cruise type
2	3/4/92			Maatsyuker Is	Commercial (Grenada)
4	26/4/92			Low Rocky Pt	Commercial (Robyn K)
5	14/4/92	42.43	148.23	E Maria	FRV Challenger
6	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
7	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
9	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
11	8/3/92	41.56	148.38	E Freycinet	Chartered Vessel (Glenn Eden)
12	26/4/92			Low Rocky Pt	Commercial (Robyn K)
14	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
15	24/4/92			Low Rocky Pt	Commercial (Robyn K)
16	23/4/92			Cape Sorell	Commercial (Robyn K)
18	25/4/92			Low Rocky Pt	Commercial (Robyn K)
21	3/4/92			Maatsyuker Is	Commercial (Grenada)
22	2/4/92			Maatsyuker Is	Commercial (Grenada)
23	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
26	9/4/92	41.17	148.40	St Helens	FRV Challenger
28	14/4/92	42.43	148.23	E Maria	FRV Challenger
29	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
31	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
33	11/3/92	41.10	148.39	St Helens	Chartered Vessel (Glenn Eden)
36	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
38	14/4/92	42.43	148.23	E Maria	FRV Challenger
43	14/4/92	42.43	148.23	E Maria	FRV Challenger
45	8/4/92	40.59	148.42	Eddystone	FRV Challenger
46	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
47	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
51	8/3/92	41.58	148.38	Freycinet	Chartered Vessel (Glenn Eden)
52	2/4/92			Maatsyuker Is	Commercial (Grenada)
55	10/4/92	41.52	148.37	Maria	FRV Challenger
56	3/4/92			Maatsyuker Is	Commercial (Grenada)
57	11/3/92	41.10	148.39	St Helens	Chartered Vessel (Glenn Eden)
59	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
61	23/4/92			Cape Sorell	Commercial (Robyn K)
63	23/4/92			Cape Sorell	Commercial (Robyn K)
64	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
65	2/4/92			Maatsyuker Is	Commercial (Grenada)
68	9/3/92	41.17	148.40	Eddystone Point	Chartered Vessel (Glenn Eden)
69	2/4/92			Maatsyuker Is	Commercial (Grenada)
70	24/4/92			Low Rocky Pt	Commercial (Robyn K)
71	8/4/92	41.03	148.42	Eddystone	FRV Challenger
74	1/4/92			Cascade	Commercial (Tasmanian Entreprise)
75	8/3/92	41.57	148.38	E Freycinet	Chartered Vessel (Glenn Eden)
77	1/4/92			Cascade	Commercial (Tasmanian Entreprise)
78	2/4/92			Maatsyuker Is	Commercial (Grenada)
79	3/4/92			Maatsyuker Is	Commercial (Grenada)
80	14/4/92	42.43	148.23	E Maria	FRV Challenger
81	14/4/92	42.44	148.23	E Maria	FRV Challenger
82	25/4/92			Low Rocky Pt	Commercial (Robyn K)
85	1/4/92			Cascade	Commercial (Tasmanian Entreprise)

TAG No	Date	Lat	Long	Area	Cruise type
86	26/4/92			Low Rocky Pt	Commercial (Robyn K)
87	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
88	2/4/92			Maatsyuker Is	Commercial (Grenada)
89	8/3/92	41.57	148.38	E Freycinet	Chartered Vessel (Glenn Eden)
91	2/4/92			Maatsyuker Is	Commercial (Grenada)
92	3/4/92			Maatsyuker Is	Commercial (Grenada)
93	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
95	26/4/92			Low Rocky Pt	Commercial (Robyn K)
96	3/4/92			Maatsyuker Is	Commercial (Grenada)
98	2/4/92			Maatsyuker Is	Commercial (Grenada)
100	23/4/92			Cape Sorell	Commercial (Robyn K)
104	10/4/92	41.53	148.37	Maria	FRV Challenger
107	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
110	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
111	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
113	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
114	10/4/92	41.53	148.37	Maria	FRV Challenger
115	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
116	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
117	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
119	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
122	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
123	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
125	14/4/92	42.44	148.23	E Maria	FRV Challenger
128	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
129	14/4/92	42.43	148.23	E Maria	FRV Challenger
131	10/4/92	41.53	148.37	Maria	FRV Challenger
134	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
135	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
136	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
137	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
138	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
139	10/4/92	41.53	148.37	Maria	FRV Challenger
144	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
146	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
148	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
150	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
182	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
199	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
202	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
203	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
204	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
205	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
207	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
210	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
211	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
213	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
215	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
216	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
217	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
218	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
221	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
222	11/3/92	41.09	148.39	St Helens	Chartered Vessel (Glenn Eden)
224	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
226	6/2/93	43.03	148.16	E Freycinet	FRV Challenger

TAG No	Date	Lat	Long	Area	Cruise type
227	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
228	9/4/92	41.17	148.40	St Helens	FRV Challenger
232	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
233	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
237	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
239	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
243	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
244	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
245	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
247	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
248	14/4/92	42.43	148.23	E Maria	FRV Challenger
249	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
251	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
252	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
254	9/4/92	41.17	148.40	St Helens	FRV Challenger
255	9/4/92	41.17	148.40	St Helens	FRV Challenger
256	9/4/92	41.17	148.40	St Helens	FRV Challenger
257	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
261	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
264	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
266	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
269	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
270	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
272	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
273	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
274	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
277	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
279	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
280	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
281	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
282	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
284	8/4/92	40.60	148.43	Eddystone	FRV Challenger
285	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
286*	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
286*	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
287	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
288	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
290	9/4/92	41.17	148.40	St Helens	FRV Challenger
291	8/4/92	41.03	148.42	Eddystone	FRV Challenger
292	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
293	8/4/92	40.60	148.43	Eddystone	FRV Challenger
294	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
296	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
297	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
301	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
303	8/4/92	40.59	148.43	Eddystone	FRV Challenger
304	10/4/92	41.53	148.37	Maria	FRV Challenger
307	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
309	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
310	14/4/92	42.43	148.23	E Maria	FRV Challenger
312	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
314	9/4/92	41.17	148.40	St Helens	FRV Challenger
315	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
317	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
318	8/2/94	43.44	147.55	30 mile patch	FRV Challenger

TAG No	Date	Lat	Long	Area	Cruise type
319	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
321	8/4/92	40.59	148.43	Eddystone	FRV Challenger
322	14/4/92	42.43	148.23	E Maria	FRV Challenger
323*	8/4/92	40.59	148.43	Eddystone	FRV Challenger
323*	8/4/92	40.59	148.43	Eddystone	FRV Challenger
324	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
325	14/4/92	42.43	148.22	E Maria	FRV Challenger
326	10/4/92	41.53	148.37	Maria	FRV Challenger
329	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
330	14/4/92	42.43	148.23	E Maria	FRV Challenger
331	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
332	14/4/92	42.43	148.22	E Maria	FRV Challenger
333	8/4/92	41.03	148.42	Eddystone	FRV Challenger
335	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
337	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
341	14/4/92	42.43	148.23	E Maria	FRV Challenger
342	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
343	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
345	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
346	14/4/92	42.44	148.23	E Maria	FRV Challenger
348	9/4/92	41.17	148.40	St Helens	FRV Challenger
349	9/4/92	41.17	148.40	St Helens	FRV Challenger
351	24/4/92			Low Rocky Pt	Commercial (Robyn K)
352	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
355	24/4/92			Low Rocky Pt	Commercial (Robyn K)
356	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
360	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
361	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
362	14/4/92	42.43	148.22	E Maria	FRV Challenger
363	24/4/92			Low Rocky Pt	Commercial (Robyn K)
364	24/4/92			Low Rocky Pt	Commercial (Robyn K)
365	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
367	24/4/92			Low Rocky Pt	Commercial (Robyn K)
368	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
369	25/4/92			Low Rocky Pt	Commercial (Robyn K)
371	25/4/92			Low Rocky Pt	Commercial (Robyn K)
372	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
375	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
377	24/4/92			Low Rocky Pt	Commercial (Robyn K)
378	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
379	14/4/92	42.43	148.23	E Maria	FRV Challenger
381	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
382	9/4/92	41.18	148.40	St Helens	FRV Challenger
383	14/4/92	42.43	148.23	E Maria	FRV Challenger
384	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
386	9/4/92	41.17	148.40	St Helens	FRV Challenger
387	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
388	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
389	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
392	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
393	14/4/92	42.43	148.23	E Maria	FRV Challenger
394	14/4/92	42.43	148.22	E Maria	FRV Challenger
395	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
396	9/4/92	41.03	148.42	St Helens	FRV Challenger
398	9/4/92	41.18	148.40	St Helens	FRV Challenger

TAG No	Date	Lat	Long	Area	Cruise type
399	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
400	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
406	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
444	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
502	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
504	24/4/92			Low Rocky Pt	Commercial (Robyn K)
505	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
506	8/4/92	40.59	148.42	Eddystone	FRV Challenger
508	25/4/92			Low Rocky Pt	Commercial (Robyn K)
509	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
511	26/4/92			Low Rocky Pt	Commercial (Robyn K)
512	11/3/92	41.10	148.39	St Helens	Chartered Vessel (Glenn Eden)
514	14/4/92	42.43	148.22	E Maria	FRV Challenger
515	2/4/92			Maatsyuker Is	Commercial (Grenada)
516	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
517	11/3/92	41.09	148.39	St Helens	Chartered Vessel (Glenn Eden)
518	24/4/92			Low Rocky Pt	Commercial (Robyn K)
520	23/4/92			Cape Sorell	Commercial (Robyn K)
521	25/4/92			Low Rocky Pt	Commercial (Robyn K)
522	3/4/92			Maatsyuker Is	Commercial (Grenada)
523	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
524	2/4/92			Maatsyuker Is	Commercial (Grenada)
525	8/3/92	41.57	148.38	E Freycinet	Chartered Vessel (Glenn Eden)
526	24/4/92			Low Rocky Pt	Commercial (Robyn K)
527	3/4/92			Maatsyuker Is	Commercial (Grenada)
528	8/3/92	41.53	148.37	E Bicheno	Chartered Vessel (Glenn Eden)
529	2/4/92			Maatsyuker Is	Commercial (Grenada)
530	2/4/92			Maatsyuker Is	Commercial (Grenada)
531	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
532	25/4/92			Low Rocky Pt	Commercial (Robyn K)
533	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
534	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
535	3/4/92			Maatsyuker Is	Commercial (Grenada)
536	26/4/92			Low Rocky Pt	Commercial (Robyn K)
540	25/4/92			Low Rocky Pt	Commercial (Robyn K)
541	9/4/92	41.17	148.40	St Helens	FRV Challenger
544	3/4/92			Maatsyuker Is	Commercial (Grenada)
545	9/4/92	41.17	148.40	St Helens	FRV Challenger
546	8/4/92	40.59	148.42	Eddystone	FRV Challenger
547	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
551	8/4/92	40.59	148.43	Eddystone	FRV Challenger
552	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
553	10/4/92	41.53	148.37	Maria	FRV Challenger
554	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
555	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
557	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
558	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
559	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
560	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
561	8/4/92	40.59	148.42	Eddystone	FRV Challenger
563	10/4/92	41.53	148.37	Maria	FRV Challenger
566	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
567	14/4/92	42.43	148.22	E Maria	FRV Challenger
568	14/4/92	42.43	148.23	E Maria	FRV Challenger
569	10/4/92	41.53	148.37	Maria	FRV Challenger

TAG No	Date	Lat	Long	Area	Cruise type
570	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
571	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
572	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
574	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
575	9/4/92	41.17	148.40	St Helens	FRV Challenger
579	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
580	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
582	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
583	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
584	10/4/92	41.53	148.37	Maria	FRV Challenger
586	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
587	8/4/92	40.59	148.43	Eddystone	FRV Challenger
591	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
592	8/4/92	40.59	148.42	Eddystone	FRV Challenger
593	14/4/92	42.43	148.23	E Maria	FRV Challenger
594	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
596	8/4/92	40.59	148.43	Eddystone	FRV Challenger
597	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
600	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
604	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
605	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
606	24/4/92			Low Rocky Pt	Commercial (Robyn K)
609*	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
609*	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
610	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
611	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
612	14/4/92	42.43	148.23	E Maria	FRV Challenger
614	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
615	24/4/92			Low Rocky Pt	Commercial (Robyn K)
616	14/4/92	42.44	148.23	E Maria	FRV Challenger
617	2/4/92			Maatsyuker Is	Commercial (Grenada)
618	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
619	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
620	24/4/92			Low Rocky Pt	Commercial (Robyn K)
621	3/4/92			Maatsyuker Is	Commercial (Grenada)
622	9/4/92	41.17	148.40	St Helens	FRV Challenger
624	14/4/92	42.44	148.23	E Maria	FRV Challenger
625	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
628	8/4/92	41.02	148.42	Eddystone	FRV Challenger
629	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
632	24/4/92			Low Rocky Pt	Commercial (Robyn K)
633	2/4/92			Maatsyuker Is	Commercial (Grenada)
634	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
636	14/4/92	42.44	148.23	E Maria	FRV Challenger
637	9/4/92	41.17	148.40	St Helens	FRV Challenger
638	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
640	2/4/92			Maatsyuker Is	Commercial (Grenada)
641	2/4/92			Maatsyuker Is	Commercial (Grenada)
642	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
644	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
647	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
649	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
651	14/4/92	42.43	148.23	E Maria	FRV Challenger
652	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
653	9/12/92	43.42	147.54	30 mile patch	FRV Challenger

TAG No	Date	Lat	Long	Area	Cruise type
654	26/4/92			Low Rocky Pt	Commercial (Robyn K)
655	25/4/92			Low Rocky Pt	Commercial (Robyn K)
657	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
658	2/4/92			Maatsyuker Is	Commercial (Grenada)
659	1/4/92			Cascade	Commercial (Tasmanian Entreprise)
662	1/4/92			Cascade	Commercial (Tasmanian Entreprise)
663	3/4/92			Maatsyuker Is	Commercial (Grenada)
664	8/4/92	40.59	148.42	Eddystone	FRV Challenger
665	2/4/92			Maatsyuker Is	Commercial (Grenada)
670	26/4/92			Low Rocky Pt	Commercial (Robyn K)
671	7/3/92	43.32	148.30	N Maria	Chartered Vessel (Glenn Eden)
672	8/4/92	40.59	148.43	Eddystone	FRV Challenger
673	9/4/92	41.17	148.40	St Helens	FRV Challenger
674	23/4/92			Cape Sorell	Commercial (Robyn K)
675	8/3/92	41.57	148.38	E Freycinet	Chartered Vessel (Glenn Eden)
677	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
679*	2/4/92			Maatsyuker Is	Commercial (Grenada)
679*	3/4/92			Maatsyuker Is	Commercial (Grenada)
680	24/4/92			Low Rocky Pt	Commercial (Robyn K)
681	25/4/92			Low Rocky Pt	Commercial (Robyn K)
682	25/4/92			Low Rocky Pt	Commercial (Robyn K)
683	7/3/92	43.32	148.30	N Maria	Chartered Vessel (Glenn Eden)
684	8/3/92	41.56	148.38	E Freycinet	Chartered Vessel (Glenn Eden)
686	2/4/92			Maatsyuker Is	Commercial (Grenada)
687	2/4/92			Maatsyuker Is	Commercial (Grenada)
688	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
693	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
694	24/4/92			Low Rocky Pt	Commercial (Robyn K)
695	7/3/92	42.34	148.28	Maria	Chartered Vessel (Glenn Eden)
697	25/4/92			Low Rocky Pt	Commercial (Robyn K)
698	9/3/92	41.17	148.40	Eddystone Point	Chartered Vessel (Glenn Eden)
699	2/4/92			Maatsyuker Is	Commercial (Grenada)
705	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
709	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
712	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
718	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
729	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
732	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
735	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
737	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
741	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
743	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
744	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
746	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
773	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
776	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
801	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
803	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
805	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
810	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
813	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
816	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
817	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
818	10/12/92	43.42	147.54	30 mile patch	FRV Challenger

TAG No	Date	Lat	Long	Area	Cruise type
822	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
823	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
824	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
825	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
826	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
827	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
830	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
831	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
832	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
833	15/4/92	43.41	147.57	30 mile patch	FRV Challenger
837	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
838	9/4/92	41.03	148.42	St Helens	FRV Challenger
839	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
841	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
842	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
843	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
845	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
847	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
850	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
853	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
855	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
856	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
857	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
858	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
861	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
862	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
869	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
870	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
871	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
872	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
873	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
875	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
878	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
880	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
884	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
885	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
886	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
889	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
891	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
892	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
893	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
894	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
895	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
897	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
898*	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
898*	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
900	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
901	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
903	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
905	9/4/92	41.18	148.40	St Helens	FRV Challenger
906	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
907	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
910	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
911	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
913	8/4/92	41.03	148.42	Eddystone	FRV Challenger

TAG No	Date	Lat	Long	Area	Cruise type
914	9/4/92	41.17	148.40	St Helens	FRV Challenger
915	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
916	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
917	9/4/92	41.18	148.40	St Helens	FRV Challenger
918	15/4/92	43.41	147.56	30 mile patch	FRV Challenger
919	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
922	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
923	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
924	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
926	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
927	14/4/92	42.43	148.23	E Maria	FRV Challenger
928	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
929	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
931	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
932	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
933	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
934	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
935	8/4/92	40.60	148.43	Eddystone	FRV Challenger
937	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
938	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
939	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
940	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
941	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
942	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
943	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
945	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
946	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
947	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
948	15/4/92	43.40	147.56	30 mile patch	FRV Challenger
952	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
954	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
957	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
958	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
961	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
964	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
966*	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
966*	6/2/93	43.03	148.16	E Freycinet	FRV Challenger
967	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
968	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
970	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
971	8/2/94	43.44	147.55	30 mile patch	FRV Challenger
972	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
977	8/12/92	43.42	147.54	30 mile patch	FRV Challenger
985	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
987	10/12/92	43.42	147.54	30 mile patch	FRV Challenger
988	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
993	9/12/92	43.42	147.54	30 mile patch	FRV Challenger
999	10/12/92	43.42	147.54	30 mile patch	FRV Challenger

Tagging of blue-eye trevalla. List of tags released in Western Bass Strait.

TAG NUMBER	RELEASE DATE	LAT	LONG	AREA	CRUISE TYPE	VESSEL
E 2367	7/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E 2368	8/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E 2369	8/03/94	37.07	138.22	Beachport	Chartered Vessel	Trieste
E 2370	8/03/94	37.07	138.23	Beachport	Chartered Vessel	Trieste
E 2371	8/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E 2372	7/03/94	35.05	138.11	Beachport	Chartered Vessel	Trieste
E 2373	7/03/94	35.05	138.11	Beachport	Chartered Vessel	Trieste
E 2374	7/03/94	35.05	138.11	Beachport	Chartered Vessel	Trieste
E 2377	8/03/94	37.07	138.23	Beachport	Chartered Vessel	Trieste
E 2378	8/03/94	37.07	138.23	Beachport	Chartered Vessel	Trieste
E 2379	8/03/94	35.05	138.11	Beachport	Chartered Vessel	Trieste
E 2381	9/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E 2382	9/03/94	37.23	139.09	Beachport	Chartered Vessel	Trieste
E 2383	9/03/94	37.23	139.09	Beachport	Chartered Vessel	Trieste
E 2384	9/03/94	37.23	139.09	Beachport	Chartered Vessel	Trieste
E 2386	9/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E 2388	9/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E 2390	9/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E 2391	9/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E 2394	9/03/94	37.06	138.11	Beachport	Chartered Vessel	Trieste
E 2395	9/03/94	37.06	138.11	Beachport	Chartered Vessel	Trieste
E 2400	9/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E 1121	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1125	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1155	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1157	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1159	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1165	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1168	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1169	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1170	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1181	26/03/94	38.45	141.23	Portland	Chartered Vessel	Margha
E 1182	26/03/94	38.45	141.23	Portland	Chartered Vessel	Margha
E 1184	26/03/94	38.45	141.23	Portland	Chartered Vessel	Margha
E 1187	26/03/94	38.45	141.23	Portland	Chartered Vessel	Margha
E 1188	26/03/94	38.45	141.23	Portland	Chartered Vessel	Margha
E 1189	26/03/94	38.46	141.22	Portland	Chartered Vessel	Margha
E 1193	26/03/94	38.45	141.23	Portland	Chartered Vessel	Margha
E 1195	26/03/94	38.45	141.23	Portland	Chartered Vessel	Margha
E 2302	24/01/94	38.28	140.51	Portland	Chartered Vessel	Ocean Eagle
E 2318	24/01/94	38.28	140.51	Portland	Chartered Vessel	Ocean Eagle
E 2322	24/01/94	38.28	140.51	Portland	Chartered Vessel	Ocean Eagle
E 2323	24/01/94	38.28	140.51	Portland	Chartered Vessel	Ocean Eagle
E 2324	24/01/94	38.28	140.51	Portland	Chartered Vessel	Ocean Eagle
E 2351	9/03/94	38.28	140.51	Portland	Chartered Vessel	Ocean Eagle
E 2375	24/01/94	38.28	140.51	Portland	Chartered Vessel	Ocean Eagle

Tagging of blue-eye trevalla. List of tags released in Western Bass Strait.

TAG NUMBER		RELEASE DATE	LAT	LONG	AREA	CRUISE TYPE	VESSEL
E	2301	24/01/94	37.06	138.11	Beachport	Chartered Vessel	Trieste
E	2304	9/03/94	37.07	138.23	Beachport	Chartered Vessel	Trieste
E	2305	9/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2306	9/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2307	7/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E	2308	7/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2309	7/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2310	9/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E	2311	9/03/94	37.23	139.09	Beachport	Chartered Vessel	Trieste
E	2312	8/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2313	8/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2314	8/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2315	8/03/94	37.07	138.23	Beachport	Chartered Vessel	Trieste
E	2317	8/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2319	9/03/94	37.06	138.11	Beachport	Chartered Vessel	Trieste
E	2321	9/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2325	8/03/94	37.06	138.11	Beachport	Chartered Vessel	Trieste
E	2326	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2328	7/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2329	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2330	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2332	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2333	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2334	7/03/94	37.23	139.09	Beachport	Chartered Vessel	Trieste
E	2335	7/03/94	35.05	138.11	Beachport	Chartered Vessel	Trieste
E	2336	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2338	8/03/94	37.07	138.23	Beachport	Chartered Vessel	Trieste
E	2339	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2340	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2341	8/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2343	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2344	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2346	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2347	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2348	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2349	9/03/94	37.06	138.11	Beachport	Chartered Vessel	Trieste
E	2350	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2352	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2353	9/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste
E	2354	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2355	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2356	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2357	7/03/94	37.23	139.10	Beachport	Chartered Vessel	Trieste
E	2358	8/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2360	8/03/94	37.06	138.11	Beachport	Chartered Vessel	Trieste
E	2362	9/03/94	37.05	138.11	Beachport	Chartered Vessel	Trieste
E	2363	9/03/94	37.06	138.10	Beachport	Chartered Vessel	Trieste

Appendix III

Mid-water trawl survey protocol and cruise reports 1, 2 and 3

MIDWATER TRAWL SURVEY PROTOCOL

OBJECTIVES

As a component of the FIRDTA program *'Assessment of the blue eye fishery and analysis of the impact of midwater trawling* - conduct exploratory midwater trawl surveys to:

- explore the potential for midwater trawl resources other than blue eye
- determine the level of by-catch and catch rates of blue eye from midwater trawl fishing,
- evaluate the vulnerability and selectivity of the blue eye populations to midwater trawling,
- collect basic biological data for all species caught.

OPERATIONAL ZONES

The continental slope grounds off Tasmania and Victoria. This area to be divided into three survey zones comprising:

- western Bass Strait (from South Australia border to south King Island)
- southwestern and southern Tasmania (from south King Island to South East Cape)
- eastern Bass Strait and eastern Tasmania (from South East Cape to Babel Island)

NUMBER OF SURVEYS

Each zone will be surveyed seasonally (once every three months) over a two year period.

SURVEY TERMS

Two opportunities exist in each zone for individual vessels to conduct surveys for one year. To qualify for selection skipper's must have prior experience of midwater trawling, and the vessels must be capable of midwater trawling have appropriate fishing gear and GPS installed and have accommodation for an additional two scientific observers.

The objective of the surveys is to allow exploratory midwater trawling for species not covered by ITQs (such as alfonsino) that may also involve by catches of blue eye. During the surveys the blue eye trip limit will be relaxed and any catches of blue eye will be taken against the blue eye Research Quota retained by AFMA for the term of the research program. The Research Quota retained by AFMA is a quantity of fish in excess of the historic catch levels made available specifically for the research program.

The blue eye trip limit will be relaxed to permit realistic by catches, however some limits will still be in force for blue eye by catches. These limits are to ensure that localised catches of blue eye do not exceed levels considered by the Blue eye Working Group to be within the bounds of permissible risk. Catches of blue eye that exceed the survey maximum (10 tonnes) will be forfeit to AFMA. Money from the sale of forfeit catches will be placed into a trust account to support research on the blue eye fishery.

SURVEY PLAN

Within each zone, the areas to be surveyed and the duration of the survey will be negotiated with the owner/skipper. The survey vessel will search for fishable marks within the chosen areas, and selected marks may be fished.

If the total catch of blue eye exceeds 1 tonne within an area of 6nm diameter, then the vessel will be excluded from fishing within 3nm of any of those shots containing blue eye. The survey will be terminated upon either completion of the negotiated survey plan or if the vessel's total catch of blue eye exceeds 10 tonnes.

OBSERVERS

All surveys will be attended by scientific observers from either the Tasmanian Department of Primary Industry, Fisheries and Energy or the Victorian Department of Conservation and Environment.

An additional observer from the Victorian or Tasmanian dropline fisheries may attend the survey with the permission of the skipper of the survey vessel.

Assessment of the Blue Eye Trevalla Fishery and Analysis of the Impact of Semi Pelagic Trawling.

Semi Pelagic Trawl Survey: Cruise Report 1,
September 1992.

Donna Carter and Ken Smith
Department of Conservation ans Natural Resources
Marine Science Laboratories
PO Box 114
Queenscliff Vic 3225

Introduction

Semi pelagic trawl surveys are to be conducted on a quarterly basis for a 12 month period as a component of the Assessment of the blue eye trevalla fishery and analysis of the impact of semi pelagic trawling program. Vessels, meeting the criteria set out in the survey protocol, (Appendix 1) were invited to express interest in participating in one of three areas. This paper reports on the first of these semi pelagic trawl surveys as carried out in the western Bass Strait region by the Zeehaan (skippered by Bert Tober of Portland) in September 1992.

Objectives of the Survey:

1. To explore the potential for semi pelagic trawl resources other than blue eye trevalla.

2. To determine the level of by-catch and catch rates of blue eye trevalla from midwater trawl fishing.

3. To evaluate the vulnerability and selectivity of the blue eye populations to midwater trawling.

A total of 56 blue eye trevalla (352 kg) were caught from 2 shots during the survey. These fish ranged in length from 50cm to 97cm (Figure 2). Shot 2 consisted of 33 small blue eye trevalla, with an even sex ratio. Shot 7 consisted of 23 large blue eye ranging from 4.6kg to 17.7kg in weight and all fish sampled were female. Preliminary ageing of fish taken during this survey indicated ages ranging from 3 to 24 years (Figure 3).

2666 kg of blue warehou were caught during the survey, primarily from shot 5. They ranged in length from 34 to 51 cm LCF (Figure 4).

By Catch

Semi-pelagic trawling has the potential to become a very efficient fishing method given the opportunity to refine the fishing technique. From our limited experience there appears to be very little if any by-catch resulting from semi pelagic trawling The catch rates during the survey, however, were too low to draw any conclusions about the effects of semi pelagic trawling .

Future Research

This survey was the first of four quarterly trips planned over a 12 month period. The next survey is scheduled for early December 1992.

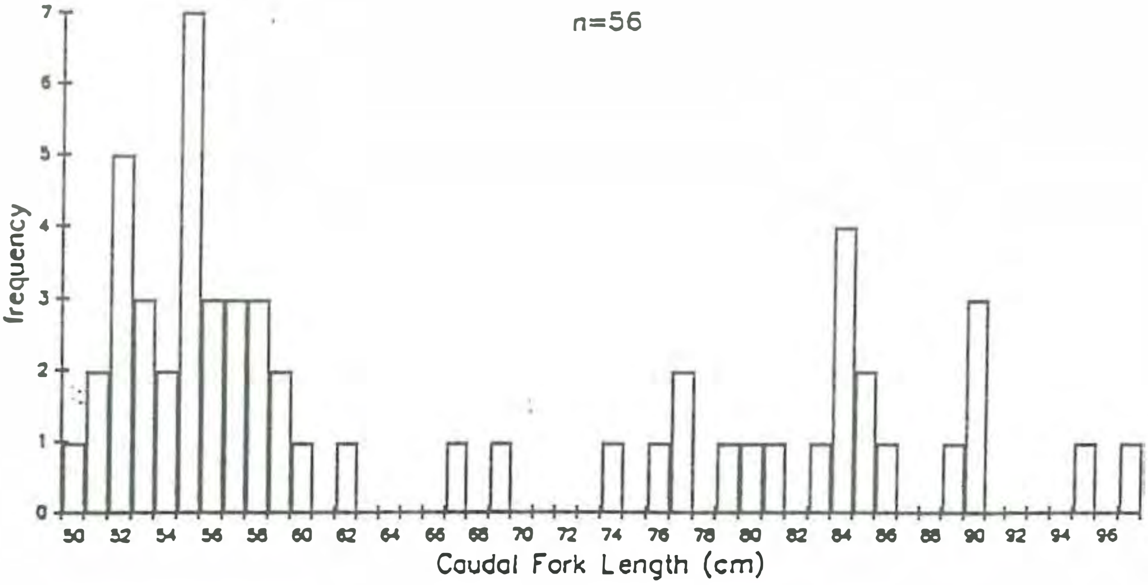


Figure 2. Length frequency distribution of blue eye trevalla caught during the semi pelagic trawl survey, September 1992.

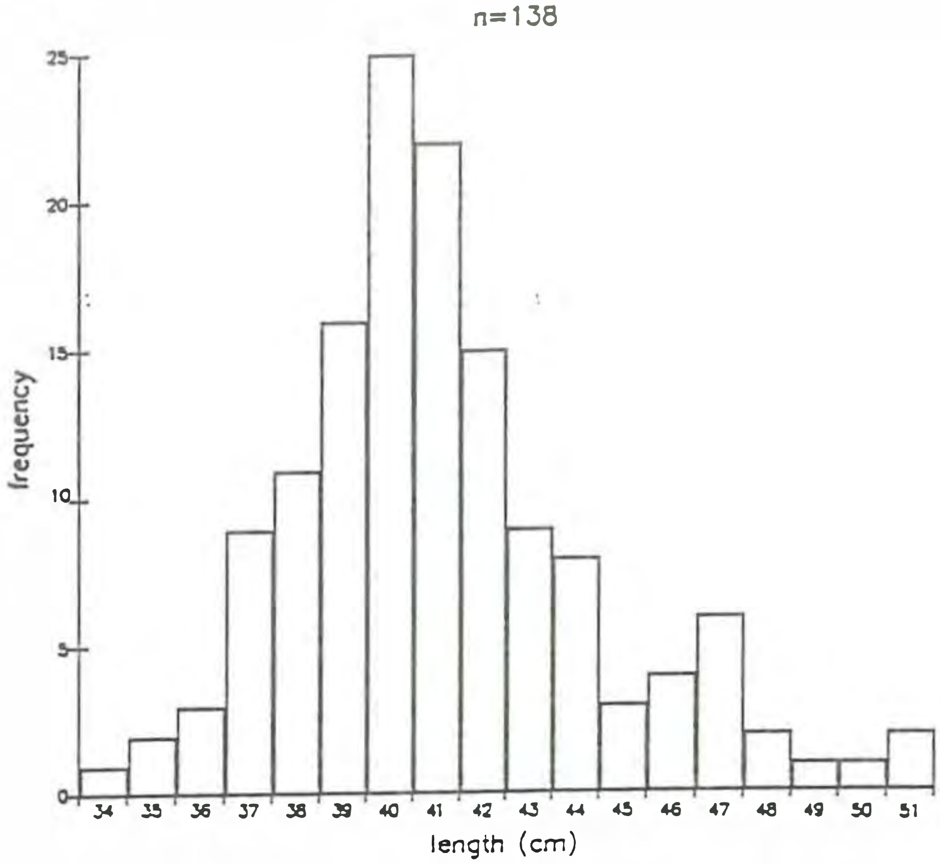


Figure 4. Length frequency distribution for blue warehou caught during the semi pelagic trawl survey, September 1992.

Assessment of the Blue Eye Trevalla Fishery and Analysis of the Impact of Semi Pelagic Trawling.

Semi Pelagic Trawl Survey: Cruise Report 2, January 1993.

Donna Carter and Ken Smith
Department of Conservation and Natural Resources
Marine Science Laboratories
PO Box 114
Queenscliff, Vic. 3225

Introduction

Semi-pelagic trawl surveys are being conducted on a quarterly basis for a 12 month period as a component of the Assessment of the blue eye trevalla fishery and analysis of the impact of semi-pelagic trawling program. The first survey took place in September 1992 (Carter and Smith, 1992). This paper reports on the second of these semi-pelagic trawl surveys as carried out in the western Bass Strait region by the Zeehaan (skippered by Gary Crapper of Portland) in January 1993.

The objectives of the survey are:

1. To explore the potential for semi pelagic trawl resources other than blue eye trevalla.
2. To determine the level of by-catch and catch rates of blue eye trevalla from midwater trawl fishing.
3. To evaluate the vulnerability and selectivity of the blue eye populations to midwater trawling.
4. To collect basic biological data for all species caught during the survey.

4. To collect basic biological data for all species caught during the survey.

Fishing methods

As this was the first survey fishable marks were searched for at predetermined sites in the region, and in surrounding areas. When a suitable mark was identified on the echo sounder the vessel would steam 1-2 miles away in order to have ample time to position the nets at the desired depth. The vessel would tow through the mark at 3-3.5 knots, with actual fishing time generally ranging from 10-15 minutes. During the tow, the netsonde gave the position of both headline and footrope in relation to the bottom and the mark. In an effort to refine and improve the fishing technique some marks were fished twice allowing the skipper to make adjustments from a known combination of net depth, tow speed and other shot characteristics.

Sampling methods

All fish caught were identified and the number and/or weight of each species for each shot was recorded. Length frequency data was collected for commercial species. Blue eye trevalla were measured, weighed and sexed, gonad stage was recorded and otoliths were removed for age determination.

Results

The Zeehaan left Portland at 1100 hours on Monday 7/9/92 and steamed south east to the first mark. Details of each shot are given in Table 1. The survey covered the area illustrated in Figure 1 and consisted of seven shots. During the seventh shot the net hit the bottom and snagged on black coral, extensive repairs were required bringing the survey to a premature end. The Zeehaan returned to Portland on Wednesday 9/9/92 at approximately 2.00pm.

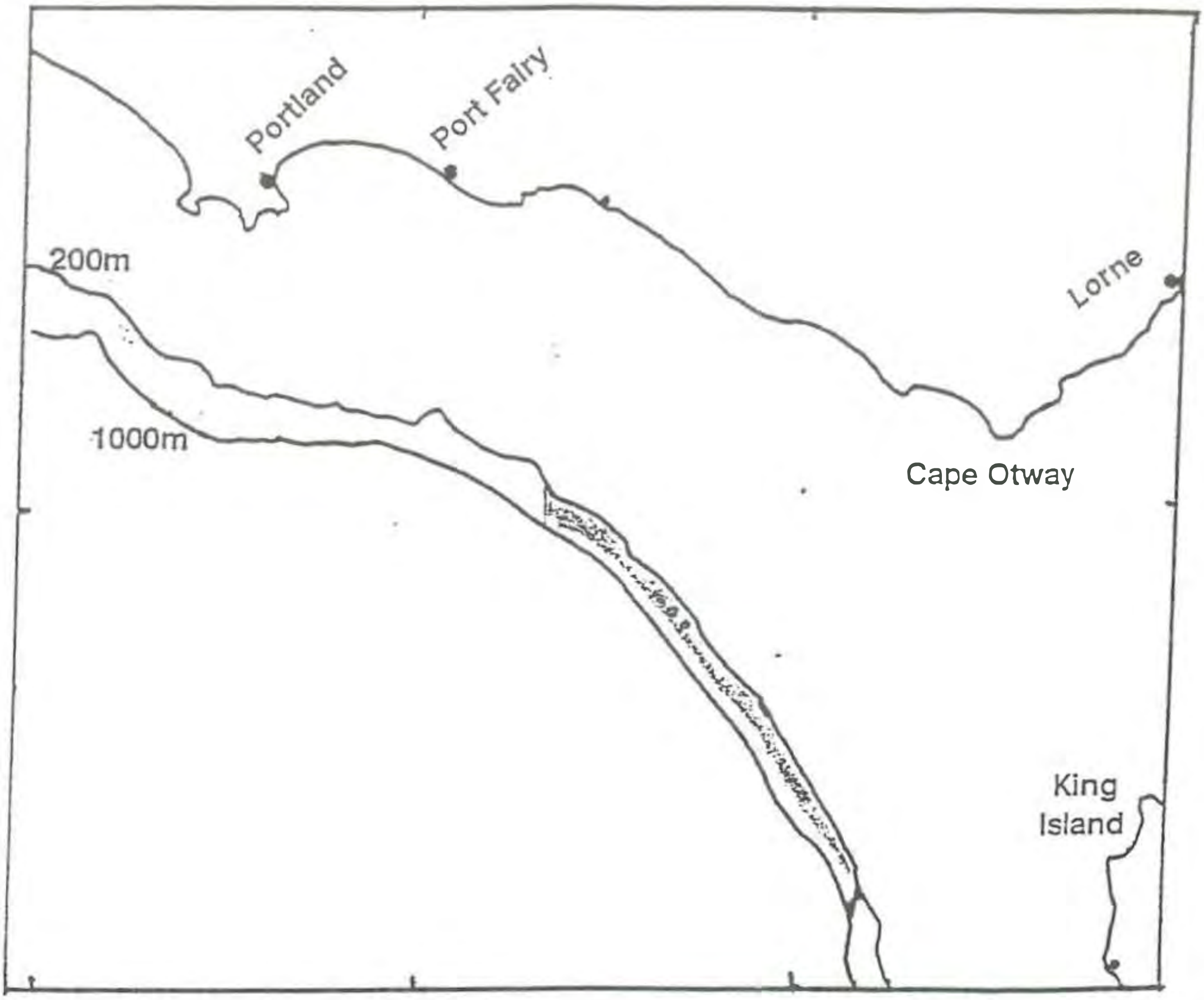


Figure 1. Area fished (shaded) during the first semi-pelagic trawl survey, September 1992.

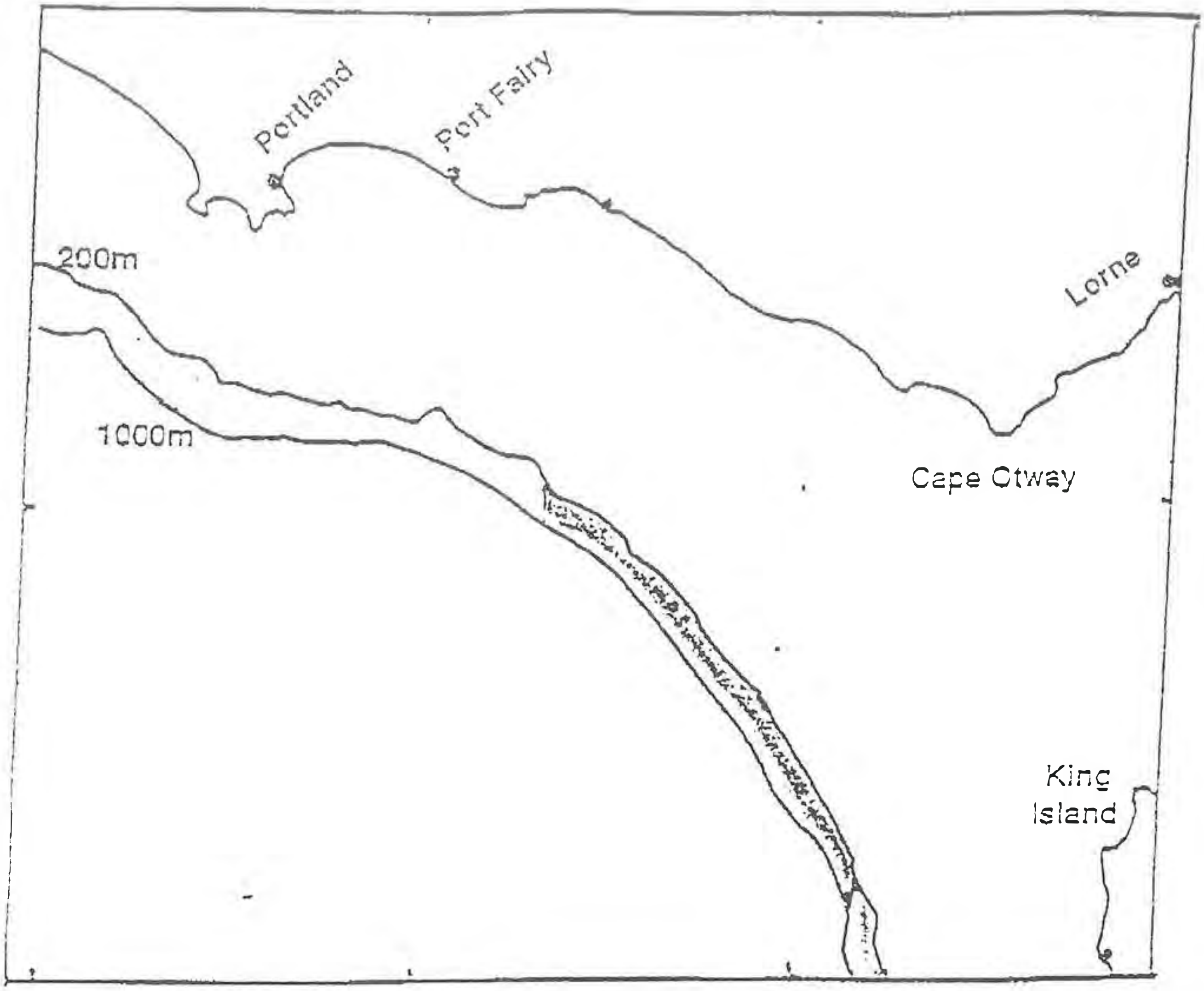


Figure 1. Area fished (shaded) during the second semi-pelagic trawl survey, January 1993.

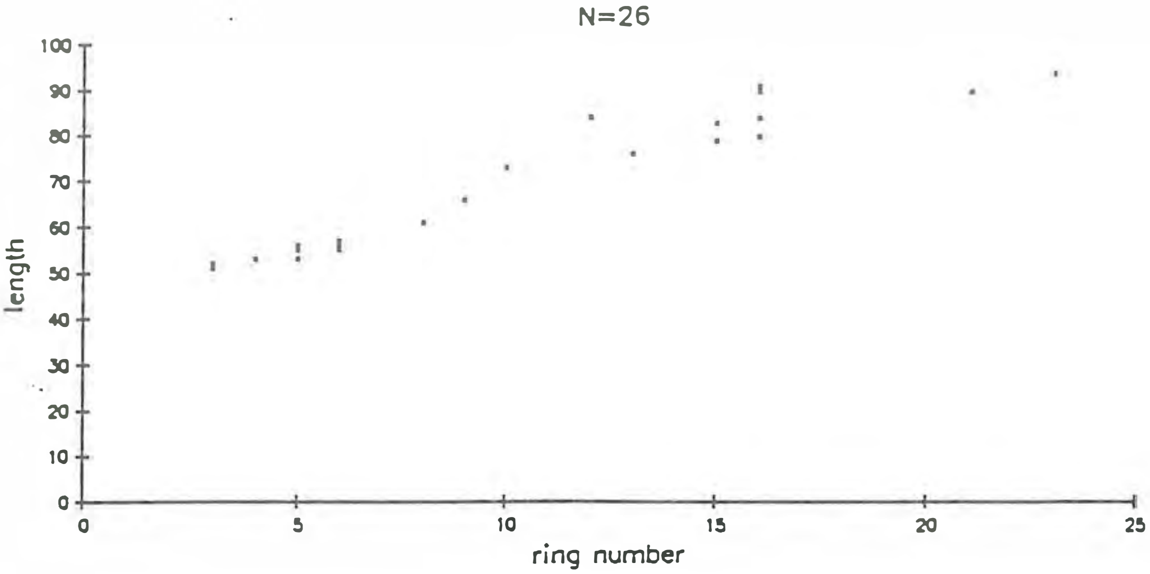


Figure 3. Age vs. length plot for blue eye trevalla caught during the semi pelagic trawl survey.

Table 1. Summary of the data recorded for each shot.

Shot Number	Time Fished	Bottom Depth (m)	Catch	No. Fish	Weight (kg)	Notes
1	1904	457	blue eye trevalla	54	155	
2	0702	502	frost fish	11	20	missed mark
3	1430	457	blue eye trevalla	60	166	

SHOT No.	TIME FISHED	BOTTOM DEPTH	CATCH	No. FISH	WEIGHT Kg	NOTES
1	2200	296	blue warehou	7	11	Shot through middle of mark
			porcupine fish	2		
2	0230	512	blue eye trevalla	33	98	Tow 5-10m off bottom
			blue grenadier	3	3	
3	1030	750	deep sea squid	8		Tow 100m off bottom
4	1745	322	couta	7	7	Tow 20m off bottom
			sunfish	1		
5	1845	322	blue warehou		2655	Repeat of previous shot
6	2230	499				Missed mark
7	2300	499	blue eye trevalla	23	254	Repeat of previous shot
						Snagged on bottom

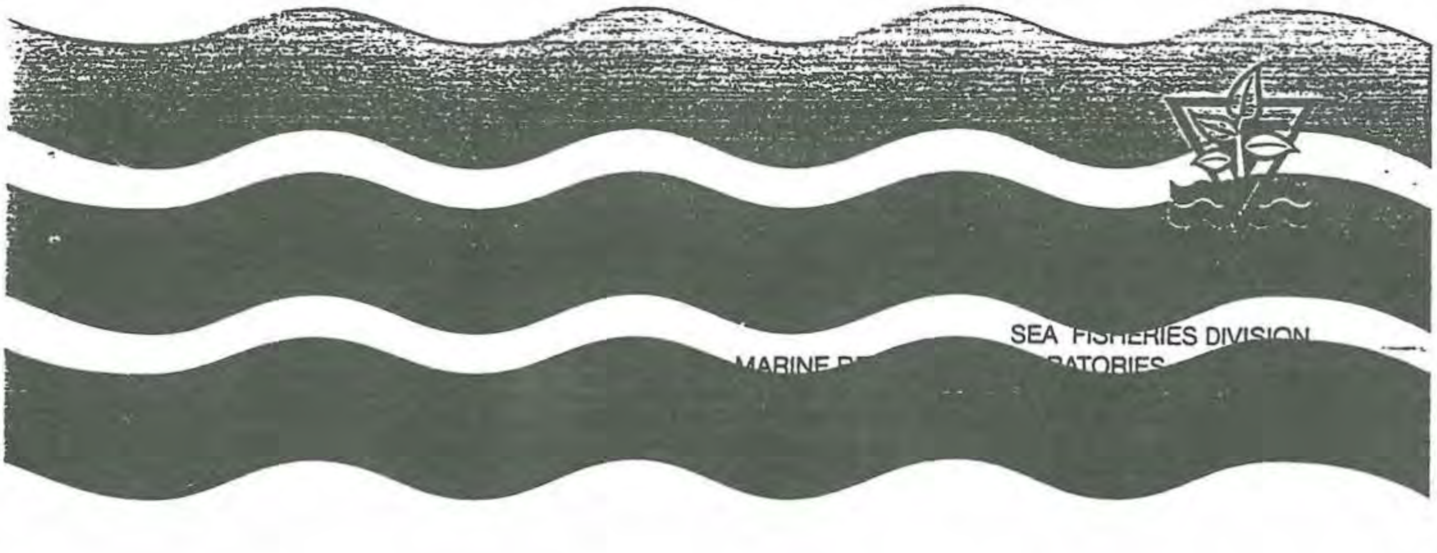
Table 1. Summary of the data recorded for each shot.

ASSESSMENT OF THE BLUE EYE TREVALLA FISHERY AND ANALYSIS OF THE IMPACT OF SEMI-PELAGIC TRAWLING

Semi-pelagic trawl survey No.3
May 1993

P. BAELDE and K. SMITH

(Not to be cited without permission)



Methods

A search was conducted throughout the region illustrated in figure 1 for fishable marks. When a suitable mark was identified on the echo sounder the vessel would steam 1-2 miles away in order to have ample time to position the nets at the desired depth. The vessel would tow through the mark at 3-3.5 knots, with actual fishing time generally ranging from 10-15 minutes. During the tow, the netsonde gave the position of both headline and footrope in relation to the bottom and the mark.

All fish caught during the survey were identified and the number and/or weight of each species for each shot was recorded. Length frequency data was collected for commercial species. Blue eye trevalla were measured, weighed and sexed, gonad stage was recorded and otoliths were removed for age determination.

Results

The Zeehaan left Portland at 1400 hours on Monday 4/1/93. The search for fishable marks began south of Cape Bridgewater, continuing south east to the south coast of King Island and back again. The search for fishable marks was largely unsucessful, resulting in only three shots being attempted. Details of each shot are given in Table 1. The Zeehaan returned to Portland on Thursday 7/1/93 at approximately midnight.

A total of 114 blue eye trevalla (321 kg) were caught from 2 shots during the survey. These fish ranged in length from 47cm to 63cm (Figure 2),and similar to shot 2 in the first survey there was an even sex ratio for fish of this size distribution (Carter and Smith 1992). Most of the blue eye trevalla caught were immature. Both shots that caught blue eye trevalla were in the same area, and possibly targetted the same school of fish.

Future Research

This survey was the second of four quarterly trips planned over a 12 month period. The next survey is scheduled for mid April 1993.

References

Carter, D.L. and Smith K. 1992: Assessment of the blue eye trevalla fishery and analysis of the impact of semi-pelagic trawling. Semi pelagic trawl survey: Cruise report 1.

0530 *Square 2B3O* : a few marks but too small.
0630 *Square 3B1D* : no marks.
0700 *Square 3B2A* : one mark found on bank.
0845 **Shot 5**: at about 400m on bank.
Catch: a few frost fish
0930 *Square 3B2A* : Small mark seen at about 400m on edge of bank. Could not be targetted because of unsuitable topography (mark above steep slope).
1030 *Squares 2B3O -3B1D* : marks searched until 4pm. Waiting for night time.
1600 *Square 2B3O* : very small mark seen on hard bottom at about 460m.
1700 *Square 2B3O* : another mark seen a bit further north-west on top of hill. Mark at about 40m above top of hill (370m). Again, problem of a mark being too close to drop of hill, but shot attempted.
1800 **Shot 6**: at about 370m on top of hill. No fish were seen entering the net. Probably missed the mark (2 trevalla were caught and the mark was still there after trawling).
Catch: 2 trevalla, 1 jack mackerel, a few squids and jelly fish.
1850 *Square 2B3O* : further search but nothing found.
1945 *Square 2B3O* : back to location of shot 6. Mark still there.
2020 **Shot 7**: as shot 6.
Catch: 1 king crab and a few squids
2100 *Square 2B3O* : further search but no marks found.
Square 3B2A : nothing.
2330 *Square 3B2E* : nothing.
Square 2B3O : several places searched but no marks found.

17/5/93

0300 *Square 2B3O* : still searching but no marks found
0520 *Square 2B3M* : back to location of shot 1. No marks found but fishing attempted.
0715 **Shot 8**: at about 370-390m, lots of "feed".
Catch: 2 blue-grenadier, 4 new-zealand dory, a few frost fish and whiptail.
0930 *Square 2B3M* : no marks found. Waiting for night time while moving to square 2A3L.
1500 *Square 2A3l* : searching for marks
1645 *Square 2A3l* : fish and "feed" marks found at about 60m above top of hill (top of hill at 420m).
1730 **Shot 9**: at about 420m on top of hill.
Catch: about 4 tonnes of trevalla (100% of catch).
Moved to another location.
1900 *Square 2A3F* : small mark seen but was probably "feed".
2100 *Square 2A3B* : nothing
2200 *Square 2A3F*: mark found on bank.
2220 **Shot 10**: at about 420m.
Catch: nil
Mark probably misinterpreted, appeared more to be "feed" during trawling .
2315 *Square 2A3L* :Mark found, high in water column and above drop of the hill but target trawling was attempted (shot 11).

18/5/93

0230 **Shot 11**: at about 450m on top of hill.
Catch: a few squids.
0320 Further unsuccessful searching before going back to Portland in the morning.

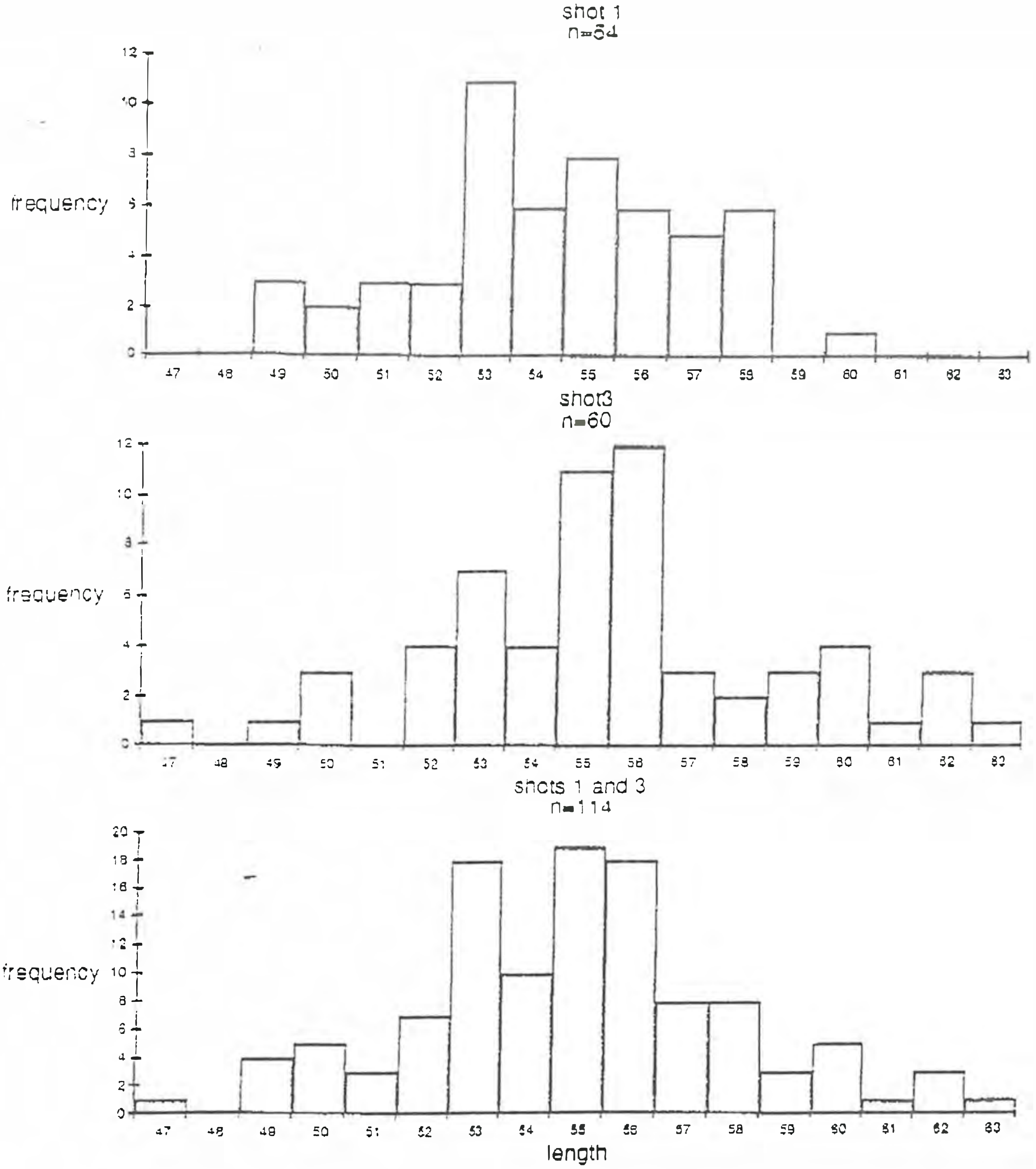


Figure 2. Length frequency distribution of blue eye trevalla caught in a. shot 1, b. shot 3 and c. both shots combined, during the second semi pelagic trawl survey, January 1993.

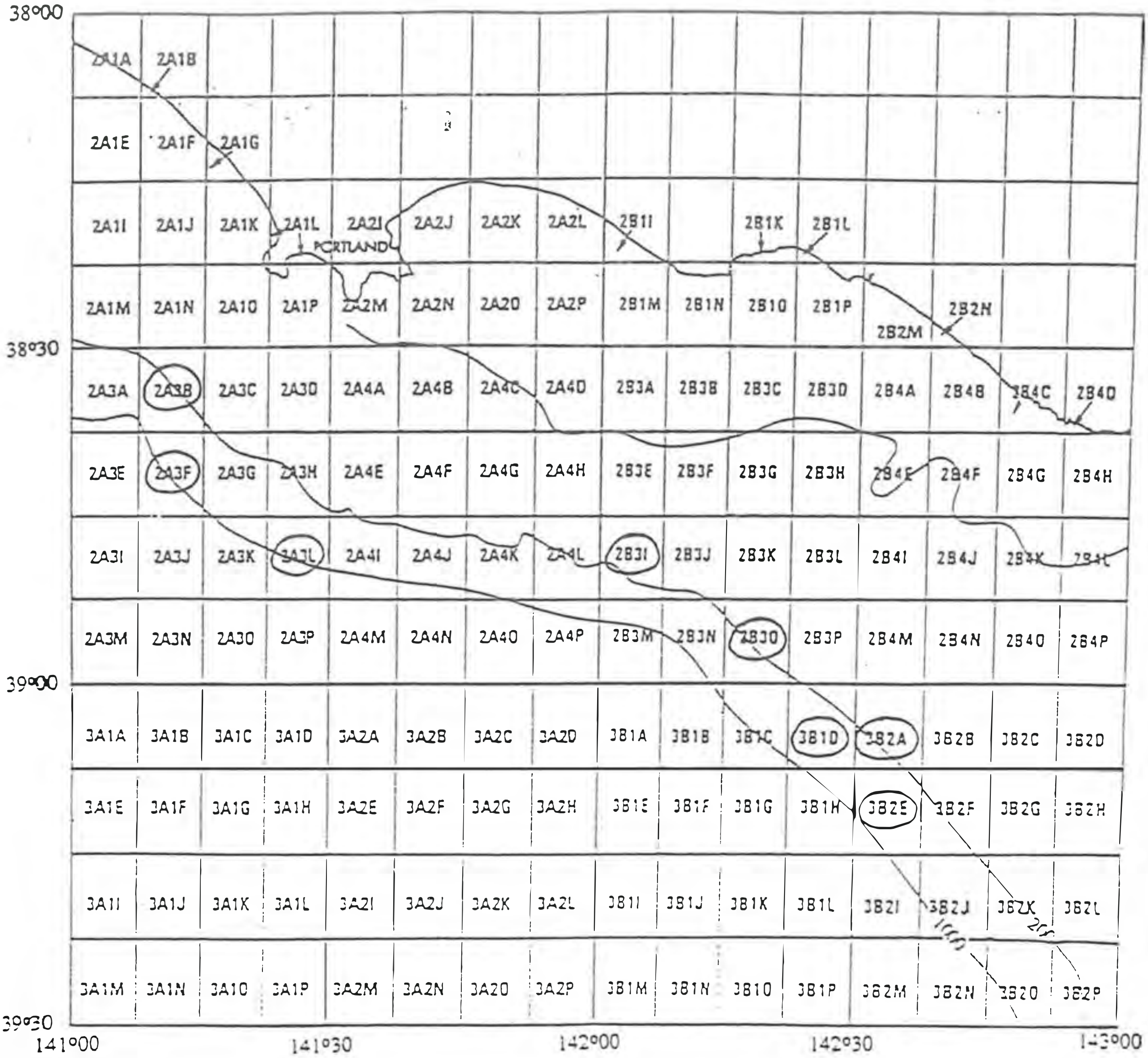


Figure 1: Fishing locations surveyed during the third mid-water trawl trial (depth in meters).

MID-WATER TRAWL SURVEY No3
MAY 1993

Vessel: ZEEHAN (Portland, Victoria), skipper: Garry Crapper

Area: Western Bass Strait.

Purpose: Exploratory mid-water trawl survey. The objectives and conditions of the survey are described in Appendix 1.

Summary: Hard bottom off Portland was surveyed at depth between 350 and 450m. Known locations (i.e. where fish marks were seen during previous trips, Figure 1) were searched as well as hard bottoms found on the way between locations. Target mid-water trawl shots were mainly conducted at night when marks were more obvious. Eleven shots were made but only one yielded a significant catch.

Scientific observers: Pascale Baelde (Sea Fisheries Division, Tasmania) and Ken Smith (Marine Science Laboratories, Victoria)

SURVEY DESCRIPTION: (see Figure 1)

11/5/93

1400 Depart Portland

1800 *Square 2B3I*: large mark seen at 290-330m, about 60m above top of hill

1915 **Shot 1**: at about 390m on top of hill.
Catch: 1 deep-sea trevalla
Problems with net sonde (cannot see the bottom line of net) ; mark may have been missed
Going further west.

12/5/93

0015 *Square 2A3L*: no marks found.

0100 *Square 2A3F* : no obvious fish marks were found (lots of "feed"), but marks were seen there during previous trips and fishing was attempted.

0220 **Shot 2**, at about 420m on a bank.
Catch: 1 deep-sea trevalla, a few frost fish and squids.
Problems with net sonde (could not get the net close enough to bottom).
Back to Portland because of bad weather and problems with net sonde.

15/5/93

1400 Depart Portland

1800 ***Square 2A3L*** : Fish and "feed" marks found above bank. Fish mark denser and round in shape at about 60m above the bottom.

1850 **Shot 3** at about 460m on bank.
Catch: a few squids.

1900 ***Square 2A3F*** : no fish marks found. Large "feed" mark about 2 miles long seen on edge of shelf.
Square 2A3L : no mark found.

16/5/93

0300 ***Square 2B3M***: small mark found at 330m, about 70m above top of hill.

0350 **Shot 4**: at about 390m on top of hill.
Catch: a few squids
No fish seen at bottom of foot-line (mark could have been "feed" or else fish did not come down to the bottom).

BIOLOGICAL DATA COLLECTED:

Biological data were collected for blue-eye trevalla, the only species caught in significant quantities during the survey. One hundred and twenty fish were sexed and measured (fork-length). Otoliths were also collected for 100 of them. All fish measured were immature or in resting condition. The sex-ratio was 1:1. The ranges of length were very similar between the sexes (from 51 to 69 cm for males and from 52 to 71 cm for females) but females had a slightly higher mean length than males (Figure 2).

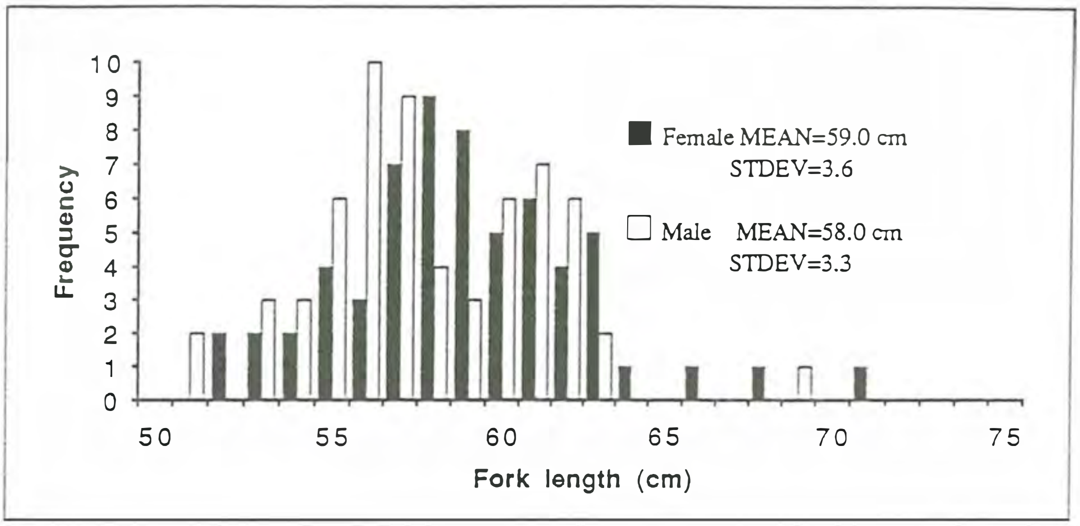


Figure 2: Length frequency distributions for female and male blue eye trevalla caught during the third mid-water trawl survey.

Appendix IV

Report on blue-eye ageing workshop, Victoria.

Report of a

Blue Eye Trevalla Ageing Workshop

held at the

Central Ageing Facility

Victorian Fisheries Research Institute

Thursday 11 November 1993

Participants

Dr Pascale Baelde, Division of Sea Fisheries Tasmania
Ms Donna Carter, Victorian Fisheries Research Institute
Mr Sandy Morison, Victorian Fisheries Research Institute
Mr Kevin Rowling, Fisheries Research Institute NSW
Dr David Smith, Victorian Fisheries Research Institute

Background and aims

Blue-eye trevalla are currently being studied in NSW, Tasmania and Victoria. It is important that an agreed ageing method is used to ensure that any differences found in age composition between areas are real, reflecting growth. Blue eye otoliths are difficult to intepret and informal discussions suggested that there may have been inconsistencies in interpretation at different laboratories.

Assigned ages for blue-eye trevalla have not been validated. Published marginal increment data from New Zealand is also not informative (Horn 1988). Throughout this report the term age will be used for brevity but the lack of validation should be borne in mind.

The maximum reported age in New Zealand is 12 years. Recent ageing at the CAF using both whole and sectioned otoliths suggests older ages than this. Results of otolith exchanges with New Zealand indicate there are some obvious differences in interpretation. These were discussed with Peter Horn, from MAF Fisheries, during his recent visit to the CAF. There was some agreement that blue-eye could well live longer than was found in New Zealand but the problem with intepretation remains. Resolution of this will be difficult until assigned ages have been validated.

The aims of this workshop were to compare methods and age estimates and attempt to arrive at an agreed interpretation. The major part of the workshop involved examination and identification of incremental structure, and decision about which increments should be counted. Future work, particularly methods to validate assigned ages were also discussed.

Length-frequencies

Length-frequency distributions of commercial line catches of blue-eye trevalla from NSW, Tasmania and Victoria all have a distinct mode at about 50 cm (Figure 1). This is thought to represent fish which have recently changed from a pelagic to a demersal habitat. Off NSW, there is a second mode at about 65 cm which persists all year. This mode is evident in samples from Tasmania during the spawning season (Figure 2.). Apart from those samples taken during the spawning season, when there appears to be an "influx" of large fish, all length frequency distributions examined were dominated by fish less than 65cm. These are not yet mature.

The modes at 50 and 65 cm were very stable and there was little indication that they represent distinct cohorts. The significance of these modes is unknown but it was suggested that they may reflect the behaviour of the fish rather than age structure. However, data are currently limited and further analysis is required.

Otoliths

Description and preparation

Blue-eye trevalla otoliths are large compared to most species; up to 4 cm long and 1.7 cm wide. They are regular and ovoid in shape, and laterally flattened. The distal face is characterised by a complex incremetal structure. There is a large opaque central region with an abrupt change to more translucent material (Figure 3).

Otoliths are "read":

- whole with reflected light against a dark background (CAF, NSW, Tas)
- broken and burnt, reflected light (NZ, Tas)
- sectioned, transmitted light (CAF).

Approximately 40 otoliths, were re-examined in detail.

Generally otoliths have three regions which correspond to morphological changes in the otolith (Figure 4). This is particularly clear when otoliths are sectioned. The increment structure within these regions are described below.

1 The central opaque region with 1-3 increments, which is common to most otoliths. A "double-ring" structure was recognised in some otoliths.

2 The region of the otolith outside the opaque material. This area is particularly difficult to interpret. In some otoliths there is an obvious banding pattern in which a number of increments can be counted as one. This pattern is visible in whole, sectioned and broken and burnt otoliths. However, there is a significant proportion of otoliths where this pattern is not clear and grouping increments into bands is difficult to justify.

3 At the margin of large otoliths there are numerous clear and regular increments in which no banding pattern is evident. These increments are much thinner and more closely spaced than those in the rest of the otolith. They are clearly seen in sectioned or broken and burnt otoliths but only in some whole otoliths.

Agreed Interpretation

It was decided that, until validation has been achieved, intepretation of blue-eye trevalla otoliths would be as follows:

- apart from obvious double-rings, increments within the opaque region would be counted as annual

- in the middle region of otoliths, each band would be treated as an annual increment (Note this is similar to the intepretation used by Peter Horn). Otoltihs in which no banding pattern was evident would be flagged for future examination and decision as to their usefulness.

- increments at the margin of the whole otoliths or revealed by sectioning or by breaking and burning are to be counted as annual.

It was also agreed that whole otoliths are adequate for ageing blue-eye trevalla except that all otoliths from fish greater than 85 cm; and ambigous otoliths and "thick" otoliths from fish less than 85 cm should be sectioned or broken and burnt to ensure that increments at the margin of the otolith are clearly revealed.

Summary

- at this stage, length-frequency distributions do not appear useful for ageing or validation but further analysis will be undertaken.

- although assigned ages have yet to be validated, interpretation amongst institutions will; now be consistent

- if the agreed interpretation is accurate (ie supported by future validation) then the maximum age could be in excess of 20 years. This has important implications for stock productivity.

- a significant proportion of the catch by all sectors comprises immature, 2-5 year old fish.

Recommendations

1 Otolith exchanges between institutions should be undertaken routinely to ensure consistency of interpretation

2 Research to validate assigned ages should be accorded a very high priority. Methods for validation could include tagging and marking otoliths with flourescent dyes, and radiometric ageing.

Reference

Horn, P.L (1988). Age and growth of bluenose, *Hyperoglyphe antarctica* (Pisces: Stromateodei) from the lower east coast, North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 22, 369-378

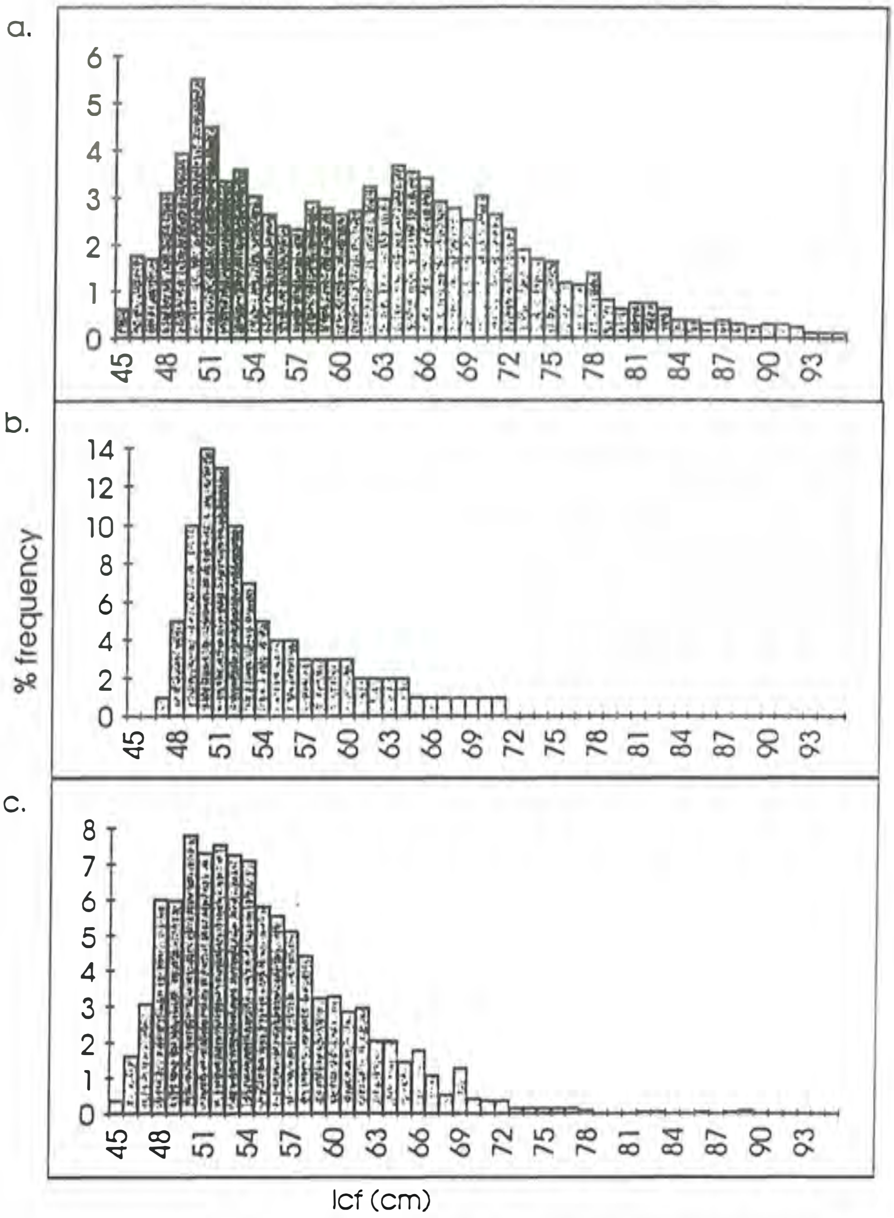


Figure 1. Length frequency distribution of commercial line catches of non spawning blue eye trevalla from a. NSW, b. Tasmania and c. Victoria.

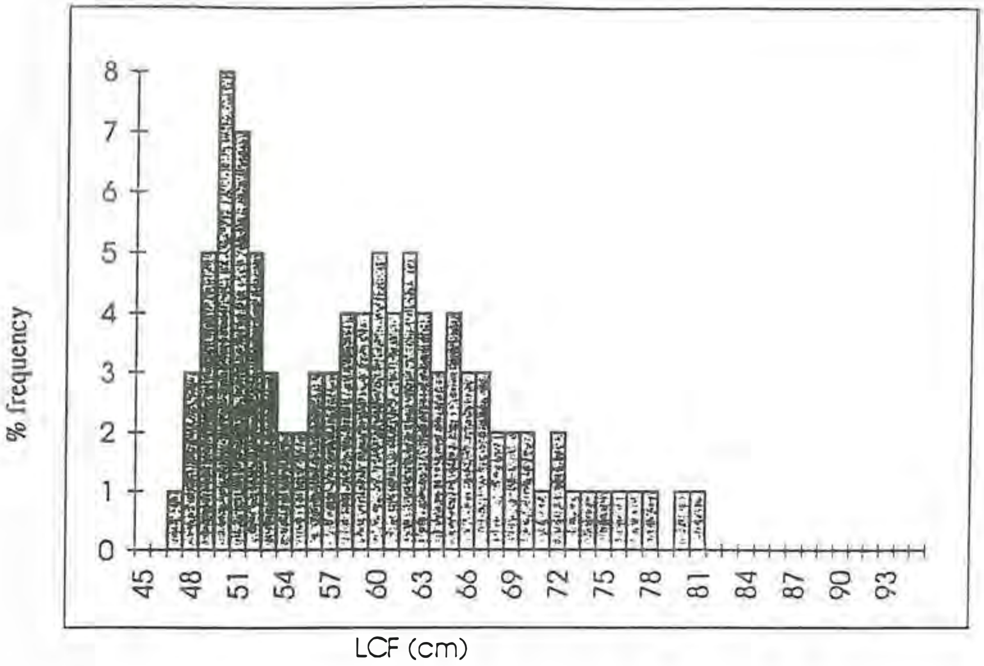


Figure 2. Length frequency distribution of blue eye trevalla sampled from Tasmania during the spawning season (January - April).

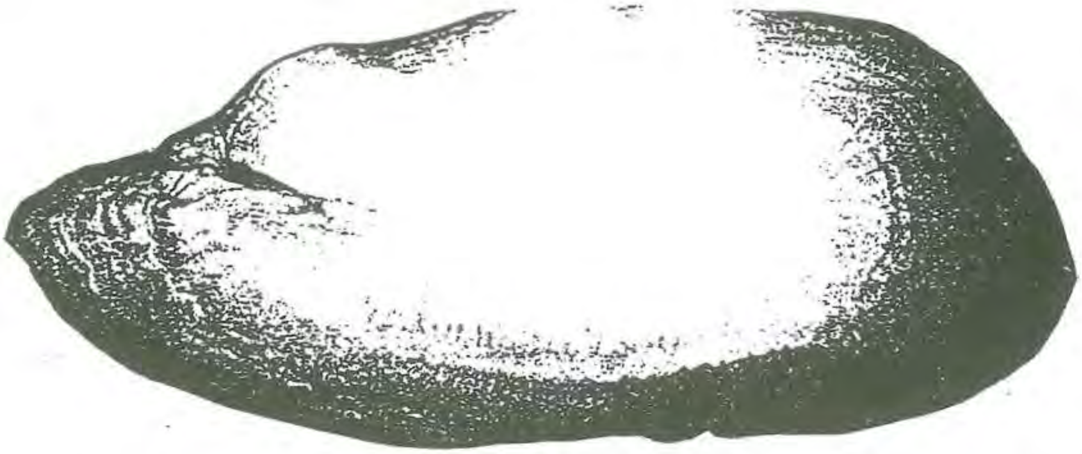


Figure 3. Distal view of a saggital otolith viewed under reflected light. The otolith was from a 75 cm fish of unknown sex and was aged at approximately 8 years.

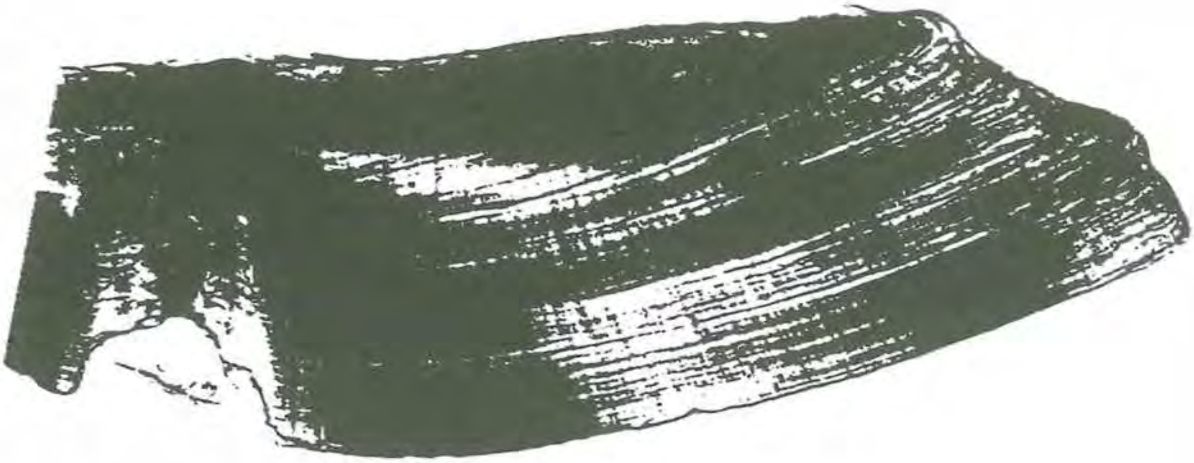


Figure 4. Transverse section of a saggital otolith viewed with transmitted light. The otolith was from a 93 cm fish of unknown sex and was aged at approximately 22 years.

Appendix V

Results of veterinary analyses

Intestinal flatworm:

Parasitic flatworms were found in the guts of many blue-eye trevalla. Specimen sent to the Animal Health Laboratory, Department of Primary Industry and Fisheries, Tasmania, were identified as Pseudiphyllidean cestodes (see attached). These are quite frequent and inconsequential in fish (J. Handlinger, personal communication).

Skin ulcers and tumours:

Fish with skin ulcers and tumours were occasionally caught by drop-liners. Analyses indicated that these lesions were of traumatic origin (shark bite for example).

DEPARTMENT OF
PRIMARY INDUSTRY, AND FISHERIES
TASMANIA
ANIMAL HEALTH LABORATORY

Accession No. : **93/0517**
Serial No : 796-

DEPARTMENT OF SEA FISHERIES
CRAYFISH POINT

TAROONA 7053

Received on : 27/01/93
Report date : 02/02/93
Case Status : **Final Case Report**

Submitter: GOODSALL

SUBMITTER'S COPY

OWNER: DEPT OF SEA FISHERIES TAROONA 7006

SPECIES: FISH FIN FISH **AGE:** 0 unknown **SEX:** Unknown
DEEP SEA TREVALLA

CASE HISTORY

PARASITOLOGY REPORT

PARASITE IDENTIFICATION]

The parasites were identified as Pseudophyllidean cestodes with a pair of large bothria composed of well developed dangling holdfast organs.

COMMENTS: The strobila are very contracted (not relaxed) which make further identification impossible. Need to relax in diustilled water for several hours before fixation.

J.H. HANDLINGER
VETERINARY PATHOLOGIST

Department of
Primary Industry
and Fisheries
Tasmania

ANIMAL HEALTH LABORATORY

Accession No. : 94/2238
Serial No : 0814

DEPARTMENT OF SEA FISHERIES
CRAYFISH POINT

TAROONA 7053

Received on : 28/04/94
Report date : 19/05/94
Case Status : **Final Case Report**

Submitter: BAELDE

SUBMITTER'S COPY

OWNER: SEA FISHERIES RESEARCH LAB CRAYFISH POINT NUBEENA CRESCENT T
AROONA 7053

SPECIES: FISH FIN FISH **AGE:** 0 unknown **SEX:** Unknown

CASE HISTORY

ULCERS/TUMOURS/SKIN

PATHOLOGY REPORT

94/2238 HISTOPATHOLOGY REPORT

Phone history: Trevalla. These samples reported as submitted to Sea Fisheries by fisherman who had held samples for 2 days at least in fridge. Samples submitted fixed, as judged unsuitable for other examinations. Large fixed muscle specimens were the only samples received. Fisherman said to have reported a number of other fish with similar lesions from a small area round the site that these fish were caught.

No history submitted for Deep Sea Cod)

Sample 1. Label in bottle = deep sea cod.]

Grossly, one sample showed a hard nodular swelling. The other showed a soft fluctuating swelling, which contained black liquid when sectioned. No pathogens or cells obvious in black material on smears, which showed granular material suggesting free melanin pigment.

Histologically the latter section showed free melanin granules in the thin fibrous cyst wall and diffusely between the adjacent muscle fibres. It was not possible to determine how much of the associated acute muscle lysis was post mortem change.

The other section shows a thick fibrous wall surrounding small degenerate granulomas.

DIAGNOSIS - DEEP SEA COD: Hard nodules showed old granulomas, soft fluctuating swelling showed residual melanin only, indicating old lesion of unknown origin.

Fish 2 and 3 (deep sea Trevalla)]

These two fish showed similar gross pathology of pale brown caseous tracts through the muscle. Small surface scars indicated initial penetrating injury was possible, but healed.

The histopathology of these two samples was also similar, though sample 2 was the more mature lesion showing predominantly chronic changes, while a greater rang of reaction seen in sample 3.

Both showed mature sinus tracts through the muscle. In sample 3, the section showed the surrounding reacting extending into the dense layer of the skin (surface epithelium lost, uncertain if premortem or artefact).

The lining of the tract showed a mature almost squamous like appearance, with pale marginated nuclei. Stains for fungus were negative. Bacterial clumps present in the caseous material, but not seen near tract wall. Muscle fragments in caseous material.

The inflammatory reaction extended well beyond the sinus wall, into surrounding muscle which showed fibre fragmentation and lysis, with marked macrophage reaction in some areas. A large number of cells (some in muscle) with heavily marginated chromatin and intense eosinophilic bodies in nucleus. (Nature of the latter uncertain, possibly artefact of cell necrosis, though some resemblance to intra-nuclear inclusions.) In some areas enlarged cell like masses with faint basophilic granules were present - also uncertain if of host origin (inflammatory granules etc), bacteria, or early calcification of necrotic muscle remnants.

Many of these changes could represent nothing more than perpetuation of a sinus tract by conventional damage by enzymes released by cell lysis causing further cell damage, but I will attempt to define the changes further if possible.

Special stains: ZN stains showed no acid fast bacteria in these lesions, though bacterial clumps of uncertain significance were confirmed. PAS stains showed no fungi or other pathogens.

DIAGNOSIS - BLUE EYED TREVALLA: Chronic tracking sinuses through muscle, with apparent healed connection to external lesion. Cause not identified.

COMMENTS - BLUE EYED TREVALLA:]

COMMENT 1. I have once seen a lesion with similar appearance in previous sample (93/4065) from this species. This suggests a common cause rather than sporadic accidental occurrence, or a common unusual response pattern to injury in this species.

The history of the previous submission did not include sufficient history to identify the area in which the fish was caught, though it was not submitted from this area.

(Copy of the report 93/4065 enclosed for Sea Fisheries submitter.)

COMMENT 2: 18/4/94 The question of possible relationship of lesions in this species to jarosite dumping has been raised recently, after these samples had been examined. At this stage I have no direct evidence that these samples were from the area of concern, though I believe these to be the samples to which reference was made.

The nature of the lesions suggests a traumatic or infectious origin and does not suggest any direct link to jarosite. However the quality and quantity of the samples is insufficient to establish a primary diagnosis, or for any studies of the possible interaction with jarosite load. The distribution of such lesions in this species in fish caught outside the area of concern would also assist in clarifying the aetiology.

COMMENT 3: Large fixed muscle samples are being held should any other examinations be required, but by their nature they are unlikely to be of value for chemical assessment of a possible link with chemical dumping.

J.H. HANDLINGER
VETERINARY PATHOLOGIST

ANIMAL HEALTH LABORATORY

Accession No. : 94/3566
Serial No : 0820

DEPARTMENT OF SEA FISHERIES
CRAYFISH POINT

TAROONA 7053

Received on : 27/06/94
Report date : 11/07/94
Case Status : **Interim Report**

Submitter: BAELDE

Extra Copy

OWNER: DEPARTMENT SEA FISHERIES NUBEENA CRESCENT TAROONA 7053

SPECIES: FISH FIN FISH **AGE:**0 unknown **SEX:** Male
DEEP SEA TREVALLA

CASE HISTORY

ULCERS/TUMOURS/SKIN

PATHOLOGY REPORT

94/3566 GROSS FINDINGS]

Fish 1.]

Superficial skin lesion present along right dorsum as a band 1.5 - 2 cm wide adjacent to dorsal fin, extending from deep jagged wound at dorsal tail base to edge of operculum. This lesion showed a reddened gelatinous shallow skinless cover over superficial muscles. Also present were shallow lateral extensions from this lesion (photographed), seen as pale superficial linear wounds without loss of skin.

The gut was thickened, suggestive of parasites, but there were no other internal lesions obvious.

Fish 2.]

This fish showed a number of shallow lesions on each flank, including one larger circular ulcer like lesion. (Locations recorded). Most were relatively shallow, but the larger lesions showed reddening of the underlying muscle.

94/3566 HISTOPATHOLOGY REPORT]

Fish 1.]

Skin / muscle lesion. Considerable autolysis, with little remaining skin epithelium, but some focal superficial inflammation. The majority of the reaction was beneath the dense dermal connective tissue layer, as an intense, mixed reaction within damaged muscle. Other section of gelatinous layer show a congested, myxoid fibrous layer suggesting rapid new deposition over eroded surface.

Other organs - Findings: Gut metazoan parasites (no apparent clinical effect). A large old granuloma within pancreas, with epithelioid wall and small apparent bacterial clumps within an otherwise amorphous matrix. Possible liver changes masked by marked autolysis.

PATHOLOGY REPORT (cont.)

Encysted fluke like parasites near swim bladder (with ova, similar to ova seen previously)

Fish 2.]

Muscle reaction similar to above, with congested damaged muscle and apparent early granulation tissue. Across the surface a thinned, flattened incomplete epithelium is present, typical of epithelial growth across wounds.

No internal parasites obvious. Liver normal.

DIAGNOSIS: Apparent traumatic wounds with early repair reaction.

COMMENT: At this stage it is not known if these are related to the type of lesion seen previously.

Both fish show superficial lesions suggestive of traumatic origin, although this is less certain with fish 2. Though traumatic events could be of a natural nature, the possibility of fishing activity induced trauma should be considered. For example, the variety of lesions of Fish 1. could well be explained by seal / shark / other predator attack of fish in lines / nets etc, with subsequent escape.

Samples for metal analyis held for future reference.

MICROBIOLOGY REPORT

SAMPLE:		Deep sea trevalla, skin lesions x 3.
MICROSCOPY:	1.	No bacteria detected.
	2.	++ Gram positive cocci.
		++ Gram negative cocci.
		++ Gram negative rods.
	3.	++ Gram positive cocci.
		++ Gram negative rods.
CULTURE:	1.	No growth.
	2.	++ Mixed bacterial flora > 4 colonial types.
	3.	++ Mixed bacterila flora > 4 colonial types.
COMMENTS:		Skin lesion 1 was a deep pocket of necrosis but with no evidence of bacterial involvement. Skin lesions 2 & 3 were more superficial; the diverse bacterial flora recoverd from these sites is consistent with contamination. This is not unexpected since the time between collection and submission was in excess of 48 hours. *Aeromonas salmonicida* was not recovered in culture.

± scant + light ++ moderate +++ heavy

Appendix VI

Research Grant Application

FISHING INDUSTRY RESEARCH AND DEVELOPMENT TRUST FUND - APPLICATION FOR GRANT

NEW GRANT

SECTION 1 - PROJECT TITLE

Assessment of the blue-eye trevalla fishery and analysis of the impact of midwater trawling.

SECTION 2 - KEYWORDS

blue-eye trevalla/stock assessment/gear competition/south eastern Australia

SECTION 3 - OBJECTIVES

- evaluate differences in the vulnerability of the population to exploitation by either line fishing or midwater trawling
- collect basic biological data on:
  - catch composition, age, growth, mortality and reproductive biology
  - movement by tagging
- assess the impact of different gears on the fishery, individually and in combination

SECTION 4 - JUSTIFICATION

The blue-eye trevalla (*Hyperoglyphe antarctica*) are distributed throughout the continental waters of the Southern Ocean. A commercial fishery for the species first developed off the east Tasmanian coast in the late 1950's, following an exploratory line fishing survey in 1954/55 (Cowper and Downie, 1957). Further survey work confirmed the potential for a fishery off western Tasmania (Wilson, 1981), Victoria (Winstanley, 1979) and South Australia (Jones, 1985). The species is now fished commercially off each of these States and off New South Wales (since the early 1970's) and Western Australia. The fishery is associated with the continental slope in depths of 200-900 m - typically these waters are under Commonwealth jurisdiction. Droplining is the primary method of capture - trotlines and longlines are also used.

At present, landings are relatively stable, with annual catches for the line fishery estimated to be around 750 tonnes . In addition, trawlers operating in the South East Trawl (SET) fishery take approximately 120 tonnes per year as a by-catch to demersal trawling operations. The value of landings is in excess of $3.5 million and the fish is highly regarded as a premium scalefish product.

Current participation in the Australian fishery may be divided into three sectors. They are:

- specialist line fishermen (estimated at around 50 vessels)
- non-dependent line fishermen, generally those diversifying fishing operations during closed seasons for their principal fishery eg. rock lobster (estimated at in excess of 400 vessels)
- SET fishermen catching blue-eye trevalla as a by-catch to demersal trawling

In addition to demersal trawling there is growing interest by SET operators in the development of midwater trawl fishing techniques for a variety of species including blue-eye trevalla. Several operators have already undertaken fishing trials with midwater gear and catches have included significant quantities of blue-eye trevalla. Analysis of catch rates for demersal trawling in the SET zone indicate that catch rates are generally low (mostly < 50 kg/hour) and rarely exceed 1,000 kg/hour (SET logbook data). Catch rates for midwater trawling are, however, likely to be considerably higher as rough bottom areas, the favoured habitat for the species, can be target fished by this method.

The main area of interest for developing a midwater trawl fishery is in the South Western Sector of the SET fishery and in particular in waters adjacent to Tasmania and Western Bass Strait. This area is similar to areas in which midwater trawl fisheries have developed in New Zealand. Several factors associated with the orange roughy fishery have provided an impetus for the development of midwater trawling - these include:

- the sophisticated fishing methods and equipment used for orange roughy are readily extended to midwater trawling
- the orange roughy fishery and likely midwater trawl grounds are in close proximity
- seasonal closures of the orange roughy grounds off Tasmania are encouraging fishermen to seek alternate fisheries (as most of the vessels are now permanently or temporarily based in Tasmania they are keen to develop fisheries in close proximity).

The status of the resource at the current exploitation level is not known so it is not possible to assess the impact of any significant increase in fishing pressure. Similarly it is not possible to assess the effects of mixed gears (taking different segments of the population) on the yield from the fishery. In addition the taxonomic status and stock distribution of blue-eye trevalla are uncertain. Catches of blue-eye trevalla are known to contain two morphs (the 'small eyed' and big eyed' forms) and these may represent two sympatric species.

A cursory examination of the Tasmanian line fishery (having the longest history) points to a limited capacity for the resource to sustain increased catches. Although landings have been stable at around 200 tonnes per annum over the last decade, the area of the fishery has changed considerably. The fishery was restricted to the east coast in the late 1970's and now extends to the southeast, southwest and west coasts with additional but sporadic catches being taken from offshore seamounts such as the Cascade Plateau. Whilst no analysis of catch per unit effort (CPUE) is currently available, the phenomenon of an increasing fishing area with static catches indicates localized depletion. Although access to the line fishery is at present unrestricted (operators are required to hold a Commonwealth fishing licence) it is unlikely that a significant increase in fishing pressure will be experienced by this sector in the short term.

Developments following the introduction of midwater trawling in New Zealand during the early 1980's may provide an indication of the implications for the Australian fishery. In a number of areas trawling has replaced line fishing as the main method of fishing for blue-eye trevalla. The New Zealand fishery has seen localized depletions and decline in CPUE in certain areas (although there is conflicting interpretation of the data). In addition it is apparent that juvenile fish are more vulnerable to midwater trawls than to line fishing techniques. As the contribution of midwater trawl catches to total landings in New Zealand has increased there has been a concomitant rise in the proportion of juvenile fish in catch composition. At present up to two thirds of the New Zealand trawl catch of blue-eye trevalla (by weight) is comprised of juvenile fish (Horn, 1987). The effect of this change in vulnerability on the productivity of the blue-eye trevalla resource is not understood and is a cause of concern.

Direct extrapolation from the New Zealand experience is complicated, however, because catches have been restricted through the use of total allowable catches (TACs). Despite TACs being applied, changes in fishing technique seen in the New Zealand fishery have given rise to concern at the future yield of the fishery.

Concerns at the potential changes that midwater trawling may have on the blue-eye trevalla resource and interaction with the established line fishery have caused considerable controversy between the different sectors of the fishing industry. These issues have been raised at Government and industry meetings and in November 1989, the South East Trawl Fishery Management Advisory Committee (SETMAC) established a working group of line fishermen (Tasmanian and Victorian), trawlermen, scientists and managers to examine the issues and seek mechanisms to resolve the conflict between fishing methods. Concerns developed around several issues, these include:

- the unknown status of the present fishery and thus the unknown capacity of the fishery to sustain increased effort and catches.
- the effect of changes in age composition of catches on sustainable yield.
- the effect of increased landings and different product quality on markets
- the effect of cost differentials between midwater trawling and line fishing on the ultimate viability of the line fishing fleet.
- the desirability of developing midwater trawl techniques for otherwise lightly exploited species such as alfonsino (*Beryx splendens*), cardinal fish (*Epigonus telescopus*), blue grenadier (*Macruronus novaezelandiae*) and squid.

The SETMAC working group recommended that as there was already a significant fishery in place and the status of the resource was unknown the status quo should be maintained until such time as research advice was available on which to assess the impact of midwater trawling. In the interim, the group advised that industry self-regulation should be attempted to contain midwater trawl catches. Failing this the group recommended the introduction of interim management pending research advice.

Attempts to introduce industry self-regulation failed and were followed by the introduction of a 500 kg trip limit of blue-eye trevalla for SET vessels. This arrangement effectively bans the target trawling of blue-eye and restricts the development of midwater trawling for other species. This is an interim arrangement to be reviewed when research advice is available.

The Demersal and Pelagic Fisheries Research Group (DPFRG) at their meeting in Hobart in November 1989, expressed concern at the lack of information available for assessment of the current status of the fishery and the potential impact of midwater trawling. DPFRG formally endorsed a research program to examine these matters and ranked this research as being of high priority. This support has been reiterated at the meeting of DPFRG in Canberra in December 1990. The need for research has also gained support from SETMAC and a working group formed by SETMAC on blue-eye trevalla, and the fisheries agencies of the Commonwealth, Tasmania, Victoria, South Australia and New South Wales.

The study outlined here seeks to address the resource based issues and thus provide sound advice to management. It will receive support in the provision of fishery statistics and market measuring from the Division of Sea Fisheries - Tasmania (DSF); Fisheries Division, Victoria (FDV); Fisheries Research Institute - New South Wales; Department of Fisheries - South Australia and the Australian Department of Primary Industry and Energy.

This program would benefit greatly from the research proposed by the CSIRO Division of Fisheries Research in their application to FIRDC 'Population structure of the blue eye (deepsea trevalla), *Hyperoglyphe antarctica*' . The interpretation of the results of the work conducted under this program will be dependent upon the taxonomic status of the fish studied and the degree to which populations may be separated..

The success of the proposal may be evaluated by the following criteria:

- the success of the program in deploying tags,
- the development of a model to simulate the effect of the different gears on the fishery,
- the utility of advice arising from the research to management questions.

SECTION 5 - PROPOSAL IN DETAIL

(a) Plan of Operation

(i) Method of Procedure

EVALUATING DIFFERENCES IN VULNERABILITY

Catch composition and basic biological data will be examined to determine the characteristics of fish taken by the different gears. Of interest is any difference in length composition, age, sexual maturity and sex ratios of fish caught. In addition the areas fished by the different techniques will be monitored. Age at full recruitment to the different fisheries and total mortality rates will be estimated from the age structure of the catch.

(a) The line fishery

Observers attending line fishing operations will collect data on size, sex, age and gonad stage on a monthly basis.

In addition to information collected at sea, this research program will have access to data collected by the market measuring programs of the south eastern states. The principal use of market measuring will be in providing information on the size composition of landings by fishing method and area.

(b) The midwater trawl fishery

The Australian Fisheries Service will support this work by issuing three Scientific Permits to midwater trawlers, allowing the 500 kg trip limit to be exceeded under controlled circumstances. The Scientific Permits will be issued subject to the following conditions:

- that only four trips may be conducted each year and that these will be on a seasonal basis,
- a trip limit of 10 tonnes of blue-eye trevalla will apply,
- observers will attend each trip, and
- some fishing operations may be predetermined.

On a seasonal basis midwater trawl fishing campaigns will be conducted. All fishing operations will be attended by observers and in addition some fishing operations will predetermined. It is planned to concentrate predetermined fishing operations for blue-eye at two sites to simulate the effect of heavy long-term trawling on the grounds. Catch rates and biological information will be closely monitored.

COLLECTION OF BIOLOGICAL DATA

Throughout 1990 and 1991, observers attending both line and midwater trawl fishing operations off south eastern Australia will support the various logbook reporting programs, collect basic biological information from catches and collect samples for the proposed FIRDTA program 'Population structure of the blue eye (deepsea trevalla), *Hyperoglyphe antarctica*', conducted by the CSIRO. Biological data will include sex, gonad stage, length, weight and age. Spawning in blue-eye trevalla is not well understood. Supplementary biological data relating to spawning will be collected by the FRV *Challenger* in a series of cruises during March and April (the anticipated spawning season). Spawning will be confirmed by macroscopic and microscopic gonad staging.

All biological information and market measuring data will be separated for the 'big eyed' and 'small eyed' blue-eye trevalla forms. In addition the ratios of the co-occurring forms in catches will be recorded. The further treatment of this data will be subject to the results of the taxonomic study conducted by the CSIRO for FIRDC.

Fish ages will be determined from otoliths. The Central Fish Ageing Facility will conduct the ageing of stored otoliths from Tasmanian research cruises dating from 1981 to 1985, and will age otoliths collected during this program. Age determination from otolith annuli has been partially validated as an ageing technique in New Zealand (Horn, 1988). Future routine ageing may be conducted by the Central Fish Ageing Facility at the FDV (subject to funding for this species).

Tagging will be undertaken to examine the movement of fish between fishing grounds and may yield information relating to susceptibility to different fishing methods. Tagging of blue-eye trevalla with breakaway tags has proven successful in New Zealand where a recovery rate of 2.2% has been achieved (Horn, 1989). The FRV *Challenger* will conduct tagging cruises off Tasmania, whilst tagging in western Bass Strait will be undertaken by chartered commercial fishermen. Up to 4,000 tags will be distributed through the western, southern and southeastern areas of the fishery. A reward system will be introduced with $5 per tag. This program will be publicised directly to the fishing industry and processors, through SETMAC, *Australian Fisheries* and industry meetings.

As well as the collection of basic biological data relevant to the assessment of the blue-eye trevalla fishery described above, this research program would provide a valuable opportunity for collecting biological data on other poorly understood species. The developing midwater trawl fishery, will probably target species such as alfonsino, cardinal fish and blue grenadier. It is likely that significant midwater trawl fisheries will develop around these other species in the future. At present there is little information available for alfonsino and cardinal fish in Australian waters. It is possible for data to be collected for these species by the observers in tandem to their work on deep sea trevalla.

ASSESSING THE IMPACT OF DIFFERENT GEARS

Information derived from both the line and midwater trawl fisheries will be used to assess the impact of these fishing techniques (alone and in combination) on the fish population.

Given that:

- the age structure of the catches made by the different fishing gear can be determined,
- a time series of relative abundance by area can be derived from CPUE data
- estimates of natural mortality can be made, and
- growth rates can be determined,

a generalised age structured model will be developed for the blue-eye trevalla fishery. Such a model will provide a framework for examining the effects on the fish population of the different fishing techniques. Whilst a model of this nature will not give absolute estimates of biomass levels, it will indicate the reaction of the stock to various fishing regimes.

STAFFING

This research program would be a joint program between the Division of Sea Fisheries, Tasmania (DSF) and the Fisheries Division, Victoria (FDV). The proposed research program will be staffed by three personnel with additional involvement from researchers from the DSF and FDV.

The DSF will coordinate the direction of the overall program. Much of this work will require close collaboration between the researchers from the different agencies for collation and interpretation. Sub-programs may be identified and allocated to the various agencies as indicated below.

The DSF will be responsible for:

- field work conducted in waters off the west, south and east coasts of Tasmania,
- conducting tagging cruises from the FRV *Challenger*,
- assessment of maturity and reproduction, and
- population modelling and assessment of the impact of the different gears.

The FDV will conduct work on:

- field work conducted in Western Bass Strait,
- conducting tagging under charter off Victoria,
- ageing of historic samples and samples collected during this program, and
- analysis of growth.

REFERENCES

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Wilson, M. A. (1981) South-west coast line fishing survey's first phase ends. *FINTAS* 4(1) p 7-10

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(ii) Facilities Available

The Division of Sea Fisheries (Tasmania) has the following facilities available:

- office and laboratory space at the Taroona Marine Laboratories of the DSF
- dedicated sea time on the *Challenger* and use of associated equipment
- assistance of the Fisheries Statistics Section and the Catch Sampling program
- histological tissue processing facilities
- administrative support and library services
- use of the Divisions in-house microcomputer facilities and peripherals
- access to the Divisions minicomputer facility

The Fisheries Division (Victoria) will provide the following:

- office, laboratory space and vehicles
- microscope and computer facilities
- assistance of the Catch and Effort Unit and Fisheries Mathematician
- assistance of market measurers
- technical advice from the Central Ageing Facility

(b) Support Data

(i) Previous Work in this or Related Fields

The major research effort on blue-eye trevalla in Australia has been on developing the line fishery and assessing the gross biological characteristics of the species. Some preliminary work aimed at determining the status of the fishery was conducted on the Tasmanian fishery in the mid 1970's however this was never completed.

FIRDC has provided funds to the Division of Sea Fisheries, Tasmania to conduct a program aimed at describing the history of the fishery including the collation and appraisal of catch and effort statistics held by the various States.

The CSIRO Division of Fisheries Resources have made an application to FIRDC titled 'Population structure of the blue eye (deepsea trevalla), *Hyperoglyphe antarctica*'. This program would contribute significantly to the interpretation of results obtained under this application. The program outlined here would also collect samples for the CSIRO program.

The Division of Sea Fisheries, Tasmania has a proven ability to conduct this type of research. Personnel supervising the program have an extensive experience in the planning, conduct and completion of fisheries research including cooperative studies with other research groups. This includes demonstrated skills in:

- resource assessment of demersal fish resources both inshore and in deep water (extensive studies on trawl species including orange roughy)
- resource assessment of pelagic fish resources (jack mackerel)

- resource monitoring studies of demersal and pelagic fisheries (including the development of logbook programs)
- extensive biological data collection programs (including observers and market measurers)
- analysis of biological data (ageing, growth, fecundity and reproductive studies)

The Fisheries Division, Victoria also have an extensive experience and proven ability in this type of research.

SECTION 6 - RESEARCH PRIORITY

Within the priorities set out in FIRDC's five year plan the research proposal is of direct relevance to the points relating to fish resource assessment and resolution of conflict between resource users. The proposal will provide advice on the current status of the fishery and the likely reaction of the fishery to increased effort from the line and trawl fishing sectors.

SECTION 7 - TRANSFER OF RESULTS TO INDUSTRY

At the completion of the program a report of the research findings will be given to SETMAC. Further reports will be made to the industry groups concerned (Tasmanian Hook Fishermens Association, Finfish Commodity Group - Tasmanian Fishing Industry Council, Portland Fishermens Association etc.). Progressive reports of research findings will be published in *Fishing Today, Australian Fisheries* and *DSF Technical Report Series*.

Results and progress will be presented at yearly research reviews within the Division of Sea Fisheries, Tasmania. Where applicable the results will also be written up in manuscripts for submission to scientific journals for publication. Results will also be presented at annual meetings of the Demersal and Pelagic Fisheries Research Group, the Australian Marine Science Association and the Australian Society for Fish Biology.

SECTION 12 - BUDGET IN DETAIL

Item		Amount budgeted for 1991/92	Current estimate for 1992/93	Current estimate for 1993/94
Salaries				
DSF	Research Officer (SO II)	34,168	35,561	36,953
	Technical Officer (TO II)	24,151	24,707	25,184
	Overtime (120 seadays)	8,415	8,500	8,573
	On-costs (15.9%)	10,610	10,934	11,242
FDV	Scientific Officer (SCI 1)	24,187	24,750	26,320
	Overtime (50 seadays)	3,000	3,000	3,000
	On-costs (15%)	3,628	3,712	3,948
	Total Salaries	**108,159**	**111,164**	**115,220**
Travel Costs				
DSF	Sea victualing allowance (120 days)	2,532	2,532	1,266
	Interstate allowances (2 trips for 5 days)	1,367	1,367	1,367
	Air fares (2 return trips Melbourne)	808	808	808
FDV	Sea-going Allowances (40 days)	1,440	1,440	720
	Travel allowance (50 days)	5,022	5,022	2,511
	Interstate allowance (10 days, Sydney)	1,600	1,600	800
	Total Travel	**12,769**	**12,769**	**7,472**
Operating Costs				
DSF	Consumable equipment and maintenance of gear	4,500	4,500	2,250
	Trotline equipment (4)	3,500		
	Breakaway tags (4,000)	8,000		
	Bait (500 kgs)	1,000	1,000	
	Tag rewards (200 @ $5)	1,000		
	Fish purchases	3,000	3,000	
	Wet weather gear, film development etc.	1,500	800	800
	Software	1,000	1,000	
	Purchase/printing of monographs	850	850	850
	Short term vehicle hire (60 days)	2,400	2,400	2,400
FDV	Vessel charter (15 days)	4,500	4,500	
	Vehicle running costs	2,000	2,000	2,000
	Fish purchases	3,000	3,000	
	Miscellaneous costs	1,000	1,000	1,000
	Total Operating	**37,250**	**24,050**	**9,300**
Capital Costs				
	Total Capital	**Nil**	**Nil**	**Nil**
TOTAL PROPOSED EXPENDITURE		**158,178**	**147,983**	**131,992**

Date of compilation of financial data - 21 December 1990

JUSTIFICATION OF INFORMATION

Travel Costs

Sea victualing and sea-going allowances - the allowances are Award payments for staff undertaking work at sea.
High Priority

Air fares - two trips per year have been costed. The program is cooperative and the different cooperating agencies have discreet tasks within the overall program. Close consultation between the two research teams is required to ensure a free exchange of information and the coordination of analysis and the field programs. The last air fare will be used for travel to a Demersal and Pelagic Fisheries Research Group to report the final results.
High Priority

Interstate allowance (Melbourne) - this is based on the above air fares.
High Priority

Travel allowance - this has been costed on the basis of 10 five day trips to ports within Victoria for sampling of catches and to conduct trips on commercial vessels (principally Portland and Lakes Entrance).
High Priority

Interstate allowance - costed on the basis of two five day trips to NSW to sample fish from Eden.
High Priority

Operating Costs

Consumable equipment and maintenance of gear - includes special maintenance of deck gear used on the FRV Challenger (pothauler and winch) and disposable items (sounder paper, histological chemicals and preparations, glassware, medical instruments, knives, data sheets, measuring boards, computer consumables, film, fish bins, plastic bags, ice etc.).
High Priority

Trotline equipment - cost of materials required only (buoys, lines, clips and weights), rigging to be done by DSF
High Priority

Breakaway tags - cost of materials only (tags and stainless steel hooks), construction to be done by DSF
High Priority

Bait - required for tagging and biological sampling
High Priority

Tag rewards - a nominal figure to encourage the return of tags
High Priority

Fish purchases - biological sampling of catches, particularly from drop liners, will require the destruction of significant proportions of fishermen's catches and will require the fish to be purchased.
High Priority

Wet weather gear, film development etc. - purchase and maintenance of two sets of wet weather gear and protective clothing for FIRDTA funded staff. Cost of attending one course on survival at sea. Costs of film development.
High Priority

Software - to ensure that licensing arrangements are not breached this program will be required to be self sufficient in word processing, graphics and spreadsheet software. Statistical analysis packages and databases will be available from the DSF.
High Priority

Short term vehicle hire and vehicle running costs - required for travel to and from ports for sampling and conducting trips on commercial vessels.
High Priority

Vessel charter - tagging off Victoria will be conducted from commercial vessels. These charter costs are nominal and are a goodwill gesture aimed at defraying the costs incurred through inconvenience, not a comprehensive charter.
High Priority

Miscellaneous costs - costs of consumable equipment for the Victorian component of the program - includes protective clothing, sampling equipment and chemicals etc.
High Priority

JUSTIFICATION OF INFORMATION

Operating Costs

Consumable equipment and maintenance - includes special maintenance of deck gear used on the FRV Challenger (trawl nets, net drum winch, warp winches, high speed scientific sampling winch) and disposable items (sounder paper, histological chemicals and preparations, glassware, medical instruments, knives, data sheets, measuring boards, computer consumables, film, fish bins, plastic bags, ice etc.).
High Priority

Short term vehicle hire - required for travel to and from ports for sampling and conducting trips on commercial vessels.
High Priority

APPENDIX 1 - DETAILS OF FUNDS PROVIDED BY APPLICANT.

Division of Sea Fisheries - Department of Primary Industry, Tasmania

Item	1990/91	1991/92	1992/93
Salaries			
Dr Howel Williams (10%)	4,545	4,637	4,880
Dr Jeremy Lyle (10%)	4,360	4,453	4,545
Ms Dorothy Huber (5%)	1,708	1,778	1,848
Mr Carl Waterworth (20%)	5,147	5,147	5,147
Market Measurers (10%)	2,000	2,000	2,000
Overtime (60 seadays)	5,386	5,386	5,386
On-costs (56.7%)	13,123	13,268	13,498
Total Salaries	**36,269**	**36,669**	**37,304**
Operating Costs			
30 days *Challenger* per year (@$1,600 per day)	48,000	48,000	24,000
Administrative overhead [0.4 x total salaries]	57,771	59,133	61,009
Total Operating	**105,771**	**107,133**	**85,009**
Travel Costs			
Sea victualing allowance	1,266	1,266	1,266
Total Travel	**1,266**	**1,266**	**1,266**
Total Proposed Contribution	**143,306**	**145,068**	**123,579**

Fisheries Division, Victoria

Item	1991/92	1992/93	1993/94
Salaries & Wages			
Dr David Smith 10%	4,222	4,222	4,222
Mr Nik Dow 5% (Mathematician)	1,984	2,027	2,111
Ms Dianne Ballinger 5% (Catch Effort Unit)	1,418	1,457	1,495
Market Measurers 15%	2,923	2,923	2,923
On-costs 15%	1,582	1,594	1,613
Total Salaries	**12,129**	**12,223**	**12,364**
Operating Expenses			
Administrative overhead [0.5 x total salaries]	21,472	21,843	22,816
Total Operating	**21,472**	**21,843**	**22,816**
Total Proposed Contribution	**33,601**	**34,066**	**35,180**