Assessment of the snapper fishery in Victoria

Patrick C. Coutin,
Shellie Cashmore and K.P. Sivakumuran

Final Report
Project No. 97/128

Australian Government
Fisheries Research and Development Corporation

Victoria
The Place To Be

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FISHERIES RESEARCH & DEVELOPMENT CORPORATION

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Abbreviations

ANSA	Australian National Sportfishing Association
CPUE	Catch per unit of fishing effort. Units vary with fishing method.
DF	Degrees of freedom.
ECe	East Coast eastern region of Victoria near Mallacoota Inlet.
ECw	East Coast western region of Victoria near Corner Inlet.
F	Annual rate of fishing mortality
FL	Fork length cm
GIS	Geographic Information System. Computer mapping program.
GL	Gigalitres equivalent to 1000 megalitres
GLM	General linear regression model.
GSI	Gonosomatic Index. Gonad weight divided by fish weight x 1000
Lm_{50}	Length at 50% maturity in cm
M	Annual rate of natural mortality
ML	Megalitres
MAFRI	Marine and Freshwater Resources Institute
NSW	New South Wales
Nt	Number of fish at time t
PPB	Port Phillip Bay
P	Proportion of fish that are mature
R^2	Regression coefficient. Values close to 1.0 indicate a close correlation
SOI	Southern Oscillation Index. A measure of the El–Niño phenomenon. El Niño years have negative SOI and La Niña years have positive SOI.
TL	Total length cm
WCe	West Coast eastern region between Apollo Bay and Ocean Grove
WCw	West Coast western region between Apollo Bay and Portland
WPB	Westernport Bay
YCS	Relative year class strength. Abundance of fish spawned in each year
Z	Annual rate of total mortality

NON–TECHNICAL SUMMARY

97/127 Assessment of the snapper fishery in Victoria

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Objectives

1. Develop models to assess the eastern and western snapper stocks in Victoria and to provide advice on management options through input into management plans.
2. Undertake a statewide tagging program. Re–analyse historic tagging data using recently developed computer programs and prepare a sampling design for recreational snapper tagging for VICTAG.
3. Investigate the relationship between environmental conditions and recruitment.
4. Determine the spawning season and location for snapper in Port Phillip Bay.

Outcomes achieved

This report provides new analyses of fisheries, environmental and biological data that have been incorporated into models and used to improve stock assessments. The models that have been developed for predicting snapper recruitment, growth, and movement give a better understanding of the reasons for fluctuations in snapper catches in Victoria. The new information on the growth, size and age at maturity, and fecundity provide the basis for reviewing the legal size limit of snapper in Victoria.

More than 50 years of Victorian snapper tagging data have been documented and an ongoing statewide tagging program with the Australian National Sportfishing Association has been established. So far, 395 recaptures have been reported from the 21034 snapper released since 1995. This tagging information will benefit all stakeholders from a better understanding of the stock structure, dispersal and spatial distribution of snapper stocks.

This knowledge may help to reduce conflict between the commercial and recreational fisheries in the future through knowledge of the natural cycles in recruitment that are inherent in snapper stocks. Predictions of recruitment based on environmental cycles provide the opportunity to adjust harvest strategies to optimise fishery yields while protecting the spawning stock biomass. The outcomes of this project have been presented at stock assessment workshops and scientific conferences and used as a guide for other snapper research. Scientific advice from this project provides the basis for developing management options to improve the snapper fisheries in Victoria.

Summary

Snapper (*Pagrus auratus*) is a highly valued species that supports a commercial fishery, predominantly based on long lines set in Port Phillip Bay between October and May. Snapper is also one of the most important species of the charter boat and recreational fisheries in Port Phillip Bay, Westernport Bay and coastal waters of Victoria. At the commencement of this project there was a public perception that Victorian snapper stocks were depleted. This was mostly due to lower angling success than in the past, particularly for large snapper, and declining trends in commercial catches. However, the status of the snapper stocks was uncertain and the reasons for lower snapper catches were unclear. In 1996, snapper stock assessment workshops were initiated, but there was uncertainty about the trends in stock abundance, the movement patterns of snapper; and the size and age at maturity.

This project has provided a focus on snapper research and resulted in a better understanding of the stock status by the collection and analyses of new data on the biology, movement and fisheries of snapper in Victoria. The first objective of the project was addressed by a formal analysis of commercial fisheries data and the development of several biological models describing important aspects of snapper population dynamics such as recruitment, growth, maturity, reproduction, spatial distribution and movement. These models have been presented to stakeholders at snapper stock assessment workshops and incorporated into management advice.

The decline in the commercial catches was due to much lower fishing effort with long lines in Port Phillip Bay and lower catch rates between 1994–1997. Standardised catch per unit effort (CPUE) models were developed to take into account the area fished, month of fishing, and fishing experience. Between 1978–1999, there was no distinct CPUE trend in Port Phillip Bay and there was little evidence of a decline in snapper stock abundance. However, the stability in CPUE should be interpreted cautiously as such analyses do not necessarily remove all potentially confounding factors.

Poor recreational snapper fishing during the early 1990s was considered to be primarily due to low recruitment in previous years under the influence of unfavourable environmental conditions. The recreational fishery takes mainly smaller and younger fish and their catches are influenced more directly by low recruitment than the commercial fishery. The effects of recruitment variation on the stocks need to be taken into account to understand trends in key indicators such as catch rates.

In Victoria, snapper live up to a maximum age of 32 years and sexual maturity is reached at 42.2 cm in total length after about 5 years. The size at 50% maturity is much greater than the legal minimum length (27cm TL) when snapper are between 2–3 years old. The reproductive capacity as indicated by gonad weight, batch fecundity and total fecundity, increased dramatically with fish size and age. For example, the number of hydrated oocytes spawned in a batch increased threefold between the age of 7 and 14 years from 153,000 to 469,000 respectively. This shows the high reproductive capacity of the larger, older fish in the spawning stock that are targeted by the fisheries in Port Phillip Bay. Prior to spawning, a higher proportion of females were caught and there was a seasonal change in the sex ratio reaching 1 male to 2 females in December, when spawning occurs. The aggregation of part of the western spawning stock in Port Phillip Bay in the months prior to spawning makes the stock highly vulnerable to the combined effects of commercial and recreational fishing.

The second objective was achieved through a collaborative tagging program (VICTAG) with the Australian National Sportfishing Association involving commercial fishermen, charter boat operators and anglers. Tag retention experiments were conducted and a snapper tagging database was developed that incorporated all the available tagging data. By 2003, 395 recaptures have been reported from the 21,034 snapper (1.9%) that were tagged and released since the project began. This new tagging data along with data from previous studies in Victoria dating back to 1948 have been analysed and summarised in this report.

Analyses of the tagging data confirmed that the eastern and western stocks of snapper in Victoria are divided at Wilson's Promontory. There is now evidence of mixing within the eastern stock with westward movements from Mallacoota Inlet to Seaspray, and eastward from Seaspray to the coast of New South Wales. However, the eastern and western stocks are not completely isolated and we have shown for the first time a low level of eastward movement between the stocks.

Based on all the available tagging data, a model was developed for estimating snapper movement rates between Port Phillip Bay and western Victoria. The model incorporates estimates of the growth of tagged snapper and the selectivity of hooks used by the commercial and recreational fisheries in Port Phillip Bay and coastal waters. Assumptions for the model were established and preliminary results were obtained. Trends in commercial and recreational fishing effort and hook selectivity were estimated to reflect the changes in the snapper fisheries in Victoria between 1957 and 1999. Differential movement of small (< 30cm), medium (30–38cm) and large (>38cm) snapper was integrated into the model and separate movement rates estimated by the model for each size group. Tag retention was estimated and internal and dart tags performed better than T bar tags. The combined total mortality and tag shedding rate of internal tags was low (0.09 $year^{-1}$), which suggests that fishing mortality may not be high.

The modelling results revealed movements of snapper according to their size and time at liberty. The large number of tagged snapper recaptured in the vicinity of their release site suggests that most small immature snapper in the western stock do not disperse a great distance from their nursery grounds in Port Phillip Bay and Portland Bay for the first 2 and 4 years, respectively. More extensive movements occur as western snapper reach maturity and 4 years of age. The west coast, particularly Portland Bay, is a source of large snapper moving into Port Phillip Bay.

The movement of the mature snapper from the west coast into Port Phillip Bay during the summer spawning season is characteristic of the western stock. On the east coast, immature snapper in the coastal waters outside Corner Inlet were mostly recaptured close to where they were released so like those in the western stock there was little movement from nursery grounds. In contrast, most of the recaptures (84%) of immature snapper from Mallacoota Inlet dispersed within 1-2 years along the coast of New South Wales between 38^{o} to 29^{o} South, with some moving north to latitudes where there is winter spawning.

The third objective was achieved by collating a time series of environmental and trawl survey data that was used to develop models for predicting snapper recruitment in Port Phillip Bay. Snapper recruitment was found to be variable and strong year classes occurred in 1982, 1983, 1986, 1991, 1995 and 1996. Significant positive relationships were found between snapper recruitment and the water temperature and river flow into Port Phillip Bay in April–June, four months after the peak in spawning activity in

December. More than 70% of the variation in snapper recruitment was accounted for in models based on the river flow and water temperature during April-June. The environmental–recruitment models that were developed predicted the high recruitment in the 1970s and 1980s, the decline in recruitment between 1991–1994, and the increase in 1995 and 1996. From these models, a lower abundance of 1 year old snapper was predicted from environmental parameters between 1997 and 2000.

The westerly wind model predicted that long line snapper catches would increase to a peak in 2004 and then decline in 2008. The predicted peak in catches in 2004 is consistent with the growth of the strong year classes in 1995 and 1996 entering the fishery as 8-9 year old fish. There is uncertainty about the ecological reasons for the relationship between snapper recruitment and environmental variables as there could be direct or indirect environmental effects on spawning behaviour, egg development or survival of larval or post larval snapper.

The fourth objective was achieved by a reproductive study and an ichthyoplankton survey in Port Phillip Bay. Spawning grounds were not restricted to Port Phillip Bay as spawning fish, larvae and juveniles were also found in coastal waters. The relative importance of the different spawning grounds to subsequent recruitment however remains unknown. The onset of spawning was associated with increasing day length, water temperature and phytoplankton productivity in Port Phillip Bay. There was a short spawning season during December 1997 and daily ageing of 0+ snapper indicated that larvae in northern Port Phillip Bay hatched within a few days of the 1st of January 1998.

The information collected during this project has provided the basis for the current assessments of the Victorian snapper stocks. These assessments will be improved as tag recaptures are reported and incorporated into the movement model and sensitivity testing is conducted using new information on recreational fishing in coastal waters. In the future, development of otolith microchemistry techniques will help to identify the sources of recruitment that support the Port Phillip Bay snapper fishery. The use of archival tagging technology will help to gain a better understanding of the seasonal movements of snapper between coastal waters and the fishing grounds, which is needed overcome the limitations of conventional tags.

Keywords

Snapper, *Pagrus auratus*, Sparidae, Port Phillip Bay, Victoria, tag, movement, assessment models, recruitment, spawning, reproduction, age, growth, commercial, hook and line, recreational, charter boat, stock structure.

FINAL REPORT

97/127 Assessment of the snapper fishery in Victoria

Background

The commercial, charter boat and recreational fisheries for snapper (*Pagrus auratus*) in Victoria are supported by two stocks (Sanders 1974). The range of the western stock extends from Port Phillip Bay and Westernport Bay to the coastal waters of Portland and eastern South Australia. The eastern stock is distributed from Mallacoota Inlet to the coastal waters of NSW, but it is uncertain whether this included snapper distributed between Wilsons Promontory and Mallacoota Inlet (Winstanley 1981).

Snapper is a highly valued commercial species, and for many anglers it is the most highly prized marine species in Victoria. It is also very popular with fish consumers. The commercial fishery in Victoria was valued at $539,000 in 2000/01 (Anon 2001). Based on a proportion of the estimated expenditure by marine anglers of about $250 million in 1994 (Unkles 1997), the recreational snapper fishery and charter boat industry are a significant component of the economy associated with tourism and leisure activities.

The seasonal pattern of the commercial and recreational snapper fishery is closely related to the spawning behaviour and most catches are taken during summer in Port Phillip Bay (Coutin 2000). The distribution and movement of the spawning stock and/or stock abundance may affect commercial and recreational catches in some years. Annual variability in recruitment, which in New Zealand is related to water temperature (Francis 1993), is also likely to affect stock abundance and catches.

During the early 1990s, it was considered that the snapper stocks had become severely depleted, but the reasons were unclear and there was a lack of scientific information on the stock status. The public perception of the Victorian snapper fishery was principally based on low recreational angling success that was frequently reported in the media. At this time, the recreational peak body (VRFish) expressed serious concerns about the fishery in their vision statement that stated “a detailed study of the effect of netting and long lining in bays and inlets should be conducted as a matter of urgency”. These concerns of the recreational peak body related to the perception that commercial fishing had caused a decline in the recreational snapper catches in Port Phillip Bay.

The snapper fishery in Port Phillip Bay dates back to European settlement in Victoria and catch records have been kept since 1914 (Coutin 1997). In 1995/96, the commercial snapper catches in Port Phillip Bay were the lowest for 39 years and the available catch and effort data indicated that fishing effort and catch rates of the commercial long line fishery were in decline (Neira *et al.* 1997). Annual production fell from 200t in the late 1970s to 65t in 1994/95 and snapper catch rates decreased from 70 kg/day to 40 kg/day between 1990/91 and 1993/94. In 1996, the Victorian Premier announced a review of the net and line fisheries and this was followed by a voluntary buy–back of bay and inlet commercial licences that began in 2000.

Preliminary recreational fishing surveys in Port Phillip Bay indicated that a large catch of mostly small snapper was being taken by the recreational sector (Conron and

Coutin 1995a). A full scale survey of the night-time snapper fishery was conducted in 1996/97 providing new information on the scale of the total snapper catch by recreational anglers in Port Phillip Bay. In Victoria, there are about 120,000 powered trailer boats and boat angling effort is considerable, with estimates in Port Phillip Bay for night-time anglers of between 100,000–200,000 boat hours (Conron and Coutin 1995a). Recreational catches in Port Phillip Bay were estimated at 6–17t for the daytime fishery between 1990–94 (Coutin *et al.* 1995) and 3–12t for the night-time fishery in 1995/96 (Conron and Coutin 1995a). Night–time angler catch rates were low compared to other species, at less than 0.3 snapper per boat hour and discarding rates of undersized fish were high. In the vicinity of Corner Inlet, recreational catches from the eastern stock were about 15t in 1995/96 (Conron and Coutin 1995b).

The first comprehensive assessment of the Victorian snapper stocks was held in 1996 based on previous research and monitoring of the commercial and recreational fisheries (Coutin 1997). Previous snapper research in Victoria provided information for this assessment on snapper movements, growth, genetic structure, diet and larval distribution (Sanders 1974; Sanders and Powell 1979; MacDonald 1980; MacDonald 1982; Winstanley 1983; Jenkins 1986; Francis and Winstanley 1989). Research on snapper conducted in other states was also available (Moran 1990; Ferrell and Morison 1993; Ferrell and Sumpton 1996) and a FRDC sponsored workshop was held in Sydney in November 1996. There is more information available on the biology of snapper in New Zealand (Crossland 1977a, Crossland 1977b; Crossland 1981) and stock assessment methods are more advanced (Gilbert 1994). For example, the relationships between growth, recruitment and temperature have been reported (Francis *et al.* 1992; Francis 1993; Francis 1994a; Francis 1994b; Kingsford and Atkinson 1994; Francis *et al.* 1995).

Need

Although there was a substantial amount of scientific literature relating to snapper, more information was needed to improve Victorian snapper stock assessments. These were identified and agreed by the Bay and Inlet Fishery and Stock Assessment Group (BIFSAG). In particular, the complexity of the stock structuring and movement patterns could not be taken into account explicitly because of uncertainty about the spatial dynamics of snapper stocks. Tagging data from previous studies needed to be collated into a database and analysed so that the available data on the distribution and movement of snapper stocks could be incorporated. Although trawl surveys in Port Phillip Bay indicated annual variations in snapper recruitment, it was uncertain whether Port Phillip Bay was the only source of recruitment. The environmental influence on recruitment was considered to be large, but there was no predictive capacity for estimating year class strength. Also, there was surprisingly little information on the size and age at maturity of snapper to determine whether the legal minimum length was sufficient to allow snapper to spawn before recruitment to the fishery. There was also little information on the critical habitats that sustain snapper and the sources of food in Victorian coastal waters were undescribed.

This project was intended to provide a focus on snapper research to collect the necessary information to determine the movement of snapper between Port Phillip Bay, coastal waters and other states. Analyses of commercial catch and effort data were needed to investigate trends in catch rates. Essential biological data on the size at maturity, reproduction, age structure and growth of eastern and western snapper stocks were needed to determine the life history parameters for assessment models.

Project Objectives

1. Develop models to assess the eastern and western snapper stocks in Victoria and to provide advice on management options through input into management plans.

2. Undertake a statewide tagging program. Re–analyse historic tagging data using recently developed computer programs and prepare a sampling design for recreational snapper tagging for VICTAG.

3. Investigate the relationship between environmental conditions and recruitment.

4. Determine the spawning season and location for snapper in Port Phillip Bay.

Methods

Objective 1. Development of models to assess the snapper stocks

Modelling of fisheries data

The annual trends in standardised commercial catch rates were used to model the abundance of snapper stocks in Victorian waters. Trends in catch per unit effort (CPUE) are often used in fisheries models as an index of stock abundance. However, over time fisheries change and many factors can influence catch rates. These factors need to be identified, measured and taken into account by standardising the CPUE in order to provide a better indicator of stock abundance (Gulland 1983; Pelletier 1998).

For our investigation of the Port Phillip Bay snapper fishery, we considered that the skill of the fisher was the most important element of fishing power as fishing techniques have changed little since 1978. Anecdotal information and seasonal trends in snapper catches indicated that the fishing season was an important factor that may influence vulnerability to capture. The area fished within Port Phillip Bay was also considered to be potentially important because of the variations in substrate, depth, temperature and distance from the Yarra River and entrance to Bass Strait.

In order to develop an index of relative abundance of snapper, commercial long-line catch per unit effort (CPUE) data were standardised by applying generalised linear models (Hilborn and Walters 1992). This modelling involved using CPUE data as a dependent variable and the following independent variables: season and month, fishing area and fisher.

Methods for CPUE standardisation adopted for the snapper long line fishery were based on those developed for the shark longline fishery (Hoey and Scott 1997; Nakano 1997) and dogfish trawl fisheries (Walker *et al.* 1999). The models were developed with the GENMOD procedure which forms part of the statistical package SAS/STAT (Release Version 6.12) (SAS Institute Inc. 1997). The GENMOD procedure fits a generalised linear model to data by maximum likelihood estimation of parameters through an iterative process.

The data set was derived from the catch and effort data that have been reported for each shot by gear type by each fisher in the snapper long-line fishery since 1978. The data were initially explored and outliers were identified from box plots. The subsets of the data were produced to eliminate other likely data errors by only including daily records with snapper catches of less than 1000 kg per shot, shots with less than 800 hooks, and between 100 and 2000 hook lifts. Standardised CPUE was based on a fisher with > 5 years fishing experience using a long-line with 200 hooks during April–May 1999.

Four models were developed for each region with increasing complexity to standardise for the variation in CPUE between: fishers; fishers and months; fishers, month and area; fishers and areas. The months were grouped into October–November, December–January, February–March, April–May. The regions were divided into Port Phillip Bay (9 fishing zones), West coast (west of Port Phillip Bay excluding Westernport Bay; 4 fishing zones) and the East coast (east of Port Phillip Bay excluding Corner Inlet; 2 fishing zones). The goodness of fit of the models was determined from the scaled Pearson Chi square value, and log likelihood. A model was selected for each region based on the goodness of fit to produce a standardised CPUE value for each year in Port Phillip Bay, west and east coast waters.

Biological models

Age and growth

Otoliths were removed from 1400 snapper caught in Port Phillip Bay during research trawl surveys or by the commercial long line fishery and the recreational fishery. Fish were measured and classified as juveniles, males or females. The otoliths were removed, weighed and sectioned. Annual increments were counted and ages estimated assuming a birthdate of 1st January according to Morison *et al*. (1998).

A stochastic growth model developed by Troynikov (1998) was used to determine the age-at-length and growth parameters for male and female snapper from Port Phillip Bay, east and west Victoria. The parameters t_0, K and $L\infty$ of the von Bertalanffy growth model (von Bertalanffy 1938) were estimated by fitting the ageing data using the stochastic FORTRAN model “TGROHY”. Quantiles were estimated for the growth parameter distributions based on the assumption of log normal distributions.

Size at maturity

The size at maturity was estimated from examination of 404 female snapper (20-84 cm FL) sampled from Port Phillip Bay and coastal waters between November 1996 and January 1997. Fish were classified as mature if the gonosomatic index (GSI) exceeded a value of 3.0 and gonads were staged 3 or 4 by macroscopic examination (Table 1). The mean length at 50% maturity (Lm_{50}) was estimated using the following logistic equation (King 1995):

$$P = 1/[1 + \exp(-r \times (L - Lm_{50}))]$$

where P is the fraction of mature females (Stages 3–4), r a constant, L the fork length (cm), and Lm_{50} the length at which 50% of females are mature.

Age at maturity

The age at first maturity was determined from 50 snapper randomly sampled in December 1996 (15.0–65.0 cm FL). Fish were classified as mature if the GSI exceeded a value of 3.0 and gonads were staged 3 or 4 by macroscopic examination. The mean age at 50% maturity (Am_{50}) was estimated using the following logistic equation :

$$P = 1/[1 + exp\,(-r \times (A - Am_{50}))]$$

where P is the fraction of mature females (stages 3–4), r a constant, A is the age in years and Am_{50} the age at which 50% of females are mature.

Fecundity

Female snapper were selected from samples collected during the spawning peak in November and December 1997 and 1998. The maturity stage was assessed macroscopically and the gonad was weighed. Histological sections were prepared from the right ovary and examined to determine the spawning condition from oocyte development. The left ovary was used for measuring and counting eggs for fecundity estimation. From the centre of the left ovary, a small sub-sample (0.5gm) was removed and preserved in Davidson's solution for 1-2 months. Eggs were then transferred to Gilson's solution to assist in the breaking up of connective tissue. To estimate fecundity and egg diameter distribution, 70 samples with stage 3 gonads were chosen from samples collected in Port Phillip Bay during the spawning months (November to March) that covered a broad size distribution. From these samples, 100 eggs were removed and set aside for diameter measurements. The remainder of each sample was washed through a series of sieves. All yolked eggs > 0.5 mm were counted under a binocular microscope.

The size distribution of oocytes was determined by the measurement of 100 whole oocytes using image analysis software (Optimate). The total fecundity, which included all stages of oocytes, was estimated from the count of yolked eggs and the size distribution of all oocytes. The total fecundity estimate was based on the assumption that the oocytes destined to be spawned in a season were identifiable at the beginning of the season (Yamamoto 1956). Under this assumption, the standing stock of advanced oocytes at the beginning of the season may be considered to be equivalent to the annual fecundity for fish that spawn repeatedly during the season (Hunter and Macewicz 1985a; Baelde 1996).

Batch fecundity is the number of eggs produced in a single spawning batch that are identified by a well defined mode in the size frequency of oocytes in the gonads of ripe females. Samples were not used in the analysis if loose, hydrated oocytes were present in the lumen of the ovary (Watson *et al.* 1992) as these fish may have already released some of their eggs. Histological sections of ovaries were examined and only ovaries with hydrated oocytes that showed no sign of previous spawning in that season were used to estimate the batch fecundity. Ovaries with postovulatory follicles or major atresia that suggested recent spawning activity were also excluded from the analysis.

From the 70 fish that were examined, data from only 12 fish were selected for use in the fecundity estimation as these were the only fish about to spawn on the day that they were sampled and showed no signs of previous spawning. The criteria for inclusion in the analysis were GSI values that exceeded 5.0, the presence of hydrated oocytes and the absence of post ovulatory follicles or evidence of atresia. Fish sizes ranged between 50-68cm FL. The count of yolked oocytes > 0.5mm in each sample was used to estimate the batch fecundity. The relative fecundity was obtained by dividing by the fish weight.

$$\textit{Batch fecundity} = N_1 \times W_1 / W_2$$

where N_1 is the number of yolked oocytes > 0.5mm in the subsample, W_1 is the weight of the subsample of gonad tissue (0.5gm), W_2 is the gonad weight.

The total fecundity was estimated from the proportion of yolked oocytes > 0.5mm and oocytes < 0.5mm from the 100 oocytes that were measured.

$$\textit{Total fecundity} = N_1 / N_2 \times 100$$

where N_1 is the number of yolked oocytes > 0.5mm in the subsample (0.5gm), N_2 is the number of yolked oocytes > 0.5mm in the 100 oocytes measured.

Exponential models fitted to the data using the solver program in EXCEL were used to describe the relationships between batch and total fecundity and fork length.

The integrated movement, growth and fisheries model

Hypotheses for snapper movement were based on the results of previous tagging studies (Sanders 1974) and from anecdotal information from commercial fishermen, charter boat operators and anglers. It was believed that juvenile snapper remained on the shallow nursery grounds within Port Phillip Bay for several years and as they matured, a proportion then moved seasonally between Port Phillip Bay and western coastal waters. In order to determine whether the tag recaptures reflected this movement pattern, an integrated snapper tag movement, growth and fisheries model was developed based on a model for school sharks (*Galeorhinus galeus*) (Walker *et al.* 2000; Walker *et al.* in press).

The snapper movement model was designed for estimating movement between Port Phillip Bay and the coastal waters of west Victoria from snapper mark–recapture data collected during 1956–2001. The model estimates the catchability in each region. Growth of the tagged snapper can either be estimated directly from the tagging data or input as von Bertalanffy growth parameters. The model inputs allowed for the three types of tag used at different times. The tag reduction rate (combined natural mortality rate and tag shedding rate) was estimated separately for each type of tag. The model outputs provided estimates of the proportion of small immature snapper (< 30cm FL), medium sized snapper (30–38cm FL), and larger mature snapper (> 38cm FL) moving between regions on an annual basis.

In order to develop the model some assumptions were necessary because of the lack of data. It was assumed that recreational fishing effort was much lower in coastal waters than in Port Phillip Bay. The selectivity of fishing gear was based on the length frequency in the catches and the hook sizes used by the commercial and recreational fisheries. Movement patterns and behaviour were based on three size categories of fish that reflected immature, maturing and mature fish. The following modelling assumptions were made:

i) Fish size

The model used fork length (FL) as a measurement of fish size. Three different movement rates were used for the three size groups. The underlying hypotheses for the different length classes were 1) little or no movement, 2) increasing movement in local areas and 3) movement between regions for small, medium and large snapper.

ii) Sex

The same parameters were used for males and females so it was assumed that male and female fish behaved in the same way.

iii) Commercial fishing effort

Annual commercial effort in Port Phillip Bay (1978–1999) was estimated from the reported catch divided by the standardised CPUE in Port Phillip Bay. Commercial fishing effort was given in thousands of hook lifts. Because of the lack of data from the small coastal fishery, the annual commercial fishing effort for the west coast was estimated from the west coast catch divided by the standardised CPUE data in Port Phillip Bay.

The commercial fishing effort in Port Phillip Bay prior to 1978 was estimated from the historic annual catch data set for Port Phillip Bay divided by the 1978 CPUE. For the years prior to 1978 when catches were reported by financial year, the catch in each calendar year was estimated from the average catch of two consecutive financial years. Snapper catches for the small fishery based outside Port Phillip Bay prior to 1978/79 were estimated from the ratio of the catches outside Port Phillip Bay to the west coast catch in 1983.

iv) Recreational fishing effort

Recreational fishing effort in Port Phillip Bay was based on estimates from the four surveys in 1976/77, 1982/83, 1990-1994 and 1996/97 (Beinssen 1978; MacDonald and Hall 1987; Conron and Coutin 1995a; Coutin *et al*. 1995; Conron and Coutin 1998). These surveys covered the main fishing season for snapper (October–April) and it was assumed that winter fishing effort was 10% of this main fishing season. The recreational fishing effort in 1957/58 was assumed to be half that of 1976/77. The fishing effort was linearly interpolated between these dates, and extrapolated beyond 1996/97. In order to express fishing effort in thousand hook hours, it was assumed that on average anglers used 2 hooks when they were fishing. Recreational fishing effort along the west coast was assumed to be 10% of the recreational fishing effort in Port Phillip Bay. A recreational fishing hook was assumed to be equivalent to one commercial hook lift.

v) Commercial fishing gear selectivity

Commercial fishers use large hooks but the selectivity of these hooks was unknown. So it was assumed that snapper were not vulnerable to commercial fishing hooks until 34cm FL. It was assumed that selectivity increased linearly from 34cm FL to 40cm FL and the fish greater than 40cm were fully selected to commercial fishing gear.

vi) Recreational fishing gear selectivity

Anglers use large hooks and small hooks to catch snapper and the estimates of the relative proportion of effort with each hook type were based on angler diaries and anecdotal information. In Port Phillip Bay, it was estimated that half of the recreational effort used large hooks and half used small hooks. On the west coast, it was estimated that 90% of the recreational effort used small hooks and 10% of the recreational effort used large hooks. It was estimated that there was 100% selection of 25 cm FL to 34cm FL snapper by small hooks, but selectivity decreased linearly to zero at 40 cm FL. The same selectivity curve for large hooks was used for anglers and commercial fishers.

vii) Time steps

The model operates on annual time steps and it was assumed that movement takes place at the start of the time step, then fishing takes place over the remaining time. Other time steps could be used based on fishing season, season or month.

viii) Mortality, tag shedding and tag loss

A single value was assumed for the following confounding factors:

- 'non–reporting of tags by fishers'
- 'non–sighting of tags by fishers' (including 'predation mortality'; 'dropout mortality' and 'dislodgment of tags during recapture' in the fishing gear)
- 'initial tag survival ratio' (including 'initial capture and tag induced mortality'; and 'initial tag shedding').

This was assumed to be the same for all tag types. Natural mortality and tag shedding are also confounded (tag reduction rate). Separate rates were assumed for T–bar, dart and internal tags.

ix) Regions and catchability

The model was based on two regions, Port Phillip Bay and the west coast (west of Port Phillip Bay to Portland). A single value of catchability was used for all size classes in each area.

x) Growth

The von Bertalanffy growth parameters used in the model were ($L\infty$ = 80.39. cm, k=0.108, t_0= -1.05) based on Coutin (1997). The length used in the selectivity calculation is the release length and growth is predicted from these parameters.

Objective 2. Tagging strategies and experimental design

Three strategies were adopted to overcome the practical difficulties of releasing a large number of tagged snapper in different regions of Victoria. The first strategy was to repeat the previous experiments using internal tags with releases of large batches of tagged snapper in Portland Bay, Apollo Bay, Port Phillip Bay and Mallacoota Inlet. These fish were tagged by MAFRI technical staff working with haul seine and Danish seine fishermen and anglers from the Portland Sport Fishing Club. The anglers transferred the fish that they caught into seacages in Portland harbour, and periodically MAFRI staff tagged and released them.

The second strategy was to promote continuous widespread snapper tagging across Victoria through the VICTAG program. VICTAG is a program that coordinates the tagging of fish in Victorian waters by recreational anglers. It was established in 1994 by the Victorian branch of the Australian National Sport Fishing Association (ANSA) to promote fish tagging and release amongst Victorian anglers. At the beginning of the project, the sampling design for VICTAG addressed the need to increase the numbers of tagged snapper being released, to encourage the use of dart tags to improve tag retention, and to extend the tagging locations throughout western and eastern coastal waters. Reporting of tag recaptures was encouraged by establishing a freecall number for VICTAG (1800 677 620) and for MAFRI (1800 652 598). Publicity was also improved with the help of the media so the prizes and rewards ($500) for reporting recaptures were widely advertised.

During the project, anglers and charter boat operators were trained to use tagging equipment and to keep tag release records. The volunteer ANSA tagging coordinator recruited new members, despatched tags and maintained the VICTAG database of tag releases and recaptures. T bar and dart tags were used by anglers to tag and release small (<35cm FL) and undersized snapper (<27cm TL).

A large number of small batches of tagged snapper have been released by VICTAG anglers across Victoria in different months in successive years since 1994. Most of the tagged fish released by VICTAG anglers were in Portland Bay, Port Phillip Bay, and outside Corner Inlet near Port Welshpool (Appendix 3). Some charter boat operators and research logbook anglers also released some tags in specific locations.

The third strategy supplemented the VICTAG program by releases of a small number of large batches of T bar and dart tagged snapper in Port Phillip Bay, Westernport Bay, outside Corner Inlet near Port Welshpool and Mallacoota Inlet. These fish were mostly caught by commercial haul seine or Danish seine fishermen and tagged by MAFRI technical staff.

Number and distribution of tagged fish released

The sampling design required a large number of tags to be released because in previous studies, T bar tag recapture rates were lower than 1%. A target of 10,000 tags over two years was set for four major regions: Port Phillip Bay (2000), Westernport Bay (2000), western Victoria (4000), and eastern Victoria (2000). To ensure a wide distribution of tags released in coastal waters, the western coastal region was further sub–divided into a western zone (WCw) predominantly in Portland Bay and an eastern zone (WCe) between Apollo Bay and Ocean Grove. The eastern coast was also sub–divided into a western zone (ECw) off Port Welshpool and an eastern zone (ECe) predominantly in Mallacoota Inlet. It was anticipated that this number of tag releases would yield between 100–300 tag recaptures over a 5 year period depending on the tag type, movement rates and fishing mortality in each region.

During the first year of the project, visits were made to angling clubs to boost tagging rates in particular areas. These clubs were located in Torquay, Ocean Grove, Williamstown, Horsham, Lakes Entrance and around Westernport Bay. Charter boat operators were encouraged to participate as well as members of MAFRI's angler logbook program. In particular, tags released by charter boat operators from Port Welshpool, Barwon Heads, Altona and Portland made an important contribution.

In order to increase the number of tagged fish being released by anglers, participation in the VICTAG program was broadened by the creation of the VICTAGGERS club to allow other fishing clubs and individuals to participate in the tagging program. Anglers were also encouraged to switch from tagging other species to snapper by distributing snapper tags at no cost and by changing the priority rating for the other species. By the end of the project, the tagging rate by VICTAG anglers had increased more than fivefold and 2600 tagged snapper were released in 2000. Two additional regional tagging coordinators were required to meet the demands for training, liaison with participants, collection of release data and data entry into the VICTAG database.

Size of fish tagged

Large snapper are caught sporadically and are usually kept, so tagging was mostly restricted to small fish less than 30cm FL. Other incentives were introduced to encourage tagging of larger snapper. The ANSA merit point scheme gives recognition to members for tagging fish and a new category for large snapper was created in 2000.

Types of tags

T bar and dart tags were manufactured by Hallprint Pty Ltd in Victor Harbour, South Australia. The T bar tags were TBA 2 anchor tags that measured 5cm in length with 3.5cm of yellow tubing. The inscription printed on the yellow tubing was the tag code and “VICTAG phone 1800 677 620”. The T bar tag code series included A, M, P, W, and TR. The VICTAG series began with T bar tags (A10000-12999) and then continued from A15500 to 28499 and from A29501 onwards.

The dart tags were PDS small dart tags that measured 9.5cm in length with 9cm of yellow tubing. The inscription printed on the yellow tubing was the tag code at both ends and “VICTAG phone 1800 677 620” in the middle. The dart tag code series included A, M, DV and DR. The PDS dart tag series began with A13000-14999, but new codes were introduced to distinguish dart tags from T bar tags and those released by VICTAG (DV) and researchers (DR).

During 1999, anglers were encouraged to switch to dart tags because of the higher recapture rates of this type of tag in Victoria, South Australia and New Zealand. Although batches of tags and tagging equipment were widely distributed, dart tags were not as popular or as convenient for anglers and charter boat operators compared to T bar tagging techniques. Consequently, fewer dart tagged fish were released.

The Nesbit internal tags were made at MAFRI based on the original internal tags that were used previously (Nesbit 1933; Sanders 1974). Prototypes were modified dog registration tags made of white plastic 1.5mm thick, 8mm wide and 2.5cm in length with 10cm of fluorescent green, monofilament fishing line attached. The moulded black inscription was “Reward for date, place, fork length, 1800 652 598”. The tag code was printed on the other side. The prototype Nesbit tag series began with X 0001 and was first trialled in 1998. These were coded as NESx in the database.

Thinner Nesbit tags that were 0.5mm thick and 2.5cm in length were then developed. The width of the tag tapered from 8mm to 6 mm and the end had rounded edges that made insertion of the tag easier. The same inscription was printed in black, rather than moulded, onto the white plastic and 10cm of fluorescent green, monofilament fishing line was attached as an external streamer. The tag code was printed on the other side as a number without a tag series letter, but these have been coded as NES. These thin Nesbit tags were used in 1999 for nearly all the releases of internally tagged snapper.

Attachment of tags

T bar tags were applied using a tagging gun and needle supplied by Hallprint. The tags were inserted into the side of the body through the musculature below the dorsal fin until the anchor lodged between the pterygiophores (Whitelaw and Sainsbury 1986).

Dart tags were applied using a hollow, steel needle supplied by Portland Surgical Products. These were mounted on wooden handles for safety. The tags were inserted anteriorly through the musculature until the dart locked firmly behind a pterygiophore associated with the dorsal fin (Davies and Reid 1982).

Internal tags were placed into the body cavity through a 5mm, vertical incision through the body wall behind the pectoral fin, 5 scales in front and 5 scales above the anus (Vogelbein and Overstreet 1987). To prevent infection the tags and scalpel were disinfected with diluted antiseptic solution. Fish were also injected in the pectoral fin muscle with Terramyacin (oxytetracyclin hydrochloride) a broad spectrum antibiotic. The doseage was calculated from the fish weight, 50 mg/kg (Ferrell *et al.* 1992).

Tag release information

VICTAG anglers were given training in tagging, measuring and recording methods. The date, species, tag code, and fork and total length measurements were recorded for each tag release. The location of tag releases was based on a series of maps with grid references. The VICTAG coordinator compiled monthly tag release data received from VICTAG anglers into an ACCESS database. Every six months, this data was transferred and checked. The latitude and longitude of the release and recapture locations was assigned to the tagging data as it was incorporated into the MAFRI snapper tagging database.

Reporting of tag recaptures

A widespread and continuous publicity campaign was mounted to encourage the reporting of tagged snapper recaptures. Freecall telephone numbers with answering machines were established to record information. Press releases and radio announcements publicised the snapper tagging in Victoria and interstate. Letters and reward posters were sent to commercial fishing cooperatives and organisations, charter boat operators, angling clubs, and tackle shops. There was also publicity at major fishing competitions in Victoria. Monthly tag recapture updates and repeated instructions for reporting tagged fish recaptures were disseminated using the internet, radio, fishing magazines and newsletters. Fishcare volunteers and NRE Fisheries Officers were asked to facilitate reporting of tag recaptures. The DNRE Service Centre that received information requests from the public were provided with responses to frequently asked questions about tagging.

Telephone calls and reports of tag recaptures were generally followed up within 2 days. Records were made of the tag code, tag type, species, date and location of recaptures, fork and total length measurements, method of capture, and contact details. Every effort was made to recover the tag and recaptured fish that were above the legal size in order to verify the tag code and length measurements. If the fish was recovered, the otoliths were removed, the sex determined and samples taken for genetic analysis. The recapture location information was converted to decimal latitude and longitude and allocated an area code. Everyone who reported a tag recapture was sent a letter or certificate, tag recapture information, a poster and a prize (pen, T-shirt, cup, drink holder, or a video) with printed information on snapper tagging rewards, fish measuring, recording and contact telephone numbers.

Development of a snapper tagging database

The historic tagging data consisted of written records and correspondence with those who had recaptured a tagged fish. These were filed according to their tag number and all the available information was gleaned from these records. Fish lengths and weights were converted to metric units and the data were entered into an ACCESS database. The latitude and longitude of releases and recaptures were estimated from the location descriptions in the tagging records. In some cases the original tags were still attached to the correspondence and these were used to verify the tag types. Although most of the tags series began with A and duplication of tag codes occurred, it was found after considerable scrutiny and cross checking various sources of information, that this historic data was still intact. The distance and direction moved were calculated by plotting the release and recapture points in the GIS database and the time at liberty was determined from the dates of release and recapture.

The first attempt at snapper tagging used operculum tags (coded Aop) and occurred in Port Phillip Bay in February 1948 (Appendix 3). Operculum tags and tagging methods are described by Kesteven (1953). This type of tag was used until September 1956. During the 1950s, internal tags (Nesbit 1933) were introduced from the USA by G. Whitley and were used for tagging school sharks (*Galeorhinus galeus*) gummy sharks (*Mustelus antarcticus*), black bream (*Acanthopagrus butcheri*) and snapper (Olsen 1952; M.Olsen pers. comm.). The first snapper tagging with these internal tags (coded X) began in January 1957 and continued until March 1962. Snapper tagging resumed in October 1971 and continued until November 1974. During this period, T bar tags (coded T) and internal tags (coded ZAI) were used to tag small and large fish in Port Phillip Bay. Hallprint dart tags (coded MT) were not introduced until January 1994 and were used to tag large fish while T bar tags were used to tag small fish in Port Phillip Bay.

Database manual and description

A manual was prepared that describes the database and provides instructions for data entry. The software used for this database was upgraded from Microsoft Access Verion 2.0 to Access97 and was given a file name “snap99.mdb” on the MAFRI network. The database has a data entry screen where the user specifies the species, call sign, shot number, relase or recapture data. A series of call signs were used to specify the tagging region and year of tagging. For example, PPB97v contains the VICTAG data for tags released in Port Phillip Bay during 1997. The shot number (1-12) identifies the month that the tags were released.

The menu driven tag release screen provides fields for the following data inputs : map and area codes, location descriptions, decimal latitude and longitude, fishing method, tag series (eg A, DR), tag number (eg 10000), tag type (options Tbar, Dart Internal), date of release (format dd/mm/yyyy), Weight, fork length, total length, comment, double tag code and tag type. For tags that were re-released after recapture, the tag series was changed by adding a 2 or 3 for second and third releases (eg from A to A2), but the tag number remained the same (eg 10000).

Similarly, the tag recapture data was linked to the tag release data by the callsign and the shot number. The tag recapture screen shows the tag release details and provides fields for the following data inputs: Name and contact details of the person reporting the recapture, date of the recapture, location description and map code, decimal latitude and longitude, fork length, total length, sex, weight, condition, and comment.

Tag data analysis

The tag release and recapture data was summarised for each tag type to show the recapture rates and movement of small, medium and large snapper released in Port Phillip Bay and eastern and western coastal waters with time at liberty. The ACCESS database allows rapid sorting and selection of tag data with data export capabilities for analyses in EXCEL, mapping in ARCview GIS software, or modelling in AD Model Builder (Fournier 1996). ARCview and EXCEL were used to calculate the distance and direction moved, time at liberty, and growth of tagged fish. Maps showing tag movements were prepared using ARCview GIS software. The tagging data was exported from the database and used to develop the movement model.

Tag retention experiments

Information on tag retention rates was needed to plan tagging experiments and to compare the results of tagging studies using different types of tagging methods. Interpretation of previous tagging studies depends greatly on the level of initial tagging mortality and tag shedding. For internal tagging methods, mortality estimates are particularly important because the technique is more invasive and higher mortality might be expected. For external tagging methods, tag retention is important because a proportion of T bar and dart tags become detached over an extended period as the fish grows and swims through its environment. These experiments were intended to demonstrate the most appropriate tagging methods for snapper and to confirm the results of previous studies that showed internally tagged snapper survive for long periods.

Small snapper ranging in size between 20–32cm in fork length were caught with a commercial haul seine in Corio Bay on 5th November 1998 and transferred alive to the aquarium facilities at MAFRI in Queenscliff. In experiment 1 and 2, there were 40 tagged fish (mean size 22.2 cm fork length) and 20 untagged fish released into a seacage in Queenscliff harbour. The tagged fish were injected with tetracycline. There were 20 fish with prototype internal tags, 10 with dart tags (PDS), and 10 with T bar tags (TBA).

Initially there were problems with tidal flows and cormorant predation of fish in the seacage. Consequently, the fish were transferred to on–site tanks on 9/12/98 after 34 days and treated with formalin solution on 20/12/98 to overcome fungal infection. The fish were counted, measured and injected again with tetracycline on 8/3/00 after 84 days while the tanks were cleaned. Experiment 1 was monitored for 1281 days and concluded on 9th May 2002. Experiment 2 was monitored for 464 days and concluded on 12th February 2000. During the experiments, dead fish were removed, measured, dissected and tag codes recorded.

These experiments were repeated with a larger number of fish during 1999, but these were transferred directly into on–site tanks. Small snapper ranging in size between 14.2–23.2cm in fork length were caught with a commercial haul seine in Corio Bay on 6th April 1999. All fish were measured and injected with tetracycline before tagging. Experiment 3, involved 104 fish (mean size 16.9 cm fork length) including 78 tagged and 26 untagged fish. There were 26 fish with internal tags, 26 with dart tags (PDS), and 26 with T bar tags (TBA). Experiment 4, involved 105 fish (mean size 16.7 cm fork length) including 79 tagged and 26 untagged fish. There were 27 fish with internal tags, 26 with dart tags (PDS), and 26 with T bar tags (TBA). The fish were counted, measured and injected again with tetracycline on 8/3/00 after 84 days while the tanks were cleaned. Experiment 3 was monitored for 1129 days and concluded on 9th May 2002. Experiment 4 was monitored for 312 days and concluded on 12th February 2000. During the experiments, dead fish were removed, measured, dissected and tag codes recorded.

Tag shedding models were derived from the data collected using linear regression. The LINEST procedure in EXCEL was used. For each tag type, the natural log of the number of fish alive with tags retained was plotted against the number of days since tagging (*t*). Data from all experiments were used for internal and T bar tags and data from experiment 3 was used for dart tags. For each tag type, the number of tagged fish alive was modelled using a linear regression drived from Gulland (1983):

$$Ln\ (N_t) = Ln\ (N_0) + bt$$

where Nt is the number of tagged fish alive at time t, N_0 is the number of tagged fish at the start, b is the combined tag shedding and natural mortality, and t is the number of days since tagging. The value of b was estimated from the slope of the regression and incorporates both mortality and tag shedding rate.

Objective 3. Environment–recruitment models

Recruitment estimation from Port Phillip Bay trawl survey data

Trawl survey data, collected as a part of an ecological survey of the distribution and abundance of fish (Parry *et al.* 1995), were used to estimate the abundance of pre-recruit snapper in Port Phillip Bay in March between 1990–1997 and 1999-2000. Snapper were sampled with a wing trawl net (47 m long, 13 m wing spread, 5 m opening height and 45 m between trawl doors with a 44 mm codend liner). There were 22 depth-stratified sampling stations located on 6 transects perpendicular to the coastline around Port Phillip Bay (Figure 1).

Two trawl tows were taken at depths of 7, 12, 17 and 22 m on all transects except those in Corio Bay near Geelong where depths permitted trawling only at 7 and 12 m. Trawling speed was approximately 4 knots. The duration of each tow was 5 minutes, measured from the time the clamps were attached until the winch commenced the retrieval of the net (Parry *et al.* 1995). The latitude and longitude of the start and finish locations were recorded on each occasion and used to estimate the distance trawled. During a tow, the average area swept by the trawl net between the wings was about 6435 m^2 and between the doors was 29500 m^2. The snapper density estimate was based on the assumption that 100% of the fish were retained by the trawl in the area swept between the wings.

The number and weight of all species of fish were recorded. Generally, all snapper were weighed and lengths measured. From shots containing large quantities of snapper, the catch was weighed and a random sample of 100 were weighed and measured for length frequency distributions. A random sub-sample of 50 snapper was returned to the laboratory for processing from shots containing large quantities of snapper. Otoliths were removed and fish ages were determined from sectioned otoliths as described by Morison *et al.* (1998).

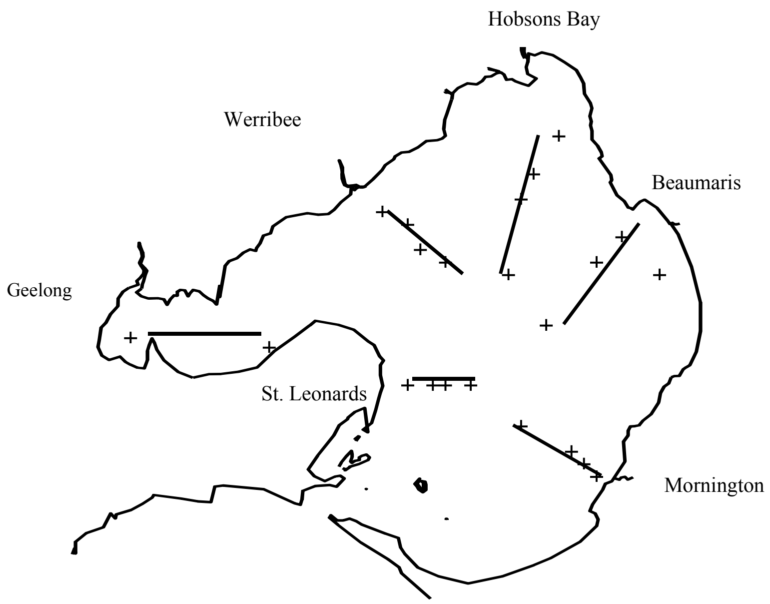


Figure 1. The locations of the 22 trawl stations in Port Phillip Bay along each transect at depths of 7m, 12m, 17m and 22m (Parry *et al.* 1995).

A weighted length-frequency distribution for snapper in the Port Phillip Bay survey area was estimated using the following method modified from Francis (1993). The length-frequency distribution of snapper using 0.5 cm class intervals was recorded for each tow. When the total catch was not measured, length frequencies were adjusted to represent the total catch. The abundance of snapper in Port Phillip Bay was estimated from the trawl surveys in five steps:

i) Snapper density for each length class per m^2 by tow

For each tow, the number of snapper in each length class was calculated from the sample weight. The number of snapper in each length class per m^2 from each tow was calculated by dividing the number of snapper in each length class by the area swept (13m between the wings of the net and the distance towed).

The total number of fish (D_{jkl}) per length class j per shot k in each depth strata l per unit area fished (m^2) was calculated by:

$$D_{jkl} = N_{jkl} / a \qquad (1)$$

where N_{jkl} is number of fish at length class j at the k th shot in the l th depth strata (7m, 12m, 17m, 22m) and a is the area fished (distance towed multiplied by the door spread in m^2).

ii) Average snapper density for each length class per m^2 in each depth strata

For each depth strata in Port Phillip Bay, the average snapper density per length class per m^2 (AV_{jl}) was calculated by summing the number of snapper caught in each length class for all tows and dividing by the number of tows made in each depth strata. The average density per m^2 per length class j in each depth strata l was calculated by:

$$AV_{jl} = \sum D_{jkl} / n \quad (2)$$

where AV_{jl} is the average snapper density per length class per m^2 and n is the number of tows in each depth strata.

iii) Average abundance of snapper for each length class in each depth strata

The average abundance of snapper for each length class per m^2 (AV_{jl}) by depth strata was multiplied by the area of each depth strata in Port Phillip Bay. The total number of fish (T_{jl}) for each length class j by depth strata l was calculated by:

$$T_{jl} = AV_{jl} \text{ x } SA_l \quad (3)$$

where SA_l = area in depth strata l. The areas for the 7m, 12m, 17m, 22m shots were estimated for depths 0-9m, 9.1-15.0m, 15.1-20.0m, and > 20m.

iv) Total snapper density in Port Phillip Bay

The total density of snapper in Port Phillip Bay (T_{PPB}) was estimated by adding together the estimates for each each length class j in each depth strata.

$$T_{PPB} = \sum T_{jl} \quad (4)$$

v) Estimation of the abundance of 1 year old snapper in Port Phillip Bay

The age-length keys determined from age reading of sectioned otoliths were applied to the length-frequency distribution and the same methods repeated to calculate the abundance of 0+, 1+ and 2+ snapper in Port Phillip Bay. Snapper were assigned to an age class based on the estimated number of annual increments. The year class was then calculated as the year of sampling minus the age of the fish.

The 0+ age class was absent from the 1992, 1997 and 1999 surveys. However the 1992 year class was present as 1+ year olds in 1993. In the 1999 survey, the 1997 year class was observed as 2+ and the 1998 year class was observed as 1+ year olds. The calculated number of 1+ snapper was used as an estimate of year class strength as this age class was represented most consistently in the samples. The relative year class strength of 1+ snapper from the trawl surveys was calculated as the ratio of the estimated numbers in each year class to the estimated numbers of the largest year class (1996). These steps were carried out separately for all trawl surveys between 1995 to 2000 under the assumption that the vulnerability, distribution by depth and area of 1+ snapper are constant in all the surveys.

Relationship between snapper recruitment and environmental conditions.

Correlation coefficients and linear regression models were used to determine the relationship between the abundance of 1+ snapper (log transformed) for each year and the mean monthly values for environmental variables. Environmental data were analysed from each of the 15 months between September prior to spawning to December at the end of the 0+ year. The Pearson product moment correlation coefficient (R) is a dimensionless index that ranges from –1.0 to 1.0 reflected the extent of a linear relationship between two datasets. The R^2 value was interpreted as the proportion of the variance in the year class strength of snapper attributable to each environmental variable.

The following environmental data sets were compiled and used to develop the environment-recruitment models. Monthly sea surface temperature, fortnightly river flow, salinity and chlorophyll *a* from Wooley Reef near Frankston have been recorded during the 1990s (Longmore *et al.* 1996; and unpublished data). Monthly means of sea surface temperature were also calculated from data collected at the St. Kilda pier and the West Channel pile near Indented Heads (Longmore pers. comm.). Monthly rainfall for Queenscliff was obtained from the Bureau of Meteorology. Information on the total monthly river discharge in megalitres (ML) from the Maribyrnong River (site 230237 at Jacksons Creek Junction) and the Yarra River (site 229143 at Kew, Chandler Highway) was provided by Melbourne Water. Fortnightly river flow that included the discharge of non-guaged flow was estimated from the monthly data by multiplying by a factor of 0.7 (Sokolov 1996). Monthly values of the Southern Oscillation Index (SOI) were obtained from the website of Queensland's Department of Primary Industry.

Year class strength estimation from the age of snapper in commercial catches

Snapper recruitment was also calculated from the abundance of different year classes in commercial catches from Port Phillip Bay. The length frequency distributions of snapper sampled from commercial catches between 1994 to 1998 were converted to age frequencies using age-length keys based on the interpretation of sectioned otoliths (Coutin 2000). Year class strength (YCS) was calculated as the average percentage contribution of each year class to the commercial catch over three years. Only year classes from 1979 to 1994 were included because they were represented in at least 3 of the 5 years (1994–1998). The relative YCS was calculated as a ratio of year class strength in each year to the average from all year classes from 1979 to 1994.

Relationship between snapper year class strength and environmental variables.

Correlation coefficients and linear regressions were calculated between the relative year class strength (log transformed) of snapper in commercial catches and monthly and seasonal environmental variables for the spawning months and during the 0+ year. Environmental variables included air temperature and rainfall at Queenscliff, average fortnightly discharge from the Maribyrnong and Yarra rivers and the Southern Oscillation Index (SOI). In order to identify which age or part of the life cycle that was being affected by environmental conditions, commercial snapper catches in Port Phillip Bay were plotted against the number of days of zonal westerly winds (Harris *et al.* 1988). Because snapper in the commercial catch mostly consists of large, old fish that are 5-15 years old, the wind data was lagged by 0-10 years.

Year classes were classified as strong or weak according to their abundance in commercial catches. Only year classes from 1979 to 1994 were included in the analyses as these were represented in at least 3 of the 5 years. Year class strength (YCS) was calculated as the average percentage contribution of each year class to the commercial catch over three years when that year class was represented. The relative year class strength was calculated as the ratio of each year class to the average year class strength from 1979 to 1994. Relative year class strength was log transformed to reduce the variation. Correlation coefficients were calculated between the relative year class strength (log transformed) and monthly and seasonal variables for the spawning months and during the 0+ year.

Objective 4. Spawning season and location

Ichthyoplankton sampling

The distribution of snapper larvae in Port Phillip Bay provided an indication of snapper spawning locations. Ichthyoplankton were sampled on nine occasions at eight locations in northern Port Phillip Bay and two locations in southern Port Phillip Bay. Surface temperatures and salinities were recorded on each sampling occasion. Samples were collected fortnightly during daytime between December 1997 and April 1998 with two 1.5 m long, 0.6 m diameter (300 µm and 500µm mesh) plankton nets. In Port Phillip Bay, the net was hauled obliquely from the bottom to the surface while being towed for fifteen minutes behind the boat. Samples were fixed in 5% formaldehyde and later preserved in 70% ethanol. Snapper larvae were sorted and counted and identified based on Neira *et al*. (1998).

Daily age estimation

Spawning dates of 0+ snapper sampled during the trawl survey in March 1998 were estimated by counting daily increments using the methods described by Francis *et al.* (1992a). Counts of the daily increments on either side of the metamorphic mark were added together to provide estimates of the age and spawning dates for 53 snapper.

Seasonal trends in GSI

The seasonal trends in the reproductive development of snapper were determined by taking monthly samples of snapper from Port Phillip Bay and eastern and western coastal regions of Victoria. In Port Phillip Bay, samples were taken from the commercial long line catches, and also from anglers’ catches during fishing competitions. Water temperatures in Port Phillip Bay at West Channel Pile near Indented Head during the study period were recorded (Longmore pers. comm.) and the mean monthly values calculated. In eastern Victoria, samples were taken from anglers’ catches in coastal waters near Lakes Entrance and when charter boats returned to Port Welshpool after fishing outside Corner Inlet. In western Victoria, samples were taken from the catches of commercial trap and Danish seine fishermen in coastal waters near Apollo Bay and also from anglers’ catches during fishing competitions at Portland.

A total of 1175 snapper (18.5–84.0 cm FL) were collected between October 1997 to April 1999 for analysis of their reproductive condition. Following capture, fish were stored on ice and examined immediately at the place of landing or returned to the laboratory for examination. For each sample, the date, region, port of landing and gear type was recorded. Each fish was measured to the nearest 0.1 cm fork length (FL) and total length (TL), weighed to the nearest 1.0 g and the sex recorded as either male, female or indeterminate. Otoliths were dissected, sectioned and the age estimated. Gonads were removed and weighed to the nearest 0.1 g (wet). Following macroscopic examination, the gonads were classified into the four stages of maturation based on Crossland (1977b) and described in Table 1. The monthly mean gonosomatic index (GSI) was calculated for both sexes using the equation given by King (1995):

$$GSI = \frac{\text{Gonad weight (g)} \times 100}{\text{Whole fish weight (g)}}$$

Table 1. Macroscopic maturation stages of snapper gonads

Maturation Stage	Macroscopic description: Female Ovary	Macroscopic description: Male Testis
Stage 1. Resting	The ovaries were small, pink and firm. Individual eggs were not visible or distinct.	The testes were small, white and undeveloped.
Stage 2. Developing	The ovaries were enlarged**,** pale pink or occasionally orange. The developing eggs were larger and individually distinct.	The testes were enlarged, firm, white but no milt was discharged with abdominal pressure.
Stage 3. Ripe	The ovaries were enlarged with a speckled appearance. The ripe eggs were clear.	The testes were enlarged with scalloped edges and milt was easily discharged with abdominal pressure.
Stage 4. Spent	The ovaries were flaccid with only a few eggs and similar to Stage 2, but darker in colour.	The testes were blotched pink or red rather than white and similar to Stage 2, but were flaccid rather than firm.

(Modified from Crossland 1977b)

Histological preparation and measurement of oocytes

Gonads were preserved in 10% formalin in seawater for 2–3 months and a 30 gm transverse, medial, sub–sample of the right gonad was taken and then transferred into Davidsons solution for 1 month (Bell *et al.* 1992). A transverse section from each sub–sample was then embedded in paraffin wax. These were sliced into 6 µm, sections, mounted on slides and stained with haematoxylin and eosin for histological examination (Luna 1968; Crossland 1977b).

All cells on each slide were examined under a microscope and classified according to the criteria shown in Table 2. The size of the most advanced stage of oocyte development, regardless of their abundance, was also used to identify the development stage (Wallace *et al.* 1987; Davis and West 1993; Baelde 1996). Particular care was taken to search for post ovulatory follicles (POF).

Oocyte size was measured by taking the mean of the maximum and minimum diameter of the largest oocytes, which had been sectioned through the nucleus. However, in some cases, ripe ovaries with hydrated oocytes made sectioning of ovarian tissue difficult and the oocytes occasionally collapsed during histological processing. Measurements were based on the best examples of hydrated oocytes that could be found. Relationships between oocyte development, ova size and reproductive development were established.

Table 2. Histological description of the oocytes of female snapper

Oocyte development	Diameter (μm)	Histological description
Chromatin nucleolar oocytes	10-12	Unyolked. Oocytes are very small oocytes and the nucleus is surrounded by a thin layer of dark blue stained cytoplasm.
Perinucleolar oocytes	20-100	Unyolked. Slightly larger oocytes with a thickened, dark blue stained cytoplasm. Nucleoli appear at the periphery of the nucleus.
Cortical alveoli oocytes	100-200	Partially yolked. Cortical alveoli are present in the pale blue stained cytoplasm. Pink stained zona radiata and oil vesicles are distinguishable. Lampbrush chromosomes are often visible in the nucleus.
Yolked oocytes	190-460	Advanced yolked. Oocytes are much larger and the cytoplasm is filled with pink stained yolk granules. Cortical alveoli and oil vesicles are increased in size and number.
Nuclear migrated ooyctes	410-700	Migratory nucleus. The nucleus is located at the periphery of the oocyte. Yolk granules become fused into yolk plates. Oil vesicles become fused into larger oil droplets.
Hydrated ooyctes	500-750	Hydrated. A further increase in the size of oocytes. All yolk granules are fused into a few large yolk plates.
Postovulatory follicles		POF. Empty follicles are large, highly convoluted with an obvious lumen and may contain fine granular material. The layered nature of thecal and granulosa cell types remain intact.
Atresic oocyte		Atresia. Zona radiata dissolves, oocyte shape loses integrity. Yolk globules are disintegrating and are less regular in shape.

Modified from (Crossland 1977b; Hunter and Macewicz 1985b; Matsuyama *et al*. 1988)

Sampling of gut contents

The stomach contents of snapper sampled from Port Phillip Bay and coastal waters for growth and reproductive studies were also examined to determine their diet and feeding habits. The gut contents were examined from fish sampled along the west coast (n =118) and the east coast of Victoria (n = 88) and Port Phillip Bay (n = 115). The fish were caught between March and August 1998 by commercial fishers and charter boat operators. The location of capture, habitat and fishing method were recorded for all samples. The fork length (FL cm), total weight (kg) and sex were recorded for each fish before the stomachs were removed and stored in 10% formaldehyde. In Port Phillip Bay, 33 snapper were sampled by long–line, and 83 were collected from haul seine catches. From the east coast, 97 and 21 snapper were sampled from the catches of charter boats and trawlers, respectively. The west coast samples consisted of 18, 62 and 12 snapper sampled with hook and line, baited traps and commercial trawlers, respectively.

Stomachs were assigned a proportion of fullness from 0.0 to 1.0 and the contents were identified to class and order level for most food categories and to species level for some bivalves. Prey categories were recorded as present or absent and the volume of each prey type was measured by displacement of water in graduated cylinders (Coleman and Mobley 1984). The number of stomachs containing a particular food type was recorded and then expressed as a percentage of the total number of stomachs examined containing food. To compare the results with other surveys, all molluscs were combined in one group. For further analysis, the Mollusca were divided into Bivalvia and Cephalopoda.

General linear models (GLM) were used to determine the effects on the log (x+1) transformed volume of each food group of zone (Port Phillip Bay, east and west coast), length, habitat (reef and sand, rocky reefs, rubbly sand, sand and seagrass), and season (autumn and winter). In order to determine the effects of fish length classes, lengths were divided into four groups; <30 cm, 30–40 cm, 40–50 cm and >50 cm FL, and length was included as a class variable in a second GLM. Season was omitted from this second GLM as it was not found to have a significant effect on the volumes of any food group. Tukey tests were used to determine the source of difference with respect to volume consumed (Neter *et al.* 1990).

Results

Commercial fisheries data analyses

Annual trends in the commercial snapper catch, effort and unstandardised catch rate since 1979/80 are shown in Figure 2. Although catch rates have changed little over the last two decades, commercial catches have dropped as fishing effort has declined more than four fold since 1979/80 from 3000 to 650 fishing days.

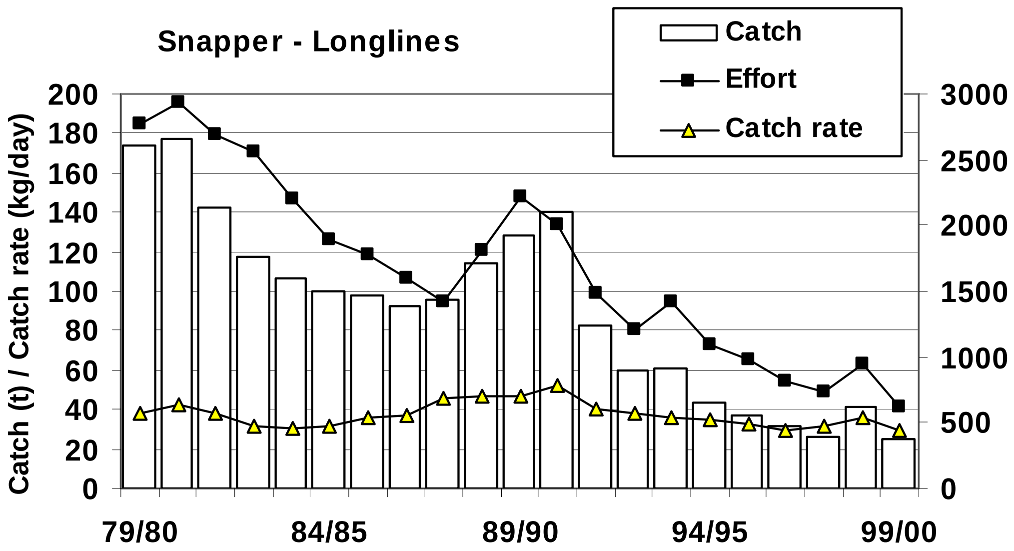


Figure 2. Catch, effort and unstandardised catch rate data for snapper caught by longline in Port Phillip Bay between 1979/80 and 1999/00

Models of standardised CPUE for Port Phillip Bay, west coast and east coast are shown in Figure 3, Figure 4 and Figure 5. The following models converged and produced standardised CPUE trends based on the scaled Pearson value. Goodness of fit was indicated by a scaled Pearson value close to 1.0.

Western stock assessment

There is little evidence of a decline in the snapper stocks from the standardised CPUE trends in Port Phillip Bay and the West Coast. Although the increasing trend in CPUE from the West Coast suggests that the stock abundance may have increased since reaching its lowest level between 1989-1990.

Eastern stock assessment

Since 1990, there appears to have been a decline in the snapper stocks from the standardised CPUE trends on the East Coast reaching low levels between 1994-1997. Higher CPUE values during 1998 and 1999 suggest some recent improvement in the stock abundance.

Port Phillip Bay standardised CPUE models

The four models given in Table 3 and shown in Figure 3 are based on 26435 records of CPUE (kg/hook lift) from 76 fishers over 22 years (1978–1999). There was no difference between the four models of the standardised CPUE in Port Phillip Bay. There was annual variation in the standardised CPUE but there was no distinct trend in the time series for the Port Phillip Bay data set. However, the greatest annual variation occurred during the 1990s and the lowest values of standardised CPUE were obtained between 1989 and 1997. For each model, the degrees of freedom (DF), log likelihood values and the scaled Pearson divided by the degrees of freedom are given.

Table 3. Standardised CPUE models for the commercial snapper fishery in Port Phillip Bay.

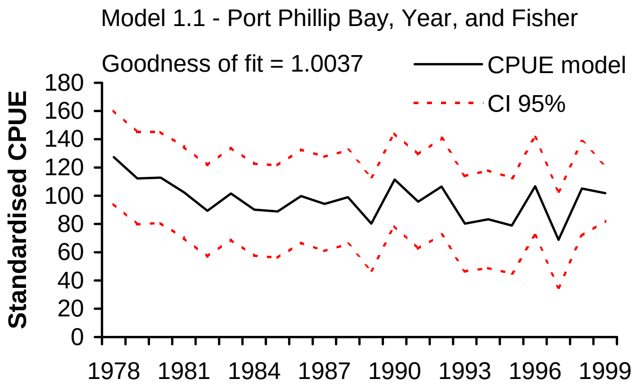
No	Area	Variables	DF	Log likelihood	Scaled Pearson x 2/DF
1.1	Port Phillip Bay	Year and fisher	26338	–163751	1.0037
1.2	Port Phillip Bay	Year, fisher, month	26334	–163462	1.0038
1.3	Port Phillip Bay	Year, fisher, month, area	26331	–163411	1.0041
1.4	Port Phillip Bay	Year, fisher, area	26329	–163666	1.0040

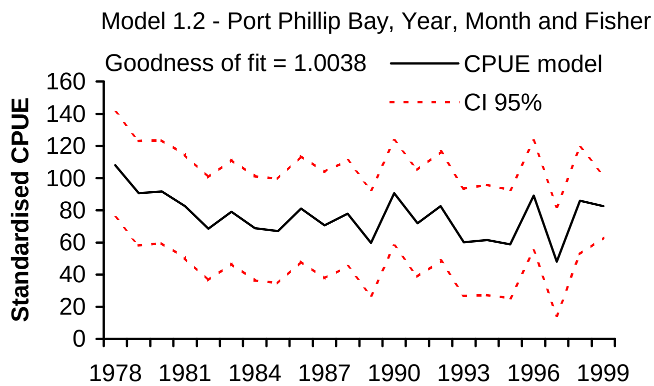
West coast standardised CPUE models

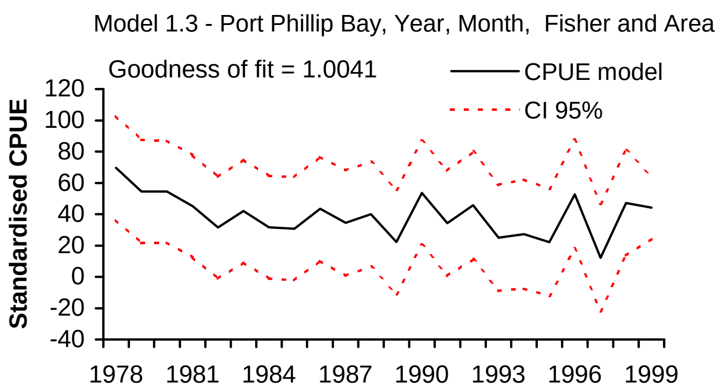
The four models were derived from 536 records of CPUE (kg/hook lift) from 7 fishers over 17 years (1983–1999). There was no difference between the four models (Table 4 and Figure 4). There was a decreasing trend in the standardised CPUE between 1983–1989, followed by an increasing trend between 1990–1999. However, the 95% confidence intervals are wide, particularly in 1993. The lowest and highest values for standardised CPUE occurred in 1990 and 1997, respectively. For each model, the degrees of freedom (DF), log likelihood values and the scaled Pearson divided by the degrees of freedom are given.

Table 4. Standardised CPUE models for the commercial snapper fishery in the west coast of Victoria

No	Area	Variables	DF	Log likelihood	Scaled Pearson x 2/DF
2.1	West coast	Year and fisher	513	–3183	1.0448
2.2	West coast	Year, fisher, month	510	–3168	1.0510
2.3	West coast	Year, fisher, month, area	508	–3166	1.0551
2.4	West coast	Year, fisher, area	511	–3181	1.0489







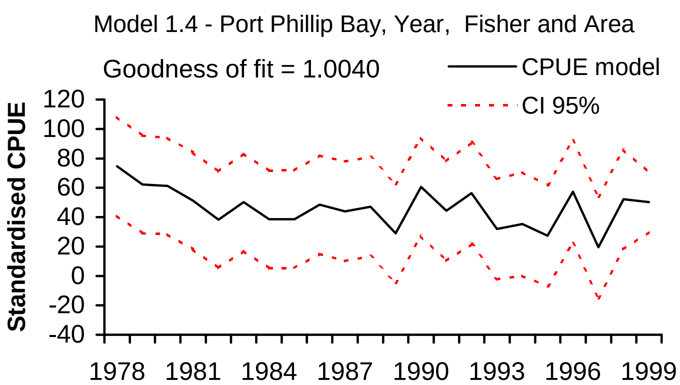


Figure 3. Standardised CPUE models for Port Phillip Bay

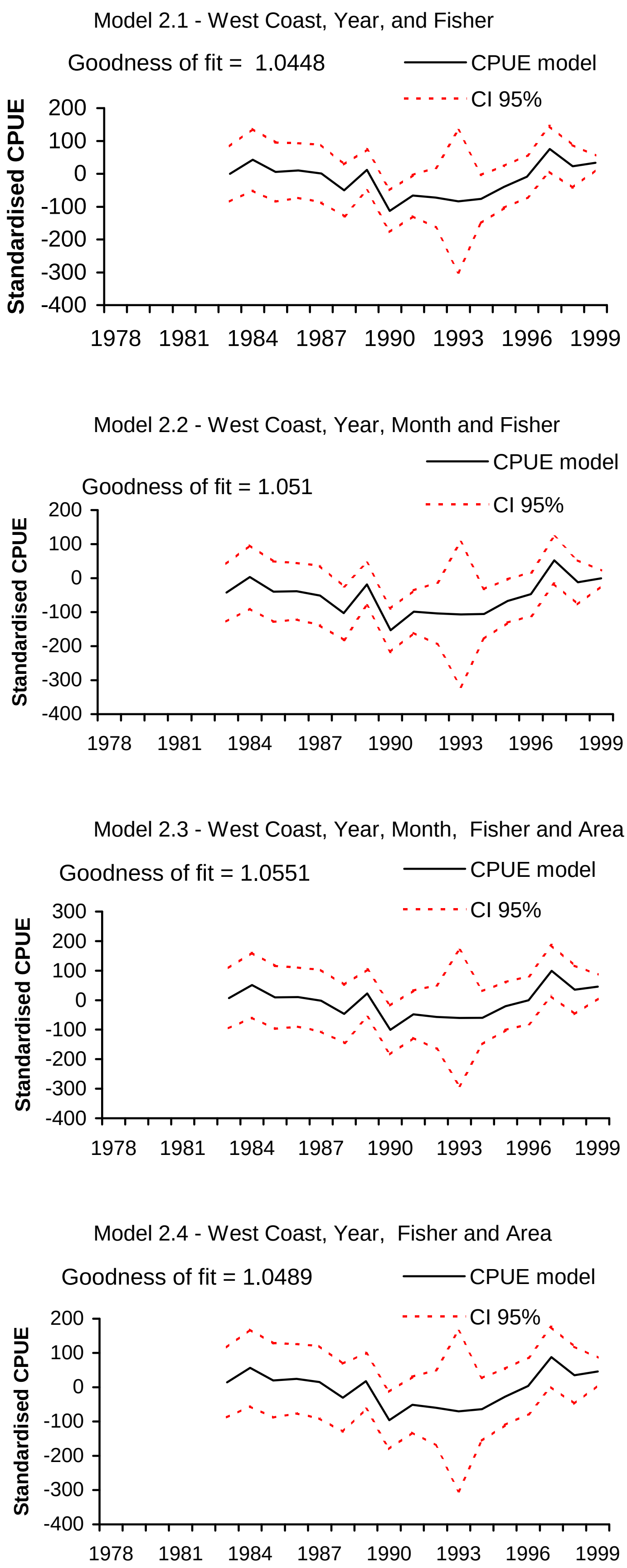


Figure 4. Standardised CPUE models for the west coast of Victoria

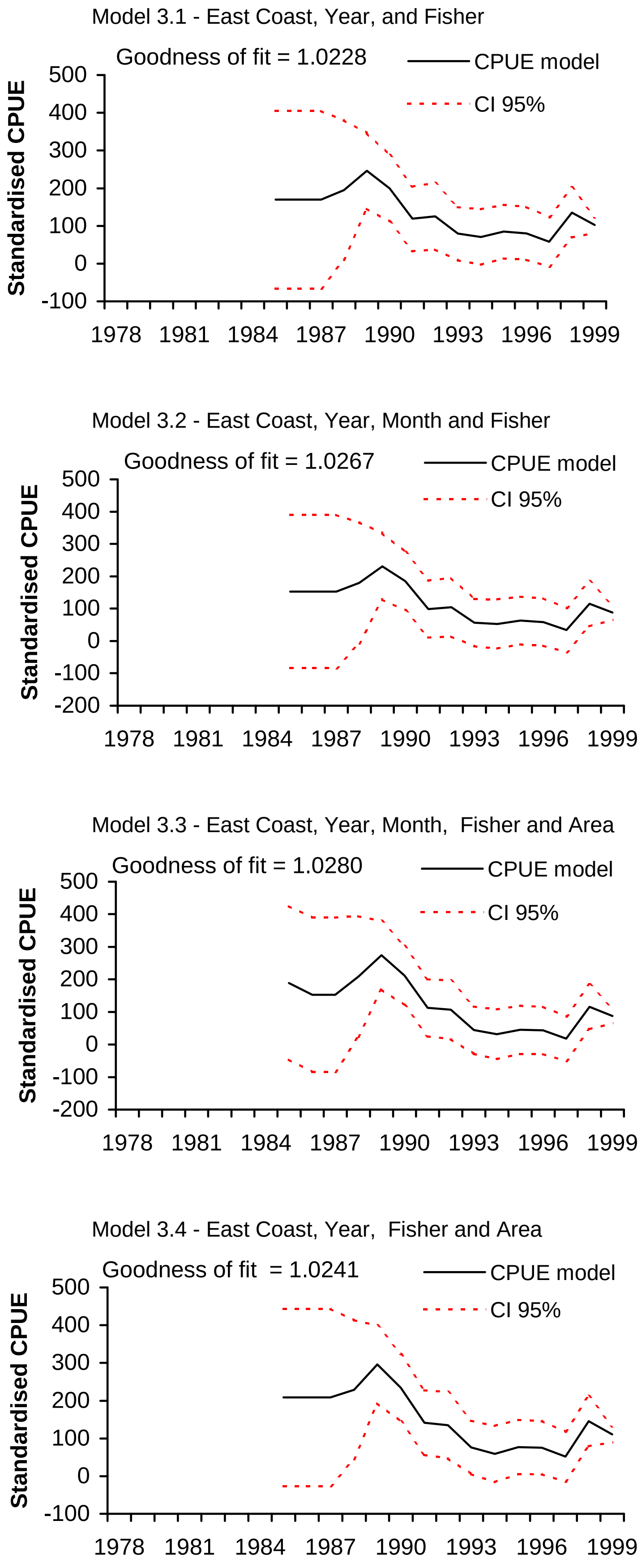


Figure 5. Standardised CPUE models for the east coast of Victoria.

East coast standardised CPUE models

The four models shown were derived from 808 records of CPUE (kg/hook lift) from 6 fishers over 13 years (1985, 1988–1999). There was no difference between the four models (Table 5 and Figure 5). There was a decreasing trend in the standardised CPUE in eastern Victoria between 1989 and 1997 followed by a recent increase in the last two years. The trends prior to 1989, are uncertain as there are few data and 95% confidence intervals are large. A period of high standardised CPUE occurred between 1988–1990 and the lowest standardised cpue occurred between 1994–1997. For each model, the degrees of freedom (DF), log likelihood values and scale Pearson divided by the degrees of freedom are given.

Table 5. Standardised CPUE models for the commercial snapper fishery in the east coast of Victoria

No	Area	Variables	DF	Log likelihood	Scaled Pearson x 2/DF
3.1	East coast	Year and fisher	790	–5181	1.0228
3.2	East coast	Year, fisher, month	787	–5174	1.0267
3.3	East coast	Year, fisher, month, area	786	–5165	1.028
3.4	East coast	Year, fisher, area	789	–5172	1.0241

Analyses and modelling of biological data

Length weight relationship

The relationship between the whole weight and fork length for female, male and all sexes combined are given below in Table 6 and Figure 6.

Table 6. Length weight relationships for snapper. Weight = a x FL ^{b}

Sex	n	a	b	R^2
All	1756	0.00004583	2.788	0.9896
Female	873	0.00004463	2.795	0.9892
Male	883	0.00004713	2.780	0.990

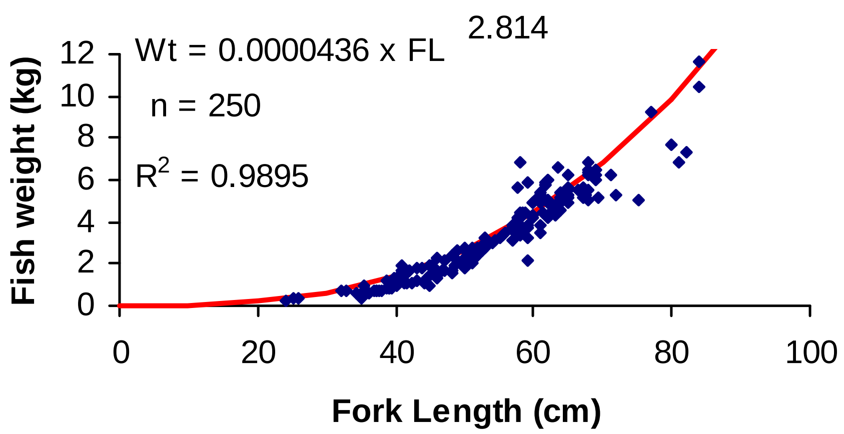
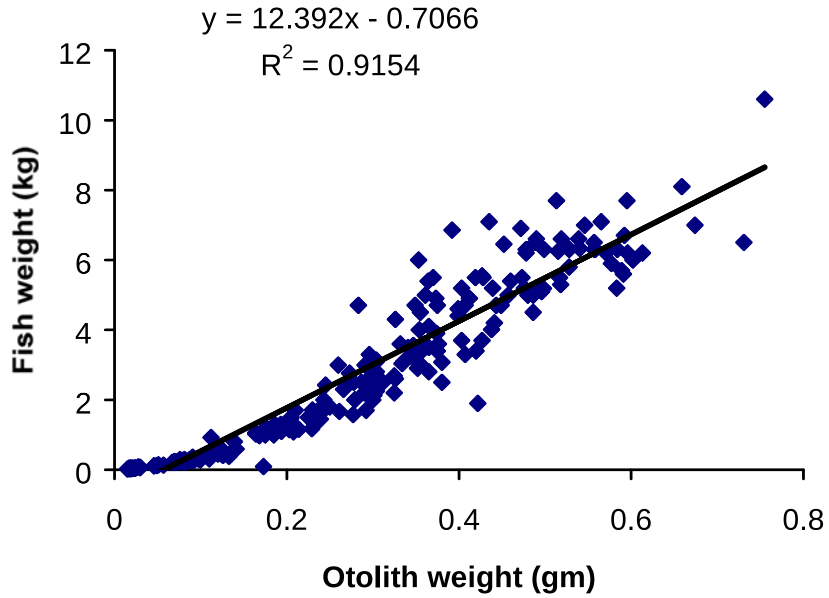


Figure 6. Fork length and weight relationship of snapper in Port Phillip Bay

Growth models

The mean length-at-age for snapper from Port Phillip Bay, east Victoria and west Victoria are given in Table 7, Table 8, and Table 9. Relationships between fish length, fish weight, age and otolith weight are given in Figure 7. The growth models for all sexes, males and females are shown in Figure 8. The predicted length frequency distributions of 1-12 year old snapper for all sexes, males and females are shown in Figure 9.

a) Otolith weight and fish weight



b) Otolith weight and age

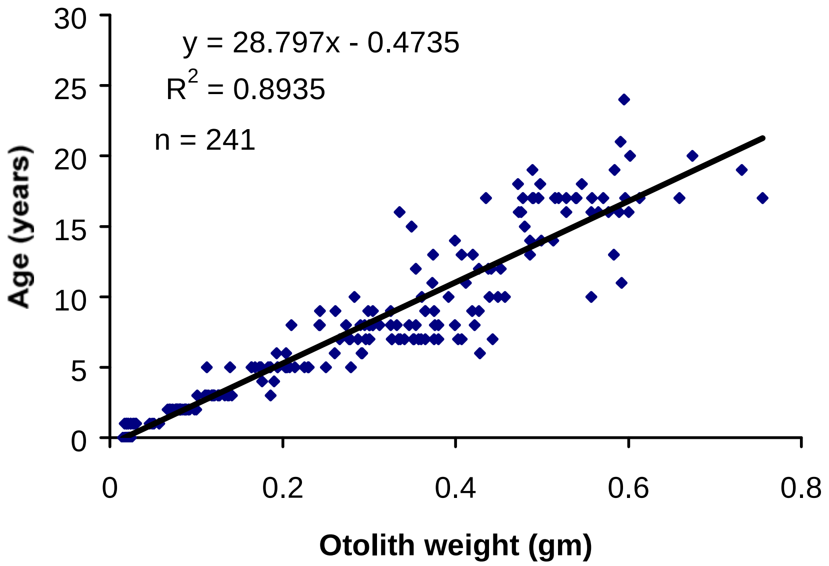


Figure 7. Relationships between otolith weight, fish weight and age for snapper

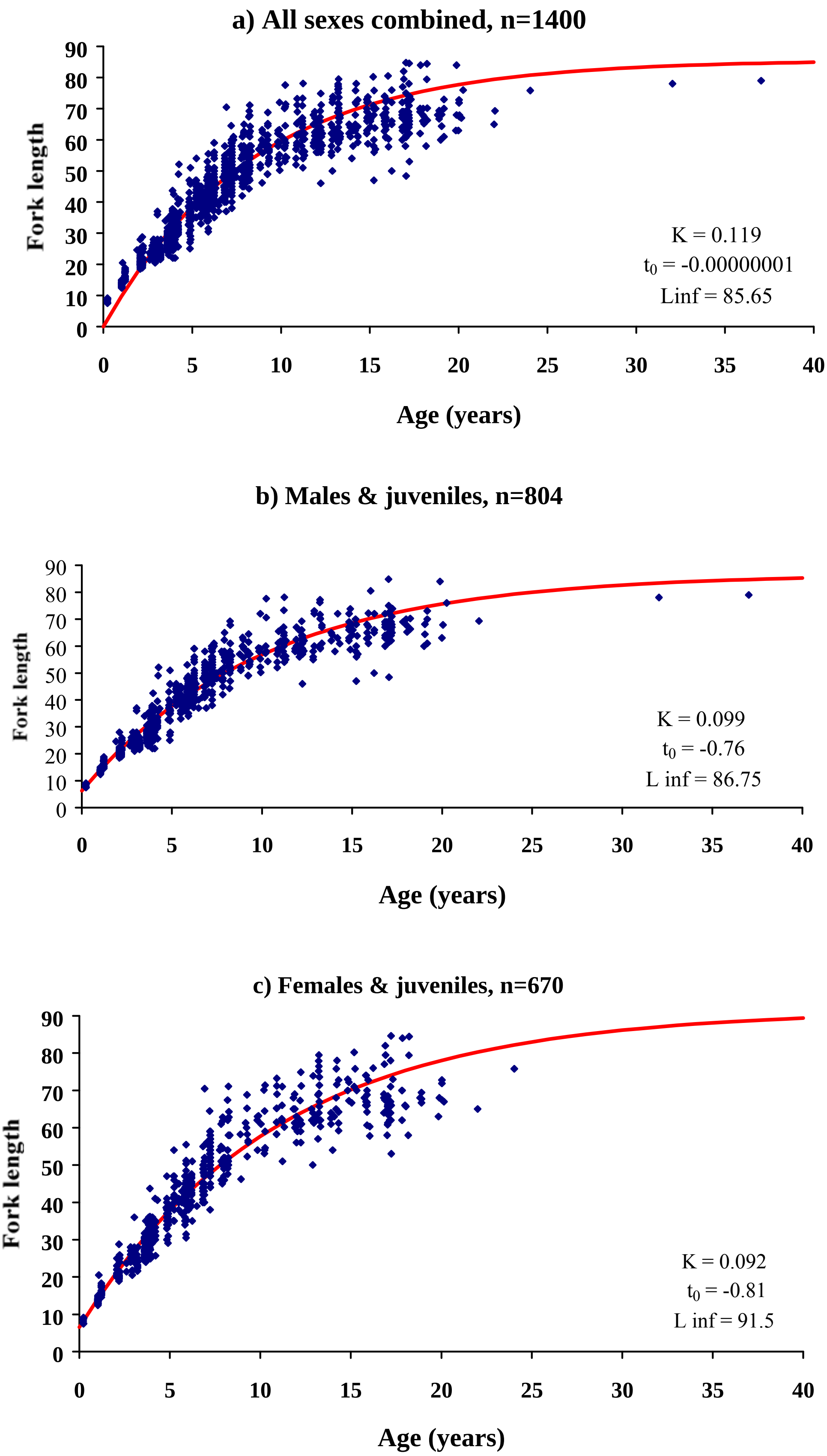


Figure 8. Age and growth of snapper in Port Phillip Bay

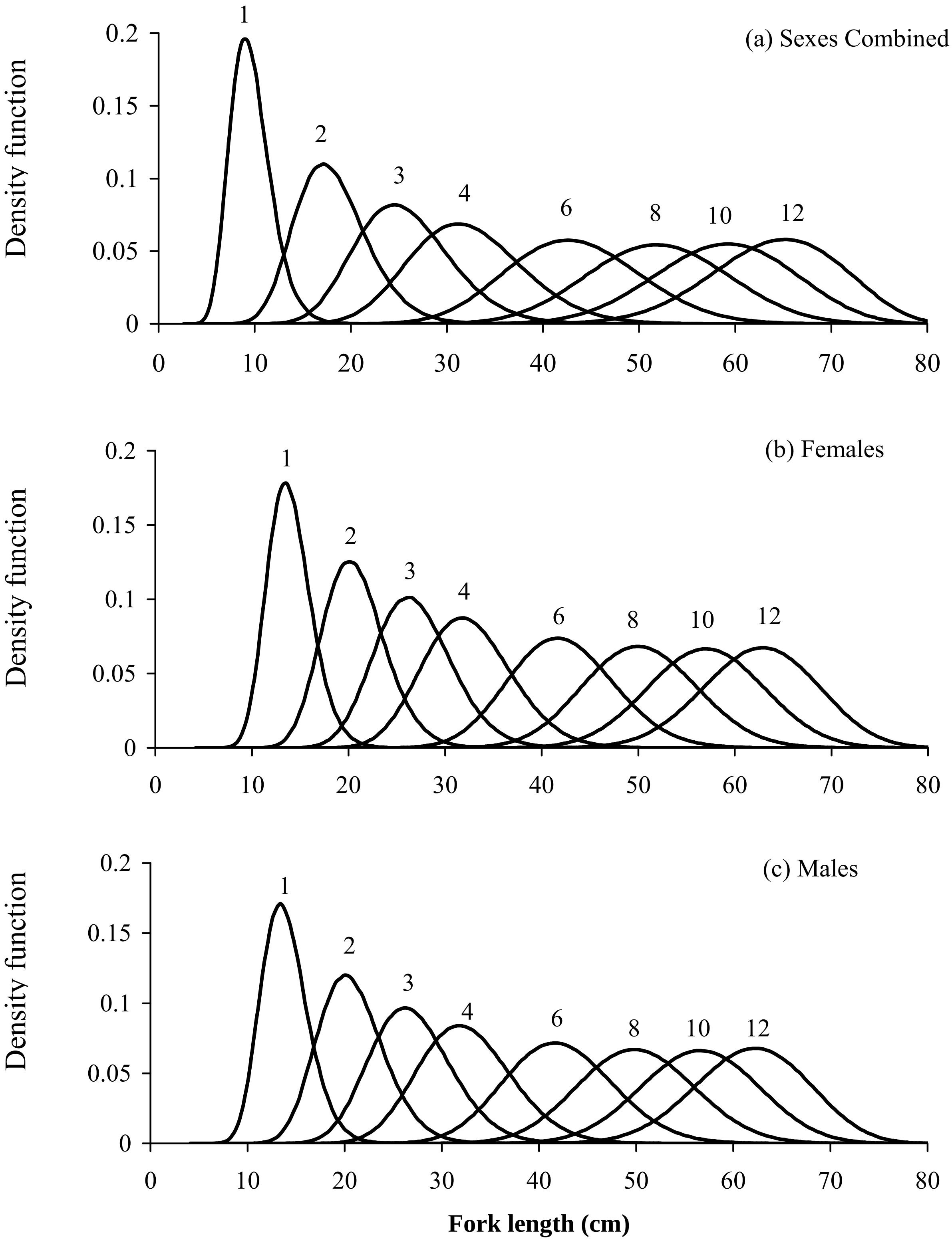


Figure 9. Predicted length frequency distribution of 1-12 year old snapper from stochastic growth models

Table 7. Mean fork length at age estimated from sectioned otoliths of snapper sampled in Port Phillip Bay.

	Female			Male			Immature			All		
AGE (years)	FL(cm) mean	s.d.	*n*	FL(cm) mean	s.d	n	FL(cm) mean	s.d	n	FL(cm) mean	s.d	n
0			0			0	8.43	0.67	7	8.43	0.67	7
1	20.50		1	21.70	4.10	2	14.72	1.50	43	15.15	2.28	46
2	23.08	2.82	37	23.40	2.66	37	21.12	2.03	21	22.77	2.73	95
3	28.46	3.32	131	28.37	4.08	139	25.27	3.00	3	28.38	3.72	273
4	34.14	4.65	50	34.41	5.79	54				34.28	5.25	104
5	42.26	4.27	66	41.66	4.53	70				41.95	4.40	136
6	45.27	5.21	54	44.97	5.05	100				45.08	5.09	154
7	52.26	4.59	72	52.68	5.03	96				52.50	4.84	168
8	55.15	7.32	19	56.12	5.33	31				55.75	6.11	50
9	60.28	4.31	13	56.14	5.43	20				57.77	5.36	33
10	62.11	7.09	16	61.25	6.69	14				61.71	6.80	30
11	62.18	4.97	15	62.08	5.61	25				62.12	5.32	40
12	63.06	5.49	18	60.67	6.03	26				61.65	5.87	44
13	66.50	7.00	21	66.82	6.12	13				66.63	6.58	34
14	68.44	5.33	17	65.13	5.04	12				67.07	5.38	29
15	69.75	5.03	15	63.57	5.84	20				66.21	6.25	35
16	69.29	7.40	14	66.46	7.01	12				67.98	7.22	26
17	66.75	7.10	26	67.43	5.46	36				67.15	6.15	62
18	70.82	9.58	6	66.70	3.21	8				68.46	6.73	14
19	65.50	3.54	2	69.07	7.79	7				68.28	7.04	9
20	69.78	3.00	4	71.95	5.73	2				70.50	3.64	6
22				67.15	3.04	2				67.15	3.04	2
24	75.80		1							75.80		1
32				78.00		1				78.00		1
37	79.00		1							79.00		1

Table 8. Mean fork length at age estimated from sectioned otoliths of snapper in eastern Victoria

AGE	Female			Male			**Immature**			All		
(years)	FL (cm)	s.d.	n	FL (cm)	s.d.	n	FL (cm)	s.d.	n	FL (cm)	s.d.	n
0			0			0	11.63	0.80	25	11.63	0.80	25
1	18.00		1			0	13.73	2.05	14	14.01	2.26	15
2	22.96	1.80	14	23.12	1.38	20				23.05	1.54	34
3	27.97	1.94	113	28.23	1.98	89				28.08	1.96	202
4	29.74	2.66	61	30.10	2.49	48				29.90	2.58	109
5	36.51	2.42	19	36.01	4.23	35				36.19	3.68	54
6	37.66	5.28	7	37.24	2.64	5				37.48	4.22	12
7	50.38	6.47	12	45.23	5.39	8				48.32	6.45	20
8	48.66	4.58	21	44.01	5.41	16				46.65	5.41	37
9	54.23	4.93	4	50.82	6.65	9				51.87	6.19	13
10				57.25	5.74	4				57.25	5.74	4
11	65.20	6.38	4	56.40	10.75	2				62.27	8.26	6
12	55.25	8.84	2	61.47	2.50	3				58.98	5.85	5
13	58.75	1.77	2	58.60	4.39	4				58.65	3.49	6
14				66.08	5.12	6				66.08	5.12	6
15	66.60		1	62.73	5.00	3				63.70	4.52	4
16	65.67	3.03	6	66.00		1				65.71	2.77	7
17	71.32	11.47	9	67.64	5.03	7				69.71	9.15	16
18	68.15	2.72	4	67.75	3.10	4				67.95	2.71	8
19	69.33	1.51	3	73.00		1				70.25	2.21	4
20	66.00		1	66.00	7.07	2				66.00	5.00	3
21				66.40		1				66.40		1
22				66.00		1				66.00		1
23	65.60		1							65.60		1
24				72.00		1				72.00		1
26				79.00		1				79.00		1

Table 9. Mean fork length at age estimated from sectioned otoliths of snapper in western Victoria

AGE	Female			Male			Immature			All		
(years)	FL (cm) mean	s.d.	n	FL (cm) mean	s.d.	n	FL (cm) mean	s.d.	n	FL (cm) mean	s.d.	n
1	26.20		1			0	16.63	0.53	8	17.69	3.23	9
2			0	27.00		1			0	27.00		1
3	28.44	2.73	33	28.35	1.53	26	16.70		1	28.20	2.71	60
4	32.59	3.53	12	33.22	3.18	19				32.98	3.27	31
5	37.65	4.23	32	37.87	4.40	40				37.77	4.30	72
6	42.02	4.42	9	41.50	5.33	19				41.67	4.98	28
7	50.40	4.16	7	50.80	4.38	5				50.57	4.06	12
8	44.10		1	50.33	6.66	3				48.78	6.27	4
11				61.00		1				61.00		1
12				58.00		1				58.00		1
13				61.50	2.12	2				61.50	2.12	2
16	71.00		1							71.00		1
17	58.00		1							58.00		1

Size and age at first maturity

Based on macroscopic stages 1 and 2 (Table 1) and GSI values less than 3.0, 27.2% of the fish (20-55cm FL) were classified as immature. Two snapper (0.5%) that we examined had ovotestes and possessed both male and female gonad tissue. The remaining 72.3% of females examined were classified as mature based on macroscopic stages 3 and 4 and GSI values greater than 3.0. The smallest mature (stage 3) female measured was 27.0 cm FL. The calculated length and age at 50% maturity was 36.3 cm FL (42.2cm TL) and 4.9 years (Figure 10). At 48cm FL, all fish were mature. The relationship between size (FL cm) or age (years) and the proportion mature (P) are expressed by the following equations:

$$P = 1 / [1 + exp\ (- 0.2514 \times (FL - 36.26\ )\ )\ ]$$

$$P = 1 / [1 + exp\ (- 0.972 \times (age - 4.86\ )\ )\ ]$$

The exponential relationships between the mean gonad weight and fork length are shown in Figure 11 for samples collected in Port Phillip Bay and in eastern coastal waters off Port Albert

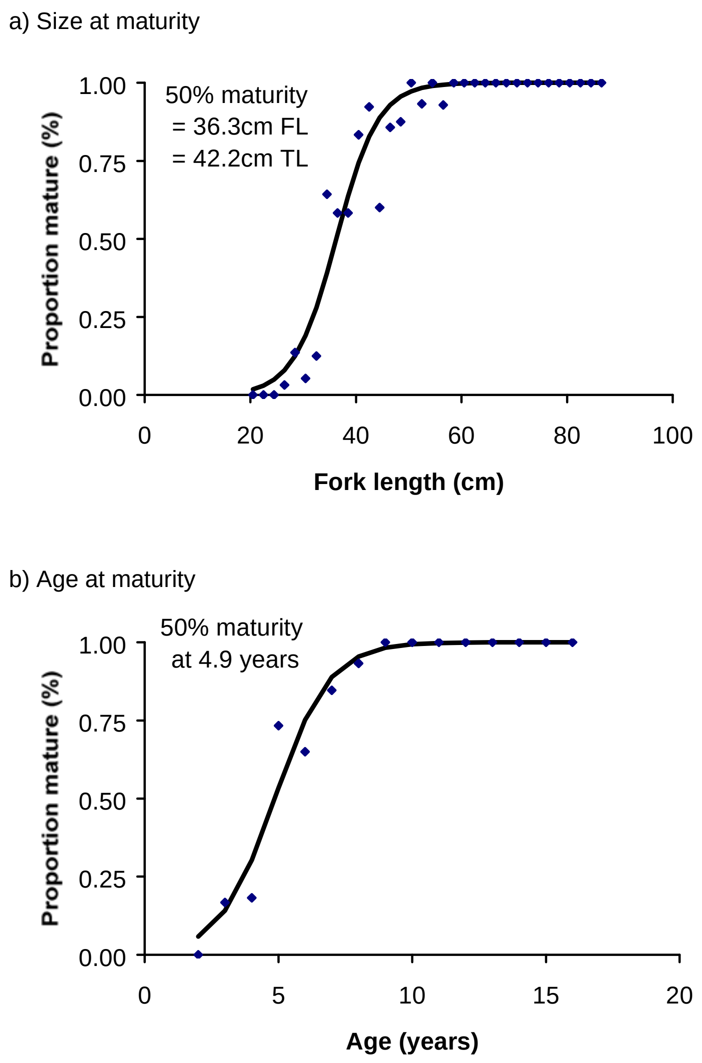


Figure 10. Size and age at maturity of female snapper in Port Phillip Bay

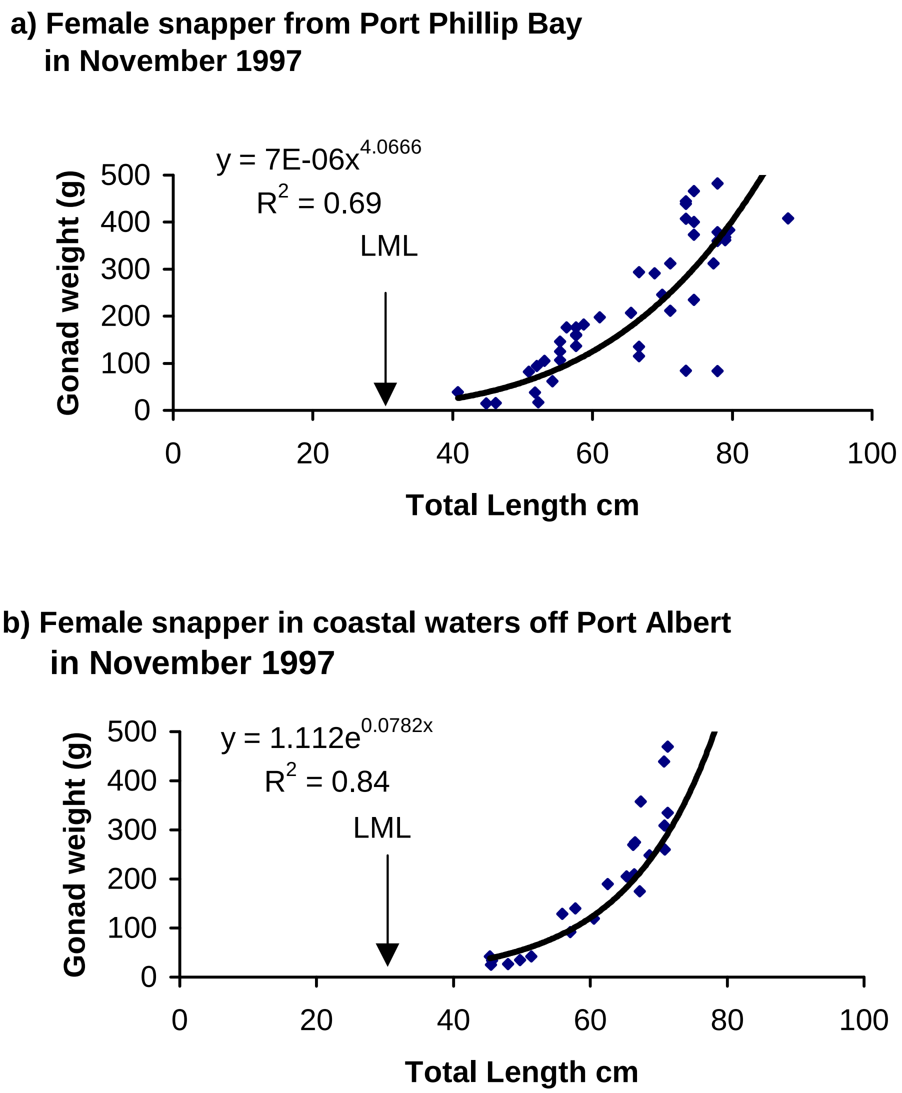
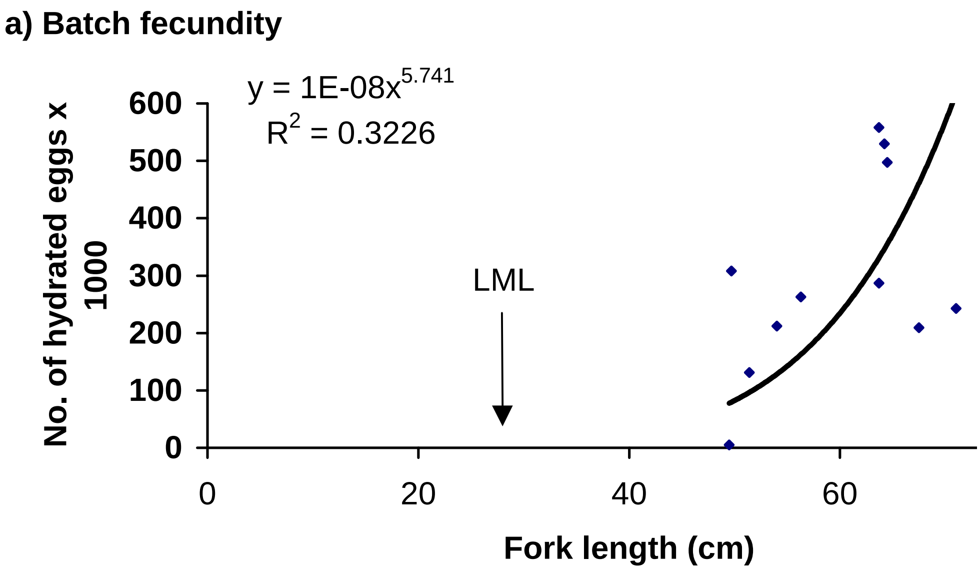


Figure 11. Relationship between gonad weight and length for snapper sampled from Port Phillip Bay and from east Victoria in November 1997. The arrow shows the current legal minimum length of 27cm TL.

Fecundity estimates

Exponential models that describe the relationships between batch fecundity and fork length (R^2, 0.32) and the total fecundity and fork length (R^2, 0.39) are shown in Figure 12a and 12b, respectively. The average batch fecundity increased from 153,000 to 469,000 hydrated oocytes between 7 and 14 years of age. The average total fecundity increased from 1 to 4.6 million oocytes between 7 and 14 years of age.



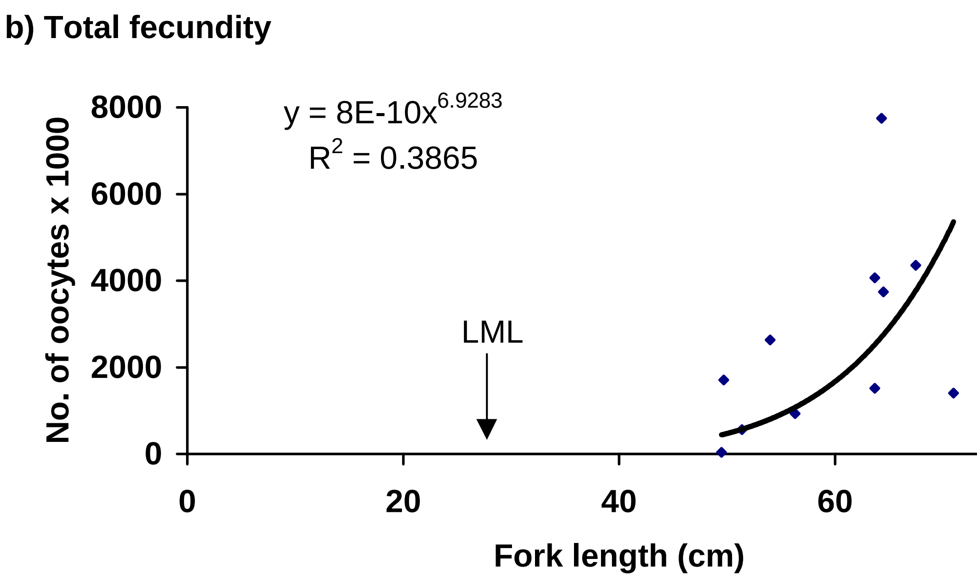


Figure 12. Batch and total fecundity of snapper during November and December in Port Phillip Bay. The arrow shows the low fecundity predicted for snapper at the current legal minimum length of 27cm TL.

Development of an integrated movement, growth and fisheries model

The development of an integrated snapper movement model was completed and tested using 13376 records of tagging data from 1950s, 1970s and 1990s. The model incorporated three tag types and initial testing was based on 5052 internal tags (38%), 7549 T bar tags (56%), and 775 dart tags (6%). Data from recaptured tags and tags that were not recaptured were used in the model.

a) Tag shedding and mortality

The model outputs indicated the relative performance of the different tag types. The combined tag shedding and total mortality rate estimated for T bar tags (0.84 yr^{-1}) was much higher than for dart tags (0.26^{-1}yr) and internal tags (0.09^{-1}yr). Independent estimates of natural mortality based on maximum age, suggest a low value of 0.1 to 0.05. Therefore the combined fishing mortality and shedding rates are likely to be between 0.74–0.79 yr^{-1} for T bar tags, 0.16–0.21 yr^{-1} for dart tags and 0–0.04 yr^{-1} for internal tags.

b) Movement

The outputs of the model runs were highly dependent on the input values for gear selectivity and fishing effort in coastal waters. Initial models runs suggested that there were differences in the proportion of fish moving between areas for the three size groups of fish used in the model. A conceptual model of the results is shown below in Figure 13.

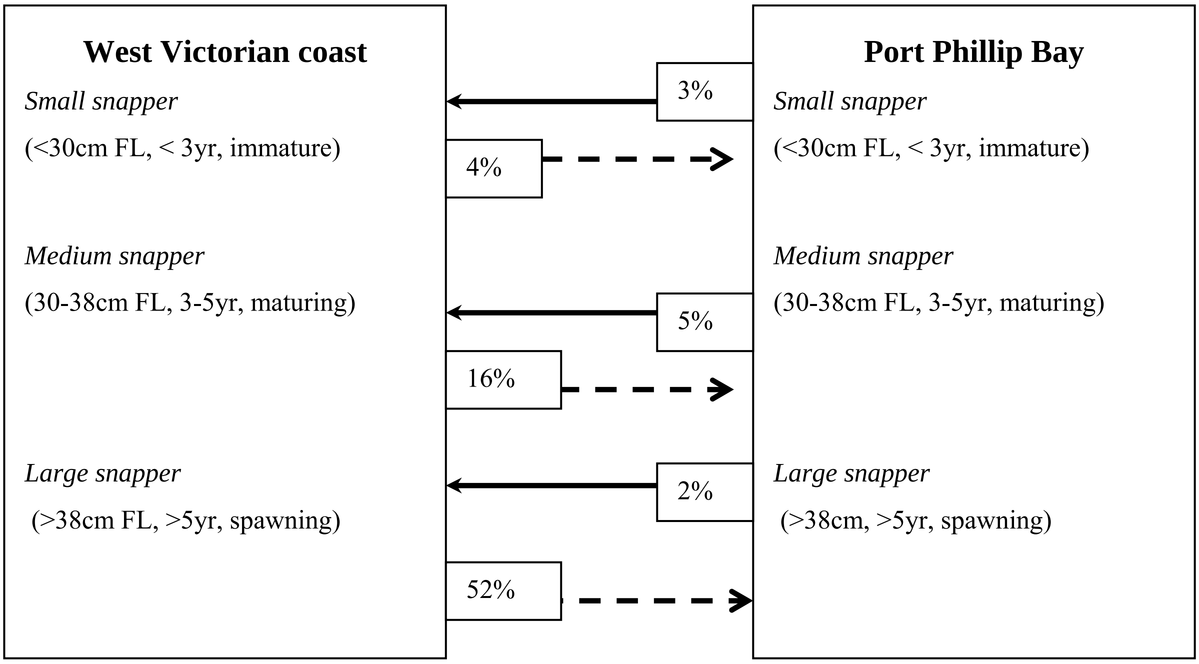


Figure 13. Conceptual model of the annual movement of small, medium and large snapper between Port Phillip Bay and West Victorian coastal waters.

Only 3% of the small fish (<30cm) moved from Port Phillip Bay to west coast waters and 4% moved from west coast waters to Port Phillip Bay. A slightly larger proportion (5%) of the medium sized fish (30–38cm) moved from Port Phillip Bay to west coast waters, but a greater proportion (16%) moved from west coast waters to Port Phillip Bay. More than half (52%) of the large fish (>38cm) moved from west coast waters to Port Phillip Bay, whereas only 2% moved from Port Phillip Bay to the west coast. These results suggest a net movement of snapper from west to east and the proportion that move increases with size, age and maturity.

However, these are preliminary results and further investigation is needed into the sensitivity of the results to the assumptions and input values. In particular, historic trends in recreational fishing effort along the coast with small and large hooks need to be estimated from information or by consulting with experienced recreational and commercial fishers. The next stage of the model development will require futher scenario testing and evaluation by the Bay and Inlet Stock Assessment Group.

Recaptures of tagged snapper by tag type and release location

The historic tagging data consisted of 375 recaptures from 8800 tagged fish released with operculum, internal, T bar and dart tags between 1948 and 1994. During the current project, 16783 snapper were tagged with internal, T bar and dart tags between 1995-2002 and 349 of these have been recaptured (2.1%). A summary of the snapper tag release and recapture data 1948–2003 is given for each type of tag and region in Table 10 and Table 11. Monthly data and the locations of tag recaptures are given in the Appendix for each tag release region with information on time at liberty and growth. A map showing the tag release locations and movements of tagged snapper with estimated age and maturity at recapture is shown in Figure 14.

Operculum tag releases 1948–1959

The first tag recapture records for snapper in Victoria were 5 operculum tagged fish released in Port Phillip Bay (1130) and Portland Bay (532) and Mallacoota Inlet (375) between 1948 and 1959. All the tagged fish were between 12 to 25cm FL at release. There was a lack of movement movements from the vicinity of their release location and recapture rates were low (0.3%) and time at liberty was short (less than 437 days).

Nesbit internal tag releases 1956–1962

A total of 4240 internally tagged fish were released mostly in Port Phillip Bay (44%), Portland Bay (27%) and in Mallacoota Inlet (24%), but smaller numbers were also released in Westernport Bay (4%) and Corner Inlet (1%). The fish were small (12–30cm in fork length) and were mostly caught with haul seines or hooks prior to release. This method of tagging considerably improved the tag recapture rate and 230 recaptures (5.4%) were obtained from fish tagged internally during this period. Recapture rates were similar for tagged fish released in Port Phillip Bay (5.4%), Portland Bay (4.9%), Westernport Bay (4.1%) and Mallacoota Inlet (6.7%). None of the tagged fish released in Corner Inlet were recaptured.

a) Port Phillip Bay

There were 102 recaptures of tagged snapper released in Port Phillip Bay (n=1878) and 24 of these were at liberty for more than 1000 days. The longest period was 7640 days but this fish showed surprisingly little displacement like most of the others that had been at liberty for more than 1000 days. This tagged fish (X 438) was released in

February 1957 at 23cm TL in Stingaree Bay, part of Corio Bay in the western part of Port Phillip Bay and it was recaptured at 75cm TL near the South Channel Fort in southern Port Phillip Bay.

The furthest displacement of tagged snapper released in Port Phillip Bay was demonstrated by recaptures in eastern South Australia. Recaptures were reported from Robe (3397 days), Kingston (1779 days) and Carpenters Rocks (673 days). Seven other tagged fish were recaptured along the western coast between Port Fairy and Portland that had been at liberty for 668–997 days and two were reported from Lorne (353 and 364 days). However, there were also eastward movements with recaptures reported from San Remo (1732 days) and in Westernport (395 days and 1446 days).

b) Westernport Bay

There were 7 recaptures of the tagged snapper released in Westernport Bay (n=169) and 3 were at liberty for more than 500 days. One fish (X 1737) that was at liberty for 3119 days had moved out to sea, westwards and was recaptured off Beaumaris in eastern Port Phillip Bay. It was released at a size of 25cm TL and recaptured when it was 66cm TL.

c) Portland Bay

There were 51 recaptures of the tagged snapper released in Portland Bay (n=1153) and 33 were at liberty for more than 1000 days. Most of these were recaptured in either Port Phillip Bay or eastern South Australia. Two of these were recaptured after 5000 days off Seaford (X5008) and off Beaumaris (X2731) in eastern Port Phillip Bay, after 5005 days and 5334 days respectively. Five recaptures from eastern South Australia were reported after 1681–3552 days when the tagged fish had grown by 22 to 47cm to reach sizes of between 44–71cm TL. The majority (95%) of the tagged fish recaptured in Portland Bay were less than 41cm TL and were at liberty for less than 1000 days. The only exception was a recapture from Portland harbour (X2896) after 1497 days when it was 61cm TL.

The greatest displacement was in an eastward direction with 25 recaptures reported in Port Phillip Bay, predominantly from the eastern region between Frankston and St. Kilda. Only one was reported in the western region of Port Phillip Bay from Point Wilson (X3226). Five recaptures in eastern South Australia indicated a westward movement that extended as far as Kingston.

d) Mallacoota Inlet

There were 70 recaptures of the tagged snapper released in Mallacoota Inlet (n=1040) in March 1959 and 42 were at liberty for more than 1000 days. The longest time was 6224 days but this fish showed less displacement than most of the others that had been at liberty for more than 1000 days. This tagged fish (X 3097) released in March 1959 at 21cm TL moved north east and was recaptured at 71cm TL near Bermagui in NSW.

Several tagged fish released in Mallacoota Inlet were recaptured in northern NSW with one reported from the Solitary Island lighthouse (X3155) after 790 days and another Port Macquarie (X3457) after 1693 days. These fish had grown from 19cm to 31cm, and 24cm to 47cm respectively, while at liberty.

Figure 14. Release locations (#) and movement directions of all tagged snapper with estimated age and maturity at recapture Latitudes and longitudes of recapture locations are given in Appendix 5

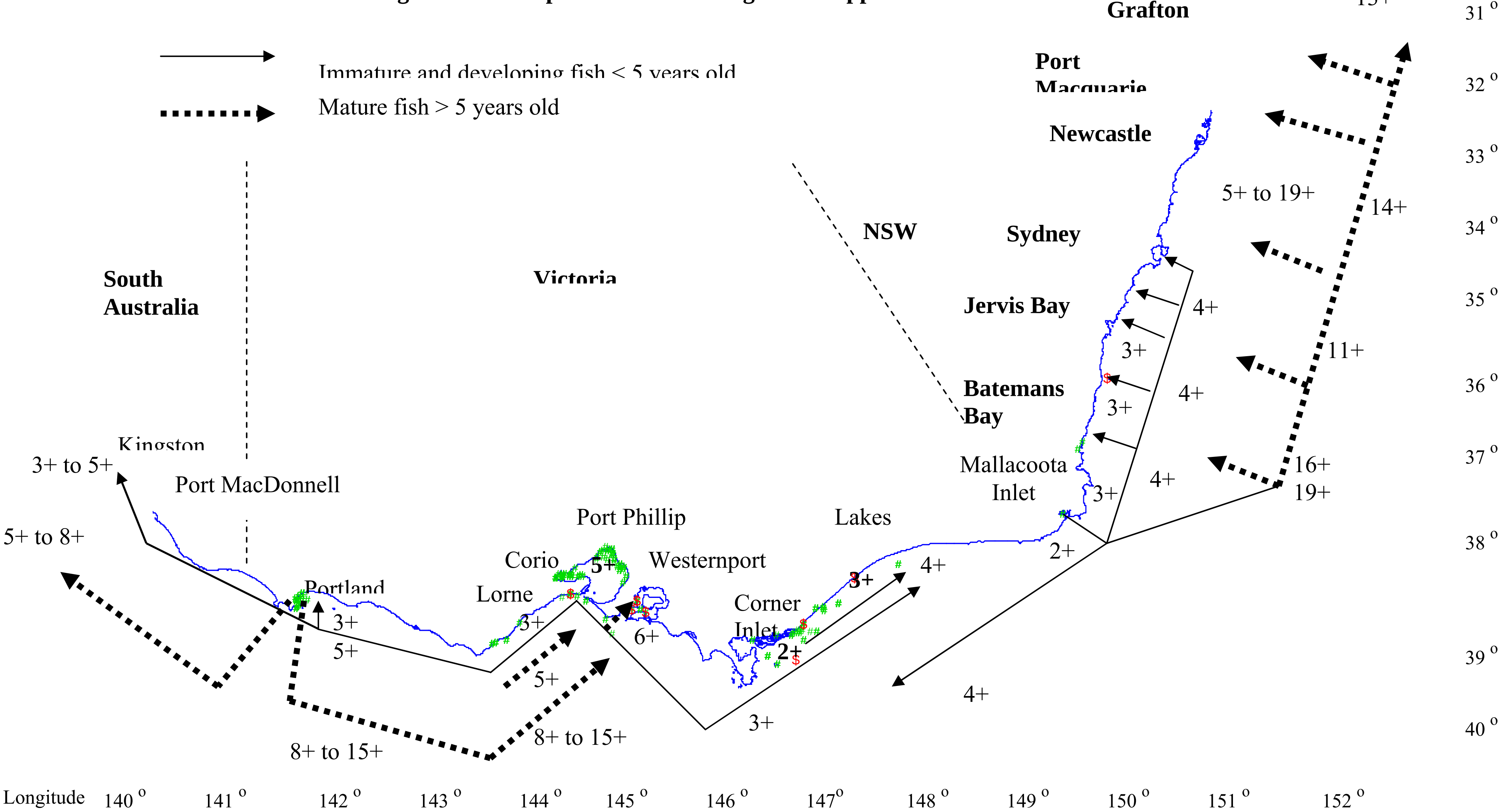


Table 10. A summary of tagged snapper released in 1948-1994 and recaptured

Year	Release Location	Type of tag	Tags released	Tags recaptured	% recaptured
1948-1959	Port Phillip Bay	Operculum	1130	2	0.2
	West coast	Operculum	532	2	0.4
	East coast	Operculum	375	1	0.3
1948-59	***Sub-total***	**Operculum**	**2037**	**5**	**0.25**
1956-1962	Port Phillip Bay	Internal	1878	102	5.4
	Westernport Bay	Internal	169	7	4.1
	West coast	Internal	1153	51	4.4
	East coast	Internal	1040	70	6.7
1956-1962	***Sub-total***	**Internal**	**4240**	**230**	**5.4**
1971-1972	Port Phillip Bay	Internal	1290	128	9.9
1971-1972	Port Phillip Bay	T bar	615	6	1.0
1994	Port Phillip Bay	T bar	548	4	0.7
1994	Port Phillip Bay	Dart	70	2	2.9
1948-1994	**Total**	**All**	**8800**	**375**	**4.3**

Table 11. A summary of tagged snapper released (n_1) in 1995-2003 and recaptured (n_2)

		Internal			Dart			Tbar		
Region	**Year**	n_1	n_2	**%**	n_1	n_2	**%**	n_1	n_2	**%**
Portland, WCw	**1995**							56	1	1.8
	1996							15	1	6.7
	1997							916	16	1.8
	1998				103	7	6.8	759	32	4.2
	1999	150	20	13.3	164	13	7.9	326	3	0.9
	2000				44	1	2.3	991	30	3.0
	2001				22	1	4.5	855	22	2.6
	2002							557	4	0.7
	2003							785	8	1.0
Subtotal		150	20	13.3	333	22	6.6	5260	117	2.2
Port Phillip Bay	**1995**				1	0		214	1	0.5
	1996							458	9	2.0
	1997	-	-	-	2	0		1072	11	1.0
	1998	7	2	28.6	55	3	5.5	1100	15	1.4
	1999	544	12	2.2	338	11	3.3	1148	24	2.1
	2000	-	-	-	439	20	4.6	1223	13	1.1
	2001	-	-	-	57	6	10.5	740	5	0.7
	2002	-	-	-	310	9	2.9	2265	14	0.6
	2003				296	6	2.0	1851	9	0.5
Subtotal		551	14	2.5	1498	55	3.7	10071	101	1.0
East Coast	**1995**				1	0	0.0			
	1996				1	0	0.0	305	1	0.3
	1997				57	0	0.0			
	1998				30	2	6.7			
	1999	998	32	3.2	17	1	5.9	481	10	2.1
	2000				2	0	0.0	143	0	0.0
	2001				1	0	0.0	48	4	8.3
	2002				11	0	0.0	26	0	0.0
Subtotal		998	32	3.2	120	3	2.5	1003	15	1.5
Westernport	**1996-2003**	-	-	-	101	3	3.0	178	2	1.1
West Coast east	**1995-2003**	151	1	0.7	24	2	8.3	596	8	1.3
Victoria	**1995-2003**	**1850**	**67**	**3.6**	**2076**	**85**	**4.1**	**17108**	**243**	**1.4**

T bar and Nesbit internal tag releases 1971–1974

Snapper tagging resumed in October 1971 and continued until November 1974. A large size range of fish was caught with a research trawler and tagged fish were released mostly between Brighton and Seaford in the eastern region of Port Phillip Bay. T bar tags (manufactured by Floy, coded T) and internal tags (coded ZAI) were used to tag small and large fish. A small proportion of fish were double tagged with internal and T bar tags. After capture, fish were kept on–board in tanks and only fish in good condition were tagged and released. A total of 615 fish with T bar tags were released but only 6 of these were recaptured (1%).

Recapture rates were much higher for internal tags in comparison to T bar tags. There were 128 internally tagged fish recaptured (10%) from the 1290 fish released and 30 were at liberty for more than 1000 days. The longest time was 9130 days but this fish showed little displacement. This tagged fish (ZAI 2190) was released in November 1971 at 36cm TL off Sandringham in the eastern part of Port Phillip Bay and it was recaptured when it was 80cm (6kg) near Brighton in November 1996. Most of the tagged fish at liberty for more than 1000 days were recaptured in the eastern region of Port Phillip Bay and only a few were detected moving into coastal waters. Eleven tagged fish were recaptured outside Port Phillip Bay and most of these were released near Sandringham between October and November 1972.

Seven recaptures indicated eastward movements into Westernport Bay and four indicated westward movements to Wye River, Port Campbell, Portland and Cape Douglas in eastern South Australia. The eastward movements occurred after 339–4020 days at liberty and fish were recaptured at sizes ranging between 29–76cm TL. The westward movements occurred after 400–1472 days at liberty and fish were recaptured at 30–39cm TL. Recaptures reported from Wye River (ZAI 2974), Port Campbell (ZAI 86), Portland (ZAI 2752) and Cape Douglas in South Australia (ZAI 2754) were at liberty for 448, 400, 1184 and 2754 days, respectively.

The longest time at liberty of the 6 recaptured T bar tagged fish was 133 days. This fish (T 418) was 40cm when it was recaptured and indicated a westward movement from Brighton in November 1971 to Lorne in March 1972. The others were recaptured in Port Phillip Bay after 2–74 days at liberty.

T bar and dart tag releases 1994

A total of 618 snapper ranging in size between 16–76cm in fork length were tagged with dart (70) and T bar tags (548). Dart tags were used for fish larger than 30cm FL. Nearly all the fish larger than 27cm TL caught by the trawl had distended swim bladders but these were deflated with a hollow needle before they were tagged and released. Only 6 fish with these tags were recaptured (1%), 4 with T bar tags (0.7%) and 2 with dart tags (2.9%).

None of the four T bar tag recaptures showed movement beyond Port Phillip Bay. The greatest time at liberty was 1035 day for a 21cm snapper released at Beaumaris in February 1994 and recaptured at 52cm TL near Carrum in December 1996.

One of the two dart tag recaptures showed movement beyond Port Phillip Bay and one was recaptured in the bay. The fish recaptured off Ocean Grove was at liberty for the greatest time. This tagged snapper (MT 1529) was 55cm when it was released on the dredge spoil grounds in northern Port Phillip Bay in March 1994 and by May

1997. It had grown by 9.3 cm to 64cm over a period of 1170 days. The other recaptured fish was caught off Point Cook close to its release location after 664 days.

Nesbit internal tag releases since 1995

a) Port Phillip Bay

In November 1998, 7 fish tagged with prototype internal tags (NESx) were released at Queenscliff and two were recaptured (28%). The remainder of the fish tagged with the thinner internal tags (NES) were released in Corio Bay in February (n=339) and March (n=205) 1999. By 2003, there were 14 recaptures from the 551 internally tagged snapper released in Port Phillip Bay during the project (2.5%). Although 6 recaptures were made in Port Phillip Bay, there were eastward movements to Lakes Entrance (476 days) and into Westernport Bay (723-999 days) and westward movements to Apollo Bay (36 days), Portland (639 days) and Peterborough (905 days).

b) West Coast

There was a high recapture rate of the 130 internally tagged snapper released in Portland harbour in March 1999 with 20 recaptured (15.4%) by 2003. All recaptures within 400 days were made within Portland Bay, but westward movements were detected to eastern South Australia after 706 and 930 days and into Port Phillip Bay after 595-981 days.

Only one of internally tagged fish released off Cape Otway was recaptured (NESx 503). This fish was recaptured at a size of 52cm near Beaumaris in eastern Port Phillip Bay after 793 days at liberty having grown by 11.5cm. This fish was one of 3 originally caught in a trap in October 1998 prior to release. None of the fish tagged after capture with a Danish seine were subsequently recaptured.

c) Mallacoota Inlet

The first batch of 499 tagged fish were released in March 1999 and 28 (5.6%) have been recaptured by 2003. The second batch of 499 internally tagged fish released in April 1999 resulted in 4 recaptures (0.8%). Only 5 were recaptured in eastern Victoria and one of these moved west to McGaurens Beach. Most were recaptured along the coast of NSW with north easterly movements to Broughton Island and Diamond Head (32-31^{o} S) after 680 days and1002 days, respectively.

Dart tag releases since 1995

a) Port Phillip Bay

Dart tagged snapper were released by VICTAG anglers in 41 monthly batches of less than 151 fish in the eastern and western regions of Port Phillip Bay since 1995. By 2003, 55 recaptures (3.7%) had been reported from the 1498 tagged fish released. Most of the recaptures were reported within Port Phillip Bay, close to where they were released even after 1106 days.

b) West Coast east

Only 24 dart tagged snapper were released in the eastern part of the West Coast. The two recaptures (8.3%) after 356 and 893 days indicated fish remained within the region.

c) Westernport Bay

Dart tagged snapper were released by VICTAG anglers in 18 monthly batches of less than 20 fish in Westernport Bay. By 2003, 3 recaptures (3.0%) had been reported from the 101 fish released. All recaptures were reported from within Westernport Bay after 6, 108 and 432 days.

d) Portland Bay

Dart tagged snapper were released by VICTAG anglers in 16 monthly batches of less than 70 fish in Portland Bay between 1998 and 2001. By 2003, 22 recaptures (6.6%) had been reported from the 333 tagged fish released. All recaptures of snapper at liberty for less than 432 days were reported from within Portland Bay. Only two were recaptured beyond Portland Bay, at Warrnambool and Port MacDonnell (SA) after 433 and 770 days, respectively.

e) East Coast

Dart tagged snapper were released in the coastal waters outside Corner Inlet by VICTAG anglers and charter boat operators in 15 monthly batches of 30 tags or less. By 2003, 3 recaptures (2.9%) had been reported from the 108 tagged fish released.

T bar tags 1995–2002

a) Port Phillip Bay

T bar tagged snapper were released by VICTAG anglers in 84 monthly batches of up to 735 fish throughout Port Phillip Bay. In November 1999, December 1999 and January 2000, larger batches of T bar tagged fish were released in Corio Bay by MAFRI staff working with commercial haul seine fishermen. By 2003, 101 recaptures (1.0%) had been reported from the 10,071 fish released. Recaptures were generally reported from batches exceeding 50 tagged fish. Most of the recaptures were reported within Port Phillip Bay, even after 1410 days (A20231).

b) Westernport Bay

T bar tagged snapper were released by VICTAG anglers in 21 monthly batches of less than 24 fish in Westernport Bay. By 2003, 2 recaptures had been reported from the 178 tagged fish released (1.1%). Both fish were 27cm when recaptured within Westernport Bay after 27 and 64 days.

c) Portland Bay (WCw)

T bar tagged snapper were released by VICTAG anglers in 75 monthly batches of up to 386 fish in Portland Bay. By 2003, 117 recaptures (2.2%) had been reported from the 5260 fish released. Most of the recaptures were reported within Portland Bay after short periods at liberty of less than a year.

Five fish were recaptured in Port Phillip Bay (A30072, A30747, A34042, A34046, A26004). These were released in Portland Bay between January and April at a size of 27 cm and were recaptured in October, November and March. The time at liberty ranged between 942–1412 days and fish ranged in size from 38–45cm when they were recaptured near Point Lonsdale and Altona. Only one was recaptured in Westernport Bay (A35253) at a size of 45cm TL after 1691 days at liberty.

d) Apollo Bay to Queenscliff (WCe)

T bar tagged snapper were released by VICTAG anglers in 52 monthly batches of less than 100 fish along the west coast between Apollo Bay and Queenscliff. By 2003, 8 recaptures (1.3%) had been reported from the 596 tagged fish released.

e) East Coast

T bar tagged snapper were released by charter boat operators and VICTAG anglers in 40 monthly batches of less than 100 fish in the coastal waters outside Corner Inlet. By 2003, 15 recaptures (1.5%) had been reported from the 1030 tagged fish released. Most of the recaptures were reported from monthly batches exceeding 30 fish.

Dispersal of the western snapper stock by location of release

a) Port Phillip Bay

Most of the tagged snapper released in Port Phillip Bay were recaptured in Port Phillip Bay (86.7%), but a small proportion were recaptured in coastal waters showing westward (8.2%) dispersal as far as Kingston in eastern South Australia and eastward (5.0%) dispersal as far as Lakes Entrance in eastern Victoria. There were only small differences in this pattern for the different tagging periods and tag types (Figure 15, 16 and 17).

For internally tagged snapper, 84% were recaptured within Port Phillip Bay, 11.5% moved west and were recaptured along the West Coast or in eastern South Australia and 4.5% moved east into Westernport Bay or off Lakes Entrance. A greater proportion of internally tagged snapper released between 1998-99 were recaptured along the west coast (36%) and in Westernport and east coast (21%) than in previous years. Two fish tagged with prototype internal tags that were released into Queenscliff harbour were recaptured off Lakes Entrance after only 94 days and near Lawrence Rocks in Portland Bay after 476 days at sizes of 36cm TL and 31cm TL, respectively. Six of the fish released in February and March 1999 were recaptured in Port Phillip Bay, four were recaptured between Apollo Bay and Portland and two were recaptured in Westernport Bay. Most of the fish that moved out of the bay were recaptured at a size larger than 30cm and were at liberty for more than 240 days. The eastward movements were shown by two fish (NES 137 and 139) and these were recaptured near Balnarring (723 days at liberty) and Hastings (999 days at liberty). The other four fish moved westward to Apollo Bay (36 days), Portland (247–639 days) and Peterborough (905 days).

For dart tagged snapper, 94% were recaptured in Port Phillip Bay and only 6% were recaptured along the west coast. There were recaptures at Angelsea (A14201), Lorne (DR6791) and Cape Otway (DV3832) after 50, 400, and 588 days respectively. For snapper with Tbar tags, 92% were recaptured in Port Phillip Bay and only 8% were recaptured after moving into coastal waters (7% east and 1% west). There were five eastward movements from Corio Bay to Westernport Bay. The size at recapture ranged was 29–40cm TL and these fish had grown by 5–16cm after between 386–1021 days at liberty. Another snapper that moved east reached Lakes Entrance (A27306) confirming the range of eastward movement shown by an internal tagged snapper (NESx 1122). Only one fish released in Corio Bay in March 2000 was detected moving westwards. This 43cm fish (A31753) was recaptured near Angelsea.

The mean displacement of snapper that were released as juvenile fish (16-24cm FL) in Port Phillip Bay increased gradually over time from 33km in the first year at liberty to

103 km,149 km and 80 km in the following three years. The mean and maximum displacement increased gradually with the estimated age at recapture (Figure 18). However, there was a much lower mean displacement of snapper that were released as developing (25-36cm FL) and mature fish (>37cm FL) in Port Phillip Bay. The mean displacement of these larger fish ranged between 23-57 km and remained relatively constant over time.

b) Westernport Bay

There was little movement detected from the internal tagged snapper released in Westerport Bay between 1957-1962. The majority (86%) were recaptured within Westernport Bay and recapture in Port Phillip Bay indicated an eastward movement after 3119 days. Similarly, both there was no movement detected from the three recaptures of dart and Tbar tagged snapper released in 1999.

c) Apollo Bay to Queenscliff

Eleven tag recaptures indicated snapper movements from the eastern part of the west coast region Eastward movements into Port Phillip Bay were detected from tagged snapper released in the eastern part of the west coast (WCe). One of the prototype internal tagged fish that was released off Cape Otway indicated a movement by a 52cm TL snapper into Port Phillip Bay over a period of 793 days. None of the other internal tagged fish released off Cape Otway in 1998 were recaptured. Mortality of these may have been high as they were initially caught in a Danish seine.

Two T bar tagged snapper (A11512, A11995) from Skenes Creek that were recaptured in Port Phillip Bay indicated a movement of 33cm TL and 51cm TL fish over periods of 549 and 1755 days, respectively. A westward movement along the coast was also indicated by a 27cm fish released near Lorne in February 1998 (MC 4001) that was recaptured after 39 days near Aireys Inlet. The remaining recaptures showed little movement and most were recaptured close to their release location. These recaptures indicate that juvenile tagged snapper (16-24cm FL) recaptured during the first 6 months at liberty generally moved less than 22 km from their release location (mean distance travelled 6.8km). Movements of >140km into Port Phillip Bay were not detected until these juvenile fish had been at liberty for more than 18 months.

d) Portland Bay

Recaptures of snapper from Portland showed that there was limited dispersal for the first 2-4 years, but aftewards dispersal was greater and older fish at liberty for longer periods were subsequently caught in Port Phillip Bay, Westernport Bay or eastern South Australia (Figure 19). There were only small differences in this pattern for the different tagging periods and tag types.

For the internal tagged snapper released in Portland Bay between 1956-59, 47% were recaptured within Portland Bay, 10% moved west and were recaptured in eastern South Australia and 43% moved east into Port Phillip Bay. There were higher recapture rates of internally tagged snapper released in 1999 in Portland Bay (75%) and only 10% were recaptures in eastern South Australia and only 15% moved east into Port Phillip Bay. This difference in the results between tagging periods is related to the shorter time at liberty and further recaptures from the 1999 releases are likely occur in Port Phillip Bay. Snapper released in Portland Bay were detected moving to eastern South Australia three years earlier in 1999.

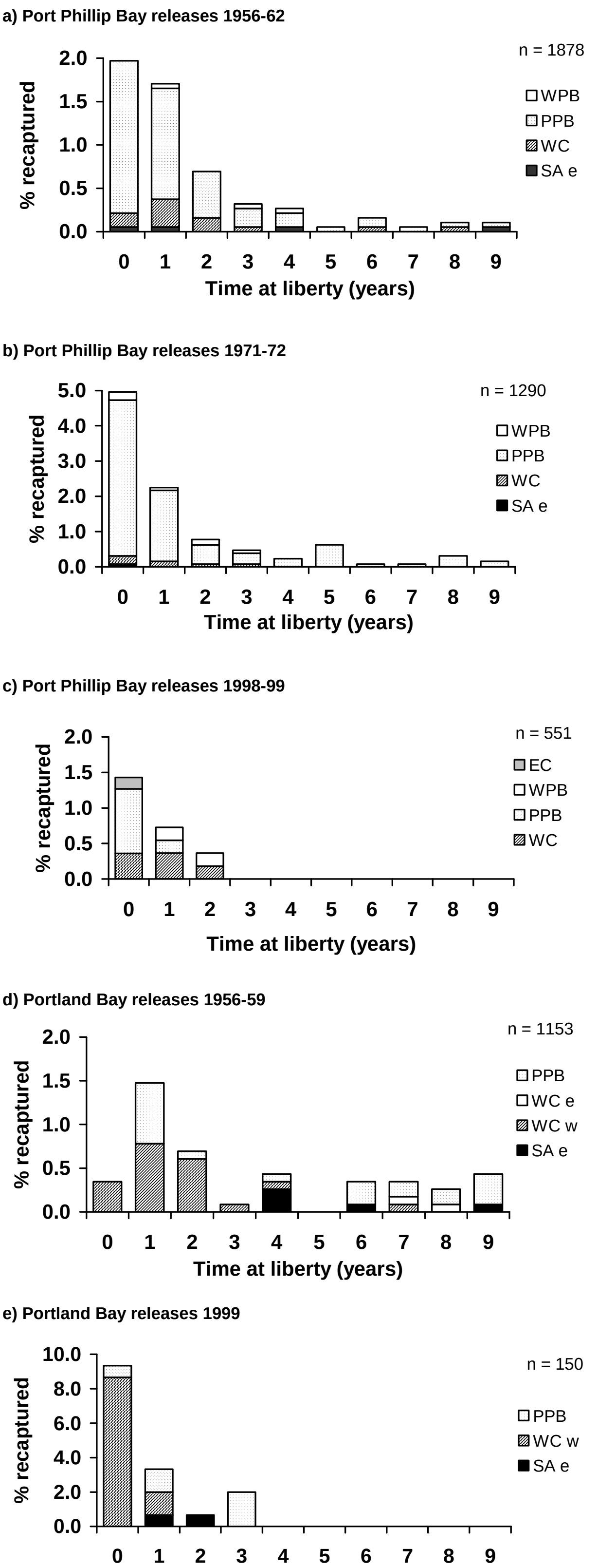
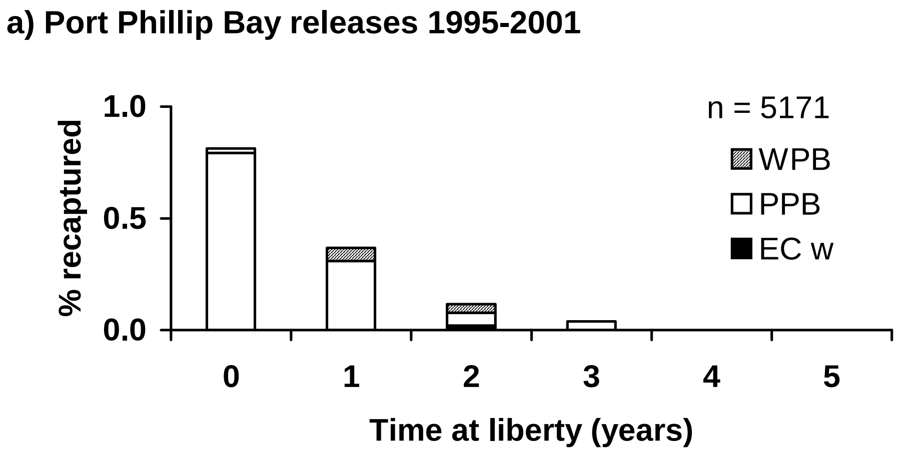


Figure 15. Internal tag recaptures with time at liberty for snapper released in Port Phillip Bay and Portland Bay in 1956-62, 1970-71 and 1998-99.

Figure 16. Dart tag recaptures with time at liberty for snapper released in Port Phillip Bay and Portland Bay in 1996-2001. The recaptures (%) are based on the number of tagged fish released (n) for each period in each location : Portland (WCw), Apollo Bay-Ocean Grove (WCe), Port MacDonnell to Kingston (SAe).



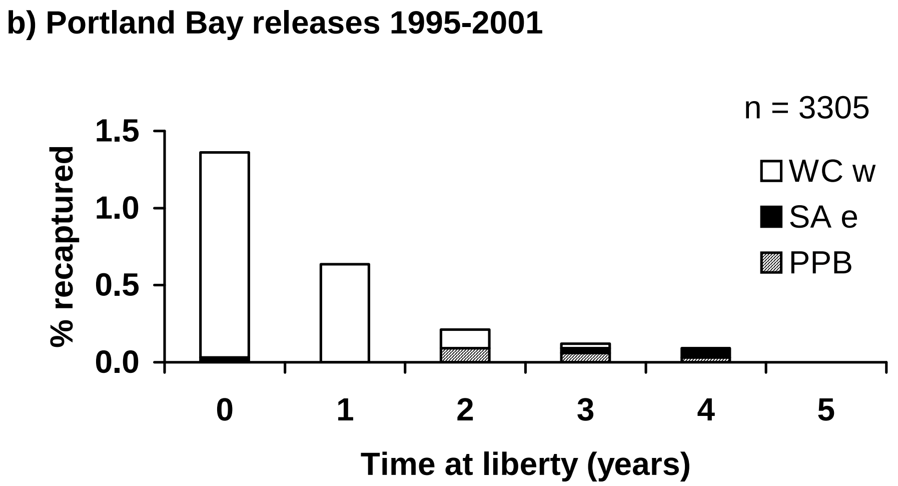


Figure 17. T bar tag recaptures with time at liberty for snapper released in Port Phillip Bay and Portland Bay in 1995-2001. The recaptures (%) are based on the number of tagged fish released (n) for each period in each location: Portland (WCw), Apollo Bay-Ocean Grove (WCe), Port MacDonnell to Kingston (SAe).

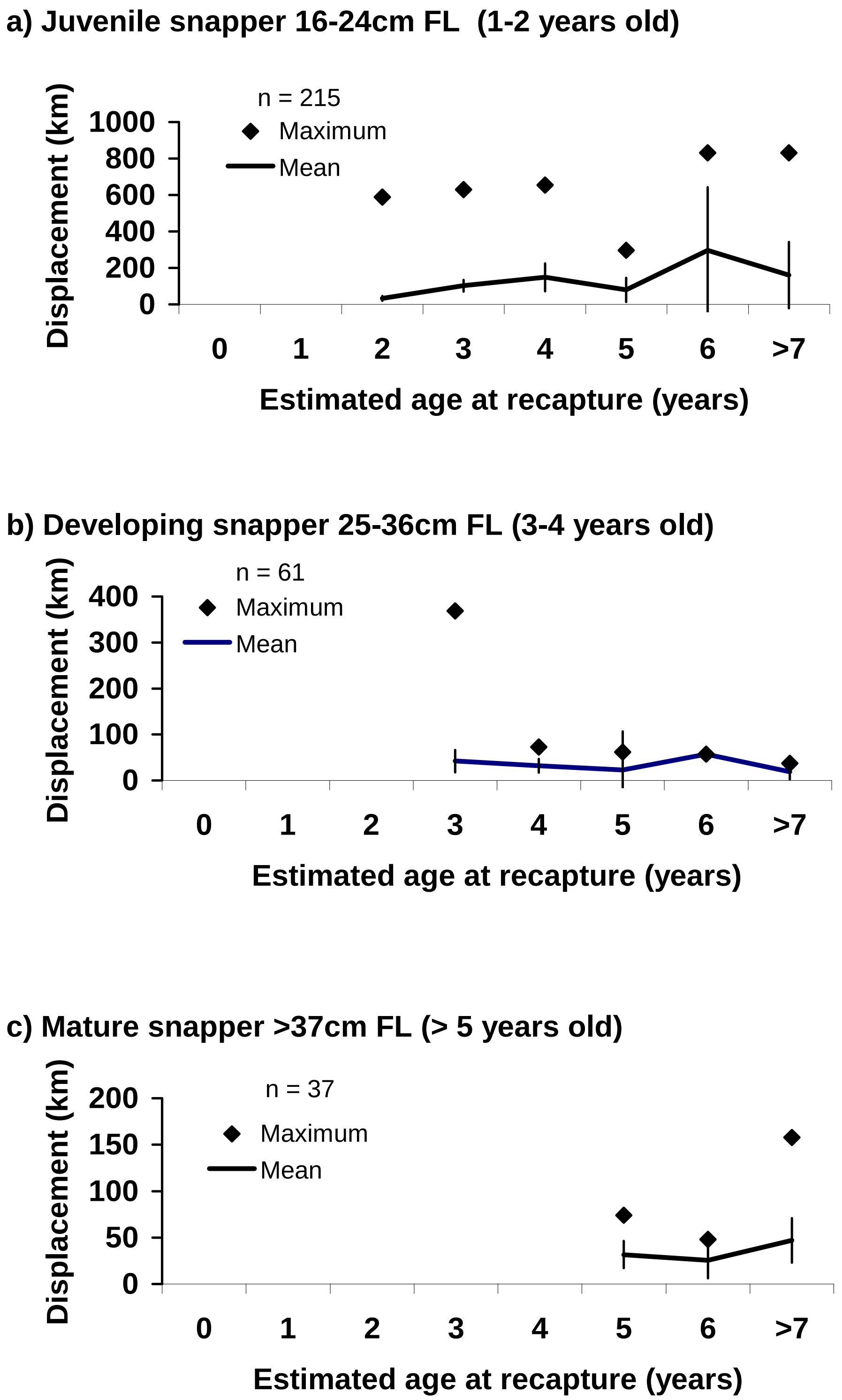


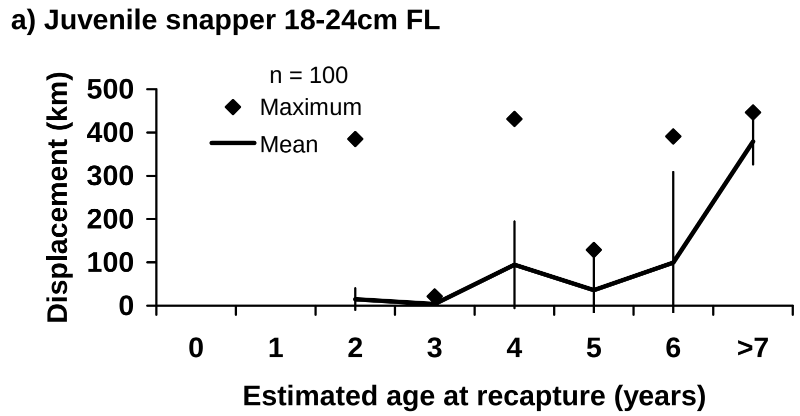
Figure 18. Mean and maximum displacement of recaptured tagged snapper that were released in Port Phillip Bay as juveniles, developing and mature fish between 1956-2000. Vertical bars show the 95% confidence intervals for the mean displacement.

Recaptures of the internally tagged fish (20) that were released in March 1999 in Portland harbour indicate the dispersal pattern of western snapper in coastal waters. For the first 400 days all the recaptures were reported from Portland Bay, but after 595 days a recapture off Carrum in eastern Port Phillip Bay (NES 1059) indicated more extensive movements. Recaptures in eastern South Australia were reported after 706 and 930 days near Port MacDonnell (NES 1049) and Beachport (NES 1041). These fish were 39 cm and 50cm in total length at recapture. Most recently tagged snapper that were released in Portland indicated movements into Port Phillip Bay and were recaptured at Pt Cook (974 days) and in Corio Bay (981 days) having grown to 50cm and 44cm TL, respectively.

Dart tagged snapper were also mostly recaptured in Portland Bay (91%) and only one (A14424) moved west to eastern South Australia (4.5%) and one (A14238) moved east to Westernport Bay (4.5%) after 770 days and 433 days, respectively. Similarly most of the Tbar tagged snapper were recaptured in Portland Bay (88%) and only 4% moved west to eastern South Australia. These were recaptured between Kingston and Port MacDonnell. In comparison, 7% moved east and were recaptured in Port Phillip Bay and Westernport Bay. The four Tbar tagged fish that moved west into eastern South Australia were recaptured off Kingston (A35137), Green Point (A26118), Port MacDonnell (A24073), and Cape Jaffa (A26007) after 317, 1355, 1637, 1665 days respectively. These were released as juveniles in Portland Bay and recaptured as 29-50cm TL fish in eastern South Australia. The six Tbar tagged fish that moved east were recaptured as 38-48cm TL fish in Port Phillip Bay near Queenscliff (1036 and 1412 days), Sandringham (981 and 1695 days), and Altona (942 days).

The longest period at liberty for a snapper tagged and recaptured in Portland Bay was 2782 days. This snapper was released at 19cm (FL) and was recaptured at 38cm (FL). Tagged snapper moving from Portland to eastern South Australia were recaptured after 317-3552 days at liberty at sizes ranging between 27-63cm (FL). The shortest period at liberty for a snapper tagged in Portland Bay and recaptured in Port Phillip Bay was 595 days, but this snapper was released at a larger size (32cm FL).

The mean displacement of snapper that were released as juvenile fish (16-24cm FL) in Portland Bay was less than 15km for the first two years at liberty. There is further evidence of residential behaviour of immature fish in Portland Bay from multiple recaptures of the same tagged snapper near their release location and the relatively low number of recaptures in other areas along the west coast (eg Warrnambool 96 km to the east). In comparison to immature fish, the mean displacement of mature fish was greater at 94km, 36 km and 99km for 4, 5 and 6 year old fish, respectively. There are many examples of movements from Portland into Port Phillip Bay (> 430 km), such as recaptures at Altona (942 days; 42cm TL), Fawkner Beacon (981 days; 45cm TL), Point Lonsdale Bight (1036 days; 38cm TL) and Werribee (1360 days, 51 cm TL. One moved further east and was recaptured off Cowes in Westernport Bay after 1691 days (45cm TL). The mean displacement increased to 379 km for fish estimated to be more than 7 years old. Tagged snapper that were released at a larger size (25-36cm FL) had a similar pattern of dispersal with a low mean displacement (< 40km) until they were more than 7 years old when the mean displacement increased to 306 km.



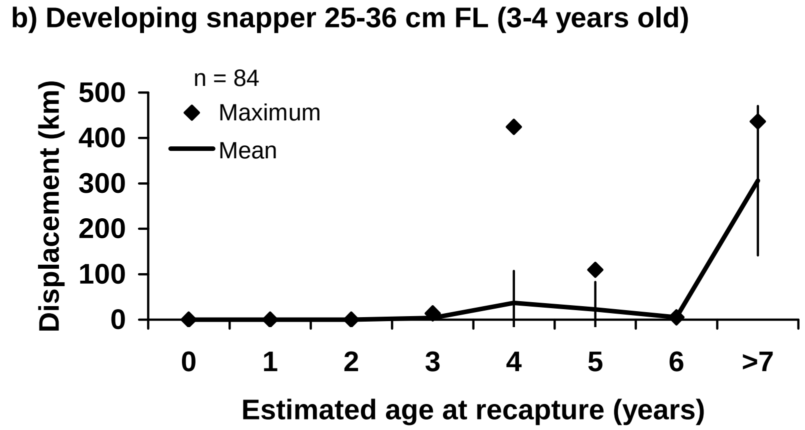


Figure 19. Mean and maximum displacement of recaptured tagged snapper released in Portland Bay as juveniles (18-24cm FL) and developing fish (25-36cm FL) between 1957-1999. Vertical bars show the 95% confidence intervals for the mean displacement.

Mean time at liberty of western snapper moving between regions

The mean time at liberty for tagged snapper that moved between regions is shown in Figure 20. For west coast snapper that were recaptured within the release region, the mean time at liberty was less than a year, whereas Port Phillip Bay snapper remained for nearly 2 years. The dispersal pattern is indicated by the increasing mean time at liberty for snapper that moved between regions. For snapper that moved from Port Phillip Bay to the west coast and into Westernport Bay, the mean time at liberty was between 2-4 years. For snapper that moved to eastern South Australia from Port Phillip Bay and Portland Bay, the mean time at liberty was greater at between 4-5 years. Generally, it took much longer for Portland snapper to move west, reaching Port Phillip Bay on average after 8.5 years.

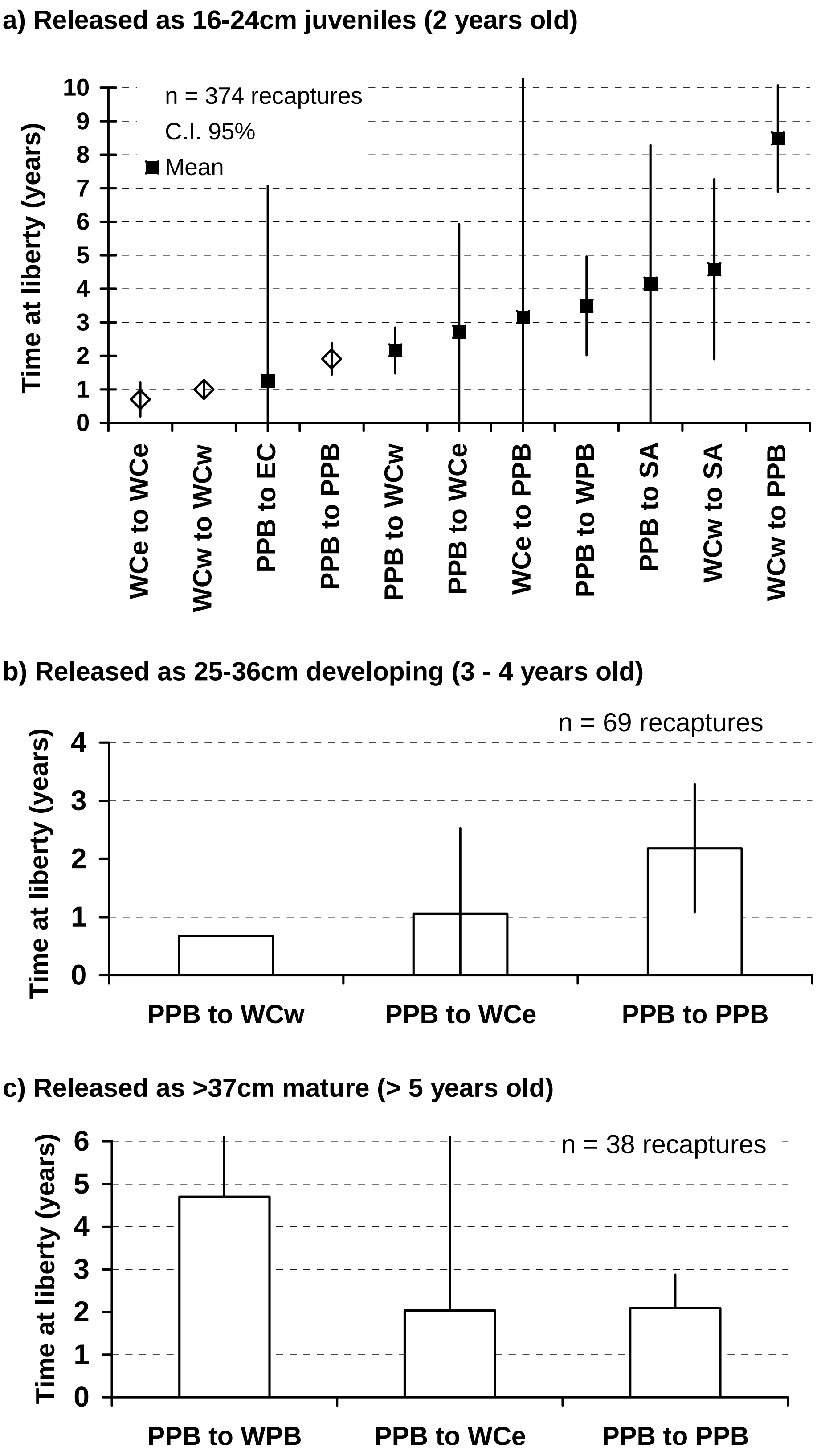
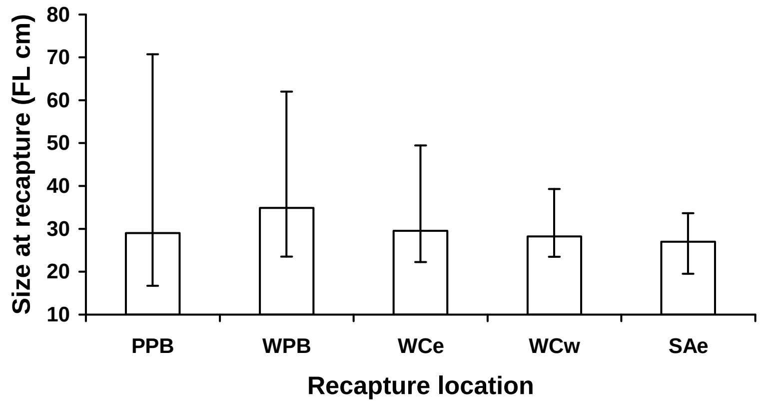


Figure 20. Mean time at liberty and 95% C.I. of tagged snapper released between 1959-2000 with displacement between regions. Movements between regions shown by closed squares and no movement between regions shown by open diamonds.

Mean, maximum and minimum size at recapture of western snapper in each region

The mean size at recapture of Port Phillip Bay snapper was similar in all regions because most of the fish released were juveniles 16-24cm and were recaptured within a few years. However the maximum size of fish recaptured in South Australia (SAe) and Portland Bay (WCw) was much lower than the fish recaptured further east in Port Phillip Bay and Westernport Bay (Figure 21). These results are consistent with an eastward movement of larger fish returning to Port Phillip Bay and Westernport Bay.

a) Juvenile snapper (16-24cm FL) released in Port Phillip Bay



b) Juvenile snapper (16-24cm FL) released in Portland Bay

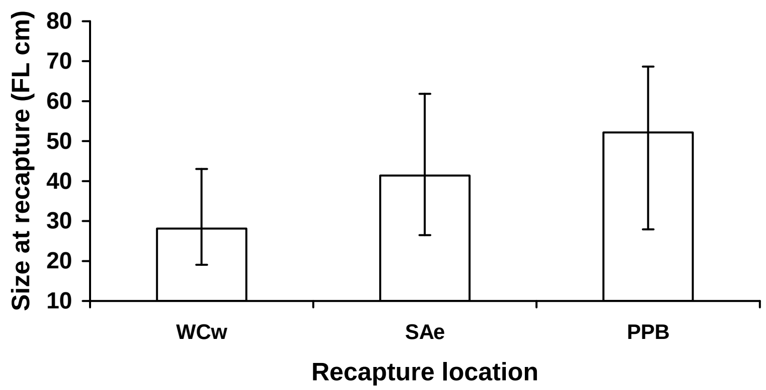


Figure 21. Mean size of recaptured tagged snapper by recapture location. Bars show the maximum and minimum sizes at recapture.

Dispersal of the eastern snapper stock by location of release

The recaptures of tagged snapper from Mallacoota Inlet with time at liberty are shown in Figure 22 and Figure 23. In comparison to the western snapper stock, dispersal of eastern snapper was more rapid and extensive with the majority moving north east along the coast of NSW. Generally, there was greater dispersal of snapper released in Mallacoota Inlet than those released in the coastal waters near Port Welshpool.

a) Port Welshpool (EC w)

For the first time, recaptures of 17 tagged snapper released outside Corner Inlet show the movement pattern of snapper from the western region of east Victoria. Only two dart tagged snapper were recaptured and these remained in eastern Victoria moving from Seapray to Rabbit Island and Lakes Entrance after 143 days and 751 days respectively. The fish (MC5404) that moved east was 30cm TL when released near Seaspray in March 1998 and it was recaptured to the east of Lakes Entrance in April 2000.

From the 15 Tbar recaptures, 67% were recaptured close to their release sites (38^{o} S), while one was recaptured to the east in Victoria off Lakes Entrance (7%). This fish (MC2771) was 32 cm TL when released near Woodside in February 1998 and had grown to 39cm TL when it was recaptured near Lakes Entrance after 746 days. Four Tbar tagged fish have been recaptured along the coast of NSW (26%) near Terrigal (33^{o} S), Montague Island (36^{o} S), Evans Head (29^{o} S) and Forster (32^{o} S) after 165, 415, 469 and 676 days, respectively.

These recaptures indicate that juvenile snapper (20-25cm FL) released near Woodside, Seaspray, Reeves beach, McLaughlins beach at the western end of the 90 mile beach generally moved less than 50km from their release location in the first 12 months at liberty. Some of the larger fish released at sizes of between 28-33cm also remain in the region and two (MC2675, MC2791) were recaptured after more than 1000 days as mature fish (6+ years old). The two recaptures off Lakes Entrance after 25 months indicate that some mature 5+ fish disperse along the east coast and these may spawn locally during summer in eastern Victoria. However, those that moved north east may spawn in winter along the NSW coast.

b) Mallacoota Inlet (EC e)

There were 70 recaptures (6.7%) of the 1040 internal tagged snapper released in Mallacoota Inlet during 1959. So far, there have been 32 recaptures (3.2%) of the 998 internally tagged snapper released during 1999. Compared to 1959, recapture rates of snapper were slightly lower in 1999 with 5.6% and 0.8% recaptured from releases in March and April 1999, respectively. Those released in 1999 were detected sooner at latitudes of 31-32^{o} and 29-30^{o} than in 1959.

After more than one year at liberty, all the recaptures of internally tagged snapper released in 1959 were reported from the NSW coast between 38^{o} to 29^{o} South. The same northward dispersal pattern was evident from those released in 1999. Four recaptures within Mallacoota Inlet (37^{o} S) showed that not all the fish dispersed during the first year. Subsequently nearly all of the recaptures (96%) were reported from the NSW coast after more than a year when fish had grown to >30cm. Recaptures were reported from the NSW coast near Batemans Bay (35 ^{o} S) and Jervis Bay (35^{o} S) after 295–371days.

The greatest northward movement was a snapper (NES 2317) that was recaptured at a size of 30cm (TL) off Coffs Harbour, NSW 30^{o} S. It had grown by 10 cm over a period of 919 days. The longest time at liberty was 1424 days for a snapper (NES 2188) recaptured at Eden, NSW (37^{o} S).

The first westward movement of an eastern snapper was indicated by the recapture of a 38cm TL fish (NES 1518) at McGaurens beach near Seaspray. The fish was 38cm when recaptured and had grown by 16.0 cm over a period of 697 days. This shows that there is a low level of mixing between regions within eastern Victoria and that not all Mallacoota snapper move northwards along the NSW coast.

The mean and maximum displacements of recaptures of juvenile snapper (15-23cm FL) indicated that there were much larger movements of these small fish during their first year at liberty compared with those released in other regions (Figure 24). For instance, a recapture near Broughton Island (32 ^{o} S) indicated a northward movement of 729 km in just 5 months. A recapture of a 26cm (FL) snapper off the Solitary Islands (30 ^{o} S) indicated a northward movement of more than 1000 km in two years and two months.

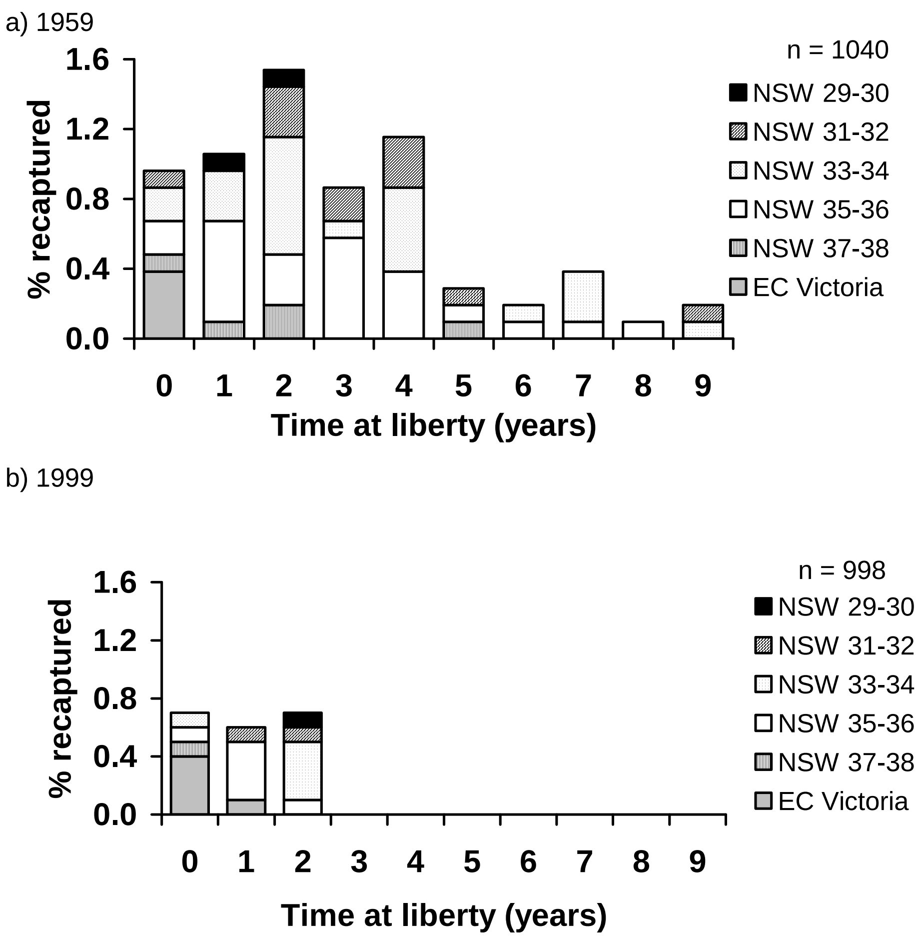


Figure 22. Internal tag recaptures with time at liberty for snapper released in Mallacoota Inlet in 1959 and 1999. Recaptures (%) are based on the number of tagged fish released (n) for each period and are shown by degrees of latitude along the NSW coast.

The mean distance moved increased each year for the first three years from 178 km during the first year at liberty to 212 km (near Moruya Heads 36^o S), 414 km (near Kiama 34^o S) and 501 km (near Sydney) over the next three years. There was no further increase in the mean or maximum displacement of the larger and older fish and subsequent recaptures were reported from between Coffs Harbour (1100 km, 30^o S) to Bermagui (158 km, 36^o S). The longest time at liberty was more than 17 years (6224 days). This internally tagged fish was released at 18cm FL in Mallacoota Inlet (37^o S) and was recaptured off Bermagui having grown to 62cm (FL).

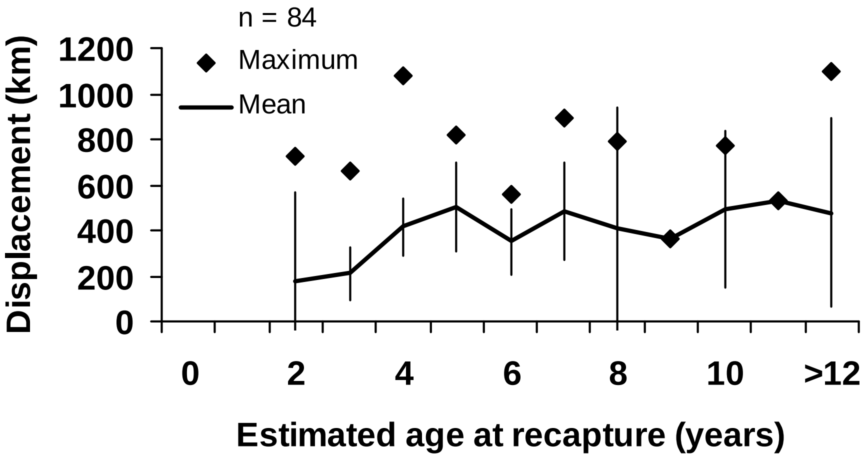


Figure 23. Displacement of recaptured tagged snapper released in Mallacoota Inlet Bay as juveniles (16-24cm FL) between 1959-1999. Vertical bars show the 95% confidence intervals for the mean displacement.

Tag retention experiments

Experiment 1

The first experiment lasted for 1281 days and was conducted between 5/11/1998 to 9/5/2002.

Internal tags

There was a high initial mortality with 4 of the 20 internally tagged fish dying after 45 days due to cormorant predation (2), tagging wound (1) and infection/formaldehyde treatment (1). After transfer to on–site tanks, the mortality rates were lower. By the end of the experiment after 1281 days, 7 internally tagged fish remained alive, 8 tagged fish had died and 5 internal tags that had been shed were found at the bottom of the tank.

Dart tags

There was a high initial mortality with 2 of the 10 dart tagged fish dying after 34 days due to cormorant predation and a further two tags were shed on transfer between the seacages and on–site tanks. After transfer to on–site tanks, the mortality rates were lower, but 3 tags were shed after 34, 84 and 245 days. At the end of the experiment after 1281 days, 2 dart tagged fish remained alive, 2 tagged fish had died and 6 dart tags were shed.

T bar tags

There was a low initial mortality with none of the 10 T bar tagged fish dying after 34 days. Tag shedding rates were higher than the other types of tags. At the end of the experiment after 1281 days, only 1 T bar tagged fish remained alive, 1 tagged fish had died and 8 T bar tags were shed.

Experiment 2

The second experiment lasted for 464 days and was conducted between 5/11/1998 to 10/2/2000.

Internal tags

There was a high initial mortality with 4 of the 20 internally tagged fish dying after 45 days due to cormorant predation and infection/formaldehyde treatment. After transfer to on–site tanks, there was no further mortality. At the end of the experiment after 464 days, 11 internally tagged fish remained alive, 4 tagged fish had died and 5 tags were shed.

Dart tags

There was a high initial mortality with 3 of the 10 dart tagged fish dying after 34 days due to cormorant predation and transfer between the seacages and on–site tanks. After transfer to on–site tanks, there was no further mortality, but shedding rates were high. At the end of the experiment after 464 days, 1 dart tagged fish remained alive, 3 tagged fish had died and 6 dart tags were shed.

T bar tags

There was a high initial mortality with 3 of the 10 T bar tagged fish dying after 34 days. At the end of the experiment after 464 days, 3 T bar tagged fish remained alive, 5 tagged fish had died and 2 T bar tags were shed.

Experiment 3

The third experiment lasted for 1129 days and was conducted between 6/4/1999 to 9/5/2002.

Internal tags

There was a low initial mortality with 1 of the 26 internally tagged fish dying after 57 days. At the end of the experiment after 1129 days, 11 tagged fish remained alive, 9 tagged fish had died and 6 tags were shed.

Dart tags

There was a low initial mortality with 1 of the 26 dart tagged fish dying after 26 days. At the end of the experiment after 1129 days, 4 dart tagged fish remained alive, 8 tagged fish had died and 14 dart tags were shed.

T bar tags

There was a low initial mortality with 1 of the 26 T bar tagged fish dying after 61 days. At the end of the experiment after 1129 days, 10 T bar tagged fish remained alive, 10 tagged fish had died and 6 T bar tags were shed.

Experiment 4

The fourth experiment lasted for 312 days and was conducted between 6/4/1999 to 12/2/2000. The experiment was concluded because all the fish died when the water pumps malfunctioned.

Internal tags

There was some initial mortality with 3 of the 27 internally tagged fish dying after 57 days. At the end of the experiment after 312 days, 16 internally tagged fish remained alive, 7 tagged fish had died and 4 internal tags were shed.

Dart tags

There was some low initial mortality with 2 of the 26 dart tagged fish dying after 16 days. Initial tag shedding rates were high with 6 tags shed after 8 days probably due to poor tagging techniques by inexperienced taggers. At the end of the experiment after 312 days, 9 dart tagged fish remained alive, 6 tagged fish had died and 11 dart tags were shed.

T bar tags

There was a low initial mortality with 1 of the 26 T bar tagged fish dying after 16 days. At the end of the experiment after 312 days, 13 T bar tagged fish remained alive, 4 tagged fish had died and 9 T bar tags were shed.

Tag retention models

Tag retention of dart tags and internal tags was higher than for T bar tags. The data from the four experiments and the models for estimating the number of fish alive with retained tags are shown in Figure 25. Although there was some variation in the number of tagged fish alive between the four experiments, the results from each tank were consistent. Tag retention data was collected for more than 3.5 years and the duration of the experiments reflect the time at liberty for most of the tag recaptures.

The parameters of the tag retention models are given in Table 12. The model of T bar tag retention shows that only 54% of the tags were retained after a year and there was an exponential decline to 31% after 2 years, 18% after 3 years and 10% after 4 years. In comparison, the model of dart tag retention was 72% retained after a year, 52% after 2 years, 37% after 3 years and 27% after 4 years. Internal tags also performed well and tag retention was 63% after a year, 47% after 2 years, 35% after 3 years and 26% after 4 years.

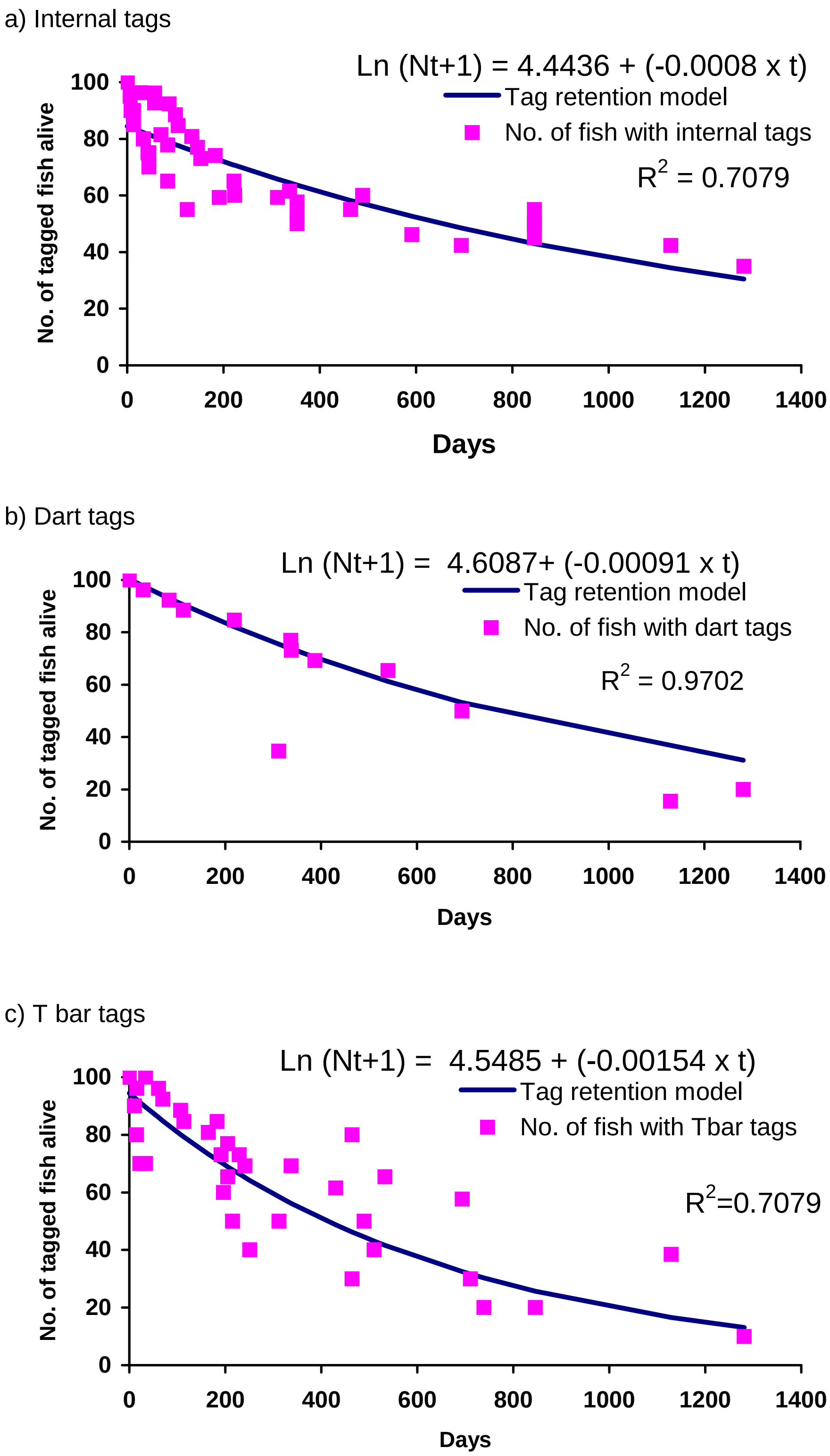


Figure 24. Tag retention models for internal, dart and T bar tags showing data points from four experiments of captive snapper.

Table 12. Tag retention models for internal, dart and Tbar tags derived from linear regressions. Ln(Nt+1) = a + (b x t) time in days.

Tag type	df	a	S.E.a	b	S.E.y	r^2
Internal	41	4.4436	0.0279	-0.0008121	0.1385	0.71
Dart	8	4.6087	0.0198	-0.0009145	0.0388	0.97
Tbar	34	4.5485	0.0592	-0.0015000	0.2435	0.70

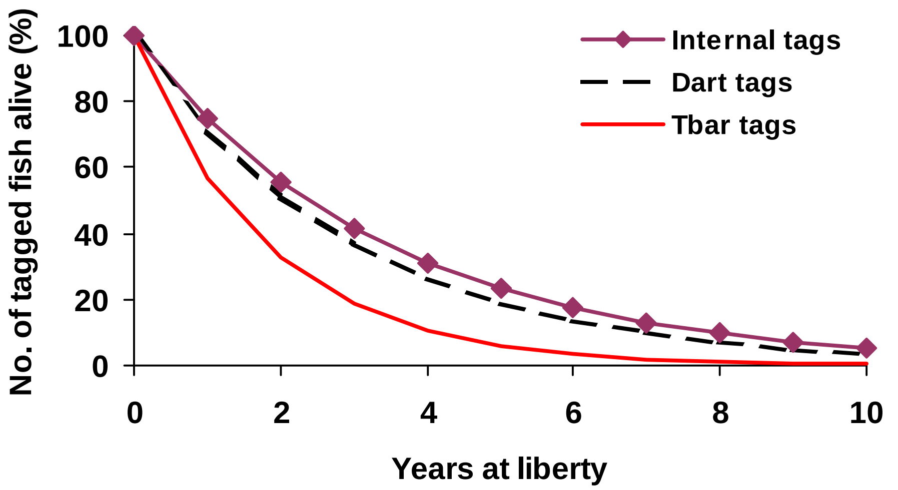


Figure 25. A comparison of tag retention models for internal, dart and T bar tags applied to captive snapper.

Environment and recruitment relationships

Trends in environmental data

Since the 1960s and 1970s, there has been a marked change in the el Niño (negative SOI) and la Niña (positive SOI) cycles. Compared to the 1960s and 1970s, negative SOI values have become much more frequent and persisted for longer periods (Figure 26). The weather conditions associated with La Niña were less common and positive values of the SOI were often relatively low and of short duration when they occurred during the 1980s and 1990s. These changes in the global climate have affected the annual and seasonal patterns of wind, rainfall, river flow and coastal waters in south-eastern Australia (Harris *et al*. 1988; Hsieh *et al*. 1991).

There was a marked reduction in the number of days with zonal westerly winds during the 1980s and the lowest values in 1987 and 1989 (Figure 27). During the early 1990s, the number of zonal westerly wind days increased reaching a peak of 103 days in 1994, but this was followed by a sharp drop to less than 10 days in 1998 and 1999. The seasonal rainfall pattern was highly variable during the 1990s (Figure 28). The three seasonal peaks in the mean monthly rainfall in May, August and December varied from year to year with differences in the amount of rain falling and the month of maximum rainfall. In several years, more than twice the monthly average rainfall occurred during the seasonal peak, whereas rainfall was very low between 1994-95.

River flows into northern Port Phillip Bay have increased since the 1980s from less than 500 GL between 1980-88 to more than 800 GL in 1993, but have fluctuated greatly with low flows in 1994, 1997 and 1998 and high flows in 1996 (Figure 29). Between 1990-94, the seasonal peak in the river flow occurred in September-October but the seasonal pattern was different in 1995 and 1996 with high river flows during June-August and April-September. In 1992 and 1993, September river flows were almost twice the average, but in 1994 the September river flow was minimal (Figure 30). High river flows were closely associated with peaks in primary production indicated by levels of chlorophyll in Port Phillip Bay (Figure 31) and reduced salinity (Figure 32).

The seasonal cycle in the water temperature in Port Phillip Bay fluctuated between 10 and 24 ^{o}C (Figure 33). There was much lower annual variation in the seasonal pattern of water temperature compared to rainfall and river flow. The difference between monthly water temperatures and the mean monthly water temperature varied by just a few degrees. In the years when river flow was high (e.g. 1993, 1994 and 1997), the water temperature was 1-2 ^{o}C below the 14 year mean. There was a decreasing trend in water temperatures from 1989 to 1997 and there were lower water temperatures in 1991, 1995 and 1996. During the late 1980s, the water temperature was up to 2.0 ^{o}C warmer in Port Phillip Bay (Figure 34), whereas water temperatures were 1.5 to 2.0 ^{o}C below the average in November and December 1995. Although water temperatures remained below the average throughout 1995/96, water temperatures were more than 1 ^{o}C higher than the average in January 1996.

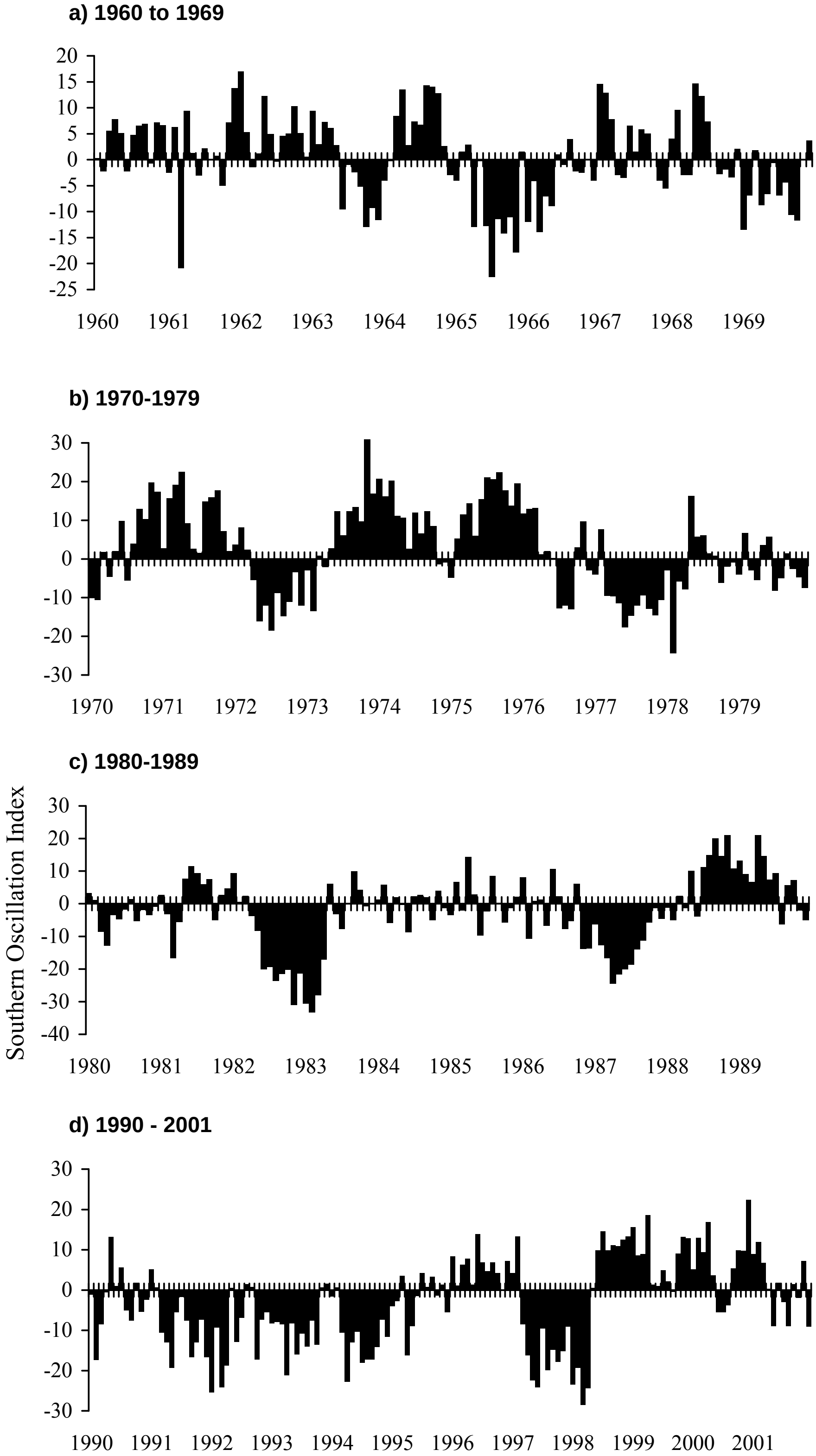


Figure 26. Monthly and annual values of the Southern Oscillation Index between 1960 and 2001.

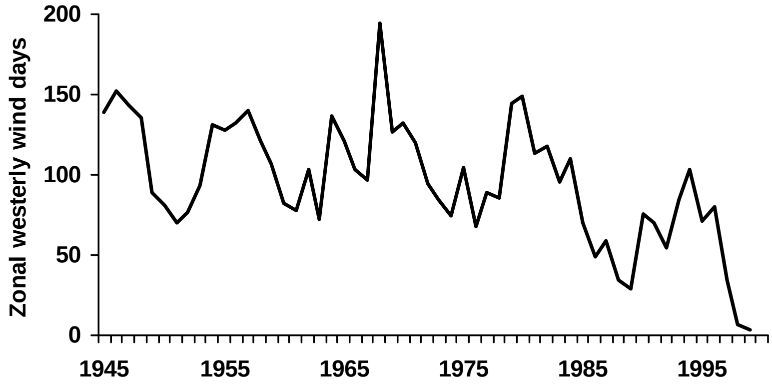


Figure 27. Trends in zonal westerly winds between 1945 – 2000

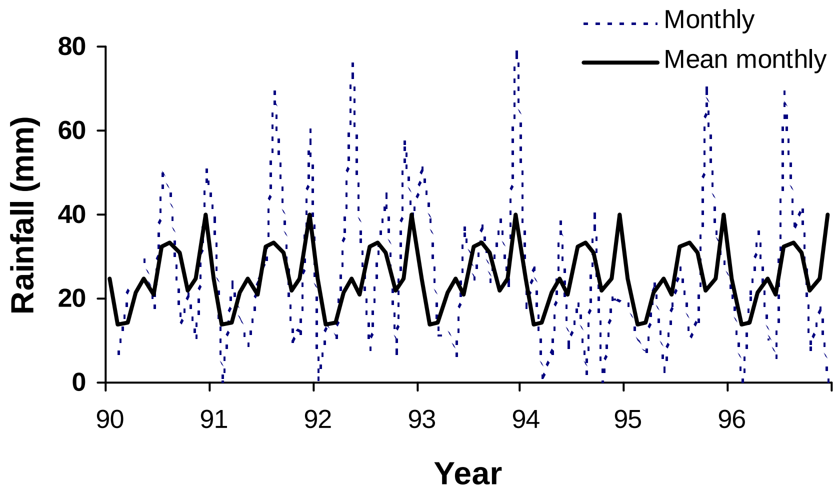


Figure 28. Mean and monthly rainfall at Queenscliff between 1990-1997

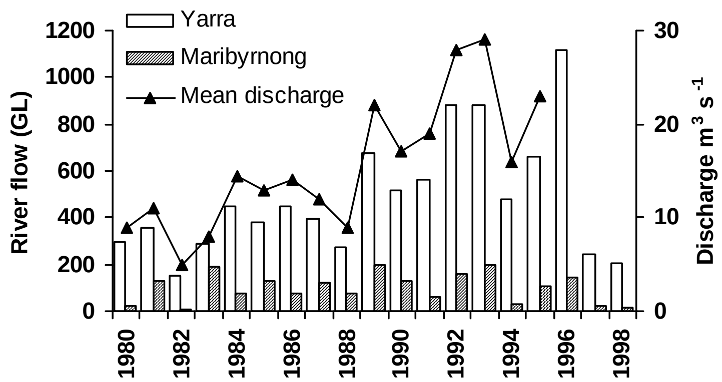


Figure 29. Annual flow and mean discharge of the Yarra and Maribyrnong rivers into Port Phillip Bay between 1980 and 1998.

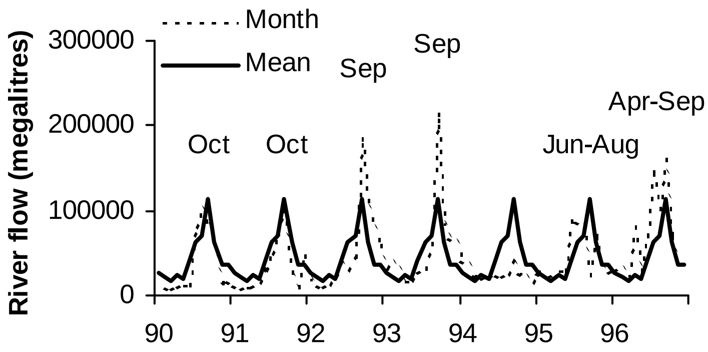


Figure 30. Monthly Yarra River flow into Port Phillip Bay and periods of high flows between 1990-1996

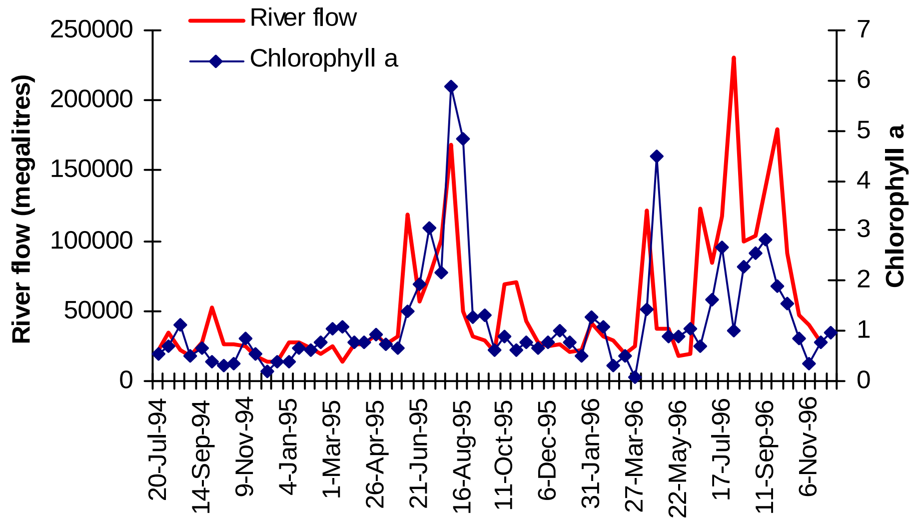


Figure 31. Relationship between the Yarra River flow and chlorophyll a concentration at Wooley Reef near Frankston in eastern Port Phillip Bay between 1994-96.

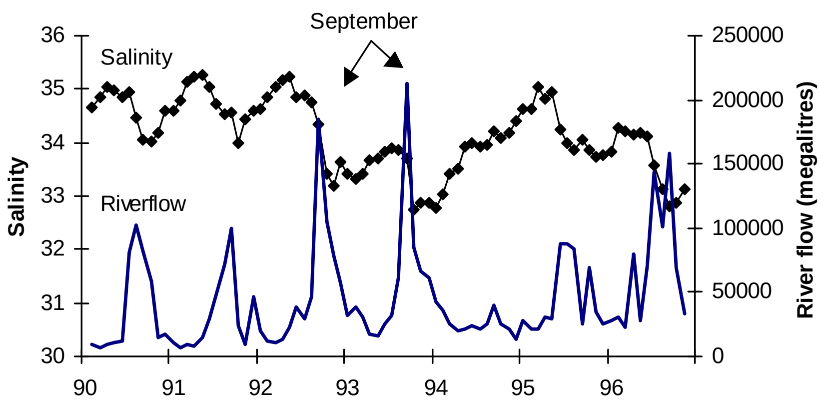


Figure 32. Relationship between the Yarra River flow and salinity at Wooley Reef near Frankston in eastern Port Phillip Bay during 1990-96.

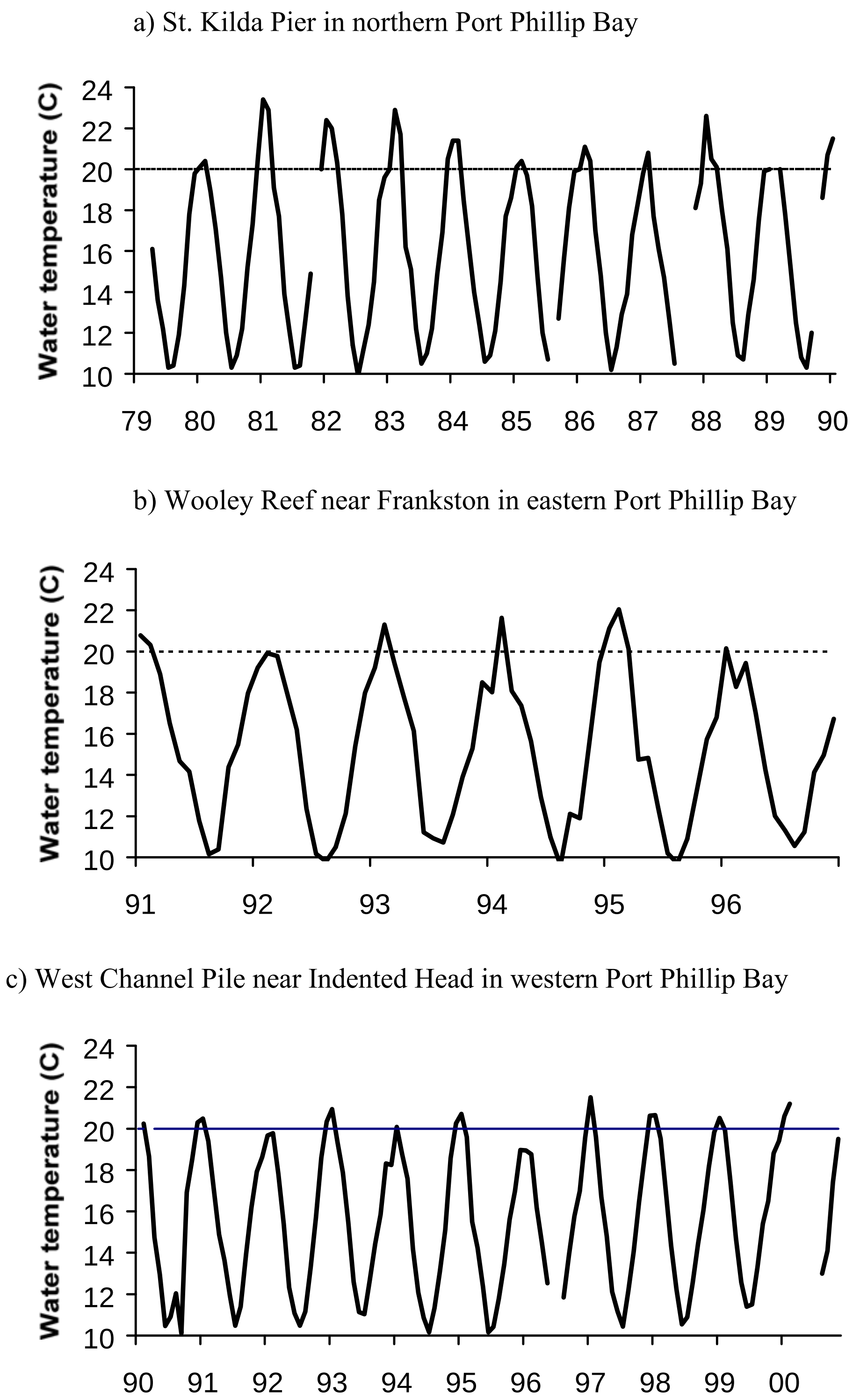


Figure 33. Mean monthly surface water temperatures in Port Phillip Bay at three locations between 1979 and 2000.

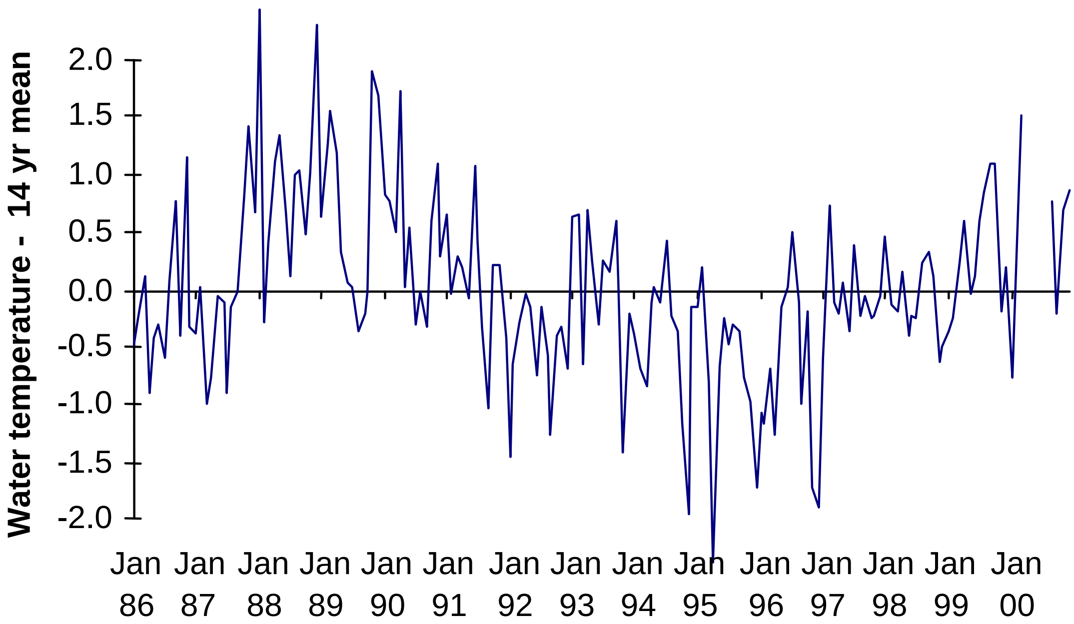


Figure 34. The difference between the mean and monthly water temperature in Port Phillip Bay between 1986-2000

Trends in snapper recruitment

a) Trawl survey data analyses

Weighted length-frequency distributions for snapper from the trawl surveys are shown in Figure 35 and Figure 36. Fork lengths ranged from 4 to 71 cm, but only lengths up to 45 cm FL are shown as 89-100% of fish caught fell within this range. Generally clear modes at 4-12 cm FL and 13-20 cm FL were observed in each survey. Age reading from sectioned otoliths indicated that these modes corresponded with the 0+ and 1+ year classes, respectively. However, the 0+ mode was absent from 1997 and 1999 surveys, and in 1994 0+ snapper were small at 4 cm FL. Occasionally a third mode 22-28 cm FL was observed and a few snapper greater than 30 cm FL were recorded during each survey.

Recruitment based on the abundance of 1+ snapper in trawl surveys between 1990 and 2000 was highly variable and between 1995 and 1996 changed by two orders of magnitude over successive years (Figure 37). High recruitment in Port Phillip Bay occurred in only two years and it was estimated that there were 3.5 million 1+ snapper recruited from spawning in 1995 and 4.7 million in 1996. Lower levels of recruitment occurred in 1993 (0.6 million) and in 1998 (1.0 million) and there was negligible recruitment from spawning in 1989, 1990 and 1994.

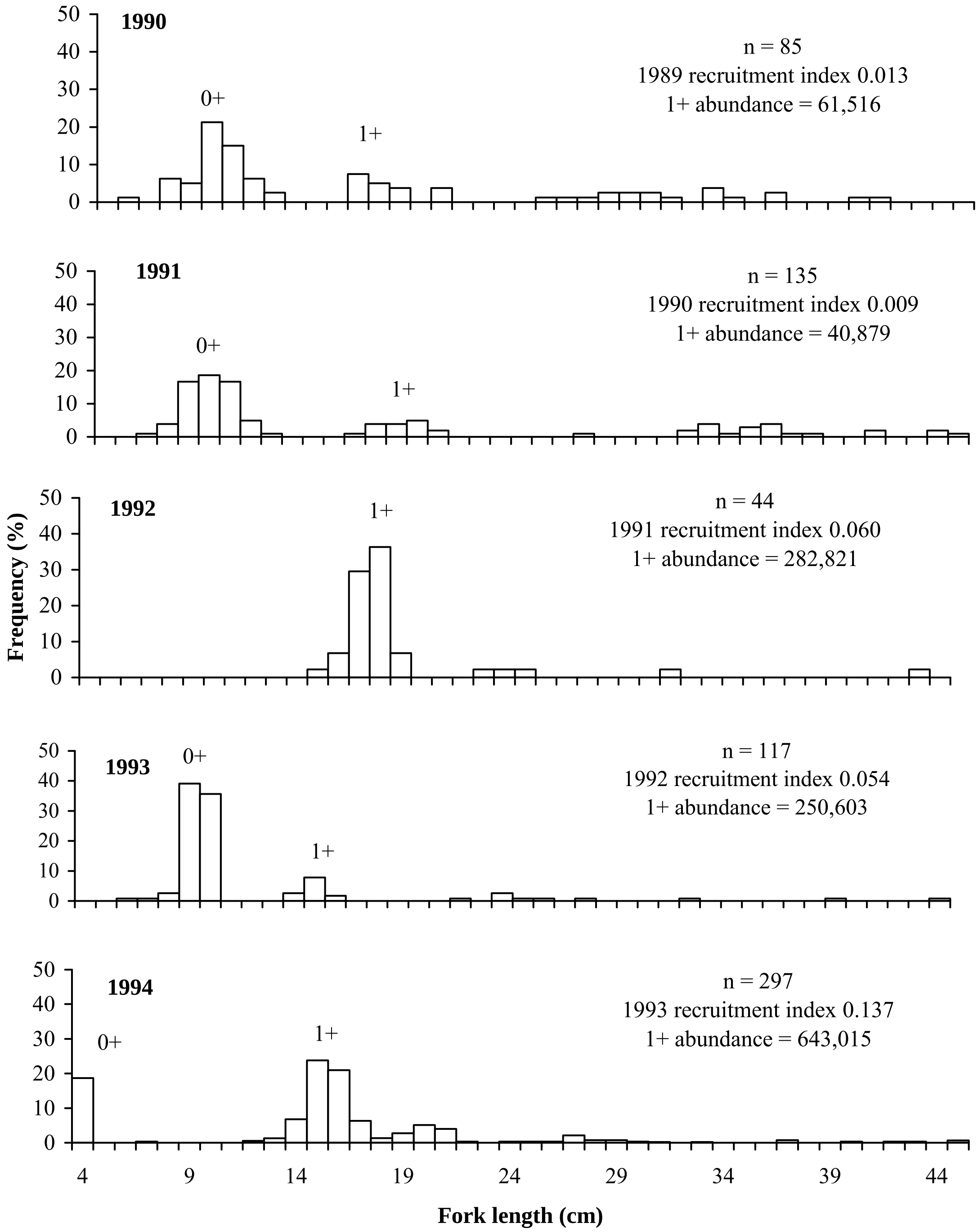


Figure 35. Length frequency of snapper sampled in trawl surveys of Port Phillip Bay during March between 1990 and 1994. The year of each survey is shown in bold and the recruitment index of 1+ snapper is shown by calender year.

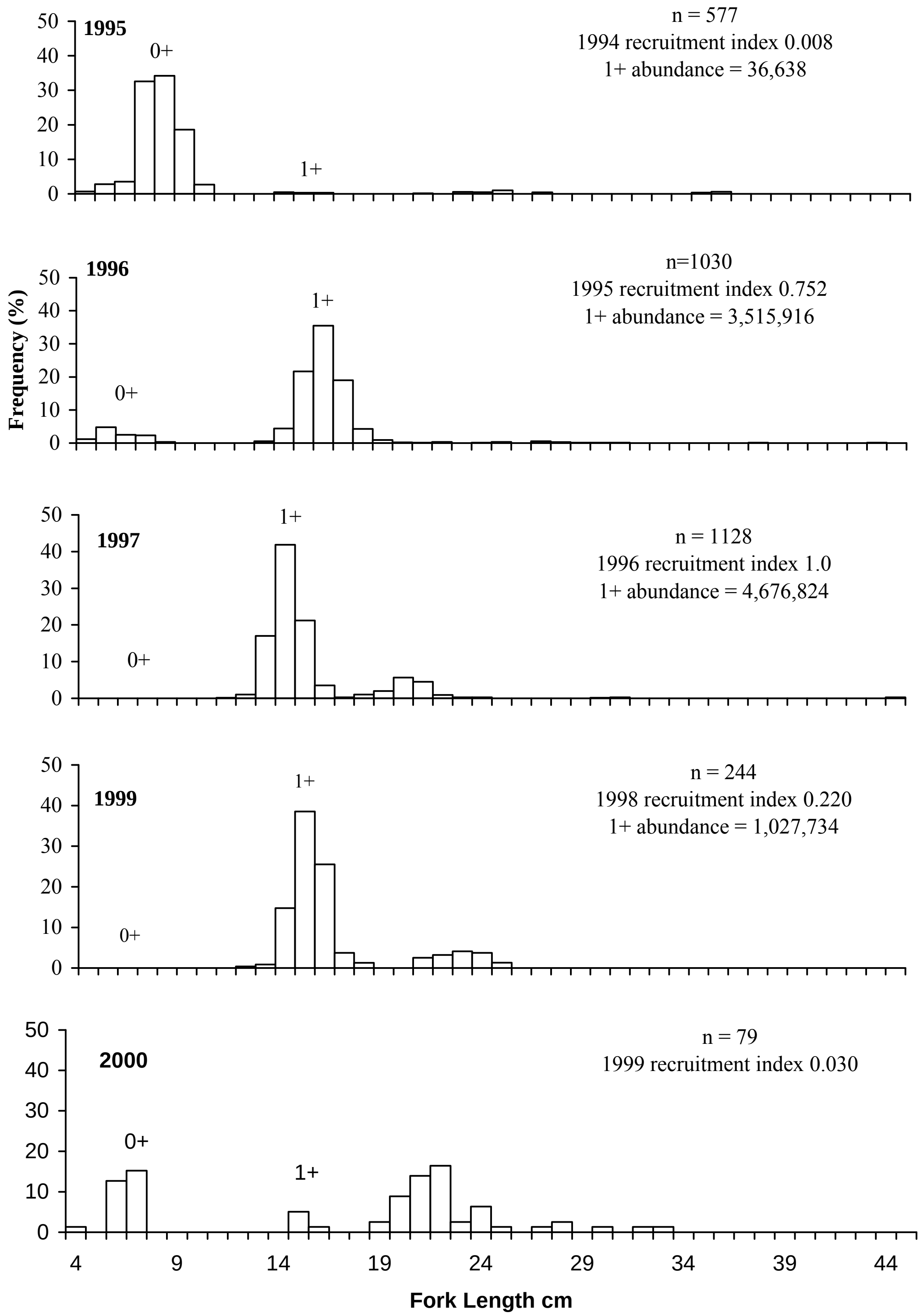


Figure 36. Length frequency of snapper sampled in trawl surveys of Port Phillip Bay during March between 1995 and 2000. The year of each survey is shown in bold and the recruitment index of 1+ snapper is shown by calender year. The trawl survey was not conducted in 1998.

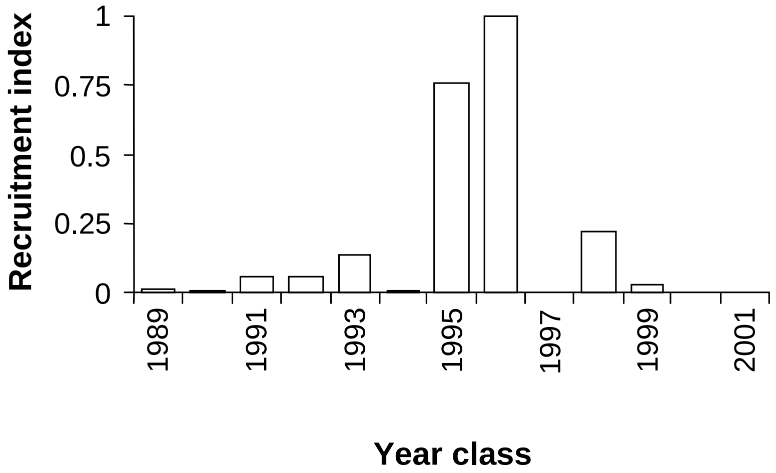


Figure 37. Recruitment index based on the abundance of 1+ snapper caught during trawl surveys in Port Phillip Bay between 1989-2000 relative to the numbers caught in 1996.

b) Length and age structure of snapper in the commercial catch

Length frequency distributions of snapper sampled from the commercial catch in Port Phillip Bay between 1993/94 and 1999/00 are shown in Figure 38 and Figure 39. Sizes ranged from 22 to 87 cm FL and the length frequency distributions were frequently bimodal. Ages of snapper in the commercial catch in Port Phillip Bay ranged from 2 to 32 years old, but the majority were between 4 and 18 years old (Figure 40). Four year classes were abundant in the age structure of samples collected between 1994 to 1998 (Figure 41). The relative year class strength of snapper in commercial catches showed that recruitment was high between 1980-83, 1985-86 and in 1991. Low relative year class strength occurred in 1987, 1988 and 1989.

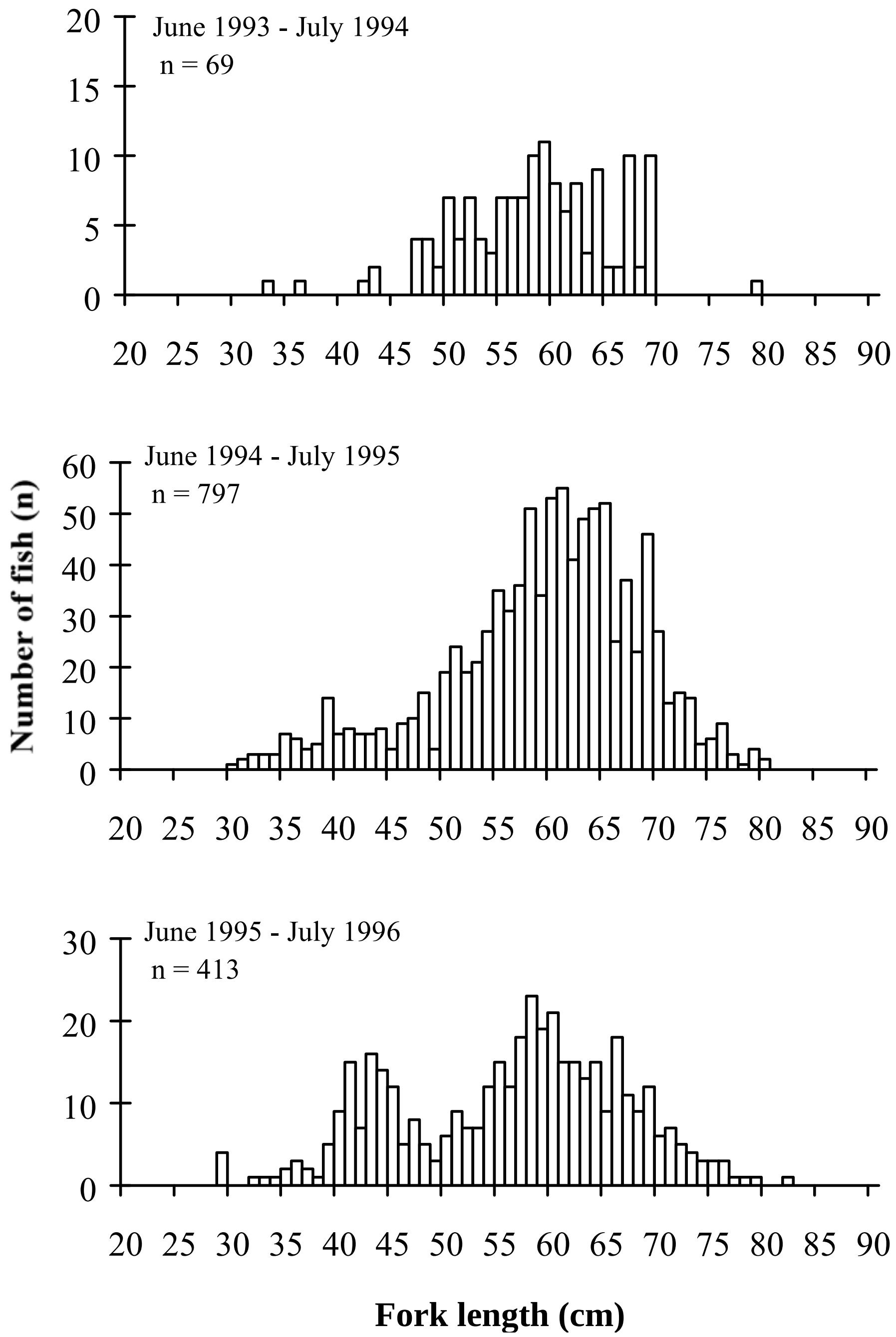


Figure 38. Length frequency of snapper from commercial long line catches in Port Phillip Bay between 1993/94 – 1995/96.

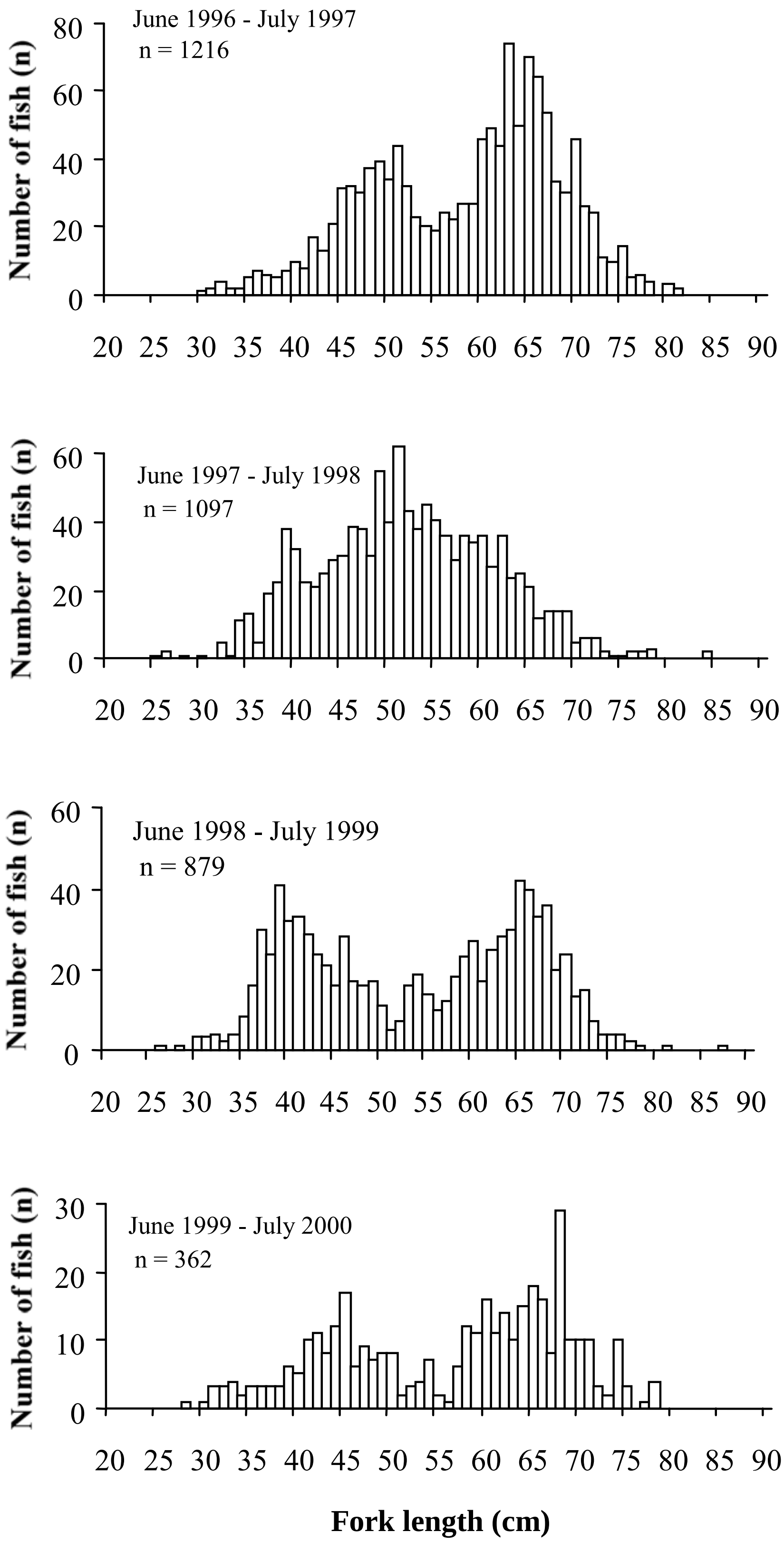


Figure 39. Length frequency of snapper from commercial long line catches in Port Phillip Bay between 1996/97 – 1999/00.

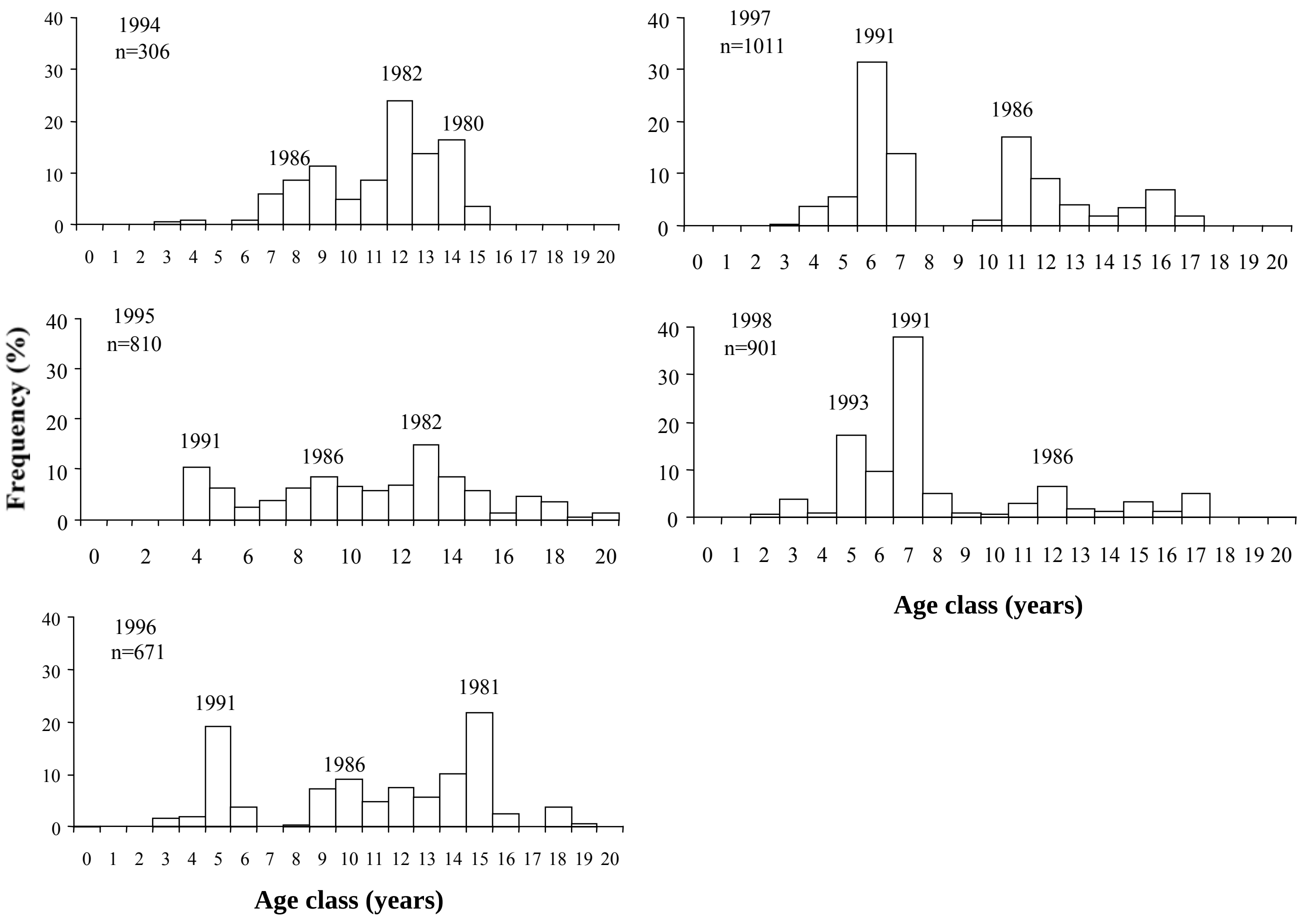


Figure 40. Age structure of snapper in commercial longline catches from Port Phillip Bay between 1994-1998

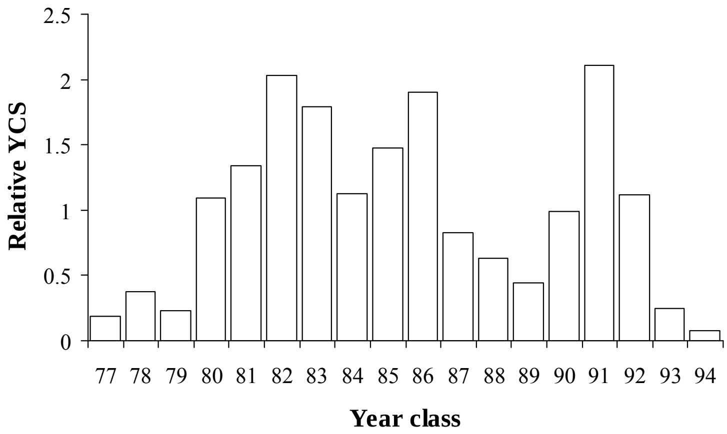


Figure 41. Relative year class strength of snapper in 1994-1998 based on the age structure in commercial catches in Port Phillip Bay. The relative YCS is the ratio of the YCS in each year to the average from all year classes between 1979-1994.

Environmental-recruitment models

During the late 1980s, when year class strength was low, the water temperature was up to 2.0 ^{o}C warmer in Port Phillip Bay. High year class strength in 1991, 1995 and 1996 was associated with much lower water temperatures. In November and December 1995, water temperatures were >1.5 ^{o}C below the average. Low river flows also occurred in 1994, 1997 and 1998 and were associated with low year class strength of snapper. High year class strength of snapper in 1994/95 and 1995/96 was associated with high river flows > 500 thousand megalitres. High recruitment in 1994/95 coincided with the peak in zonal westerly winds in 1994 and there was low recruitment during years when there were low zonal westerly winds (<60 days) between 1986-89 and 1998-99. Low recruitment in Port Phillip Bay during the early 1990s occurred when there was an extended period of negative SOI values between 1990-95. However, there was no clear relationship between snapper recruitment and the SOI.

The relationships between environmental variables and year class strength of snapper are given in Table 13 for models using trawl survey data. High river flows in April – June were correlated with high recruitment. The model with the highest regression coefficient was a linear regression of $\log_e$ (1+ snapper abundance) in trawl surveys and average fortnightly river flow between April and June in the 0+ year. This model explained 77% of the variability in year class strength between 1989-1998 (Figure 42). Average fortnightly river flows of between 40 to 60 thousand megalitres between April and June during 1995, 1996 and 1998 were correlated with recruitment of 1 to 5 million 1+ snapper in Port Phillip Bay in the following year.

A linear regression of $\log_e$ 1+ snapper abundance in trawl surveys and water temperature between April and June in the 0+ year explained 70% of the variability in year class strength between 1989-1998 (Figure 43). Average water temperatures less than 15 ^{o}C during April-June during 1995, 1996 and 1998 were correlated with high recruitment of 1 to 5 million 1+ snapper in Port Phillip Bay in the following year. Warmer temperatures were correlated with very low recruitment.

The environmental-recruitment models based on the age structure of commercial catches (Table 14) explained less of the variability in year class strength. These models predicted higher recruitment with warm November air temperatures and low river discharges in January and February. The models with the highest regression coefficients were based on November river flow and February rainfall in the 0+ year. These models explained 59% of the variability in the relative year class strength (Figure 44 and Figure 45). High snapper recruitment was correlated with low February rainfall (<20mm) and low November river flow (<50,000 megalitres). Low snapper recruitment was correlated with high February rainfall (>70mm) and high November river flow (>100,000 megalitres). Both models explained high year class strength in 1991 and predicted high recruitment in 1995. Similar models based on January and February river flow explained 57% and 54% of the variability in year class strength (Figure 46). There was a positive relationship between air temperature and year class strength, but this model only explained 33% of the variation in year class strength.

The long term trends in the frequency of westerly wind days and commercial catches 9 years later were similar (Figure 47). This period of time corresponds with the mean time at liberty of recaptured tagged snapper that moved between Portland and Port Phillip Bay. A regression model using zonal westerly wind days between 1968 to 1991 accounted for 64% of the variation in commercial snapper catches in Port Phillip Bay between 1977/78 and 2000/01. This model predicts that the commercial snapper catch will rise to a peak in 2003/04 and then decline to very low levels in 2007/08.

Table 13. Relationships between environmental variables in the 0+ year and year class strength of 1+ snapper based on trawl surveys between 1989 – 1999.

Environmental variable in the 0+ year	Regression equation	R^2
April - June river flow	$y = 0.000093\,x + 10.14$	0.77
Average April - June water temperature	$y = -2.97\,x + 57.51$	0.70
October temperature (pre-spawning)	$y = -1.8879\,x + 38.82$	0.58
April temperature	$y = -1.0511\,x + 30.78$	0.57
December temperature	$y = -1.0799\,x + 31.91$	0.57
February rainfall (mm)	$y = -0.0342\,x + 13.98$	0.38

Table 14. Relationships between environmental variables and year class strength from the abundance of +3 to +18 old snapper in commercial catches between 1994-1998.

Environmental variable in the 0+ year	Environmental- recruitment model	R^2
February rainfall	$y = -0.0260\,x + 0.4308$	0.59
November river flow of spawning season	$y = -2 \times 10^{-5}\,x + 0.6146$	0.59
January river flow	$y = -4 \times 10^{-5}\,x + 0.7902$	0.57
February river flow	$y = -5 \times 10^{-5}\,x + 0.6311$	0.55
November air temperature of spawning season	$y = 0.4046\,x - 9.0922$	0.33

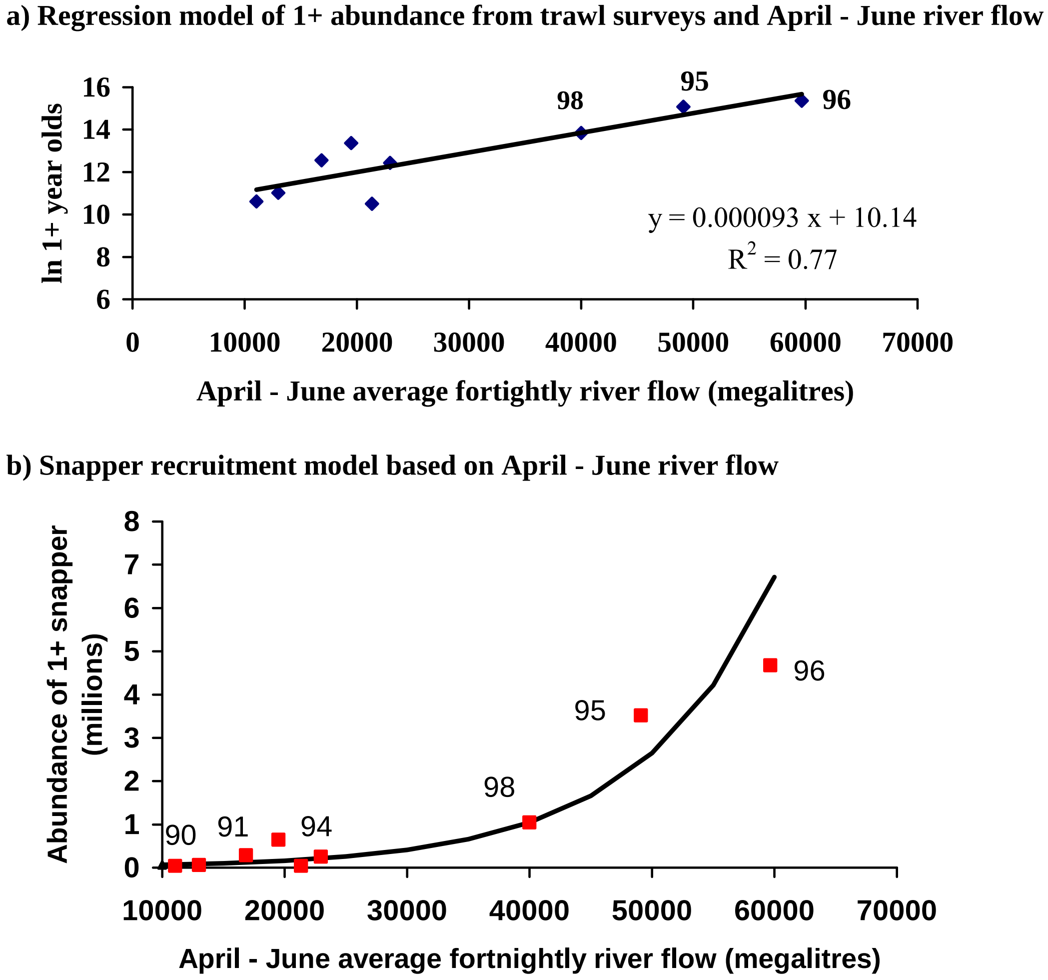


Figure 42. Snapper environment-recruitment model based on trawl surveys and autumn river flow into Port Phillip Bay during the 0+ year between 1989-1999

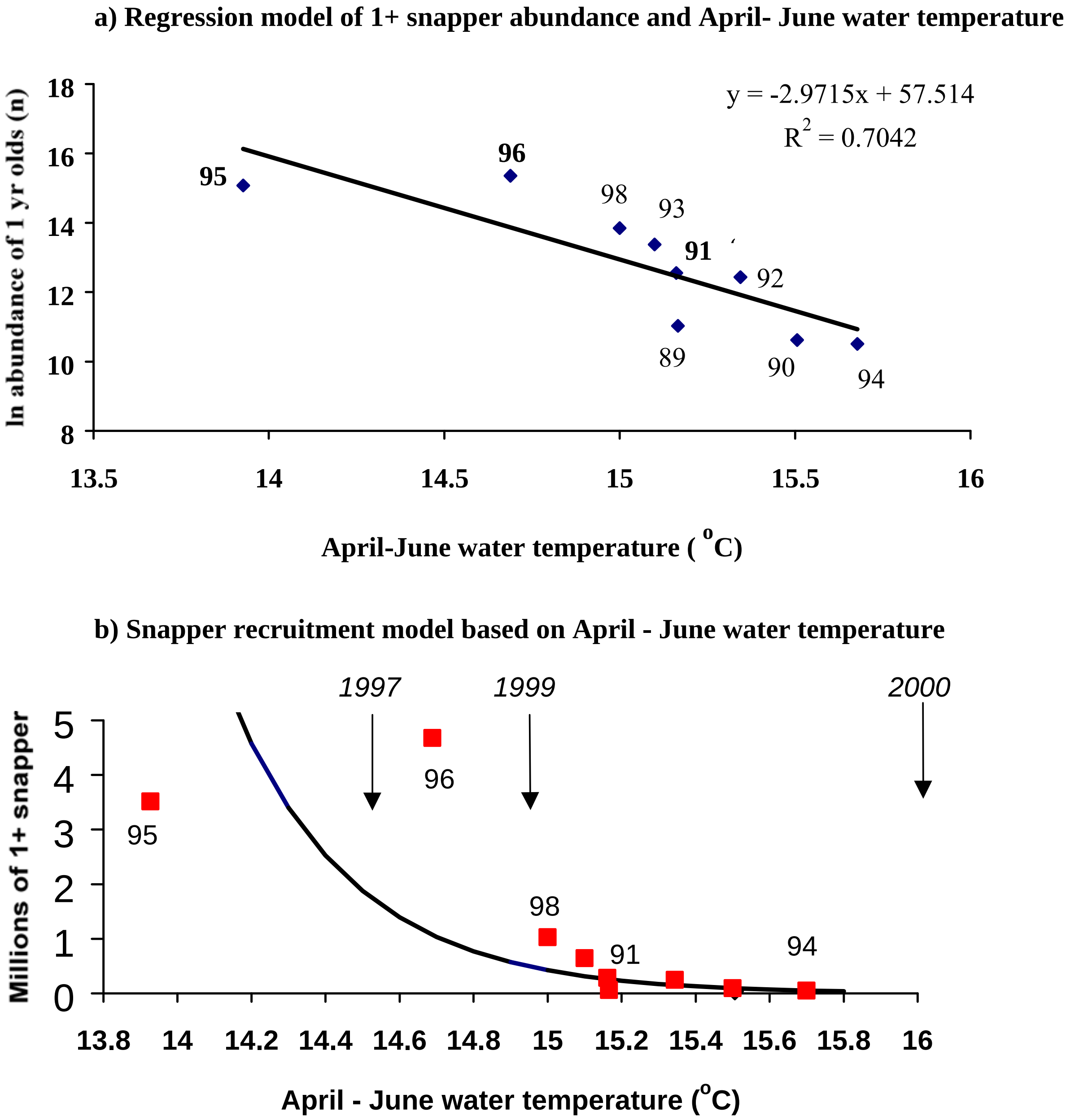


Figure 43. Snapper environment-recruitment model based on trawl surveys and surface water temperature in Port Phillip Bay during the 0+ year between 1989-1999. Arrows show measured water temperatures in 1997, 1999 and 2000

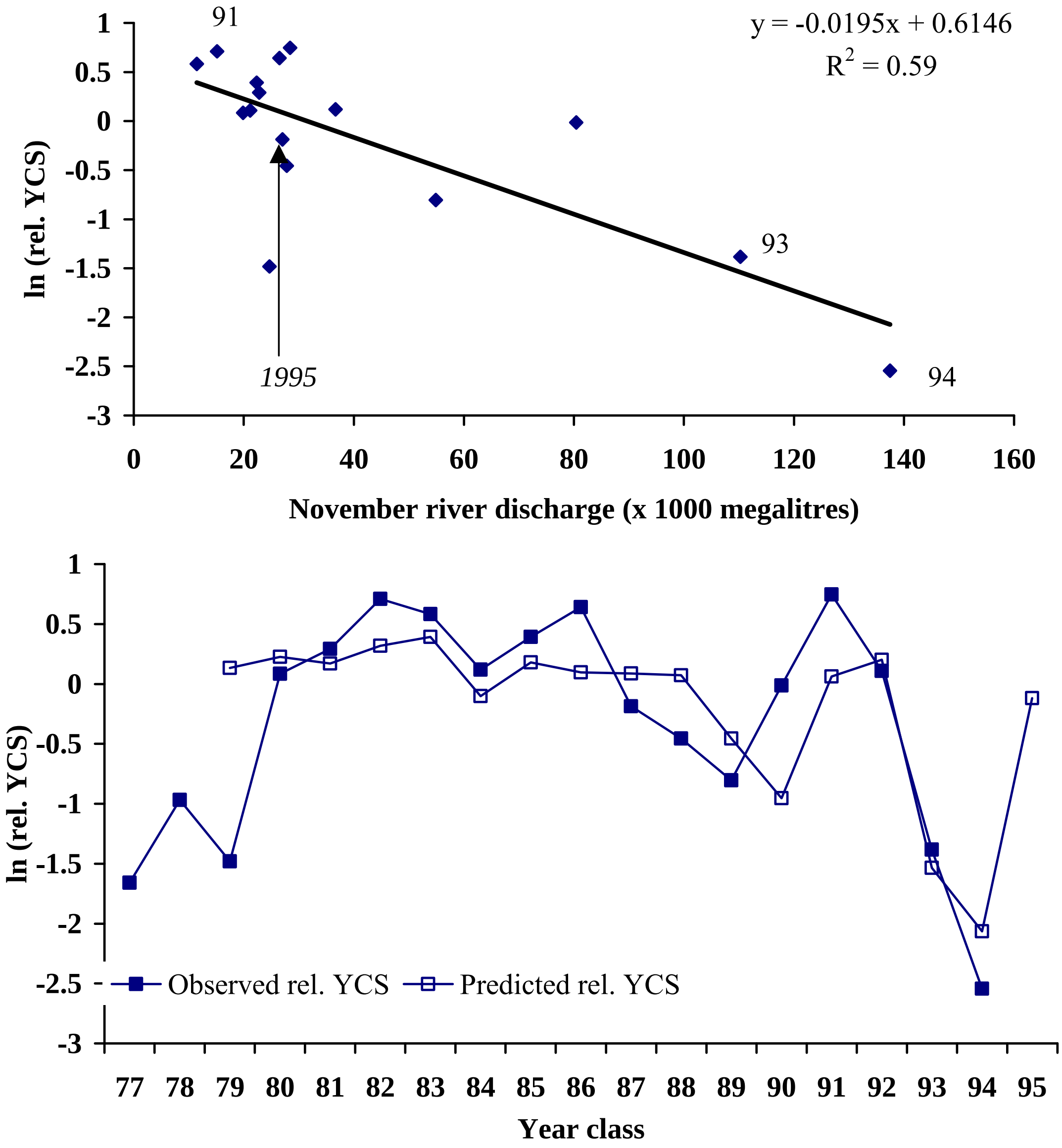


Figure 44. Environmental – recruitment model for snapper based on the age structure of commercial catches and November river flow in the 0+ year. Arrow shows river flow in 1995. High YCS (1991) and low YCS (1993 and 1994) are labelled.

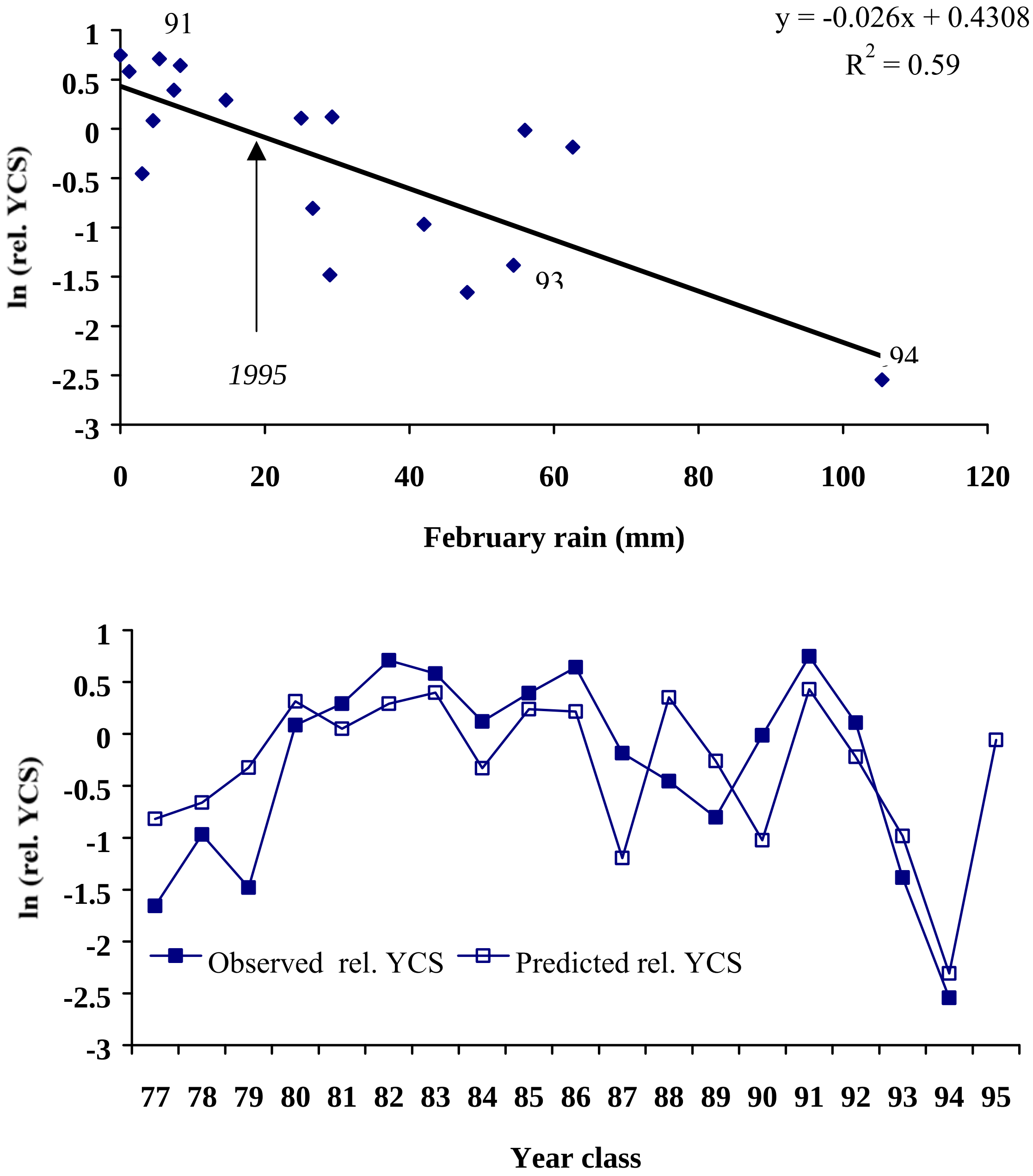
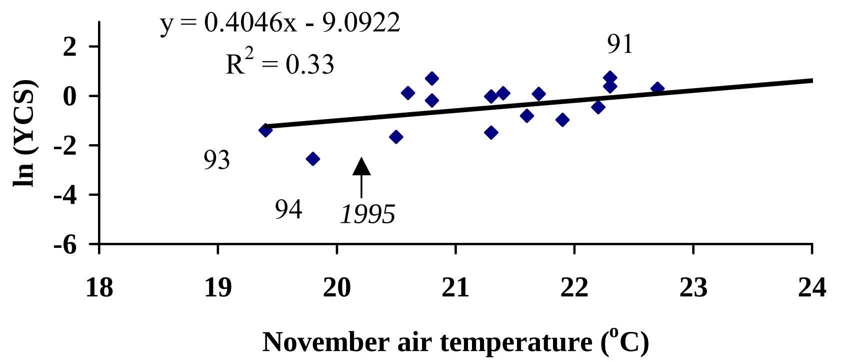
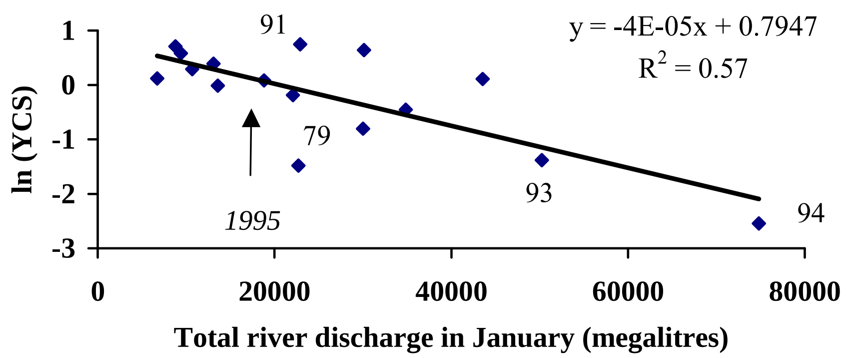


Figure 45. Environmental – recruitment model for snapper based on the age structure of commercial catches and February rainfall at Queenscliff in the 0+ year. Arrow shows rainfall in 1995. High YCS (1991) and low YCS (1993 and 1994) are labelled.

a) November air temperature model showing predicted 1995 YCS



b) January river discharge model showing predicted 1995 YCS



c) February river discharge model showing predicted 1995 YCS

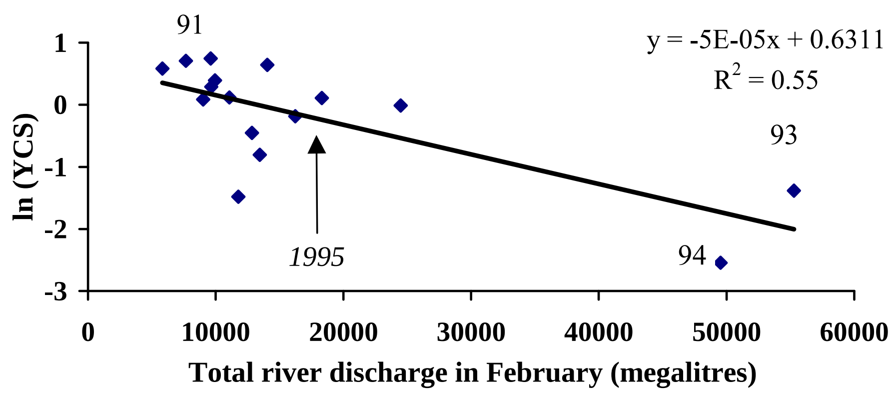
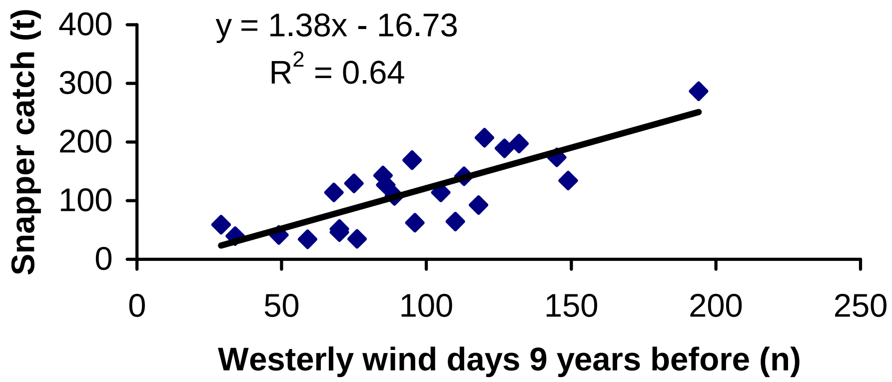


Figure 46. Environmental – recruitment models for snapper based on the age structure of commercial catches, air temperature and rainfall. Arrows show forecast recruitment for 1995. Years of high YCS (1991) and low YCS (1993 and 1994) are labelled.

a) Regression model of west wind and snapper catches 1977/78-2000/01



b) Time series of Port Phillip Bay snapper catches and west wind days

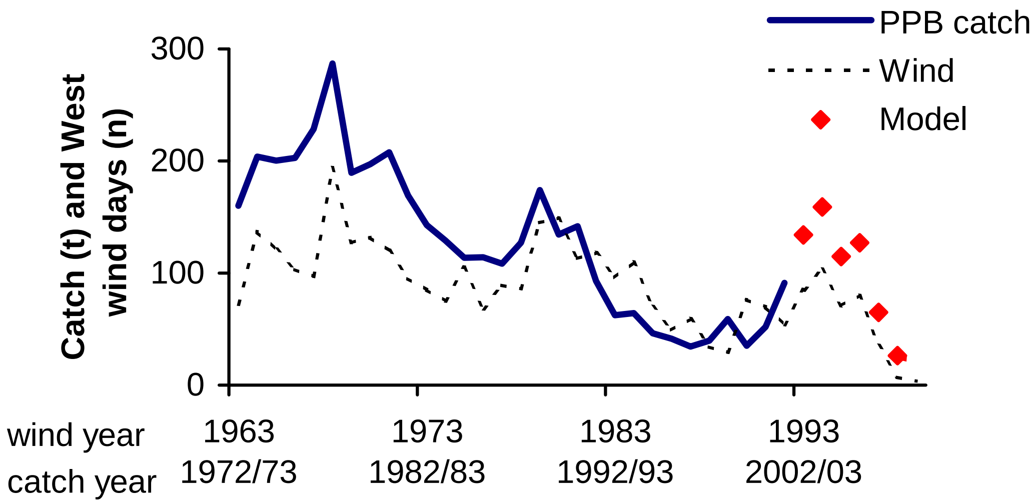


Figure 47. Regression model and time series of zonal westerly wind days and Port Phillip Bay snapper catches 9 years later.

Spawning season and location

Ichthyoplankton

Fish larvae were sorted from 168 ichthyoplankton samples from northern Port Phillip Bay. Water volumes at each station varied between 150–284 m^3. And plankton volumes ranged between 2–1700 ml. Plankton concentrations ranged between 1–778 ml/100 m^3 with an average of 65 ml/100 m^3. The most abundant species of fish larvae were anchovy (Engraulidae). Common families included: flathead (Platycephalidae), gobies (Gobiidae) gurnards (Triglidae), dragonets (Callionymidae), blennies (Blennidae), leather jackets (Monacanthidae), pipefish (Sygnathidae), garfish (Hemiramphidae) and weed fish (Clinidae). Only 22 snapper larvae were found in the 168 samples. Snapper larvae were sampled with both the 300 and 500 micron net. Larger numbers and earlier stages of snapper larvae were sampled with the 300 micron net than the 500 micron net. The small number of snapper larvae in ichthyoplankton samples was consistent with low recruitment indicated by the small numbers of 1+ snapper found during the trawl survey in the following year.

Snapper pre-flexion larvae (2.0-3.4 mm BL) were sampled in northern Port Phillip Bay on 27th January 1998 and flexion larvae (4.0-5.2 mm BL) were sampled on 2nd February 1998. None were found in samples collected during December, February, March or April. Daily ageing of these early stage snapper larvae indicated that they were spawned within a few days of 1st January. All snapper larvae were found in the deep stations (10–25m) of northern Port Phillip Bay and none were found in the shallow stations (<10m). In those samples where snapper occurred, they formed between 0.5–1.0 % of the total count of larval fishes.

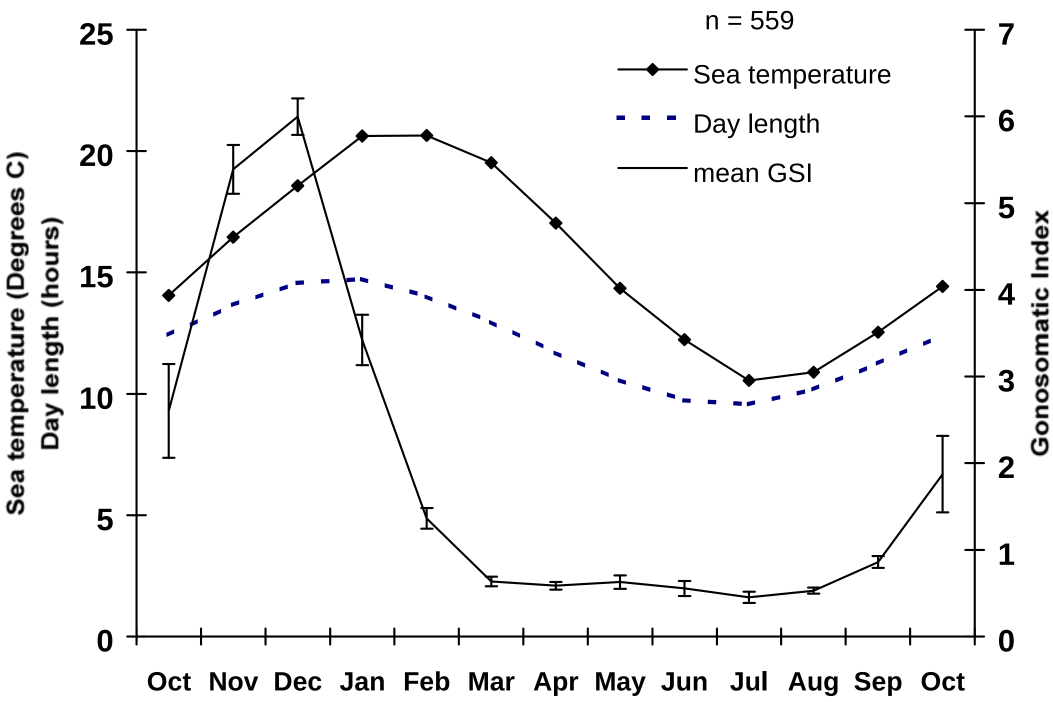
Seasonal trends in GSIs and gonadal stages

The seasonal trends in the mean GSIs of male and female snapper show the spawning season in Port Phillip Bay (Figure 48). Between March and August, the mean GSIs in male and female were <1.0 but increased from September to peaks of 4.2 (males) and 6.0 (females) in December. Peaks in GSIs coincided with increasing day length and water temperature of 18.5 °C in December, well before the February peak of 20.6°C.

Macroscopic and microscopic stages

In Port Phillip Bay, nearly all female snapper (99.5%) examined between March and September 1998 had resting or maturing ovaries (macroscopic Stage 2) (Figure 49). Examination of histological sections showed that ovaries sampled between March and September contained unyolked or partially yolked oocytes in the early stages of development. In October 1998, 32% of females had ripe ovaries (macroscopic Stage 3), but histological examination indicated that oocytes were still undeveloped in the unyolked and yolked stages. The proportion of ripe fish increased through the spawning season reaching 55% in November 1998 and 95% in December 1998. Ovaries sampled in November and December contained developed oocytes that were in the hydrated, migratory nucleus or post ovulatory follicle stages. The size of oocytes increased with each development stage (Table 15). The percentage of females with ripe ovaries (macroscopic stage 3) decreased in January 1999 to 65% and histological sections revealed atresia and old post ovulatory follicles that indicated these fish had spawned. By March 1999, the fish were mostly either spent (28%) or in the resting stage (52%) and contained unyolked oocytes.

a) Female snapper



b) Male snapper

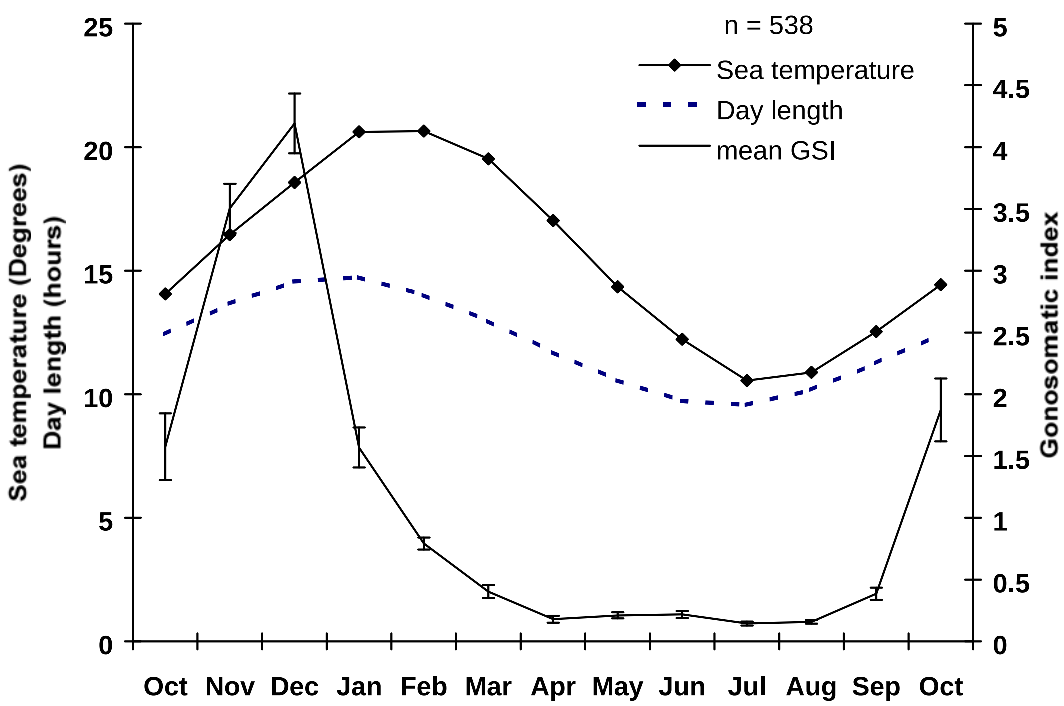
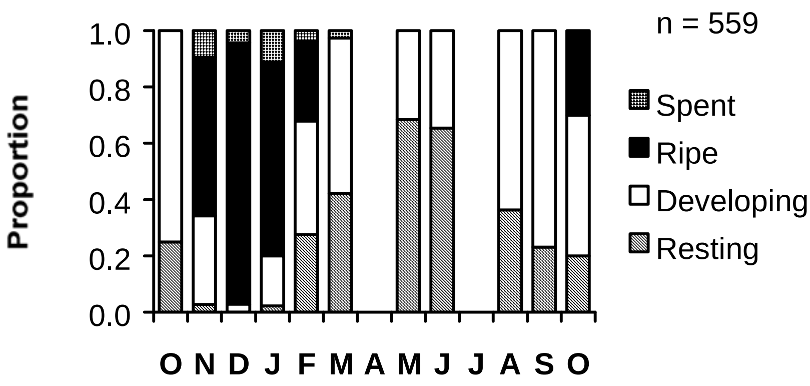


Figure 48. Seasonal trends in the gonosomatic index for female and male snapper with water temperature in Port Phillip Bay and day length between October 1997 and October 1998. Standard errors of the mean gonosomatic index are shown as vertical bars.

a) Females



b) Males

Figure 49. The female and male snapper reproductive cycle indicated by the seasonal change in the proportion of snapper sampled with different stages of gonad maturation.

Table 15. Size frequency distribution of oocytes in different stages of development from oocyte diameter measurements.

Diameter mm	Unyolked n=280	Partially yolked n=50	Advanced yolked n=60	Migratory nucleus n=60	Hydrated n=184
0.000-0.050	37.9				
0.051-0.100	51.4	10.0			
0.101-0.150	9.6	30.0			
0.151-0.200	0.7	18.0			
0.201-0.250	0.4	6.0			
0.251-0.300		18.0	8.3		
0.301-0.350		12.0	1.7		
0.351-0.400		4.0	13.3		
0.401-0.450		2.0	35.0	6.7	0.5
0.451-0.500			25.0	16.7	4.9
0.501-0.550			13.3	36.7	15.9
0.551-0.600			3.3	18.3	34.6
0.601-0.650				16.7	25.9
0.651-0.700				5.0	16.7
0.701-0.750					1.5

The diet of snapper in Port Phillip Bay and coastal waters

Stomach fullness

Of the 321 snapper stomachs sampled 18% were empty, with the highest percentage of empty stomachs observed in Port Phillip Bay (21%). Across all zones and particularly in Port Phillip Bay, there was a slight increase in the percentage of empty stomachs with increasing size and it was lower in autumn than in winter (Table 16) There was no significant difference in percentage of empty stomachs between males (19.8%) and females (17.2%).

Food categories

Crustaceans were consumed by 26.1% of all snapper with stomachs containing food. The crustaceans found in snapper stomachs included isopods, amphipods, crabs and shrimps. Crustaceans were identified from the presence of appendages, carapace and whole crabs and shrimps. Generally they were found crushed, but occasionally whole crabs were found in stomachs.

Molluscs were consumed by 22% of all snapper with stomachs containing food. Bivalves and cephalopods were the main classes representing 11.3% and 9.2% by volume of molluscs respectively. Bivalves were readily identified by the presence of crushed shell and many could be sorted into three species including *Mytilus sp*., *Electroma sp.* and *Pecten sp*. Cephalopods were observed in gut samples by the presence of tentacles or whole octopus. On five occasions more than one octopus was observed in a single snapper stomach.

Teleosts were observed in 38.3% of snapper stomachs containing food and were identified from the presence of scales, fins, vertebrae, gills and gill rakers, flesh and whole fish. Generally fish were already digested but on a few occasions the species could be identified and these included pipefish (*Stigmatopora sp.*), pilchards (*Sardinops sagax*) and other small bait fish. Pieces of Australian salmon (*Arripis sp.*) were also observed in the stomach contents and identified as bait used for baiting traps off western Victoria. Items identified as bait were not included as “Teleosts” in the results.

Other prey categories observed in snapper stomachs included holothurians, ascidians, asteroids, polychaetes, and algae. Together, these categories occurred in 13.1% of snapper stomachs containing food.

Table 16. The percentage of empty stomachs observed in each zone by season and length class (cm FL).

Season and Length Class	Western Victoria %	Eastern Victoria %	Port Phillip Bay %	All zones %
Autumn	6.52	13.48	4.17	9.29
Winter	19.57	37.04	35.48	30.37
< 30 cm	14.29	22.22	41.51	29.23
30-40 cm	13.64	12.82	12.50	13.00
40-50 cm	12.00	25.00	0.00	11.76
50+ cm	11.11	0.00	0.00	2.70

Difference in the diet of snapper among zones

The diet of snapper differed by frequency of occurrence and volume, among zones in respect to the major food classes Crustacea, Bivalvia, Cephalopoda and Teleostomi (Figure 50). Polychaetes, echinoderms and ascidians were only observed in the diet of snapper caught in coastal waters. In Port Phillip Bay, snapper fed mostly on crustaceans (Table 17), whereas in coastal waters the main prey was teleost fish and cephalopods (Table 18 and Table 19).

The diet of snapper varied between bay and coastal waters. Crustaceans and bivalves were observed more frequently in the stomachs of snapper caught in Port Phillip Bay, whereas cephalopods and teleosts were observed more frequently in snapper caught in coastal waters. Polychaetes and echinoderms were only observed in snapper from coastal waters.

Using the Tukey test to identify the source of difference with respect to the volume of food groups, significantly more Crustacea ($F_{2,302}$ =22.16; p<0.0001) and less Cephalopoda ($F_{2,302}$ = 2.58; p<0.05) were consumed by snapper in Port Phillip Bay than coastal waters (Table 20). A higher volume of bivalves was consumed in Port Phillip Bay, however this value was not significant from that observed from the east or west coast. The volume of teleosts consumed by snapper was higher in the west than in the bay or along the east coast. There was no significant difference in the volume of molluscs consumed by snapper from the bay and the coastal waters.

Differences in snapper diet among length classes

In Port Phillip Bay, diet differed among length classes (Figure 51). The volume of molluscs eaten by snapper >50 cm FL was higher than all other lengths. Bivalves made up the majority of molluscs eaten by snapper in Port Phillip Bay, therefore the volume of bivalves was greater for the 50–60 cm FL length class. Teleosts were the most preferred food of the 40–50 cm length class. Crustaceans were the most preferred food of snapper <30 cm FL, however the stomachs of snapper from this length class mainly contained unidentifiable digested material.

In eastern Victoria, there was a higher volume of molluscs eaten by snapper >40 cm FL than by smaller snapper. Cephalopods made up the majority of molluscs in the diet in eastern Victoria, whereas in Port Phillip Bay bivalves were more important. There was less variation in the diets of snapper of different length classes in western Victoria. Fish represented a higher volume in the diet of 30–50 cm snapper and were found more frequently in snapper <30 cm FL. Smaller snapper (<30 cm FL) in Port Phillip Bay fed mostly on crustaceans, whereas those from coastal waters preyed mostly on molluscs.

Snapper >30 cm FL fed mostly on crustaceans and bivalves in the bay and on fish and cephalopods in coastal waters. All length classes sampled in coastal waters had eaten cephalopods, however, only snapper >40 cm FL had consumed this food group in Port Phillip Bay. No snapper >40 cm FL caught in coastal waters had consumed bivalves. The volume of crustaceans consumed by snapper varied significantly with length class ($F_{3,292}$ = 5.79, P<0.001), with larger snapper (>50 cm FL) eating significantly higher volume than snapper < 40 cm FL. There were also significant interactions between length class and habitat and zone. No significant effects of length class were observed with the volume of total molluscs, bivalves, cephalopods and teleosts, however significant interactions were observed between length class/habitat and length class/zone for both total molluscs and cephalopods (Table 20).

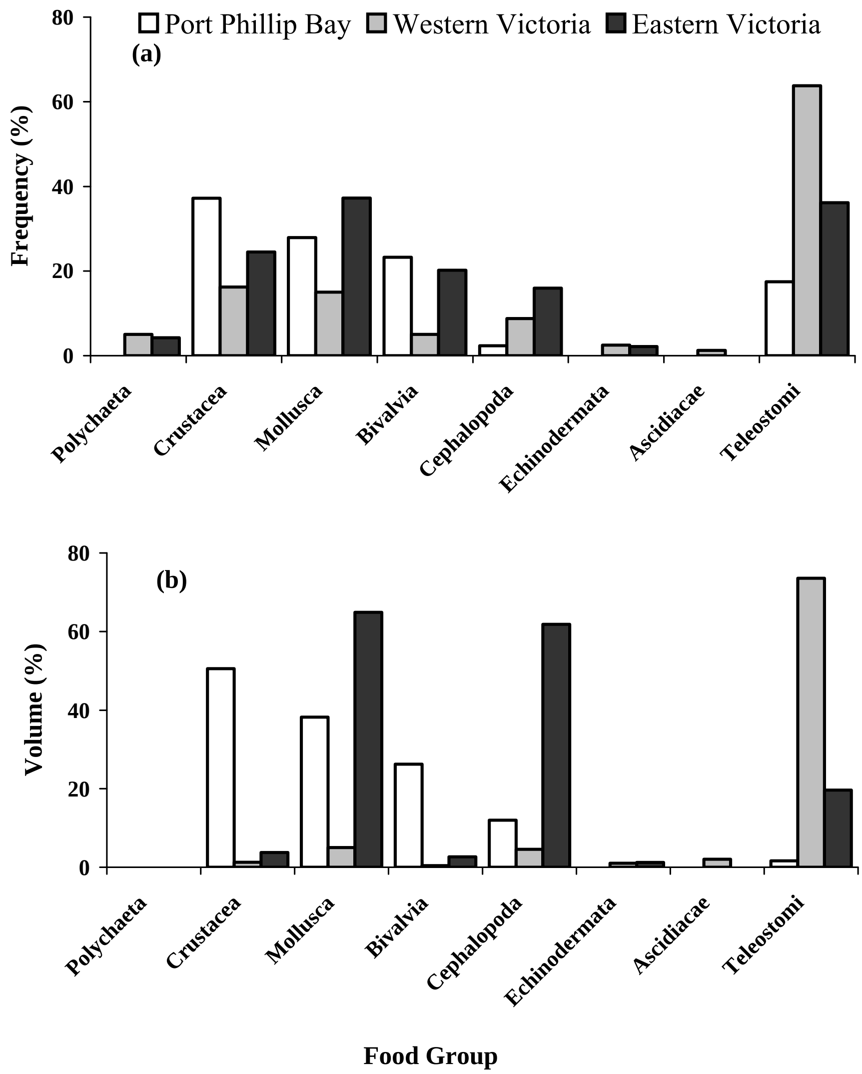


Figure 50. Change in (a) frequency occurrence and (b) percentage contribution by volume of food groups to the diet of snapper (all length classes combined) caught in Port Phillip Bay and coastal waters from east and west Victoria.

Effects of habitat and season on snapper diet.

The frequency occurrence of all food groups varied with habitat (Table 20). Snapper sampled from all habitats consumed teleosts, but those sampled in the vicinity of reefs fed on teleosts more frequently. Snapper caught over sand consumed significantly more bivalves ($F_{4,302}$=2.72, P<0.05) and crustaceans ($F_{4,\ 302}$=13.99, P<0.0001), than fish or cephalopods. The lowest occurrence of bivalves in stomach contents was from snapper caught over reefs. Cephalopods were mostly eaten over rubbly sand ($F_{4,\ 302}$=2.58, P<0.05), and were absent from the diets of snapper caught over seagrass and reef and sand. Echinoderms were only observed in less than 5 % of all stomachs of snapper caught over reefs and sandy substratum. There was no significant preference of any food group over seagrass, however crustaceans were observed most frequently. There was no significant variation in the volumes of food groups eaten by snapper between seasons.

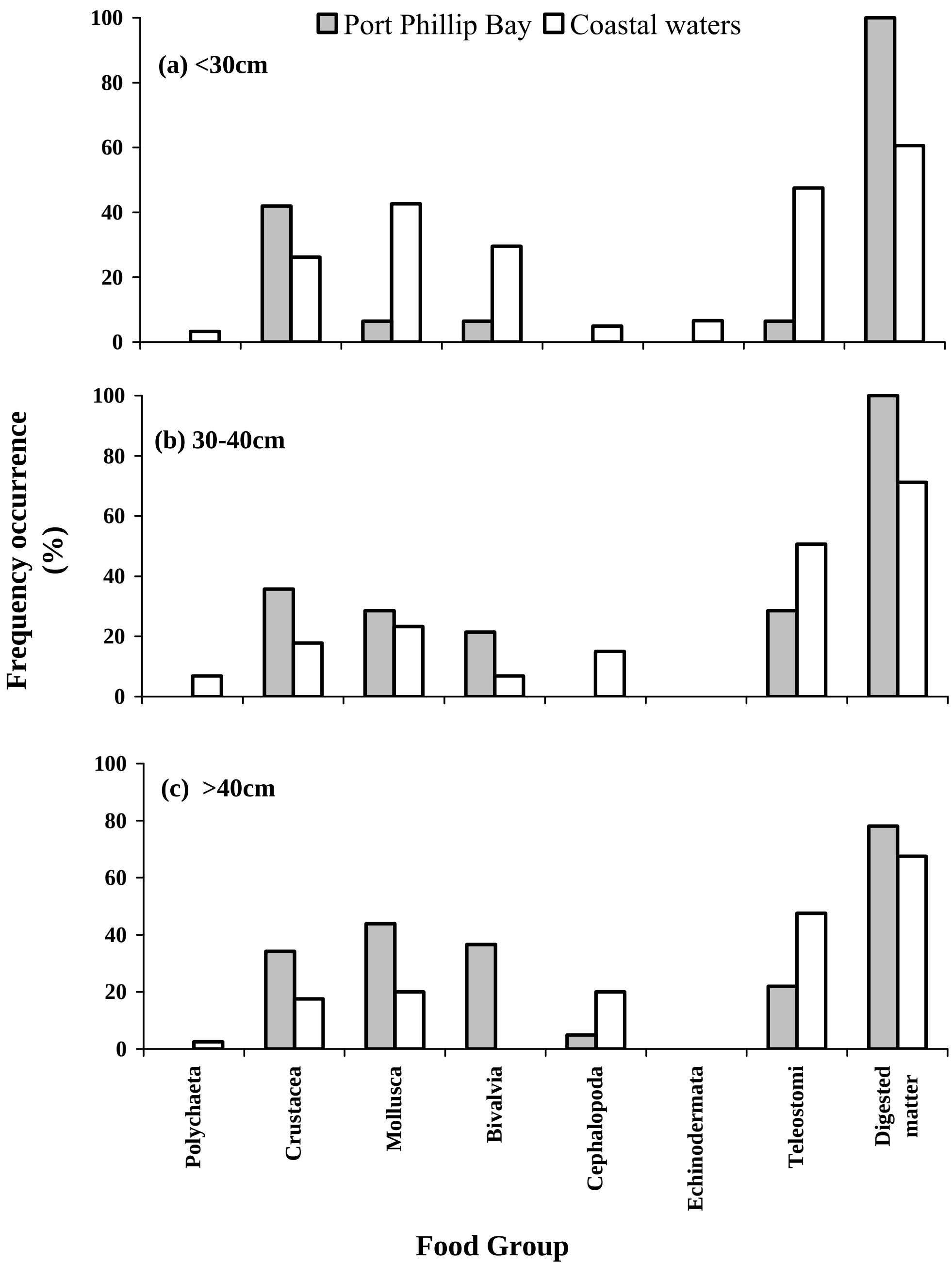


Figure 51. Changes in the frequency occurrence of food groups in the diets of snapper (a) <30 cm FL, (b) 30 – 40 cm FL and (c) > 40 cm FL caught in Port Phillip Bay and Victorian coastal waters (east and west combined).

Table 17. Changes in diet of snapper (n= 115) caught in Port Phillip Bay with length class. Analysis of contribution of food group by frequency occurrence (Freq) and volume (Vol.).

	Fish length (FL cm)											
Food Group	**10-19.9 cm**		**20-29.9 cm**		**30-39.9 cm**		**40-49.9 cm**		**50-59.9 cm**		**60+ cm**	
	Freq %	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**
Polychaeta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crustacea	40.00	27.27	42.31	69.55	35.71	78.84	40.00	50.32	25.00	21.05	35.71	49.47
Isopoda	0.00	0.00	3.85	38.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00	0.00	7.14	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda	40.00	27.27	26.92	27.24	21.43	78.57	33.33	49.64	25.00	21.05	35.71	49.47
Unidentified	0.00	0.00	11.54	3.85	7.14	0.25	6.67	0.68	0.00	0.00	0.00	0.00
Mollusca	0.00	0.00	7.69	6.41	28.57	14.94	46.67	25.38	16.67	78.95	64.27	49.89
Gastropoda	0.00	0.00	0.00	0.00	7.14	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Bivalvia	0.00	0.00	7.69	6.41	21.43	14.92	33.33	2.76	16.67	78.95	57.13	43.07
Mytilus sp.	0.00	0.00	0.00	0.00	0.00	0.00	13.33	1.13	0.00	0.00	7.14	0.64
Pecten sp.	0.00	0.00	0.00	0.00	7.14	9.95	0.00	0.00	0.00	0.00	7.14	1.71
Electroma sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.28	6.40
Cephalopoda	0.00	0.00	0.00	0.00	0.00	0.00	6.67	22.62	0.00	0.00	7.14	6.82
Octopus	0.00	0.00	0.00	0.00	0.00	0.00	6.67	22.62	0.00	0.00	7.14	6.82
Squid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Echinodermata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asteroidea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Holothuroidea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Teleostomi	20.00	72.73	7.69	6.41	28.57	6.22	40.00	1.67	0.00	0.00	21.43	0.64
Bait	0.00	0.00	0.00	0.00	0.00	0.00	6.67	22.62	8.33	0.00	0.00	0.00
Digested material	80.00	0.00	100.00	16.03	100.00	0.00	80.00	0.00	75.00	0.00	78.57	0.00
Other	0.00	0.00	3.85	1.60	7.14	0.00	6.67	0.00	0.00	0.00	0.00	0.00
No. of stomachs	5		48		16		15		12		14	
No. empty	0		22		2		0		0		0	
Mean fullness %	80.00		43.19		40.36		76.67		75.00		82.69	

Table 18. Changes in diet of snapper (n= 88) caught in coastal waters in eastern Victoria with length class. Analysis of contribution of food group by frequency occurrence (Freq) and volume (Vol.).

	Fish Length (FL cm)							
Food Group	**20-29.9 cm**		**30-39.9 cm**		**40-49.9 cm**		**50+cm**	
	Freq %	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**
Polychaeta	2.04	0.00	5.88	0.00	11.11	0.00	0.00	0.00
Crustacea	30.61	8.05	17.65	0.41	22.22	0.00	0.00	0.00
Isopoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphipoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda	22.45	8.05	14.71	0.41	11.11	0.00	0.00	0.00
Unidentified	8.16	0.00	2.94	0.00	11.11	0.00	0.00	0.00
Mollusca	48.98	9.57	26.47	30.34	55.56	33.33	50.00	33.33
Gastropoda	2.04	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Bivalvia	34.69	6.25	5.88	0.00	0.00	0.00	0.00	0.00
Mytilus sp.	2.04	0.24	2.94	0.00	0.00	0.00	0.00	0.00
Pecten sp.	10.20	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Electroma sp.	10.20	3.55	0.00	0.00	0.00	0.00	0.00	0.00
Cephalopoda	4.08	2.37	20.59	30.34	55.56	33.33	50.00	33.33
Octopus	0.00	0.00	17.65	22.22	55.56	33.33	50.33	33.33
Squid	0.00	0.00	2.94	0.47	0.00	0.00	0.00	0.00
Echinodermata	4.08	2.84	0.00	0.00	0.00	0.00	0.00	0.00
Asteroidea	4.08	2.84	0.00	0.00	0.00	0.00	0.00	0.00
Holothuroidea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Teleostomi	38.78	41.92	41.18	2.44	11.11	0.00	0.00	0.00
Bait	4.08	8.05	2.94	5.69	11.11	0.00	0.00	0.00
Digested material	67.35	0.47	82.35	0.00	66.67	0.00	100.00	0.00
Other	2.04	0.00	2.94	0.03	0.00	0.00	0.00	0.00
No. of stomachs	63		39		12		2	
No. empty	14		5		3		0	
Mean fullness %	47.47		49.48		46.66		62.50	

Table 19. Changes in diet of snapper (n= 118) caught in coastal waters in western Victoria with length class. Analysis of contribution of food group by frequency occurrence (Freq) and volume (Vol).

	Fish Length (FL cm)							
Food Group	**20-29.9 cm**		**30-39.9 cm**		**40-49.9 cm**		**50+cm**	
	Freq %	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**	**Freq %**	**Vol %**
Polychaeta	8.33	0.00	7.14	0.00	0.00	0.00	0.00	0.00
Crustacea	8.33	1.35	16.67	1.91	16.67	0.42	12.5	0.00
Isopoda	0.00	0.00	2.38	0.7	4.17	0.00	12.5	0.00
Amphipoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda	8.33	1.35	7.14	0.61	4.17	0.02	0.00	0.00
Unidentified	0.00	0.00	7.14	0.61	8.33	0.40	0.00	0.00
Mollusca	16.67	9.76	19.05	3.39	8.33	4.96	0.00	0.00
Gastropoda	0.00	0.00	2.38	0.09	0.00	0.00	0.00	0.00
Bivalvia	8.33	1.01	7.14	0.52	0.00	0.00	0.00	0.00
Mytilus sp.	0.00	0.00	2.38	0.00	0.00	0.00	0.00	0.00
Pecten sp.	8.33	1.01	2.38	0.52	0.00	0.00	0.00	0.00
Electroma sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cephalopoda	8.33	8.75	9.52	2.78	8.33	4.96	0.00	0.00
Octopus	8.33	8.75	7.14	1.74	8.33	4.96	0.00	0.00
Squid	0.00	0.00	2.38	1.04	0.00	0.00	0.00	0.00
Echinodermata	16.67	8.08	0.00	0.00	0.00	0.00	0.00	0.00
Asteroidea	8.33	1.35	0.00	0.00	0.00	0.00	0.00	0.00
Holothuroidea	8.33	6.73	0.00	0.00	0.00	0.00	0.00	0.00
Teleostomi	83.33	51.88	54.76	68.67	62.50	69.39	37.50	47.92
Bait	0.00	0.00	7.14	17.40	12.50	10.13	12.50	52.08
Digested material	33.33	0.00	57.14	0.00	45.83	0.00	100.00	0.00
Other	0.00	0.00	2.38	0.00	4.17	0.00	0.00	0.00
No. of stomachs	14		45		24		9	
No. empty	2		6		3		1	
Mean fullness %	67.1		52.4		60.8		55.0	

Table 20. The F values and significance from general linear models used to assess the effects of habitat, zone (Port Phillip Bay, east and west coast), and length class (LC; <30 cm, 30-40 cm, 40-50 cm, >50 cm FL) interactions on the volumes (log (x+10 transformed) of food groups. Degrees of freedom (df) and length class (LC)

Source	df	Crustaceans	Molluscs	Bivalves	Cephalopods	Teleosts
Habitat	4,292	21.81***	11.56***	4.16*	9.13***	6.88***
Zone	2,292	58.49***	10.94***	9.59***	12.26***	21.34***
LC	3,292	5.79**	0.76	1.00	2.10	0.53
LC*Habitat	10,292	4.08***	2.16*	0.90	3.64***	1.50
LC*Zone	4,292	7.27***	3.16*	0.47	6.11***	1.14
R^2 of model		**0.39**	**0.29**	**0.26**	**0.27**	**0.33**

*p <0.05, ** p <0.001, *** p < 0.0001

Discussion

Snapper stock abundance

Fish population models are often based on a time series of fishery statistics that use trends in catch rates as an indicator of stock abundance. However, raw catch rates may be affected by a range of factors other than the abundance of the target species (Gulland 1983). The models that we developed to assess the snapper stocks in Victoria were based on a GLM approach to control for the effects of some of the other factors that effect CPUE in order to reveal the underlying annual variation that is more likely to indicate stock abundance. However, these results should be interpreted with caution as such analyses do not necessarily successfully remove all potentially confounding factors.

The specific factors included in the analyses of the commercial fisheries data were the different levels of experience of fishers operating in each year, and the changes from year to year in the level of effort applied in different months and in different areas. For the western stocks, we found no distinct trend in the standardised CPUE in Port Phillip Bay, but there was a decreasing trend in the west coast between 1983-89 followed by an increasing trend during the 1990s. For the eastern stocks, there was a decreasing trend between 1989-97 followed by a small increase during the 1998 and 1999.

There are several ways to interpret these long line CPUE trends in terms of snapper stock abundance. From the size and age structure of snapper, it is clear that the long line fishery in Port Phillip Bay was sustained by more than three strong age classes aged between 5-18 years old between 1994 and 1998. One interpretation of the long line CPUE trends is that the accumulated stock biomass in these age classes has remained quite stable in Port Phillip Bay, but there has been a reduction in stock biomass distributed in western and eastern coastal waters.

However, an alternative interpretation that would be a cause for concern is that a stable CPUE trend indicates hyperstability caused by other factors that have maintained the CPUE while the stock abundance drops (Hilborn and Walters 1992). Targeted fishing on known areas of spawning aggregations may lead to CPUE hyperstability as catchability increases with diminishing stock size. Examples of other species that form spawning aggregations but have declined in this manner include the Nassau grouper (*Epinephelus striatus*) in the Caribbean and the coral trout (*Plectropomus leopardus*) (Samoilys 1997; Sala *et al.* 2001).

An increase in fishing power due to technology is just one of the many fishing effects that could contribute to CPUE hyperstability. In South Australia, Jones and Luscombe (1993) found that snapper catch rates were maintained as fishing effort declined by the installation of colour sounders and global positioning systems (GPS). Changes in fishing practises can also cause CPUE hyperstability (Davies and McKenzie 2001). Paul (1974) analysed the New Zealand commercial line fishery statistics and found that fishermen ceased to fish when catches were low. If some of these factors are influencing the Port Phillip Bay snapper fishery, the long line CPUE trend may be a poor indicator of snapper stock abundance. Although, in the other regions of South Australia, the long line CPUE and hand line CPUE trends have been related to changes in snapper abundance and year class strength in Spencer Gulf and Gulf St. Vincent (McGlennon and Jones 1997; McGlennon *et al*. 2000; Fowler 2002).

While it is difficult to interpret the CPUE trends in Victoria, there are several positive indicators of the status of the western snapper stocks. The increasing CPUE trend during the 1990s, the stability in the size and age structure of snapper in commercial catches from Port Phillip Bay since the 1970s (Coutin 2000) and improved recruitment in Port Phillip Bay are all positive indicators for the spawning stock biomass. There is no evidence of a major reduction in biomass and if fishing mortality was too high, a decrease in the proportion of older fish would be expected. It is possible, however, that there has been a decrease in the proportion of large snapper from coastal waters moving into Port Phillip Bay and recaptures of tagged fish over time will be an important source of information in the future.

The status of the Eastern snapper stock is much less certain because there is insufficient fishery data for providing trends in CPUE, less data on the size and age structure of the stocks and no recruitment monitoring. Also there are significant movements of the eastern stocks from Victorin waters along the NSW coast, where there area subtantial commercial and recreational snapper fisheries.

Integrating snapper movement, growth and in fisheries assessment

In order to assess the snapper stocks in Victoria, the spatial structure of the stocks, movement by size and age, growth and the distribution of fishing effort need to be taken into account. The level of fishing effort, the size of fish and the season of recaptures are important factors that must be considered when interpreting this type of tag recapture data because without fishing the movements cannot be detected. In Victoria, commercial and recreational fishing effort mostly occur between October and April and is greatest in Port Phillip Bay with much lower levels in coastal waters (Neira *et al.* 1997; Conron and Coutin 1998). Most anglers catch small snapper of less than 30cm, but at night commercial fishermen and boat anglers use larger hooks to target the larger snapper mostly in Port Phillip Bay (Conron and Coutin 1998). It is thought that there is comparatively little coastal snapper fishing in Victoria and eastern South Australia, and that recreational fishing occurs mostly in daytime (Conron pers. comm.). However, recreational fishing effort is likely to be higher during summer holidays particularly wherever there are snapper fishing competitions, charter boat operators and access to boat ramps such as the Portland region (C.Cooper pers. com.). In Victoria, coastal fishing effort is likely to be lower than in NSW, but higher than the west coast in South Australia (Anon 1997) because of differences in the number of access sites, charter boats, and population levels between the states.

In NSW, Steffe *et al.* (1996) found that charter boat fishing effort exceeded 24,500 trips per year and that there were 3.more than 210,000 boat trips made by anglers from large access sites along the coast. This high levels of recreational fishing effort and the high commercial fishing effort with fish traps (Ferrel and Sumpton 1996) are reflected in the large number of tagged fish from the eastern stock that were recaptured along the NSW coast.

The movement patterns of tagged snapper indicated by the assumed trends in fishing effort and gear selectivity suggested only a small but equal proportion (4%) of small immature fish (<30cm) moved between Port Phillip Bay and the west coast. In contrast, the model suggested that whereas more than half (52%) of the large mature fish (>38cm) from the west coast moved into Port Phillip Bay, only 2% moved in the other direction. If true, these movement patterns would support theories that snapper utilise Port Phillip Bay as a nursery ground, remaining there until maturity before commencing seasonal migrations into and out of the Bay. The higher movement of snapper into Port Phillip Bay by mature snapper also suggests that this area is an important spawning ground for the stock distributed along the west coast. However, these are preliminary results and there is insufficient data to determine whether snapper movement patterns between coastal waters and Port Phillip Bay have changed over time. Further scenarios of fishing effort and sensitivity testing will be required as part of the on–going stock assessment process and model development.

Snapper tagging and movement studies

Movements from the west Victorian coast

From recapture data of tagged snapper released in Portland Bay and in the eastern part of the west coast, it appears that most small snapper remained in this area at least until they were > 4 years old, 40cm (TL) and had reached maturity. Periodic upwelling (Rochford 1977; Lewis 1981) of cold water influences the eastern coast of South Australia and this may affect the movements and distribution of snapper along the west Victorian coast at certain times. However, a lack of reported movement does not necessarily mean no movement if there was low fishing effort in other areas.

As fish from the eastern part of the west coast grow to 30-47cm (FL) and reach maturity, they move into Port Phillip Bay after a mean time at liberty of 1152 days when they were >4 years old. The mean time at liberty for tagged snapper moving from Portland to South Australia was 1672 days and the mean size at recapture was 41 cm (FL). However, there was a much greater mean time at liberty (3097 days) for snapper that moved east from Portland to Port Phillip Bay and these were mostly larger mature fish.

Movements from Port Phillip Bay

Relatively few of the tagged snapper released in Port Phillip Bay were recaptured along the east and west coast of Victoria and in eastern South Australia. The majority were recaptured in Port Phillip Bay or Westernport Bay. From the recapture of tagged snapper released in Port Phillip Bay, it appears that most juvenile snapper disperse less than 20km from their nursery grounds for the first 6-12 months. There is more widespread dispersal (> 200km) of 4 to 6 year old fish with movements throughout Port Phillip Bay and into coastal waters to Westernport Bay (28-44cm TL) and Portland Bay (28-46cm TL), but extending as far as eastern South Australia (24-39cm TL) and eastern Victoria (36-40cm TL).

Movements from the east Victorian coast

In eastern Victoria, the recaptures of tagged snapper released at the western end of the 90 mile beach indicated that most juvenile snapper remain in the vicinity of Corner Inlet. There is wider dispersal of 5+ fish towards Lakes Entrance and 6+ fish (>40cm FL) either remained in or returned to the coastal waters outside Corner Inlet. In contrast, juvenile snapper disperse widely from their nursery grounds in Mallacoota Inlet as +2 fish. The dispersal from Mallacoota Inlet expanded to the west into eastern Victoria and to the north into NSW and the mean displacement increased for 3+ and 4+ fish. There was no further increase in the mean displacement of larger, older fish but subsequent recaptures were widely distributed along the NSW coast between Coffs Harbour and Bermagui. The recapture of snapper from Mallacoota Inlet indicated northward movements in the opposite direction of the Eastern Australian Current, which is seasonal and sporadic in strength along the Victorian coast. Ferrell and Sumpton (1996) suggested that this may occur because of southward drift of snapper larvae from winter spawning grounds in the north.

Comparison of snapper dispersal behaviour

The pattern of dispersal of tagged snapper released in Victoria between 1948 - 2001 has been remarkably consistent and there is no compelling evidence to suggest that snapper movements have changed during this period. It is therefore unlikely that the perceived decline in snapper catches in Port Phillip Bay was related to a long term change in dispersal patterns.

The distances moved by tagged snapper in Victoria, are far greater than those observed from tagged snapper released in Shark Bay in Western Australia and the Hauraki Gulf in New Zealand. In Western Australia, there was no evidence of mixing between snapper that were tagged inside the two gulfs of Shark Bay and the adjacent waters (Anon 1984a and b; Moran *et al.* in press). In New Zealand, Crossland (1982) reported a maximum distance moved of 163km with less than 2% of tag recaptures from outside Hauraki Gulf. Gilbert and McKenzie (1999) also reported that the majority of snapper tag recaptures (up to 91%) were reported from within the area of release or adjacent statistical areas. Willis *et al.* (2001) provided further evidence of residential behaviour and reported that a few tagged snapper (23-35 cm FL) were observed within the Leigh marine reserve on several occasions over periods of 1-3 years. The results of these studies suggested that the home range of snapper in New Zealand was less than 20km.

In Victoria, tag recaptures have shown extensive snapper movements between bays and inlets and coastal waters. The results of the movement model suggest that there is an equal exchange of a small proportion of small snapper (<30cm FL) between Port Phillip Bay and the west Victorian coast. However a larger proportion of medium (30-38cm FL) and large (>38cm FL) snapper move into Port Phillip Bay from the west Victorian coast. This change in the behaviour of snapper as they grow and mature is consistent with the observed changes in the size and abundance of snapper in the Gulf waters in South Australia. McGlennon and Jones (1997) proposed that some juveniles were residential while others moved to the coast but as they grew older, an increasing proportion returned to Gulf waters during the spawning season. It was also suggested that an increasing proportion of 12-15 year old fish remained in the Gulf and became residential.

Our results have shown that the displacement of juvenile snapper (16-24cm FL) increased with time at liberty, size, and age until maturity. These changes in behaviour with size and age may be associated with changes in both the diet and reproductive development. Juvenile snapper were mostly residential on nursery grounds where they were feeding on small crustaceans and molluscs. After several years at liberty, there was widespread dispersal to the coast as snapper reached first maturity and they began to feed at a higher trophic level on fish and octopus. This ontogenetic shift in the diet may benefit growth and gonad development, whereas movements towards river estuaries and warmer waters during the summer may optimise spawning and larval survival. However, the dispersal pattern of juvenile snapper in east and west Victoria was different. The dispersal of Eastern snapper is probably influenced by the Eastern Australian Current and related to winter spawning on the east coast of Australia (Ferrell and Sumpton 1996).

The movements of mature adult snapper are less certain, because snapper recaptured close to their release location after a long time at liberty may have been residential or they could have moved and then returned. Although it is assumed that there is a seasonal movement of large snapper into Port Phillip Bay for spawning, there is little evidence of this from conventional tag recapture data. If snapper in Victoria disperse across the shelf to depths exceeding 100m as in NSW (Henry 1990), these movements are unlikely to be detected unless tagged fish are taken as bycatch in other coastal fisheries. Recaptures mostly occur when fish return to commercial or recreational snapper fishing grounds in shallower depths. Future studies using electronic archival data storage tags (Metcalfe and Arnold 1997; Arnold 2000) and otolith microchemistry (Edmonds *et al.* 1999; Gillanders and Kingsford 2000) would enable these possibilities to be explored.

Stock structure and population boundaries

The spatial and temporal structure of snapper populations in Victorian waters is a crucial consideration in the assessment and management of the fisheries and a major source of uncertainty when catches decline in a particular location such as Port Phillip Bay. Analyses of the data from these tagging studies have provided new evidence of the dispersal of snapper with size and age from each tagging location.

Analyses of all the tag recapture data supports the hypothesis of two snapper stocks proposed by Sanders (1974) as there was only a low level of mixing between the western and eastern stocks of snapper in Victoria. Western snapper that were tagged and recaptured mostly moved between Port Phillip Bay, Westernport Bay, western coastal waters and eastern South Australia. Eastern snapper that were tagged in Mallacoota Inlet and in coastal waters adjacent to Corner Inlet generally moved east and north east along the eastern coast of Victoria and into the coastal waters of southern New South Wales. However, we have shown for the first time that some movement of juvenile snapper occurs between the western and eastern stocks. Two small snapper tagged in Port Phillip Bay on separate occasions were subsequently recaptured in the eastern coastal waters of Victoria off Lakes Entrance.

Extensive movements of snapper from Victoria into the coastal waters of adjacent states indicate the range of the western and eastern stocks. These results are quite consistent with previous tagging and genetic studies in south-eastern Australia. Snapper from Port Phillip Bay are genetically different and geographically isolated from the stocks of snapper in Spencer Gulf and Backstairs Passage near Kangaroo Island (South Australia) (MacDonald 1980; Donnellan and McGlennon 1996). Meggs *et al.* (2003) showed that there was a low level of genetic heterogeneity amoung Victorian snapper populations with no distinct eastern boundary between stocks. With the extensive movements of snapper from eastern Victoria along the NSW coast, inter breeding is likely to occur when they mature and after spawning some eggs and larvae may drift south with the prevailing coastal currents. Thomson (1959b) showed a single northward movement of snapper tagged and released in Lake Macquarie in southern New South Wales. MacDonald (1980) concluded that there was some gene flow from snapper moving along the east coast of Australia.

Previous studies have shown that only a few tagged snapper released in Spencer Gulf and Gulf St. Vincent moved southwards beyond the gulfs, but none have been detected moving through Backstairs passage towards eastern South Australia (Jones 1981; Jones 1984; Fowler 2002). The genetic and tagging studies both indicate that the western boundary of the western snapper stock is likely to be in the region between Kangaroo Island and the mouth of the Murray River. The greatest westward movement by snapper from the western stock in Victoria was from Corio Bay to Cape Jaffa on the east coast of South Australia. The extent to which snapper move around is probably greater than is shown by the tag recapture data, because these can only record the distance between the release and recapture. Tagging data may not show the extent of offshore seasonal movements if fish return to the fishing grounds and are recaptured close to their release location. However, these movements of tagged fish do show the range of snapper populations and are within the 1200 km estimated from genetic studies as the average distance between populations (MacDonald 1980).

Performance of different types of tags

The tagging experiments and the analyses of tag recapture data in the integrated movement, growth and fisheries model outputs indicated the relative performance of the different tag types. The results of the tagging experiments showed that dart tags and internal tags had a relatively high performance compared to the T bar tags. The combined tag mortality and shedding rates of T bar tags estimated by the integrated model were 3–4 times higher than dart tags and nearly 20 times higher than internal tags. The relatively high rates of tag shedding rates of T bar tags over more than four years impedes the quantitative interpretation of the T bar tag recaptures.

Our results support the findings of previous snapper tagging studies and show that T bar tags do not perform as well as other tagging techniques, but they are convenient for anglers to use and may be more appropriate for very small fish and short term studies. Crossland (1976) found that dart tags performed 3–4 times better than anchor tags (similar to the T bar tags). In Japan, hatchery reared *P.major* (8-10cm) were tagged with anchor tags and recapture rates were less than 3% in Tokyo Bay (Smith and Hataya 1982). In Spencer Gulf, 2.75% of snapper tagged with Floy anchor tags and released between 1977 and 1981 were recaptured (Jones 1981), whereas 11.1% of dart tags and 16.1% of loop tags were recaptured from a later tagging program conducted during 1987-1992 (McGlennon and Partington 1997). Although from different periods, the tagging studies in South Australia also indicate that recaptures of dart tags are 4 times higher than T bar tags and our models indicate that this is due to a higher tag shedding rate. For future snapper tagging studies, the use of dart tags and internal tags is recommended for fish > 25cm FL to improve tag recapture rates and time at liberty.

Environment-recruitment models

The size and age structure of snapper sampled in Port Phillip Bay certainly showed clear evidence of variable recruitment in the past. The abundance of the 1988, 1989 1993 and 1994 year classes was particularly low and only one strong year class that was spawned in 1991 emerged from the early 1990s. These weak year classes would have begun to impact the daytime recreational fishery for small snapper just above the legal minimum length (27 cm TL) with lower catches occurring just 3–4 years later. The commercial long line fishery, the night-time recreational fishery and angling competitions that target the spawning aggregations of large snapper in November and December would have been impacted 7–8 years after this period of low recruitment. This information from the age structure of the snapper stocks suggests that the lower snapper catches experienced during the early 1990s were related to periods of poor recruitment during the 1980s.

In South Australia, McGlennon *et al.* (2000) also found that highly variable year class strength had a strong effect on the commercial catches of the hand line and long line fisheries in northern Spencer Gulf. As in Port Phillip Bay, the 1991 year class was also strong in the Spencer Gulf and there was also low recruitment in other years (1974-78 and 1980-88) which was followed by lower catches there (Fowler, 2002). However, it is likely that a combination of local and regional environmental factors is affecting the snapper stocks and fisheries across south eastern Australia.

Poor recruitment was considered by the Bays and Inlets Stock Assessment Group to be one of the possible causes of the perceived decline in the snapper stocks in Port Phillip Bay (Coutin 2000). The effects of scallop dredging and exotic species on benthic habitats have often been suggested as other reasons for poor snapper recruitment in the past. The results of our study have shown a high degree of correlation between snapper recruitment and environmental factors. Although the causes of low recruitment have yet to be determined, these fluctuations in recruitment appear to have been part of a natural cycle. Low recruitment does appear to have been the main cause of the perceived decline in the snapper fisheries during the early 1990s. The models that we have developed indicate that climatic cycles, which affect river flow and water temperatures, particularly between April-June during autumn, account for most of the variation in snapper recruitment.

Our environment-recruitment models also suggest that commercial snapper catches in Port Phillip Bay are related in some way to the number of days of zonal westerly winds that occurred 9 years previously. However, the ecological mechanism that links environmental variability with snapper recruitment from coastal waters and Port Phillip Bay is unclear. Most of the variation in the abundance of 1 year old snapper in Port Phillip Bay, based on the trawl survey data, was explained by flows of the Yarra and Maribyrnong rivers (77%) and water temperature (70%) during autumn, several months after spawning. High river flows (>40 thousand megalitres) and lower water temperatures (< 15 ^{o}C) during autumn resulted in high abundances of 1 year old snapper. Low river flows during the spawning season in November, January and February were also associated with high abundances of 1 year old snapper and explained between 54-59% of the variability.

One plausible scenario is that the survival of the early life stages of snapper could be enhanced by low river flow during the spawning season and high river flow during the autumn after post larval settlement. During low river flows, the water column over the spawning grounds in northern Port Phillip Bay become thermally stratified (Mickelson 1990). When snapper spawn, they have been observed swimming vertically to release their eggs and sperm (Smith 1986) and water stratification over the spawning grounds (Cassie 1956a) may enhance fertilisation if the eggs and sperm are concentrated or retained in the surface layers. Snapper eggs hatch within 2 days, larval feeding commences after 4-5 days but without food larvae die of starvation after 8 days (Pankhurst *et al.* 1991). Larval survival rates in the micro-climate of the surface water layer could be further enhanced by higher temperature, oxygen levels and food availability, and lower salinity and predation. The westerly wind drives the circulation in Port Phillip Bay (Harris *et al.* 1996) creating gyres that influence the micro-climate of surface waters as well as the distribution of snapper eggs and larvae. The wind is also important and may affect the advection or retention of snapper larvae from coastal waters onto nursery grounds as Nakata and Hirano (1988) found for red seabream, *Pagrus major* in Shijiki Bay in southern Japan.

Other fisheries and fish stocks are known to be affected by inter-annual differences in the climate and oceanography of southern Australian waters. In Tasmania, rock lobster (*Jasus edwardsii*) catches and the age structure of migrating brown trout (*Salmo trutta*) have been related to annual variations in rainfall and westerly winds (Harris *et al.* 1988). Gunn *et al.* (1989) found that interannual changes in water temperature were related to variation in the spawning season of blue grenadier (*Macruronus novaezelandiae*). Adult jack mackerel (*Trachurus declivis*) moved from the continental shelf to the slope during years of La Niña episodes (Jordan 1991). The recruitment of *Heteroclinus* sp., a viviparous rocky reef fish, and King George whiting (*Sillaginodes punctata*) have also been related to environmental variability (Thresher *et al.* 1989; Jenkins *et al.* 2001). The population dynamics of some estuarine fish stocks in Victoria are also greatly influenced by environmental conditions and high recruitment of black bream (*Acanthopagrus butcheri*) in the Gippsland Lakes has been related to warm temperatures and high rainfall (Walker *et al.* 1998).

If theories based on the timing of recruitment and food availability are valid (Cushing 1975), snapper recruitment could be related to the ecological effects of autumn river flow on the abundance and size of prey for post larval snapper in Port Phillip Bay. Westerly winds affect wave height and turbulence along the north east shoreline of Port Phillip Bay re-suspending sediments and nutrients which boosts the productivity of benthic microalgae and the phytoplankton (Harris *et al*. 1996). Nutrients, phytoplankton and zooplankton production are also greatly enhanced by high river flows into Port Phillip Bay (Arnott and Hussainy 1972; Arnott 1974a; Longmore *et al*. 1996) and zooplankton volumes are lower in Bass Strait off Cape Schank, than in Port Phillip Bay and Westernport Bay (Arnott 1974b). However, the variables that we have used in our models may only be correlates of the environmental factors causing this recruitment effect. The relative importance of Port Phillip Bay as a snapper spawning and nursery ground may be related to the seasonal abundance of suitable prey for the early life stages of snapper at critical times of the year.

There is a succession in the dominance of zooplankton species in northern Port Phillip Bay and the biomass, consisting mostly of copepods, increases from May to reach a maximum in August (Arnott 1974a). *Acartia clausii* was abundant from April to December and *Paracalanus parvus*, *Oithona nana* and *Tortanus barbatus* were abundant from April to August (Arnott 1974a). Similar zooplankton species have been shown to be important in the diet of *P. major* (Tanaka *et al*., 1987). Following settlement at a size of 8mm (SL), *P. major* feeds on copepods (Fukuhara 1984) and *Acartia clausi* is their predominate prey (Tanaka 1985). It is possible that when river flow is high during autumn after the snapper spawning season, there is a greater abundance of food available to 0+ snapper on their nursery grounds in Port Phillip Bay. When these environmental conditions prevail, enhanced growth and survival of 0+ snapper may lead to higher survival of 1+ snapper and strong year classes.

Environmental variation like westerly wind patterns and river flows, may affect snapper recruitment through food supply and mortality at different stages of the early life history and in several different ways. However, there are many other biological explanations for the relationships between the environmental variables and recruitment (Chambers and Trippel 1997). Environmental conditions could affect the spawning of snapper by restricting gonad development, fecundity, distribution, movement, area of suitable spawning grounds. Spawning success in coastal waters could be related to water temperature, the strength of coastal currents and winds that drive upwelling. The wind strength and rainfall could also directly effect fishing or influence the vulnerability of the snapper spawning stock in Port Phillip Bay. There maybe indirect ecosystem effects such as competition and predation with other species that have a highly variable abundance (eg. jelly fish *Catostylus mosaicus, Pseudorhiza haeckeli*, anchovy *Engraulis australis*, pilchards *Sardinops sagax*, Australian salmon *Arrips trutta*, and barracouta *Thyristes atun*). The ecological mechanisms linking snapper recruitment, the food web and the environment are highly complex and further research is required to understand these mechanisms.

Comparison with other snapper recruitment studies

In Port Phillip Bay, the abundance of 1+ snapper between 1989-98 was low with a mean of 1.2 million fish and a maximum of 4.7 million fish in 1996. In New Zealand, where there are much larger snapper fisheries, the abundance of 1+ snapper in the Hauraki Gulf between 1983-89 varied from 1.2 to 20.1 million fish with a mean of 7.7 million fish (Francis 1993). He found a strong positive correlation between year class strength of snapper (based on trawl surveys) and autumn (April-June) sea surface temperatures during the 0+ year that explained 94% of the variability in year class strength. Similar positive relationships have been found between spring-summer air temperature and year class strength from the age structure in other snapper stocks in New Zealand (Gilbert and Taylor 2001). In contrast, our analyses show that there is a negative relationship between sea surface temperature during the same period and snapper year class strength in Port Phillip Bay. This is a surprising result that indicates quite different effects of temperature on the recruitment process in Victoria and New Zealand. It is possible that snapper recruitment is mostly influenced by the productivity of estuarine water that flow into the Victorian bays and coastal waters whereas in New Zealand marine productivity could be a more important factor.

Limitation and improvement of models

The time series of ageing data indicated that environmental conditions during the spawning season were important. However, the lack of data available from coastal waters is a limitation and it remains uncertain whether coastal spawning is variable or significant for snapper recruitment. Our environment-recruitment models could be improved by incorporating several environmental variables and the relationship between westerly wind and snapper catches in Port Phillip Bay. The models that we have developed are limited because only 3 strong year classes occurred in the time series of trawl survey data. Although these strong year classes correspond with abundant age classes in commercial and recreational catches, a longer time series of data is needed. Annual recruitment monitoring and further modelling combining several environmental parameters, trawl data and age data would greatly improve our understanding of snapper recruitment.

Snapper recruitment forecasts

The environment–recruitment models developed from trawl survey data now provide a basis for predicting snapper recruitment from rainfall and river flow. The fluctuations in recruitment may now be anticipated and used to plan research, improve stock assessments and adjust management arrangements. From predictions based on the April-June water temperature, the high recruitment in 19995 and 1996 is likely to diminish with lower recruitment in 1998 and 1999 and very low recruitment in 2000. The results from recent trawl surveys in 1999 and 2000 provide a test of these predictions. They showed that recruitment was indeed very low for the 1998 and 1999 year class. The most recent trawl survey in 2002 showed that recruitment of the 2001 year class was high. Based on the trends in zonal westerly winds, commercial snapper catches are likely to peak in 2004 with the growth of the abundant year classes, followed by a decline in 2008. However, these predictions should be treated with caution until these relationships have been tested.

Reproductive biology

a) Spawning season

The trend in mean monthly GSIs and histological examinations of ovary tissues described in this study indicate that snapper in Port Phillip Bay spawn between November and December. The presence of hydrated and migratory nucleus oocytes in ovaries during this period shows that snapper were on the verge of spawning and post ovulatory follicles provide histological evidence that spawning had recently occurred. A summer spawning season for snapper in Victoria was confirmed by ichthyoplankton surveys during 1997/98 and daily age estimates of larvae. Snapper larvae were estimated to be 3-4 weeks old and were only found in 4 of the 84 samples, in water 10-25m, between 27th January and 2nd February 1998. No snapper larvae were found at other times during sampling between December and April. Our results show that the snapper spawned in Victoria at a similar time of year as stocks in Spencer Gulf in South Australia, along the south coast of Western Australia and in New Zealand, but snapper in northern Western Australia and in Queensland spawned in different months.

In Spencer Gulf, South Australia, Jones (1979) reported that snapper >31cm (TL) and > 3 years old were in spawning condition between November and January. On the south coast of Western Australia, snapper also spawn in November (Lenanton 1974). In New Zealand, snapper spawn in summer over an extended period between October to February (Cassie 1956a), but there are interannual variations in the timing of the peak spawning period (Scott and Pankhurst 1992). In contrast, for more northern snapper populations from Shark Bay in Western Australia, Queensland and NSW, the spawning peak occurs during the winter months of June, July and August (Thomas 1985; Ferrell and Sumpton 1996; Jackson and Cheng 2001). Although, snapper larvae occur in Lake Macquarie throughout the year (Miskiewicz 1986), elevated water temperatures from power station outlets may contribute to an extended spawning period in this location.

In Japan, a species closely related to snapper, *Pagrus major* spawns between April and May, but the spawning peak varied with location and spawning was delayed by about 4 weeks where water temperatures were 1^{o}C lower (Kojima 1981; Sakamoto 1984). Further south off northern Taiwan, *P.major* spawns earlier between February and March (Huang *et al.* 1974). It seems that latitude, day length and water temperature have a similar effect on the spawning seasons of both *P.auratus* and *P.major*.

b) Relationships between spawning and environmental conditions

The environmental conditions during the snapper spawning season in Port Phillip Bay were very similar to those in New Zealand and Western Australia. In New Zealand, the onset of snapper spawning is related to the rise in sea surface temperatures from 15 to 18^{o}C and spawning ceased at between 19-21^{o}C (Cassie 1956a; Scott and Pankhurst 1992). Lenanton (1974) also reported that snapper spawned in Western Australia when surface temperatures were 18.5^{o}C.

The spawning season in Port Phillip Bay occurred just prior to the peak in water temperatures and close to the maximum day length. Average monthly water temperatures during 1997 off Indented Head in Port Phillip Bay (Longmore *et al.* 1996), increased from October (14.1^{o}C) to November (16.5 ^{o}C) and reached 18.6^{o}C in December so the development of snapper larvae occurred at peak temperatures of 20.6 ^{o}C in January. Jenkins (1986) also found snapper larvae in Port Phillip Bay during December-March at water temperatures of 19-21 ^{o}C. However, the timing and location of spawning may vary annually with environmental conditions as water temperature and photoperiod are likely to influence the hormone levels that determine oocyte development and the duration of the spawning season.

Water temperatures greatly influence egg hatching and larval development of snapper (Francis 1994a) and the timing and location of spawning probably reduces mortality and maximises opportunities for larval feeding (Cassie 1956b; Pankhurst *et al.* 1991; Battaglene and Talbot 1992). Multiple spawning over several weeks may enable snapper to reduce the effects on larval mortality of short-term environmental variability (Zeldis 1993).

Cassie (1956a) considered that the depth of the thermocline influenced snapper spawning in New Zealand and thought that fertilisation could be enhanced if the volume of water where eggs and milt mix is reduced by stratification of the water column. If this is the case, the effects of brackish water may amplify the effects of water temperature. As in Victoria, some of the snapper nursery grounds in New Zealand and Western Australia are also located close to river estuaries (Lenanton 1974; Horn 1986a). Environmental conditions affecting the water structure in the vicinity of river mouths may be an important factor in spawning success and recruitment to nearby nursery grounds.

c) Spawning location and behaviour

Schools of snapper are thought to move into Port Phillip Bay from western Bass Strait around the beginning of October (Winstanley 1981) and form pre-spawning aggregations that move progressively northwards along the eastern shoreline of Port Phillip Bay. MacDonald (1982) described the spawning behaviour of snapper and associated seasonal migrations into shallow waters with the congregation of fishes on spawning grounds. Jenkins (1986) found snapper larvae well inside the bay and we found snapper larvae between 10-25m depth in northern Port Phillip Bay.

The extent of snapper spawning in coastal waters is uncertain and how early life stages enter nurseries in other bays and inlets is unknown. We found mature snapper in spawning condition in coastal waters which indicates that Port Phillip Bay is not the only spawning ground of the western snapper stock. Ichthyoplankton surveys have found small numbers of snapper larvae in coastal waters of NSW (Miskiewicz 1986) and in the south of Western Australia (Neira and Potter 1992; Neira *et al.* 2000). Juvenile snapper are common in bays, inlets and lakes along the coasts of Victoria (Ramm 1983; McCarraher 1986) and New South Wales (Anon 1981; West and Jones 2001). However, the relative importance of different spawning locations to subsequent recruitment remains unclear.

d) Size and age at maturity

Protandrous sex inversion is a common feature of sparid fishes (Pollock 1985; Buxton and Garratt 1990) and *P.major* does not become reproductively active until after sex inversion (Huang *et al.* 1974). Reproductive development in *P.auratus* has been described as juvenile sex inversion and functional gonochorism (Francis and Pankhurst 1988). During the first year, the gonads of *P.auratus* are undifferentiated, but by the second year, ovaries develop and all become immature females. Half of these immature females later change sex into males and after 5-7 years nearly all have developed into either males or females (MacDonald 1982; McGlennon and Jones 1997). However, we found a small proportion of snapper had ovotestes and possessed both male and female gonad tissue.

The size at first maturity (27.0 cm FL) found in female snapper in Port Phillip Bay was just above that reported for snapper in New Zealand (23-26cm FL) and South Australia (28 cm FL) (Crossland 1977b; Horn 1986b; Jones *et al.* 1990). However, our estimate of the size at 50% maturity (36.3 cm FL, 42.2 cm TL) is larger than that reported elsewhere. In New Zealand, Crossland (1977b) reported that 50% of snapper were mature at 23cm (FL), but this was based on just 9 fish <25cm. Ferrell and Sumpton (1996) found that 50% of snapper in New South Wales and Queensland were mature at 22cm (FL) when they were just 22 months old. In comparison, the smallest ripe female with hydrated oocytes sampled by Thomas (1985) in Moreton Bay was 32 cm FL. The differences in the results may be attributed to sampling times and methods of classifying mature fish. In some cases, fish may have been classified as mature if the sex could be determined, but snapper that are less than 2+ are unlikely to be mature because of sexual inversion (Francis and Pankhurst 1988). Snapper are also unlikely to spawn unless their ovaries contain hydrated oocytes during the peak spawning period. Observations of snapper spawning at "Underwater World" in Mooloolaba indicate that fish <40cm were segregated from the larger spawning fish (Ferrell and Sumpton 1996). It is possible that only larger fish are involved in spawning or that only migratory females participate in spawning and non-migratory fish resorb yolk stage oocytes like yellowfin bream (Pollock 1984).

In New Zealand, the youngest fish showing gonad development were 2 years old (Paul 1976) and all 4 year old snapper were mature (Horn 1986b). In South Australia, Jones (1979) found from scale reading that the minimum age of fish in spawning condition was 3 years old. Huang *et al.* (1974) considered that female *P.major* reached sexual maturity at 5 years old because of observations of vitellogenesis, the prelude to ovum maturation. Our results based on sectioned otoliths from *P.auratus* in Victoria showed that female snapper reached 50% maturity at 4.9 years of age.

At the current LML (23.7cm FL, 28cm TL), snapper are 2-4 years old and most would not have reached maturity. The length at which 50% of snapper become mature is far greater than the current LML in Victoria and snapper must survive approximately 2 years of fishing pressure until they reach 36cm FL (42 TL) and 4-5 years of age before they participate in spawning. Even then, the number of eggs produced by a

36cm FL snapper compared to larger older fish is relatively low. An increase in the LML above the size of 50% maturity will increase egg production from the spawning stock, but this biological effect is dependant on the level of fishing mortality.

e) Fecundity

Our estimates of batch fecundity assume that all oocytes in the ovary during November and December that were larger than 0.5mm in diameter develop and are released in a batch. This represents the number of eggs released daily at the peak of the spawning season. We estimated the batch fecundity for 50-71cm (FL) snapper from Port Phillip Bay ranged between 131 to 652 thousand hydrated oocytes. This is similar to the batch fecundity estimated for Spencer Gulf snapper which ranges between 9 to 760 thousand hydrated oocytes depending on fish size (McGlennon and Jones 1997; Fowler 2000). These estimates are consistent with the batch fecundity of snapper in New Zealand (Crossland 1977; Zeldis and Francis 1998) where 0.7 kg snapper produce batches of 46 thousand hydrated oocytes.

However, it is not certain whether batch size changes during the spawning season and whether each female spawns every day. In Western Australia, South Australia and New Zealand between 50-83% of females were spawning at a time (Zeldis 1993; Jackson and Cheng 2001; Fowler 2002). The viability of oocytes in each batch decreases rapidly with time and fertilisation was below 50% within 6 hours after ovulation (Hobby and Pankhurst 1997). Therefore our estimates of batch fecundity may well be much higher than the average number of viable eggs released by snapper per day during the spawning season.

Our estimates from counts of oocytes sampled from snapper gonads are within the range of between 100-200 thousand ripe eggs per day estimated by Okamoto (1969) for 3-4kg (65-70cm) female *P.major* in culture. The number of eggs in daily batches from 6-7 year old *P.major* increased by about 100% every fortnight from the beginning of the spawning season in early March reaching a peak in mid-April, then diminishing in May and June (Smith and Hataya 1982). Egg production in *P.major* in culture ranges from 270 thousand eggs in small, 3-4 year old females (27-30cm FL, 300-600gm) to 4.8 million in large 6-12 year old females (40-50cm FL, 3-4kg). These authors also found that eggs are released daily in batches of 50-100 thousand eggs and that only a proportion of the eggs in the ovary are released during a spawning season that lasted for 50-73 days. Fukuhara (1984) found that between 2-5 million viable eggs could be obtained from a 3-6 year old female *P. major* captured from the wild during the spawning season under natural spawning conditions in tanks. This corresponds to the number of yolk vesicle stage oocytes observed in the gonads of 40-50cm *P.major* by Kojima (1981). These observations of the egg production of *P.major* in culture are of the same order of magnitude as our estimates for total fecundity based on yolked oocytes in snapper ovaries.

The relationship between total fecundity and size of snapper was similar in Victoria and South Australia where the fecundity of female snapper increased greatly with size from 0.35 million eggs at 38cm to 11.8 million at 95cm (Jones *et al*. 1990). Glover and Olsen (1985) reported that three year old snapper produce 0.3 million eggs with fecundity increasing to 6 million for six year old snapper (56cm TL, 2kg). In Moreton Bay in Queensland, Thomas (1985) found that snapper fecundity increased from 0.43 million at 28cm to 1.6 million at 41cm (FL). These estimates were mostly lower than those of Crossland (1977a), but this is probably due to differences in assumptions and methods. In our study, we assumed all yolked oocytes were spawned, whereas

Crossland (1977a) estimated fecundity by subtracting counts of all stages of oocytes at the end of the spawning season from counts made at the beginning of the season.

Snapper diet

Comparison of snapper diet with size

Snapper is an opportunistic predator that forages among a wide variety of marine habitats in bay and coastal waters in Victoria. The diet varies with size as the mouth gape increases and there are changes in jaw strucutre and dentition. Small snapper (< 30 cm FL) fed mostly on bivalves and crustaceans, whereas large snapper also fed on on fish and cephalopods, particularly in coastal waters.

Comparison of snapper diet in Victorian bay and coastal waters

Snapper diets varied between bay and coastal waters. Port Phillip Bay snapper mostly fed on crustaceans and bivalves, whereas in coastal waters, cephalopods and fish were eaten more frequently. Small snapper (<30cm FL) in Port Phillip Bay fed mostly on crustaceans, whereas in coastal waters, small snapper fed predominantly on fish. Large snapper in Port Phillip Bay were mostly feeding on crustaceans and bivalves, whereas fish and cephalopods were the main prey of large snapper in coastal waters. Differences in the feeding behaviour of small and large snapper and differences in the abundance of prey between habitats may influence the growth, spatial distribution and movement patterns of snapper.

Comparison of snapper prey in Victioria and other locations

Snapper occupy a broad feeding niche in the benthic and pelagic habitat in Victorian coastal waters and Port Phillip Bay. Analyses of snapper stomach contents during this study revealed that polychaetes, crustaceans, molluscs, and teleosts were the main food categories consumed. These were also the food categories of snapper in Victoria found in other studies (Winstanley 1983; Coleman and Mobley 1984; Parry *et al*. 1995). Our results are also consistent with other dietary studies of snapper in Moreton Bay, Queensland (Thomas, 1985), in Botany Bay, New South Wales (Anon 1981) and in Spencer Gulf, South Australia (Jones 1981), and in the Bay of Plenty, New Zealand (Godfriaux, 1974).

Snapper diets are also similar to *P. major* in Japan, where the juveniles (<14 cm) inhabit nursery grounds in the shallow waters of sheltered bays feeding on aggregations of pelagic copepods and amphipods (Tanaka 1985; Tanaka *et al.* 1987). The diet of *P.major* also changes as they grow to >14cm and move into the ocean waters, where they mostly feed on decapod crustaceans (Okada 1965).

The predominance of crustaceans in the diet was common to both *P. auratus* and *P. major* and the major prey were similar to those in previous studies in Victoria and in other regions. The main differences that we found were that bivalve molluscs, fish and cephalopods were more important components of the diet of snapper in Victoria compared to other regions.

Changes in snapper diet with time

Over the last 20 years, there has been an increase in the abundance of some indigenous and exotic species of polychaetes, crustaceans and molluscs in some locations (Currie and Parry 1999). Wilson *et al*. (1998) attributed the changes in the benthic communities to a reduction in nutrient load and an increase in the abundance of exotic species. There have also been environmental concerns about the effects of scallop fishing and port dredging. However, environmental impacts appear to have had little effect on the broad feeding preferences of snapper.

The prey items in the diets of snapper in Port Phillip Bay in the 1950's (Winstanley, 1983) and in our study were very similar. The only types of prey that we did not find were echinoderms, ascidians and seagrass and these were only observed infrequently (<5%) during the 1950s (Winstanley 1983). This indicates that there has been little change in the diet of snapper in Port Phillip Bay over the last 40 years. Although, it is possible that snapper either consumed different prey species within each of the food groups or foraged selectively in areas where the benthic community has not changed over time.

Crustaceans were recorded as the most important food type for snapper in both the 1950s and our study. Generally, there was a higher proportion of smaller snapper feeding on crabs than larger snapper (Winstanley, 1983). The proportion of molluscs in the diets of snapper increased with length during both surveys, peaking in the 50–59.9 cm FL and 40–49.9 cm FL length classes for the 1998 and 1950s studies, respectively. During both studies the majority of molluscs eaten were bivalves. In the 1950s, mussels were the most commonly described bivalve in stomachs of snapper (MacDonald 1982), but they were less common in 1998. Although the abundance of polychaetes in Port Phillip Bay has increased over the last 25 years (Wilson *et al*., 1998), there was no corresponding increase in the frequency of occurrence for this food group in snapper diets. Cephalopods were more common in the diets during the 1950's survey and there was very little change in the preference for fish between the two surveys.

Snapper feeding grounds and habitats

Benthic communities in sandy habitats of Port Phillip Bay are dominated by crustacean and polychaetes (Wilson *et al*. 1998; Cohen *et al*. 2000). The high proportion of crustaceans in the stomach contents suggests that sandy habitats are important feeding grounds and the low proportion of polychaetes in the diet may be attributed to higher rates of digestion of polychaetes compared to other types of food (Godfriaux, 1974; Thomas, 1985).

Our samples of snapper were caught over a variety of habitats including seagrass beds, sand and reefs and the observed diets varied with habitat type. In Port Phillip Bay, snapper 16–30 cm FL are commonly caught near seagrass beds and near reefs. Winstanley (1983) observed pieces of seagrass in the gut contents of snapper (20–40 cm) caught in the south of the Bay, and concluded that snapper foraged among seagrass beds that characterise this area. We also found species that are associated with seagrass communities in the stomachs of snapper, such as pipefish, and *Electroma*, a small bivalve mollusc. Pipefish attach themselves to seagrass, mimick the movement, orientation and colour of seagrass to avoid predation whilst feeding on small epibenthic crustaceans (Howard and Koehn 1985). *Electroma* settles on seagrass or seaweeds in shallow water (Morgan 1986) and becomes very abundant in Port Phillip Bay during spring (N. Hickman pers. comm.). Consequently, seagrass habitats are considered to be another shallow habitat that is trophically significant for snapper.

Larger snapper (>30 cm FL) were often associated with sand and reefs and their diet also changed with habitat type. Compared to small snapper, large snapper (>50cm) in Port Phillip Bay fed on bivalve molluscs to a greater extent, so it is more likely that they utilise the deeper muddy substrates of central Port Phillip Bay where the benthic community is dominated by molluscs (Wilson *et al*. 1998). Cephalopods were most commonly associated with larger snapper caught over rubbly sand and some reefs and fish were the most common dietary component of larger snapper caught in the vicinity of reefs. The water column and reef habitats are important feeding grounds for snapper, particularly along the coast. Reef habitats also provide shelter and refuges from tidal flows after foraging over exposed sandy areas (Thomas 1985).

In Botany Bay and Lake Macquarie in New South Wales, the prey consumed by snapper closely reflected the benthic fauna and juvenile snapper sampled from sandy areas fed mostly on amphipods and polychaetes, whereas bivalves were practically absent from the diet (Thomson 1959a; Anon 1981). In New Zealand, Francis (1995) found that juvenile snapper were most abundant on shell-sponge habitats in the Kawau Island region compared to other adjacent habitats in eastern Hauraki Gulf. It is likely that shell-sponge habitats with high abundances of benthic infauna are also important feeding grounds for snapper in Victoria.

Stomach fullness

In contrast to previous studies (Colman 1972; Godfriaux 1974; Winstanley 1983; Thomas 1985), we found that there was an increase in stomach fullness of snapper with length particularly in Port Phillip Bay. Colman (1972) suggested that larger fish feed less frequently since he observed a higher number of empty stomachs. Thomas (1985), however considered that the absence of full stomachs in larger snapper was caused by involuntary regurgitation on capture induced by the pressure difference experienced as large snapper are brought up from greater depths.

The method of capture may have also influenced stomach fullness in this study. Larger snapper caught during this survey were generally caught by longline in Port Phillip Bay, by anglers along the east coast, and by traps along the west coast of Victoria. All three methods rely on the feeding responses of fish for capture and hence would more likely catch fish that have been feeding or are still in search of food. However, the seine nets and trawl nets that were used to catch the smaller snapper are equally likely to capture satiated and hungry snapper (Thomas, 1985). It is also possible that snapper are similar to yellowfin bream, *Acanthopagrus australis* and feeding behaviour may be related to gonad maturation and spawning migration (Pollock 1984).

Feeding and reproduction

Several studies have indicated that feeding and diet may influence growth and reproduction of snapper. Cassie (1957) found that the condition factor of snapper in New Zealand reached a peak just prior to spawning with the body weights declining during the spawning season. In studies of captive *P. major*, egg quality was affected by the food consumed just prior to spawning and a diet containing cephalopods improved egg buoyancy and subsequent larval survival by 55% (Watanabe *et al.* 1984a; Watanabe *et al.* 1984b). The abundance and type of food consumed by adult snapper just prior to spawning may influence batch fecundity and also reproductive development in some fish.

Fishery Management Implications

Stock biomass

The trends in standardised long line CPUE and the size and age structure of the western Victorian snapper stock do not indicate that the snapper stock biomass is declining. However, it is difficult to make conclusions about the stock biomass because standardised CPUE may not be a good indicator of stock biomass, and the trends in commercial CPUE are not distinct, but are different in each region. The only positive trend in the data was the recent increase in CPUE in the west coast between 1990-99 which is consistent with recent recruitment events. Elsewhere, the trends are not positive. In particular, the lowest CPUE in Port Phillip Bay occurred in 1997 and in east Victoria, CPUE was lower between 1994-97 than in previous years. These trends indicate that a cautious management approach and other monitoring methods are required to develop a reliable index for snapper stock stock biomass in Victoria.

Stock structure

Tag and movement studies confirm two stocks of snapper in Victorian waters east and west. While there was evidence of a small amount of mixing between stocks, there is no basis for changing the current assumptions in the management strategy. However, as there was a high incidence of movement of snapper from eastern Victoria into New South Wales, fisheries management arrangements may need to recognise that some of the recruitment to NSW snapper fisheries originates from the eastern snapper stock in Victoria, particularly from Mallacoota Inlet.

In order to increase the number of snapper movement records and to test the movement model, further tagging studies are required to assess what proportion of the western stock move into Port Phillip Bay from year to year. As the highest amount of snapper fishing takes place within Port Phillip Bay, tagging in coastal waters and Westernport Bay is particularly important.

Growth and recruitment overfishing

The catch of small juvenile snapper, mostly by the recreational fishery, is constrained by the legal minimum length. There is little impact on the longline fishery because few fish below 36cm FL are taken due to the selectivity of the hooks and the depth of the fishing grounds. Our estimates of size at first maturity (27.0 cm FL) and 50% maturity (36.3 cm FL) indicate that the current LML (27 cm TL) in Victorian waters makes snapper vulnerable to capture before they have had a chance to spawn and egg production may be limited at high levels of fishing mortality.

Because large snapper produce larger quantities of eggs, protection through size limits are used in addition to recreational bag limits to manage snapper fisheries. The LMLs for snapper are higher in NSW (28 cm TL) and in South Australia (38cm TL) (Ferrell and Sumpton 1996; McGlennon and Jones 1997). In Western Australia, the LMLs for Wilson Inlet, Perth and Shark Bay are 28, 41, and 50cm, respectively. McGarvey and Jones (2000) found that catch reductions produced more favourable outcomes in terms of egg production than upper size limit scenarios in egg per recruit models. In Victoria, much higher levels of egg production could be achieved by increasing the size limit to allow smaller snapper to reach maturity and by reducing exploitation rates. Both these strategies should be considered as a means of improving management of the Victorian snapper fishery as they would reduce the risks of recruitment overfishing and achieve benefits in terms of growth, egg production and recruitment.

Recruitment

The commercial and recreational fisheries rely on the growth of recruits from Port Phillip Bay and the seasonal movement of the spawning stock from coastal waters onto their fishing grounds in Port Phillip Bay. High recruitment that occurred between 1995 and 1996 is likely to be followed by lower recruitment in 1998, 1999 and 2000 and high recruitment in 2001. Based on these predictions for snapper recruitment, it is anticipated that catches of large snapper will be variable with peak catches in 2004 and low catches in 2008. However, these predictions should be treated with caution until these models have been shown to be reliable.

Annual monitoring of the size and age structure, recruitment and environmental conditions are important requirements for snapper fisheries assessment and management. A longer time series of data would provide a better understanding of the recruitment dynamics. Predictions of variability in snapper recruitment would allow fisheries management to adjust fishing pressure during periods of low recruitment and this may help to prevent overfishing.

Protection of snapper feeding grounds

In Victoria, snapper feed predominantly on crustaceans, bivalve molluscs, fish and cephalopods and depend on a variety of habitats in Port Phillip Bay and coastal waters. Adverse environmental impacts on benthic communities on reef, sand and seagrass habitats are likely to affect snapper feeding grounds, but there appears to have been little change to the broad feeding preferences of snapper over time. The introduction of exotic species and physical disturbance represent the main environmental threats to the habitats that support the snapper stocks.

Planned Outcomes

In March 2002, another workshop was held and the outcomes of this project were presented to representatives of the commercial fishing industry, charter boat operators and anglers. Size and age frequency data collected from the commercial and recreational fisheries will be analysed and the results of the national recreational survey will be incorporated into the integrated movement, growth and fisheries model for stock assessment. It is envisaged that the biological data and models that have been developed during this project will form the basis for an age structured model if the age composition is monitored on a long term basis.

Trawl surveys in Port Phillip Bay were conducted in March 2002 and 2003. The abundance of 1+ snapper will be used to test and improve the environment-recruitment models based on autumn river flow and water temperature monitoring data. Based on the outcomes of this project, it is envisaged that environment-recruitment models will incorporate multiple environmental parameters and these will be improved in the future.

Snapper otoliths collected from tag recaptures and from tank experiments are being used in the development of microchemistry techniques (FRDC Project 99/134). These samples provide an opportunity to investigate variability in microchemistry of otoliths from tetracycline marks in the otoliths, known environmental conditions and known movements.

Tagging by anglers in the VICTAG program will continue in collaboration with the Australian National Sportfishing Association and recaptures will be incorporated into the snapper tagging database and movement models in the future.

A new snapper tagging project is being conducted in collaboration with the Victorian Gamefishing Association has commenced to trial the new generation of archival tags that record depth, temperature with time. If successful, this technology will be used to gain a better understanding of diurnal and seasonal behaviour of snapper behaviour. Experience gained during this project from internal tagging and holding captive fish in tanks for long periods will be beneficial.

Tissue samples collected during this project have been used in a genetic study conducted in collaboration with Deakin University in Warrnambool. One paper has already been published (Meggs *et al.* 2003) and another is in preparation. This new genetic information supports the results of the tagging studies and provides more evidence of the snapper stock structure in south eastern Australia linking previous FRDC projects (93/074 and 94/168) by Ferrell and Sumpton (1996) and Donnellan and McGlennon (1997).

In July 2003, a snapper workshop will be held in Wellington New Zealand during the annual conference of the Australian Society for Fish Biology. The results of this project will be presented to delegates and scientific papers from this work will be prepared and published in the future.

Benefits

Estimates of snapper movement rates between Port Phillip Bay and coastal waters and inclusion of tag recapture data will reduce uncertainty in the stock assessments of snapper in Victoria. The project has provided more information on the biology of snapper, the size and age at maturity, recruitment and trends in the commercial snapper fishery. It has confirmed the importance of migratory dynamics in stock assessments and has led to further research using otolith microchemistry. Our research provides a sound basis for improving the management of the snapper fisheries that should help to ensure economic viability of the commercial fishery and sustainability of the recreational and charter boat fisheries. The flow of benefits are allocated as 80% Victoria, 10% South Australia and 10% New South Wales.

Further Developments

Snapper tags released during this project will continue to be recaptured and reported for many years into the future. These recaptures will continue to be incorporated into the snapper tagging database. The database is a source of essential data for on–going assessments of the snapper stocks and will form the basis for further analyses, scientific papers and assessment reports in the future.

At future stock assessment workshops, scenarios for different levels of fishing effort and gear selectivity need to be tested in the movement model. As more information on the recreational fishery in coastal waters becomes available through the National Recreational Fishing Survey, these data will be used to improve the movement model for hypothesis testing.

Uncertainties about seasonal movements need to be addressed in the future by the application of new tagging technology such as data storage tags and acoustic tags. This technology could be used in the future to examine the more detailed behaviour of snapper associated with spawning and seasonal movements to deeper habitats.

The environment-recruitment model will be developed and used to predict snapper abundance. Predictions from models will be compared with observed recruitment to test and refine the models. Forecasts of recruitment will be incorporated into assessment models to assist decision making and management of the fisheries.

Genetic samples that have been collected will provide the basis for DNA analyses and used for testing hypotheses about stock mixing and stock structure. Otoliths that have been collected from tag recaptures and from captive fish held in tanks will be used to validate otolith microchemistry techniques and methods of age determination.

Conclusion

The research conducted during this project has provided more information on the biology, movement and fisheries of snapper in Victoria. The snapper tagging database now forms the basis for further development of an integrated movement, growth and fisheries model. This integrated model will allow the importance of different sources of uncertainty in future assessments to be evaluated as tag recaptures are reported.

Environmental–recruitment modelling has helped to explain the variability in year class strength, particularly the low catches during the early 1990s. These models have shown that the environmental conditions in northern Port Phillip Bay immediately before and after spawning are critical to recruitment for the snapper stocks that support the fisheries in Port Phillip Bay. Abundant year classes in 1994/95 and 1995/96 have subsequently recruited into the recreational and commercial fisheries and snapper catches in recent times have increased. In the future, model predictions will be tested as more data on snapper recruitment and environmental variables becomes available.

Although, it is difficult to make conclusions about the stock biomass from trends in standardised CPUE, there is no evidence that the western stocks of snapper are declining. The signs of recent high recruitment and stable size and age compositions are positive indicators for the western stock, but the status of the eastern stocks is less certain. At the current LML most of the recreational catch consists of immature fish. Research on the reproductive biology of snapper has shown that after 5 years and at 42cm (TL) 50% of snapper are mature. Consequently, the current legal minimum length of 27cm (TL) needs to be reviewed.

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The success of this project can be attributed to the active participation and cooperation of members of the public, media, commercial, charter boat and recreational fishing sectors, fisheries managers, technical and scientific staff at the Marine and Freshwater Resources Institute. We wish to thank all the participants for this achievement that would not have been possible without funding from the Fisheries Research and Development Corporation, the Department of Natural Resources and Environment and the Natural Heritage Trust.

Appendix 1: Intellectual Property

No intellectual property has arisen from the research that is likely to lead directly to significant commercial benefits, patents or licences. Intellectual property associated with information produced from the project will be shared equally by the Fisheries Research and Development Corporation and by the Victorian Department of Natural Resources and Environment.

Appendix 2 : Staff

The organisation and position of staff who participated in the project are listed below:

Patrick C. Coutin	Principal Investigator
Shellie Cashmore	Scientist
K.P. Sivakumuran	Scientist
Anne Gason	Statistician
Bruce Taylor	Modeller
Simon Conron	Scientist
David McKeown	Technical Officer
Anthony Sheehan	Technical Officer
Pam Oliveiro	Technical Officer
Sharon Berrie	Technical Officer
Ian Duckworth	Technical Officer
Sean Brody	Technical Officer
Michael Kirwin	Technical Officer
Chester Conron	Technical Officer

Appendix 3 : Extension

Stock assessment workshop

Snapper stock assessment workshops were held on 10–11th December 1997 and 13th March 2002 at the Marine and Freshwater Resources Institute in Queenscliff. These meetings brought together members of the commercial fishing industry, charter boat operators, recreational fishing community, fisheries managers, and regional enforcement officers. At the workshops, biological, fisheries and tagging data were presented and a report of the 1997 workshop (Coutin 2000) was prepared and widely distributed in Victoria and to other states.

VICTAG meetings, videos and newsletters

Annual meetings were held with members of the Australian National Sportfishing Association, the VICTAG coordinator and fisheries managers to review progress of the VICTAG program. Snapper tagging results were presented at two annual meetings of the Australian National Sportfishing Association and at a tagging weekend for VICTAG anglers held in April 2000. A short segment on tagging was included in a video that was widely distributed. The Australian National Sportfishing Association published tagging results in the newsletter VICTAG News. Regular contact was maintained with angler based tagging programs in other states, particularly Queensland and South Australia.

Fisheries officers and FISHCARE volunteers

Regular briefings were given to fisheries officers and FISHCARE volunteers to provide feedback to the public on progress with snapper research and the results of the tagging program.

Charterboat and commercial fishing industry

Extension to these industries was most effective by working cooperatively at sea, or through casual meetings at boat ramps or telephone calls.

Public extension

The results were disseminated each year to the public at major events such as the Melbourne and Geelong Fishing and Boating Shows. The research was also explained at Victorian fishing clubs and snapper fishing competitions on many occasions throughout the state during the project. Specialist teachers at the Marine Discovery Centre at Queenscliff were also kept up to date with snapper research so that the results could be incorporated into their public education programs.

Fishing guide, website, public hotline and tagging prizes

Information on tagging was included in the fishing guide distributed with fishing licences. Responses to 14 frequently asked questions were placed on the NRE website and assisted the operators to answer calls from the public. To facilitate extension, the results of the tagging program were sent with prizes to every commercial fisherman, fish processor or angler who reported a recapture of a tagged snapper.

Tag and tagging equipment suppliers

Regular contact and feedback was provided to Hallprint Pty Ltd in Victor Harbour, South Australia on the results of the tagging experiments and tag recaptures.

Media

In order to promote the project and encourage reporting of tag recaptures monthly extension using the local and national press, radio and internet has occurred on an on–going basis. Chat boards on Fish Internet Australia (www.fishnet.com.au) received 24,000 visits during March 2000 and so tagging results were disseminated widely. Many articles were also written and published in newsletters and magazines as well as for fax and email newsgroups. Some of these articles are listed below:

National and Regional Press : Herald Sun October 1998, March 1999, December 1999, 19th April 2000, 27th November 2000, Geelong Echo March 1999, Geelong Advertiser March 1999, Geelong Independent November 1999, Geelong Advertiser January 2000, Bairnsdale advertiser March 1999, Portland Observer March 1999, Portland Fishing Guide 1999.

Magazines : Southwest Fishing Autumn 2000 Issue 11, p.15, Saltwater Fishing Issue 18, Autumn 2000 p.66–71; Modern Fishing Magazine May 2001, p.51; Journal of Fisheries Victoria (Fins Issue No.3)

Newsletters : SIV News April 2000, Fishing Lines, VRFish October 1999, November 1999, December 1999, p.6, February 2000 p.6, April 2000 p.7, Regional Ripples June 2000 vol. 7 no. 2 , p.2, May 2002 Waves vol. 8 no.4 p.6-8. Fish–Fax : Issue 3 January 2000, Issue 18 August 2000, Issue 22 October 2000, Issue 28 December 2000, Issue 33 March 2001, Issue 57 February 2002.

Radio: Colac ABC radio October 1998, Sale ABC radio October 1998, Traralgon radio 3TR October 1998, Shepperton radio 3SR October 1998, Mount Gambier radio October 1998, Warrnambool 3YB radio December 1999, Regional ABC radio March 1999, 3CR radio “Lets go Fishing” March 1999, Mallacoota radio March 1999, Rex Hunt Fishing Show May 1999, 3SER radio May 1999, Glen Knight 3 AK radio September 1999, Hi–Tide 2KY radio (NSW) April 2000.

Scientific conferences

Information from the project was disseminated to scientists by presenting seminars on snapper research progress at the annual conferences of the Australian Society for Fish Biology. Four posters were also prepared and displayed at several conference venues. Snapper research was incorporated into lectures for universities and TAFE courses. Seminars were also given at CSIRO and at the Centre for Environment Fisheries Aquaculture Science in Lowestoft, UK.

Appendix 4

Snapper tag release and recapture data

Table 21. Port Phillip Bay operculum tag releases (n_1) in 1948-58 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
February	**1948**	**Brighton, PPBe**	**29**	**0**		Aop				
March	**1948**	**Geelong, PPBw**	**23**	**0**		Aop				
January	**1949**	**Frankston, Mt Eliza, PPBe**	**25**	**1**	**4.0**	Aop				
						Aop 5315	Frankston	437	20	6.1
January	**1950**	**Seaford, PPBe**	**17**	**0**		Aop				
February	**1950**	**Geelong, PPBw**	**9**	**0**		Aop				
February	**1950**	**Sandringham, PPBe**	**15**	**0**		Aop				
January	**1956**	**Pt Lillias Corio Bay, PPBw**	**32**	**0**		Aop				
February	**1956**	**Corio Bay, PPBw**	**758**	**1**	**0.1**	Aop				
						Aop6100	Geelong	1	20	0.0
March	**1956**	**Corio Pay PPBw**	**156**	**0**		Aop				
April	**1956**	**Pt Cook PPBn**	**15**	**0**		Aop				
April	**1956**	**Mentone PPBe**	**48**	**0**		Aop				
January	**1958**	**Pt Henry Geelong PPBw**	**3**	**0**		Aop				
Total	**1948-58**	**Port Phillip Bay**	**1130**	**2**	**0.2**					

Table 22. Portland Bay operculum tagged snapper releases (n_1) in 1956-59 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
August	**1956**	**Portland harbour, WCw**	**213**	**0**		Aop				
September	**1956**	**Portland harbour, WCw**	**290**	**2**		Aop				
						Aop7878	Portland breakwater	111	25	6.0
						Aop7894	Portand	330	21.1	2.4
October	**1957**	**Portland harbour, WCw**	**6**	**0**		Aop				
January	**1958**	**Portland harbour, WCw**	**8**	**0**		Aop				
March	**1959**	**Portland Harbour, WCw**	**15**	**0**		Aop				
Total 1956-59		**Portland, WCw**	**29**	**2**	**0.4**					

Table 23. Mallacoota Inlet operculum tagged snapper releases (n_1) in 1954-59 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
January	**1954**	**Mallacoota Inlet, ECe**	**329**	**1**		**Aop**				
						Aop7261	Mallacoota Inlet	92		
March	**1959**	**Mallacoota Inlet, ECe**	**46**	**0**		**Aop**				
Total	**1956-59**	**Mallacoota Inlet ECe**	**46**	**1**	**0.3**					

Table 24. Port Phillip Bay internally tagged snapper releases (n_1) in 1956-62 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
January	**1956**	**Corio Bay, PPBw**	**28**	**1**	**3.6**	**X**				
						X 8552	Pt. Lillias Corio Bay, PPBw	1461	33	13.2
March	**1956**	**Corio Bay, PPBw**	**47**	**1**	**2.1**	X				
						X 8579	Port Fairy, WCw	1232	25	6.4
January	**1957**	**Mornington, PPBs**	**103**	**10**	**9.7**	X				
		Bird Rock, Mornington, PPBs				X 80	Mornington PPBs	41	23	1.1
		Bird Rock, Mornington, PPBs				X 75	Williamstown PPBn	95	31	10
		Bird Rock, Mornington, PPBs				X 58	Mornington PPBs	346	27	4.3
		Bird Rock, Mornington, PPBs				X 35	Mornington PPBs	396	28	4.2
		Bird Rock, Mornington, PPBs				X 17	Sandringham, PPBe	412	32	11.2
		Bird Rock, Mornington, PPBs				X 79	Rosebud PPBs	430	29	7.2
		Bird Rock, Mornington, PPBs				X 82	Rosebud PPBs	1068	37	15.6
		Bird Rock, Mornington, PPBs				X 21	San Remo, WPB	1732	42	22.7
		Bird Rock, Mornington, PPBs				X 31	Portarlington PPBw	2101	55	32.7
		Frankston, PPBe				X 112	Carrum PPBe	2855	66	45.6

Table 24 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
February	**1957**	**Corio Bay, PPBw**	**486**	**25**	**5.1**	**X**				
		Stingaree Bay, PPBw				X 264	Outer Corio Bay, PPBw	3	27	3.2
		Stingaree Bay, PPBw				X 297	Point Wilson, PPB w	9	29	4.2
		Avalon, PPB w				X 587	Williamstown, PPBn	25	24	0
		Stingaree Bay, PPBw				X 421	Williamstown, PPBn	27	27	1.5
		Stingaree Bay, PPBw				X 339	Ricketts Point, PPBe	35	30	1.2
		Stingaree Bay, PPBw				X479	Bosuns Point, Robe SAe	252	24	0.7
		Stingaree Bay, PPBw				X 390	Avalon PPBw	290	29	5.2
		Avalon, PPB w				X 589	Bird Rock, Corio Bay, PPBw	302	32	8.4
		Point Henry, PPBw				X 150	Queenscliff, PPBs	355	31	5.6
		Stingaree Bay, PPBw				X 312	Eagle Rock, Westernport Bay	395	33	9.5
		Stingaree Bay, PPBw				X 323	Rip, PPBs	410	28	5.0
		Point Henry, PPBw				X 168	Carpenters Rock SAe	673	33	7.9
		Stingaree Bay, PPBw				X 205	Williamstown, PPBn	717	38	14.1
		Avalon, PPB w				X 584	Geelong, PPBw	1021	38	14.4
		Stingaree Bay, PPBw				X 326	Corio Bay, PPBw	1041	30	6.4
		Avalon, PPB w				X 538	Portarlington, PPBw	1097	33	10.1
		Point Henry, PPBw				X 157	Williamstown, PPBn	1163	45	19.2
		Stingaree Bay, PPB				X 350	Black Rock, PPBe	1355	41	16.6
		Stingaree Bay, PPBw				X 449	Williamstown, PPBn	1536	42	20.4

Table 24 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
		Stingaree Bay, PPBw				X 410	Swan Bay, PPBs	2507	51	28.5
		Avalon, PPB w				X 505	Safety Beach, PPBe	4269	83	56.3
		Point Henry, PPBw				X 159	St. Kilda, PPBn	4295	71	45.4
		Stingaree Bay, PPBw				X 289	Port Melbourne, PPBn	6415	75	52.4
		Stingaree Bay, PPBw				X 438	South Channel Fort, PPB	7640	75	52
March	**1957**	**Corio Bay, PPBw**	**723**	**29**	**4.0**	X				
		Bird Rock, PPBw				X 842	Mentone, PPBe	17	31	4.6
		Stingaree Bay, PPBw				X 785	Altona, PPBn	30	31	5.8
		Bird Rock, PPBw				X 881	Mordialloc, PPBe	31	27	1.2
		Stingaree Bay, PPBw				X 781	Parkdale, PPBe	35	27	2.0
		Bird Rock, PPBw				X 856	Grassy Point, PPBw	228	27	0.4
		Bird Rock, PPBw				X 991	Geelong, Corio Bay, PPBw	290		
		Bird Rock, PPBw				X 821	Geelong, PPBw	290		
		Bird Rock, PPBw				X 956	Geelong, PPBw	290		
		Bird Rock, PPBw				X 973	Bird Rock, Corio Bay, PPBw	290		
		Bird Rock, PPBw				X 862	Point Lillias, PPBw	301	32	6.2
		Avalon, PPBw				X 1309	Corio Bay, PPBw	311	28	5.1
		Bird Rock, PPBw				X 920	Geelong, PPBw	335	27	3.3
		Bird Rock, PPBw				X 871	Corio Bay, PPBw	337	30	4.2
		Bird Rock, PPBw				X 1058	Geelong, PPBw	337	27	3.5

Table 24 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
		Bird Rock, PPBw				X 972	Ricketts Point, PPBe	347	29	3.7
		Limeburners Point, PPBw				X 612	Lorne, WCe	353	31	2.6
		Avalon, PPBw				X1314	Williamstown PPBn	370	29	5.9
		Bird Rock, PPBw				X1012	PPB	377		
		Bird Rock, PPBw				X1066	Narrawong, Portland Bay WCw	668	28	5.0
		Stingaree Bay, PPBw				X 641	Allestree, Portland Bay WCw	686	33	8.2
		Bird Rock, PPBw				X1062	Portland harbour WCw	742	34	7.4
		Stingaree Bay, PPBw				X 786	Narrawong, Portland Bay, WCw	992	37	11.5
		Stingaree Bay, PPBw				X 777	Portland Breakwater, WCw	997	36	10.8
		Bird Rock, PPBw				X1003	Black Rock, PPBe	1083	36	13.7
		Sandringham, PPBe				X2979	Mentone, PPBe	1107	33	8.5
		Stingaree Bay, PPBw				X 728	Kingston, SAe	1779		
		Bird Rock, PPBw				X1029	Portland Harbour, WCw	2196	46	21.3
		Avalon, PPBw				X 802	Queenscliff, PPBs	2430	59	35.1
		Stingaree Bay, PPBw				X 650	Point Cook, PPBw	5368	70	44.4

Table 24 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
April	**1957**		**5**	**0**		X				
November	**1957**	**Seaford, PPBe**	**7**	**1**	**14.3**	X				
		Seaford, PPBe				X2220	Mornington, PPBs	868		
December	**1957**		**9**	**0**		X				
January	**1958**	**Corio Bay, PPB**	**194**	**13**	**6.7**	X				
		Point Henry, PPBw				X 2350	Limeburners Point, PPBw	7	27	4.0
		Point Henry, PPBw				X 2279	Portland, WCw	337	28	5.4
		Point Henry, PPBw				X 2257	Point Henry, PPBw	351	29	3.0
		Point Henry, PPBw				X 2291	Point Cook, PPBn		31	5.0
		Point Henry, PPBw				X 2378	Swan Island, PPBs	360	29	6.9
		Point Henry, PPBw				X 2317	Williamstown, PPBn	405	34	8.4
		Point Henry, PPBw				X 2390	Corio Bay, PPBw	619	29	8.8
		Point Henry, PPBw				X 2262	Portland harbour, WCw	670	33	10.7
		Point Henry, PPBw				X 2371	Port Fairy, WCw	705	32	9.8
		Point Henry, PPBw				X 2267	Halfmoon Bay, PPBe	747	36	11.9
		Point Henry, PPBw				X 2277	Williamstown, PPBn	763	34	9.5
		Point Henry, PPBw				X 2333	Black Rock, PPBe	775	42	16.9
		Point Henry, PPBw				X 2393	McCrae, PPB	6201	81	56.6

Table 24 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
February	**1958**	**Corio Bay, PPBw**	**241**	**20**	**9.7**	**X**				
		Limekilns, PPBw				X 2570	Corio Bay, PPBw	333	32	6.0
		Limekilns, PPBw				X 2588	Kirks Point, PPBw	333	35	10.3
		Mount Martha, PPBe				X 2625	Lorne, WCe	364	27	4.6
		Limekilns, PPBw				X 2498	Altona, PPBn	366	32	5.7
		Limekilns, PPBw				X 2491	Indented Heads, PPBw	377	31	6.2
		Limekilns, PPBw				X 2569	Altona, PPBn	397	31	8.4
		Limekilns, PPBw				X 2472	Rosebud, PPBs	399	31	8.7
		Limekilns, PPBw				X 2466	Mordialloc, PPBe	401	30	8.4
		Limekilns, PPBw				X 2452	Williamstown, PPBn	429	29	5.0
		Mount Martha, PPBe				X 2627	St. Leonards, PPBw	674	31	9.6
		Limekilns, PPBw				X 2577	South Channel, PPBs	690	34	13.2
		Limekilns, PPBw				X 2469	Portland, WCw	690	31	6.4
		Limekilns, PPBw				X 2542	Williamstown, PPBn	765	40	14.0
		Mount Martha, PPBe				X 2615	Seaford, PPBe	1315	51	23.7
		Mount Martha, PPBe				X 2607	Mordialloc, PPBe	1750	46	24.3
		Limekilns, PPBw				X 2573	Corinella, Westernport Bay	1446	44	20.4
		Limekilns, PPBw				X 2459	Hampton, PPBe	1799	43	19.2
		Limekilns, PPBw				X 2435	Robe, SAe	3397	-	-
		Limekilns, PPBw				X 2520	Rosebud, PPBs	3626	65	40.8
		Limekilns, PPBw				X 2487	Point Cook, PPBn	4311	53	31.3

Table 24 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
March	**1959**	**Brighton, PPBe**	**27**	**2**	**7.4**	X				
		Sandringham, PPBe				X 2965	Point Henry, Corio Bay, PPBw	695	33	15.2
		Point Ormond, PPBe				X 2957	Queenscliff Rip, PPBs	3172	57	40.7
November	**1959**		**4**	**0**		X				
March	**1960**		**4**	**0**		X				
Total	**1956 to 1960**	**Port Phillip Bay**	**1878**	**102**	**5.4**					

Table 25. Westernport Bay internally tagged snapper releases (n_1) in 1957 – 1962 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
May	**1957**	**Westernport Bay**	**96**	**5**	**5.2**	X				
						X 1728	Prison camp, Westernport Bay	22	27	2.8
						X 1726	Crib Point, Westernport Bay	44	27	0.5
						X 1800	Tooradin, Westernport Bay	255	28	3.4
						X 1798	Tooradin, Westernport Bay	953	43	21.7
						X 1737	Beaumaris, PPBe	3119	66	41.0
February	**1958**	**Westernport Bay**	**8**	**0**		X				
March	**1958**	**Westernport Bay**	**10**	**0**		X				
March	**1962**	**Westernport Bay**	**55**	**2**	**3.6**	X				
		Corinella, WPB				X 4030	Rhyll, Westernport Bay	346	28	8.2
		Corinella, WPB				X 4010	Westernport Bay	677	33	10.9
Total	**1957 to 1962**	**Westernport Bay**	**169**	**7**	**4.1**					

Table 26. Mallacoota Inlet internally tagged snapper releases (n_1) in 1959 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
March	**1959**	**Mallacoota Inlet**	**1040**	**70**	**6.7**	X				
		Mallacoota Inlet				X 4457	Mallacoota Inlet, ECe	22	33	14.8
		Mallacoota Inlet				X 3531	Bermagui NSW	110	28	2.2
		Mallacoota Inlet				X 3788	Broughton Island NSW	153	27	2.8
		Mallacoota Inlet				X 3834	Malabar NSW	191	26	2.5
		Mallacoota Inlet				X 4450	Sydney 60 miles north, NSW	250	28	3.8
		Mallacoota Inlet				X 3783	Green Cape Lighthouse NSW	281	25	-0.3
		Mallacoota Inlet				X 3532	Montague Island NSW	315	31	4.8
		Mallacoota Inlet				X 3968	Mallacoota Inlet, ECe	354	27	7.2
		Mallacoota Inlet				X 3049	Mallacoota Inlet, ECe	358	27	8.7
		Mallacoota Inlet				X 2986	Mallacoota Inlet, ECe	360	27	5.4
		Mallacoota Inlet				X 3874	Bermagui NSW, ECe	455	28	8.4
		Mallacoota Inlet				X 3865	Terrigal NSW	476	31	5.6
		Mallacoota Inlet				X 3855	Point Perpendicular NSW	497	27	5.5
		Mallacoota Inlet				X 3868	Jervis Bay NSW	581	32	11.4
		Mallacoota Inlet				X 3572	Kioloa NSW	595	32	6.6
		Mallacoota Inlet				X 3839	Botany Bay NSW	651	31	11.9
		Mallacoota Inlet				X 3573	Green Cape Lighthouse NSW	764	36	10.6
		Mallacoota Inlet				X 3166	Greenwell Point NSW	770	36	11.1
		Mallacoota Inlet				X 3029	Jervis Bay NSW	772	33	12.5
		Mallacoota Inlet				X 3920	Terrigal NSW	772	31	11.4

Table 26 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
		Mallacoota Inlet				X 3155	Solitary Lighthouse NSW	790	31	11.6
		Mallacoota Inlet				X 3963	Coogee NSW	792	34	10.6
		Mallacoota Inlet				X 3616	Bondi NSW	793	35	9.2
		Mallacoota Inlet				X 3799	North Head Sydney NSW	798	25	4.4
		Mallacoota Inlet				X 3661	Jervis Bay NSW	807	32	12.5
		Mallacoota Inlet				X 3078	Bermagui NSW	825	36	10.6
		Mallacoota Inlet				X 3686	Sydney Heads NSW	831	32	10.9
		Mallacoota Inlet				X 4473	Crowdy Head NSW	841	32	7.3
		Mallacoota Inlet				X 3553	Bateman Bay NSW	1038	36	9.9
		Mallacoota Inlet				X 3137	Tuncurry NSW	1073		
		Mallacoota Inlet				X 3923	Tuncurry NSW	1074	38	13.8
		Mallacoota Inlet				X 3196	Black Head Kiama NSW	1092	41	16.9
		Mallacoota Inlet				X 3567	Tuncurry NSW	1106		
		Mallacoota Inlet				X 3048	Tuncurry NSW	1111		
		Mallacoota Inlet				X 3910	Moruya Head NSW	1153	33	8.0
		Mallacoota Inlet				X 3836	Ulladulla NSW	1216	33	14.4
		Mallacoota Inlet				X 4496	Ulladulla NSW	1226	42	17.1
		Mallacoota Inlet				X 4467	Brush Island Ulladulla NSW	1240		
		Mallacoota Inlet				X 3424	Moruya Congo Park NSW	1291	43	18.8
		Mallacoota Inlet				X 3110	Batemans Bay NSW	1291	36	10.6
		Mallacoota Inlet				X 4451	Mona Vale NSW	1348	30	12.2

Table 26 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
		Mallacoota Inlet				X 2994	Nowra NSW	1522	42	19.9
		Mallacoota Inlet				X 3515	Ulladulla NSW	1552		
		Mallacoota Inlet				X 3157	Terrigal NSW	1595	41	16.8
		Mallacoota Inlet				X 3416	Bermagui NSW	1608	46	20.2
		Mallacoota Inlet				X 3605	North Head Sydney NSW	1632	41	17.5
		Mallacoota Inlet				X 3457	Port Macquarie NSW	1693	47	23.0
		Mallacoota Inlet				X 3494	Cronulla NSW	1707	0	
		Mallacoota Inlet				X 3414	Bermagui NSW	1739	38	18.1
		Mallacoota Inlet				X 3850	Batemans Bay NSW	1749	42	18.4
		Mallacoota Inlet				X 4380	Jervis Bay NSW	1758	48	29.9
		Mallacoota Inlet				X 3191	Broughton Island NSW	1781	48	24.7
		Mallacoota Inlet				X 3487	Port Stephens NSW	1791	46	18.7
		Mallacoota Inlet				X 3042	Ulladulla NSW	1942	39	13.8
		Mallacoota Inlet				X 3536	Greenwell Pt NSW	1980	50	27.2
		Mallacoota Inlet				X 4477	Cape Hawke Forster NSW	2136	0	
		Mallacoota Inlet				X 3561	Palm Beach Sydney NSW	2235	58	34.9
		Mallacoota Inlet				X 3128	Moruya, south coast NSW	2245	37	16.0
		Mallacoota Inlet				X 3007	Jervis Bay NSW	2661	52	29.4
		Mallacoota Inlet				X 3462	Melbourne Fish Market	2759	48	23.6
		Mallacoota Inlet				X 3637	Woolongong NSW	2853	51	23.1
		Mallacoota Inlet				X 3001	Marouba NSW	2905	61	41.6

Table 26 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
		Mallacoota Inlet				X 3612	Batemans Bay, NSW	2941	67	42.5
		Mallacoota Inlet				X 3710	Sydney NSW	3393	59	35.0
		Mallacoota Inlet				X 4338	Broughton Island NSW	3622	61	41.4
		Mallacoota Inlet				X 4488	NE Wooli River NSW	3789	56	30.4
		Mallacoota Inlet				X 3422	Bondi NSW	4173	61	35.6
		Mallacoota Inlet				X 3556	Disaster Bay NSW	4314	72	47.5
		Mallacoota Inlet				X 3163	Tabourie Ulladulla NSW	5098	71	44.3
		Mallacoota Inlet				X 3097	Bermagui River NSW	6224	71	50.1
Total 1959		**Mallacoota Inlet**	**1040**	**70**	**6.7**					

Table 27. Portland Bay internally tagged snapper releases (n_1) in 1956-1959 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
August	**1956**	**Portland**	**15**	**0**		X				
April	**1957**	**Portland harbour**	**381**	**11**	**2.9**	X				
		Portland harbour				X 1597	Portland harbour WCw	651	29	6.8
		Portland harbour				X 1703	Lady Bay Warrnambool WCw	988	37	12.1
		Portland harbour				X 1705	Portland harbour WCw	1000	34	11.7
		Portland harbour				X 1667	Melbourne Fish Market	1006	33	8.8
		Portland harbour				X 1403	Narrawong, WCw	2782	41	19.2
		Portland harbour				X 1378	Fawkner Beacon PPB	2867	58	37.8
		Portland harbour				X 1635	Williamstown PPBn	3152	60	37.5
		Portland harbour				X 1707	Queenscliff PPBs	3168	76	49.8
		Portland harbour				X 1392	Sandringham PPBe	3483	65	43.5
		Portland harbour				X 1344	Beaumaris PPBe	4329	64	39.7
		Portland harbour				X 1684	McRae Lighthouse PPB	4626	69	45.4
May	**1957**	**Portland Bay**	**169**	**8**	**6.4**					
		Portland Bay				X 1862	Portland harbour WCw	379	30	5.5
		Portland harbour				X 1923	Portland pier WCw	459	34	11.2
		Portland Bay				X 1884	Portland Breakwater WCw	871	33	9.7
		Portland Bay				X 1861	Portland Bay WCw	970	34	11.2
		Portland Bay				X 1893	Albert Park, PPBn	2741		
		Portland Bay				X 1880	Gellibrand Lighthouse, PPBn	3091	74	50.2
		Portland harbour				X 1933	Ricketts Pt PPBe	3830	57	35.6
		Portland Bay				X 1891	Portland harbour WCw	377	31	7.8

Table 27 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
June	**1957**	**Portland Bay**	**147**	**3**	**2.0**	X				
		Portland harbour				X 2072	Portland harbour WCw	608	28	4.9
		Portland harbour				X 2007	Portland harbour WCw	953	34	12.6
		Portland harbour				X 2099	Sorrento, PPBs	2327		
August	**1957**	**Portland Bay**	**91**	**5**	**5.5**	X				
		Portland harbour				X 2178	Portland harbour WCw	535	28	5.4
		Portland harbour				X 2132	Lawrence Rocks, WCw	614	31	8.9
		Portland harbour				X 2168	Pt MacDonnell SAe	1685	44	21.8
		Portland harbour				X 2143	Pt MacDonell, SAe	3552	71	48.6
		Portland harbour				X 2136	Rosebud PPBe	4818	76	54.5
March	**1958**	**Portland Bay**	**55**	**7**	**12.7**	**X**				
		Portland harbour				X 3236	Portland WCw	734	37	10.43
		Portland harbour				X 3239	PortlandWCw	1026	36	11.36
		Portland harbour				X 3232	Seaford PPBe	1734		
		Portland harbour				X 3245	Pt Cook PPBn	2456		
		Portland harbour				X 3244	Queenscliff Rip PPBs	2829	48	22.8
		Portland harbour				X 3226	Pt Wilson PPBw	3620	64	38.7
		Portland harbour				X 3263	Brighton PPBe	4609	66	40.4

Table 27 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
September	**1958**	**Portland Bay**	**103**	**6**	**5.8**	X				
		Portland harbour				X2715	Portland, WCw	163	32	3.4
		Portland harbour				X2695	Nora Crema & Rolee SAe	1681	58	28.0
		Portland harbour				X2742	Parkdale PPBe	2260	56	25.0
		Portland harbour				X2687	Wrights Bay, Kingston SAe	2342		
		Portland harbour				X2705	Black Rock, PPBe	3724	71	41.1
		Portland harbour				X2731	Beaumaris, PPBe	5334		
October	**1958**	**Portland Bay**	**89**	**3**	**3.4**	X				
		Portland harbour				X2770	Portland WCw	449	28	0.0
		Portland harbour				X2754	Blacknose Pt Portland WCw	1137	43	14.2
		Portland harbour				X2848	Frankston PPBe	3637	69	43.7
February	**1959**	**Portland Bay**	**103**	**8**	**7.8**	X				
		Portland harbour				X2865	Portland WCw	309	30	0.0
		Portland harbour				X2887	Portland WCw	335	34	2.2
		Portland harbour				X2881	Portland Breakwater WCw	343	32	2.5
		Portland Lighthouse				X2908	Portland WCw	378	34	3.6
		Portland harbour				X2896	Portland harbour WCw	1497	61	28.0
		Portland harbour				X2876	Pt MacDonnell SAe	1822	56	24.3
		Portland breakwater				X2927	Mentone PPBe	3561	60	32.0
		Portland, North shore				X2932	Seaford PPBe	5008	79	48.4
Total	**1956 to 1959**	**Portland Bay**	**1153**	**51**	**4.4**					

Table 28. Port Phillip Bay internally tagged snapper releases (n_1) in each region in 1971-72 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
September	**1972**	**Altona, PPBn**	**9**	**0**		ZAI				
November	**1972**	**Point Cook, PPBn**	**23**	**2**	**8.7**	ZAI				
		Point Cook				208	Altona Jetty, PPBn	486	53	20.3
		Point Cook				223	Port Melbourne Pier, PPBn	5196		
Total		**PPBn**	**32**	**2**	**6.3**	ZAI				
November	**1972**	**Werribee**	**81**	**8**	**9.9**	ZAI				
		Werribee River				313	Queenscliff , PPBs	312	46	1.7
		Werribee River				231	Dromana, PPBe	360	38	0.9
		Werribee				247	Bonbeach, PPBe	437	51	7.4
		Werribee River				236	Point Cook, PPBn	1226	71	25.6
		Werribee				277	Prince George Light, PPBw	2151	67	23.5
		Werribee				274	Edithvale, PPBn	2172		
		Werribee River				237	Brighton, PPBe	2970		
		Werribee				248	Fawkner Beacon, PPBe	4692	78	48.2
Total		**PPBw**	**81**	**8**	**9.9**					
August	**1972**	**Mornington, PPBs**	**36**	**0**		ZAI				
September	**1972**	**Mornington, PPBs**	**23**	**0**		ZAI				
October	**1972**	**Queenscliff, PPBs**	**3**	**1**	**33.3**	ZAI				
		Symonds Channel				2301	Crib Point WPB	1899	76	8.2
Total		**PPBs**	**62**	**1**	**1.6**					

Table 28 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
November	**1971**	**Brighton, PPBe**	**30**	**5**	**16.7**	ZAI				
		Brighton beach reef				2192	Gellibrand Light, PPBn	451	53	17.8
		Brighton beach reef				2510	Queenscliff, PPBs	328	27	
		Brighton beach reef				2507	Point Cook, PPBn	1914	53	10.1
		Brighton beach reef				2193	Westernport main channel	2160	71	27.1
		Brighton beach reef				2189	St.Kilda marina, PPBn	2189	64	29.3
November	**1971**	**Sandringham**	**100**	**19**	**19.0**	ZAI				
		Sandringham, PPBe				2136	Beaumaris, PPBe	67	32	
		Sandringham, PPBe				2166	Beaumaris, PPBe	82	32	
		Sandringham, PPBe				2160	Pt Wilson , PPBw	88	41	1.6
		Sandringham, PPBe				2162	Halfmoon Bay , PPBe	100	34	2.9
		Sandringham, PPBe				2526	Black Rock PPBe	118	34	3.7
		Sandringham, PPBe				2112	St. Helens, Geelong PPBw	145	32	10.0
		Sandringham, PPBe				2153	Black Rock, PPBe	183	41	2.7
		Sandringham, PPBe				2149	Sandringham, PPBe	433	44	10.7
		Sandringham, PPBe				2130	Frankston PPBe	693	65	9.7
		Sandringham, PPBe				2179	Portarlington, PPBw	711	41	5.34
		Sandringham, PPBe				2139	Mornington PPBs	779	76	2.4
		Sandringham, PPBe				2127	Mornington PPBs	2940	85	49.1

Table 28 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
		Sandringham, PPBe				2150	Rip, Sorrento PPBs	1044	62	19.0
		Sandringham, PPBe				2529	Rip Sorrento PPBs	1044	62	18.8
		Sandringham, PPBe				2521	Seaford, PPBe	1088	71	12.7
		Sandringham, PPBe				2144	No.4 Buoy, PPBn	1390	46	8.2
		Sandringham, PPBe				2118	Williamstown, PPBn	2168	69	
		Sandringham, PPBe				2176	Port Phillip Bay	3367		
		Sandringham, PPBe				2190	Brighton, PPBe	9103		
December	**1971**	**Brighton**	**7**	**1**	**14.3**	ZAI				
		Brighton, PPBe				3302	Fawkner Buoy PPBe	406	46	7.8
December	**1971**	**Sandringham**	**24**	**3**	**12.5**	ZAI				
		Sandringham PPBe				3700	Point Cook PPBn	84	28	4.7
		Sandringham PPBe				3613	Halfmoon Bay, PPBe	85	31	
		Sandringham PPBe				3609	Black Rock PPBe	139	43	3.8
August	**1972**	**Carrum/Dromana**	**190**	**2**	**1.1**	ZAI				
		Artificial Reef , PPBe				2624	Mornington, PPBs	208	27	6.7
		Artificial Reef , PPBe				2626	Rosebud, PPBs	224	28	5.9
October	**1972**	**Carrum**	**19**	**1**	**5.3**	ZAI				
		Artificial Reef, PPBe				2442	Portarlington, PPBw	347	61	2.8

Table 28 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Release Location	Days at sea	Size TLcm	Growth cm
October	**1972**	**Frankston**	**7**	**2**	**28.6**	ZAI				
		Frankston, PPBe				2488	Mt. Eliza, PPBe	471	69	24.7
		Frankston, PPBe				2490	Hastings, Westernport Bay	1091	68	8.3
October	**1972**	**Sandringham**	**11**	**1**	**9.1**	ZAI				
		Sandringham, PPBe				2480	San Remo, Westernport Bay	4020		
October	**1972**	**Seaford**	**3**	**0**		ZAI				
November	**1972**	**Carrum, PPBe**	**14**	**0**		ZAI				
November	**1972**	**Bonbeach, PPBe**	**181**	**25**	**13.8**	ZAI				
		Bonbeach, PPBe				2801	Black Rock PPBe	64		
		Bonbeach, PPBe				2042	Mordialloc Pier PPBe	67	20	0.2
		Bonbeach, PPBe				2828	Channel PPBe	74	33	11.5
		Bonbeach, PPBe				2803	Mt Eliza ,PPBe	77	23	3.2
		Bonbeach, PPBe				2875	Mordialloc, PPBe	81	26	4.6
		Bonbeach, PPBe				2870	Ranlagh Bay , Mt Eliza PPBe	90	24	1.9
		Bonbeach, PPBe				2076	Bristol Reef Chelsea PPBe	96	28	6.3
		Bonbeach, PPBe				2846	Mordialloc pier PPBe	98	35	14.3
		Bonbeach, PPBe				2012	Frankston PPBe	109	32	6.4
		Bonbeach, PPBe				2070	Mordialloc PPBe	110	25	4.0
		Bonbeach, PPBe				2863	Frankston PPBe	112	30	9.3
		Bonbeach, PPBe				2066	Rosebud PPBs	114	28	5.6
		Bonbeach, PPBe				2855	Mordialloc Pier PPBe	121	27	4.1

Table 28 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
		Bonbeach, PPBe				2040	Melbourne Fish Market	123	28	6.3
		Bonbeach, PPBe				2877	Rosebud PPBs	129	25	3.9
		Bonbeach, PPBe				2880	Black Rock PPBe	145	28	6.1
		Bonbeach, PPBe				2834	Mordialloc PPBe	156	28	8.0
		Bonbeach, PPBe				2049	Black Rock PPBe	187	28	7.9
		Bonbeach, PPBe				2051	Tortise Head Westernport	339	29	7.7
		Bonbeach, PPBe				2807	unknown	363	29	6.7
		Bonbeach, PPBe				2824	Dendy St. Beach PPBe	459	36	13.1
		Bonbeach, PPBe				2100	Mornington PPBs	533	74	3.46
		Bonbeach, PPBe				2831	Geelong Pier PPBw	780	38	17.6
		Bonbeach, PPBe				2872	Queenscliff PPBs	1089	35	14.2
		Bonbeach, PPBe				2864	Beaumaris PPBe	1243	47	25.7
November	**1972**	**Brighton, PPBe**	**11**	**2**	**18.2**	ZAI				
		Brighton, PPBe				317	Quarantine jetty, PPBs	74	41	1.44
		Brighton, PPBe				322	Brighton beach PPBe	90	27	6.57
November	**1972**	**Mordialloc, PPBe**	**39**	**0**		ZAI				
November	**1972**	**Ricketts Point, PPBe**	**38**	**3**	**7.9**	ZAI				
		Ricketts Point, PPBe				148	Beaumaris beach PPBe	123	28	6.1
		Ricketts Point, PPBe				123	St.Leonards PPBw	470	33	11.7
		Ricketts Point, PPBe				119	Mt Martha PPBs	3644		

Table 28 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
November	**1972**	**Mount Eliza, PPBe**	**21**	**3**	**14.3**	ZAI				
		Mount Eliza, PPBe				2308	Mt Martha PPBs	38		
		Mount Eliza, PPBe				2459	Mornington PPBs	159	44	0.05
		Mount Eliza, PPBe				2311	Werribee PPBw	1814	56	
November	**1972**	**Sandringham, PPBe**	**314**	**32**	**10.2**	ZAI				
		Sandringham, PPBe				2946	Mordialloc Beach PPBe	67	24	2.7
		Sandringham, PPBe				2798	Mordialloc PPBe	77	69	
		Sandringham, PPBe				110	Parkside Geelong PPBw	86	24	3.9
		Sandringham, PPBe				34	Sandringham PPBe	106	30	6.2
		Sandringham, PPBe				2969	Brighton PPBe	113	28	7.0
		Sandringham, PPBe				2780	Mt Martha PPBs	117	25	4.9
		Sandringham, PPBe				2777	Edithvale PPBn	128	28	8.3
		Sandringham, PPBe				2784	Mentone PPBe	143	27	3.9
		Sandringham, PPBe				2740	Mordialloc pier PPBe	144	32	10.6
		Sandringham, PPBe				2957	Black Rock PPBe	148	36	6.5
		Sandringham, PPBe				2730	Black Rock PPBe	150	36	8.4
		Sandringham, PPBe				84	Black Rock PPBe	276	31	4.4
		Sandringham, PPBe				2752	Portland harbour WCw	400	30	9.4
		Sandringham, PPBe				2997	Albert Park, PPBn	411	28	6.4
		Sandringham, PPBe				2955	Queenscliff Swan Island PPBs	413	29	8.0
		Sandringham, PPBe				2974	Point Sturt Wye River WCe	448	32	8.5

Table 28 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
November	**1972**	Sandringham, PPBe				2935	Hampton, PPBe	465	46	15.8
		Sandringham, PPBe				2799	Brighton PPBe	467	31	4.9
		Sandringham, PPBe				2435	Brighton PPBe	472	41	12.0
		Sandringham, PPBe				2949	Brighton Beach PPBe	492	39	17.8
		Sandringham, PPBe				2438	Black Rock PPBe	523	43	15.2
		Sandringham, PPBe				105	Corinella Westernport Bay	750	42	19.5
		Sandringham, PPBe				86	Port Cambell WCw	1184	37	17.1
		Sandringham, PPBe				2781	Apollo Bay WCw	1192	35	13.4
		Sandringham, PPBe				2754	Cape Douglas SAe	1472	39	18.3
		Sandringham, PPBe				3000	Altona PPBn	1825	48	26.3
		Sandringham, PPBe				2725	Black Rock PPBe	2542	70	28.4
		Sandringham, PPBe				90	Cowes Westernport Bay	2625	58	37.0
		Sandringham, PPBe				37	Fawkner Beacon PPB	2931	64	44.1
		Sandringham, PPBe				2432	Spoil ground PPB	3701		
		Sandringham, PPBe				2437	Frankston PPBe	4147	60	30.6
		Sandringham, PPBe				32	Elwood Bay PPBn	5102	74	54.5

Table 28 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
November	**1972**	**Seaford, PPBe**	**105**	**18**	**17.1**	**ZAI**				
		Seaford, PPBe				2926	Point Cook PPBn	6	41	
		Seaford, PPBe				2324	Parkdale PPBe	30	41	
		Seaford, PPBe				2326	Patterson River PPBe	67	52	
		Seaford, PPBe				2369	Safety Beach Dromana PPBe	80	28	
		Seaford, PPBe				2912	Black Rock PPBe	92	31	1.4
		Seaford, PPBe				2914	Ricketts Point PPBe	100	31	4.3
		Seaford, PPBe				2902	Mordialloc pier PPBe	104	23	1.1.2
		Seaford, PPBe				2323	Carrum PPBe	115	34	4.6
		Seaford, PPBe				2382	Frankston reef PPBe	128	43	
		Seaford, PPBe				2325	unknown	158	51	11.2
		Seaford, PPBe				2918	St. Kilda Marina PPBn	364	61	
		Seaford, PPBe				2893	unknown	411	0	
		Seaford, PPBe				2895	St. Leonards PPBw	434	31	8.0
		Seaford, PPBe				2899	Brighton pier PPBe	462	33	11.1
		Seaford, PPBe				2904	Ricketts Pt PPBe	813	45	24.4
		Seaford, PPBe				2925	Mordialloc beach PPBe	1193	64	17.6
		Seaford, PPBe				2921	Ricketts Point PPBe	1558	69	0.9
		Seaford, PPBe				2333	Parkdale PPBe	3259	69	37.8
1971-1972		**Total PPBe**	**1114**	**117**	**10.5**					
1971-1972		**Total PPB**	**1290**	**128**	**9.9**					

Table 29. Port Phillip Bay Tbar tagged snapper releases (n_1) in 1971 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
October	**1971**	**Port Phillip Bay east**	**12**	**0**		T				
November	**1971**	**Port Phillip Bay east**	**475**	**4**	**0.8**	T				
		Brighton, PPBe				T 310	Altona PPBn	2	41	0
		Carrum, PPBe				T 178	Mt. Martha, PPBe	40	73	0
		Brigthon, PPBe				T418	Lorne, WCw	133	40	3
		Brighton,PPBe				T 1547	Ormond Beach PPBe		45	
December	**1971**	**Port Phillip Bay east**	**128**	**2**	**1.6**					
						T1799	Mordialloc, PPBe	66	46	1
						T1805	Mordialloc, PPBe	74	48	0
Total	**1971**		**615**	**6**	**1.0**					

Table 30. Port Phillip Bay releases (n_1) of Tbar tagged snapper in 1994 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1994**	**Port Phillip Bay east**	**3**	**0**		MT				
February	**1994**	**Port Phillip Bay east**	**204**	**1**	**0.5**	MT				
		Beaumaris,PPBe				MT686	Carrum Downs, PPBe	1035	52	31.0
March	**1994**	**Port Phillip Bay east**	**342**	**3**	**0.9**					
		Halfmoon Bay PPBe				MT921	Ricketts Pt. PPBe	68	37	5.0
		PPB Spoil grounds, PPBn				MT951	Black Rock, PPBe	66	37	6.0
		PPB Spoil grounds, PPBn				MT848	Williamstown, PPBn	183	29	3.0
Total	**1994**		**548**	**4**	**0.7**					

Table 31. Port Phillip Bay releases (n_1) of dart tagged snapper in 1994 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
February	**1994**	**Port Phillip Bay east**	**2**	**0**		MT				
March	**1994**	**Port Phillip Bay east**	**68**	**2**	**2.9**	MT				
		PPB Spoil grounds, PPBn				MT 1530	Pt. Cook, PPBn	664		
		PPB Spoil grounds, PPBn				MT1529	Ocean Grove, WCe	1170	64	9.3
Total	**1994**	**Port Phillip Bay east**	**70**	**2**	**2.9**					

Table 32. Port Phillip Bay releases (n_1) of internally tagged snapper in 1998 – 1999 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
November	**1998**	**Port Phillip Bay south**	**7**	**2**	**28**	NESx				
		Queenscliff PPBs				NESx1122	Lakes Entrance ECw	94	36	
		Queenscliff PPBs				NESx1118	Lawrence Rocks, WCw	476	31	7.0
Total 1998		**Port Phillip Bay south**	**7**	**2**	**28**					
Febuary	**1999**	**Port Phillip Bay west**	**339**	**11**	**3.2**	NES				
		S.Corio Bay, PPBw				NES 13	Point Wilson, PPBs	25	31	0.8
		S.Corio Bay, PPBw				NES 39	Point Wilson, PPBs	25	27	1.2
		S.Corio Bay, PPBw				NES 253	Cunningham Pier, PPBw	28	29	1.5
		S.Corio Bay, PPBw				NES 253	Rock Pt. Apollo Bay WCe	36	31	0.0
		S.Corio Bay, PPBw				NES 36	Ricketts Point, PPBe	244	30	
		S.Corio Bay, PPBw				NES 34	Dutton Way, Portland WCw	247	32	2.6
		S.Corio Bay, PPBw				NES 241	Limeburner Pt. PPBw	361	32	2.1
		S.Corio Bay, PPBw				NES 327	Portland Bay, WCw	639	31	12.2
		S.Corio Bay, PPBw				NES 137	Balnarring, Westernport Bay	723	28	8.5
		S.Corio Bay, PPBw				NES 155	Peterborough, WCw	905	37	15.0
		S.Corio Bay, PPBw				NES 139	Hastings, Westernport Bay	999	40	18.8
March	**1999**	**Port Phillip Bay west**	**205**	**1**	**0.5**					
		S.Corio Bay, PPBs				NES 552	Black Rock, PPBe	430	29	8.7
Total	**1998-1999**	**Port Phillip Bay west**	**551**	**14**	**2.5**					

Table 33. West coast releases (n_1) of internally tagged snapper in 1998 – 1999 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TL cm	Growth
October	**1998**	**Apollo Bay, WCe**	**3**	**1**	**33.3**	NESx				
		Cape Otway				503	Beaumaris, PPBe	793	52	11.5
April	**1999**	**Apollo Bay # WCe**	**148**	**0**		NES				
Febuary	**1999**	**Portland**	**7**	**0**		NES				
March	**1999**	**Portland**	**130**	**20**	**15.4**	NES				
		Portland Harbour ,WCw				1057	Portland Harbour ,WCw	214	34	1
		Portland Harbour ,WCw				1093	Henty Bay Portland WCw	256	39	2.5
		Portland Harbour ,WCw				1099	Northshore Portland WCw	261	34	1.5
		Portland Harbour ,WCw				1180	Northshore Portland WCw	279	30	1.5
		Portland Harbour ,WCw				1181	Northshore Portland WCw	295	35	1.9
		Portland Harbour ,WCw				1167	Snapper Pt. Portland WCw	296	33	1
		Portland Harbour ,WCw				1168	Snapper Pt., Portland WCw	296	32	3
		Portland Harbour ,WCw				1098	Snapper Pt., Portland WCw	298	34	4
		Portland Harbour ,WCw				1055	Julia Reef, Portland WCw	299	32	1.4
		Portland Harbour ,WCw				1060	Snapper Pt., Portland WCw	332	39	5
		Portland Harbour ,WCw				1004	Northshore Portland WCw	346	36	4.3
		Portland Harbour ,WCw				1006	Northshore Portland WCw	346	36	2.3
		Portland Harbour ,WCw				1169	Surrey River Portland WCw	353	41	4
		Portland Harbour ,WCw				1028	Northshore Portland WCw	383	-	-
		Portland Harbour ,WCw				1059	Carrum PPBe	595	43	5.5
		Portland Harbour ,WCw				1066	Narrawong WCw	692	40	6.5
		Portland Harbour ,WCw				1049	Danger Pt. Port MacDonell	706	39	7.5
		Portland Harbour ,WCw				1041	Beachport, SAe	930	51	15.5
		Portland Harbour ,WCw				1078	Pt Cook, PPBn	974	50	15.4
		Portland Harbour ,WCw				1161	Corio Bay, PPBw	981	44	10.5
April	**1999**	**Portland**	**2**	**0**						
May	**1999**	**Portland**	**11**	**0**						

Caught by Danish seine

Table 34. Mallacoota Inlet releases (n_1) of internally tagged snapper in 1999 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location and Latitude	Days at sea	Size TL cm	Growth cm
March	**1999**	**Mallacoota Inlet**	**499**	**28**	**5.6**	NES				
						1886	Mallacoota Inlet ECe 37	27	17	0.2
						1513	Batemans Bay NSW 35	295	29	4.9
						1957	Rabbit Is. Mallacoota ECe 37	310	29	8.8
						1610	Howe Bight, Mallacoota ECe 37	323	25	3.4
						1685	Currarong, Jervis Bay NSW 34	332	31	5.1
						1767	Eden, NSW 37	334	30	3.9
						1645	Lower Lake Mallacoota ECe 37	363	37	12.7
						1743	Sussex Inlet Jervis Bay NSW 35	371	30	6.5
						1901	Bermagui, NSW 36	542	35	8.0
						1770	Bunga Heads NSW 36	632	32	5.0
						1928	Montague Island, NSW 36	672	34	10.5
						1533	Broughton Island, NSW 32	680	30	15.2
						1518	McGaurens, Seaspray ECw 38	697	38	16.0
						1810	Drum Reef, Jervis Bay NSW 35	836	34	16.8
						1828	Woombarra, NSW 34	985	32	9.0
						1826	Greenwell Point, NSW 37	991	34	11.4
						1838	Diamond Head, NSW 31	1002	34	9.7
						1619	Moruya Head NSW 36	1008	31	8.6
						1744	Woombarra, NSW 34	1058	34	9.4
						1511	Nambucca Heads NSW 30	1117	30	10.9
						1821	Wollongong, NSW 34	1121	36	12.2
						1655	Wyong Head, NSW 33	1141	33	11.2
						1829	Nora Head, NSW 34	1217	34	16.8
						1539	Montague Island, NSW 36	1282	34	13.4
						1802	Batemans Bay, NSW 35	1303	33	11.0
						1806	Batemans Bay, NSW 35	1332	37	11.7
						1591	Stanwell Park, NSW 34	1412	37	17.2
						1612	Broughton Island, NSW 32	1609	47	22.6

Table 34. (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
April	**1999**	**Mallacoota Inlet**	**499**	**4**	**0.8**	NES				
						2172	Woombarra, NSW 34	844	34	15.0
						2317	Coffs Harbour NSW 30	919	30	10.2
						2247	Wyong Head, NSW 33	974	35	12.8
						2188	Eden, NSW 37	1424	35	12.3
Total	**1999**	**Mallacoota Inlet**	**998**	**32**	**3.2**					

Table 35. Port Phillip Bay releases (n_1) of dart tagged snapper in 1996-1998 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TL cm	Growth cm
January	**1996**	**Port Phillip Bay**	**1**	**0**		A				
January	**1997**	**Port Phillip Bay**	**2**	**0**		A				
January	**1998**	**Port Phillip Bay**	**1**	**0**		A				
November	**1998**	**Port Phillip Bay**	**1**	**0**		A				
December	**1998**	**Port Phillip Bay**	**38**	**2**	**5.3**	A				
December	**1998**	**Port Phillip Bay**	**14**	**1**	**7.1**	Md				
December	**1998**	**Port Phillip Bay**	**1**	**0**		DV, DR				
		S. Corio Bay, PPBw				A14504	Outer Corio Bay, PPBw	115	40	5.0
		S.Corio Bay, PPBw				A14500	Williamstown, PPBn	501	43	11.0
		S. Corio Bay, PPBw				Md1593	Melbourne Fish Market	966	46	14.0
Total 1996-98			**58**	**3**	**5.2**					

Table 35.(continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1999**	**Port Phillip Bay**	**92**	**2**	**2.2**	A				
January	**1999**	**Port Phillip Bay**	**14**	**0**		DV, DR				
		S. Corio Bay PPBw				A14546	Corio Quay, PPBw	45	33	4.5
		Ricketts Pt. PPBe				A14605	Altona PPBn	73	28	1.0
February	**1999**	**Port Phillip Bay**	**10**	**0**		A				
February	**1999**	**Port Phillip Bay**	**117**	**2**	**1.3**	DV, DR				
		S. Corio Bay				DR 6716	Ricketts Pt. PPBn	526	36	7.0
March	**1999**	**Port Phillip Bay**	**8**	**0**		A				
March	**1999**	**Port Phillip Bay**	**1**	**0**		DV, DR				
April	**1999**	**Port Phillip Bay**	**3**	**1**	**33.3**	A				
April	**1999**	**Port Phillip Bay**	**20**	**0**		DV, DR				
		Carrum PPBe				A13309	Patterson Lakes PPBe	343	32	3.0
June	**1999**	**Port Phillip Bay**	**2**	**0**		DR DV				
August	**1999**	**Port Phillip Bay**	**4**	**1**	**25.0**	DR DV				
		Beaumaris, PPBe				DR6593	Willamstown, PPBn	90	26	
October	**1999**	**Port Phillip Bay**	**1**	**0**		A				
October	**1999**	**Port Phillip Bay**	**12**	**0**		DR				
November	**1999**	**Port Phillip Bay**	**21**	**3**	**14.3**	DR, DV				
		S.Corio Bay				DR6749	St. Helens, Corio PPBw	45	35	0.0
		S.Corio Bay				DR6747	Limeburners Corio PPBw	349	40	5.0
		Mornington PPBe				DV3832	Cape Otway, WCe	588	52	8.5
December	**1999**	**Port Phillip Bay**	**18**	**1**	**5.3**	A				
December	**1999**	**Port Phillip Bay**	**15**	**1**	**6.7**	DR				
		St. Kilda PPBn				A14637	St. Kilda, PPBn	405	33	8.0
		S. Corio Bay				DR6763	Wharf, Corio Bay PPBw	1106	66	33.5
Total	**1999**		**338**	**11**	**3.3**					

Table 35.(continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**2000**	**Port Phillip Bay**	**67**	**2**	**3.0**	A				
January	**2000**	**Port Phillip Bay**	**61**	**3**	**4.9**	DR,DV				
		S. Corio Bay, PPBw				DR 6775	Corio Bay PPBw	20	28	1.0
		S. Corio Bay, PPBw				DR 6780	Williamstown, PPBn	35	28	2.0
		Mordialloc, PPBe				A13340	Black Rock, PPBe	121	28	4.5
		Mordialloc, PPBe				A13346	Black Rock, PPBe	132	28	4
		Carrum, PPBe				DV2032	Black Rock, PPBe	573	31	5.5
February	**2000**	**Port Phillip Bay**	**43**	**2**	**4.7**	A				
February	**2000**	**Port Phillip Bay**	**42**	**2**	**4.8**	DR,DV				
		S.Corio Bay, PPBw				DR 6790	Clifton Springs PPBw	30	26	0.4
		St.Kilda PPBn				A14682	Williamstown, PPBn	100	28	1.2
		St. Kilda PPBn				A14681	Altona PPBn	259	25	3
		S. Corio Bay, PPBw				DR 6791	Lorne Wce	400	31	5.0
March	**2000**	**Port Phillip Bay**	**5**	**1**	**20.0**	A				
March	**2000**	**Port Phillip Bay**	**83**	**3**	**3.6**	DR,DV				
		Corio Bay PPBw				A14201	Angelsea, Wce	50	43	3
		S. Corio Bay PPBw				DR 8634	Pt. Wilson PPBw	202	27	1.0
		Williamstown				DV 1036	St. Kilda, PPBn	350	31	7.0
		Williamstown				DV 1016	Black Rock, PPBe	397	35	8.0
April	**2000**	**Port Phillip Bay**	**2**	**0**		A				
April	**2000**	**Port Phillip Bay**	**98**	**2**	**2.1**	DR,DV				
		Beaumaris, PPBe				DV829	Black Rock, PPBe	32	28	2.5
		Beaumaris, PPBe				DV874	Port Melbourne, PPBn	427	34	7.0

Table 35 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
August	**2000**	**Port Phillip Bay**	**1**	**0**		DR,DV				
October	**2000**	**Port Phillip Bay**	**1**	**0**		A_2				
October	**2000**	**Port Phillip Bay**	**8**	**0**		DR,DV				
November	**2000**	**Port Phillip Bay**	**9**	**1**	**11.1**	DR,DV				
		Carrum, PPBe				DV 2003	Melbourne Fish Market	469	41	2.0
December	**2000**	**Port Phillip Bay**	**19**	**4**	**21.1**	DR,DV				
		Werribee PPBw				DR 7411	Queenscliff Rip, PPBs	63	40	0.0
		S.Corio Bay PPBw				DR 8648	Melbourne Fish Market,PPB	116	35	6.0
		Werribee PPBw				DR 7413	Pt Cook PPBn	340	42	5.0
		Werribee, PPBw				DR 7419	Pt. Cook PPBn	354	43	10.0
Total	**2000**		**439**	**20**	**4.6**					
January	**2001**	**Port Phillip Bay**	**5**	**0**		DR,DV				
February	**2001**	**Port Phillip Bay**	**12**	**0**		DR,DV				
March	**2001**	**Port Phillip Bay**	**17**	**0**		DR,DV				
May	**2001**	**Port Phillip Bay**	**9**	**3**	**33.3**					
		Port Melbourne, PPBn				DR 7422	Port Melbourne, PPBn	19	32	0.0
		Port Melbourne, PPBn				DR 7423	Port Melbourne, PPBn	19	33	0.0
		Port Melbourne, PPBn				DR 7422	Port Melbourne, PPBn	19	33	0.0
September	**2001**	**Port Phillip Bay**	**4**	**1**	**25.0**					
		Black Rock, PPBe				DV 1071	Black Rock, PPBe	12	33	0.0
October	**2001**	**Port Phillip Bay**	**2**	**0**						
November	**2001**	**Port Phillip Bay**	**2**	**1**						
		Sandringham, PPBe				DR8092	Fawkner Beacon, PPBn	371	50	10.0
December	**2001**	**Port Phillip Bay**	**6**	**1**						
		Mornington, PPBs				DV1601	Port Phillip Bay	347	46	4.5
Total	**2001**		**57**	**6**	**10.5**					

Table 35 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**2002**	**Port Phillip Bay**	**32**	**0**		DV				
February	**2002**	**Port Phillip Bay**	**40**	**1**		DV				
		Albert Park, PPBn				DV5224	Albert Park, PPBn	19	35	0.0
March	**2002**	**Port Phillip Bay**	**114**	**1**	**0.9**	DV, DR				
		S. Corio Bay, PPBw				DR8688	Pt. Cook, PPBn	363	31	4.5
April	**2002**	**Port Phillip Bay**	**71**	**6**	**8.5**	DR, DV				
		S. Corio Bay, PPBw				DR5118	Williamstown, PPBn	81	31	2.0
		S. Corio Bay, PPBw				DR5119	Port Phillip Bay	204	28	1.0
		S. Corio Bay, PPBw				DR5091	S. Corio Bay, PPBw	220	36	3.5
		S. Corio Bay, PPBw				DR5087	Williamstown, PPBn	224	45	0.0
		S. Corio Bay, PPBw				DR5085	Pt Wilson, PPBw	319	41	1.6
		S.Corio Bay, PPBw				DR5111	Seaford, PPBe	328	28	2.0
May	**2002**	**Port Phillip Bay**	**25**	**0**		DR, DV				
October	**2002**	**Port Phillip Bay**	**1**	**0**		DV				
November	**2002**	**Port Phillip Bay**	**4**	**1**		DR				
		Sandringham, PPBe				DR8092	Fawkner Beacon, PPBn	371	50	13.0
December	**2002**	**Port Phillip Bay**	**23**	**0**						
January	**2003**	**Port Phillip Bay**	**111**	**3**		DR, DV				
		Williamstown, PPBn				DV5501	Williamstown, PPBn	12	26	0.0
		Corio Bay, PPBw				DR5164	Yarra river mouth, PPBn	50	28	3.0
		Williamstown, PPBn				DV5505	Williamstown, PPBn			
February	**2003**	**Port Phillip Bay**	**57**	**1**		DR, DV				
		Williamstown, PPBn				DV5518	Williamstown, PPBn	31	27	0.0
March	**2003**	**Port Phillip Bay**	**66**	**1**		DR, DV				
		Williamstown, PPBn				DV5524	Altona, PPBn	56	28	2.0
April	**2003**	**Port Phillip Bay**	**58**	**1**		DR, DV				
		Corio Bay, PPBw				DR5093	Corio Bay, PPBw	367	39	0.0
May	**2003**	**Port Phillip Bay**	**5**	**0**		DR, DV				
Total 1996-2003			**1498**	**55**	**3.7**					

Table 36. Westernport Bay releases (n_1) of dart tagged snapper in 1999-2003 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size cm	Growth cm
February	**1999**	**Westernport Bay**	**19**	**0**		DR				
March	**1999**	**Westernport Bay**	**2**	**0**		A				
April	**1999**	**Westernport Bay**	**4**	**0**		DR				
November	**1999**	**Westernport Bay**	**3**	**1**	**33.3**	A				
		Cowes				A14802	Cowes Westernport Bay	108	39	2.0
December	**1999**	**Westernport Bay**	**1**	**0**		A				
December	**1999**	**Westernport Bay**	**12**	**1**	**8.3**	DR				
		Tortoise Head				DR6671	Stony Point Westernport Bay	432	35	9.0
January	**2000**	Westernport Bay	**3**	0		A				
November	**2000**	**Westernport Bay**	**2**	0		A				
December	**2000**	**Westernport Bay**	**3**	0		A				
January	**2001**	**Westernport Bay**	**3**	0		DR, DV				
			3	0		A				
February	**2001**	**Westernport Bay**	**3**	0		A				
			2	0		DR				
March	**2002**	**Westernport Bay**	**6**	0		A				
November	**2002**	**Westernport Bay**	**4**	0		A				
December	**2002**	**Westernport Bay**	**1**	0		A				
January	**2003**	**Westernport Bay**	**12**	0		A				
February	**2003**	**Westernport Bay**	**18**	**1**	**5.6**	A				
		Sandy Point				A14887	Cowes, Westernport Bay	6	28	0.0
Total 1999-2003		**Westernport Bay**	**101**	**3**	**3.0**					

Table 37. West Coast east releases (n_1) of dart tagged snapper in 1998-2002 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size cm	Growth cm
December	**1998**	**West Coast east**	**1**	**0**						
January	**1998**	**West coast east**	**5**	**1**	**20.0**					
		London Bridge, Wce				DR6508	Portsea surf beach, Wce	356	32	4
February	**1999**	**West Coast east**	**11**	**1**	**9.1**	DR				
		Portsea beach, Wce				DR 6525	Cape Schank, Wce	893	43	17.0
April	**1999**	**West Coast east**	**1**	**0**						
March	**2002**	**West Coast east**	**6**	**0**		A				
Total 1998-2002			**24**	**2**	**8.3**					

Table 38. Portland Bay releases (n_1) of dart tagged snapper in 1998-2001 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size cm	Growth cm
October	**1998**	**Portland Bay**	**1**	**0**		**A**				
November	**1998**	**Portland Bay**	**57**	**2**	**3.5**	**A**				
		Portland Harbour WCw				A14901	Portland Bay WCw	430	30	4.5
		Portland Harbour WCw				A14996	Portland Harbour WCw	444	40	14
December	**1998**	**Portland Bay**	**45**	**5**	**11.1**	**A**				
		Portland Harbour WCw				A14917	Portland Harbour WCw	3	27	0
		Portland Harbour WCw				A14944	Allestree Portland Bay WCw	69	34	2
		Portland Bay WCw				A14948	Northshore Portland WCw	383	36	6
		Portland Harbour WCw				A14911	Portland Harbour WCw	390	34	8
		Portland Bay WCw				A14926	Northshore Portland WCw	400	37	6.1
Total	**1998**		**103**	**7**	**6.8**					

Table 38 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	Size	Growth
January	**1999**	**Portland Bay**	**39**	**5**	**12.8**	**A**				
		Allestree, WCw				A14403	Allestree Portland Bay WCw	33	32	1.0
		Allestree, WCw w				A14402	Allestree, Portland Bay WCw	64	31	1.0
		Allestree, WCw				A14407	Allestree, Portland Bay WCw	64	32	2.0
		Whalers Pt, WCw				A13847	Portland harbour WCw	184	31	2.0
		Allestree, WCw				$A_2$14403	Northshore, WCw	380	35	3.0
		Minerva Reef, WCw				A14424	Port MacDonnell, SAe	770	39	9.0
February	**1999**	**Portland Bay**	**70**	**2**	**2.9**	**A**				
		Allestree, WCw				$A_2$14403	Northshore, WCw	347	35	3.0
		Allestree WCw				A14446	Allestree Portland Bay WCw	384	37	7.0
November	**1999**	**Portland Bay**	**2**	**0**		**A**				
December	**1999**	**Portland Bay**	**53**	**6**	**11.3**	DR DV				
		Allestree WCw				DR 5824	Wally's ramp, WCw	16	35	0.0
		Allestree WCw				DR 5819	Portland Northshore WCw	37	37	1.0
		Allestree WCw				DR 5821	Minerva Reef, WCw	40	34	0.6
		Allestree WCw				DR 5842	Snapper Pt. WCw	43	36	1.0
		Allestree WCw				DR 5806	Portland Harbour WCw	47	26	0.0
		Allestree WCw				DR 8828	Minerva Reef, WCw	56	28	0.0
January	**2000**	**Portland Bay**	**7**	**1**	**14.3**	**DR DV**				
		Snapper Pt. WCw				DR 5894	Portland Northshore WCw	771	46	12.0
February	**2000**	**Portland Bay**	**20**	**0**		**DR DV**				
March	**2000**	**Portland Bay**	**10**	**0**		**A**				
April	**2000**	**Portland Bay**	**5**	**0**		**DV**				
April	**2000**	**Portland Bay**	**1**	**0**		**A**				
December	**2000**	**Portland Bay**	**1**	**0**		**A**				
January	**2001**	**Portland Bay**	**6**	**0**		**A**				
February	**2001**	**Portland Bay**	**12**	**1**	**8.3**	**A**				
		Harbour, WCw				A14238	Warrnambool, Eagle Rock	433	35	4.0
June	**2001**	**Portland Bay**	**2**	0						
July	**2001**	**Portland Bay**	**2**	0						
Total	**1999- 2001**		**230**	**15**	**6.5**					

Table 39. East Coast releases (n_1) of dart tagged snapper 1995 – 2002 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
December	**1995**	**Outside Corner Inlet**	**1**	**0**		A				
April	**1996**	**Outside Corner Inlet**	**1**	**0**		A				
January	**1997**	**Outside Corner Inlet**	**4**	**0**		M				
February	**1997**	**Outside Corner Inlet**	**12**	**0**		M				
February	**1997**	**Outside Corner Inlet**	**1**	**0**		A				
March	**1997**	**Outside Corner Inlet**	**15**	**0**		M				
April	**1997**	**Outside Corner Inlet**	**21**	**0**		M				
May	**1997**	**Outside Corner Inlet**	**4**	**0**		M				
March	**1998**	**Outside Corner Inlet**	**30**	**2**	**6.7**	M				
		Seaspray				MC1915	Rabbit Island, ECw	143	33	9.3
		Seaspray				MC5404	Lakes Entrance, ECe	751		
January	**1999**	**Eden NSW**	**1**	**0**		A				
March	**1999**	**Eden, NSW**	**10**	**1**		A				
		Eden				A13533	Eden, NSW	14	23	
December	**1999**	**Outside Corner Inlet**	**6**	**0**		M, DR				
February	**2000**	**Outside Corner Inlet**	**2**	**0**		DV				
January	**2001**	**Outside Corner Inlet**	**1**	**0**		DV				
February	**2002**	**Outside Corner Inlet**	**4**	**0**		DV				
May	**2002**	**Outside Corner Inlet**	**7**	**0**		DV				
Total	**1995-2002**	**East coast**	**120**	**3**	**2.5**					

Table 40. Port Phillip Bay releases (n_1) of T bar tagged snapper in 1995 –2003 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1995**	**Port Phillip Bay**	**57**	**1**	**1.8**	**A**				
		Sandringham, PPBe				A17223	Hampton, PPBe	268		
February	**1995**	**Port Phillip Bay**	**120**	**0**		A				
March	**1995**	**Port Phillip Bay**	**26**	**0**		A				
November	**1995**	**Port Phillip Bay**	**4**	**0**		A				
December	**1995**	**Port Phillip Bay**	**7**	**0**		A				
January	**1996**	**Port Phillip Bay**	**10**	**0**		A				
February	**1996**	**Port Phillip Bay**	**53**	**0**		A				
March	**1996**	**Port Phillip Bay**	**118**	**3**	**2.5**	A				
		Williamstown				A11014	Williamstown PPBn	308	27	12.4
		St. Kilda, PPBn				A11084	Queenscliff PPBs	715	32	12.1
		St.Kilda, PPBn				A20231	Portarlington, PPBw	1410	28	9.5
April	**1996**	**Port Phillip Bay**	**31**	**0**		A				
May	**1996**	**Port Phillip Bay**	**32**	**2**	**6.3**	A				
		Mordialloc PPBe				A22406	Rhyll, Westernport Bay	593	34	14.0
		Mordialloc PPBe				A22387	Altona, PPBn	599	35	14.0
June	**1996**	**Port Phillip Bay**	**6**	**0**		A				
September	**1996**	**Port Phillip Bay**	**2**	**0**		A				
October	**1996**	**Port Phillip Bay**	**2**	**0**		A				
November	**1996**	**Port Phillip Bay**	**50**	**0**		A				
December	**1996**	**Port Phillip Bay**	**154**	**4**	**2.6**	A				
		S. Corio Bay, PPBw				A27235	Corio Bay, PPBw	59	27	4.3
		S. Corio Bay, PPBw				A27219	Coronet Bay, Westernport	472	35	13.0
		S. Corio Bay, PPBw				A27222	Williamstown, PPBn	530		
		S. Corio Bay, PPBw				A27225	Tortoise Head Westernport	738	36	13.0
Sub-total	**1995-96**		**672**	**10**	**1.5**					

Table 40 **(continued)**

Month	Year	Release Location	n_1	n	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1997**	**Port Phillip Bay**	**266**	**3**	**1.1**	A				
		St. Kilda PPBn				A25742	Corio Bay, PPBw	757		
		S. Corio Bay PPBw				A27306	Lakes Entrance ECw	815	40	15.0
		S. Corio Bay PPBw				A27366	Eagle Rock Westernport	1021	40	16.0
February	**1997**	**Port Phillip Bay**	**311**	**2**	**0.6**	A				
		S. Corio Bay PPBw				A27416	Frankston PPBe	22	30	3.0
		S. Corio Bay PPBw				A27473	Woolamai, Westernport	386	29	5.0
March	**1997**	**Port Phillip Bay**	**35**	**0**		A				
April	**1997**	**Port Phillip Bay**	**6**	**0**		A				
May	**1997**	**Port Phillip Bay**	**2**	**0**		A				
June	**1997**	**Port Phillip Bay**	**3**	**0**		A				
August	**1997**	**Port Phillip Bay**	**8**	**0**		A				
September	**1997**	**Port Phillip Bay**	**51**	**0**		A				
October	**1997**	**Port Phillip Bay**	**5**	**0**		A				
November	**1997**	**Port Phillip Bay**	**121**	**2**	**1.7**	A				
November	**1997**	**Port Phillip Bay**	**18**	**3**	**16.7**	M				
		S. Corio Bay PPBw				M1506	Limeburners Pt. PPBw	56	30	2.0
		S. Corio Bay PPBw				M1501	Pt. Henry PPBw	83	29	3.0
		S. Corio Bay PPBw				M1500	Corio Bay, PPBw	103		
		Williamstown PPBn				A32751	Altona PPBn	444	51	9.5
		Williamstown PPBn				A32752	Altona PPBn	444	52	13.0
December	**1997**	**Port Phillip Bay**	**212**	**0**		A				
December	**1997**	**Port Phillip Bay**	**34**	**1**	**2.9**	M				
		S. Corio Bay, PPBw				M1522	Stingaree Bay PPBw	73	32	2.0
Sub total	**1997**		**1072**	**11**	**1.0**					

Table 40 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
January	**1998**	**Port Phillip Bay**	**55**	**1**	**1.8**	A				
January	**1998**	**Port Phillip Bay**	**96**	**2**	**2.0**	M				
January	**1998**	**Port Phillip Bay**	**1**	**0**		Ws				
		Outer Corio Bay PPBw				A31510	Corio Bay , PPBw	21	46	
		S. Corio Bay, PPBw				M2533	Pt. Henry PPBw	21	32	1.0
		S. Corio Bay, PPBw				M2563	Anonyma Shoals, PPBe	605	35	6.0
February	**1998**	**Port Phillip Bay**	**193**	**3**	**1.6**	A				
February	**1998**	**Port Phillip Bay**	**214**	**2**	**0.9**	M				
		S. Corio Bay, PPBw				A31753	Angelsea WCw	16	28	0
		S. Corio Bay, PPBw				M3839	Corio Bay, PPBw	17	30	0
		S. Corio Bay, PPBw				A10945	Pt. Wilson, PPBw	24	30	0
		S. Corio Bay, PPBw				A19357	Williamstown PPBn	31	31	
		S. Corio Bay, PPBw				M3912	Williamstown, PPBn	987	42	17.0
March	**1998**	**Port Phillip Bay**	**113**	**0**		M				
March	**1998**	**Port Phillip Bay**	**114**	**0**		A				
April	**1998**	**Port Phillip Bay**	**16**	**0**		A				
April	**1998**	**Port Phillip Bay**	**22**	**0**		M				
April	**1998**	**Port Phillip Bay**	**25**	**0**		Ws				
May	**1998**	**Port Phillip Bay**	**51**	**0**		A				
June	**1998**	**Port Phillip Bay**	**2**	**0**		A				
October	**1998**	**Port Phillip Bay**	**17**	**1**	**5.9**	Ws				
		S. Corio Bay, PPBw				Ws 4135	Corio Bay PPBw	59	35	1.0
November	**1998**	**Port Phillip Bay**	**10**	**1**	**10.0**	A				
November	**1998**	**Port Phillip Bay**	**51**	**2**	**3.9**	M				
November	**1998**	**Port Phillip Bay**	**87**	**3**	**3.4**	Ws				
		S. Corio Bay, PPBw				Ws 4179	Rippleside, Corio PPBw	31	32	0
		S. Corio Bay, PPBw				A16170	Corio Bay PPBw	113	34	8.5
		S. Corio Bay, PPBw				M1594	Port Melbourne PPBn	131	40	6.2
		S. Corio Bay, PPBw				Ws 4178	Corio Wharf PBw	397	42	8.0
		S. Corio Bay, PPBw				M1576	Williamstown PPBn	512	40	12.0
		S. Corio Bay, PPBw				Ws 4224	Limeburners Pt PPBw	739	41	12.5
December	**1998**	**Port Phillip Bay**	**33**	**0**		A				
Sub total	**1998**		**1100**	**15**	**1.4**					

Table 40 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1999**	**Port Phillip Bay**	**12**	**0**		A				
February	**1999**	**Port Phillip Bay**	**62**	**0**		A				
March	**1999**	**Port Phillip Bay**	**41**	**0**		A				
April	**1999**	**Port Phillip Bay**	**30**	**3**	**10.0**	A				
		Williamstown, PPBn				A40204	Frankston, PPBe	220	60	0.0
		Carrum, PPBe				A36029	Williamstown PPBn	419	33	4.5
		Black Rock, PPBe				A39119	Black Rock, PPBe	428	24	3.0
May	**1999**	**Port Phillip Bay**	**8**	**0**		A				
June	**1999**	**Port Phillip Bay**	**14**	**0**		A				
October	**1999**	**Port Phillip Bay**	**4**	**0**		A				
October	**1999**	**Port Phillip Bay**	**28**	**2**	**7.1**	TR				
		Queenscliff, PPBs				TR646	Swan Bay, PPBs	51	24	2.0
		Queenscliff, PPBs				TR642	Swan Bay, PPBs	409	32	10.4
November	**1999**	**Port Phillip Bay**	**24**	**0**		A				
November	**1999**	**Port Phillip Bay**	**28**	**2**	**7.1**	TR				
		S. Corio Bay, PPBw				TR1422	Corio Wharf, PPBw	84	25	5.0
		S. Corio Bay, PPBw				TR1423	Corio Wharf, PPBw	112	28	5.5
Jan-Nov	**1999**		**251**	**7**	**2.8**					

Table 40. (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
December	**1999**	**Port Phillip Bay**	**60**	**3**	**5.0**	**A**				
December	**1999**	**Port Phillip Bay**	**245**	**5**	**2.0**	**P**				
December	**1999**	**Port Phillip Bay**	**592**	**9**	**1.5**	**TR**				
		Clifton Springs, PPBw				TR 357	Corio Bay, PPBw	39	28	4.6
		S. Corio Bay, PPBw				P 4763	Indented Head PPBw	40	28	3.9
		S. Corio Bay, PPBw				P 4868	Corio Quay PPBw	55	24	1.9
		Clifton Springs, PPBw				TR 138	Corio Bay, PPBw	67	28	1.5
		Clifton Springs, PPBw				TR 314	Clifton Springs, PPBw	79	27	2.3
		Clifton Springs,PPBw				TR 444	Clifton Springs, PPBw	79	25	2.5
		S. Corio Bay, PPBw				P 4790	Clifton Springs PPBw	79	25	2.1
		S. Corio Bay, PPBw				P 4879	Cunningham Pier PPBw	120	28	5.5
		Altona, PPBn				A 41080	Black Rock, PPBe	150	41	18.5
		S. Corio Bay, PPBw				TR 1480	Williamstown, PPBn	163	30	7.5
		S. Corio Bay, PPBw				TR 1489	Williamstown, PPBn	163	30	7.5
		Port Melbourne, PPBn				A 41652	Williamstown, PPBn	188	27	4.3
		Clifton Springs, PPBw				TR 286	Altona, PPBn	279	28	4.9
		Clifton Springs, PPBw				TR 270	Altona, PPBn	284	26	3.6
		S. Corio Bay, PPBw				P 4800	Clifton Springs PPBw	387	33	10.3
		Pt. Henry PPBw				A 32962	Corio Bay, PPBw	506	28	6.0
		Clifton Springs, PPBw				TR 600	Sandringham, PPBe	653	30	7.7
Total	**1999**		**1148**	**24**	**2.1**					

Table 40 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
January	**2000**	**Port Phillip Bay**	**95**	**0**		A				
January	**2000**	**Port Phillip Bay**	**130**	**4**	**3.1**	TR				
		S. Corio Bay, PPBw				TR2148	Williamstown, PPBn	46	27	2.0
		S. Corio Bay, PPBw				TR2107	Black Rock, PPBe	180		4.0
		S. Corio Bay, PPBw				TR2142	Clifton Springs, PPBw	368	31	8.8
		S. Corio Bay, PPBw				TR2181	Brighton, PPBe	765	33	10.0
February	**2000**	**Port Phillip Bay**	**119**	**1**	**0.8**	A				
February	**2000**	**Port Phillip Bay**	**43**	**0**		TR				
		St. Kilda PPBn				A43496	St. Kilda Pier PPBn		33	6.5
March	**2000**	**Port Phillip Bay**	**256**	**2**	**0.7**	A				
March	**2000**	**Port Phillip Bay**	**64**	**1**	**1.6**	TR				
		Corio Bay PPBw				A41991	Black Rock, PPBe	49	29	0.0
		Clifton Springs PPBw				A16623	St. Leonards PPBw	185	39	1.0
		S. Corio Bay, PPBw				TR2281	Black Rock, PPBe	955	33	8.5
April	**2000**	**Port Phillip Bay**	**198**	**2**	**1.0**	A				
April	**2000**	**Port Phillip Bay**	**28**	**0**		TR				
		Teahouse, PPBe				A44442	Altona, PPBn	168	25	0.0
		Ricketts Pt, PPBe				A44426	St. Helens Corio, PPBw	646	30	10.5
May	**2000**	**Port Phillip Bay**	**76**	**2**	**2.6**	A				
		Small G reef, PPBe				A44220	Altona PPBn	162	25	1.0
		Small G reef, PPBe				A 44381	Altona PPBn	393	32	6.0
June	**2000**	**Port Phillip Bay**	**56**	**0**		A				
July	**2000**	**Port Phillip Bay**	**13**	**0**		A				
August	**2000**	**Port Phillip Bay**	**32**	**0**		A				
September	**2000**	**Port Phillip Bay**	**20**	**0**		A, TR				

Table 40. (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
October	**2000**	**Port Phillip Bay**	**64**	**0**		A				
November	**2000**	**Port Phillip Bay**	**18**	**0**		A				
			5	**1**	**20.0**	TR				
		Corio Bay, PPBw				TR 2326	Swan Bay, PPBs	447	34	10.0
December	**2000**	**Port Phillip Bay**	**6**	**0**		A				
Total	**2000**		**1228**	**13**	**1.1**					

Table 40 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
January	**2001**	**Port Phillip Bay**	**15**	**1**	**9.1**	A				
			4	**0**		TR				
		Rippleside, Corio PPBw				A59376	Rippleside, Corio PPBw	15	18	0.0
February	**2001**	**Port Phillip Bay**	**52**	**0**		A				
			23	**0**		TR				
March	**2001**	**Port Phillip Bay**	**98**	**1**	**1.0**	A				
			16	**0**		TR				
						A45774	Ricketts Pt, PPBe	415	29	7.0
April	**2001**	**Port Phillip Bay**	**54**	**1**	**1.9**	A				
			19	**0**		TR				
		Williamstown, PPBn				A52333	Altona, PPBn	53	24	3.0
		Altona, PPBn				A_2 52333	Altona reef, PPBn	357	28	6.5
May	**2001**	**Port Phillip Bay**	**145**	**0**		A				
June	**2001**	**Port Phillip Bay**	**53**	**0**		A				
July	**2001**	**Port Phillip Bay**	**46**	**0**		A				
August	**2001**	**Port Phillip Bay**	**19**	**0**		A				
September	**2001**	**Port Phillip Bay**	**88**	**2**	**2.3**	A				
		Altona, PPBn				A57427	Altona, PPBn	5	22	2.0
		Altona, PPBn				A57434	Altona, PPBn	131	23	1.0
October	**2001**	**Port Phillip Bay**	**19**	**0**		A				
November	**2001**	**Port Phillip Bay**	**14**	**0**		A				
December	**2001**	**Port Phillip Bay**	**75**	**0**		A				
Total	**2001**		**40**	**5**	**0.7**					

Table 40 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
January	**2002**	**Port Phillip Bay**	**163**	**2**	**1.2**	A				
			6	**0**		TR				
		Williamstown, PPBn				A52047	Williamstown, PPBn	455	33	8.0
		Rippleside Corio PPBw				A59376	Rippleside Corio PPBw	15	18	0.0
February	**2002**	**Port Phillip Bay**	**356**	**5**	**1.4**	A				
			21	**1**		TR				
		Williamstown, PPBn				A59122	Altona Reef, PPBn	5	27	0.0
		Eastern Beach, PPBw				A59417	Stingaree Bay, PPBw	16	18	0.0
		Windmill, Corio PPBw				A61297	Pt Henry Corio, PPBw	24	10	0.0
		Eastern Beach, PPBw				A61345	Pt Henry Corio, PPBw	24	20	0.0
		Windmill, Corio PPBw				A61275	Pt Henry Corio, PPBw	29	21	0.0
		St. Kilda, PPBn				TR2673	Altona, PPBn	243	25	0.0
March	**2002**	**Port Phillip Bay**	**544**	**1**	**0.2**	A				
			7	**1**	**14.3**	TR				
		Williamstown, PPBn				A59189	Port Phillip Bay	140	30	0.5
		Port Melbourne, PPBn				TR2729	Altona, PPBn	328	32	3.7
April	**2002**	**Port Phillip Bay**	**382**	**0**		A				
			19	**0**		TR				
May	**2002**	**Port Phillip Bay**	**289**	**1**	**0.4**	A				
		Williamstown, PPBn				A52131	Mornington, PPBs	257	33	1.8
June	**2002**	**Port Phillip Bay**	**35**	**0**		A				
August	**2002**	**Port Phillip Bay**	**16**	**0**						
October	**2002**	**Port Phillip Bay**	**36**	**0**		A				
			22	**2**	**9.1**	TR				
		Altona, PPBn				TR4416	Altona, PPBn	195	29	2.0
		Altona, PPBn				TR4420	Altona, PPBn	142	28	5.0
November	**2002**	**Port Phillip Bay**	**140**	**1**	**0.7**	A				
			16	**0**		TR				
		Williamstown, PPBn				A63232	Corio, PPBw	80	23	2.2
December	**2002**	**Port Phillip Bay**	**201**	**0**		A				
			12	**0**		TR				
Total	**2002**	**Port Phillip Bay**	**2265**	**4**	**0.6**					

Table 40 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TL	Growth
January	**2003**	**Port Phillip Bay**	**210**	**2**	**0.5**	**A**				
			30	**0**		**TR**				
		Corio, PPBw				A54185	Corio Bay, PPBw	69	26	2.0
		Williamstown, PPBn				A63289	Williamstown, PPBn	70	27	2.2
February	**2003**	**Port Phillip Bay**	**735**	**3**	**0.4**					
		Altona, PPBn				A65136	Altona, PPBn	2	23	0.0
		Altona, PPBn				A65137	Altona, PPBn	2	24	0.0
		Williamstown, PPBn				A63425	Williamstown, PPBn	**8**	**23**	0.0
March	**2003**	**Port Phillip Bay**	**492**	**3**	**0.6**					
		Altona, PPBn				A69131	Williamstown, PPBn	1	22	0.0
		Williamstown, PPBn				A63526	Altona, PPBn	3	27	0.0
		Williamstown, PPBn				A63476	Williamstown, PPBn	12	29	1.0
April	**2003**	**Port Phillip Bay**	**273**	**1**	**0.4**					
		Corio, PPBw				A67524	Point Wilson, PPBw	14	28	2.0
May	**2003**	**Port Phillip Bay**	**95**	**0**						
June	**2003**	**Port Phillip Bay**	**16**	**0**						
Total	**2003**		**1851**	**9**	**0.5**					
Grand Total	**1995-2003**		**10071**	**101**	**1.0**					

Table 41. Westernport Bay releases (n_1) of Tbar tagged snapper in 1996-2003 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1996**	**Westernport Bay**	**8**	**0**		A				
May	**1996**	**Westernport Bay**	**1**	**0**		A				
February	**1997**	**Westernport Bay**	**20**	**0**		A				
December	**1997**	**Westernport Bay**	**3**	**0**		A				
January	**1998**	**Westernport Bay**	**4**	**0**		A				
March	**1998**	**Westernport Bay**	**1**	**0**		A				
November	**1998**	**Westernport Bay**	**1**	**0**		A				
December	**1998**	**Westernport Bay**	**5**	**0**		A				
January	**1999**	**Westernport Bay**	**13**	**0**		A				
November	**1999**	**Westernport Bay**	**10**	**1**	**10.0**	A				
		Cowes				A35462	Tortoise Head, Westernport Bay	27	27	1.5
February	**2000**	**Westernport Bay**	**2**	**0**		A				
September	**2000**	**Westernport Bay**	**3**	**0**		A				
November	**2000**	**Westernport Bay**	**1**	**0**		A				
January	**2001**	**Westernport Bay**	**21**	**0**		A				
February	**2001**	**Westernport Bay**	**21**	**0**		A				
February	**2002**	**Westernport Bay**	**2**	**0**		A				
March	**2002**	**Westernport Bay**	**2**	**0**		A				
December	**2002**	**Westernport Bay**	**23**	**1**	**4.3**	A				
		Rhyll channel				A65253	Rhyll channel, Westernport Bay	64	27	2.7
January	**2003**	**Westernport Bay**	**20**	**0**		A				
February	**2003**	**Westernport Bay**	**17**	**0**		A				
March	**2003**	**Westernport Bay**	**7**	**0**		A				
April	**2003**	**Westernport Bay**	**3**	**0**		A				
Total	**1996-2003**	**Westernport Bay**	**178**	**2**	**1.1**					

Table 42. Portland releases (n_1) of Tbar tagged snapper in 1995-2003 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
February	**1995**	**Portland Bay**	**4**	**0**		A				
March	**1995**	**Portland Bay**	**39**	**1**	**2.6**	A				
		Harbour, WCw	0			A17069	Portland Harbour WCw	146	25	1.0
April	**1995**	**Portland Bay**	**1**	**0**						
June	**1995**	**Portland Bay**	**3**	**0**		A				
October	**1995**	**Portland Bay**	**1**	**0**		A				
November	**1995**	**Portland Bay**	**7**	**0**		A				
December	**1995**	**Portland Bay**	**1**	**0**		A				
Total	**1995**		**56**	**1**	**1.8**					
June	**1996**	**Portland Bay**	**1**	**0**		A				
November	**1996**	**Portland Bay**	**2**	**0**		A				
December	**1996**	**Portland Bay**	**12**	**1**	**8.3**	A				
		Northshore, WCw				A26237	Snapper Pt Portland Bay WCw	409	47	24.0
Total	**1996**		**15**	**1**	**6.7**					

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
January	**1997**	**Portland Bay**	**15**	**0**		A				
February	**1997**	**Portland Bay**	**14**	**0**		A				
March	**1997**	**Portland Bay**	**386**	**9**	**2.3**	A				
		Harbour, WCw				A23991	Snapper Pt. Portland Bay WCw	2	37	0.0
		Harbour, WCw				A26015	Allestree WCw	63	26	0.0
		Harbour, WCw				A24060	Portland Harbour WCw	281	28	3.5
		Harbour, WCw				A24059	Northshore Portland Bay WCw	1053		
		Harbour, WCw				A26026	Narrawong, WCw	1096	36	8.0
		Harbour, WCw				A26118	Green Point SAe	1355	40	16.0
		Harbour, WCw				A 24073	Port MacDonnell, SAe	1637	48	22.0
		Harbour, WCw				A 26007	Cape Jaffa, SAe	1665	50	26.0
		Harbour, WCw				A 26004	Fawkner Beacon, PPBe	1695	48	23.0
April	**1997**	**Portland Bay**	**149**	**2**	**1.3**	A				
		Harbour, WCw				A30355	Allestree WCw	1058	44	20.0
		Harbour, WCw				A30072	Queenscliff Rip, PPBs	1412	41	15.5
May	**1997**	**Portland Bay**	**69**	**0**		A				
June	**1997**	**Portland Bay**	**18**	**0**		A				
September	**1997**	**Portland Bay**	**9**	**0**						
October	**1997**	**Portland Bay**	**17**	**0**		A				
November	**1997**	**Portland Bay**	**37**	**1**	**2.7**	A				
						A30257	Portland Harbour WCw	733	33	6.7
December	**1997**	**Portland Bay**	**202**	**4**	**1.2**	A				
		Portland Bay, WCw				A22995	Portland Harbour WCw	18	29	4.0
		Narrawong, WCw				A30733	Portland Harbour WCw	38	28	3.0
		Narrawong, WCw				A30724	Portland Harbour WCw	403	33	6.5
		Allestree, WCw				A30534	Portland Harbour WCw	407		
Total	**1997**		**916**	**16**	**1.8**					

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
January	**1998**	**Portland Bay**	**203**	**7**	**3.5**	A				
		Portland harbour, WCw				A33888	Portland Harbour WCw	20	25	0.1
		Maretimo, WCw				A33882	Portland Harbour WCw	64	30	4.0
		Dutton Way, WCw				A30514	Portland Harbour WCw	352	34	3.0
		Maretimo, WCw				A30545	Maretimo Portland Bay WCw	374	32	5.0
		Dutton Way, WCw				A30503	Portland Harbour WCw	380	31	6.0
		Portland harbour, WCw				A30828	Portland Harbour WCw	386	31	6.0
		Portland harbour, WCw				A30747	Point Lonsdale PPBs	1036	38	12.0
February	**1998**	**Portland Bay**	**131**	**3**	**2.3**	A				
		Portland Bay, WCw				A30975	Snapper Pt. Portland Bay WCw	19	29	0.0
		Maretimo, WCw				A34220	Maretimo Portland Bay WCw	54	32	4.0
		Dutton Way, WCw				A34204	Maretimo Portland Bay WCw	250	31	4.0
March	**1998**	**Portland Bay**	**265**	**11**	**4.2**	A				
		Portland harbour, WCw				A34054	Northshore Portland Bay WCw	24	34	3.0
		Maretimo, WCw				A34041	Allestree, WCw	303	34	8.0
		Cape Nelson, WCw				A35137	Pinks Beach Kingston SAe	317	29	4.5
		Maretimo, WCw				A35170	Allestree WCw	333	33	4.0
		Portland harbour, WCw				A34841	Allestree, WCw	357	33	6.0
		Codsplat, WCw				A35159	Portland Harbour WCw	624	35	10.0
		Maretimo, WCw				A34044	Snapper Pt. Portland Bay WCw	630	33	5.8
		Maretimo, WCw				A34048	Portland Bay WCw	670	37	7.4
		Portland harbour, WCw				A35172	Lawrence Rocks, Portland WCw	712	37	13.2
		Northshore, WCw				A34042	Altona,PPBn	942	42	15.0
		Maretimo, WCw				A34046	Fawkner Beacon, PPBe	981	45	17.0

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth
April	**1998**	**Portland Bay**	**68**	**4**	**5.9**	A				
		Maretimo, WCw				A34237	Northshore Portland Bay WCw	308	33	1.5
		Maretimo, WCw				A34250	Allestree WCw	625	36	9.0
		Minerva reef, WCw				A30553	Werribee, PPBw	1360	51	25.0
		Harbour, WCw				A35253	Cowes, Westernport Bay, WCe	1691	45.5	25.5
September	**1998**	**Portland Bay**	**7**	**0**		A				
November	**1998**	**Portland Bay**	**52**	**3**	**5.8**	A				
		Harbour, WCw				A36380	Maretimo, WCw	379	31	5.0
		Harbour, WCw				A30997	Portland Harbour WCw	408	30	5.0
		Harbour, WCw				A36357	Snapper Pt. Portland Bay WCw	452		
December	**1998**	**Portland Bay**	**33**	**4**	**12.1**	A				
		Bay, WCw				A37002	Northshore Portland Bay WCw	18	31	0.0
		Bay, WCw				A37021	Henty Bay, Portland Bay WCw	436	38	7.5
		Bay, WCw				A37014	Allestree, WCw	463	35	7.0
		Harbour, WCw				A33988	Portland Harbour WCw	1090	38	12.0
Total	**1998**		**759**	**32**	**4.2**					
January	**1999**	**Portland Bay**	**5**	**0**		A				
February	**1999**	**Portland Bay**	**1**	**0**		A				
March	**1999**	**Portland Bay**	**7**	**0**		A				
April	**1999**	**Portland Bay**	**125**	**0**		A				
May	**1999**	**Portland Bay**	**4**	**0**		A				
June	**1999**	**Portland Bay**	**9**	**0**		A				
July	**1999**	**Portland Bay**	**37**	**0**		A				
August	**1999**	**Portland Bay**	**10**	**0**		A				
September	**1999**	**Portland Bay**	**5**	**0**		A				
October	**1999**	**Portland Bay**	**22**	**0**		A				
November	**1999**	**Portland Bay**	**45**	**1**	**2.2**	A				
		Harbour, WCw				A40397	Portland Harbour WCw	433	29	6.8
December	**1999**	**Portland Bay**	**56**	**2**	**3.6**	A				
		Allestree, WCw				A39761	Snapper Pt. Portland Bay WCw	19	31	0.0
		Harbour, WCw				A39793	Portland Harbour WCw	366	29	7.5
		Harbour, WCw				A39779	Portland Canal, WCw	694	32	9.0

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**2000**	**Portland Bay**	**194**	**10**	**5.1**	**A,** A_2				
		Snapper Pt. WCw				A41792	Surrey River WCw	16	34	0.0
		Snapper Pt. WCw				A44575	Snapper Pt. Portland Bay WCw	18	33	1.0
		Snapper Pt. WCw				$A_2$44575	Allestree, WCw	26	33	1.0
		Allestree, WCw				A41779	Surrey River WCw	26	30	0.0
		Harbour, WCw				A42308	Portland Harbour WCw	27	22	0.0
		Harbour, WCw				A47906	Portland Harbour WCw	31	31	3.0
		Maretimo, WCw				A41776	Snapper Pt. Portland Bay WCw	32	31	8.5
		Snapper Pt, WCw				$A_2$41776	Snapper Pt, WCw	42	31	8.5
		Harbour, WCw				A44559	Portland harbour, Wcw	385	30	6.0
		Narrawong, WCw				A38256	Allestree, WCw	459	33	9.0
February	**2000**	**Portland Bay**	**262**	**6**	**2.3**	**A,** A_2				
		Harbour, WCw				A10213	Portland Harbour WCw	8	25	0.0
		Snapper Pt. WCw				A44581	Snapper Pt. Portland Bay WCw	12	27	0.0
		Snapper Pt. WCw				$A_2$44581	Snapper Pt. Portland Bay WCw	43	27	0.0
		Portland harbour, WCw				A41975	Portland harbour, WCw	341	28	5.0
		Snapper Pt WCw				A44577	Allestree, WCw	352	28	2.0
		Harbour, WCw				A41961	Minerva Reef, Portland WCw	360	29	7.0
March	**2000**	**Portland Bay**	**144**	**3**	**2.1**	**A**				
		Snapper Pt, WCw				A46271	Snapper Pt. Portland Bay WCw	24	28	0.0
		Snapper Pt, WCw				A46284	Narrawong, WCw	312	38	4.0
		Narrawong, WCw				A40440	Snapper Pt. Portland Bay WCw	320	29	2.7
April	**2000**	**Portland Bay**	**106**	**0**		**A**				
August	**2000**	**Portland Bay**	**10**	**0**		**A**				
October	**2000**	**Portland Bay**	**4**	**0**		**A**				
November	**2000**	**Portland Bay**	**94**	**1**	**1.1**	**A**				
		Allestree, WCw				A50861	Allestree, WCw	89	30	3.0

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
December	**2000**	**Portland Bay**	**177**	**10**	**5.7**	**A**				
		Snapper Pt, WCw				A47853	Northshore Portland Bay WCw	4	35	1.0
		Harbour, WCw				A47888	Portland Harbour WCw	8	26	0.0
		Harbour, WCw				A47869	Portland Harbour WCw	41	30	1.7
		Allestree, WCw				A50886	Allestree, WCw	47	32	2.0
		Harbour, WCw				A49359	Portland Harbour WCw	47	28	1.5
		Snapper Pt. WCw				A47851	Snapper Pt. Portland Bay WCw	50	30	0.0
		Harbour, WCw				A47887	Portland harbour, WCw	79	28	3.5
		Allestree, WCw				A52990	Northshore Portland Bay WCw	82	32	4.0
		Harbour, WCw				A47870	Cape Grant 50m, WCw	208	27	2.0
		Cape Grant 50m WCw				$A_2$47870	Portland Harbour, WCw	746	38	12.0
Total	**2000**		**991**	**30**	**3.0**					

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**2001**	**Portland Bay**	**209**	**8**	**3.8**	**A,** A_2				
		Narrawong				A47897	Narrawong, WCw	1	26	1.0
		Narrawong				A52922	Minerva Reef Portland Bay WCw	22	32	3.0
		Narrawong				A48202	Northshore Portland Bay WCw	23	28	1.0
		Allestree, WCw				A47231	Allestree, WCw	29	30	0.0
		Narrawong				A47896	Snapper Pt. Portland Bay WCw	31	28	2.0
		Narrawong				A47891	Snapper Pt. Portland Bay WCw	32	30	0.0
		Narrawong, WCw				A52908	Minerva Reef Portland Bay WCw	32	32	2.0
		Allestree				A53154	Allestree, WCw	34	34	3.5
February	**2001**	**Portland Bay**	**240**	**7**	**2.9**	**A,** A_2				
		Nuns Beach, WCw				A50307	Portland harbour, WCw	4	26	0.0
		Dutton Way, WCw				A43008	Portland harbour, WCw	5	28	0.0
		Northshore, WCw				A52998	Portland Bay WCw	24	28	1.0
		Allestree, WCw				A50808	Allestree, WCW	351	32	2.1
		Harbour, WCw				A31774	Portland harbour, WCw	354	38	10.0
		Harbour, WCw				A31773	Portland harbour, WCw	364	31	3.0
		Allestree, WCW				A55503	Allestree	393	35	5.0
March	**2001**	**Portland Bay**	**55**	**2**	**3.6**	**A,** A_2				
		Harbour, WCw				A48110	Portland harbour, WCw	313	35	5.0
		Harbour, WCw				A48113	Portland harbour, WCw	651	40	9.5
April	**2001**	**Portland Bay**	**43**	**0**		A				
May	**2001**	**Portland Bay**	**36**	**0**		A				
June	**2001**	**Portland Bay**	**123**	**3**	**2.5**	A				
		Cape Nelson, WCw				A56593	Port Fairy, WCw	54	30	0.5
		Cape Nelson, WCw				A56573	Cape Nelson, WCw	68	29	1.0
		Cape Nelson, WCw				A56568	Northshore, Portland, WCw	236	33	3.0

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
July	**2001**	**Portland Bay**	**84**	**1**	**1.3**	**A,** A_2				
		Cape Grant 50m, WCw				$A_2$4787	Portland harbour, WCw	538	38	11.0
August	**2001**	**Portland Bay**	**18**	**0**		**A,** A_2				
September	**2001**	**Portland Bay**	**2**	**0**		A				
October	**2001**	**Portland Bay**	**8**	**1**		A				
		Cape Grant, WCw				A57836	Portland harbour, WCw	349	31	2.5
November	**2001**	**Portland Bay**	**5**	**0**		A				
December	**2001**	**Portland Bay**	**32**	**0**		A				
Total	**2001**		**855**	**22**	**2.6**					
January	**2002**	**Portland Bay**	**69**	**1**	**1.4**	A				
		Northshore, WCw				A59909	Allestree, WCw	15	33	0.0
February	**2002**	**Portland Bay**	**35**	**0**		A				
March	**2002**	**Portland Bay**	**39**	**1**	**2.6**	A				
		Allestree, WCw				A55905	Northshore, WCw	359	35	3.0
April	**2002**	**Portland Bay**	**61**	**0**		A				
May	**2002**	**Portland Bay**	**34**	**0**		A				
June	**2002**	**Portland Bay**	**5**	**0**		A				
August	**2002**	**Portland Bay**	**14**	**0**						
October	**2002**	**Portland Bay**	**1**	**0**		A				
November	**2002**	**Portland Bay**	**203**	**0**		A				
December	**2002**	**Portland Bay**	**96**	**2**	**2.1**	A				
		Maretimo, WCw				A61991	Maretimo, WCw	22	24	0.0
		Julia Reef, WCw				A64377	Narrawong, WCw	112	31	1.0
Total	**2002**		**557**	**4**	**0.7**					

Table 42 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**2003**	**Portland Bay**	**284**	**6**	**2.1**	**A**				
		Portland harbour, WCw				A54124	Portland harbour, WCw	0	22	0.0
		Portland harbour, WCw				A54141	Portland harbour, WCw	2	22	0.0
		Portland harbour, WCw				A54144	Portland harbour, WCw	5	21	0.0
		Portland harbour, WCw				A64566	Portland harbour, WCw	17	24	1.0
		Portland harbour, WCw				A74420	Portland harbour, WCw	19	21	1.0
		Portland harbour, WCw				A64209	Portland harbour, WCw	32	24	1.5
February	**2003**	**Portland Bay**	**215**	**2**	**0.9**	A				
			11	**0**		TR				
		Portland harbour, WCw				A59817	Portland harbour, WCw	1	23	0.0
		Narrawong, WCw				A64843	Northshore, WCw	17	27	0.0
		Narrawong, WCw				A64808	Northshore, WCw	18	24	0.0
		Alestree, WCw				A56839	Northshore, WCw	27	28	2.0
March	**2003**	**Portland Bay**	**156**	**0**		**A**				
April	**2003**	**Portland Bay**	**56**	**0**		A				
			35	**0**		TR				
May	**2003**	**Portland Bay**	**28**	**0**		A				
Total	**2003**		**785**	**8**	**1.0**					
Grand Total		**Portland Bay**	**5260**	**117**	**2.2**					

Table 43. West Coast east releases (n_1) of T bar tagged snapper in 1994 – 2003 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days	TLcm	Growth cm
April	**1994**	**West coast east**	**4**	**1**	**25.0**	A				
		Skenes Creek, WCe				A11512	St.Leonards, PPBw	549	33	11.0
May	**1994**	**West coast east**	**5**	**0**		A				
January	**1995**	**West coast east**	**6**	**0**		A				
March	**1995**	**West coast east**	**35**	**1**	**2.9**	A				
		Skenes Creek, Wce				A11995	Mornington, PPBs	1755	51	25.5
April	**1995**	**West coast east**	**6**	**0**		A				
May	**1995**	**West coast east**	**2**	**0**		A				
December	**1995**	**West coast east**	**1**	**0**		A				
February	**1996**	**West coast east**	**2**	**0**						
March	**1996**	**West coast east**	**2**	**0**		A				
April	**1996**	**West coast east**	**25**	**0**		A				
May	**1996**	**West coast east**	**94**	**1**	**1.1**	A				
		Apollo Bay, WCe				A11880	Wild Dog Creek, WCe	156	25	7.0
July	**1996**	**West coast east**	**1**	**0**		A				
April	**1997**	**West coast east**	**18**	**0**		A				
May	**1997**	**West coast east**	**18**	**0**		A				
February	**1998**	**West coast east**	**3**	**0**		A				
March	**1998**	**West coast east**	**5**	**1**	**20.0**	MC				
		Lorne				MC4001	Aireys Inlet, WCe	39	28	1.0
April	**1998**	**West coast east**	**1**	**0**		A				
October	**1998**	**West coast east**	**2**	**0**		A				
November	**1998**	**West coast east**	**9**	**0**		A				
December	**1998**	**West coast east**	**25**	**0**		A				
January	**1999**	**West coast east**	**3**	**0**		A				
February	**1999**	**West coast east**	**11**	**2**	**18.2**	A				
		Ocean Grove, WCe				A12944	Ocean Grove, WCe	360	32	7.0
		Ocean Grove, WCe				A19750	Barwon Heads, WCe	361	31	3.0
March	**1999**	**West coast east**	**6**	**0**		A				
October	**1999**	**West coast east**	**2**	**0**		A				
December	**1999**	**West coast east**	**4**	**0**		A				

Table 43 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**2000**	**West coast east**	**4**	**0**		A				
February	**2000**	**West coast east**	**24**	**0**		A				
March	**2000**	**West coast east**	**61**	**1**	**1.6**	A				
		Torquay WCe				A46786	Torquay	405	31	3.0
April	**2000**	**West coast east**	**44**	**0**		A				
May	**2000**	**West coast east**	**18**	**0**		**A,** A_2				
June	**2000**	**West coast east**	**3**	**0**		A				
September	**2000**	**West coast east**	**5**	**0**		A				
November	**2000**	**West coast east**	**3**	**1**	**33**	A				
		Torquay WCe				A50630	Torquay, WCe	39	28	1.0
December	**2000**	**West coast east**	**4**	**0**		A				
January	**2001**	**West coast east**	**15**	**0**		A				
February	**2001**	**West coast east**	**28**	**0**		A				
March	**2001**	**West coast east**	**5**	**0**		A				
April	**2001**	**West coast east**	**7**	**0**		A				
May	**2001**	**West coast east**	**6**	**0**		A				
October	**2001**	**West coast east**	**14**	**0**		A				
November	**2001**	**West coast east**	**2**	**0**		A				
December	**2001**	**West coast east**	**9**	**0**		A				
January	**2002**	**West coast east**	**13**	**0**		A				
March	**2002**	**West coast east**	**3**	**0**		A				
April	**2002**	**West coast east**	**4**	**0**		A				
May	**2002**	**West coast east**	**11**	**0**		A				
November	**2002**	**West coast east**	**6**	**0**		A				
December	**2002**	**West coast east**	**4**	**0**		A				
January	**2003**	**West coast east**	**5**	**0**		A				
February	**2003**	**West coast east**	**1**	**0**		A				
March	**2003**	**West coast east**	**5**	**0**		A				
April	**2003**	**West coast east**	**2**	**0**		A				
Total 1994-2002		**West coast east**	**96**	**8**	**1.3**					

Table 44. East Coast releases (n_1) of T bar tagged snapper in 1996 – 2003 and recaptures (n_2)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1996**	**Lakes Entrance**	**1**	**0**		A				
February	**1996**	**Outside Corner Inlet**	**1**	**0**		A				
April	**1996**	**Outside Corner Inlet**	**11**	**0**		MC				
November	**1996**	**Outside Corner Inlet**	**2**	**0**		A				
December	**1996**	**Outside Corner Inlet**	**5**	**0**		A				
January	**1997**	**Outside Corner Inlet**	**8**	**0**		A				
January	**1997**	**Outside Corner Inlet**	**6**	**0**		MC				
February	**1997**	**Outside Corner Inlet**	**4**	**0**		A				
February	**1997**	**Outside Corner Inlet**	**17**	**0**		MC				
March	**1997**	**Outside Corner Inlet**	**7**	**0**		A				
March	**1997**	**Outside Corner Inlet**	**16**	**0**		MC				
April	**1997**	**Outside Corner Inlet**	**18**	**0**		A				
April	**1997**	**Outside Corner Inlet**	**112**	**0**		MC				
May	**1997**	**Outside Corner Inlet**	**4**			MC				
November	**1997**	**Outside Corner Inlet**	**3**	**0**		A				
November	**1997**	**Outside Corner Inlet**	**16**	**0**		MC				
December	**1997**	**Outside Corner Inlet**	**11**	**0**		A				
December	**1997**	**Outside Corner Inlet**	**63**	**1**	**1.6**	MC				
						MC2878	Reeves Beach ECw	433	34	7.0
Subtotal	**1996-97**		**305**	**1**	**0.3**					

Table 44 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**1998**	**Outside Corner Inlet**	**13**	**0**		A				
January	**1998**	**Outside Corner Inlet**	**30**	**0**		**MC**				
February	**1998**	**Outside Corner Inlet**	**45**	**3**	**6.7**	**MC**				
February	**1998**	**Outside Corner Inlet**	**8**	**1**	**12.5**	**A**				
		Seaspray Ecw				A26545	Seaspray Ecw	64	33	5
		Woodside Ecw				MC2771	Lakes Entrance Ecw	746	39	12.0
		Woodside Ecw				MC2791	McLaughlins Ecw	1008	53	16.8
		Woodside Ecw				MC2675	Woodside Ecw	1093	46	2.0
March	**1998**	**Outside Corner Inlet**	**97**	**1**	**1.0**	**MC**				
March	**1998**	**Outside Corner Inlet**	**16**	**2**	**12.5**	**A**				
		Manns Beach, Ecw				A26562	Manns Beach Ecw	207	34	
		Woodside Ecw				MC2883	Montague Island, NSW 36	415	40	12.0
		Manns Beach, Ecw				A26556	Reeves Beach Ecw	700	40	4.5
December	**1998**	**Outside Corner Inlet**	**6**	**0**		A				
December	**1998**	**Outside Corner Inlet**	**5**	**0**		MC				
February	**1999**	**Outside Corner Inlet**	**4**	**0**		MC				
March	**1999**	**Outside Corner Inlet**	**30**	**0**		MC				
April	**1999**	**Outside Corner Inlet**	**2**	**0**		MC				
April	**1999**	**Mallacoota Inlet**	**179**	**1**	**0.6**	TR				
		Mallacoota Inlet				TR1156	Mallacoota Inlet	329	28	9.3
June	**1999**	**Gippsland Lakes**	**4**			TR				
July	**1999**	**Gippsland Lakes**	**1**			TR				
October	**1999**	**Outside Corner Inlet**	**2**	**0**		MC				
November	**1999**	**Outside Corner Inlet**	**4**	**0**		MC				
December	**1999**	**Outside Corner Inlet**	**35**	**2**	**5.7**	**MC**				
		McLoughlins Ecw				MC4262	Toora Channel, Corner Inlet	422	33	17.5
		Woodside, Ecw				MC4250	McLoughlins, Ecw	459	35	7.0
Total	**1998**		**481**	**10**	**2.1**					

Table 44 (continued)

Month	Year	Release Location	n_1	n_2	%	Code	Recapture Location	Days at sea	Size TLcm	Growth cm
January	**2000**	**Outside Corner Inlet**	**8**	**0**		MC				
		Gippsland Lakes	**3**	**0**		TR				
February	**2000**	**Outside Corner Inlet**	**8**	**0**		A				
		Outside Corner Inlet	**25**	**0**		MC				
March	**2000**	**Outside Corner Inlet**	**19**	**0**		MC				
April	**2000**	**Outside Corner Inlet**	**20**	**0**		MC				
November	**2000**	**Outside Corner Inlet**	**37**	**0**		MC				
December	**2000**	**Outside Corner Inlet**	**23**	**0**		MC				
Total	**2000**		**143**	**0**						
January	**2001**	**Outside Corner Inlet**	**13**	**0**		MC				
February	**2001**	**Outside Corner Inlet**	**20**	**3**	**15.0**	**MC**				
		Woodside, ECw				MC4426	Woodside, ECw	8	27	0.0
		Woodside, ECw				MC4418	Terrigal, NSW 33	165	29	0.5
		McGaurens, ECw				MC4415	Forster, NSW 32	676	32	7.0
March	**2001**	**Outside Corner Inlet**	**4**	**0**		**A**				
April	**2001**	**Outside Corner Inlet**	**11**	**1**	**9.1**	**A**				
		Letts Beach, ECw				A40815	Evans Head, NSW 29	469	34	7.0
Total 2001			**47**	**4**	**8.5**					
January	**2002**	**Outside Corner Inlet**	**18**	**0**		**A**				
February	**2002**	**Outside Corner Inlet**	**2**	**0**		**A**				
March	**2002**	**Outside Corner Inlet**	**6**	**0**		**A**				
Total 2002			**26**	**0**						
March	**2003**	**Lake Tyers**	**7**	**0**		**A**				
April	**2003**	**Lake Tyers**	**7**	**0**		**A**				
May	**2003**	**Corner Inlet**	**13**	**0**		**A**				
Total	**2003**		**27**	**0**						
Total -	**1996-2003**		**030**	**15**	**1.5**					

APPENDIX 5

Latitude and longitude of recaptures

Table 45. Latitude and longitude tag recapture locations in decimal degrees

Location	Latitude	Longitude
Northern Port Phillip Bay (PPB n)		
Albert Park	-37.85	144.95
Altona	-37.88	144.83
Edithvale	-38.06	145.11
Elwood Bay	-37.89	144.98
Fawkner Beacon	-37.91	144.92
Targets Williamstown	-38.87	144.87
Point Cook	-37.93	144.80
Port Melbourne Pier	-37.85	144.91
Port Melbourne	-37.85	144.93
Port Melbourne, Channel	-37.88	144.92
St. Kilda	-37.87	144.95
Williamstown	-37.88	144.92
Williamstown, Gellibrand Pier	-37.87	144.92
Williamstown inshore reef	-37.87	144.91
Eastern Port Phillip Bay (PPB e)		
Albert Park	-37.86	144.96
Anonyma Reef	-37.95	144.98
Artificial Reef	-38.17	144.90
Beaumaris	-38.00	145.04
Black Rock	-37.98	145.00
Bonbeach	-38.06	145.11
Brighton	-37.91	144.94
Bristol Reef Chelsea	-38.05	145.10
Carrum	-38.08	145.03
Dendy St. Beach	-37.91	144.98
Dromana	-38.33	144.97
Edithvale	-38.04	145.09
Frankston	-38.16	145.09
Gellibrand Light Williamstown	-37.92	144.88
Good reef Channel	-38.06	145.09
Half moon bay	-37.97	145.01
Hampton	-37.94	144.99
Inner Artificial Reef Carrum	-38.07	145.00
Kirks Point off Alfreds Buoy	-38.07	144.58
Mentone	-38.00	145.05
Middle Brighton pier	-37.91	144.98

Table 45 **(continued)**

Location	Latitude	Longitude
Eastern Port Phillip Bay (PPB e)		
Mordialloc	-38.01	145.08
Mount Eliza	-38.19	145.05
Mount Eliza Ranlagh Bay	-38.18	145.07
Mount Martha	-38.17	145.08
Ormond Beach	-37.88	144.93
Parkdale	-38.00	145.07
Patterson Lakes	-38.08	145.11
Prince George Light	-38.10	144.73
Point Ormond	-37.91	144.98
Ricketts Point	-38.00	145.03
Safety Beach Dromana	-38.33	144.97
Sandringham	-37.95	144.99
Seaford	-38.11	145.12
Small G reef	-38.00	145.03
South Channel turning point	-38.33	144.88
Spoil ground	-38.04	144.88
St.Kilda Marina	-37.86	144.97
Table Rocks Ricketts Point	-38.00	145.03
Teahouse	-38.00	145.03
Wooley Reef	-38.16	145.09
Southern Port Phillip Bay (PPB s)		
Coles Beacon near submarine	-38.25	144.70
Hovell Light McCrae	-38.33	144.90
Morisons Beach, Mornington	-38.21	145.03
Mornington	-38.21	145.03
Mt Martha	-38.27	144.94
Port Phillip Bay Heads	-38.29	144.63
No.4 Channel Buoy	-38.30	144.73
Point Lonsdale Bight	-38.28	144.67
Quarantine jetty, South Channel	-38.31	144.70
Queenscliff	-38.27	144.67
Queenscliff Swan Island	-38.25	144.71
Queenscliff Symonds Channel	-38.20	144.76
Queenscliff, West Channel	-38.25	144.71
Rosebud	-38.35	144.90
South Channel Fort	-38.31	144.83
Swan Bay	-38.22	144.68
Swan Bay West Channel	-38.25	144.72
Swan Island Submarine	-38.25	144.70
Swan reef	-38.23	144.72

Table 45 (continued)

Location	Latitude	Longitude
Western Port Phillip Bay (PPB w)		
Avalon	-38.09	144.42
Bird Rock outer Gap	-38.10	144.44
Clifton Springs	-38.15	144.47
Corio Bay	-38.12	144.51
Corio Bay middle	-38.08	144.58
Corio Bay outer	-38.12	144.44
Corio Bay St.Helens	-38.13	144.40
Corio Bay Stingaree Bay,	-38.14	144.41
Corio Bay, last channel buoy	-38.12	144.38
Corio Quay	-38.13	144.37
Cunningham Pier Corio	-38.13	144.37
Geelong Mudspit	-38.14	144.36
Geelong SEC Power Station	-38.14	144.36
Geelong Shell Refinery Pier	-38.09	144.39
Geelong, Pt Henry	-38.13	144.43
Grassy Pt. Portarlington	-38.11	144.68
Indented Heads	-38.15	144.72
Lime Kilns	-38.14	144.38
Limeburner Pt Corio Bay	-38.14	144.39
Outer Corio Bay	-38.12	144.44
Parkside Geelong	-38.13	144.36
Point Henry Corio Bay	-38.13	144.43
Point Wilson	-38.10	144.51
Portarlington	-38.11	144.65
Point Lillias,	-38.09	144.44
Point Wilson	-38.09	144.55
Prince George Light	-38.12	144.75
Rippleside Corio	-38.13	144.37
Sands Caravan park	-38.13	144.55
Shell Wharf, Corio Bay	-38.10	144.38
Southern Corio Bay	-38.15	144.47
St Helens No.15 Beacon	-38.12	144.37
St. Leonards	-38.17	144.72
St.Leonards, west channel No.5	-38.19	144.76
Stingaree Bay Corio	-38.14	144.41
Werribee	-37.98	144.69

Table 45 (continued)

Location	Latitude	Longitude
Westernport Bay (WPB)		
BHP Jetty	-38.30	145.23
Balnarring	-38.42	145.13
Corinella, Red Bluff	-38.42	145.38
Coronet Bay	-38.43	145.38
Cowes	-38.43	145.23
Crib Point	-38.35	145.22
Eagle Rock,	-38.26	145.27
Elizabeth Island	-38.42	145.37
Hastings	-38.31	145.20
McLeods Prison settlement,	-38.38	145.41
Rhyll	-38.35	145.23
San Remo	-38.52	145.37
Stony Point	-38.37	145.25
Tooradin Westernport	-38.22	145.37
Tortoise Head	-38.42	145.25
Woolamai	-38.58	145.38
West Victorian coast (east)		
Aireys Inlet	-38.47	144.12
Angelsea	-38.42	144.19
Apollo Bay	-38.75	143.70
Barwon Heads	-38.29	144.51
London Bridge, Portsea	-38.33	144.67
Lorne	-38.54	143.99
Lorne pier	-38.53	144.00
Ocean Grove	-38.28	144.53
Point Sturt Wye River	-38.64	143.90
Portsea Back Beach	-38.35	144.72
Rock Point Apollo Bay	-38.75	143.70
Skenes Creek	-38.74	143.73
Sorrento Back Beach	-38.36	144.74
Stoney Creek Lorne	-38.54	143.98
Waterfall Apollo Bay	-38.75	143.70
Wild Dog Creek	-38.74	143.74

Table 45 (continued)

Location	Latitude	Longitude
West Victorian coast (west)		
Allestree	-38.30	141.65
Blacknose Pt Portland	-38.38	141.65
Cape Nelson Portland	-38.44	141.55
Dutton Way Portland Bay	-38.32	141.60
Henty Bay Portland	-38.35	141.62
Julia Reef, Fitzroy Mouth	-38.27	141.81
Lady Bay Warrnambool	-38.40	142.48
Lawrence Rocks	-38.41	141.68
Maretimo	-38.33	141.62
Minerva Reef	-38.28	141.67
Narrawong	-38.27	141.70
Northshore Portland	-38.27	141.69
Patterson Wharf Portland	-38.35	141.62
Port Campbell	-38.63	142.95
Port Fairy	-38.39	142.25
Portland	-38.35	141.62
Portland Harbour	-38.35	141.62
Portland Water Tower	-38.33	141.63
Portland, North shore	-38.27	141.68
Snapper Point, Portland	-38.28	141.66
Surrey River	-38.26	141.70
Wally's Boat Ramp, Portland	-38.29	141.65
Worm Bay cliffs, Peterborough	-38.61	142.88
South Australia east (SA e)		
"Bondry" Nora Crema & Rolee	-37.30	139.81
Beachport south	-37.79	140.10
Bosuns Point Robe	-37.07	139.74
Bungalow Bay, Carpenters Rock	-37.95	140.41
Cape Douglas-Nene Valley	-38.04	140.50
Danger Point Port MacDonnell	-38.08	140.80
Green Point	-38.02	140.54
Kingston	-36.83	139.84
Orwell Rocks Port MacDonnell	-38.13	140.71
Pinks Beach, Kingston	-36.58	139.45
Port MacDonnell	-38.17	140.67
Port MacDonell, Nene Valley Rd	-38.07	140.70
Port MacDonnell Danger Point	-38.13	140.71
Robe	-37.17	139.26
Wrights Bay, Kingston	-37.07	139.71

Table 45 (continued)

Location	Latitude	Longitude
East Victorian coast west (EC w)		
Lakes Entrance offshore	-38.18	147.73
Lakes Entrance - Seaspray	-38.13	147.54
Lakes Entrance Pier	-37.89	147.97
Mannings Beach	-38.65	146.96
McGaurens Beach	-38.44	147.15
McLaughlins	-38.64	146.92
Rabbit-Cliffy Island	-38.87	146.62
Rabbit Island	-38.91	146.52
Reeves Beach	-38.56	147.00
Seal Islands	-38.93	146.62
Seaspray	-38.38	147.22
Seaspray	-38.42	147.20
Six mile reef, Lakes Entrance	-37.91	147.97
Toora Channel, Corner Inlet	-38.72	146.35
Woodside off Omega Tower	-38.64	146.92
East Victorian coast east (EC e)		
Goodwin sands, Mallacoota	-37.53	149.77
Howe Bight, Mallacoota	-37.57	149.77
Kangaroo Bight, Mallacoota	-37.55	149.76
Lower Lake Mallacoota	-37.53	149.77
Mallacoota Inlet	-37.53	149.76
Narrows, Mallacoota Inlet	-37.52	149.73
Mallacoota Main channel	-37.56	149.76
Mallacoota Tea tree Point	-37.56	149.76
Rabbit Is. Mallacoota	-37.57	149.77

Table 45 (continued)

Region	Location	Latitude	Longitude
New South Wales			
NSW 29	Evans Head	-29.12	153.45
NSW 29	Wooli River	-29.88	153.27
NSW 30	Solitary Lighthouse	-30.03	153.26
NSW 30	Coffs Harbour	-30.28	153.46
NSW 31	Port Macquarie	-31.42	152.93
NSW 31	Diamond Head	-31.75	152.89
NSW 31	Tuncurry	-31.96	152.62
NSW 32	Crowdy Head	-32.04	152.85
NSW 32	Cape Hawke, Forster	-32.19	152.55
NSW 32	Forster	-32.20	152.52
NSW 32	Seal Rocks, Port Stephens	-32.45	152.53
NSW 32	Broughton Island	-32.62	152.30
NSW 33	Wyloung Head	-33.28	151.60
NSW 33	Terrigal	-33.55	151.59
NSW 33	Mona Vale	-33.67	151.32
NSW 33	Bondi Beach	-33.84	151.30
NSW 33	Sydney Heads	-33.84	151.33
NSW 33	Marouba	-33.95	151.41
NSW 33	Malabar near Maraubra Bay	-33.97	151.26
NSW 33	Botany Bay	-33.99	151.19
NSW 34	Cronulla	-34.09	151.34
NSW 34	Woombarra	-34.25	151.17
NSW 34	Woolongong	-34.54	150.88
NSW 34	Black Head Kiama	-34.82	150.86
NSW 34	Drum reef north Jervis Bay	-34.83	150.79
NSW 34	Sir John Young Banks	-34.83	150.79
NSW 34	Currarong, north of Jervis Bay	-34.90	150.76
NSW 34	Nowra	-34.90	150.76
NSW 35	Jervis Bay	-35.07	150.73
NSW 35	Sussex Inlet	-35.07	150.73
NSW 35	Point Perpendicular	-35.09	150.81
NSW 35	Ulladulla	-35.35	150.49
NSW 35	Kioloa Ulladulla	-35.54	150.39
NSW 35	Brush Island Ulladulla	-35.54	150.42
NSW 35	Wasp Island	-35.67	150.33
NSW 35	Bateman Bay	-35.74	150.29
NSW 36	Moruya Heads	-35.91	150.20
NSW 36	Montague Island	-36.25	150.22
NSW 36	Bermagui	-36.42	150.08
NSW 36	Bunga Heads	-36.57	150.11
NSW 37	Eden North Head	-37.06	149.94
NSW 37	Greenwell Point	-37.24	150.05
NSW 37	Disaster Bay	-37.26	149.97
NSW 37	Green Cape Lighthouse	-37.26	150.05