Description of the biology and an assessment of the fishery for Silver Trevally *Pseudocaranx dentex* off New South Wales.

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NON-TECHNICAL SUMMARY

97/125	Description of the biology and an assessment of the fishery for silver trevally off New South Wales.

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OBJECTIVES:

1. To describe the size and age composition of the catch of silver trevally taken by each of the sectors utilising the resource in NSW waters.
2. To investigate the reproductive biology of silver trevally, including determination of the size at first maturity, spawning period and fecundity.
3. To refine techniques to age silver trevally and apply these to samples from commercial and recreational catches, and to develop a growth rate model for this species in NSW.
4. To incorporate all relevant data in an initial stock assessment, describing the relative impact on the silver trevally stock of the various fishery sectors.
5. To provide advice on the status of the silver trevally stock, and the appropriateness or otherwise of establishing a minimum legal size for silver trevally.

NON TECHNICAL SUMMARY:

Silver trevally occur in estuarine and near-shore ocean waters of all Australian states, and form a significant component of both commercial and recreational fisheries in many areas. Despite this, very little was known about the species' biology and population dynamics in Australian waters. This research project sampled both commercial and recreational catches of silver trevally from NSW waters between 1997 and 1999, to obtain information on growth and mortality rates for the species. The research involved the refinement of techniques to age individual fish using thin transverse sections of otoliths, and an experiment in which the growth of fish held in captivity was followed over a 12 month period. The size at maturity and the duration of the breeding season were also studied using samples from commercial catches over two full breeding seasons. The size and age compositions of trevally catches during 1997-99 were compared with data available for earlier periods in the history of the fishery, and likely trends in mortality rates were estimated.

Recorded commercial catches of silver trevally showed a rapid increase from less than 200 t per annum in the 1960s to around 1500 t in the late 1980s. Commercial catches, which were above 1000 t until the early 1990s, significantly declined in the late 1990s, and in 1999 the total commercial catch of silver trevally reported from waters off NSW was 340 t. Catches of silver trevally by recreational fishers probably also increased significantly between the 1960s and the 1980s, although no firm estimates of the recreational catch exist for this period. In the early 1990s it was estimated that the recreational catch of silver trevally from ocean waters off NSW was

around 120 t per annum and it is likely that a similar quantity was taken by recreational fishers in estuarine waters. Taking both commercial and recreational catches into account, it is estimated that annual catches of silver trevally peaked at about 1800 to 2000 t in the late 1980s, but have declined during the 1990s, to less than 500 t in 1999.

Silver trevally were found to be a relatively long lived and slow growing species with a maximum age in excess of 20 years. The largest trevally sampled were about 60 cm (LCF - length from snout to caudal fork) and close to 4 kg in weight, however the average size of fish in commercial catches during 1997-99 was 28.4 cm or 500 g. Recent commercial catches contained a high proportion of young fish with trevally less than 5 years old comprising almost 50% of the catch. Trevally older than 10 years were estimated to comprise just 7% of the commercial catch in 1997-99. It is probable that the lightly fished trevally population which existed in the 1960s contained a much greater representation of fish between 10 and 25 years of age, but the age composition of the unexploited stock could not be accurately estimated due to a lack of data from the early years of the fishery.

Catch sampling for reproductive biology conducted over two full spawning seasons confirmed previous indications regarding size at maturity and spawning period. Recruitment to the overall fishery generally coincides with maturation, which occurs between about 18 and 26 cm LCF for both sexes. Female trevally were found to have moderate fecundity, with individual batch fecundity estimated to range up to 220,000 eggs for a 37 cm fish. Silver trevally appear to be partial spawners, with several batches of eggs possibly being released over an extended period from spring to autumn. It is also likely that larger female trevally may have greater fecundities, perhaps ranging up to around 1 million eggs, but ripe fish of this size were not sampled during the present study.

A preliminary assessment of the current status of the silver trevally stock determined that the trawl fishery was the most significant sector of the fishery, but trap and line, recreational and estuarine sectors were also important. The size and age composition of trevally caught varied among the various fishery sectors, with catches by the estuary and trawl sectors showing the highest proportion of small (less than 25 cm LCF) fish. Fishing has apparently had a significant impact on the trevally stock since exploitation increased in the 1980s. There is evidence from both commercial and recreational catches of a significant decline in the average size of trevally since catches increased in the 1980s, which is consistent with the ‘fishing down’ of the larger and older animals in the population. Data for recent years suggest that the fishery may not be at equilibrium, and that the stock may be continuing to decline.

Preliminary yield modelling indicated the current size at first capture for the fishery as a whole was well below the optimum size. Results for a range of likely natural mortality and growth rates suggested the optimum size at first capture for silver trevally to be well above 30 cm LCF, whereas the size at first capture for the current fishery is in the range 20 to 25 cm. The status of the silver trevally stock can be described as ‘growth overfished’, with the fish being caught, on average, well below the size at which the optimum biological yield would result. Advice from industry was that the desirable market size for trevally is also well above the present average size in the catch. It would therefore be appropriate to establish a minimum legal length for silver trevally to improve the yield (per recruit) from the fishery, and probably significantly increase the economic value of the catch. However, the selectivity of the different fishing gears which target silver trevally (especially fish trawls) will need to be addressed to prevent the capture and discarding of large quantities of undersized fish. This and other issues relevant to setting an optimum size at first capture need to be discussed with relevant stakeholders in the range of fisheries which target silver trevally.

1. INTRODUCTION

1.1 Background

Silver trevally, *Pseudocaranx dentex*, occur in estuarine and near-shore ocean waters of all Australian states, and form a significant component of both commercial and recreational fisheries in many areas. The majority of the Australian commercial catch is taken off NSW (Kailola *et al.* 1993), where annual landings increased from less than 500 t prior to 1980 to over 1500 t by the late 1980's. A significant export market developed, and in the early 1990s the commercial catch of silver trevally from NSW was valued at around $2 million per annum. Silver trevally are also taken in significant numbers by recreational fishers, and have been consistently reported to be amongst the five most important species in recreational catches from both estuarine and ocean waters.

Despite the significance of silver trevally to both commercial and recreational fisheries, very little was known about the species' biology and population dynamics in Australian waters. The relevant South East Fishery stock assessment report (Tilzey, 1995) described the status of the silver trevally stock as "uncertain", and acknowledged that the lack of appropriate data meant that the effects of fishing on the resource could not be assessed, and management strategies could not be evaluated. The market value for specific sizes and quality of silver trevally increased dramatically with the advent of the export market, potentially increasing fishing pressure on fish of the desired size range (35 to 45 cm fork length and 800 g to 1.5 kg in weight). There was considerable interest by commercial fishers in modifying existing fishing gear and practices to better target the preferred size classes and achieve a consistently high quality product. With the poor knowledge available concerning the size and age structure of the silver trevally population, it was not possible to provide advice on appropriate management strategies to ensure the sustainable utilisation of the resource.

1.2 Need

Because of the increasing significance of silver trevally to a number of fisheries off NSW (including the trawl sector of the SEF, where it is one of 16 species managed by an annual Total Allowable Catch), and the lack of data with which to assess the impact of fishing on the stock, it was important to undertake research which would lead to an understanding of the current status of the silver trevally resource.

There was a need to determine the basic biological parameters for silver trevally, including growth rates and spawning biology, for use in stock assessment modelling. There was also a need to document the portion of the stock utilised by the various fishery sectors, and to determine the relative impacts on the stock by each sector. All the available information then needed to be drawn together into a basic assessment of the status of the silver trevally stock, which could be used to provide advice about appropriate management measures for the sustainable utilisation of the resource.

1.3 Objectives

The objectives of this research were:

1. To describe the size and age composition of the catch of silver trevally taken by each of the sectors utilising the resource in NSW waters.

2. To investigate the reproductive biology of silver trevally, including determination of the size at first maturity, spawning period and fecundity.

3. To refine techniques to age silver trevally, and to apply these to samples from commercial and recreational catches, and develop a growth model for the species in NSW.

4. To incorporate all relevant data in an initial stock assessment, describing the relative impact on the silver trevally stock of the various fishery sectors.

5. To provide advice on the status of the silver trevally stock, and the appropriateness or otherwise of establishing a minimum legal size for silver trevally.

1.4 Achievement of objectives

1. Achieved - Recent and historic size composition data were analysed for both commercial and recreational sectors, although sample sizes for recreational data were small. Age compositions were determined by application of an age-length key to the size composition data, which assumes no change in growth over time.

2. Achieved – Catch sampling for reproductive biology was conducted over two full spawning seasons, and the results confirmed previous indications regarding size at maturity and spawning period. New information was gathered on fecundity levels of female trevally.

3. Achieved – A relatively large sample of sectioned otoliths was aged, but the sample available in 1997-99 was deficient in large fish which are now uncommon in NSW catches. Other ageing methods were examined (whole otoliths, vertebrae) but were considered less effective. An experiment involving fish held in captivity was conducted to validate annual ring formation. A growth model was developed that was adequate for the purposes of an initial assessment of the stock, but this could be improved by better representation of very small and very large fish.

4. Achieved – The trawl fishery was determined to be the most significant sector of the fishery in terms of catch quantity, but trap and line, recreational and estuarine sectors were also important. Fishing has apparently had a significant impact on the trevally stock since exploitation increased in the 1980s. Preliminary yield modelling indicated the current size at first capture was well below the optimum size.

5 Achieved – The status of the silver trevally stock can be described as growth overfished. It would therefore be appropriate to establish a minimum legal length, but the selectivity patterns of the different fishing gears which target silver trevally (especially fish trawls) need to be addressed as well.

2. AGEING TECHNIQUES FOR SILVER TREVALLY

2.1 Introduction

Previous studies of ageing in silver trevally are limited. James (1984) used whole and broken and burnt otoliths to age trevally caught in research traps, demersal trawls and pelagic purse seine nets around the north island of New Zealand between 1970 and 1978. The fish sampled ranged in length from 5 to 51 cm (length to caudal fork - LCF). The majority of fish from demersal trawl catches were estimated to be less than 3 years of age, however smaller numbers of fish were aged between 5 and 35 years. Fish from purse seine catches were on average much older, most estimated to be between 10 and 25 years of age. The oldest trevally aged in the study was a 43 cm fish estimated to be 47 years old. It was concluded that in New Zealand, trevally grew relatively quickly for the first few years of life, reaching a mean length of about 35 cm LCF at 5 years of age, but growth slowed markedly thereafter.

James (1984) validated his interpretation of the otoliths of juvenile trevally by length frequency modal progression, which showed the growth of single cohorts of fish from a mean length of about 12 cm in one summer to a mean length of about 18 cm in the following summer (this transition approximately corresponded to growth of the fish from age 1 to age 2). The periodicity of ring formation on the otoliths of fish aged 1 to 5 years was also used to validate the ageing technique.

In Australia, previous ageing studies were restricted to a short study conducted at the Australian National University (Kalish and Johnston, 1997) using a total of 207 specimens obtained in 1994 from NSW commercial catches and catches made by the NSW Fisheries Research Vessel *Kapala*. Transverse sections of sagittal otoliths were used to estimate fish age, which was related to standard length (SL) rather than LCF. The fish sampled ranged in length from 17 cm to 50 cm SL, and assigned ages ranged from 2 to 21 years, with the majority between 2 and 10 years of age. The results from this study were compared with the results from the New Zealand ageing studies, and it was concluded that trevally from NSW grew more slowly, but attained a greater asymptotic length (L_∞) than trevally from New Zealand.

Kalish and Johnston (1997) provided a validation of their age estimates for silver trevally using the ‘bomb radiocarbon’ technique (Kalish, 1995). Trends in the concentration of radioactive carbon in the otoliths of four of the silver trevally (ranging in estimated age from 5 to 20 years) closely reflected those found in time series of redfish (*Centroberyx affinis*) and snapper (*Pagrus auratus*) otoliths sampled over the previous two decades from south-western Pacific waters.

The results of the ANU research only became available to us after the present study had been commenced. Also, a recently published study (Walsh *et al*, 1999) described the size and age composition of silver trevally from commercial catches (demersal single and pair trawls, and purse seines) in New Zealand during 1997-98. This study reviewed James' (1984) ageing methodology, and re-aged a sample of his original otolith collection, before deciding to use baked thin sections of otoliths for age determination. Fish sampled ranged from 25 to 68 cm LCF and were estimated to be from 3 to 43 years of age. The resulting age compositions suggested that there may be significant variations in year class strength in the New Zealand stocks of silver trevally.

The present study assessed both whole and sectioned otoliths, and also examined the usefulness of vertebrae for age determination of silver trevally. To aid in our understanding of otolith structure, a short experiment was conducted to assess the periodicity of ring formation in the otoliths of silver trevally held in captivity for 12 months.

2.2 Methods

Samples for age determination were purchased monthly at the Sydney Fish Market, from catches for which the location and method of capture were known. Samples consisted of one box (25-30 kg) from each of the 'northern' and 'southern' areas of NSW, with the dividing line at Barrenjoey Pt, latitude 33°35'S (see Figure 2.1). Samples of small trevally which were generally discarded from commercial catches were also collected from southern estuarine locations.

Data collected for each fish in a sample included length to caudal fork (LCF), total length (TL), whole weight and gutted weight, sex, gonad weight and gonad maturity stage. Both sagittal otoliths were carefully removed by paring away the ventral surface of the brain case, and stored in a small plastic vial. Trevally otoliths are small and delicate, with an elongated rostrum, and require careful handling and storage. After drying at room temperature for several weeks all whole otoliths were weighed to the nearest 0.00001 g. Where both otoliths from the same fish were whole, both were weighed together and the resulting weight was divided by two. Vertebrae were also removed from a small number of fish sampled for otoliths.

2.2.1. Otoliths

Both whole otoliths and transverse sections through the nucleus were assessed for their usefulness for ageing. Whole otoliths required much less preparation before ageing and so were examined first. One sagitta was immersed in a small petri dish of lavender oil and examined under reflected light against a black background using a stereomicroscope. Whole otoliths were assigned an age by counting the opaque zones, which appeared light in colour, wherever clearest on the otolith, without reference to fish size. An Index of Average Percent Error (Beamish and Fournier, 1981) was calculated for repeat readings by the same reader and for comparing ages assigned by two readers.

Transverse sections were prepared by embedding one otolith of each pair in resin, and taking a thin section through the core using two fixed diamond blades in a Buehler Isomet low speed saw. Sections were then permanently mounted on glass slides, and examined under reflected light against a black background using a stereomicroscope. Sections were assigned an age by counting the opaque marks which were generally clearest near the edge of the sulcus acusticus (Figure 2.2). Sections were aged without reference to fish size. All otolith sections were aged twice (approximately two months apart) by the primary reader (Reader A). During the second examination, each otolith section was assigned a 'readability' factor as follows:

1 - opaque zones clearly visible and easily interpreted;
2 - opaque zones difficult to interpret, but age assigned with reasonable certainty;
3 - opaque zones very difficult to interpret, age assigned after considerable interpretation.

A sample of 700 of the otolith sections was aged using a similar technique by a second reader (Reader B), and the results were compared with the ages assigned by Reader A to determine inter-reader variability. An Index of Average Percent Error was calculated for comparing ages assigned by the two readers.

Figure 2.1 Map of the New South Wales coast showing the location of the ports of landing from which samples of silver trevally were obtained during the study.

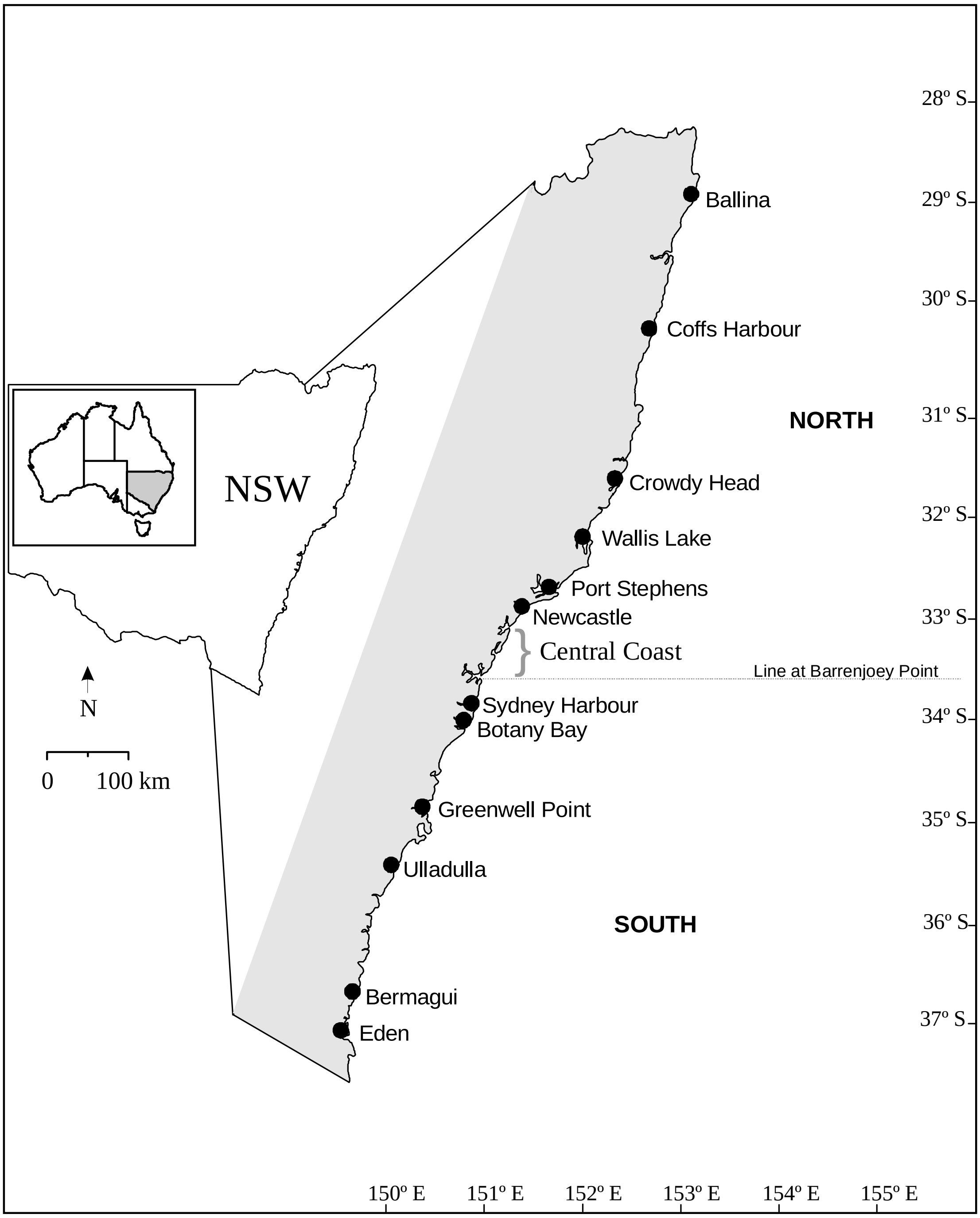
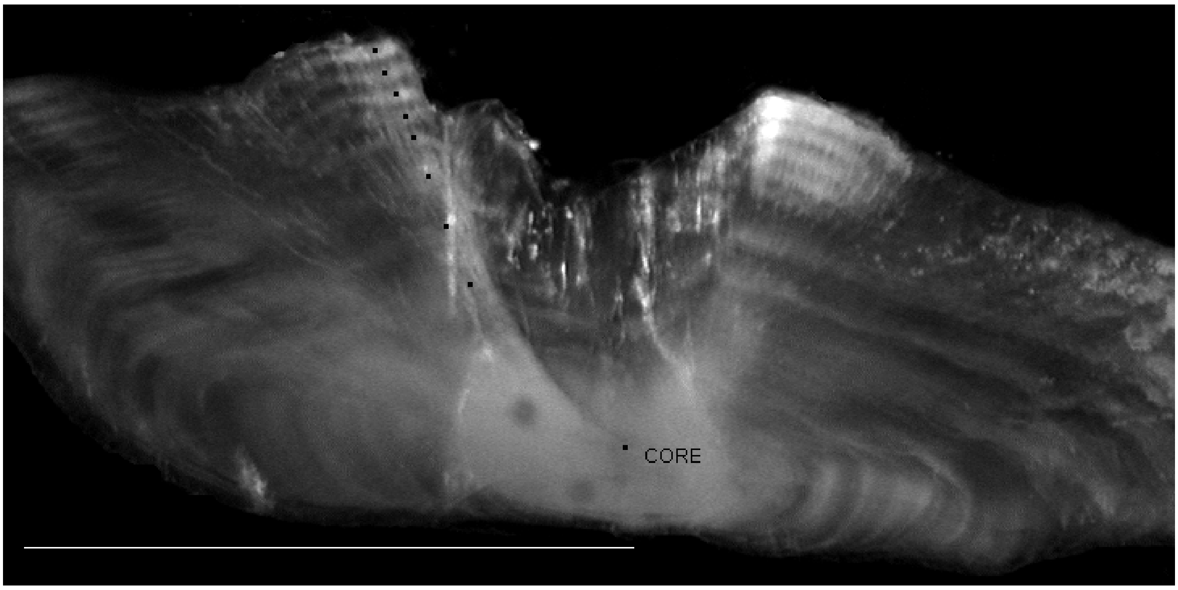


Figure 2.2 Cross section of an otolith from a 33 cm LCF silver trevally, estimated age 8 years.

Otolith core and opaque rings marked with black dots. Scale bar is 1 mm.



2.2.2 Vertebrae

Vertebrae were collected from a subsample of the fish sampled for otoliths. After relevant information about length, weight and reproduction was recorded and the otoliths removed, each fish was filleted for easier access to frame. The first four to five vertebrae were collected as an intact section, and excess material was removed before the vertebrae were soaked in 50% bleach solution until being further cleaned and processed. Each vertebra was separated and the cone jelly was carefully removed with tweezers. Cleaned vertebrae were placed in a solution of alizarin red S (Berry *et al.*, 1977) for several hours. Vertebrae were then removed and rinsed in tap water before being placed in labelled bags and stored frozen.

Stained vertebrae were examined under a stereomicroscope using reflected light. All vertebrae collected for each individual fish were examined and an age was determined from counts of ridges on the inner surface of the vertebra following the methods outlined by Gillanders *et al.* (1999).

2.2.3 Validation of Annulus Formation using Oxytetracycline

With little prior knowledge of the age composition of silver trevally, we attempted to collect fish for this study over as broad a size range as possible. Fish were collected during January - February 1998 from commercial haul net fishers in Botany Bay and transported to the NSW Fisheries Research Institute aquaria facilities. Small fish, not caught by the haul nets, were collected using small fish traps in Port Hacking and Botany Bay. All fish were initially held in two 4500 L tanks for 2-3 months undergoing prophylactic treatments (oxytetracycline solution at 100 mg/l) to reduce possible infection arising from capture and handling and to improve water quality. In May, 1998 all fish were anaesthetised using Ethyl-P-amino benzoate (benzocaine) at 50 ppm in seawater, measured, weighed and injected with oxytetracycline (OTC) at the rate of 50 mg/kg fish weight in the intraperitoneal cavity. Injected fish then transferred to a large (80 m^3) pen in the main aquarium pool at the Fisheries Research Institute, which had a flow through water exchange from Port Hacking at ambient temperature and salinity. Care and handling of the fish during this experiment conformed to the methods recommended by Barker (1999).

Each month between June 1998 and April 1999 a sample (N = 8) of silver trevally was removed from the pen (using handlines with baited hooks) and euthanased with benzocaine at 100 mg/l in a saltwater bath, prior to processing. In May 1999 all remaining fish (N = 12) were removed and sampled. Data collected for each fish processed included LCF, total length (TL), whole and gutted weights, sex, gonad stage and gonad weight. The otoliths were removed from each fish and stored in small vials in the dark**,** so as to minimise decomposition of the OTC.

All otoliths (N = 99) were processed in one batch at the conclusion of the experiment, following the methods described in section 2.2.1 above. To guard against the reader (Reader A) assuming that all otoliths had an OTC mark present, 30 sections from the commercial ageing sample were randomly mixed with the sections from the pool experiment prior to examination (Stewart *et al,* 1998). Using an image processing system, fish age was estimated from the transverse section of each otolith, and the following distances were measured: core to first opaque zone; otolith edge to last opaque zone; and the distance between the penultimate and the last opaque zones. Each section was then viewed under ultraviolet (UV) light, and if an OTC mark was visible the distance from this mark to the otolith edge was measured. All measurements were taken near the edge of the sulcus acusticus (see Figure 2.2).

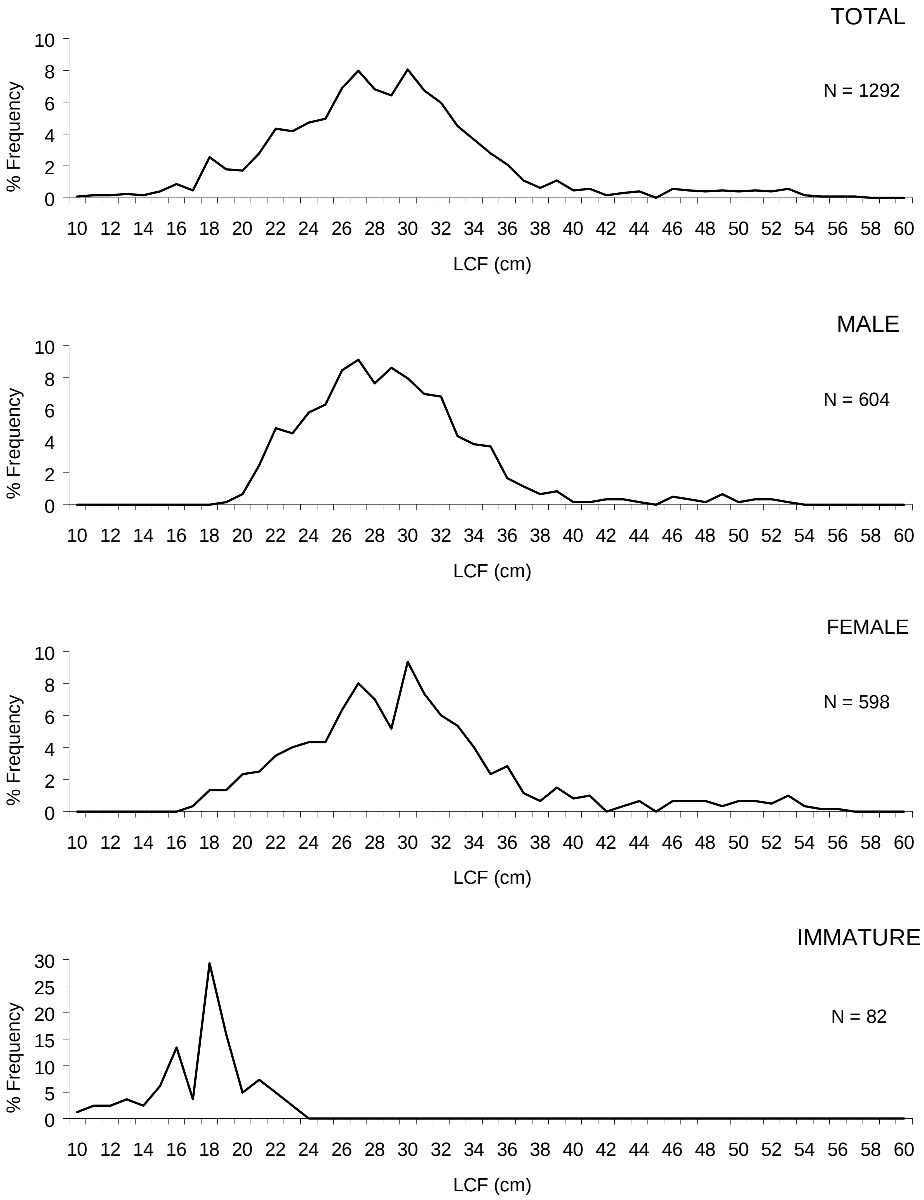
2.2.4 Growth Curves

Ages estimated from otolith sections by Reader A (2nd reading) were used with the length and weight data for the fish sampled to describe the growth of silver trevally. Individual length / age data points were used to estimate the von Bertalanffy growth in length parameters for males and females, for fish sampled from the 'north' and 'south' areas (see Figure 2.1), and for all trevally aged during the project. Parameters describing the von Bertalanffy growth-in-weight equation were also estimated using mean weight at age data derived from the full sample. Growth curves were fitted to the selected data set by least squares methods using the NLIN procedure of SAS (Anon., 1988).

2.3 Results

A total of 1292 silver trevally were sampled for ageing, ranging from 10 to 57 cm LCF, with the majority of fish between 18 and 40 cm (Figure 2.3). Immature fish comprised just over 6% of the ageing sample. The ratio of male to female fish in the ageing sample was almost exactly 1:1, and the size compositions of male and female fish were similar. A broader range of size classes was sampled from the southern region (Figure 2.4), which was probably due to the different mix of fishing methods in the two regions (catches from the southern area tended to be mostly from the trawl and estuary sectors, whereas catches from traps were more significant in the northern region). The size composition of fish sampled for otoliths from each commercial fishery sector is compared with the size composition of the catch determined for the sector in Figure 3.1 in the next section of this report.

Figure 2.3 Size composition of silver trevally sampled for age determination.



2.3.1 Comparison of Whole versus Sectioned Otoliths

Results for the duplicate readings of whole and sectioned otoliths are given in Table 2.1. Whole otoliths were found to be more difficult to age consistently (especially for larger/older fish), with only about 20% absolute agreement between repeat readings, and about 60% of repeat ages within 1 year of the original age. Sectioned otoliths, while still difficult to read, were considered by both readers to provide more consistent ages, especially for larger/older fish, with around 30% absolute agreement and 70-80% of repeat ages within 1 year of the original age.

Figure 2.4 Size composition of silver trevally sampled for age determination from the 'north' and 'south' areas.

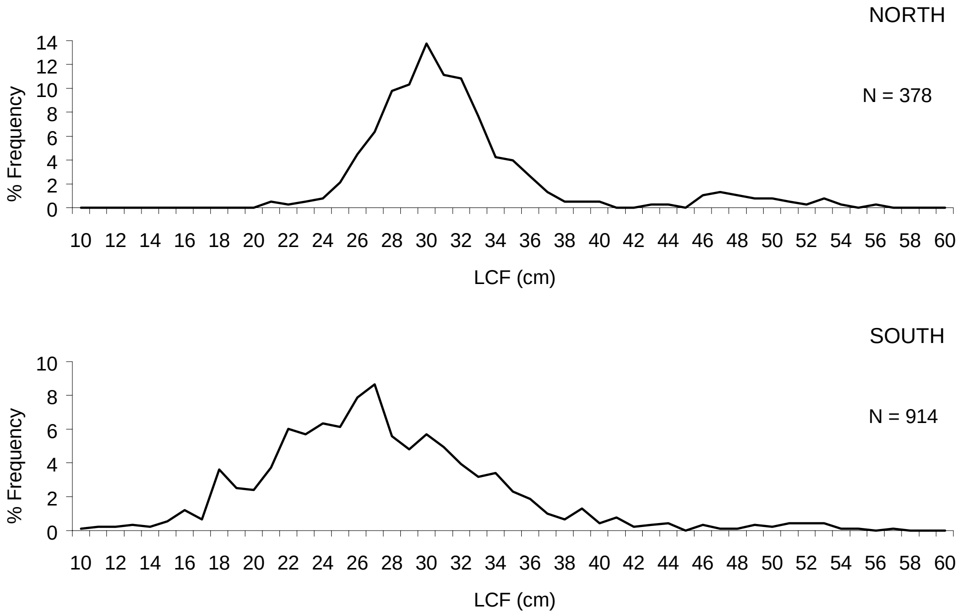


Table 2.1 Summary of results of comparisons of repeat age determinations by the two readers for samples of silver trevally otoliths.

N - sample size. IAPE - Index of Average Percent Error.

Comparison	N	% agreement	% ± 1 year	IAPE
Whole otoliths				
Reader A (duplicate)	72	18.1%	55.6%	15.5%
Reader B (duplicate)	87	24.1%	59.8%	10.3%
Reader A vs Reader B	69	26.1%	60.9%	10.9%
Sectioned otoliths				
Reader A (duplicate)	1229	36.9%	81.8%	10.2%
Reader A vs Reader B	697	27.8%	71.9%	15.3%

The spread of results for the comparison of ages determined from duplicate readings of sectioned otoliths by Reader A is shown in Table 2.2, and a similar comparison of ages determined for a sample of sectioned otoliths by the two readers is shown in Table 2.3. These results indicate a slight tendency for Reader B to assign older ages than Reader A, although 602 (87.8%) of the estimated ages were within 2 years of the age assigned by the other reader in this sample. For older fish in the sample (fish aged from 10 to 21 years) there is a reasonable level of agreement between the two readers. Duplicate readings of otolith sections by the primary reader showed agreement within ± 1 year for 82% of samples and an index of average percent error of 10.2%, demonstrating a high degree of repeatability (noting that 63 otoliths which were considered to be too difficult to age on the first occasion were assigned ages on the second reading).

Table 2.2 Comparison of ages assigned for otolith sections by Reader A on the first read (vertical axis) with ages assigned by the same reader on the second read (horizontal axis).

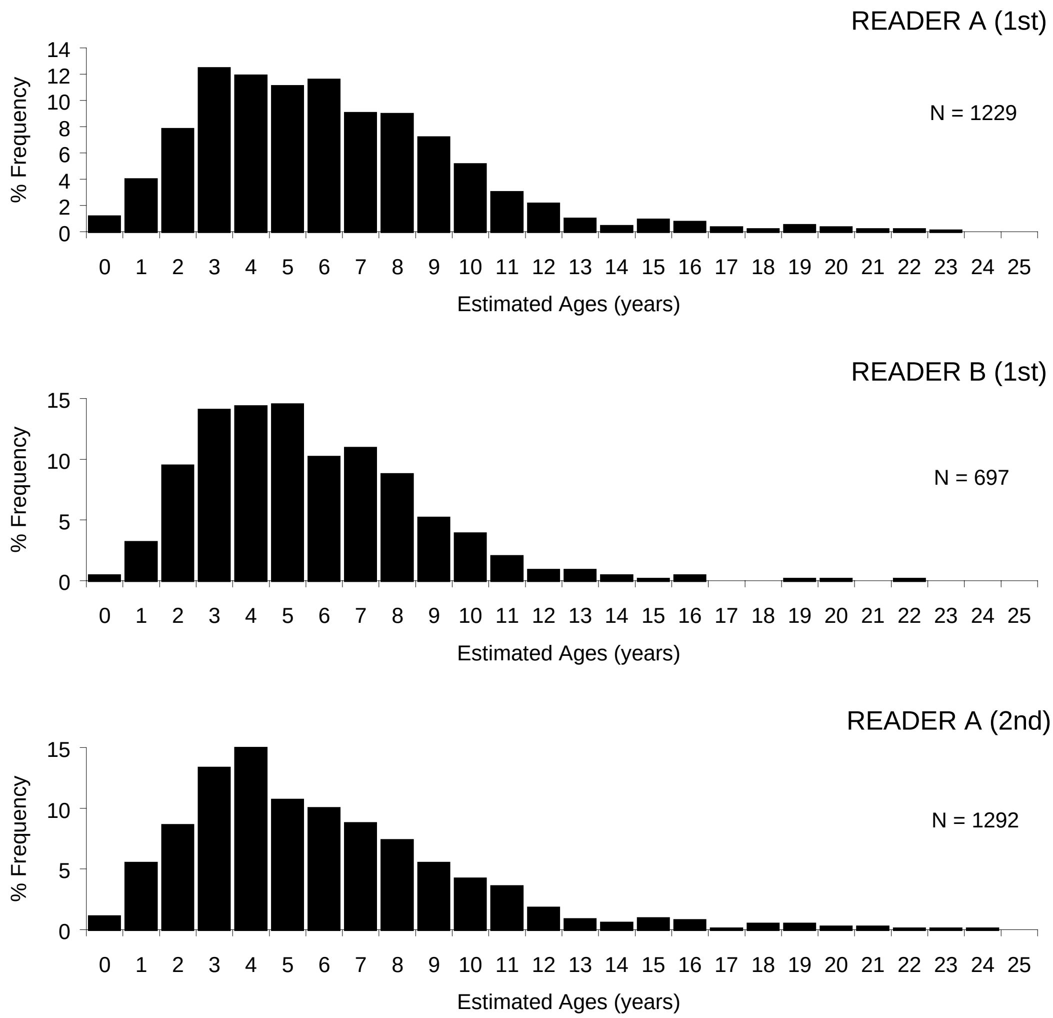
	<1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
<1	5	3	6																							14
1	2	33	6	7	1																					49
2	4	14	45	21	11	1																				96
3	1	8	34	68	37	4		1																		153
4	1	7	9	46	68	12	2	1																		146
5		2	5	16	52	42	15	4																		136
6		1		1	14	54	50	19	3																	142
7				1	3	18	41	30	13	5																111
8					1	4	12	34	36	16	5	1	1													110
9					1		2	10	31	23	14	5	2													88
10								4	8	18	16	15	2													63
11									1	5	15	11	3	1		1										37
12											3	11	7	3	1	1										26
13										1		1	4	4	1	1										12
14													1	1	2				1							5
15														1	1	4	3	1	1							11
16														1		3	5									9
17															1		2		1							4
18																			1		1					2
19																				3	2	1				6
20																			1	2		1				4
21																				1				1		2
22																						1			1	2
23																							1			1
24																										0
Total	13	68	105	160	188	135	122	103	92	68	53	44	20	11	6	10	10	1	5	6	3	3	1	1	1	1229

Table 2.3 Comparison of ages assigned by Reader B (vertical axis) for a sample of silver trevally otolith sections with the ages assigned for the same sections on the second read by Reader A (horizontal axis).

	<1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
<1	3																							3
1	5	4	8	4	1																			22
2	2	12	27	19	5	1																		66
3	1	11	17	30	30	7	1	1																98
4		5	12	22	36	19	4	1	1															100
5		10	10	8	29	29	13	1		1														101
6		4	8	6	10	21	12	7	2				1											71
7		2	2	3	5	8	27	18	10	1														76
8			1	1		4	5	20	20	7	2	1												61
9				1	1		1	9	12	8	1	3												36
10								2	7	11	2	4		1										27
11								1	2	3	3	2	1	2										14
12						1				1	1	1		1		1								6
13											1		4			1								6
14													1	1		1								3
15																		1						1
16											1						2							3
17																								0
18																								0
19																				1				1
20																						1		1
21																								0
22																					1			1
Total	11	48	85	94	117	90	63	60	54	32	11	11	7	5	0	3	2	1	0	1	1	1	0	697

The relative distribution of estimated ages in the respective samples did not vary greatly between duplicate readings, with the majority of fish estimated to be between 2 and about 12 years of age, full recruitment at about 4 years of age, and a long 'tail' of older age classes from 12 to 24 years of age (Figure 2.5). The readability scores given by Reader A on the second read showed that only a very small percentage of otoliths were easily interpreted, while on average about 60% of otolith sections were able to be aged with a reasonable degree of certainty (Figure 2.6).

Figure 2.5 Age compositions of samples aged by readers A and B using sectioned otoliths.



Weights were measured for a total of 1082 whole otoliths. Trevally otoliths are very small and light, and otoliths from even the largest fish weighed less than 0.05g (Figure 2.7). For fish greater than about 25 cm LCF, there was a very large range in otolith weight for a given fish length. Despite the variability in otolith weight with fish length, there was a linear relationship between estimated fish age and otolith weight (Figure 2.8), which suggests that the otoliths continue to grow throughout the life of the fish and are therefore suitable for use in ageing studies for all size classes.

Figure 2.6 Distribution of readability scores by age class (Reader A, second read, N=1292).

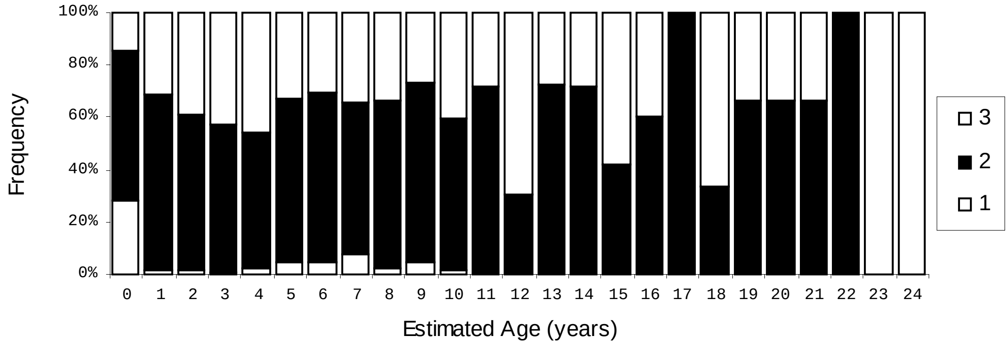


Figure 2.7 Relationship between fish length (LCF) and otolith weight for silver trevally.

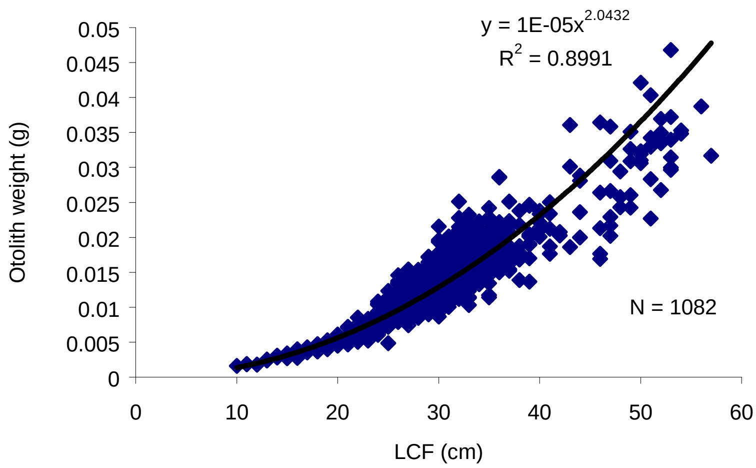


Figure 2.8 Relationship between age estimated from otolith sections (Reader A, 2nd read) and whole otolith weight for silver trevally.

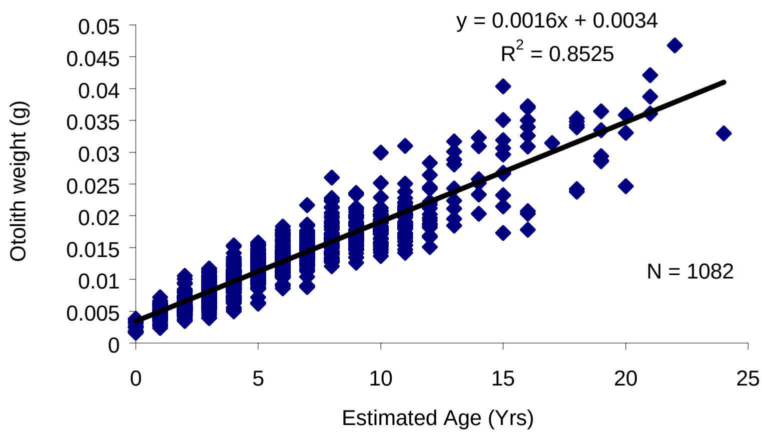


Table 2.4 Age-length key for silver trevally ages determined from sectioned otoliths by Reader A.

LCF	Number at Age																									
(cm)	<1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
10	1																									1
11	2																									2
12	2																									2
13	2	1																								3
14		2																								2
15	2	3																								5
16	2	7	2																							11
17	1	4	1																							6
18	2	18	9	4																						33
19		6	12	4	1																					23
20		6	10	5	1																					22
21		13	17	5	1																					36
22		6	25	19	5	1																				56
23		2	14	25	12	1																				54
24		2	6	29	20	2	2																			61
25		1	5	21	24	9	4																			64
26			7	17	29	19	9	6	1	1																89
27			2	21	31	23	17	6	2	1																103
28				10	18	23	17	10	4	2	4															88
29				3	21	11	18	13	7	7	2	1														83
30			1	5	12	21	18	17	11	8	8	2	1													104
31				2	7	12	11	18	14	9	7	4	1	1		1										87
32				1	4	5	8	11	17	11	5	8	4	1	1	1										77
33					2	8	12	5	7	9	8	6				1										58
34					3	2	4	6	11	8	6	5	1				1									47
35				1	2	1	2	6	4	6	2	6	2	3					1							36
36							5	2	7	1		3	5		1	1				2						27
37							1	4	1	2	1	2					2			1						14
38							1	2	3				1						1							8
39								3	1	3	4	1	1								1					14
40										1		5														6
41								1	2	1	1	1			1											7
42											2															2
43								1						2								1				4
44										1		1		2	1											5
45																										0
46								1	1		2		1				1			1						7
47								1			1		1		1	1					1					6
48													2	1	1					1						5
49									1				2			1	2									6
50												1			1	2						1				5
51									1				1			1			1		1				1	6
52																1	2		1	1						5
53											1					1	2	1					1	1		7
54																			2							2
55																1										1
56																						1				1
57														1												1
Total	14	71	111	172	193	138	129	113	95	71	54	46	23	11	7	12	10	1	6	6	3	3	1	1	1	1292

The distribution of ages assigned for fish in each length class (termed the "Age-Length Key") for 1292 otolith sections aged at the second reading by the primary reader is shown in Table 2.4. The sample contained a reasonably good representation of trevally up to about 40 cm LCF and 12 years of age, but larger and older fish were poorly represented in the sample, with only about 5% of the sample being longer than 40 cm or aged greater than 12 years. A considerable degree of variation in growth is apparent, even for young fish. Trevally which were estimated to be 4 years of age ranged in length between 19 and 35 cm LCF, while fish of 30 cm LCF ranged in age from 2 to 12 years. The largest trevally sampled was a 57 cm fish which was estimated to be 13 years of age, while the oldest fish was a 51 cm female which was estimated to be 24 years of age.

2.3.2 Vertebrae

Vertebrae were examined from 29 silver trevally ranging in size from 23 to 33cm LCF. Results from the staining procedure were variable. All vertebrae showed ridges that could be interpreted as annual growth zones, although for some fish the number of zones counted differed between individual vertebrae. Comparison of the ages determined from duplicate readings of vertebrae, and with the ages determined from sectioned otoliths, are shown in Table 2.5 (all readings were done by Reader A). Agreement of ages assigned from duplicate readings of vertebrae was reasonably good (27.6%, with 62% of ages within 1 year of the original age), however not as good as for duplicate readings of sectioned otoliths by the same reader (see Table 2.1). Agreement between ages assigned from vertebrae and those from otolith sections was noticeably poorer, with less than 40% of ages assigned from vertebrae being within 1 year of the age assigned from the otolith section.

Table 2.5 Comparison of age determination for silver trevally for duplicate ageing of vertebrae, and for sectioned otoliths from the same fish (second read, Reader A).

Comparison	% Agreement	% ± 1 year	IAPE
Vertebrae duplicate age determinations	27.6%	62.1%	10.9%
Vertebrae (1st read) vs otolith sections	17.2%	41.4%	18.6%
Vertebrae (2nd read) vs otolith sections	10.3%	34.5%	20.6%

2.3.3 Validation Experiment

Trevally injected with OTC ranged in length from 10 to 31 cm, but the majority of fish were obtained from commercial fishing operations and were greater than 22 cm LCF (Figure 2.8). Monthly samples generally comprised eight fish, although in November 1998 and February and March 1999 the otoliths of one fish in each sample were damaged during extraction and could not be read (Table 2.6). Of the total of 96 otolith sections examined, 88 (91.7%) had visible OTC marks when examined under UV light. The proportion of fish in each monthly sample with an opaque ring determined from the measurements taken to be outside the position of the OTC mark increased from zero in July to 100% in January. For one fish sampled in February a completed opaque ring was not yet discernible outside the position of the OTC mark.

Figure 2.8 Size composition of silver trevally injected with OTC for age validation study.

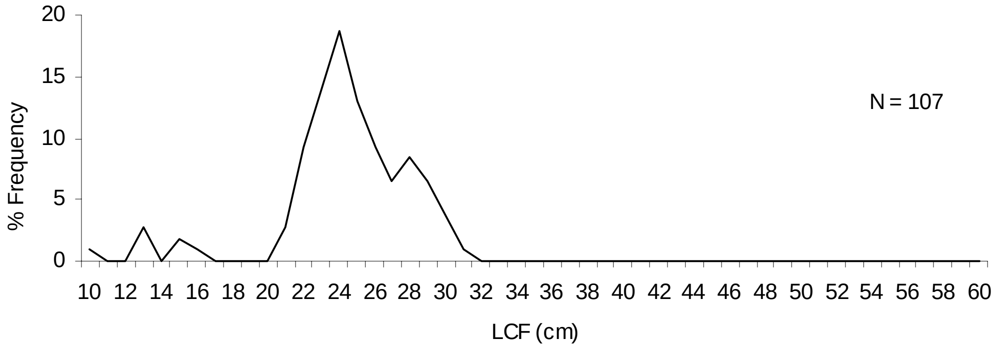


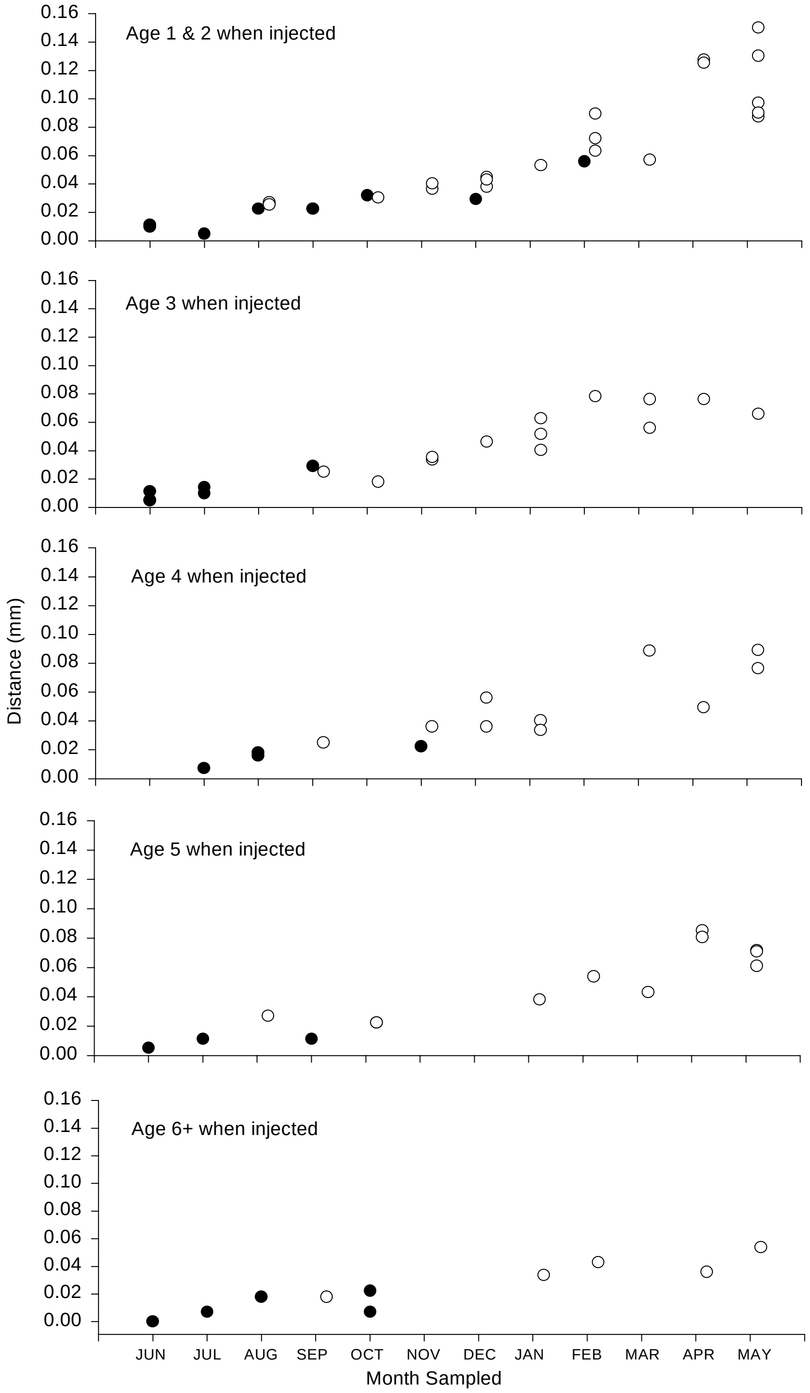
Table 2.6 Proportion of fish with OTC mark visible in the otolith section by month of sampling for silver trevally injected during May 1998.

Month	No. Sampled	% with OTC mark visible	% with ring outside OTC mark
June 98	8	87.5	0
July	8	75	0
August	8	87.5	37.5
September	8	87.5	37.5
October	8	87.5	50
November	(8)7	85.7	71.4
December 98	8	87.5	75
January 99	8	100	100
February	(8)7	100	85.7
March	(8)7	100	100
April	7	100	100
May 99	12	100	100
Total	**96**	**91.7**	**-**

The silver trevally used in the validation study were mostly estimated to be aged between 2 and 5 years at the time they were injected with OTC, although ten fish were aged 6 years or greater. All fish which were held in captivity for more than 1-2 months showed significant growth of the otolith outside the OTC mark and the older fish showed smaller otolith growth increments over the period studied than the younger fish (Figure 2.9). Formation of opaque rings appeared to be completed for all age classes of silver trevally by about January / February.

Figure 2.9 Distances from the OTC mark to the otolith edge, by time of sampling, for sectioned silver trevally otoliths from fish of different age classes at the time of OTC injection.

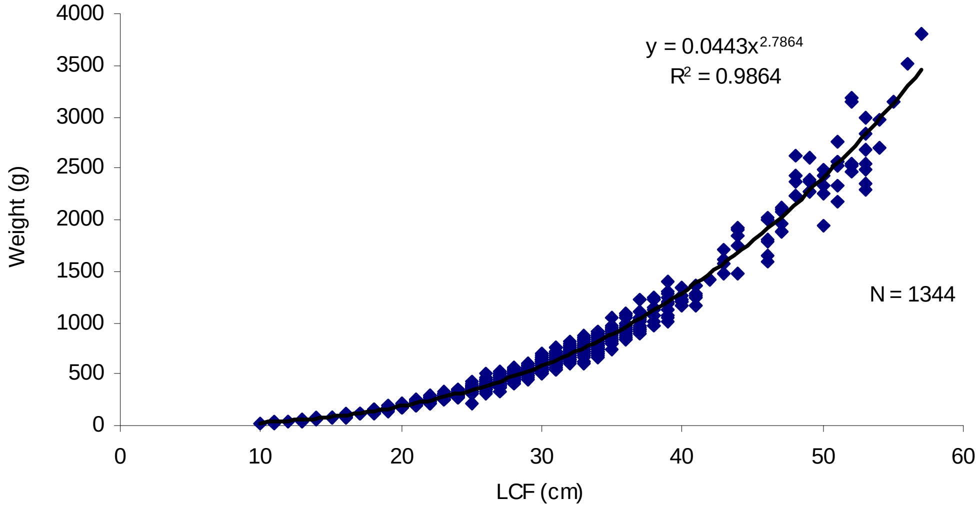
Trevally which had formed an opaque ring outside the position of the OTC mark are shown by open circles, while fish which had not formed another ring are shown by filled circles.



2.3.4 Growth Curves

The relationship between fish length and whole weight for silver trevally was well described by the data obtained from sampling of commercial catches (Figure 2.10), although the number of large fish (> 50 cm) in the sample was limited. The data suggest a significant degree of variation in the weight of large fish of comparable lengths (e.g. fish of 50 - 53 cm length ranged in weight from 2 to more than 3 kg).

Figure 2.10 Relationship between length to caudal fork (LCF) and whole weight for silver trevally sampled from commercial catches.



There were no obvious differences in the pattern of length at age for comparisons between males and females (Figure 2.11) or fish sampled from the 'northern' and 'southern' regions (Figure 2.12), although sample sizes were small for ages older than 12. These individual data sets were generally not adequate to produce realistic von Bertalanffy growth parameters when growth curves were fitted (Table 2.7). Data for all trevally for which age determinations were available showed very large ranges in length at age, and even greater variability in ages for a given length class (Figure 2.13 and Table 2.4). The von Bertalanffy growth function provided a reasonable fit to the total data set, and produced estimates of L_∞ of 63.16 cm and K of 0.051 yr^{-1} (Table 2.7). Despite the occurrence in the data set of very young trevally (less than 2 years old), a large negative t_o value (-6 yr) indicated that the length at age data for the younger age classes are probably biased because of selection by the fishery of faster growing individuals. The parameters estimated for the von Bertalanffy growth-in-weight function for silver trevally are also shown in Table 2.7. W_∞ for silver trevally was estimated to be just greater than 4 kg.

Figure 2.11 Length at age data determined from sectioned otoliths for male and female silver trevally sampled from commercial catches.

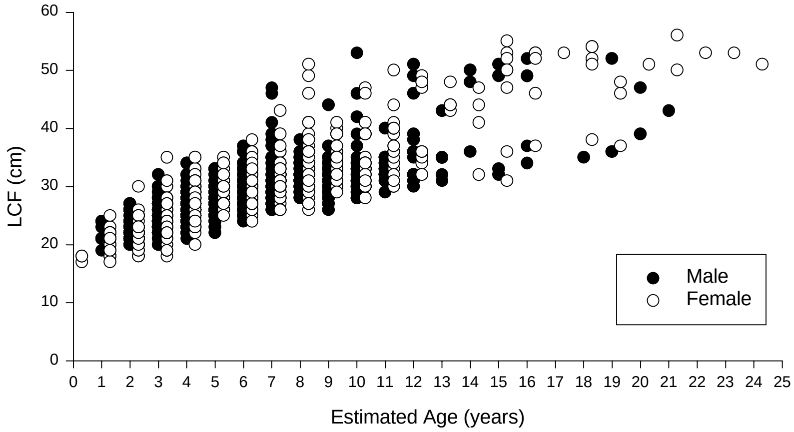


Figure 2.12 Length at age data determined from sectioned otoliths for silver trevally sampled from the 'northern' and 'southern' regions (see Figure 2.1).

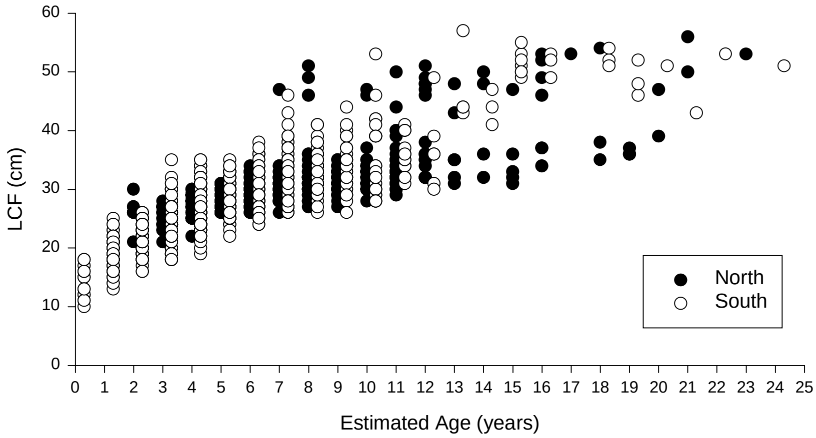


Figure 2.13 Age at length data for all silver trevally aged using sectioned otoliths, showing the trajectory of the von Bertalanffy growth curve fitted to these data.

Parameters of the growth curve are those given for "Total Sample" in Table 2.7.

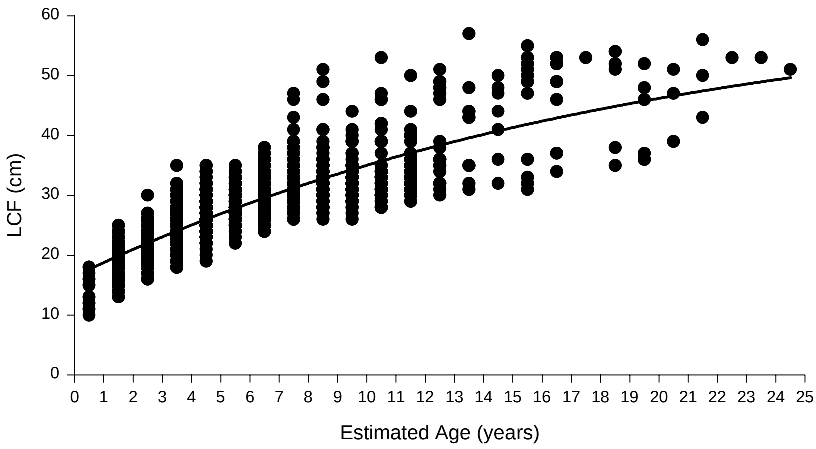


Table 2.7 Von Bertalanffy growth parameters estimated using different data sets for silver trevally sampled from commercial catches.

Asymptotic standard errors are shown for each estimate.

Growth in length	**N**	**L∞** cm	**K** yr^{-1}	$\mathbf{t_o}$ yr
North	378	197.9 ± 1080.8	0.009 ± 0.011	-11.58 ± 11.69
South	914	74.69 ± 7.03	0.043 ± 0.007	-5.95 ± 0.46
Males	604	57.51 ± 8.15	0.048 ± 0.015	-8.91 ± 1.52
Females	598	107.59 ± 2.16	0.022 ± 0.001	-8.95 ± 0.46
Total Sample	**1292**	**63.16 ± 4.31**	**0.051 ± 0.007**	**-6.47 ± 0.50**

Growth in weight	**N**	**W∞** g	**K** yr^{-1}	$\mathbf{t_o}$ yr
Total Sample	**1292**	**4056 ± 1183**	**0.075 ± 0.027**	**-3.67 ± 2.74**

2.4 Discussion

The samples obtained for age determination of silver trevally covered almost the entire size range for the species in NSW waters (with the exception of the very large fish, 60 - 90 cm LCF, found in waters around Lord Howe Island - it is uncertain if these fish belong to the same stock as the trevally from NSW coastal waters). A high proportion of the fish sampled for age determination were between 25 and 35 cm LCF. Large fish (greater than about 50 cm LCF) and very small fish (less than 20 cm LCF) were sampled in smaller numbers.

After examining the material available from whole and sectioned otoliths, and stained vertebrae, the authors were of the opinion that sectioned otoliths provided the most precise and cost effective method of obtaining accurate growth data for silver trevally in NSW. Whole otoliths were more difficult to interpret, especially near the otolith edge. For relatively long lived fish with comparatively small otoliths such as trevally, it is probable that ages of older fish will be underestimated using whole otoliths because of difficulties in seeing the fine ring structure near the edge of the otolith. Vertebrae were considered to be less effective for ageing because of their small size (difficult to read whole), the time needed to process each sample, problems with even staining, and apparent variability in ring patterns between individual vertebrae.

The results for ageing of silver trevally reported here are generally consistent with previously reported age determinations for the species in Australasian waters. The extensive ageing studies carried out on trevally from New Zealand waters by James (1984) suggested a reasonably fast initial growth rate for the first 5 years of life, followed by a long period of very slow growth to a maximum age of around 40 years. James reported difficulty with fitting a von Bertalanffy growth curve to the ageing data available for trevally because of the very slow growth of fish after about 10 years of age, and his best estimate for each of the parameters was L_∞ = 44 cm, K = 0.42 yr^{-1} and t_o=-0.6 yr. This value of L∞ was considerably less than the maximum size of trevally regularly caught by commercial fishers in New Zealand of 50 - 55 cm, but continues to be used for stock assessments of trevally in New Zealand waters (Annala *et al.*, 1999). From the results of ageing a small sample of trevally from NSW waters, Kalish and Johnston (1997) calculated values of L_∞ = 54 cm LCF, K = 0.145 yr^{-1} and t_o = -1.8 yr. These values suggest a faster growth rate for NSW trevally than was found in the present study (K = 0.051), but sample sizes were small for ages greater than 5 years in the Kalish and Johnston study.

Williams and Lowe (1997) reported growth data based on otolith daily increments for *Pseudocaranx dentex* from Hawaiian deep slope waters, which resulted in estimates of L∞ in excess of 100 cm. These authors report a maximum recorded size of 131 cm for this species in Hawaii, and it appears unlikely to have a similar growth regime to *P. dentex* in NSW waters (and may even be a different species).

IAPE results in the range 10-15% indicated a relatively high degree of inconsistency in assigning ages for silver trevally, but for age determinations from sectioned otoliths there was an acceptable level of agreement within ±1 year (more than 70%). Also using otolith sections, Kalish and Johnston (1977) reported significantly better agreement between readers and lower IAPE values than were found in the current study (e.g. they reported replicate ages within ±1 year for 95% of 207 otolith sections read by their two primary readers, resulting in an IAPE value of just 0.46%). It is possible that the two "experienced" readers used in the Kalish and Johnston study had developed a better mutual understanding of the ageing technique through previous discussions and experience. In the current study, neither reader had any previous experience with age determination of silver trevally otoliths, and each sample was aged independently with a minimum of communication between the readers, to give a true representation of the degree of difficulty involved in this ageing technique.

For the large sample aged in the current study, we found a reasonably high degree of overlap in length at age for silver trevally, suggesting quite a variable growth rate for the species in NSW waters. Trevally of 30 cm LCF were estimated to range from 2 to 12 years of age, while fish estimated to be 10 years of age ranged in fork length from 28 to over 50 cm. This degree of variation implies that sample sizes for determining 'average' growth parameters for silver trevally need to be large, and representative of the full size range of fish in the population.

There was little difference in the ranges of length at age for male and female trevally sampled from NSW waters during the current study, although males had a significantly higher K value and a significantly lower L_∞ value than females. These differences appear more likely to be associated with variations in the composition of the sample aged for each sex, rather than real differences in growth rates between the sexes. In general, the results from the current study confirm earlier observations by James (1984) and Kalish and Johnston (1997) that the growth rates of male and female trevally are not significantly different. A similar conclusion can be drawn about variation in growth between the 'northern' and 'southern' regions of the NSW coast - the significant (and, for the northern data, unrealistic) variations in growth parameters appear to result from variations in the composition of the samples rather than a real difference in growth rates between the two areas.

While the L_∞ and K values estimated for the full sample aged provide reasonable estimates for these parameters, the value estimated for t_o of –6.47 yr is apparently biased by the partial recruitment of the younger age classes to the commercial catch. The progressive recruitment to commercial catches of trevally between about 15 and 26 cm LCF suggests that catches include only the faster growing individuals in age classes less than about 6 or 7 years. This positive bias in the mean length at age of these age classes leads to a flatter von Bertalanffy curve, with a greater negative t_o value than would be the case if unbiased estimates of size at age were available for these younger age classes. Because of the correlation between the parameters of the von Bertalanffy growth curve it is possible that K has been underestimated due to this bias in size at age of the younger age classes.

The results of the validation study, where trevally injected with OTC were held in captivity for 12 months, suggest that fish from a range of age classes deposited just one ring on their otoliths during the year after injection. These results support the use of sectioned otoliths to accurately age silver trevally, and reinforce the previous validation of growth rates of juvenile trevally (James, 1984) and confirmation of the longevity of the species to at least 20 years using the 'bomb radiocarbon' technique (Kalish and Johnston, 1997).

3. THE SIZE AND AGE COMPOSITION OF SILVER TREVALLY CATCHES

3.1 Introduction

A description of the current size and age composition of the silver trevally population is needed because this is one of the main inputs required in the development of a population model for the species. Although no historic age structure data are available for silver trevally, size composition data are available for commercial and recreational catches for isolated periods in the history of exploitation of the trevally stock. Comparison of the historic and recent data will allow an assessment of changes which might have occurred in the structure of the population since exploitation commenced.

This chapter describes the methods used to obtain an estimate of the current size and age structure of commercial and recreational catches of silver trevally in NSW, and presents the results for each of the fishery sectors. The comparison of these results with the available historic data, and their incorporation in an initial assessment of the silver trevally stock, are discussed in section 5 of this report.

3.2 Methods

3.2.1 Size Composition

Commercial catches of silver trevally were measured at the Sydney Fish Markets and at district Fishermen's Co-operatives from mid 1997 to early 1999. The date, total weight caught, location and method of capture, and name of the fisher or boat were recorded for each catch measured (catch location and method details were frequently checked by contacting the fisher or co-operative concerned). The length of each fish in a sample was measured from snout to caudal fork (LCF), to the nearest whole cm below the true length.

Due to the multiple fishing methods and points of landing along the NSW coast, and the tendency for some fishers to grade catches by fish size, entire catches were measured where possible. For large catches, a representative subsample of the catch was measured, and the results scaled up to the total catch by proportional weighting. Regular communication was maintained with the main commercial fishers to provide an understanding of fishing methods used to target silver trevally, handling and sorting of the catch, and marketing protocols. Contact was also made with the exporters of silver trevally to determine the requirements of the export market.

Roving creel surveys of recreational catches were beyond the scope of this project, and sampling effort was therefore directed to times and locations likely to yield the most information. Two important recreational fishing tournaments were sampled - Crowdy Head F.C.A. Competition in October 1997 and the Port Stephens Trailerboat Fishing Tournament in April 1998. Silver trevally weighed in at each tournament were measured, and competitors at the Port Stephens tournament were also given data sheets to record the lengths of trevally caught and released at sea (for fish not large enough to be landed for the competition).

3.2.2 Age Composition

Samples for age determination were obtained from each of the commercial fishery sectors, however for some sectors these samples were deliberately biased towards the smaller or larger fish caught by that sector to obtain the best possible information on growth of trevally over their whole size range. Estimates of the age composition of the catch of each sector were therefore based on an age/length key approach (Kimura, 1977; Lai, 1993) where the relative frequency of ages in each length class for the whole aged sample was applied to the size composition determined for each sector, and for the total commercial fishery. A similar technique was used to estimate the age composition of recreational catches.

3.3 Results

3.3.1 Size Composition by Sector

A total of 33,266 silver trevally were measured from commercial catches during the sampling period. The smallest fish measured was 13 cm LCF and the largest 61 cm, and the majority of fish were between 20 and 35 cm (top graph in Figure 3.1).

The sampling procedure used ensured that sample sizes generally reflected the relative quantities marketed by each of the fishery sectors. Just over half of the trevally measured (N = 17,411) came from trawl catches, which contained a relatively high representation of fish between 20 and 30 cm LCF (Figure 3.1). Trevally from trawl catches ranged in length from 15 to 59 cm LCF, with only a very small proportion of the catch being comprised of fish greater than 40 cm. There was a significant difference in the size compositions determined for trawl catches from the 'north' and 'south' areas (Figure 3.2), with a high proportion of small fish (<25 cm LCF) in trawl catches from the northern area.

In total, 9,517 trevally were measured from trap catches. These fish ranged in length from 16 to 61 cm LCF, with the majority being between 25 and 35 cm (Figure 3.1). The length distribution was characterised by a strong mode at 28 to 30 cm, which was evident in the trap catches from both the northern and southern areas (Figure 3.2).

The results of the size composition monitoring showed that trawl landings from the more northern ports contained a higher proportion of small fish (Figure 3.3). This was particularly evident for the large sample measured from the Newcastle trawl catch, with the majority of fish in these catches being less than 25 cm LCF. Trap catches did not display the same geographic trend, with small fish (<25 cm) being evident in catches from both the northernmost and southernmost ports (Figure 3.4).

Figure 3.1 Size compositions of silver trevally measured (solid line) and sampled for otoliths (broken line) from commercial catches by the different fishery sectors during the study period.

Sample sizes are given for the number of fish measured 'C' and the number sampled for otoliths 'O'.

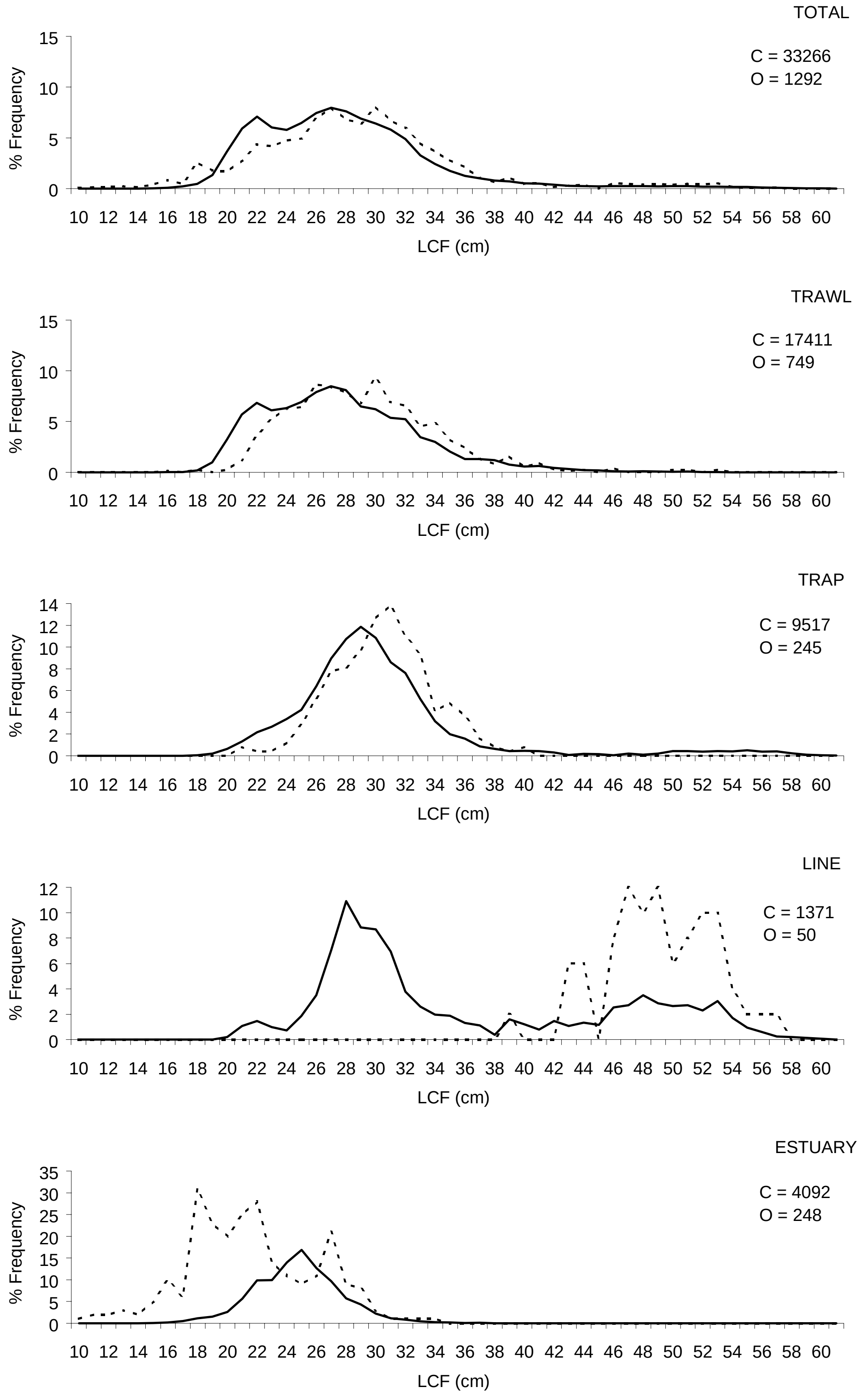
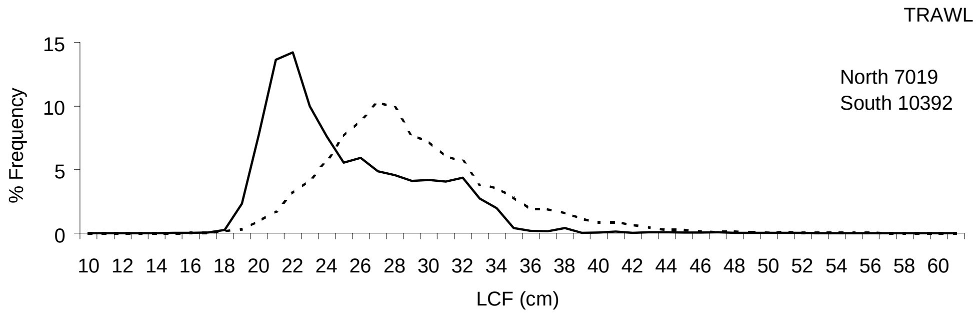
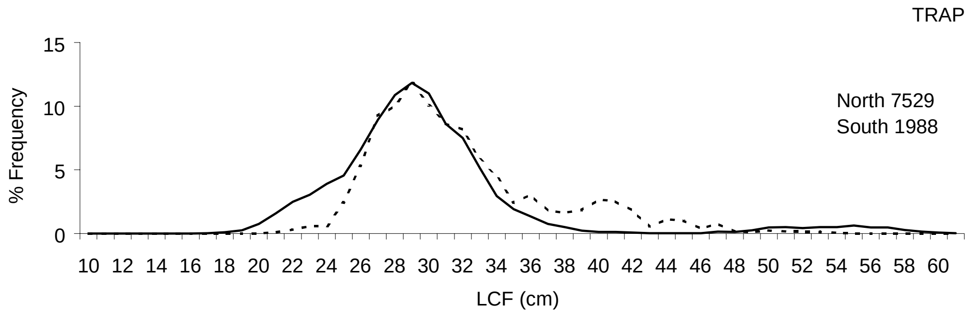


Figure 3.2. Size compositions of trawl and trap catches of silver trevally from the 'northern' (solid line) and 'southern' (dashed line) areas sampled.

Sample sizes are given for each area for each method.





Smaller numbers of trevally were measured from estuary (N = 4092) and line (N = 1371) catches (Figure 3.1). Landings from these fishery sectors tended to be more sporadic or seasonal during the sampling period. Estuary catches were taken predominantly by hauling nets and samples contained trevally ranging from 13 to 43 cm LCF, however the majority of fish were between 20 and 30 cm. Catches by commercial line fishers contained a large size range, from 20 to 60 cm LCF, and although dominated by fish between 25 and 35 cm, there was also a significant representation of larger fish (>40 cm) in catches taken by the line sector (Figure 3.1).

One catch of small silver trevally was sampled from a purse seine fisher in July 1998, and it appeared these fish were taken incidentally to fishing operations targeted at yellowtail *Trachurus novaezelandiae* and blue mackerel *Scomber australasicus*. The total weight of trevally consigned in this catch was 240 kg, and the sample measured comprised fish between 17 cm and 24 cm, with a modal length of 20 cm.

The recreational tournaments sampled were notable for the very poor catches of silver trevally taken, despite the fact that these tournaments were targeted because of the likelihood of good trevally catches. A total of only 130 fish were measured from recreational catches, the majority of which were between 30 and 40 cm LCF (Figure 3.5).

Figure 3.3 Size compositions of trawl catches of silver trevally measured from the main ports of landing during the study period.

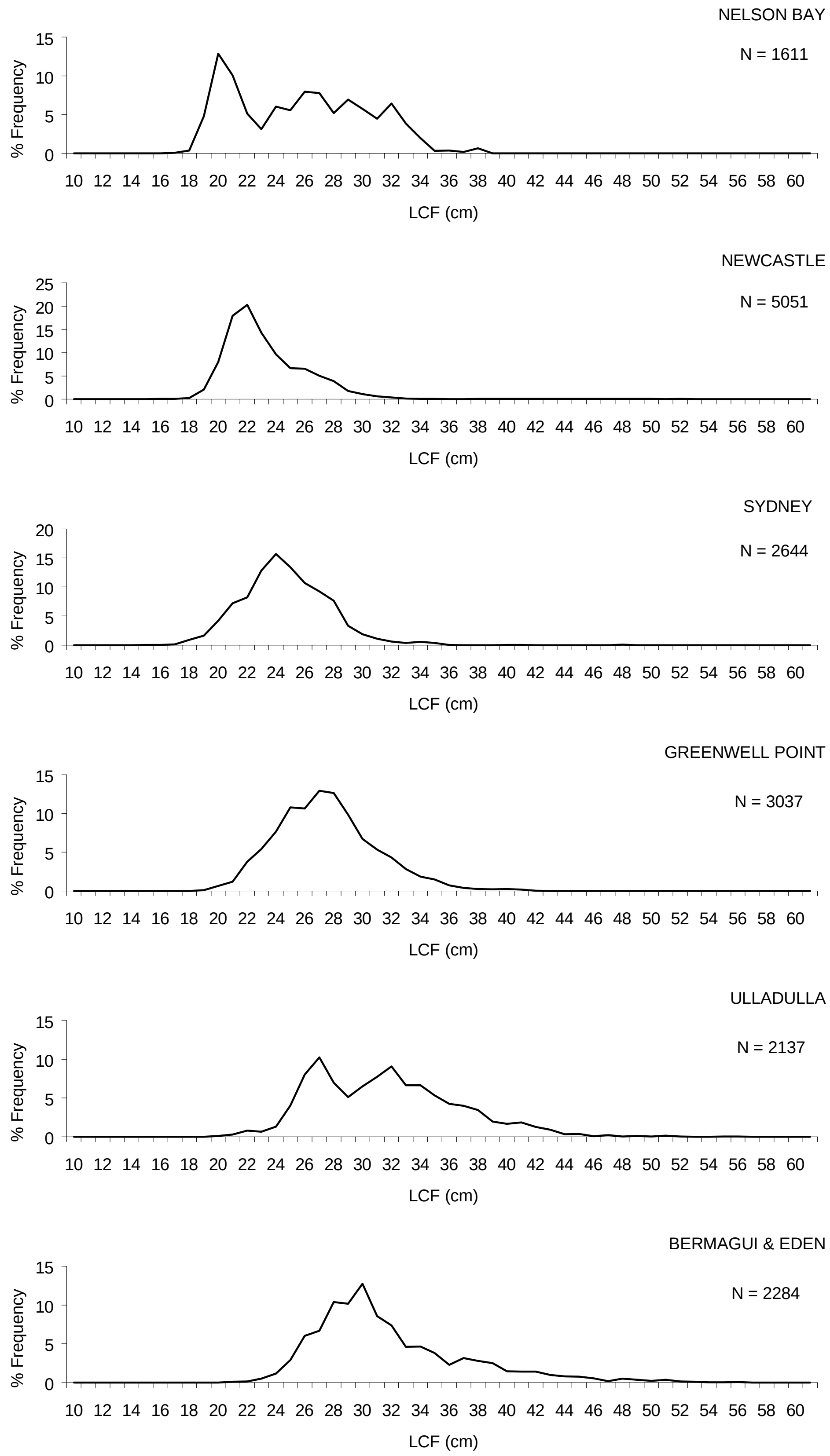


Figure 3.4 Size composition of trap catches of silver trevally measured from the main areas of landing during the study period.

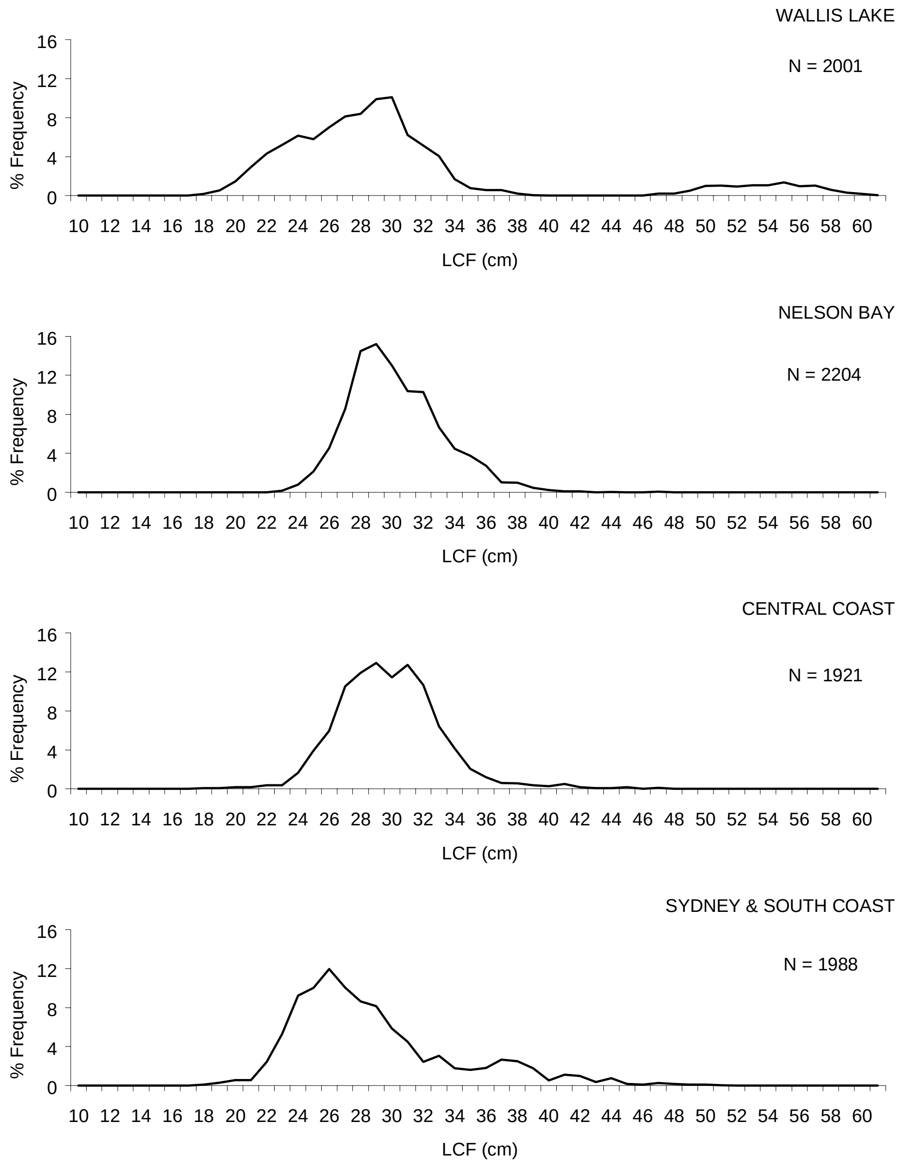
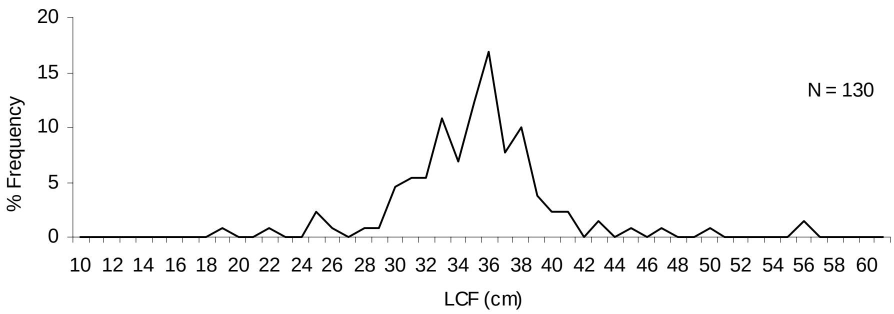


Figure 3.5 Size composition of recreational catches of silver trevally measured during this project.



3.3.2 Age Composition by Sector

For the trawl and trap sectors, which comprised the bulk of the fish sampled, the size compositions of silver trevally sampled for age determination were generally similar to the total size compositions measured (see broken lines in Figure 3.1). However, samples taken for ageing from the estuary and line sectors were deliberately biased towards the smaller and larger fish available from these two sectors. Despite this deliberate structuring of the samples from two of the fishery sectors, the size composition of the total aged sample was similar to the total size composition measured for commercial catches of silver trevally throughout the study (top graph in Figure 3.1).

The age compositions estimated by application of the age-length key to the size composition data for each fishery sector varied significantly (Figure 3.6). Trawl and trap catches, which comprised the bulk of commercial landings, had similar age compositions, with the majority of fish estimated to be between 2 and 10 years of age. Trawl catches had a slightly greater representation of 1 to 3 year old fish than trap catches, and trevally appear to be almost fully recruited to trawl catches by age 3, whereas full recruitment to the trap fishery does not appear to occur until 4 years of age. Estuary catches comprised mostly fish from 1 to 5 years of age, with few fish older than 7 years, and full recruitment by about age 3. Line catches, which were dominated by fish between 4 and 10 years of age, also contained significant numbers of fish greater than 10 years of age.

The age composition determined for the total commercial catch of silver trevally (top graph in Figure 3.6) suggested that full recruitment to the fishery occurred by about age 3 to 4, and the majority of fish in the commercial catches were less than 6 years of age. However, significant numbers of fish between 6 and 12 years of age were estimated to be present in the population during the period sampled, and small numbers of fish survived to between 12 and 24 years of age.

Application of the age-length key to the size composition of 130 silver trevally measured from recreational catches during the study suggested that the bulk of these fish were aged between 5 and 12 years (Figure 3.7).

3.4 Discussion

Overall, the size range of silver trevally measured from commercial and recreational catches during the present study ranged between about 15 and 60 cm LCF, with the majority of fish being between 20 and 35 cm. Very few fish greater than 40 cm LCF were measured from recent catches, despite indications that fish of these sizes were relatively common in trevally catches during earlier years (see results in Section 5). The age compositions of catches by the different fishery sectors were estimated by applying the age-length key determined from the recently aged sample to the size composition data for earlier years. This method assumes that the distribution of length at age for silver trevally in earlier years was similar to that found in the recent samples, and it is possible that the relative abundance of older age classes may be under-estimated for the earlier years.

Figure 3.6 Age compositions estimated for the catch of silver trevally by each of the important commercial fishery sectors, and for the total commercial catch.

Fish shown as '0' were estimated to be < 1 year of age.

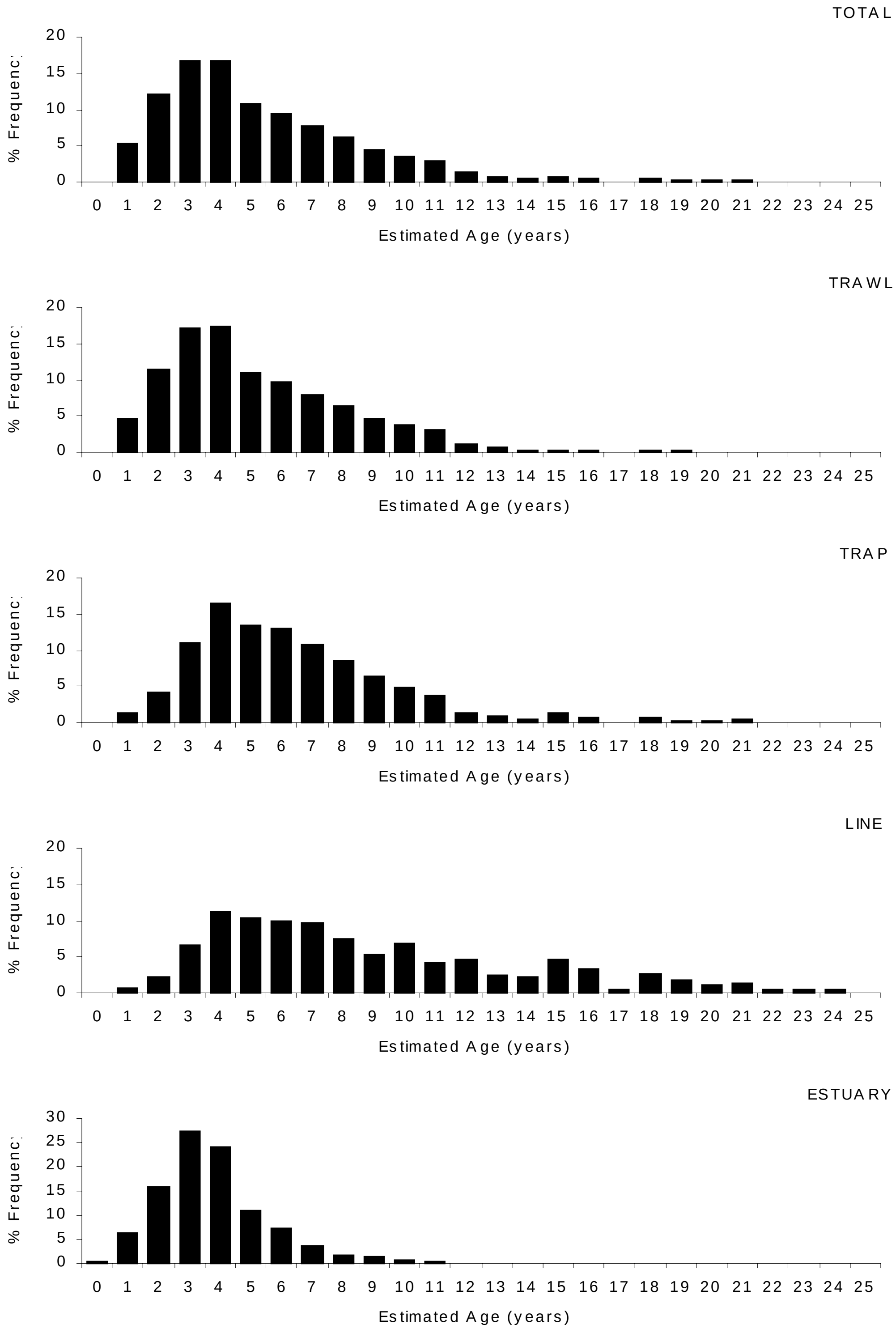
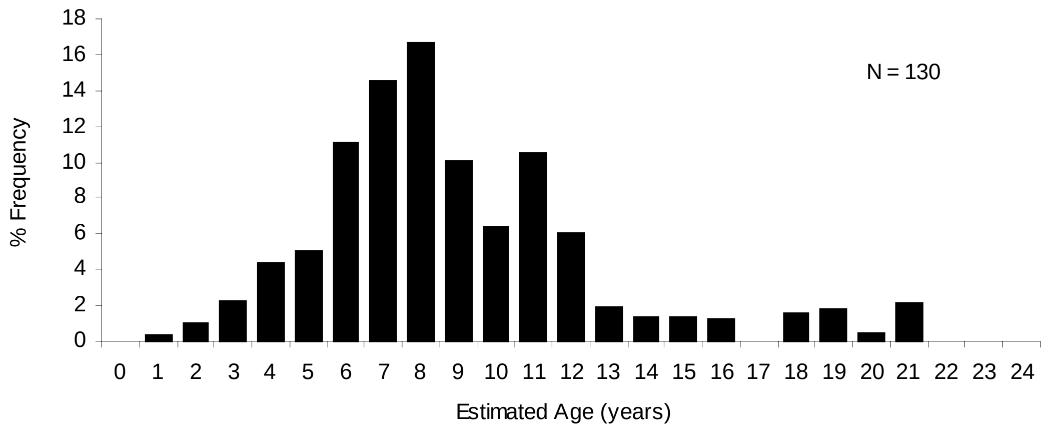


Figure 3.7 Age composition estimated for recreational catches of silver trevally measured during the study period.



The results from monitoring of commercial and recreational catches suggest a large degree of overlap in the size and age ranges of silver trevally caught by the various fishery sectors. Trevally less than about 5 years of age (less than 30 cm LCF) predominate in catches from estuary waters, suggesting that juvenile trevally probably occur mostly in estuarine and near shore waters. However, between the ages of about 3 and 10 years (and between 20 and 30 cm LCF) silver trevally are taken by all five fishery sectors (estuarine, trawl, trap, line and recreational). The catchability of trevally older than about 10 years appears to be greatest by line fishing methods.

There was considerable overlap in catches by the trawl and trap sectors in terms of the size and age composition of fish caught. However, trevally are selected by the trawl fishery at smaller sizes (and younger ages) than the trap fishery, with ages 3 and 4 predominating in trawl catches, while trap catches predominantly comprised fish aged 4 to 6 years. Catches by the line sector contained a higher proportion of the older age classes (greater than 10 years of age).

Purse seine catches were very low and sporadic during the period sampled, and comprised small fish, apparently taken incidentally in shots targeting yellowtail. Historically, catches of large mature silver trevally were sometimes taken from spawning aggregations in spring/summer by purse seine fishers off the NSW south coast, but no such catches were sampled or reported during the current study.

There was a suggestion from trawl catches that smaller trevally were more prevalent in the northern part of the range off NSW, however this may be due to fishing down of the larger fish in some areas which are subject to relatively heavy trawling effort, as trap catches do not show the same trends in size composition. The results are also consistent with local variations in the fishing gear or techniques used to catch silver trevally.

Selection of small trevally varies between the different sectors of the fishery. Catches by the trawl and estuary sectors contain a relatively high proportion of fish <25 cm LCF, whereas trevally do not appear to be fully selected by the trap and line sectors until about 27-28 cm, and only a small proportion of the catch of these sectors is less than 25 cm. The sample obtained from recreational catches during this study comprised mostly fish between 30 and 40 cm LCF (estimated to be mostly 5 to 12 years old). This small sample may not be representative of the total recreational catch of trevally, especially those caught in estuaries, but it does suggest that very young fish (<5 years of age) are not caught in large quantities by recreational fishers in ocean waters.

The results from this research program will be used by NSW Fisheries to develop an ongoing monitoring program for commercial catches of silver trevally landed in NSW. Monitoring of the recreational catch is more problematic, but should be assisted by the results of the National Survey of Recreational Fishing which is currently underway.

4. THE REPRODUCTIVE BIOLOGY OF SILVER TREVALLY

4.1 Introduction

A knowledge of the reproductive biology of silver trevally, including the size at maturity, spawning period and the relationship between fish size and fecundity, is considered necessary for the development of management regulations to ensure the maintenance of adequate levels of spawning fish. Previous studies described the eggs and larval stages of trevally in New Zealand (James, 1976) and from central NSW (Neira et al., 1998). Trevally eggs are pelagic, typically spherical and about 0.9 mm in diameter. Larvae occur in coastal waters off Sydney between August and May (Gray, 1993), suggesting an extended 'spring -summer -autumn' spawning period. James (1977) noted that in New Zealand female trevally did not mature until about 32 to 37 cm LCF, and probably did not "produce significant numbers of eggs until they reach 38 to 40 cm". Kalish and Johnston (1997) reported findings that the standard length at 50% maturity for a small sample of NSW trevally was 20.9 cm for males and 20.3 cm for females, which suggested the Australian fish were maturing at around 20 cm LCF, significantly smaller than the New Zealand fish. Kalish and Johnston also concluded that trevally were "extremely fecund", with relative fecundities of 4 to 6 million per kg of body weight, and estimates of absolute fecundity of around 2 million for 25 cm fish ranging up to more than 10 million for 50 cm fish.

To better document the important aspects of the reproductive biology of silver trevally in NSW, we investigated the size at maturity and the relationship between fish size and fecundity for female trevally, and the duration of the spawning period, by taking regular samples from commercial catches.

4.2 Methods

The monthly samples taken for age determination between August 1997 and March 1999 were also used to study the reproductive biology of silver trevally. Individual fish were sexed, and their gonads were removed, macroscopically staged (see Table 4.1 for staging criteria) and weighed to the nearest 0.1 g. Gonadosomatic Index (GSI) values were calculated for individual fish by dividing the gonad weight by the gutted weight of the fish, and multiplying this value by 100.

For trevally sampled between November 1998 and March 1999, sections (approximately 5 mm thick) from the centre of female gonads were collected, weighed to the nearest 0.01 g, and stored in Bouins solution for later microscopic examination. Each month, up to five representative samples from each female gonad stage were chosen for measurement of egg diameters. Firstly, eggs were loosened from connective tissue by shaking the sample and washing under running tap water over a 20 micron mesh sieve. Large pieces of tissue were transferred to a petri dish, further separated with pointers, and returned to the sieve. A sample of eggs was then collected by running the flat blade of a scalpel through the egg mass, and transferred to a 'Z tray' for examination under a stereomicroscope. For each sample, the diameters of 100 eggs were measured using an eye piece graticule - only fully visible, whole eggs were measured along random vertical transects. For female fish in these samples which were macroscopically staged as "ripe" (stage 4), fecundity was determined by carefully separating all developed eggs in the sample from the connective tissue, and counting the whole sample (eggs were classified as developed if they contained an oil droplet - West, 1990). Total fecundity for each fish was then calculated by scaling up the number of eggs counted in the weighed sample to the total gonad weight for that fish.

Table 4.1 Descriptions used to macroscopically stage silver trevally gonads.

MALE		**FEMALE**	
Stage	Description	Stage	Description
1	Gonad thin, sinew-like.	1	Ovary fully reduced, containing clear fluid with no visible eggs or oocytes.
2	Testes developing structure, lobes apparent, containing some milt.	2	Ovary developing, orange in colour, primary oocytes visible.
3 **Ripe**	Large in size and multi-lobed, with firm texture, white in colour, milt easily expressed.	3	Ovary large, yellow in colour with some vitellogenic oocytes visible.
4	Spent, reduced size, pink-grey in colour, loose in texture.	**4** **Ripe**	Fully extended with increased vascularisation. Mature eggs large and golden in colour.
	(Stage 5 was not used for males)	5	Spent, ovary still enlarged but loose in texture, fluid filled, may be darker in colour.

4.3 Results

The size compositions of male, female and immature fish sampled for reproductive condition were the same as for the age determination samples and are given in Figure 2.3. The proportions of fish in the monthly samples which fell into each of the macroscopic gonad stages are shown separately for males and females in Figure 4.1. Ripe males occurred between September and April, and comprised the bulk of the samples taken between November and February, while ripe females, which were much less abundant in samples, were found between October and March. The majority of fish sampled between April and September were staged as 'spent'. Mean GSI values showed a broad peak for each sex between September and March, indicating an extended spawning period from spring to autumn (Figure 4.2).

Figure 4.1 Proportion of male and female silver trevally allocated to each macroscopic gonad stage by month sampled.

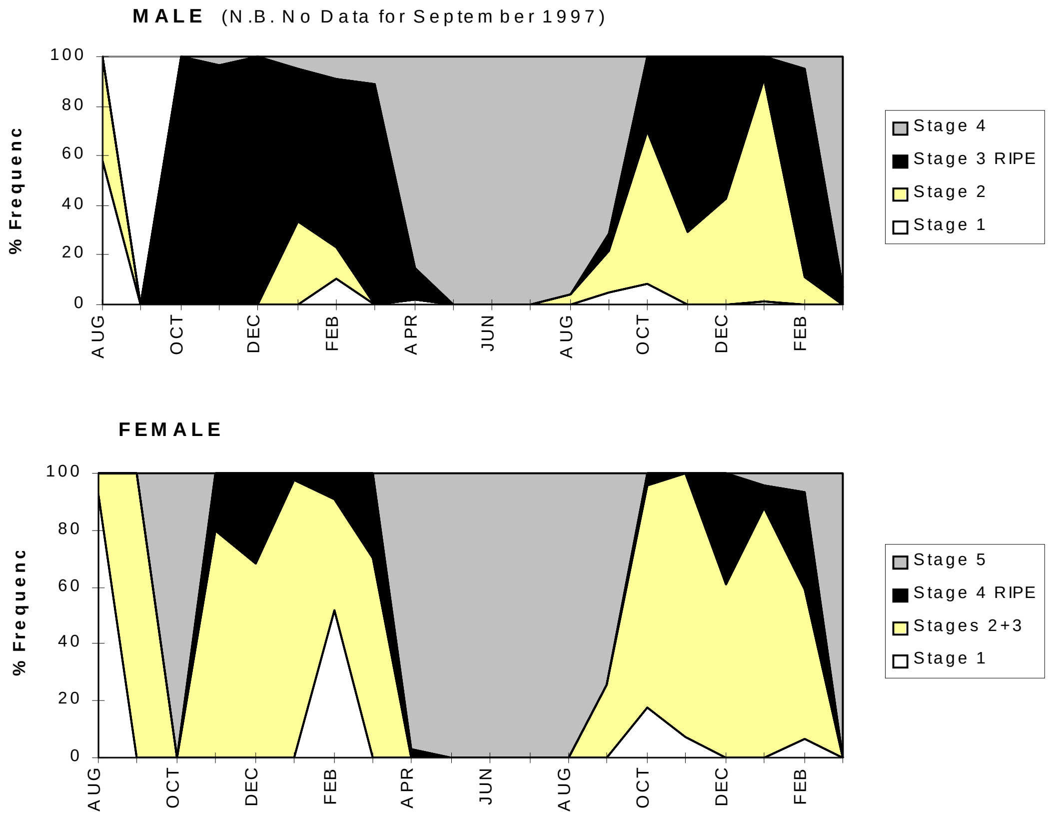
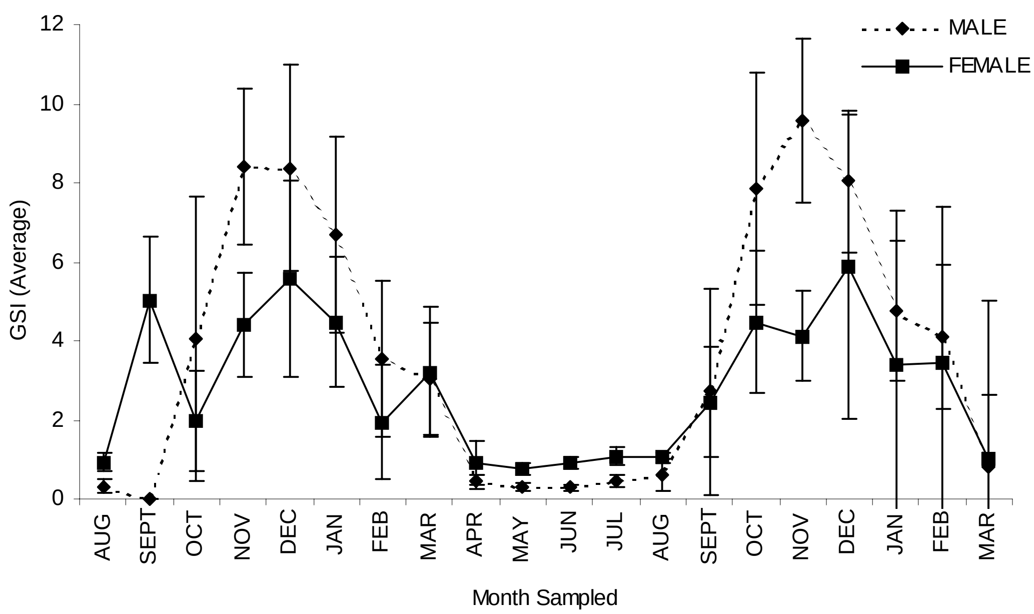


Figure 4.2 Mean values (± 1 standard deviation) of Gonadosomatic Index (GSI) for male and female silver trevally sampled between August 1997 and March 1999.



During the spawning period, mean GSI values were generally higher for males than for females. This may reflect the higher proportion of 'ripe' males found in samples, and is also influenced by the fact that the mean gonad weight of ripe males (34.02 g) was greater than the mean gonad weight of ripe females (31.68 g). The smallest male trevally staged as 'ripe' were five 22 cm fish which had gonad weights ranging from 5 to 10 g, while the smallest female staged as ripe was a 21 cm fish which had a gonad weight of 10 g. The largest male fish staged as ripe were two 49 cm fish, which had gonad weights of 154.5 and 168.0 g, and the largest female staged as ripe was a 37 cm fish which had a gonad weight of 86.3 g. Of the fish sampled. The length at 50% maturity was around 19 cm LCF (Figure 4.3). The size composition of trevally of each sex which were considered to have either 'developing', 'ripe' or 'spent' gonads was similar to the sexed composition of fish sampled from each sex (Figure 4.4), indicating that the commercial fishery is based mostly on trevally which have reached, or are capable of reaching, sexual maturity.

Female trevally assigned to gonad stages 1 and 2 were characterised by having two size classes of oocytes, with approximate mean diameters of 0.2 and 0.4 mm (Figure 4.5). Oocytes in the gonads of stage 3 fish were mostly 0.4 mm diameter, with a small number of 'hydrating' eggs (diameters > 0.5 mm). Fish assigned to stage 4 (ripe) had significant numbers of hydrated eggs between 0.5 and 1 mm in diameter, while 'spent' fish (stage 5) had a similar distribution of egg diameters as fish assigned to stages 1 and 2.

Estimates of fecundity were made for a total of 17 stage 4 female fish ranging in length from 23 to 37 cm (Table 4.2). The majority of these fish had an estimated fecundity between 30 and 100 thousand eggs, the exception being the 37 cm fish which was estimated to have 220 thousand eggs. Most samples examined were estimated to have 2500 to 3000 hydrated eggs per gram of gonad tissue, however a group of fish between 32 and 36 cm LCF had much lower numbers of eggs per gram of gonad tissue, and consequently lower estimated fecundity.

Figure 4.3 Proportion of silver trevally staged as immature, by length class.

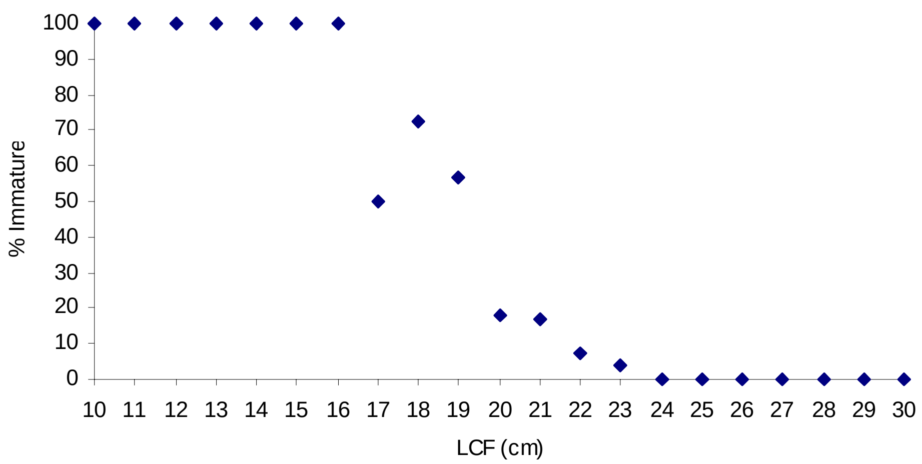


Figure 4.4 Size compositions of male and female silver trevally staged as 'ripe' (closed bars) or 'developing' or 'spent' (open bars).

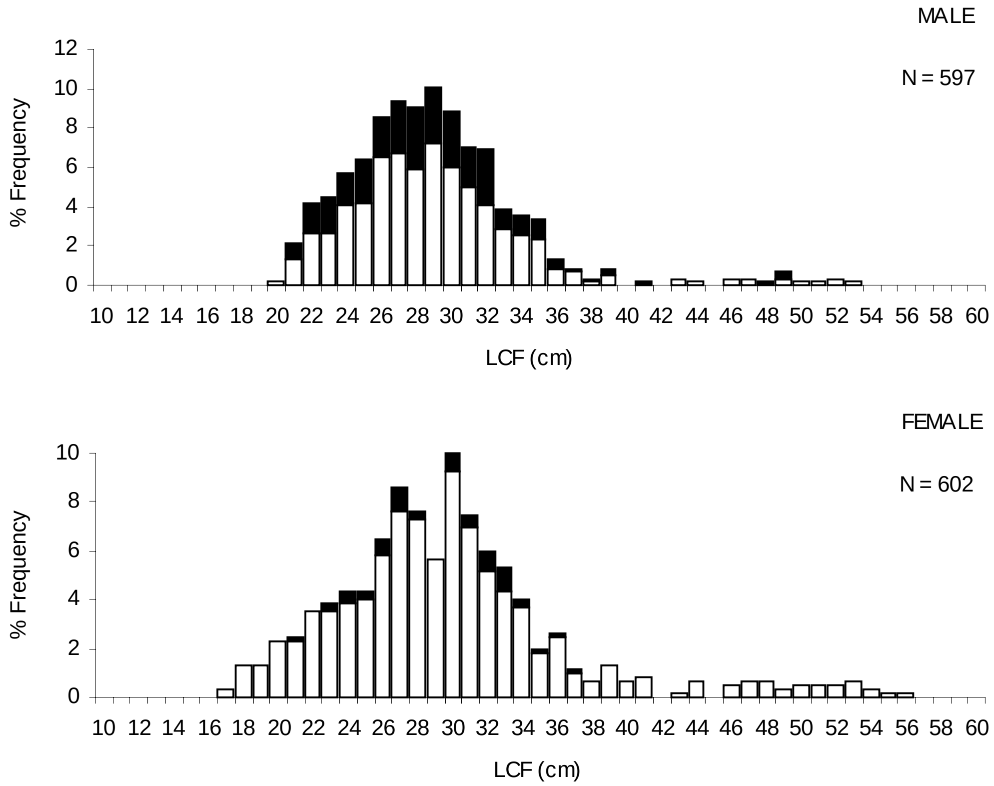
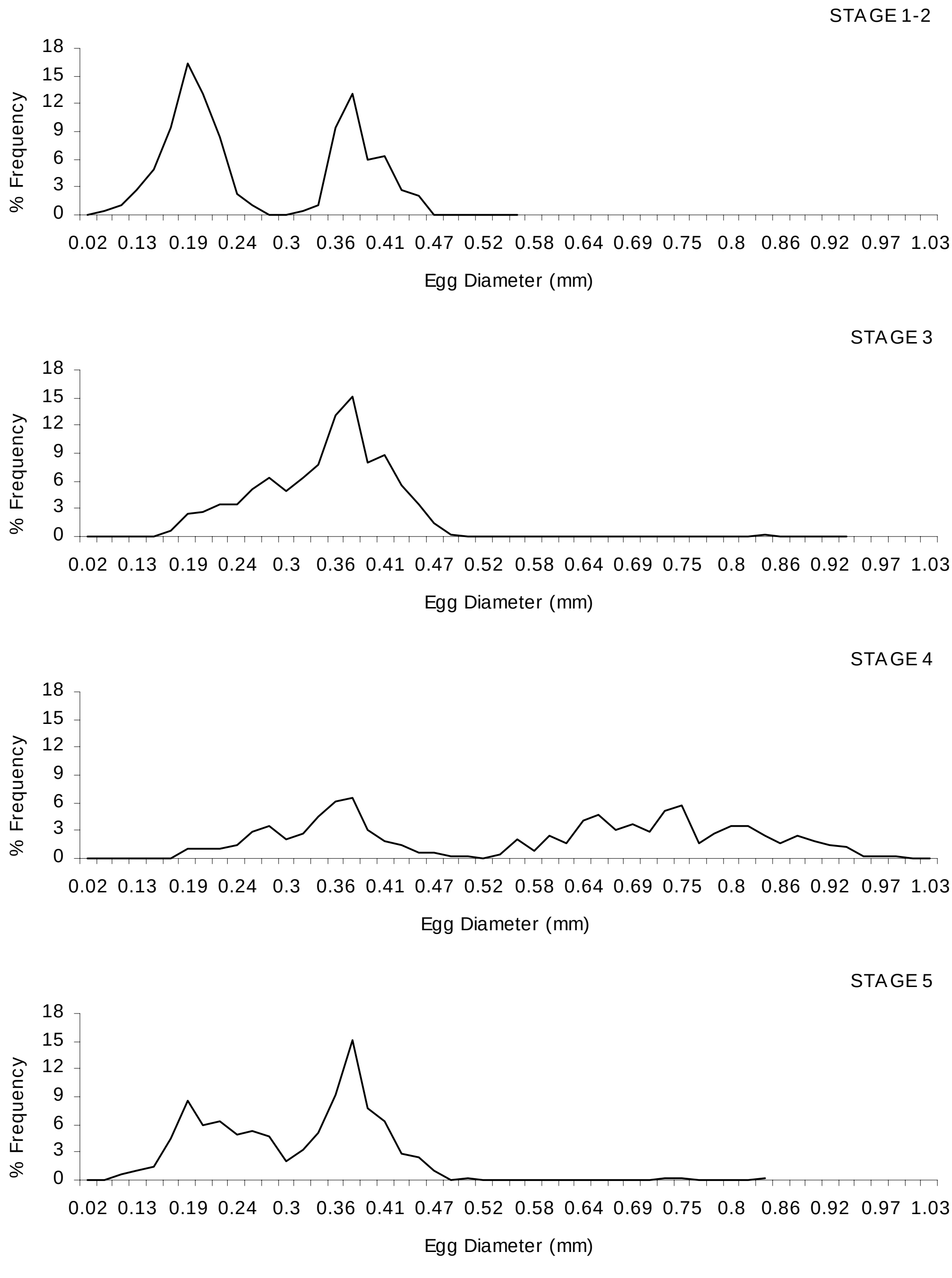


Table 4.2 Summary of data for stage 4 female silver trevally used for estimation of fecundity.

LCF (cm)	Fish Weight g	Gonad Weight g	Sample Weight g	Fecundity	Eggs/gram of Gonad Weight	Eggs/gram of Fish Weight
23	299	20.8	1.8	**70997**	3413	237
23	286	22.5	1.5	**60915**	2707	213
24	326	14.2	1.2	**42363**	2983	130
25	362	12.1	0.8	**36708**	3034	101
26	377	27.9	2.5	**80698**	2892	214
26	442	28.7	2.1	**76260**	2657	173
26	414	33.4	2.4	**88482**	2649	214
27	446	28.0	2.3	**77840**	2780	175
27	427	33.1	2.4	**99024**	2992	232
27	429	39.5	4.1	**100253**	2538	234
32	695	49.2	3.24	**48881**	994	70
33	697	36.0	2.85	**34863**	968	50
33	698	42.6	2.81	**64158**	1506	92
34	755	30.1	3.39	**46597**	1548	62
34	891	44.1	3.78	**49805**	1129	56
36	937	25.0	2.71	**32011**	1280	34
37	1003	86.3	6.55	**220098**	2550	219

Figure 4.5 Size composition of eggs measured from samples of female silver trevally with different gonad stages.



4.4 Discussion

Silver trevally in NSW have an extended spawning period from September to March. The results of our analyses suggest that spawning occurs throughout the range of the population, although little is known about spawning behaviour in the species. There have been occasional reports of surface schools of trevally being sighted (and sometimes caught) by NSW commercial fishers, and it has been suggested this behaviour may have been associated with spawning. Extensive analyses of trevally catches from New Zealand waters (including catches from a purse seine fishery which targeted surface schools) led James (1977 and 1979) to question whether trevally do in fact school to spawn, as no concentrations of spawning fish had been identified. It is likely that a similar situation prevails in NSW, as few surface schools have been reported in recent years, and the occurrence of ripe female fish in catches was sporadic.

Analysis of samples of silver trevally from commercial catches over two spawning seasons showed that although males and females are both capable of maturing at very small sizes (18 - 20 cm LCF), maturation appears to be progressive for both sexes, with full maturation not achieved until a length of 26 - 28 cm. The majority of the trevally population sampled by commercial fishers appears to be capable of spawning, with only 6% of fish sampled being classed as immature (these fish were less than 22 cm LCF). However, only a small proportion of the fish sampled were actually close to spawning (especially for female fish) and it appears that trevally may not be particularly vulnerable to the (demersal) fishery during the spawning process.

Estimates of fecundity for female trevally between 23 and 37 cm LCF ranged from 30 to 220 thousand eggs. These estimates are lower than those reported for similar sized trevally (2 to 5 million eggs for 25 to 35 cm SL females) by Kalish and Johnston (1997), however the methods used to arrive at these higher estimates were not described, and it is unclear if these estimates refer to developed eggs or to all eggs present in a sample. During this project we failed to sample any large female trevally (> 50 cm) which were in a 'ripe' condition, and it is probable that fish of these sizes would have a much greater fecundity than that found for the largest fish in Table 4.2, (perhaps as high as 1 million eggs). However the data gathered during the current study do not support earlier estimates that silver trevally are "extremely fecund", and estimates of fecundity of around 10 million seem to be far too large.

Silver trevally are reported to be partial spawners, releasing several batches of eggs over a spawning season (Annala *et al.*, 1999), and it is the 'batch' size and frequency of spawning which need to be determined to understand the reproductive output for such species. Our estimates of the number of 'hydrated' eggs probably reflect the 'batch size', although for the fish between 32 and 36 cm in Table 4.2 it is possible that some mature eggs may have been shed from the gonad just prior to or during capture, reducing the estimate of fecundity.

The results reported here support earlier observations (Kalish and Johnston, 1997) that in NSW both male and female trevally are capable of maturing at a relatively small size (around 20 cm). However, the data also indicate that trevally are probably not fully mature until about 28 cm, which agrees with the findings of an earlier study of trevally biology in Botany Bay (Anon., 1981a). The estimates of fecundity reported here suggest that, for fish sizes common in recent catches (20 to 35 cm) batch fecundities of tens to hundreds of thousands of eggs per fish are likely.

5. PRELIMINARY ASSESSMENT OF THE STATUS OF THE SILVER TREVALLY STOCK

5.1 Introduction

Despite the significance of silver trevally to both commercial and recreational fish catches in south-east Australia since at least the early 1970s, very little research has been conducted on the species, and the general biology and life history of *Pseudocaranx dentex* are only partially known. The species appears to be broadly distributed in Australia from southern Queensland to Western Australia, and has been reported from estuarine and near-shore coastal waters to a depth of about 100 m. The bulk of the Australian commercial catch is taken from waters off NSW and north-eastern Victoria, and it is possible that catches from waters west of Tasmania might be dominated by a different (but almost identical) species *Pseudocaranx wrighti*. The two species are very difficult to correctly identify in the field (*P. dentex* has 34-46 scutes at the posterior end of the lateral line, whereas *P. wrighti* has 24-35 scutes, according to Yearsley *et al.* 1999). This, and the fact that silver trevally occupy a diverse range of habitats ranging from estuarine to offshore, and demersal to pelagic, has contributed to the problems in accurately recording occurrences of the species.

In this section we summarise relevant information on the fishery for silver trevally in NSW, and develop a preliminary assessment of the likely status of the silver trevally stock. We also address the fifth aim of this research project - whether the introduction of a Minimum Legal Length (MLL) would assist in the sustainable management of the fishery for silver trevally.

5.2 Stock Structure of *Pseudocaranx dentex*

The stock structure of *P. dentex* is poorly understood. Taxonomic studies (James and Stephenson, 1974) of specimens from southern Australia and New Zealand suggested some structuring within the Australian population (chiefly groups of fish with 24 versus 25 vertebrae, and variation in some body ratios), however there was insufficient material to draw definite conclusions. Results of tagging studies in New Zealand (James, 1980) showed only limited movements, and lent some support to the hypothesis that separate stocks with limited mixing might exist in the Bay of Plenty and the Hauraki Gulf. [Note that current management of silver trevally in New Zealand is based on a number of 'fishstocks' for quota management purposes, the two most important being TRE1 which includes both the Bay of Plenty and Hauraki Gulf, which has an annual TAC of 1506 t, and TRE7 which covers the west coast of the north island and the north-west coast of the south island, and has an annual TAC of 2153 t (Annala *et al.*, 1999). The stock boundaries used in the management of silver trevally fisheries in New Zealand do not appear to be based on any documented genetic structuring of the New Zealand populations.]

In Australia there has been only limited study of silver trevally stock structure, and annual TACs for the South East Fishery (SEF) for *P. dentex* are determined under the assumption of a common stock in the SEF area, from South Australia to NSW (Tilzey, 1995). Recaptures of silver trevally tagged as part of the NSW Gamefish Tagging Program (Matthews and Deguara, 1992) also showed only limited movements off NSW, even for fish at liberty for periods of up to six years. For 26 tagged trevally at liberty for periods greater than one year, only three fish were recaptured more than 50 nautical miles from their point of release, and only one fish had moved a large distance (from Sydney to Eden). Another tagged trevally was observed to move from Port Stephens to the Eden area during just 17 days at liberty in October/November 1987. This relatively large (52 cm LCF) fish was recaptured by a commercial purse seine fisher amongst a surface school of trevally, and it was thought possible this movement was associated with a (southward) pre-spawning migration. These results support the validity of the assumption of a single biological stock of silver trevally in NSW waters.

An unpublished study using enzyme electrophoresis of specimens of silver trevally from coastal NSW and northern New Zealand (J. Kalish, pers. com.) found minor levels of genetic heterogeneity within the NSW samples, suggestive of a single biological stock with some population structuring. The results of this study also suggested that trevally from New Zealand were genetically distinct from the NSW coastal fish, but the analysis unfortunately did not include any specimens from Lord Howe Island. There is a need for more detailed genetic studies to better define the stock structure of *P. dentex* throughout its range. However, research results available to date suggest that it is reasonable to regard silver trevally from NSW coastal waters as coming from a single stock, even though the precise boundaries of the stock and its affiliation with trevally in other areas are not clear at the present time.

5.3 Catches by Commercial and Recreational Fisheries

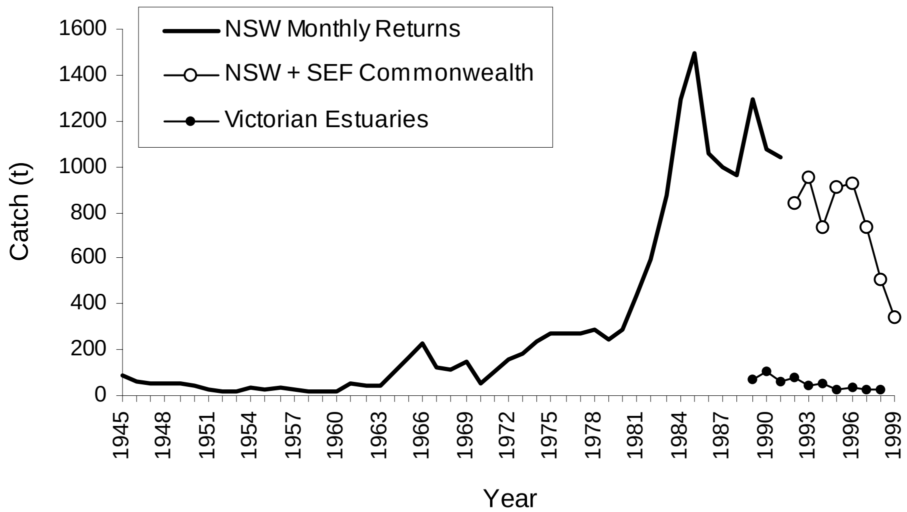
5.3.1 Commercial Catches

Commercial fishers licensed in NSW have been required to report their landings by species on a monthly basis since the 1940s (Pease and Grinberg, 1995). These data provide consistent records of silver trevally landings in NSW from 1945 until the declaration of the Commonwealth managed South East Trawl Fishery (SEF) in the mid 1980s. Since that time, trawl catches by Commonwealth endorsed trawl fishers have been reported in a daily logbook, although most dual endorsed fishers continued to report their trawl catches on the NSW returns until the introduction of an Individual Transferable Quota system in the Commonwealth fishery in 1992. The reported annual landings for silver trevally by commercial fishers off NSW are shown in Figure 5.1. The data prior to 1992 are for fiscal years from the NSW Fisheries Catch / License System database. Data for later years are estimates for calender years, obtained by adding the catch reported taken from Commonwealth waters (from SEF quota monitoring data) to the total reported NSW catch for each calender year. (Note: There is the possibility of some over-estimation of the total catch for the years between 1992 and 1997, caused by possible double-counting of catches taken in Commonwealth waters during this period. Also the data for 1999 should be regarded as preliminary, as estimates may increase after further data entry of late returns for the 1999 year.) Commercial landings of silver trevally from eastern Victorian estuaries (Anon, 1998) declined from 70 - 100 t in the late 1980s to 30 - 50 t in recent years, and these figures are also shown in Figure 5.1

Commercial catches of silver trevally were probably very low prior to the 1960s, as there was little market demand for the species. Silver trevally was not recorded amongst the twelve most abundant species found during development of the NSW trawl fishery (1918-1923), and interviews with fishers who participated in the steam trawl fishery which operated off NSW from that time until the 1960's indicated that only small catches of silver trevally were taken, and these were mostly discarded at sea because they were unmarketable (Klaer and Tilzey, 1996). With the development of a modern diesel powered trawl fishery off NSW during the late 1960s it is probable that catches of silver trevally increased significantly, however the majority of the catch continued to be discarded at sea due to poor market demand. It was not until market acceptance of silver trevally increased during the 1970s that commercial catches began to be landed with any consistency. It is probable that trevally were increasingly targeted by trawlers during the 1980s, with the development of lighter and faster trawl gear, and some trawlers off southern NSW tried pair trawling for 'fast swimming' species such as trevally in the mid 1980s.

Commercial catches of silver trevally off NSW peaked at around 1500 t in 1985 and remained around 1000 - 1200 t per annum until the early 1990s. Since that time there appears to have been a consistent decline in annual landings, although this is not evenly reflected across all ports or sectors of the fishery (see discussion below). The total commercial catch reported during 1999 was just 340 t, the lowest annual catch reported since the early 1980s. Catches by commercial fishers in estuaries in eastern Victoria are much lower than NSW landings, and have also declined over the past decade (Anon., 1998).

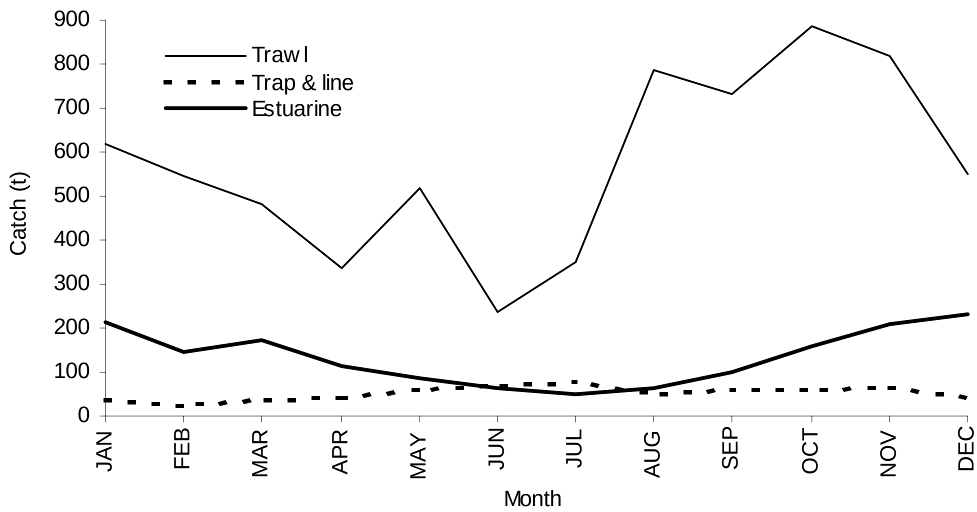
Figure 5.1 Reported commercial catches of silver trevally by NSW, Victorian and Commonwealth fishers.



5.3.1.1 Trends in NSW commercial catches

Data were analysed from the NSW commercial catch database for the period from 1984 to 1999, during which a total of 12,725 t of silver trevally were recorded as landed by NSW commercial fishers. Of the total catch reported, 88% was taken from ocean waters and 12% from estuarine waters. Many monthly returns from the early part of this period included catches for multiple fishing methods, so it was difficult to apportion the total catch to specific fishing methods. However for those returns where trevally catches could be attributed to a fishing method, it was apparent that trevally were caught by all methods throughout the year (Figure 5.2). Estuary catches were highest during the summer and early autumn, while trawl catches peaked in the spring and were lower through the winter months when trawl fishing effort shifted to deepwater grounds. Trevally catches by trap and line fishers were relatively stable throughout the year, with a slight increase in the winter months.

Figure 5.2 Monthly distribution of commercial catches of silver trevally by the main fishing methods, from NSW monthly returns.



In July 1997, separate monthly returns were introduced for each of the restricted fisheries in NSW, and it is possible to more accurately determine the breakdown of trevally catches by fishing method for the two full years of data which are now available (Table 5.1). Demersal fish trawling accounted for just over half the catch reported in each of the years, with fish trapping and line fishing in ocean waters accounting for another 25 - 30 % of the catch. Commercial catches from estuarine waters (predominantly taken with hauling nets) accounted for 21% of the total in 1997/98 but declined to 11% of the total in 1998/99. Trevally catches using other methods were comparatively minor during this period.

Table 5.1 Catches (kg) of silver trevally reported by NSW commercial fishers for the years 1997/98 and 1998/99.

Catches for ocean waters are split by fishing method. Estuary catches are for all methods (but silver trevally are principally caught using hauling nets).

Fishery/Method	1997/98	1998/99
Estuary	92,425 (21%)	41,897 (11%)
Fish Trawl	227,788 (52%)	199,370 (54%)
Fish Trap	92,917 (21%)	95,437 (26%)
Line	18,230 (4%)	21,749 (6%)
Ocean Haul	2,372 (1%)	8,353 (2%)
Other	1,331 (-)	3,518 (1%)
Total	**435,063 kg**	**370 324 kg**

Commercial catches of silver trevally from NSW estuarine waters have come mainly from the central coast, with Botany Bay (61% of the trevally catch), Port Jackson (12%) and the Hawkesbury River (11%) being the most important locations. Annual commercial landings of trevally reported for NSW estuaries increased from less than 10 t in the mid 1950s to 156 t in 1965/66 and then declined again to around 30 t in the mid 1970s (Pease and Grinberg, 1995). Estuarine catches then increased again to exceed 100 t in the early to mid 1980s, and peaked at 167 t in 1989/90. Since then there has been an overall decline in the commercial catch of silver trevally from NSW estuaries, although there have been some marked fluctuations between years in the catch from the main estuary, Botany Bay (Figure 5.3). It is not possible to determine to what extent these fluctuations in annual catches resulted from changes in the level of fishing effort, as the effort data available prior to 1990 have poor resolution by fishing method. However the magnitude of the inter-annual changes in catch suggest that the fluctuations were more likely the result of changes in the relative abundance or catchability of the fish rather than variations in fishing effort.

Trends in reported catches of silver trevally from ocean waters have also varied significantly among the major ports of landing in NSW (Figure 5.4). The southern most ports of Bermagui and Eden recorded the highest catch of silver trevally for the period analysed, but the bulk of this was taken between 1984 and 1990, primarily by fish trawling (it was in this area in the early to mid 1980s when pair trawling was conducted, and annual trevally catches in 1984 and 1985 exceeded 500 t). Trevally catches have declined substantially in the Eden/Bermagui area since 1990. The next most significant area in terms of trevally catch was the Newcastle/Port Stephens area, where fish trawling was again responsible for the majority of the catch. Trevally landings peaked in this area in the late 1980s at over 300 t per year, but this was followed by a sharp decline to less than 100 t per year. A secondary peak of 200 t per year occurred in 1996, followed by a return in recent years to less than 100 t. Trevally landings at the other main ports have shown increases at various times during the period analysed, but all have shown a downward trend since about 1996 (Figure 5.4).

Figure 5.3 Annual catches of silver trevally reported by commercial fishers for NSW estuaries.

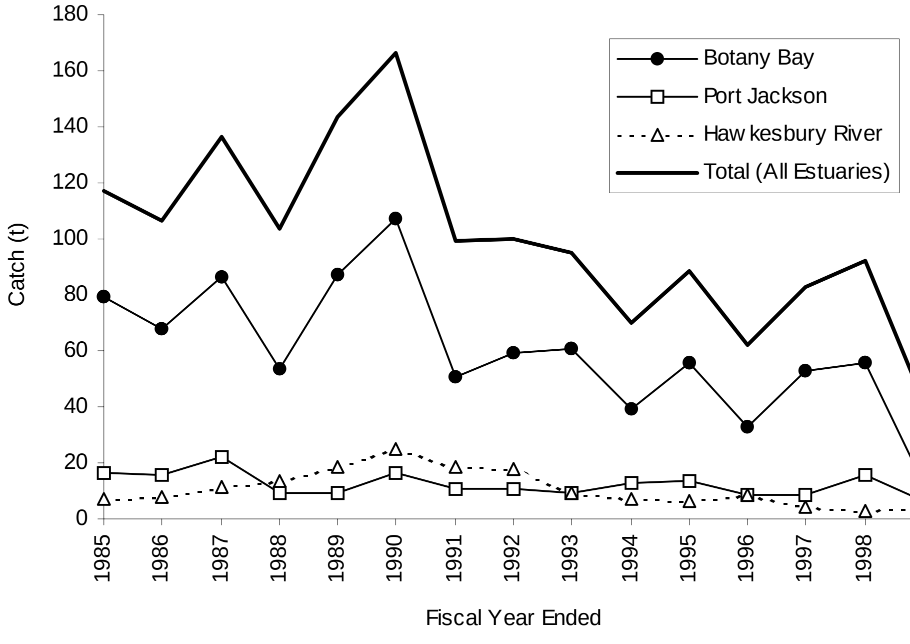
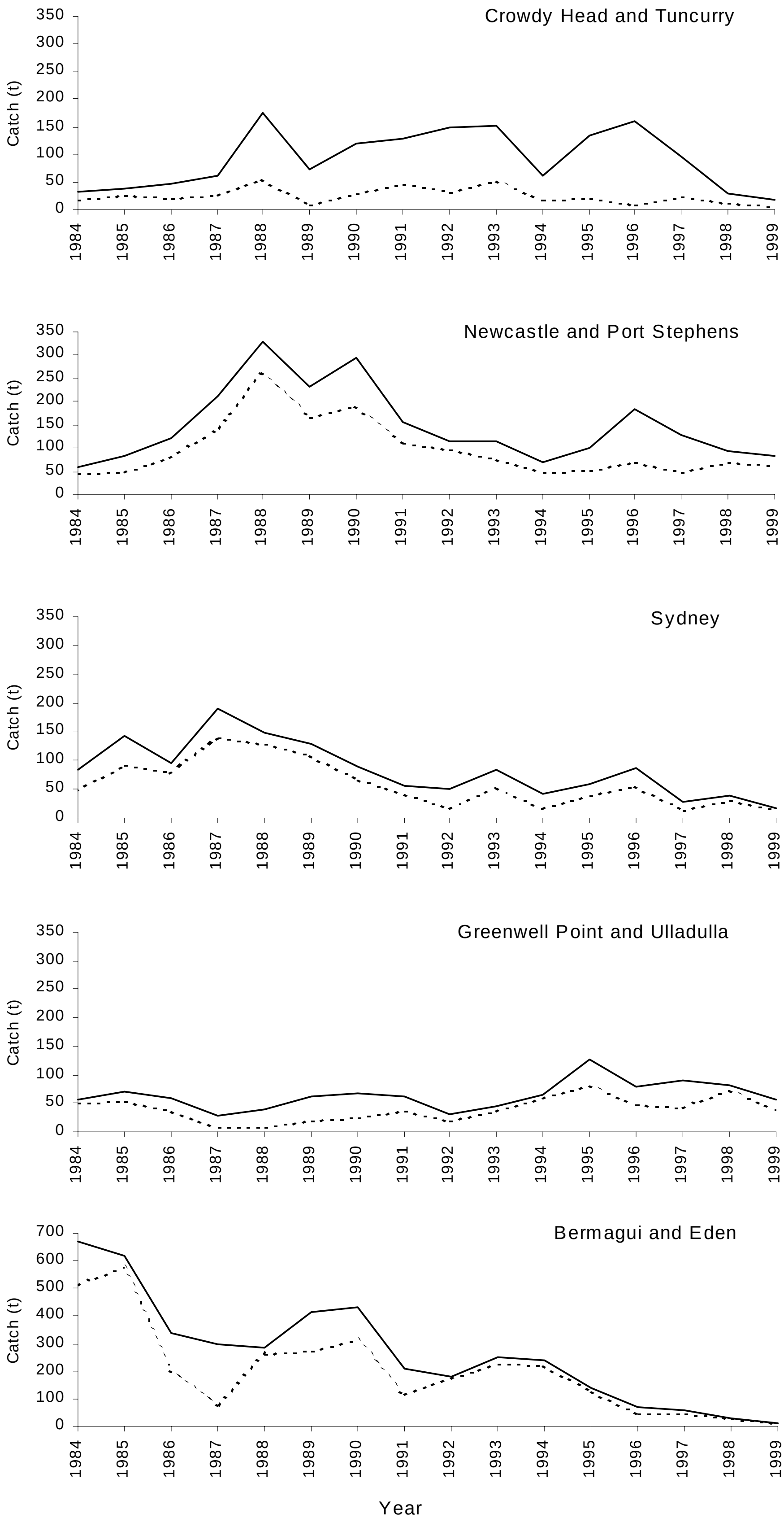


Figure 5.4 Annual landings of silver trevally reported from ocean waters by NSW commercial fishers by all methods (solid line) and trawl (dashed line), for important ports of landing.



5.3.1.2 Trends in SEF commercial catches

Data from SEF trawl catches off NSW and eastern Victoria were analysed for the years 1986 to 1998 (data obtained were monthly catches by individual trawlers, so as to be comparable with the data analysed from the NSW database). During this period a total catch of 4,238 t of silver trevally was reported, with an average of 65 trawlers operating per year (the number of trawlers reporting trevally catches in any year ranged between 57 and 78). The most notable feature of this data set was the high degree of variability in the total catch of trevally reported in each year (ranging between 193 and 439 t), and in the patterns of catches reported by individual vessels over the period analysed. Observer studies in the years after 1993 showed almost negligible discarding of silver trevally by SEF trawlers (Liggins, 1996; Knuckey and Sporcic, 1999) so it is likely that the reported catches closely reflected the actual catches taken by these boats. It also appears that the implementation since 1992 of an annual Total Allowable Catch (TAC) for silver trevally taken from Commonwealth managed waters (further than 3 nautical miles from the coast) has had little effect on catches of the species. This is thought to be due partly to the main occurrence of the species in NSW managed waters, where no catch restrictions have been in place, and partly to the relatively high level (600 t per annum) of the Commonwealth TAC.

The total annual catch reported by SEF trawlers was relatively low in 1987, but increased in the following years to peak in 1990 and again in 1995 (Figure 5.5). (It should be remembered that annual landings of silver trevally by SEF trawlers were higher, exceeding 500 t during 1984 and 1985, before the SEF logbook was implemented). In recent years there has been a steady decline in the total catch of trevally reported by SEF trawlers, from 411 t in 1995 to 194 t in 1998. In 1999, with an allocated TAC of 600 t, SEF trawlers recorded a total catch of silver trevally of just 156 t (73 t from Commonwealth waters and 83 t from waters under NSW jurisdiction).

The variability in silver trevally catch trends for individual trawlers complicated the analysis of the catch and effort data set. Landings by the "top 5" catching vessels in each year accounted for 32-61% (mean 47%) of silver trevally caught by SEF trawlers in the year, suggesting that trevally might be significantly targeted by a small number of boats. Out of 13 possible appearances in the list of the "top 5" boats, eight trawlers appeared on five or more occasions, and it was decided to analyse the catch and effort information for this "standard fleet" of eight boats separately (under the assumption that these fishers more consistently targeted silver trevally). To capture a broader range of data for trawlers which may have targeted silver trevally on a more opportunistic basis, catch and effort information was also analysed for all vessels which caught greater than 10 t of trevally in the year. The total catches reported in each year by the "top 5" boats, boats catching >10 t, and those included in the "standard fleet" are shown relative to the total for all SEF trawlers in Figure 5.5. Vessels in the "top 5" and "standard fleet" categories caught almost 50% of the total landings of silver trevally through the period analysed, while vessels in the ">10 t" category caught 70% of the total landings. (The number of vessels in this latter category ranged between 6 and 17 per year).

Catch rates were determined for individual vessels by dividing their total catch of trevally in a year by the number of months in which their trevally catch exceeded 1 t (to estimate the number of months in which trevally were targeted, as target species were generally not specified on SEF logbook entries). As a check on possible biases introduced by the adoption of this arbitrary criterion, for the standard fleet vessels 'mean monthly catch' of trevally was calculated for all months in which fishing was reported.

Figure 5.5 Annual catches of silver trevally reported by SEF trawlers, 1986 to 1998.

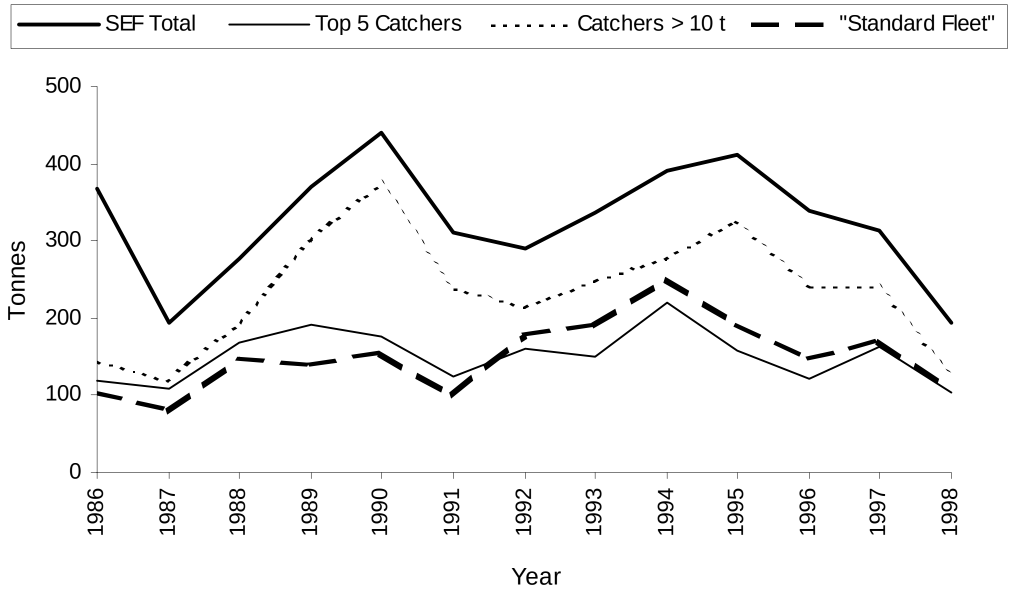
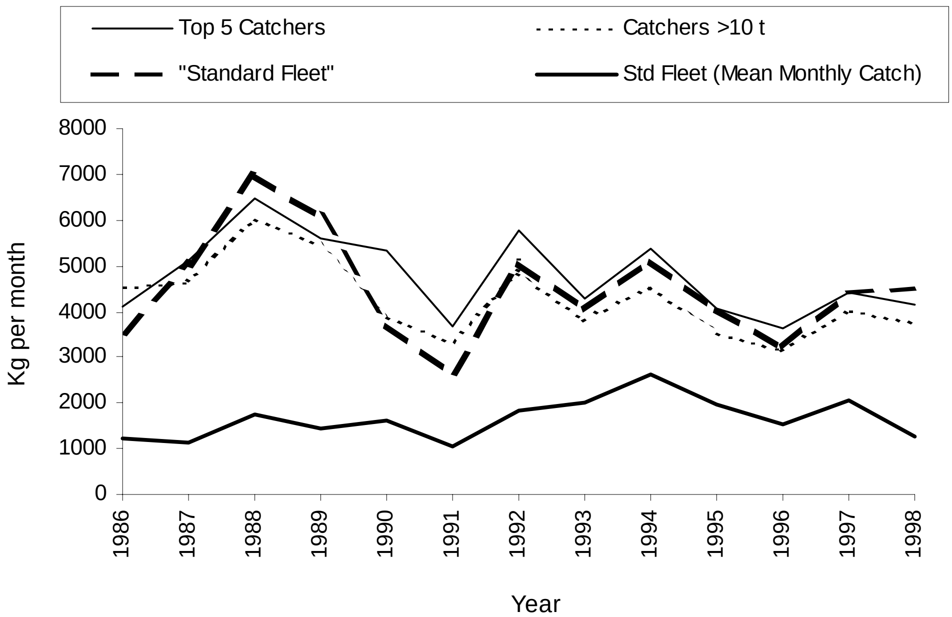


Figure 5.6 Catch rates of silver trevally by SEF trawlers, 1986 to 1998



Catch rates calculated for each of the vessel groups all showed very similar trends over the period analysed (Figure 5.6), with a peak in catch rates in 1988 and 1989, followed by variable, but overall stable catch rates for the period 1990 to 1998. "Mean monthly" catch rates calculated for the standard fleet vessels were also relatively stable and showed no declining trend through the period analysed. These results suggest that the annual catch and average catch rates of silver trevally by SEF trawlers targeting the species have been relatively consistent since the late 1980s, except for the last five years when annual landings have consistently declined. Average catch rates have remained reasonably high (around 4 t per month per vessel) in recent years, despite the decline in overall landings. Silver trevally are known to be a schooling fish, and catch rates may reflect the ability of fishers to target schools of trevally, rather than the overall abundance of the population. Further detailed analyses of the data, and advice from industry members about targeting practices, would be needed to determine how well catch rate might index abundance for silver trevally.

5.3.2 Recreational Catches

Quantitative information on silver trevally caught by recreational anglers is much more limited than that available for the commercial sector. Data on silver trevally catches by recreational fishers in NSW were reported by the following studies:

- A study of recreational catches in Tuggerah Lakes (on the NSW Central Coast) in 1978/79 concluded that silver trevally comprised just 0.04% of the total recreational catch (Henry and Virgona, 1980).
- Silver trevally was ranked the third most important species by weight (and the eighth most important by numbers) in recreational catches of anglers interviewed during 1979/80 in Botany Bay (Anon., 1981b). It was estimated from the results of this study that recreational fishers caught 6.2 t or nearly 16 thousand silver trevally in Botany Bay annually.
- From interviews conducted with recreational fishers in Sydney Harbour between September 1980 and August 1981 it was estimated that the annual recreational catch of trevally in this estuary was around 19 thousand fish or just over 14 t (Henry, 1984).
- A study of NSW offshore trailer boat and charter boat anglers (Steffe *et al.*, 1996) found silver trevally to be the third most significant catch in terms of weight by the trailer-boat sector during 1993-1995. Annual landings of silver trevally by offshore trailer boat anglers were estimated to be around 100 - 120 t, with a further 8 - 10 t being landed by charter boat fishers in the Sydney area alone.

If the catches reported in the most recent study were extrapolated to take account of charter boat catches in other areas, and recreational catches from ocean beaches, rocky foreshores and estuarine waters, resulting estimates of recreational catches of silver trevally in NSW waters in the mid 1990s might have been in the vicinity of 250 t per annum. However, the trends in recreational catch of silver trevally prior to and after the mid 1990s survey are unknown. Anecdotal evidence from recreational fishers in NSW points to a significant decline in recreational catch since the 1980's (especially for larger fish, >50 cm LCF, which were once the mainstay of recreational fishing competitions held in the Port Stephens area in early spring each year). However, we were unable to locate documentary evidence to support these observations.

5.3.3 Conclusions Regarding Catches of Silver Trevally from NSW Waters

Analysis of the available data indicates that catches of silver trevally in NSW were probably quite low prior to the development of suitable market opportunities in the late 1970s and early 1980s. Prior to this time, silver trevally were taken incidentally by fishing targeted at other species, and were mostly discarded. Trevally were taken by recreational fishers, but did not enjoy a good reputation as a table fish, and were not highly sought after (Anon., 1981b). The development of a modern diesel powered trawl fishery in the 1970s almost certainly led to increased incidental catches of silver trevally, however as trevally were not being specifically targeted it is likely that catches remained relatively low.

The availability of suitable markets encouraged an increase in commercial targeting of trevally during the early 1980s, and probably resulted in a decline in the proportion of the catch which was discarded. It is also probable that the recreational catch of silver trevally increased significantly during the 1980s, as a result of a general increase in the numbers of recreational fishers, especially those with boats capable of fishing offshore, and an increase in the popularity of 'sportfishing', as opposed to simply fishing for food (trevally, especially large fish, were regarded as a prime target for sportfishers because of their strong fighting abilities).

Landings of silver trevally from all sectors probably peaked in the mid to late 1980s at around 1800 to 2000 t per annum. It appears from the scant data available that reasonably high (1000 to 1500 t) annual catches of trevally continued to be made into the early 1990s, but that catches commenced a significant downward trend in the mid 1990s, which has continued to the present day. The total catch of silver trevally from all sectors (including recreational) during 1999 is not accurately known, but it is likely to have been less than 500 t.

5.4 Trends in the Size and Age Composition of Silver Trevally Catches

5.4.1 Trends in Size Composition of the Catch

Data on the size composition of silver trevally catches throughout the period of exploitation are sporadic. The earliest known data comprise measurements made at the Sydney Fish Market from March to September 1967 of fish caught in commercial beach haul nets in Botany Bay. These data were collected just after a period of heavy commercial catches from Botany Bay, with a total of over 200 t reported taken during the preceding two years (1965 and 1966) (Pease and Grinberg, 1995). The size composition shows two distinct modes (Figure 5.7) - larger fish of 26 to 36 cm, which were present in catches during all months sampled, and a group of smaller fish, 20 to 25 cm, which appeared in catches in the winter months from June to August. These data are not directly comparable with the size composition determined for recent catches from beach hauling in Botany Bay (which comprise the bulk of the data for 'estuary' catches in Figure 3.1) as the recent fishery operates during the summer months, whereas the 1967 data were collected between autumn and early spring. However the data suggest that fish >30 cm in length contributed a significant proportion of commercial catches in Botany Bay in 1967, whereas in recent years fish >30 cm have contributed only a small proportion of estuary catches (Figure 3.1).

Figure 5.7 Size composition of commercial haul net catches of silver trevally from Botany Bay from March to September 1967.

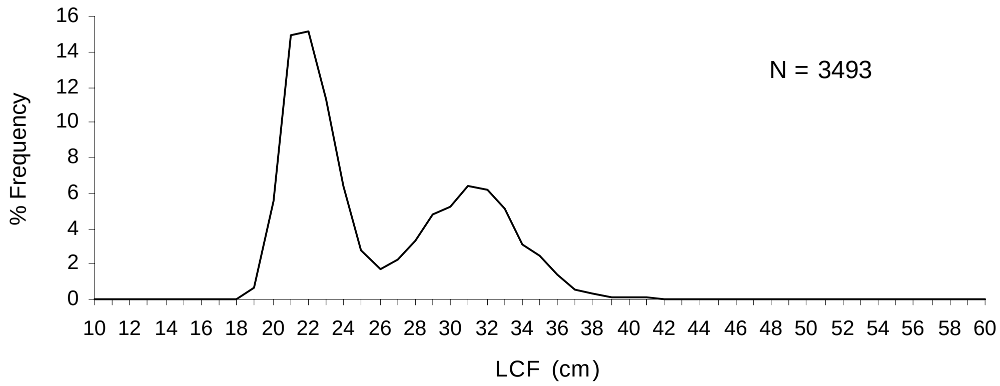


Figure 5.8 Size composition of recreational catches of silver trevally from Botany Bay, 1979/80.

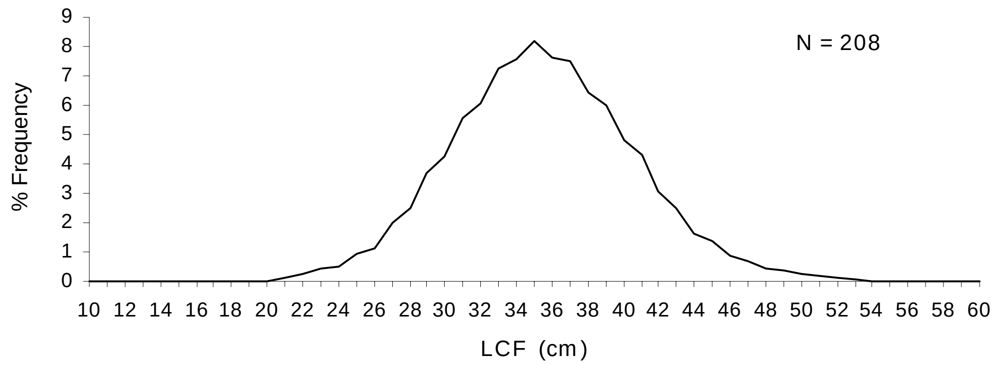


Figure 5.9 Size composition of commercial catches of silver trevally measured at the Sydney Fish Market between 1987 and 1990.

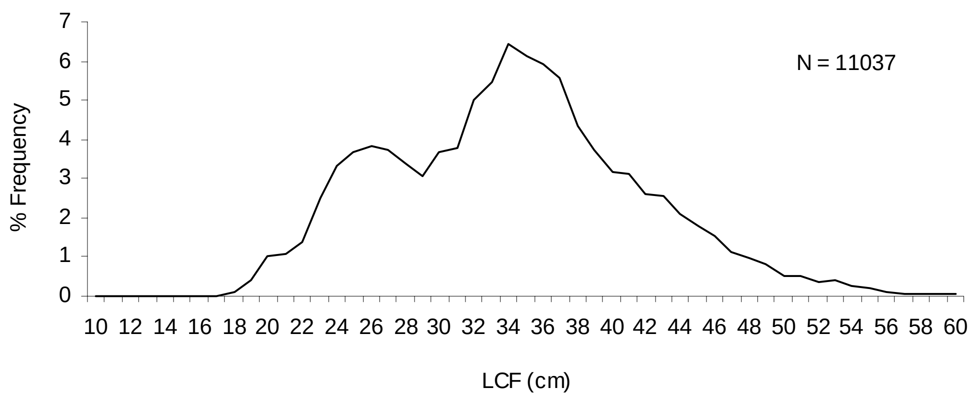
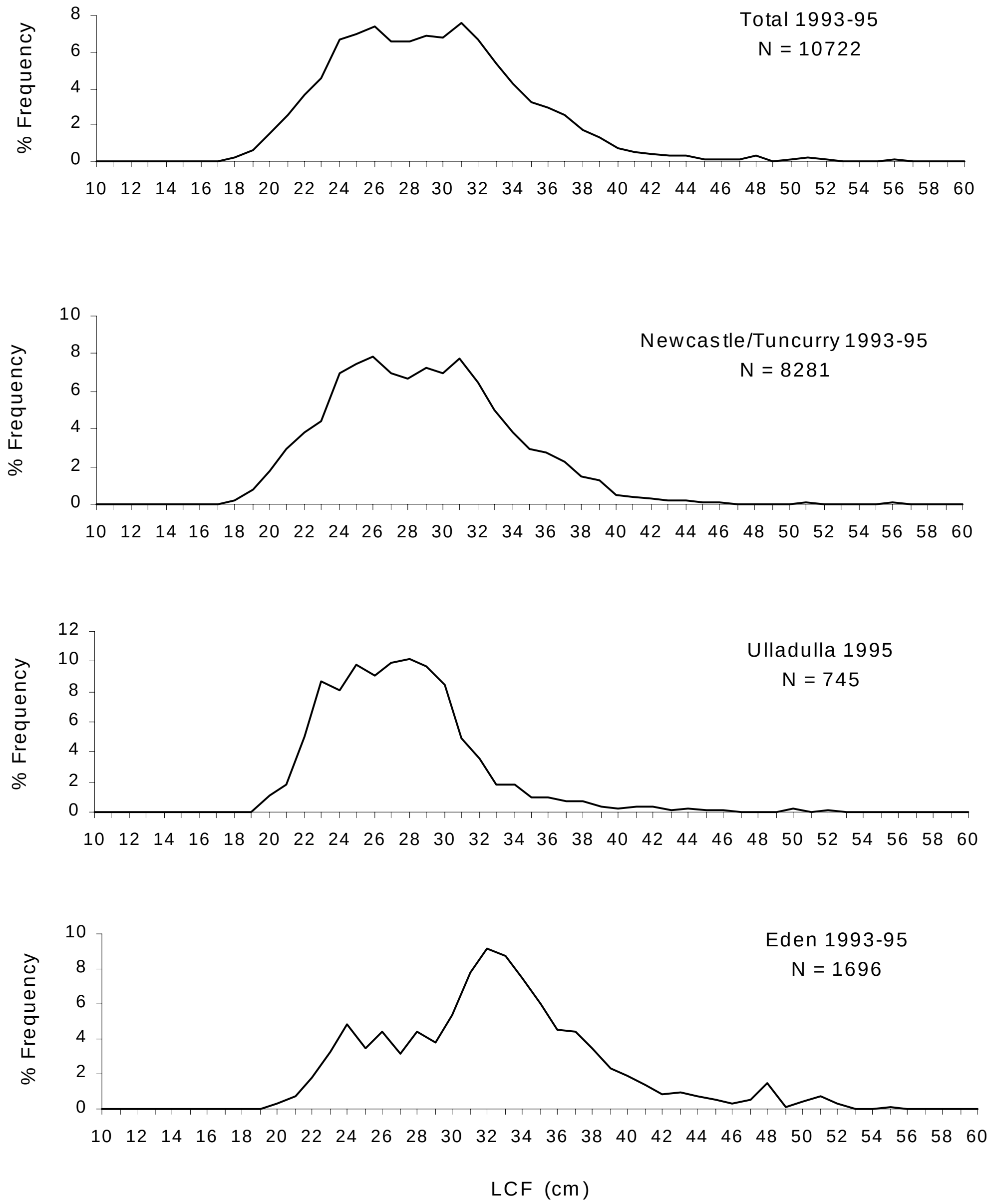


Figure 5.10 Size compositions of trawl catches of silver trevally measured by onboard observers during 1993-95 (Liggins, 1996).

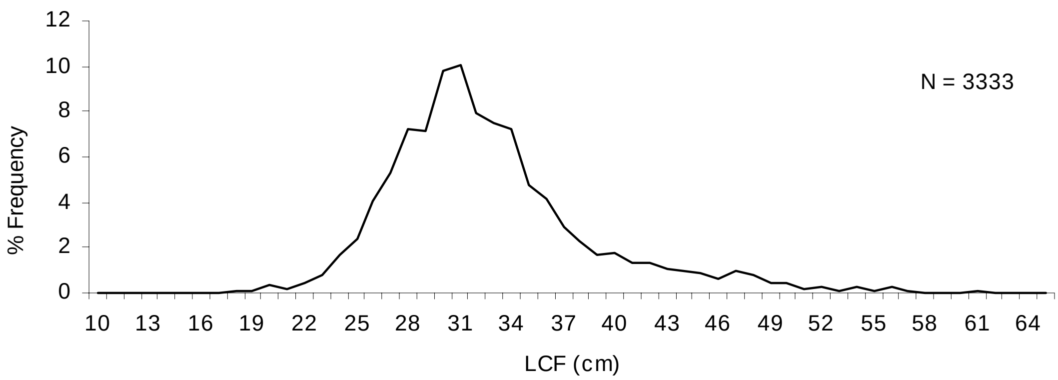


Data on the size composition of recreational catches of silver trevally in Botany Bay were reported by a further study in the late 1970's (Anon,. 1981b). A total of 208 trevally were measured during this study, with the majority of fish being between 30 and 45 cm LCF (Figure 5.8 – note that the original data were smoothed due to aggregation of size classes). During the late 1980s a routine market sampling program carried out at the Sydney Fish Market by NSW Fisheries research staff measured representative samples of commercial catches for a number of important species, including silver trevally. Between 1987 and 1990 more than 11,000 trevally were measured, with the majority of fish in these catches being greater than 30 cm (Figure 5.9). The size composition showed a major mode at about 34 cm LCF and a minor mode at 25 cm.

Between 1993 and 1995, observers aboard NSW trawlers measured representative samples of silver trevally from trawl catches. The greatest number of fish were measured off the northern ports of Newcastle and Tuncurry (Wallis Lake) where catches were relatively high (Liggins, 1996). The weighted total size composition showed two modes of approximately equal strength, at 25 cm and 31 cm LCF. (Figure 5.10). The size composition of the total sample reflected mostly that of the large number of fish measured off the northern ports, although a similar size composition was found for the smaller sample measured aboard Ulladulla based trawlers. Eden catches contained a higher proportion of large fish, with a strong mode at 32-33 cm. Monitoring of SEF trawl catches has continued, with recent data showing an increase in the proportion of small trevally, <25 cm LCF, in catches off Sydney and Ulladulla (Knuckey and Sporcic, 1999). These findings are consistent with the size composition data collected during the current study (see Figure 3.3).

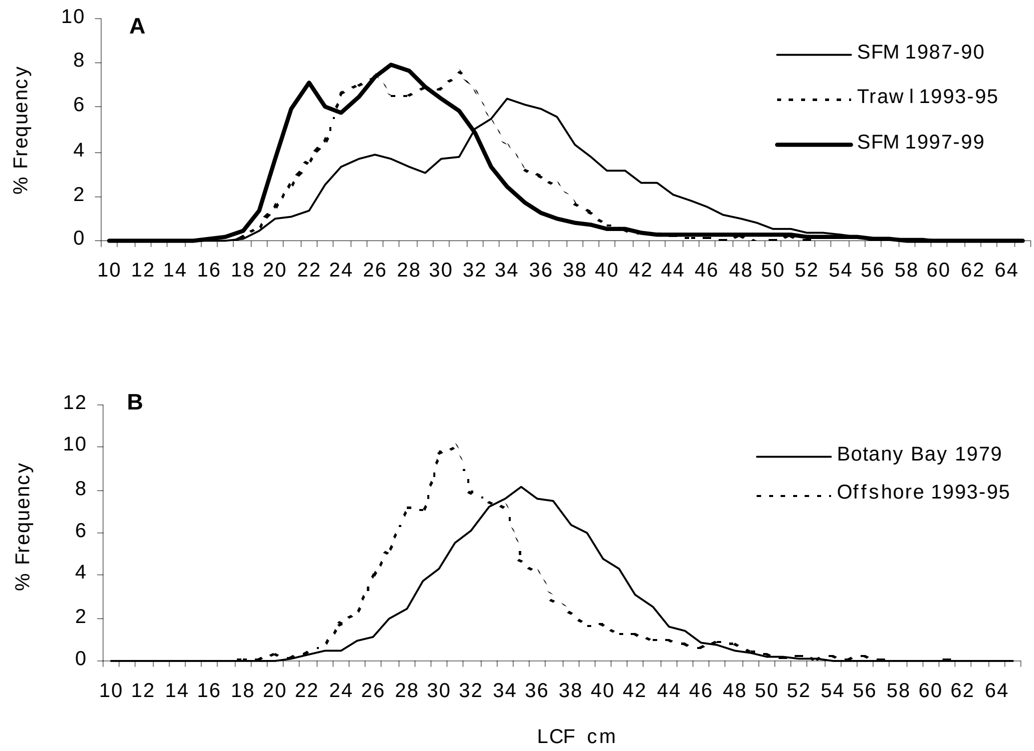
From September 1993 to August 1995, offshore recreational trailer boat fishers were interviewed and representative samples of their catches were measured by observers working at boat ramps (Steffe *et al.*, 1996). The size composition of silver trevally measured during this survey shows a strong mode at 30 cm LCF, and a long 'tail' of larger fish up to 64 cm (Figure 5.11). Trevally less than 25 cm comprised only a very small proportion of catches, which might reflect poor selection of fish less than this length by hooks used in the recreational fishery.

Figure 5.11 Size composition of silver trevally measured from catches by offshore recreational trailer boat fishers between September 1993 and August 1995 (Steffe et al., 1996).



Changes in the size composition of commercial and recreational catches of silver trevally are summarised in Figure 5.12. It appears that the modal length of trevally in catches during the 1980s was around 35 cm LCF. By the early 1990s the modal length had declined to around 30 cm, and trawl catches included a significant representation of fish between 24 and 28 cm. By the late 1990s the modal length had declined further, to 26–28 cm, and there was a significant representation of fish <24 cm in catches, with a secondary mode at 21-22 cm. In conclusion, the available data suggest there has been a very significant decline in the average size of silver trevally in commercial (and probably recreational) catches since targeting of the species increased in the 1980s. Fish greater than 35 cm LCF are now very poorly represented in catches, with the majority of the catch being comprised of fish between 20 and 30 cm in length. The mean length of trevally in commercial catches during 1997-99 was 28.4 cm LCF, significantly less than the mean length of fish in commercial catches during 1987-90 of 34.7 cm.

Figure 5.12 Changes in the size composition of samples of silver trevally from (A) commercial and (B) recreational catches in NSW between 1979 and 1997-99.

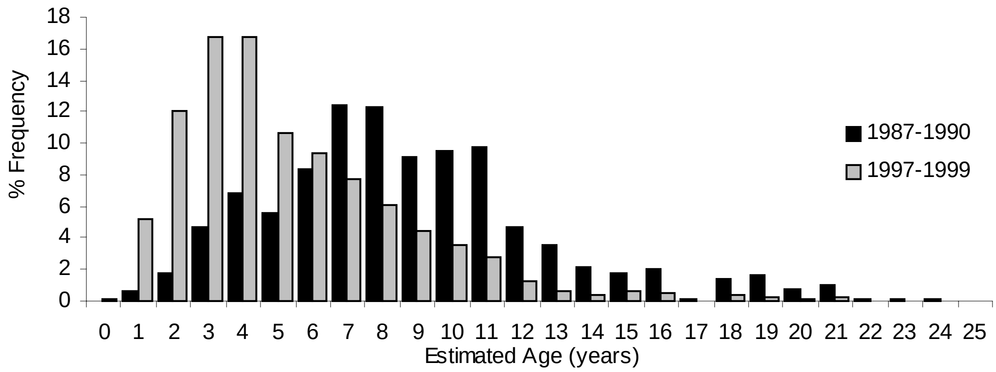


5.4.2 Trends in Age Composition of the Catch

Changes in the age composition of commercial catches of silver trevally between 1987-90 and 1997-99 were estimated by application of the age-length key determined during the current study to the size composition data for these periods (assuming that growth rates of trevally did not change significantly over this period). Since the late 1980s there has been a significant increase in the proportion of the catch contributed by the younger age classes, which is consistent with the fishing down of the older age classes in the population (Figure 5.13). During this period there appears to have been a decline in the mean age of recruitment to commercial catches - fish were not fully recruited until 7-8 years of age in 1987-90, but full recruitment in recent years appears to occur by 3-4 years of age.

It should be noted that a considerable period of targeted fishing for silver trevally occurred prior to 1987, including the development of pair trawling on the south coast of NSW. It is likely that changes in the age structure of the trevally stock from that which prevailed in the ‘unexploited’ stock had already occurred prior to the 1987-90 period, and that catches during the 1970s and early 1980s contained a higher proportion of trevally older than 12 years.

Figure 5.13 Age compositions estimated from size composition data for commercial catches of silver trevally for the periods 1987-90 and 1997-99.

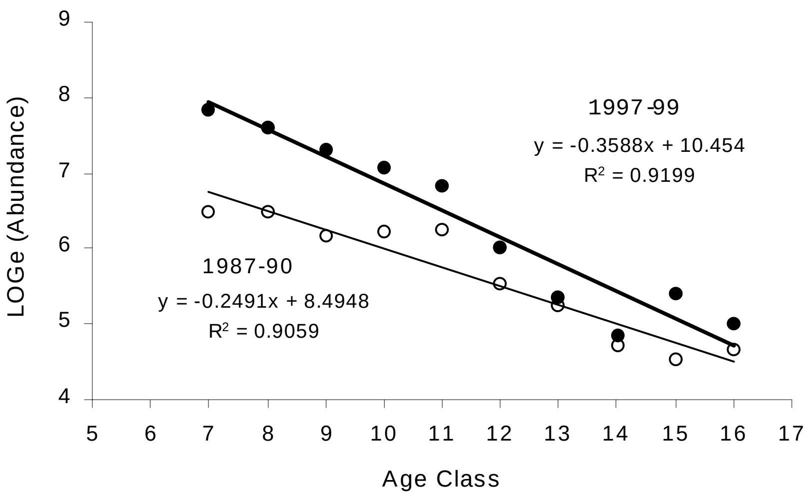


5.5 Estimation of Mortality Rates and Yield

5.5.1 Estimation of Instantaneous Total Mortality Rate (Z)

The estimates of age composition for the periods 1987-90 and 1997-99 allow a calculation of the average instantaneous total mortality rate (Z) applying in each of these periods by the method of catch curve analysis (Gulland, 1969). As trevally were not fully recruited to the fishery in the 1987-90 period until age 7, total mortality was estimated for ages 7 to 16 for each period (the upper limit was chosen because sample sizes were small for age classes greater than 16 in the age-length key). The results (Figure 5.14) suggest a significant increase in total mortality rate between the late 1980s (Z = 0.249) and the recent period (Z = 0.359).

Figure 5.14 Catch curves for silver trevally estimated for the periods 1987-90 (open circles) and 1997-99 (filled circles).



5.5.2 Estimation of Instantaneous Natural Mortality Rate (M)

The natural mortality rate defines the underlying productivity of a fish stock, but is usually extremely difficult to estimate unless data on the age or size composition of a lightly exploited stock are available. James (1984) estimated *M* for silver trevally from the Bay of Plenty trawl fishery in New Zealand by catch curve analysis of age composition data for a period early in the history of the fishery (1971-74). James acknowledged that his estimate of *M* = 0.03 for age classes 6 to 34 was extremely low compared with estimates for other fish species, but he considered that low *M* values may be typical for slow growing temperate species such as trevally. He also estimated a significant increase in *M* (to 0.30) for trevally between 35 and the maximum age of 46 years. James' (1984) estimate of *M* = 0.03 was considered to be "conservative" and recent modelling of silver trevally population dynamics in New Zealand has used a value of *M* = 0.1, determined from the equation $M = \log_e 100$/maximum age, where the maximum age specified was 45 years (Annala *et al.*, 1999; MAF unpublished data). [Note: using a maximum age of 30 years in this calculation results in a value of *M* = 0.15.]

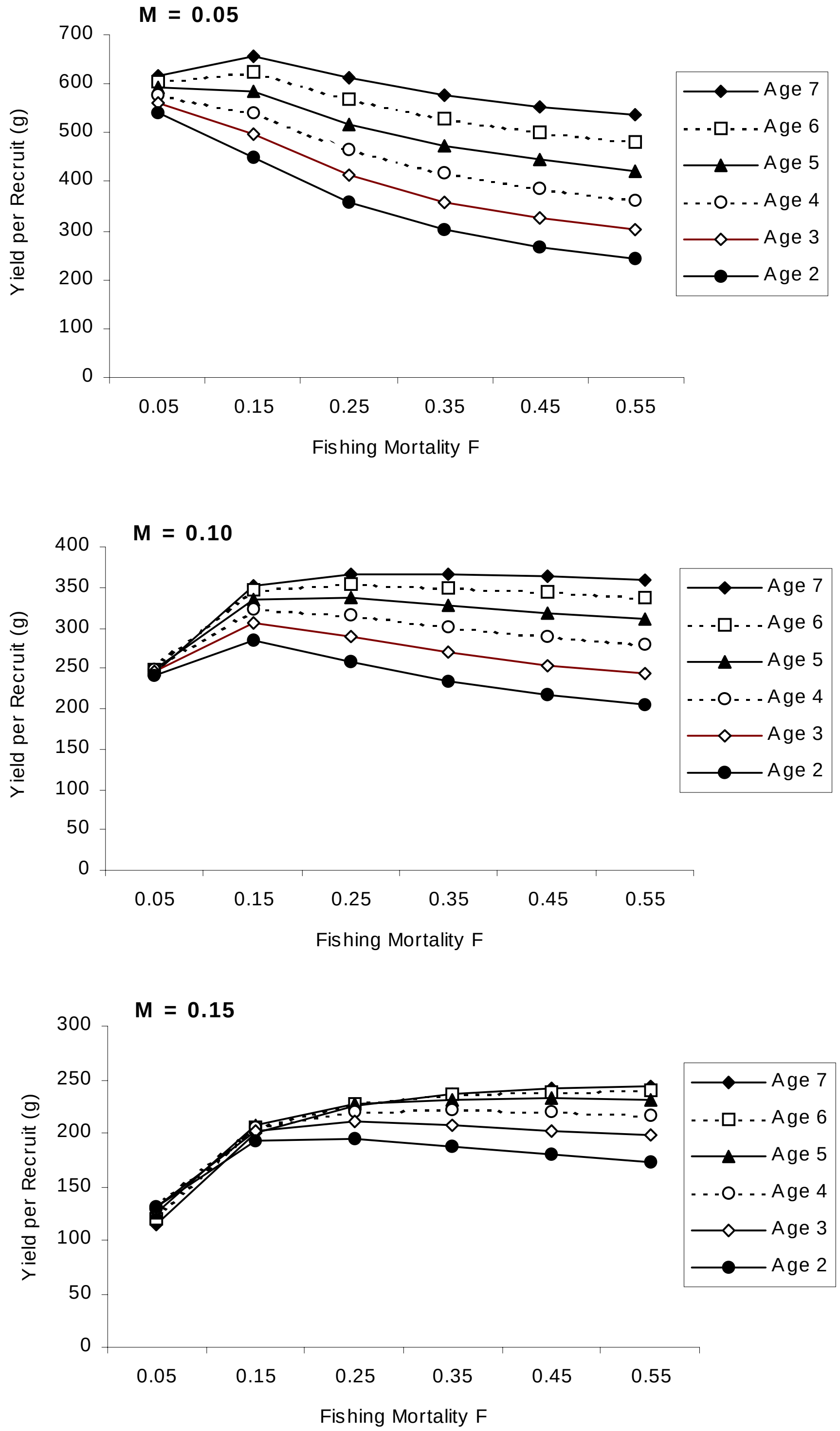
In NSW, the silver trevally stock was subject to considerable fishing in the years before the period for which the first reliable estimates of mortality rate can be made (1987-90). It is therefore reasonable to deduce that *Z* in the 1960s (prior to significant removals from the stock by fishing, which would be close to the instantaneous natural mortality rate *M*) was much less than 0.249. Given this, and the magnitude of the increase in mortality rate between 1987-90 and 1997-99, for the purposes of the following yield calculations *M* for silver trevally in NSW was assumed to lie in the range 0.05 to 0.15.

5.5.3 Yield per Recruit Calculations

Given the apparent impact of fishing on the NSW stock of silver trevally, and the significant decline in length and age at first capture since the 1980s, it is appropriate to undertake analyses to estimate yield per recruit for the current fishery, and to provide information on the conditions required to improve the yield from the resource.

Two approaches, both of which are variations on the yield per recruit function derived by Beverton and Holt (1957), were taken to examine yield for silver trevally. Initially, the von Bertalanffy growth in weight parameters (see Table 2.7) and estimates of *M* were used (program "B-H3" in Saila *et al.*, 1988) to calculate yield per recruit for specified ranges of age at first capture and fishing mortality rate *F*. The yield per recruit trajectories determined for three estimates of *M* ranging from 0.05 to 0.15 are shown in Figure 5.15. The results indicate that yield per recruit generally increases for increasing age at first capture (from 2 to 7), but decreases with increasing fishing mortality above about *F* = 0.15, especially for the lower rates of natural mortality. For all values of *M* examined, relatively high exploitation rates are predicted to lead to declining yield, with a lesser decline when age at first capture is higher (6 to 7 years). For *M* = 0.10, yield is maximised at an *F* value of 0.15, for all except the oldest ages at first capture.

Figure 5.15 Summary of results of 'B-H3' (Saila *et al.*, 1988) yield per recruit analysis for silver trevally for M = 0.05 and M = 0.15, using growth in weight parameters from Table 2.7.



Because of the large range in length at age for silver trevally, and the fact that selection to the fishery is more likely to be a function of fish length rather than age, yield per recruit was also estimated as a function of length at first capture (L_c, as a proportion of L_∞) and exploitation rate using the program "YPER" (Ault *et al.*, 1996). YPER calculates relative equilibrium yield per recruit from the Beverton and Holt model as a function of the ratio of *M*/*K*. The resulting yield per recruit isopleths for *M*/*K* = 1 and 3 are shown in Figure 5.16, and the combinations of exploitation rate and length at first capture which yield the maximum yield per recruit for different ratios of *M*/*K* are shown in Figure 5.17. The optimum lengths at first capture estimated from the YPER program for different combinations of exploitation rate and *M*/*K* value are given in Table 5.2.

Table 5.2 Optimum lengths at first capture (cm LCF) estimated for silver trevally in relation to exploitation rate and *M*/*K* value, from "YPER" (Ault *et al.*, 1996) for L_∞ = 63.16 cm.

	Exploitation Rate *E*				
M*/*K	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.5	42.4	45.3	47.8	50.2	52.2
1.0	36.9	39.5	41.8	43.8	45.7
1.5	32.7	35.0	37.1	39.0	40.6
2.0	29.4	31.5	33.4	35.1	36.6
2.5	26.7	28.6	30.3	31.8	33.2
3.0	23.2	26.2	27.8	29.2	30.5

If the ratio of *M*/*K* for silver trevally is less than 3, then for likely estimates of exploitation rates ranging from 0.5 to 0.7, the current size at first capture of 25 cm is well below that which will produce the optimum yield per recruit. It is likely that *M* for silver trevally is close to 0.1 and that the true value of *K* lies in the range 0.1 to 0.2. Therefore, the most likely values of *M*/*K* lie in the range 0.5 to 1.0, and recent exploitation rates would be estimated to be around 0.6 to 0.7. The approximate locations of the current fishery ('c') and the combination which produces the optimum yield per recruit ('o') are marked on the yield isopleths for *M*/*K* = 1 in Figure 5.16. The results suggest that only small gains in yield per recruit would be expected if the exploitation rate was reduced from the current level, however significant gains in yield per recruit would result from an increase in the size at first capture. The figures in Table 5.2 suggest that the optimum length at first capture for silver trevally is likely to be in the range 35 – 40 cm LCF, which is greater than the length at which the species is recruited to the catch by each fishery sector (see Figure 3.1), but is similar to the length at full recruitment suggested by the data for earlier periods in the fishery (see Figure 5.12).

Figure 5.16 Relative yield per recruit isopleths (nominal units) for silver trevally as a function of exploitation rate and length at first capture, for M/K = 1 and M/K = 3.

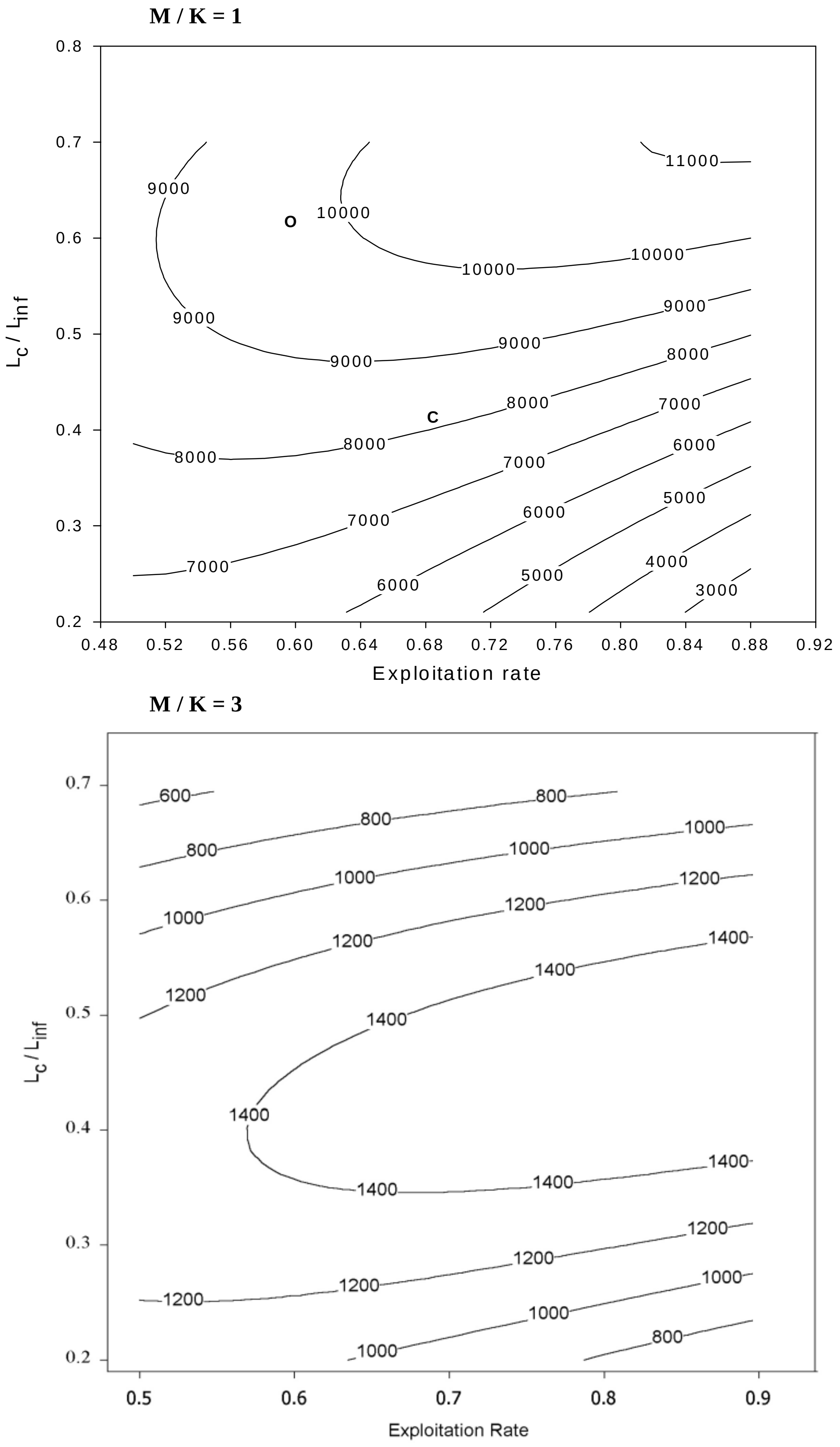
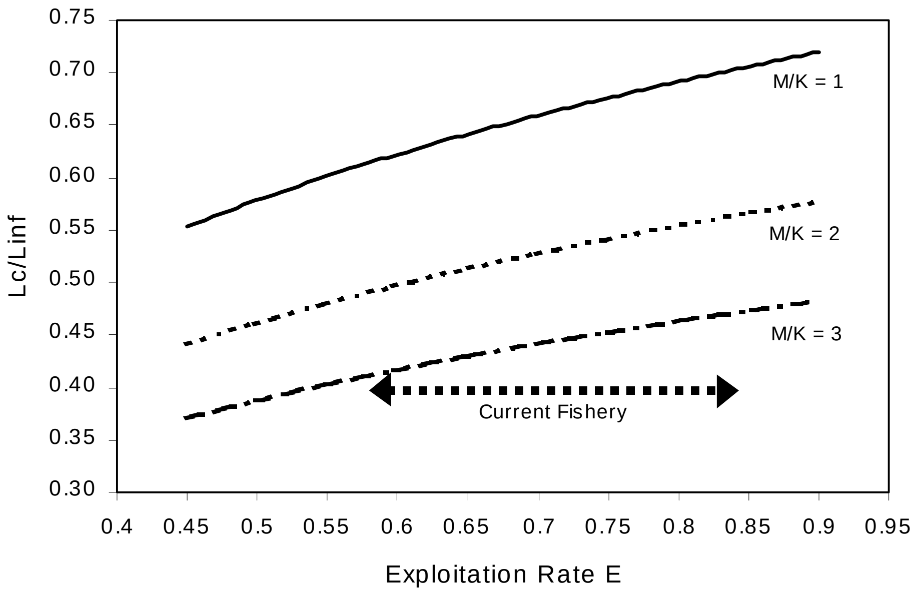


Figure 5.17 Maximum yield per recruit trajectories for different values of M/K for silver trevally, showing the likely range of exploitation rates for the current fishery at the approximate size at first capture of 25 cm LCF.



5.6 A Preliminary Assessment of the Status of the Silver Trevally Stock in NSW

The available biological information indicates that silver trevally is a relatively long lived and slow growing species. The maximum age of 24 years found in this study is probably less than the biological maximum for the species in NSW waters, as the sample aged contained only a small number of fish greater than 40 cm LCF. Trevally larger than this size are no longer abundant in NSW catches. For such a long lived species, silver trevally are fished from a very young age, with fish less than 5 years old comprising almost 50% of recent catches. Trevally older than 10 years were estimated to comprise just 7% of the commercial catch in 1997-99.

Female trevally were found to have moderate fecundity, and appear to be partial spawners over an extended period from spring to autumn. Recruitment to the overall fishery generally coincides with maturation, and occurs between about 18 and 26 cm LCF, although recent trawl catches from north of Sydney contain significant numbers of trevally less than 24 cm in length, the majority of which would be expected to be immature. Trevally are not known to aggregate for spawning, and this fact, together with the occurrence of unsightly extensions of the swim bladder into the flesh of fish larger than about 45 cm LCF which make the large fish difficult to market (Wilson and Machin, 1981) results in little targeting of the larger fish. Mature and near-spawning trevally do not therefore appear to have a high vulnerability to fishing. However, no biomass estimates are available from the work done to date, and current levels of spawning biomass are not known.

Silver trevally comprised a low level incidental catch of fishing targeted at other species prior to the development of markets for trevally in the late 1970s. Targeting of trevally by both commercial and recreational fishers increased during the 1980s. Commercial fishers principally used fish trawls and traps in ocean waters, and beach haul nets in estuarine waters, to target trevally, while recreational fishers were only permitted to use lines with baited hooks or lures. Landings of silver trevally in NSW increased rapidly to an estimated peak of 1800 – 2000 t in the mid to late 1980s, but have steadily declined since the early 1990s. In 1999 commercial landings of trevally were just 340 t, but the size of the recreational catch is not known. It is likely that the total catch of trevally off NSW in 1999 was less than 500 t.

Information on the size composition of silver trevally catches prior to the late 1980s is sparse. The available data suggest that early catches comprised mostly trevally greater than 30 cm LCF, with a modal length of around 35 cm or more. Data collected from commercial catches at the Sydney Fish Market between 1987 and 1990 showed an increasing proportion of smaller trevally (24 to 30 cm) in the catch, but the bulk of landings still comprised fish greater than 30 cm. Between 1993 and 1995, data collected from both commercial and recreational catches of silver trevally from NSW ocean waters showed a surprising correspondence, with a prominent mode at 30-31 cm, and a steady decline in the relative abundance of larger fish to a low level around 40 cm LCF (see Figure 5.12). (Note that trawl catches in 1993-95 also exhibited a mode of smaller fish, 24-26 cm, which were not prominent in recreational catches.) Data collected during the current research program indicate that, since 1993, there has been a further decline in the modal size of trevally in commercial catches to around 27 cm, and an increase in the proportion of small trevally in the catch, with a prominent mode at 21-22 cm. For commercial catches measured during 1997-99, only 10% of fish were greater than 35 cm LCF, whereas in 1987-90 trevally of these sizes comprised 48% of the catch.

Data on the age composition of historic catches of silver trevally are non-existent. The changes in size composition referred to above were used to indicate the likely changes in age composition over the past decade by applying the ‘age-length key’ for the 1997-99 period to the relevant size composition data. The results suggest that in the late 1980s trevally were gradually recruited to the commercial fishery between the ages of about 2 and 7, and that the majority of the catch was comprised of fish between 5 and 12 years of age. In 1997-99, recruitment to the fishery occurred much earlier, between 1 and 3 years of age, and the bulk of fish in the catch were less than 6 years of age. Although it is not possible to accurately estimate the age composition of the lightly exploited stock of silver trevally, it is probable that it comprised mostly fish older than 5 years of age, and contained a significant representation of fish between 10 and 25 years of age.

The indications are that the stock of silver trevally in NSW waters has been significantly impacted by exploitation over the past two decades, resulting in the ‘fishing down’ of the larger and older fish in the population and an increase in the relative proportion of younger fish in the stock. Such changes in the size and age composition of a fish stock are expected to result from increased exploitation of a relatively long lived and slow growing species such as silver trevally. The fact that annual yields of less than 2000 t have resulted in the significant changes observed in the structure of the trevally population over a relatively short period since the late 1980s indicates that the initial (unexploited) biomass of trevally was probably not large (possibly of the order of 10,000 t) and silver trevally comprise a relatively unproductive stock.

Records show that since 1985, of the 13,300 t of silver trevally taken by commercial fishers off NSW, about 8,000 t was caught by trawling, with 3,700 t being taken by trap and line fishers and 1,600 t from estuarine waters. The total recreational catch taken during this period cannot be estimated accurately, but for comparison it is likely to have been between 2000 and 3000 t, which represents approximately 13% to 18% of total trevally catches during this period. (These figures were estimated by assuming recreational catches increased from 150-200 t per annum during the mid 1980s, to 200-250 t in the early 1990s, and declined to 120-150 t in recent years – based on the estimates presented by Steffe *et al.*, 1996, and likely trends in the availability of trevally in recent years.) It is concluded that the most significant fishery sector in terms of the quantity of trevally caught is the trawl sector (about 50% of total catch), followed by the commercial trap and line sector (25%), the recreational sector (15%) and the estuarine commercial sector (10%).

The yield modelling indicates that, on average, silver trevally in NSW are being caught well below the optimum size for such a slow growing species with a relatively low natural mortality rate. It is clear that, for the likely range of *M*/*K* values for silver trevally, reducing the current exploitation rate would be expected to result in only a small increase in yield for a given recruitment. However significant increases in yield would be expected to result from increasing the size at first capture at current exploitation rates. Trevally recruit to the different fishery sectors over a range of lengths, however the trawl and estuarine haul net sectors take the highest proportion of small fish (<25 cm LCF). Recruitment of trevally to the trap and line fisheries occurs mostly at larger size classes (26 to 28 cm LCF), although information on recruitment to recreational line catches is limited. Given the trawl sector's larger share of the total catch of trevally, exceeding 50%, and the relatively small size at which trevally are recruited to trawl catches, it could be argued that the trawl sector is having a much greater impact on the silver trevally resource than the other fishery sectors.

5.7 Uncertainties in the Preliminary Assessment

The lack of data which could be used to estimate the age composition of the stock of silver trevally during the early period of the fishery results in significant uncertainty about the age structure of the unexploited stock, and therefore about the likely rate of natural mortality. The age structure of the samples obtained during 1997-99 appears to be deficient in fish greater than about 12 years of age. The use of this length/age distribution to estimate age composition from size composition samples for earlier years may lead to biases in estimates of the relative abundance of older age classes in the population. Specifically, the estimate of total mortality rate for the 1987-90 period may be greater than the true value, because of under-estimation of the relative abundance of the older age classes in the catch. The estimates obtained for total mortality rates in this study should therefore be used cautiously.

There is also evidence that the fishery and the trevally population are not currently at equilibrium, and 'fishing down' of the stock may be continuing. Indicators of this include an increasing proportion of small fish in recent year's catches, and the significant decline in total catch of trevally in recent years. Although there is no indication of any problem with recruitment to the stock to the present time, the possibility of recruitment overfishing will need to be considered if these declines in population indicators continue.

The uncertain estimates of most of the parameters used in the yield modelling result in uncertainty about the actual size at first capture which would produce the optimum yield per recruit for silver trevally. The implications of this uncertainty may be better quantified by further modelling, which considers a range of plausible estimates of growth and natural mortality rates, however it is clear that for realistic combinations of *M* and *K* the optimum size at first capture of trevally is significantly greater than is the case for the current fishery. The relative importance of improving or maximising yield per recruit needs to be determined, amongst the other fishery management goals which may be relevant for silver trevally. These issues should be discussed with the broad range of stakeholders who have an interest in the trevally fishery.

5.8 The Need for a Minimum Legal Length for Silver Trevally

The results of this research project suggest that it would be beneficial to increase the size at which silver trevally are retained by commercial (and probably also recreational) fisheries. One way of achieving this would be to introduce a minimum legal length (MLL), with fish below this length having to be returned to the water if caught. While such a regulation might be appropriate for sectors where small trevally make up only a minor proportion of the catch and suffer minimal trauma during capture (e.g. line or trap fisheries), for trawl and perhaps haul fisheries it would also be necessary to introduce appropriate gear modifications to prevent, as far as possible, the capture of large quantities of undersized fish. As these are mostly mixed species fisheries, the development of appropriate gear to select trevally at the desired size will involve compromises as far as the selection of other species is concerned. The larger the MLL which may be introduced for silver trevally, the greater will be the problem of identifying the optimal fishing gear.

These issues of gear selectivity, which need to be addressed across a broad range of fisheries, are the subject of several current research projects funded by FRDC, and it is recommended that silver trevally be specifically considered when reviewing the outcomes of these projects:

- 1998/204 Effects of trawling subprogram: Maximising yield and reducing discards in the South East Trawl Fishery through gear development and evaluation (MAFRI / NSWF / AMC)
- 1998/138 Mesh selectivity in the NSW demersal trap fishery (NSWF)
- 1997/207 Development of discard reducing gears and practices in the estuarine prawn and fish haul fisheries of NSW (NSWF).

6. RECOMMENDATIONS AND IMPLICATIONS

6.1 Benefits

This research project has:

- ✓ documented, for the first time, changes in the population structure of silver trevally as evidenced by commercial and recreational catches;
- ✓ provided information on the size at maturity and the extended spawning period of silver trevally, and the first firm estimates of fecundity;
- ✓ added to the confidence that ageing techniques developed for silver trevally can be used to accurately reflect growth of the species, and can also be used to estimate the age composition of the exploited population;
- ✓ conducted a preliminary assessment of the silver trevally stock, which concluded that the stock is likely to have been significantly impacted by fishing over the past two decades, and current size at first capture is well below the optimum size;
- ✓ provided the background to enable more detailed assessment of the trevally stock, and discussion about the need for a minimum legal length to take place in a more informed environment with regard to the biology of silver trevally.

6.2 Intellectual Property

No intellectual property of any commercial value arose from this project, however the results of the research will be utilised in stock assessment fora at both the state and Commonwealth level, to assist in the sustainable management of fisheries which catch silver trevally. The results of the research will be presented to industry/management meetings in connection with assessment and management of NSW restricted fisheries and the Commonwealth South East Fishery.

6.3 Further Developments

The stock assessment presented in this report could be further developed by more detailed analyses of catch and effort data available for sectors of the trevally fishery, to assess whether catch rates can be considered to index abundance for this species. Attempts could also be made to develop an age-structured dynamic model of the trevally population, which could more effectively investigate the sensitivity of the stock assessment to variations in parameter values and the paucity of data from the early years of the fishery.

The specification of an appropriate minimum size limit for silver trevally will only be possible following consultation with members of the different fishery sectors regarding the many issues which will need to be taken into account (gear selectivity, catchability of the different size classes, market factors etc). This research project has provided a basis from which to commence those discussions.

6.4 Staff

Staff directly employed on this project with FRDC funds:

Ms Leeanne Raines (full time)

Ms Veronica Silberschneider (temporary, part time)

Staff who contributed to the project but were not directly funded by FRDC:

Mr Kevin Rowling (Supervising scientist)

Mr Dennis Reid (Biometrician)

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