IMPACT OF GILLNET FISHING ON INSHORE TEMPERATE REEF FISHES, WITH PARTICULAR REFERENCE TO BANDED MORWONG

R.J. Murphy and J.M. Lyle

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1 NON-TECHNICAL SUMMARY

95/145 Impact of gillnet fishing on inshore temperate reef fishes, with particular reference to banded morwong

Principal Investigator: Dr Jeremy Lyle

Project Research Officer: Raymond Murphy

Address: Tasmanian Aquaculture and Fisheries Institute
Marine Research Laboratories
Taroona, Tasmania 7053
Telephone: (03) 6227 7277 Fax: (03) 6227 8035
E-mail: Ray.Murphy@dpiwe.tas.gov.au

Objectives:

(1) Describe life history and population parameters of the key commercial reef fish species.
(2) Determine gillnet mesh selectivity for commercial, and by-catch, reef species.
(3) Determine the size/age composition of banded morwong populations at different sites off the east coast of Tasmania, with particular attention to the impact of differing levels of fishing pressure.
(4) Determine patterns of movement for banded morwong, wrasse and bastard trumpeter.
(5) Assess the level of by-catch and discarding in the inshore gillnet fishery.
(6) Conduct yield per recruit analyses to determine appropriate legal size limits.

Non-technical summary:

The 'live fish' fishery for banded morwong commenced in 1993, resulting in a dramatic increase in catches. In its early development, many fishers showed considerable interest in the fishery and in an attempt to limit catch and effort, management restrictions such as limited entry, minimum and maximum size limits (33 and 43 cm, respectively) and a closed season were introduced. Since 1995, landings have stabilised at approximately 80 tonne per annum.

Banded morwong are targeted using large mesh gillnets, set on inshore rocky reefs, on the east coast of Tasmania, predominantly in depths of 5 to 25 m. The fishery is strongly weather dependant.

Banded morwong spawn on inshore rocky reefs between late February and early May. Both sexes grow rapidly for the first 4 to 6 years but growth in females then slows dramatically, with the onset of sexual maturity. Males grow faster and reach a larger maximum size than females. The maximum size recorded for males is about 55 cm FL compared to 51 cm for females, although very few females attain sizes larger than 45 cm. Growth rates were slightly faster in the Bicheno region, in the north, compared to the Tasman Peninsula, in the south. Approximately 50% of females are mature at 32 cm (4 years) and almost 100% are mature at 37 cm (8 years). Size at maturity in males is unknown. Maximum recorded ages are 86 years for females and 81 years for males. Ageing protocols for sectioned otoliths were validated using fluorochemical marking techniques. Estimates of natural mortality are very low, ranging between 0.03 and 0.07.

Distinct size structuring of banded morwong was observed between individual reefs. Comparisons between populations in a marine reserve (Governor Island) and adjacent exploited reefs provided no clear evidence of different size structure that could be related to the effects of fishing.

The size composition of commercial catches of banded morwong are largely determined by the selectivity of the gillnets used in the fishery. In a effort to produce a representative population size structure, selectivities for a range of mesh sizes were determined for banded morwong and applied to commercial length frequency data. The size distribution of the commercial catch reflects the population structure for females, but the number of males below 46 cm is over-represented and the number over 46 cm is under-represented in commercial catches. Because of their slower growth rate and generally smaller size, females dominate the retained catch, the fishery being regulated by minimum and maximum size limits.

Yield per recruit and egg per recruit analyses demonstrated that the minimum and maximum size limits that applied during the bulk of this study were inappropriate, effectively offering minimal protection for females, the minimum size being only just above the size at 50% maturity and very few females exceeding the maximum size. As a result of recommendations from this study, including a workshop with industry, size limits were increased to 36 and 46 cm, respectively

The utility of commercial catch sampling, research and tagging data, collected from the live fish fishery, was greatly enhanced by the use of a biopsy probe to determine the sex of banded morwong in a non-destructive manner. The biopsy probe also proved successful in taking gonad samples to assess the stage of maturity in live fish. This method may have an application for other studies examining sex composition of catches in the field.

By-catch is minimal in the banded morwong fishery, the target species dominating the catch. Draughtboard shark, marble fish and banded morwong (outside of legal size limits) comprise the bulk of the by-catch and are generally returned to the water alive. The large mesh sizes used by banded morwong fishers contributing largely to the limited by-catch. Smaller mesh sizes used by other commercial gillnet and recreational fishers take a greater number of by-catch species.

Only a small number of other species are also available to the inshore gillnet fishery, including striped trumpeter, bastard trumpeter and marble fish which dominated the catch in a range of mesh sizes.

During the course of this study, a large number of juvenile striped trumpeter and bastard trumpeter recruited to inshore rocky reefs in southern Tasmania. Strong cohorts of both trumpeter species, based on the 1993 spawning season, were recorded, as well as a relatively large cohort of the 1994 year class of striped trumpeter. Anecdotal evidence suggests that, prior to this time, very few striped trumpeter had recruited to these reefs over the previous two decades. The strength of these cohorts allowed growth in juveniles of both trumpeter species to be described.

Tag-recapture data showed that banded morwong and juveniles striped and bastard trumpeter are predominantly residential rocky reef fish, most recaptures of all three species occurring within 5 km of the tagging location. For each species, there was no obvious trend between the distance moved and fish size or time at liberty, although for striped trumpeter the average distance moved tended to increase as the time at liberty increased.

Keywords:

Gillnet, mesh selectivity, by-catch, rocky reef, Cheilodactylidae, Latridae, banded morwong, trumpeter, growth, tagging.

2 BACKGROUND

The community structure of Tasmania's inshore temperate reef fishes has been described in a number of studies (Schaap and Green 1988; Edgar 1981, 1984; Barrett *et al.* 1994). A number of scalefish species, including striped trumpeter (*Latris lineata*), bastard trumpeter (*Latridopsis forsteri*), banded morwong (*Cheilodactylus spectabilis*) and several species of wrasse (Family Labridae), are commonly found associated with inshore rocky reefs and are the subject of intense fishing pressure by gillnet, hook and trap fishing methods. Concern about the impact of gillnet fishing, in particular, on the reef fish communities has been expressed for many years by fishers, scientists and the broader community (Schaap and Green 1988, Harries and Croome 1989).

Traditionally, bastard trumpeter was the primary scalefish species targeted by both commercial and recreational gillnet fishers, the species being exploited since European settlement. Concerns were first expressed about the status of the resource as early as the 1880s, resulting in a Royal Commission to investigate the problem. The commercial catch history suggests at least two periods of major declines in abundance, in the late-1910s and again in mid-1970s (Harries and Croome 1989). Recent commercial landings have been in the order of 50 tonnes per annum (Lennon 1998).

In 1993, development of *live fish* markets for banded morwong, blue-throated wrasse (*Pseudolabrus tetricus*) and purple wrasse (*P. fucicola*) resulted in a dramatic expansion in fishing effort directed at these reef species, particularly banded morwong. Reported landings of banded morwong increased from just 11 tonnes in 1992 to 105 t the following year (Fig. 2.1). By 1994, reported landings had peaked at over 150 t (Lennon 1998). However, it is likely that these catches were overstated because fishers believed that the banded morwong

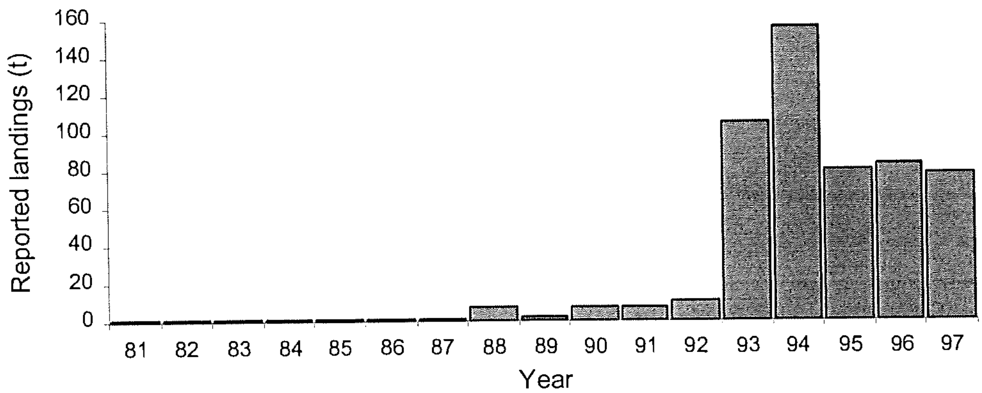


Fig 2.1. Annual reported landings of banded morwong, 1981 - 97

fishery was about to become a limited entry fishery, with access based on catch history. On 31st May 1994, a Ministerial statement was issued to all fishers indicating that catches prior to this date would not be used in determining catch history in the scalefish fishery. Since 1995, reported landings have been relatively stable, at approximately 80 t per annum. During the same period, wrasse landings rose from 80 t to a peak of over 190 t in 1994 and have since been maintained at about 100 t (Lennon 1998). Again, it is suspected that wrasse landings were overstated in 1994.

Historically, banded morwong and wrasse had little commercial value and were used mainly as rock lobster bait; a practice that continues despite their premium value as live fish. These species currently command a beach price of between $7-12 per kg. Based on value, by 1995 banded morwong had become the most important species in the inshore scalefish fishery, with an estimated annual value of approximately $0.8 million.

For the live fish market, banded morwong are targeted exclusively with large mesh gillnets (130-140 mm stretched mesh) whereas wrasse are targeted with handlines and fish traps. Some operators target both banded morwong and wrasse, using lines or traps for wrasse while nets are set for banded morwong. In addition to targeted fishing, both banded morwong and wrasse are taken as a bycatch in commercial and recreational gillnets targeting trumpeters and blue warehou (*Seriolella brama*) set on inshore rocky reefs (Lyle 1998).

The banded morwong fishery is centred mainly along the east coast of Tasmania, between St Helens in the north and the Tasman Peninsula in the south, with the largest catches coming from the central east coast around Bicheno (Fig. 2.2). The primary markets for Tasmanian banded morwong and wrasse are Asian restaurants in mainland Australia, with small quantities exported to south-east Asia.

During its early development, all Tasmanian Fishing Boat Licence (TFBL) holders had unrestricted access to the live fish fishery. Many small diversified fishers showed considerable interest in the fishery and in 1993 over 130 licence holders reported landings of banded morwong and/or wrasse (Murphy 1994). In an attempt to limit catch and effort in these rapidly expanding fisheries, various management restrictions were introduced. In late 1994, minimum and maximum size limits were applied to banded morwong (33 and 43 cm FL) and wrasse (28 and 43 cm TL). The rationale for these size limits was twofold, to maintain adequate egg production by protecting large adults and to reflect market requirements by restricting the size range to that of highest value. A closed season for banded morwong (March and April inclusive) was introduced in early 1995 and was timed to coincide with the peak spawning period. The closed season was implemented to minimise wastage of live fish at a time when post-capture rates of mortality are highest.

In 1996, an interim *Live Fish Endorsement* was introduced, with eligibility based on demonstrated catch history. This effectively restricted the number of fishers with access to both live banded morwong and wrasse to around 90. As part the recently released Scalefish Management Plan, provision has been made to create two separate *Fishing Licences*, one for the taking of live banded morwong and the other for live wrasse (Anon. 1998). The introduction of these licences, planned for November 1998, will significantly reduce the number of fishers able to market live banded morwong and wrasse because more stringent qualification criteria will be applied.

Of particular concern to resource managers and industry is the ability of the target and associated reef species to sustain the current or future levels of fishing pressure. Both banded morwong and wrasse are generally considered to be residential on a particular reef (McCormick 1989a; Barrett 1995), suggesting that they could be susceptible to localised depletion. Anecdotal reports from fishers suggest that in some areas catch rates have already declined markedly since the commencement of the fishery. For banded morwong, the risk of overfishing is compounded by the reported slow growth rate and longevity (approx. 60 yrs) of the species, as indicated in New Zealand studies (McCormick 1986). A preliminary

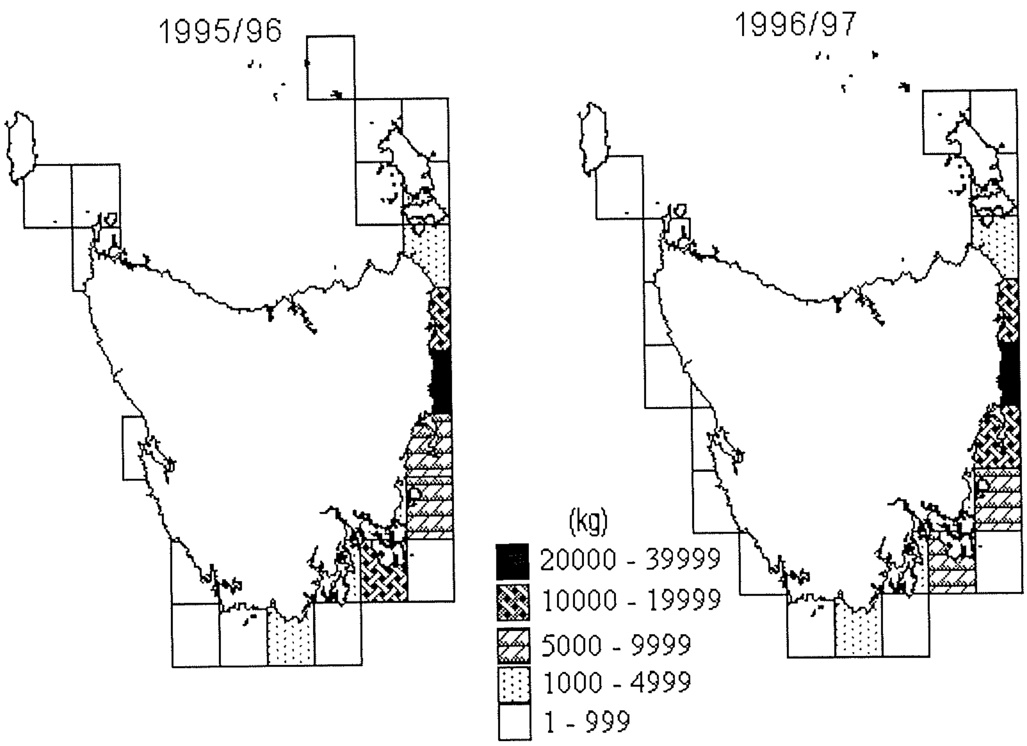


Fig 2.2. Reported landings of banded morwong by ½ degree fishing blocks for the 1995/96 and 1996/97 financial years

evaluation of sectioned otoliths from banded morwong from Tasmania supported New Zealand findings, with over 70 annuli present on some otoliths (Robertson and Green 1994). However, as the frequency with which annuli are formed was not known, these ages were not validated.

Age validation is essential for banded morwong and is feasible through tagging and the use of fluoro-chemical markers such as oxytetracycline (OTC) to mark the otoliths. These techniques would also appear feasible for age validation in bastard trumpeter. The suitability of tagging banded morwong and bastard trumpeter had been confirmed prior to this study, with each of these species undergoing handling and tagging trials during aquaria confinement, resulting in minimal mortality (A. Ritar unpublished data, R. Murphy unpublished data). In addition, tagging can provide information about movement, growth and, potentially, rates of exploitation.

3 NEED

The rapid growth of the live fish trade has placed increasing pressure on Tasmania's inshore reef fishes. The sustainability of the fishery at current or future levels of activity is uncertain and a matter of considerable concern to fishers and resource managers. Assessment of the impact of fishing requires a thorough understanding of the dynamics of the commercial (and recreational) fishery and, in conjunction with life history information and population parameters of the main species, can provide for scientifically based management decisions.

Apart from the target species, a number of other commercial and non-commercial species are taken as a by-catch of gillnet fishing for live banded morwong. Commercial by-catch species include bastard trumpeter, striped trumpeter, blue warehou, wrasse and long-snouted boarfish (*Pentaceropsis recurvirostris*). Non-commercial by-catch species include marble fish (*Dactylosargus arctidens*), draughtboard shark (*Cephaloscyllium laticeps*) and various species of leatherjacket (family Monacanthidae). At best, only rudimentary biological information is available for both target and by-catch species.

In draft Tasmanian Scalefish Fishery and Recreational Fishery management plans released in late 1994 it was proposed to increase the minimum gillnet mesh size ('graball' net) for commercial and recreational fishers from 100 to 125 mm. This was amended to a minimum of 108 mm in the final Scalefish Management Plan, with the possibility of a move to 115 mm to be investigated for the next life of the plan (Anon. 1998). If the optimum mesh size for the fishery is to be determined, taking into account by-catch and yield per recruit considerations, then the impact of the present range of mesh sizes and any proposed minimum mesh size requires investigation. In addition, an understanding of gillnet mesh selectivity is essential when assessing population structures based on gillnet sampling.

The present study has been designed to investigate the biology and dynamics of the principal commercial reef fish species, through a program of commercial catch sampling and research fishing. Particular attention has been given to assessing mesh selectivity and the appropriateness of mesh size and fish size limits, particularly in relation to yield per recruit. Tagging has been used to validate ageing and determine patterns of movement.

4 OBJECTIVES

The objectives of this study as stated in the original FRDC research proposal were to:-

(1) Describe life history and population parameters of the key commercial reef fish species.
(2) Determine gillnet mesh selectivity for commercial, and by-catch, reef species.
(3) Determine the size/age composition of banded morwong populations at different sites off the east coast of Tasmania with particular attention to the impact of differing levels of fishing pressure.
(4) Determine patterns of movement for banded morwong, wrasse* and bastard trumpeter.
(5) Assess the level of by-catch and discarding in the inshore gillnet fishery.
(6) Conduct yield per recruit analyses to determine appropriate legal size limits.

* this part of the study was not undertaken because wrasse captured in gillnets were not generally in good condition suitable for tag and release

5 METHODS

5.1 *Commercial catch sampling*

Commercial catch sampling of the banded morwong fishery was conducted between December 1994 and November 1997. Sampling was divided into three general fishing 'seasons', Summer (Dec-Feb), Autumn (Mar-May) and 'Winter' (Jun-Nov). A total of 9 seasons were sampled over the three years of the study.

The east coast of Tasmania was divided into four general fishing regions; St. Helens (1/8 degree fishing blocks 4H3O, 5H1C, 5H1G, 5H1K, 5H1L); Bicheno (5H3C, 5H3G, 5H3K, 5H3O, 6H1C); Maria Island (6H3A, 6H3B, 6H3E, 6H3F, 6H3I) and Tasman Peninsula (6G4P, 6H3M, 7G1D, 7G2A, 7G2B, 7G2D, 7G2F, 7G2G, 7G2H, 7H1E) (Fig. 5.1).

Fishers involved in commercial catch sampling were experienced in capturing banded morwong and had a high level of participation in the fishery. In four of the seasons surveyed (summer 95, autumn 95, autumn 96 and autumn 97) the fishery was closed for the majority of the season and commercial banded morwong vessels were chartered to undertake fishing. Fishers under charter were instructed to operate nets in an manner consistent with their normal fishing practices.

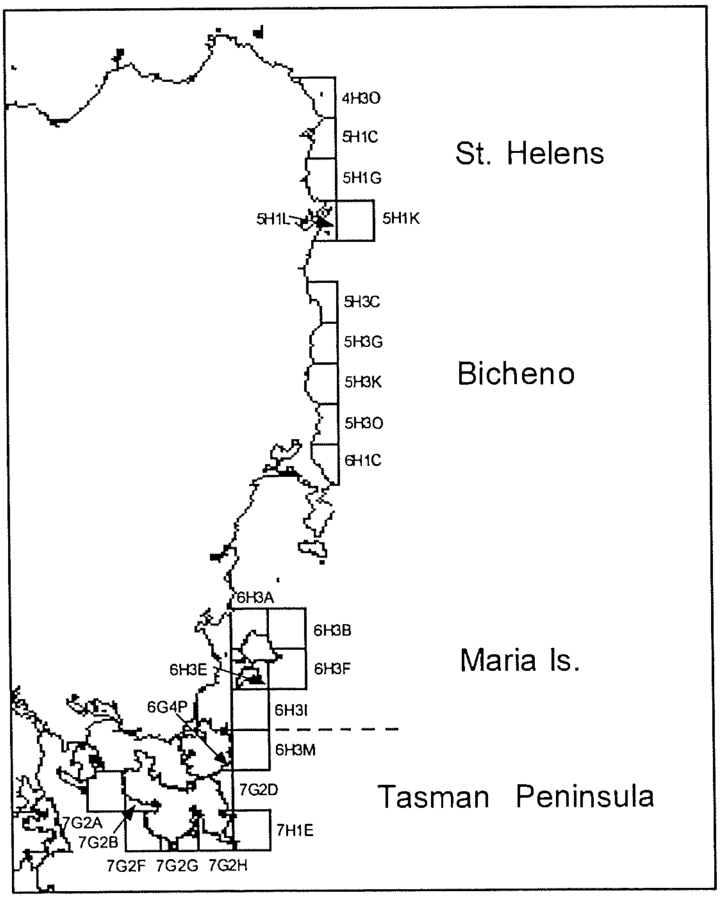


Fig. 5.1. East coast of Tasmania showing general fishing regions of banded morwong commercial catch sampling

Bottom set gillnets were deployed on inshore rocky reefs from commercial vessels. All nets were set and hauled during daylight hours. The timing and location of fishing on a given day depended heavily on the prevailing weather and sea conditions. Fishing was generally conducted in water that was not affected by strong tidal flow, in less than 1.5 m of swell and less than 15 knot winds. Net length (m), mesh size (mm) and the minimum and maximum depth (m) for each net deployment was recorded. Substrate characteristics and depth were determined using either colour or black and white echosounders. Deployment time was recorded to the nearest minute and was defined as the time from the completion of setting the net to the end of the haul. Depending on the vessel, nets were either hauled by hand or by net reel.

For each net deployment, the fork length of each banded morwong captured was recorded to the nearest mm and the weights of banded morwong retained (*i.e.* legal sized) and discarded (*i.e.* non-legal sized) was determined. Generally, all commercially important species (striped trumpeter, bastard trumpeter and boarfish) were also measured. The total weight of each by-catch species, retained and discarded, was determined for each net deployment. All weights were recorded to the nearest 0.1 kg using either a 5 kg or 10 kg spring balance. Generally, banded morwong outside of the legal size limit were tagged and released (see section 5.4). From summer 97 on, all banded morwong greater than 33 cm FL were sexed using the biopsy probe method (see section 5.5). Prior to this date fish were not routinely sexed in the field.

Catch per unit effort (CPUE) of banded morwong, is expressed as either the number or weight captured per 100 m net hour.

5.2 Mesh selectivity

Gillnet mesh selectivity trials were conducted seasonally between August 1995 and May 1997, with a total of six seasons sampled. Gillnets of five different mesh sizes were set on rocky reefs. The five experimental gillnets were 89, 105, 114, 130 and 133 mm (3 ½ to 5 ¼ inches) stretched mesh, all mesh sizes that are commercially available in Tasmania. Each net was approximately 30 m in length and was constructed using monofilament nylon bunt and 6 to 7 mm diameter polypropolyene rope for the headline and leadline. Other net specifications varied with mesh size (Table 5.1). Nets were constructed to closely match those used by commercial fishers.

Nets were set from either a 5 or 6 m aluminium research vessel. Personnel involved in the mesh selectivity study were involved in commercial catch sampling of the banded morwong fishery and were experienced in the capture of rocky reef fish using gillnets. In addition, approximately 125 net deployments were trialed using a variety of the experimental gillnets prior to commencement of this study, including a 64 mm mesh that was not used in the selectivity study.

Sampling was concentrated at six sites around the Tasman Peninsula and North Bruny Island, the site fished on each fishing day being determined by the prevailing weather and sea conditions. Sampling sites were: The Sisters; Fortescue Bay; Monroes Bight; Haines Bight; Port Arthur (Tasman Peninsula) and Cape Queen Elizabeth (north Bruny Island) (Fig. 5.2).

Sampling was depth stratified, with three strata recognised; shallow (0-9 m), medium (10-19 m) and deep (20-29 m). A sampling station was defined as, one gillnet of each of the five experimental mesh sizes being set in one of the depth strata. Where feasible, one station in each depth strata was sampled concurrently. Generally, between one and two stations were sampled in each depth strata, on each fishing day. However, fewer stations were deployed in the deep stratum because suitable rocky reef habitat is limited or does not extend deeper than about 20 m in some sites, *e.g.* Port Arthur. Substrate and depth was determined using a JRC (JVF-55) black and white echosounder.

Nets were always set and hauled during daylight hours. A 1.4 kg lead weight was attached to the leadline at one end of the net and a buoy was attached with a buoy line to either end of the net. Nets were set parallel to the shoreline, generally following a depth contour, and were positioned at least 30 m apart. Nets were hauled by hand and set duration was recorded as for commercial fishing. For each net deployment, the total weight of each species captured was recorded to the nearest 0.1 kg and the lengths (mm) of banded morwong, striped trumpeter, bastard trumpeter and wrasse (*i.e.* commercial species) were measured. For the first 3 seasons surveyed, the lengths of marble fish (a non-commercial species) were also recorded.

Table 5.1. Variable characteristics of experimental gillnets.

Mesh size (mm)	Average net length (m)	Net depth (m)	Nº of meshes deep	Twine diameter (mm)	Hanging ratio	Wt. upthrust (g/10m)	Wt. down-thrust (g/10m)	Bunt colour
64 *	31.2	1.60	50	0.38	0.55	680	1200	green
89	28.7	1.78	40	0.45	0.47	450	1320	grey
105	30.4	1.73	33	0.52	0.52	420	1100	grey
114	29.3	1.43	25	0.38	0.51	390	1300	grey
130	30.7	2.15	33	0.60	0.48	510	1280	blue
133	32.4	0.80	12	0.38	0.58	560	1400	green
140*	50.0	1.12	16	0.38	0.50	340	1360	grey

* not used in mesh selectivity study

CPUE for banded morwong, striped trumpeter, bastard trumpeter and marble fish was determined for each mesh size. CPUE was calculated as weight or number per 100 m net h for each net deployment. A three factor analysis of variance (ANOVA) was applied to CPUE and mean length data to assess the effects of mesh size, depth strata and season on CPUE and mean size. The effects of site were not tested. CPUE data were log transformed [ln(CPUE+1)] for this analysis. All factors were tested at the P=0.05 significance level for rejection of the null hypothesis. In order to determine whether the assumptions of ANOVA were violated, that is normality of the data and heterogeneity of the variances (Underwood 1981), scatterplots of residuals versus the expected normal order statistic and fitted values, were examined.

Since the effective effort levels for each combination of mesh size and depth stratum varied slightly in each season, it was necessary to adjust the effort (and therefore catch of banded morwong in each size class) to a common level within each season (refer section 6.2 for description of effort weighting).

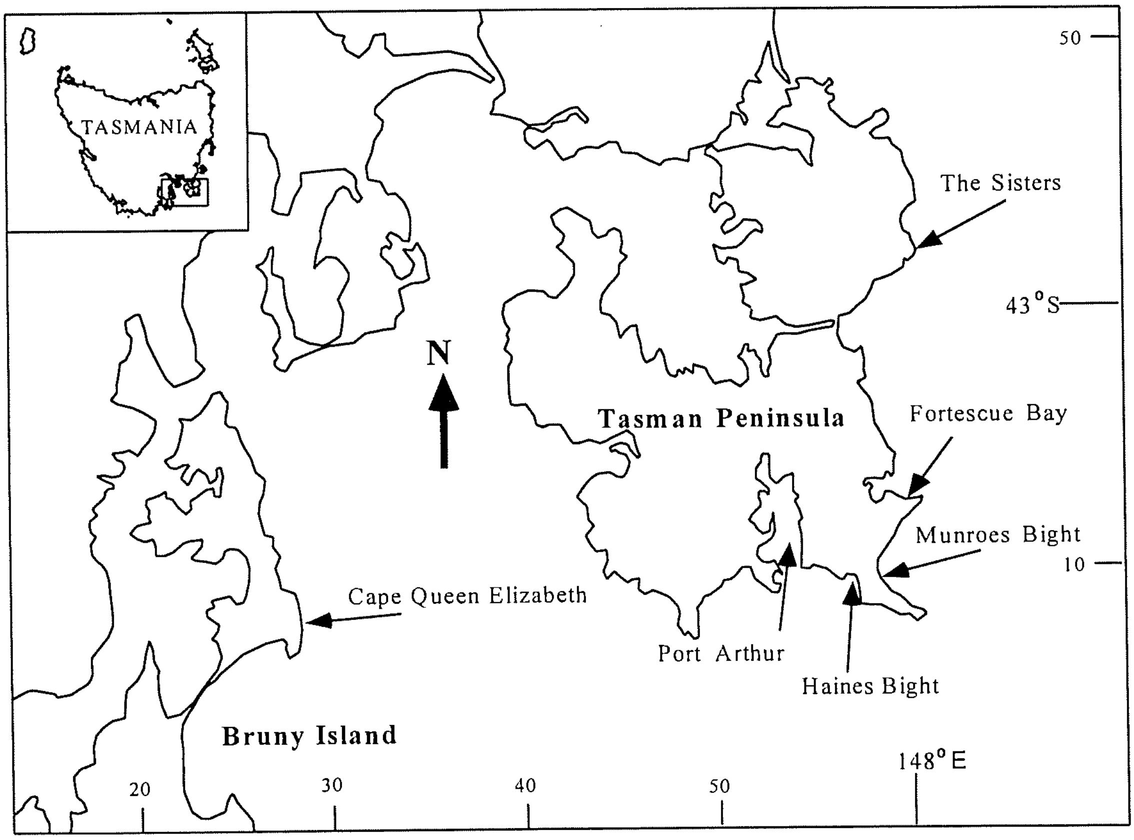


Fig. 5.2. Sampling sites of mesh selectivity study in south-eastern Tasmania

Length specific gillnet selectivities were estimated for the five mesh sizes using the gamma distribution model (Kirkwood and Walker 1986),

$$(l/\alpha\beta)^{\alpha}\exp(\alpha - l/\beta) \qquad \text{(Eqn. 1)}$$

where l is length and α and β are parameters of the probability density function of a gamma distribution with a mode $\alpha\beta$ and variance $(\alpha + 1)\beta^2$. α and β are specified in terms of the mesh size m_i and length class l_j. Assumptions of the model are that, the length at maximum selectivity for net i is proportional to mesh size so that $\alpha\beta=\theta_1 m_i$, where θ_1 is a constant of proportionality, and the variance is a constant, θ_2, over different mesh sizes. These assumptions lead to a quadratic equation for positive β and imply that

$$\beta = -0.5[\theta_1\, m_i - (\theta_1^{\,2}\, m_i^2 + 4\theta_2)^{0.5}] \qquad \text{(Eqn. 2)}$$

The mean selectivity for banded morwong in 30 mm length classes was approximated as the selectivity evaluated at the mid-length of the length class. The gamma distribution model (Eqn. 1) was fitted to the effort corrected data by maximum likelihood estimation obtained using the 'solver' function in *Excel 7* (Microsoft). Estimated selectivities were checked to ensure that the assumptions of the model (right skewed, fishing powers of the nets are equal) were satisfied. Residual plots of observed and predicted catches were examined.

Selectivity, particularly by wedging and gilling, was not thought to be influenced by sex because McCormick (1989a) found that pectoral girth was one of several morphological factors that contributed least to discrimination between male and female banded morwong. Similarly, Schroeder *et. al.* (1994) excluded pectoral girth from a morphometric analysis of sex discrimination in the closely related red morwong (*C. fuscus*). Therefore estimated gillnet size selectivities were applied regardless of sex.

The size structure of the banded morwong population from east coast Tasmanian waters was determined by applying selectivity co-efficients for the 133 mm mesh to commercial length frequency data.

For striped trumpeter, bastard trumpeter and wrasse, length specific gillnet selectivities were not modelled. For these species, size composition data by mesh size was summarised.

In addition to nets deployed in the mesh selectivity, a number of 140 mm mesh nets were constructed, using 8 mm headline and leadline, in order to increase the number of banded morwong captured for tagging (see section 5.4). The 140 mm nets were set on rocky reefs on an *ad hoc* basis during the mesh selectivity study but have not been included in the calculation of mesh selectivity parameters.

5.3 Comparison of marine reserve and adjacent exploited area

In order to investigate the possible impacts of gillnet fishing on banded morwong populations, research fishing was undertaken inside the Governor Island marine reserve, Bicheno (closed to fishing since September 1991) and adjacent reef areas that are subject to fishing. Fishing was conducted between March 1996 and December 1997. The exploited reef areas targeted were Diamond Island, to the north, and rocky reef areas between the marine reserve and Cape Lodi, to the south (Fig 5.3). All exploited areas were within 4 km of the marine reserve.

Nets were deployed from research vessels, except for the first two days of the survey in March 1996 when a commercial vessel under charter was used. Catch and effort details were recorded as for mesh selectivity trials. All nets were between 30 and 50 m in length and had a stretched mesh of either 133 or 140 mm (refer Table 5.1). To minimise the effects of time

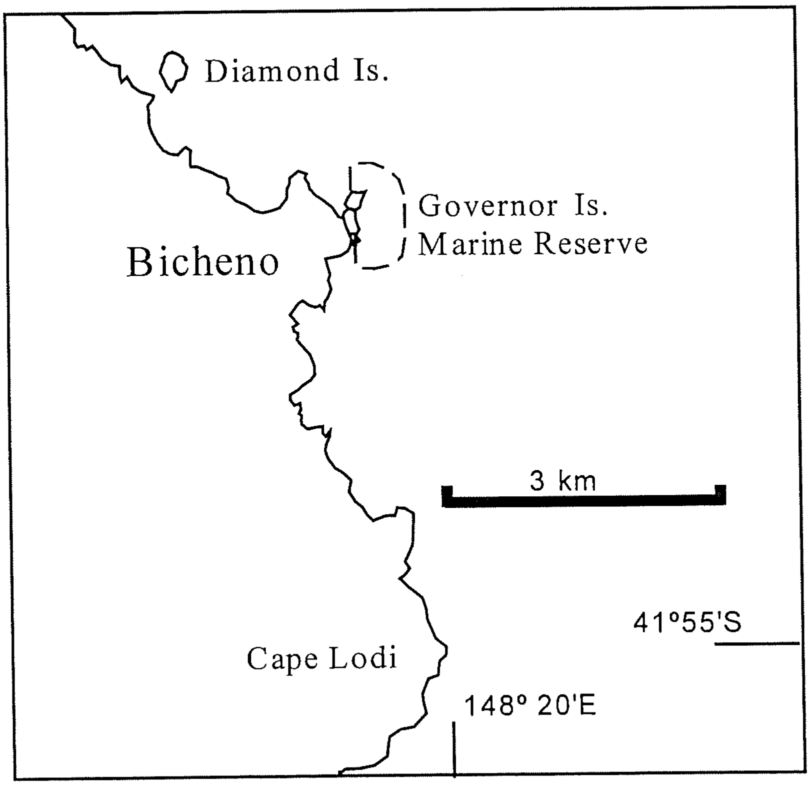


Fig 5.3. Governor Island marine reserve and adjacent exploited areas

of the day on catch rates, every effort was made to have the same amount of fishing gear in the water, concurrently, in both the marine reserve and the adjacent exploited area.

Data were pooled for each month surveyed and the total catch and CPUE for all species, by weight and number, was calculated for each month for inside and outside of the marine reserve.

Prior to June 1997, all banded morwong captured within the marine reserve and in the adjacent exploited area were tagged and released (refer section 5.4).

Using tag recapture data (ignoring the effects of mesh selectivity and tag loss), the stock size of banded morwong within the reserve and available to the fishing gear was calculated for each fishing day using the simple equation of Ricker (1945),

$$P = \frac{N_t Y_n}{N_r} \qquad \text{(Eqn. 3)}$$

where P is the estimate of stock number; N_t is the number tagged, N_r is the number recaptured, and Y_n is the catch in numbers.

5.4 Tagging

Banded morwong were tagged off the east coast of Tasmania, between July 1994 and May 1997. Researchers tagged banded morwong captured during mesh selectivity trials, the marine reserve study and from *ad hoc* sampling with the 140 mm mesh gillnets. Researchers also tagged banded morwong that were outside of the legal size limits and caught during commercial catch sampling. A number of commercial fishers voluntarily participated in the reef fish tagging program and tagged under and oversized banded morwong that they released. During the mesh selectivity trials, striped trumpeter and bastard trumpeter were also tagged.

All species were tagged below the dorsal fin with T-bar anchor tags (Hallprint) and were measured to the nearest millimetre fork length before being released. In an attempt to assess tag loss, most of the banded morwong and bastard trumpeter, and a subsample of the striped trumpeter, caught during research fishing were double tagged.

Between January 1995 and February 1997, most banded morwong and bastard trumpeter captured during research fishing were injected with Engemycin 100 [oxytetracycline hydrochloride 100 mg/mL (OTC)] at the time of tagging to assist with age validation. OTC was administered as a peritoneal injection at a dosage of 50 mg/kg (McFarlane and Beamish 1987). White coloured tags were used to distinguish OTC injected fish, as opposed to yellow tags that were used for routine tagging.

Fishers involved in tagging, and those likely to recapture fish, were provided with maps of their fishing area in which the coastline had been divided into small fishing regions between 1 and 4 km in length (based on prominent geographic features). The tagging location or recapture location was recorded as being the point on the coastline in the middle of the appropriate fishing region.

The position of recaptures reported by recreational fishers, or commercial fishers not provided with tagging maps, was recorded as accurately as possible from descriptions of geographic landmarks. Assuming that fishers accurately recorded the tagging/recapture region, this system will provide precision in position reporting of ± 2 km.

The tagging program was widely publicised in industry magazines and fishing newspapers (Lyle 1995; Lyle and Waterworth 1995; Murphy *et. al.* 1996). A poster that described the requested protocol to follow if a tagged fish was recaptured was placed in fishing supply shops and in shop windows around popular fishing areas. All reports of recaptures were entered into an annual tag lottery and a monetary reward was offered for OTC injected fish. All fishers reporting recaptures were provided with tagging details of the fish they had recaptured, including growth, distance moved and time at liberty.

5.5 Biological studies

Approximately 500 banded morwong captured while charter fishing during each of the 1996 and 1997 closed seasons were retained for detailed biological examination. In both years, approximately half of the fish were taken from the Bicheno region, the remainder coming from the Tasman Peninsula. Samples were collected live from the vessel, placed on ice and transported to the laboratory. Biological examination was conducted on the fresh specimens within 48 h of capture. Additional specimens, either mortalities from fish processors or tag recaptures, were also examined biologically.

All fish were measured to the nearest mm (FL) and weighed to the nearest gram (total weight). A subsample was also measured for total length (mm) to allow fork length-total length relationships to be calculated.

Sagittal otoliths (from now on referred to simply as *otoliths*) were removed from each fish, cleaned and stored in individual plastic vials. All tubes were labelled with a unique identity number that gave no biological or geographic information about the fish. If tag recaptures had been injected with OTC, the otoliths were stored in blackened plastic vials, out of direct light.

McCormick (1989a) was able to detect sexual dimorphism in banded morwong based on a number of morphometric characteristics, namely snout angle (due to the presence of pre-orbital nodules in mature males), mid-body length and pectoral fin length. This provided the potential to determine sex externally, an advantage for assessing fisheries where the catch is sold alive. The utility of McCormick's method was tested in the laboratory. In a random sample (n=366) from the 1996 sample, the sex of fish greater than 30 cm FL was judged using the morphometric features for sexing banded morwong described by McCormick (1989a). Particular attention was paid to the presence of pre-orbital nodules and snout angle (but ignoring any distension of the body due to the ovaries). Fish were then dissected and the sex determined.

All gonads were staged macroscopically according to modified criteria of Davis and West (1992) and weighed to the nearest 0.1 g. Females were classified as mature if they were at least stage 4, that is, where individual ova are clearly visible when examined without magnification.

In addition to morphometric characteristics, an alternative approach to sexing banded morwong was tested using a biopsy probe. For the 1997 sample, the sex of each fish greater than 30 cm FL in a random sample (n=401) was assessed by attempting to insert a polyproylene endometrial biopsy probe (Pipelle de Cornier CCD-PIP) into the cloaca. If the biopsy probe could be inserted greater than 20 mm the fish was recorded as female. If the biopsy tube could not be inserted the fish was recorded as male. The fish were then dissected and the sex determined.

The maturation ogive was determined by fitting the sigmoid curve function using a generalised linear model with a logit link function and binomial distribution of errors,

$$p = \frac{e^{A+B.x}}{1+e^{A+B.x}} \qquad \text{(Eqn. 4)}$$

where p is proportion mature at a given cm size class, x is length in cm and A and B are parameters of the logit regression.

The relationship between length and gonad weight was described for females where the ovaries were stage 4 (*i.e.* only stage 4) by fitting non-linear data to the power equation,

$$G=aL^b \qquad \text{(Eqn. 5)}$$

where G is gonad weight (g), L is fork length (mm) and *a* and *b* are constants. The relationship was calculated by least squares regression of log transformed data. By assuming that gonad weight of stage 4 ovaries is directly proportional to potential fecundity, the relationship between fish length and fecundity can be approximated. For the purpose of conducting egg per recruit analyses, the parameters of the length-gonad weight relationship are sufficient because it is the *relative* fecundity, not *absolute* fecundity, of each size class that is required for the analyses.

To determine whether maturation and the onset of spawning in female banded morwong could be detected non-destructively, biopsy samples of gonad tissue were obtained from females from the Tasman Peninsula region, between November 1996 and May 1997, using the biopsy probe. Biopsies were obtained every 2-3 weeks from the first 10 to 20 individuals captured during mesh selectivity studies or commercial catch sampling. Samples were preserved in 4% formaldehyde in filtered seawater and stored at room temperature. Gonad samples were examined with a binocular microscope under transmitted light and an image analysis system (NIH Image 1.6) was used to capture an image of each biopsy sample and display it on a computer screen. The biopsy was described on the basis of the appearance of the most developed oocytes present. A random sample of 10 of the most developed oocytes from each biopsy were selected off the captured image and the diameter (μm) of each oocyte was measured in a horizontal plane.

A sub-sample of whole ovaries collected during the spawning season were preserved in 4% formaldehyde in filtered seawater and stored at room temperature. The ovaries were examined to determine whether the most developed oocytes within the gonad, and the mean size of the 10 most developed oocytes, are influenced by the location within the gonad from which a biopsy sample is taken. Whole ovaries, macroscopically staged as either stage 3, 4 or 5 (Davis and West 1992), were divided into the anterior, middle and posterior portions. Each portion was examined as described for biopsy samples and the diameter of 10 of the most developed oocytes from each portion were measured. Single factor analysis of variance was used to determine if there was a difference in the mean size and position of the most developed oocytes in the ovary.

Striped trumpeter and bastard trumpeter specimens were also retained for biological examination. Additional samples of larger trumpeter were obtained from CSIRO research cruises, fishing offshore reefs in eastern Bass Strait.

For banded morwong, striped trumpeter and bastard trumpeter, the relationship between total length and fork length was described by simple linear regression,

$$TL = b\,FL + a \qquad \text{(Eqn. 6)}$$

where TL is total length (mm), FL is fork length (mm) and a and b are constants. The relationship between length and weight was described by fitting non-linear data to the power equation

$$W = aL^{b} \qquad \text{(Eqn. 7)}$$

where W is total weight (g), L is fork length (cm) and a and b are constants. The relationship was calculated by least squares regression of log transformed data. For banded morwong, analysis of covariance was used to determine whether there were significant differences in length-weight relationships between sexes; regions; and females in spawning and non-spawning condition.

5.6 Age and growth

Otolith preparation and interpretation

In this report, the term *winter* follows that of Francis *et. al.* (1992) to loosely describe the cool period in the southern hemisphere in about the middle of the calendar year in which fish growth slows or ceases, rather than referring to specific months. The otolith structure nomenclature used follows that of Secor *et. al.* (1995). Interpretation of sectioned otoliths viewed under transmitted light follows that of Anderson *et. al.* (1992), where relatively narrow, opaque zones represent slow winter growth and the relatively broader, translucent zones represent faster summer growth. By contrast, the structure of whole otoliths viewed under reflected light was interpreted as consisting of relatively narrow, translucent zones representing slow winter growth and relatively broader, opaque zones representing faster summer growth.

Banded morwong

Banded morwong otoliths collected in Autumn 96 and Autumn 97 were used for age and growth determination. One undamaged otolith was selected from each pair and weighed to the nearest 0.001 g. Otoliths were embedded in rows of four to five in clear polyester casting resin and four to six transverse sections were cut using a modified gem cutting saw. Section thickness was approximately 0.3 mm. Sections were mounted on microscope slides under coverslips using further casting resin.

Sections were viewed under transmitted light on a binocular microscope at either X25 or X50 magnification. All sections from each otolith were inspected and the clearest section closest to the primordium was used for age estimation. In about 5% of the prepared otoliths there were no readable sections. An image of each otolith was captured and displayed on a computer screen. The enhancement processes available on the image analysis system (eg. sharpen; smooth) were not used to alter the image. Two images were retained of each otolith. One image was unmarked and labelled only with the otolith identity number. On the second image the position and number of annuli that were interpreted for the main reading were indicated. Otoliths were read without reference to fish length, weight or area of capture.

For the main reading, annuli were counted from the captured image with reference to the microscope when more detail was required. The first 4 to 6 annuli were counted and numbered outwards from the primordium along the plane of the ventral groove, with subsequent annuli counted along the ventral side of the sulcul groove. The position of the annuli was marked as being on the *inward* side of the opaque zone at the boundary between the opaque and translucent zones. In a random sample of 449 otoliths, the distance (μm) of the first two annuli from the primordium along the plane of the ventral groove was measured. Single factor ANOVA was used to determine if the position of the first and second annuli was different. An estimated age was assigned to each otolith based on the number of annuli counted and a nominal birthday of 1st March.

Secondary readings by both the main reader (RM) and a secondary reader were conducted on the unmarked image, without microscopic examination of the original section. The main reader read a random sub-sample of images from 238 banded morwong otoliths (24% of total) as a secondary reading. The secondary reader read a random sub-sample of images from 272 otoliths (27% of total). The index of average percent error (APE) (Beamish and Fournier 1981) and the distributions of the differences between secondary readings and the initial reading by the main reader were calculated as indicators of ageing accuracy and bias.

Secondary readings were conducted without reference to fish length, weight, area of capture or previous readings.

Otoliths from OTC injected banded morwong, recaptured after at least 200 days were sectioned and aged as described above, the sections being stored in darkness. Sections were illuminated by a mercury lamp through a blue-violet filter (slightly back-lit with normal transmitted light) and viewed at X10 or X20 magnification on a monocular microscope. For otoliths where a fluorescent mark was visible, its position was noted in relation to the position of the annuli.

Trumpeters

For trumpeter smaller than 45 cm FL, one otolith was randomly selected from each pair and immersed whole in a drop of water in a glass petri dish. The distal surface was viewed under reflected light on a binocular microscope, at either X6 or X12 magnification, with the aid of the image analysis system. A marked and unmarked image was retained, as for banded morwong.

For the main reading, annuli were counted from the captured image with reference to the microscope when more detail was required. Annuli were counted and numbered outwards from the primordium. The position of the annuli was marked as being on the *outward* side of the translucent zone at the boundary between the translucent and opaque zones. The distance from the primordium (μm) to the first two annuli, towards the ventral side of the otolith in the dorso-ventral axis, was measured. A single factor ANOVA used to determine if the position of the first two annuli were characteristic.

An estimated age was assigned to each otolith based on the number of annuli counted and a nominal birthday of 1st October for both trumpeter species.

Secondary readings of whole trumpeter otoliths were conducted on the unmarked image. The main reader read a random sub-sample of 61 striped trumpeter otoliths (24% of total) and 67 bastard trumpeter otoliths (38% of total) as a secondary reading. The secondary reader read a random sub-sample of 100 striped trumpeter otoliths (40% of total) and 85 bastard trumpeter otoliths (48% of total) as a secondary reading. The index of APE and the distributions of the differences between secondary readings and the initial reading by the main reader were calculated.

For both trumpeter species, a sub-sample of 60 otoliths was selected where either 0, 1 or 2 annuli were counted on the whole otolith, with 20 otoliths selected from each of the three age classes. The position of the primordium was marked with a pencil and each otolith was embedded in resin on a microscope slide. The otolith was ground to a section in the dorso-ventral plane using wet sandpaper and polished with graphite paste.

Otoliths from trumpeters larger than 45 cm FL were embedded and sectioned as for banded morwong. Sections were viewed under transmitted light on a binocular microscope, at either X6 or X12 magnification, with the aid of the image analysis system. A marked and unmarked image was retained. The position of each annuli was marked as being on the *outward* side of the opaque zone at the boundary between the opaque and translucent zones. Secondary readings were conducted on all sections. The index of APE and the distributions of the differences were calculated between secondary readings and the initial reading by the main reader and between ages estimated from whole otoliths and sectioned otoliths.

Growth models

For banded morwong, estimated ages from the initial reading by the main reader were used in all analyses of age and growth. Mean lengths at estimated age determined from sectioned otoliths were calculated separately for females and males, for the Bicheno and Tasman Peninsula regions, and for both areas combined. Both sexes displayed asymptotic growth and the growth equation of von Bertalanffy (1938) was applied,

$$L_t = L_\infty[1-e^{-K(t-t_0)}] \qquad \text{(Eqn. 8)}$$

where L_t is length (cm) at age t, L_∞ is asymptotic length, K is the rate at which length reaches L_∞, and t_0 is the hypothetical age at which length is zero if growth had always occurred in the manner described by the equation. The equation was fitted to estimates of length at age by a non-linear least squares procedure of the GenStat statistical package. Differences in growth curves were tested between sexes, and between regions for each sex, by an analysis of the residual sum of squares (ARSS) (Chen *et. al.* 1992). In ARSS,

$$F = \frac{RSS_p - RSS_s}{3(k-1)} \bigg/ \frac{RSS_s}{N-3k} \qquad \text{(Eqn. 9)}$$

where RSS_p is the residual sum of squares (RRS) of the von Bertalanffy growth equation for pooled data, RSS_s is the RSS of each von Bertalanffy growth equation for each sample, N is the total sample size, and k is the number of samples in the comparison.

In addition, growth parameters were determined from tag recapture data following the method of Fabens (1965), using the Genstat statistical package. Recaptures that were at liberty for less than 200 days were not included in the Fabens analysis.

Total mortality (Z) for both sexes was calculated using catch curve analysis. Population age structures were determined from the aged sample, the commercial catch sample, and the commercial catch sample adjusted for the effects of mesh selectivity. The natural logarithm of the frequency of each age class was plotted against age, and a regression line was fitted between age classes to the right of the highest point on the catch curve to age classes to the left of the first age class that had a frequency of zero. Z is equal to the slope of the regression line with the sign of the slope changed.

Estimates of Z (actually an estimate of natural mortality, M, because the assumption is that fishing mortality, F, is zero) were also obtained using the Hoenig (1983) approximation for determining total mortality in lightly exploited stocks,

$$\log_e Z = 1.46 - 1.01 \log_e t_{max} \qquad \text{(Eqn. 10)}$$

where t_{max} is the maximum age in years.

Estimates of M were also obtained using the Sparre *et. al.* (1989) approximation,

$$M = \log_e 100/A_{max} \qquad \text{(Eqn. 11)}$$

where A_{max} is the maximum age reached by approximately 1% of the virgin population.

Von Bertalanffy growth parameters (Eqn. 8) were also derived for both trumpeter species. For striped trumpeter, length at age was determined by assigning a decimal age to all specimens ≤ 45 cm, based on whether they were from the 1993 or 1994 cohort, and from sectioned otoliths in specimens > 45 cm. For bastard trumpeter, length at age was determined from whole otoliths in specimens ≤ 45 cm and from sectioned otoliths in specimens > 45 cm.

In addition, growth parameters were determined for both trumpeter species using Fabens (1965) parameterisation of tag-recapture data. Recaptures that were at liberty for less than 200 days were not included in the Fabens analysis.

5.7 *Yield per recruit and egg per recruit analyses*

To assess the potential effect on yield of varying minimum size limits, yield per recruit (YPR) analyses were conducted for female and male banded morwong at different combinations of F, ranging from 0.1 to 1.0, and three estimates of M, 0.025, 0.05 and 0.10. YPR analyses that assess the potential affect on yield of varying maximum size limits (YPRmax) were conducted for male banded morwong, used in conjunction with minimum size limits of either 36 or 37 cm, and the same ranges for M and F used for YPR analyses. Data parameters required for YPR and YPRmax analyses are the von Bertalanffy growth parameters L_∞, K and t_0 (Eqn. 8), the constants a and b from the length-weight relationship (Eqn. 7), an estimate of maximum age and estimates of M and F, for females and all males. For females, the constants a and b that were used from the length-weight relationship were those for non-spawning fish.

Egg per recruit analyses (EPR) analyses were conducted to estimate the percentage of virgin egg production maintained at different minimum size limits. The data parameters used in the EPR analyses are the same as those used for YPR, plus the constants A and B from the maturation ogive (Eqn. 4) and the constants a and b from the length-gonad weight relationship (Eqn. 5). An assumption of this analysis is that gonad weight is directly and equally proportional to fecundity across all size classes, where the ovary is at stage 4.

6 DETAILED RESULTS

6.1 Commercial catch sampling

Gear

A total of 54 commercial fishing trips targeting banded morwong were sampled, representing 96 fishing days. Gillnets were deployed from 14 different commercial vessels, although three fishers accounted for 79% of the effort (100 m net h) monitored and 75% of the banded morwong (by number) captured. Vessels from which nets were hand hauled accounted for 69% of the effort monitored.

Fishers carried between 520 and 2000 m of net and lifted between 520 and 6500 m of net per fishing day. Nets hauled by hand ranged in length between 25 and 100 m, with an average length of 55 m. Where nets are hand hauled, fishers carried up to 24 individual nets per fishing day. Nets hauled by net reel ranged between 300 and 800 m in length, with an average length of 460 m. Where nets are hauled by net reel, fishers carried up to 5 individual nets.

The mesh size of gillnets used in the banded morwong fishery ranged from 114 to 140 mm stretched mesh, with 94% of nets lifts being either 133 mm or 140 mm mesh. The minimum depth fished was 2 m and the maximum depth fished was 42 m. The average minimum depth fished was 13 m and the average maximum depth fished was 18 m. Soak times ranged from ½ to 6 ½ h per net, the mean soak time being 3.0 ± 1.1 h per net.

Fishing practices

Fishers generally deployed all of the nets being carried at the start of a fishing day and this usually took between 1 and 2 h. When the soak time of the first net was between 2 and 3 h fishers commence hauling the gear, usually starting with the first net that was set. For hand hauled nets, the first 3 to 6 nets were usually redeployed once they were cleared of fish. On vessels equipped with a net reel, each net was usually redeployed once the catch had been cleared. If good catches were taken, nets were redeployed in the same general location. Where catches were low, nets tend to be moved to different locations, but still within the same general fishing area. Fishers continue to haul and redeploy all nets in this manner throughout the fishing day. A maximum of 66 individual net deployments in a day were recorded from a vessel where nets were hand hauled and up to 13 net deployments from a vessel equipped with a net reel.

The fishing operation may be interrupted by the presence of fur seals (*Arctocephalus* sp.) around the fishing gear. If seals are seen swimming around the nets or throwing fish in the air (presumably removed from the nets), fishers are forced to alter their mode of operation. Fishers may attempt to minimise the effects of seal interference by reducing soak times, increasing the distance between groups of nets and/or by moving to a different location. Seals were observed either throwing fish in the air or in the vicinity of nets on 14% of fishing days and 4% of all net deployments monitored.

Catch

A total of 10277 fish, representing 53 species, were caught on inshore rocky reefs in east coast Tasmania waters. However, 33 species were represented by less than 10 individuals and 12 were represented by a single individual. Over 95% of the total catch, by both weight and number, was represented by eight species or species groups (*e.g.* the five species of leatherjackets were pooled into a single 'species group'). The percentage contribution of these eight species to the catch in each region is shown in Table 6.1. The total catch by weight in all regions was dominated by three species, banded morwong, marble fish and draughtboard shark, which together comprised over 85% of the catch for Bicheno and over 90% in each of the other three regions. These species also dominated the catch by number, comprising over 80% of the total for each region. The catch of all species, by weight and number, and the effort expended in each region during commercial sampling is presented in Table 6.2 (Appendix A shows the common and scientific names and CSIRO identification codes for all species caught during this study).

Table 6.1. Percentage catch of the eight dominant species in the total catch, by weight and number, in each region

	weight (%)					number (%)				
Region	St. H	Bich	Mar. I	Tas. P	Total	St. H	Bich	Mar. I	Tas. P	Total
Draughtboard shark	6.1	10.7	21.1	19.1	15.0	2.6	5.0	11.0	9.3	7.2
Long snouted boarfish	2.7	5.3	1.5	0.6	2.6	2.8	5.0	2.8	1.2	2.9
Marble fish	9.2	14.8	8.0	28.3	18.0	6.5	10.4	6.7	19.7	12.7
Banded morwong	75.6	61.2	64.5	45.6	57.8	77.8	67.3	68.8	53.8	64.1
Bastard trumpeter	0.5	0.6	0.6	1.5	0.9	1.2	1.1	1.0	3.8	2.1
Blue-throated wrasse	2.2	3.5	1.6	1.1	2.1	2.3	3.2	2.6	2.1	2.6
Purple wrasse	1.1	1.5	0.3	0.8	1.0	2.7	2.6	0.7	2.9	2.4
Leatherjackets	0.7	0.6	0.3	0.1	0.4	1.1	1.3	1.3	0.6	1.0
Others	2.0	1.9	2.1	2.9	2.3	2.9	4.1	5.1	6.5	5.0

Table 6.2. Total catch of each species, by weight and number, and effort monitored during commercial catch sampling of banded morwong fishery for St. Helens (St. H), Bicheno (Bich), Maria Island (Mar. I) and Tasman Peninsula (Tas. P)

	weight (kg)					number				
Region	St. H	Bich	Mar. I	Tas. P	Total	St. H	Bich	Mar. I	Tas. P	Total
Port Jackson shark	8.5	14.0			22.5	1	4			5
Draughtboard shark	135.3	574.8	582.9	1196.6	2489.6	39	165	183	354	741
Skates/Rays		1.0	6.9	8.3	16.2		1	3	3	7
Stingarees	1.5	4.7	8.9	11.8	26.9	5	11	22	22	60
Bearded rock cod			1.9		1.9			2		2
Red cod	0.8	8.0	1.6	3.3	13.7	1	5	1	5	12
Silver dory	2.1	2.7	1.4	1.4	7.6	4	9	5	4	22
Common seadragon				0.1	0.1				1	1
Red gurnard perch	0.1	1.0			1.1	1	1			2
Ruddy gurnard perch			1.5	0.9	2.4			2	1	3
Thetis fish				1.0	1.0				1	1
Red velvet fish	0.5		2.0	1.7	4.2	2		3	3	8
Sand flathead				0.6	0.6				1	1
Butterfly perch	0.3	0.6	0.4	0.3	1.6	2	2	2	1	7
Barber perch			0.7		0.7			2		2
Long finned pike	0.4			0.7	1.1	1			2	3
Jack mackerel		4.6	0.2	8.7	13.5		18	1	34	53
Silver trevally	7.6		5.8	5.5	18.9	5		3	2	10
Common bullseye		6.8	4.5	0.9	12.2		24	19	5	48
Luderick	1.0				1.0	1				1
Sweep	2.0			1.2	3.2	1			1	2
Old wife		0.4			0.4		1			1
Long snouted boarfish	60.3	285.9	41.6	37.0	424.8	42	166	47	47	302
Marble fish	203.1	792.7	221.3	1768.1	2985.2	96	348	111	748	1303
Magpie perch				0.9	0.9				2	2
Grey morwong	6.5				6.5	3				3
Jackass morwong	1.6	35.5	5.7	4.0	46.8	1	31	5	6	43
Dusky morwong				1.4	1.4				1	1
Banded morwong	1668.6	3286.1	1783.2	2852.3	9590.2	1149	2244	1145	2048	6586
Striped trumpeter				30.3	30.3				46	46
Bastard trumpeter	10.3	31.8	16.5	94.6	153.2	17	35	17	146	215
Real bastard trumpeter				3.6	3.6				14	14
Yellow eye mullet				0.5	0.5				2	2
Wrasse sp.	0.8	0.2	0.5	1.5	3.0	1	1	1	3	6
Blue throated wrasse	47.5	188.3	45.4	66.4	347.6	34	107	43	80	264
Purple wrasse	23.7	79.9	7.3	52.5	163.4	40	87	12	111	250
Rosy wrasse		0.5		2.1	2.6		2		6	8
Herring cale	11.0	14.3	8.2	11.0	44.5	13	18	9	15	55
Common stargazer			3.4		3.4			1		1
Weedfish sp.				0.7	0.7				1	1
Blue warehou		0.9	3.5	55.7	60.1		3	3	42	48
Leatherjackets	14.5	30.6	9.5	9.3	63.9	16	44	21	24	105
Shaw's cowfish	0.2	0.2	0.3	3.2	3.9	1	1	1	12	15
Globefish		1.0			1.0		1			1
Octopus sp.				14.0	14.0				3	3
Crabs sp.		0.4		0.6	1.0		2		3	5
Southern rock lobster		2.9		3.4	6.3		1		5	6
Total	2208.2	5369.8	2765.1	6256.1	16599.2	1476	3332	1664	3805	10277
Effort (100 m net h)	464.0	1675.2	989.0	1829.4	4957.5	464.0	1675.2	989.0	1829.4	4957.5

CPUE

Table 6.3. summarises the catch of banded morwong and effort monitored during commercial catch sampling in each region, by season. In general, CPUE was highest in the autumn spawning season (closed season) and lowest during winter (Fig 6.1). In each of the areas, apart from the Tasman Peninsula, this seasonality was quite pronounced. In the Tasman Peninsula, catch rates were consistently low in relation to other areas and varied little between seasons (generally between 1.00 and 1.75 kg/100 m net h)

The total CPUE of banded morwong by weight, for all regions and seasons, was 1.93 kg/100 m net h, ranging between 0.74 and 7.98 kg/100 m net h for seasonal samples by region. By number, total CPUE was 1.33 fish per 100 m net h, ranging between 0.50 and 4.72 per 100 m net h for seasonal samples by region. The total CPUE by weight during the normal fishing season (non-spawning period) was 1.54 kg/100 m net h, ranging from 0.74 to 3.39 kg/100 m net h for seasonal samples by region. CPUE of weight retained during the normal fishing season was 0.91 kg/100 m net h, ranging from 0.47 to 2.03 kg/100 m net h for seasonal samples by region.

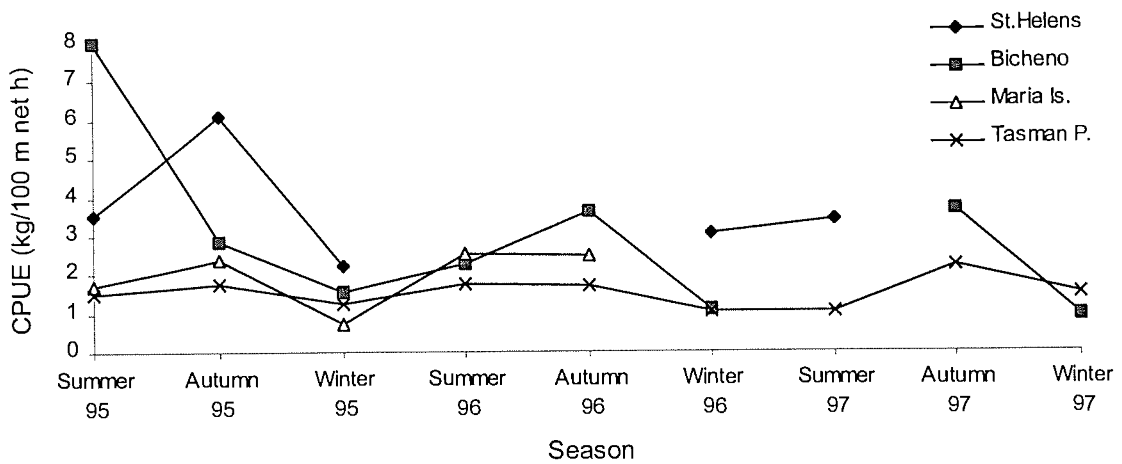


Fig. 6.1. Mean CPUE (kg per 100 net h) of banded morwong by region and season

Table 6.3. Summary of catch, effort, CPUE and fishing practices from the commercial banded morwong fishery, Dec 94 - Nov 97. (* is charter fishing)

Season	Region	number captured (n)	weight captured (kg)	weight retained (kg)	effort (100 m net h)	CPUE (n/100 m net h)	CPUE (kg/100 m net h)	CPUE retained (kg/100 m net h)	average depth (m)	minimum depth (m)	maximum depth (m)	average mesh size (mm)
Summer 95	St.Helens	208	313.9	*	89.9	2.31	3.49	*	13	5	20	132
	Bicheno	172	286.8	*	36.5	4.72	7.98	*	19	10	41	140
	Maria Is	301	479.4	*	279.1	1.08	1.72	*	17	4	25	133
	Tasman P.	416	621.4	*	418.1	1.00	1.49	*	15	4	32	132
Autumn 95	St.Helens	320	457.2	*	75.0	4.27	6.10	*	17	5	35	135
	Bicheno	161	215.2	*	76.3	2.11	2.82	*	17	12	26	133
	Maria Is.	317	475.7	*	198.5	1.60	2.40	*	19	7	42	133
	Tasman P.	154	203.4	*	115.9	1.33	1.75	*	16	4	40	133
Winter 95	St.Helens	108	150.9	97.1	68.4	1.58	2.21	1.42	15	7	24	136
	Bicheno	418	584.1	352.5	382.9	1.09	1.53	0.92	22	12	32	135
	Maria Is.	128	191.5	124.4	258.0	0.50	0.74	0.48	20	10	32	133
	Tasman P.	209	290.4	189.4	235.0	0.89	1.24	0.81	12	3	30	136
Summer 96	Bicheno	329	452.6	253.9	197.6	1.67	2.29	1.29	13	6	20	133
	Maria Is.	195	330.9	160.6	130.8	1.49	2.53	1.23	19	10	27	133
	Tasman P.	257	359.8	213.7	206.0	1.25	1.75	1.04	18	5	35	134
Autumn 96	Bicheno	424	668.7	*	185.0	2.29	3.61	*	17	4	32	139
	Maria Is.	204	305.7	*	122.6	1.66	2.49	*	14	5	28	133
	Tasman P.	373	523.1	*	305.7	1.22	1.71	*	13	4	25	137
Winter 96	St.Helens	195	291.4	165.3	96.6	2.02	3.02	1.71	11	2	25	136
	Bicheno	138	223.5	97.8	209.6	0.66	1.07	0.47	14	6	22	140
	Tasman P.	27	34.9	21.7	33.5	0.81	1.04	0.65	14	10	20	136
Summer 97	St.Helens	318	455.2	272.2	134.1	2.37	3.39	2.03	12	2	22	139
	Tasman P.	73	92.2	54.7	88.9	0.82	1.04	0.62	14	4	25	138
Autumn 97	Bicheno	267	419.8	*	114.1	2.34	3.68	*	17	10	20	140
	Tasman P.	219	290.0	*	132.0	1.66	2.20	*	15	5	28	140
Winter 97	Bicheno	335	435.4	261.1	473.3	0.71	0.92	0.55	21	10	31	136
	Tasman P.	320	437.1	291.1	294.1	1.09	1.49	0.99	11	2	28	140

Size composition

The length frequency distributions, pooled over all regions, were similar for the three years of the study (1995 - 97), being right skewed with a dominant mode at approximately 37 - 41 cm and a mean length of approximately 41 cm (Fig. 6.2). Fish within the legal size range constituted between 67 and 70% of the numbers in each year. Between 5 and 7% of the catch were below the legal minimum size (*i.e.* < 33 cm) and 23 to 28% were above the legal maximum size (*i.e.* > 43 cm). There was no obvious change in the proportion of under and/or over sized fish in the samples over time.

Length frequency distributions for each of the four fishing regions varied slightly but all had the dominant mode within the 37 - 41 cm range (Fig. 6.3). Mean lengths ranged between 39.9 cm for the Tasman Peninsula region and 41.6 cm for Maria Island and were generally consistent within each region for each year sampled (Fig. 6.4). In addition to the dominant mode, a secondary mode was observed at approximately 41 - 43cm for Bicheno and at 46 - 51 cm in the other regions in some years (*e.g.* St. Helens all years, Maria Is. in 1996, Tasman Peninsula 1996 and 1997). The overall frequency distribution within a region was also relatively consistent between years. The proportion of fish within the legal size in each region was very similar (*i.e.* 67 - 70%) though the proportion of under and over sized fish varied between regions. For instance, in each of the years 7 - 10% of fish were below 33 cm and 18 - 23% were over 43 cm for the Tasman Peninsula. This compares with just 2 - 5% and 24 - 31%, respectively, for the other three regions. This is, in part, reflected in the slightly smaller mean size of banded morwong from the Tasman Peninsula.

Spatial and temporal variability in length frequency distributions is apparent from the seasonal samples from each region (Fig. 6.5 to 6.8). There is no consistent pattern among regional and seasonal length frequency distributions over time, but in some instances the distributions are based on relatively small sample sizes. The observed variability is partially explained if sexed length frequency distributions are considered (Fig. 6.9 to 6.11). Banded morwong show distinct size structuring by sex. Males attain larger sizes than females, the largest male from the sexed samples was 55 cm, 4 cm larger than the biggest female. In fact our data indicate that very few females attain sizes larger than 45 cm. Despite this, there were significantly more females than males in the overall sexed catch (fish ≥ 33 cm FL) ($\chi 2$ analysis, $P < 0.001$). There were significantly more females in the autumn 1996 and autumn 1997 samples from Bicheno and the autumn and winter 1997 samples from the Tasman Peninsula ($P < 0.01$). However, sex ratios were not significantly different from 0.5 ($P > 0.05$) for the other samples where sex was determined. The proportion of female banded morwong in seasonal catches varied from 0.51 to 0.79 depending on the region. Within the legal size range of 33 to 43 cm

FL, the sex ratios were significantly different from 0.5 in all seasonal samples in each region ($P < 0.001$). The proportion of females within this size ranged from 0.63 to 0.86, with an overall proportion of 0.75. Therefore, the commercial catch of banded morwong is predominantly female. The 37 - 43 cm mode seen in commercial catches is dominated by females whereas the secondary mode at 46 - 51 cm is comprised almost entirely of males.

Examination of the length frequency data by 1/8 degree fishing blocks reveals some distinct differences in the size structure, indicating structuring at a small spatial scale (Fig. 6.12). This is particularly evident for the fishing blocks 5H3C and 5H3G (St. Patricks Head area), and 5H3K and 5H3O (Bicheno Town area), which together comprise the Bicheno region of the original sampling design. Similarly, heterogeneity is apparent when fishing blocks, 6G4P and 7G2D (Eagle Hawk area), 7H1E and 7G2H (Cape Pillar area), and 7G2G, 7G2F, 7G2B and 7G2A (Nubeena area), which together comprise the Tasman Peninsula region, are treated separately (Fig 6.13). The St. Patricks Head area shows bi-modality in the size structure with a distinct trough at approximately 40 - 42 cm whereas the Bicheno Town area has a smoother distribution with a peak at 41 - 43cm. These characteristic distributions within the larger Bicheno region were apparent in each of the three years sampled (Fig. 6.14). Distinct differences could be seen between the three areas comprising the Tasman Peninsula region, pooled by year, but the distributions by year for each area were not as distinct or consistent as that seen for the Bicheno region. However, in some instances sample sizes are small and may not be representative (Fig 6.15).

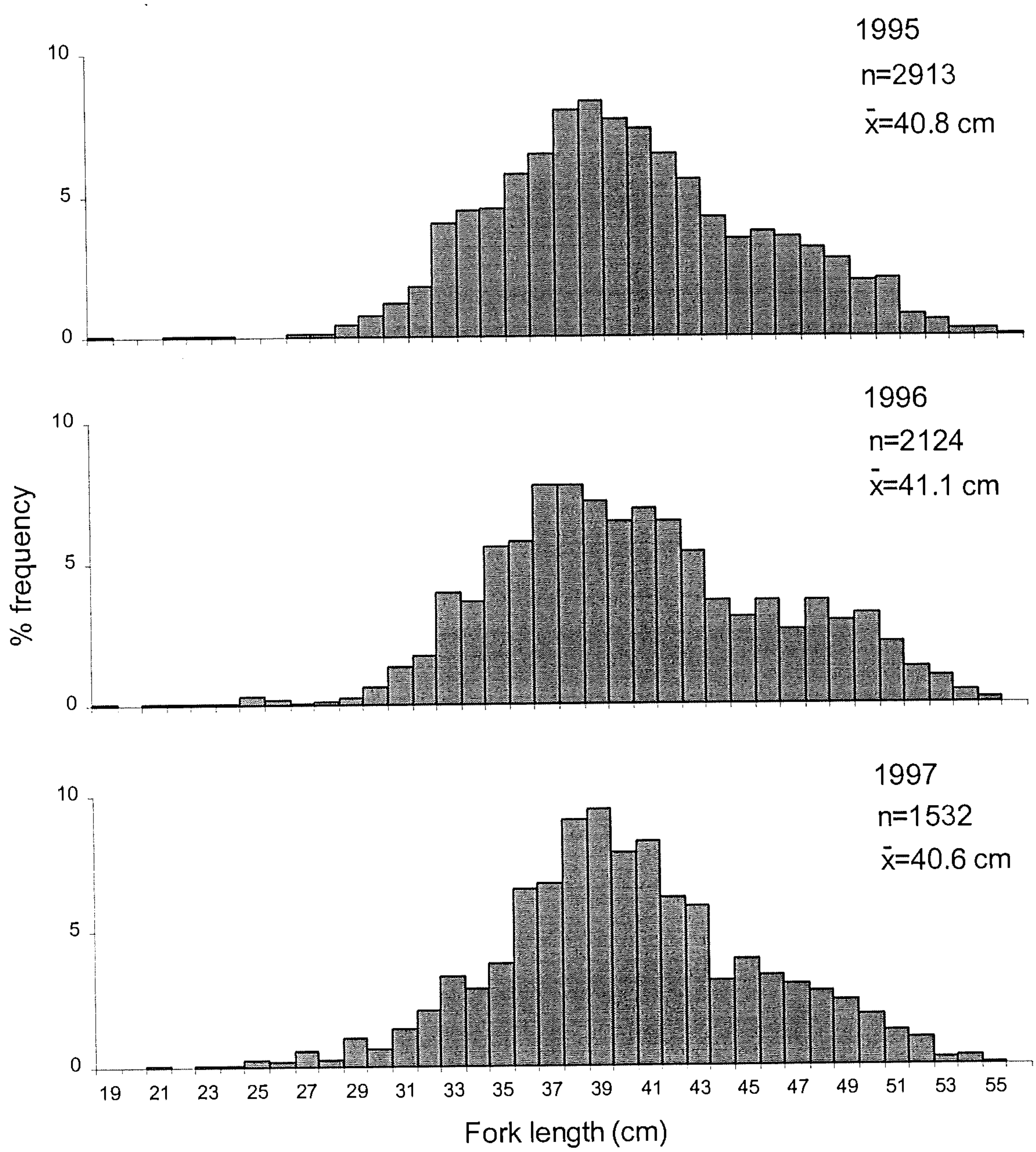


Fig. 6.2. Length frequency of banded morwong from east coast Tasmania by year, pooled by region (n=sample size, x=mean length)

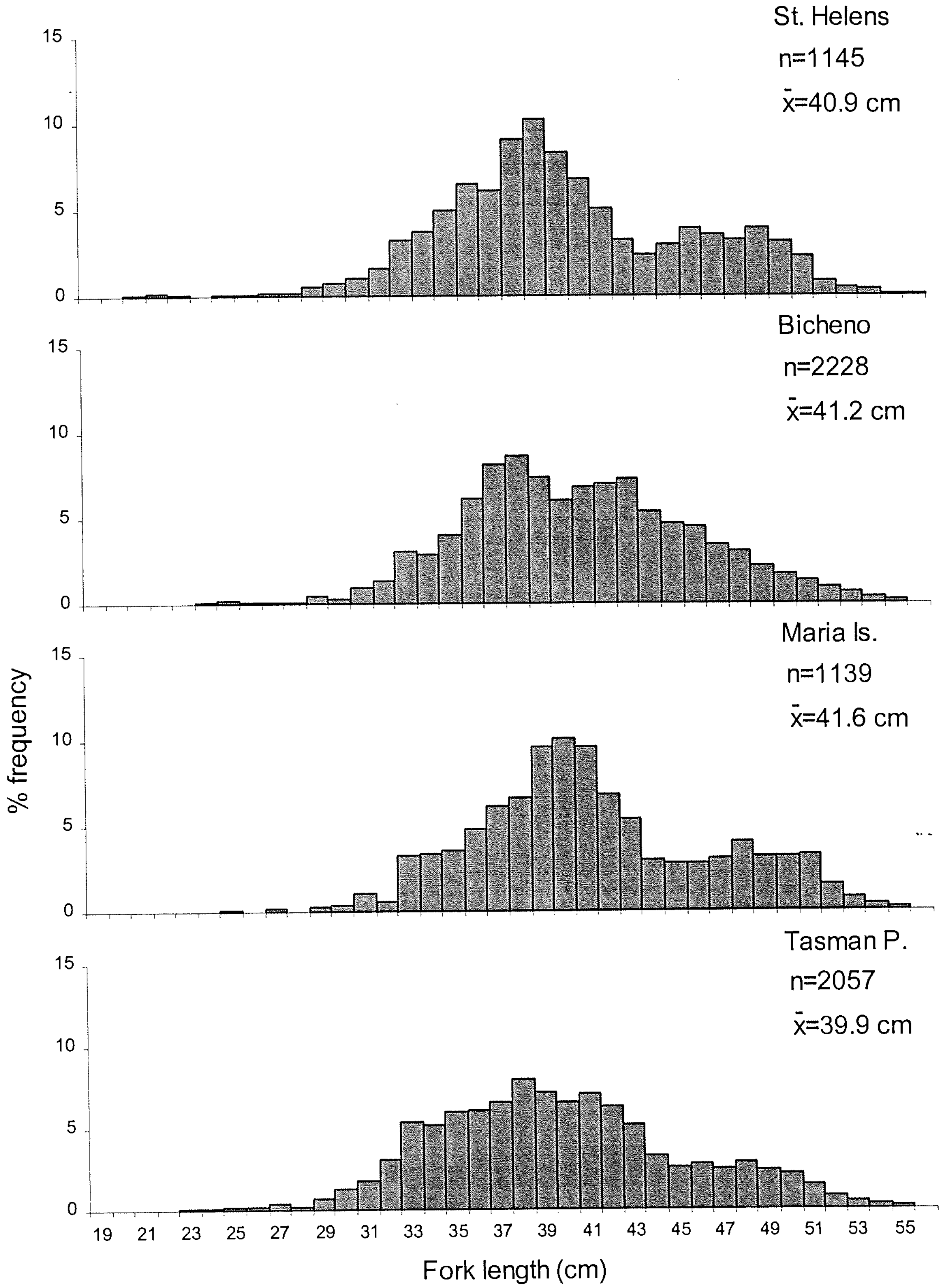


Fig. 6.3. Length frequency of banded morwong by region, pooled by year

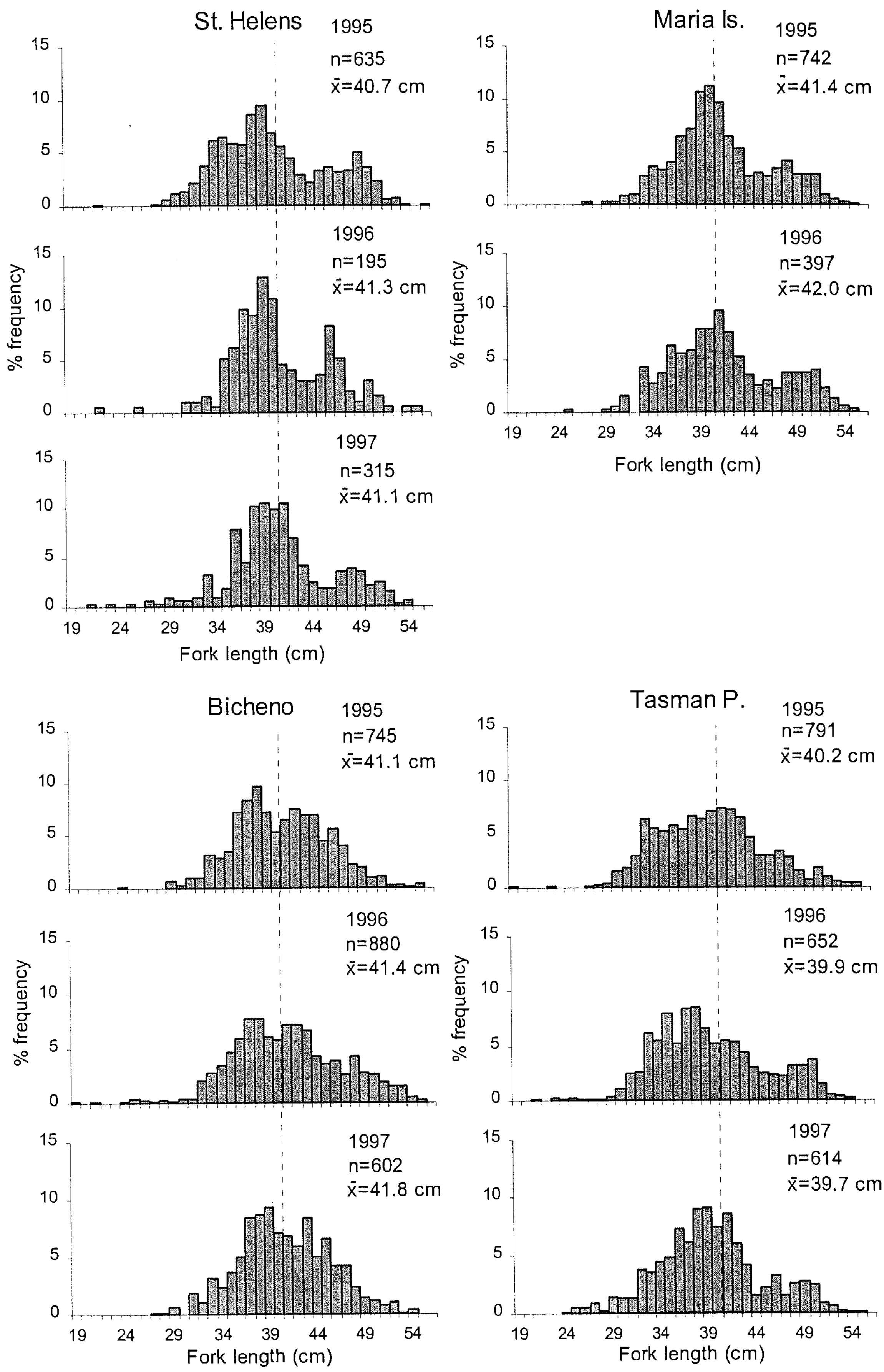


Fig. 6.4. Length frequency of banded morwong by region and year (The broken reference line is to aid visual interpretation of the figure and marks the point between 40 and 41 cm FL)

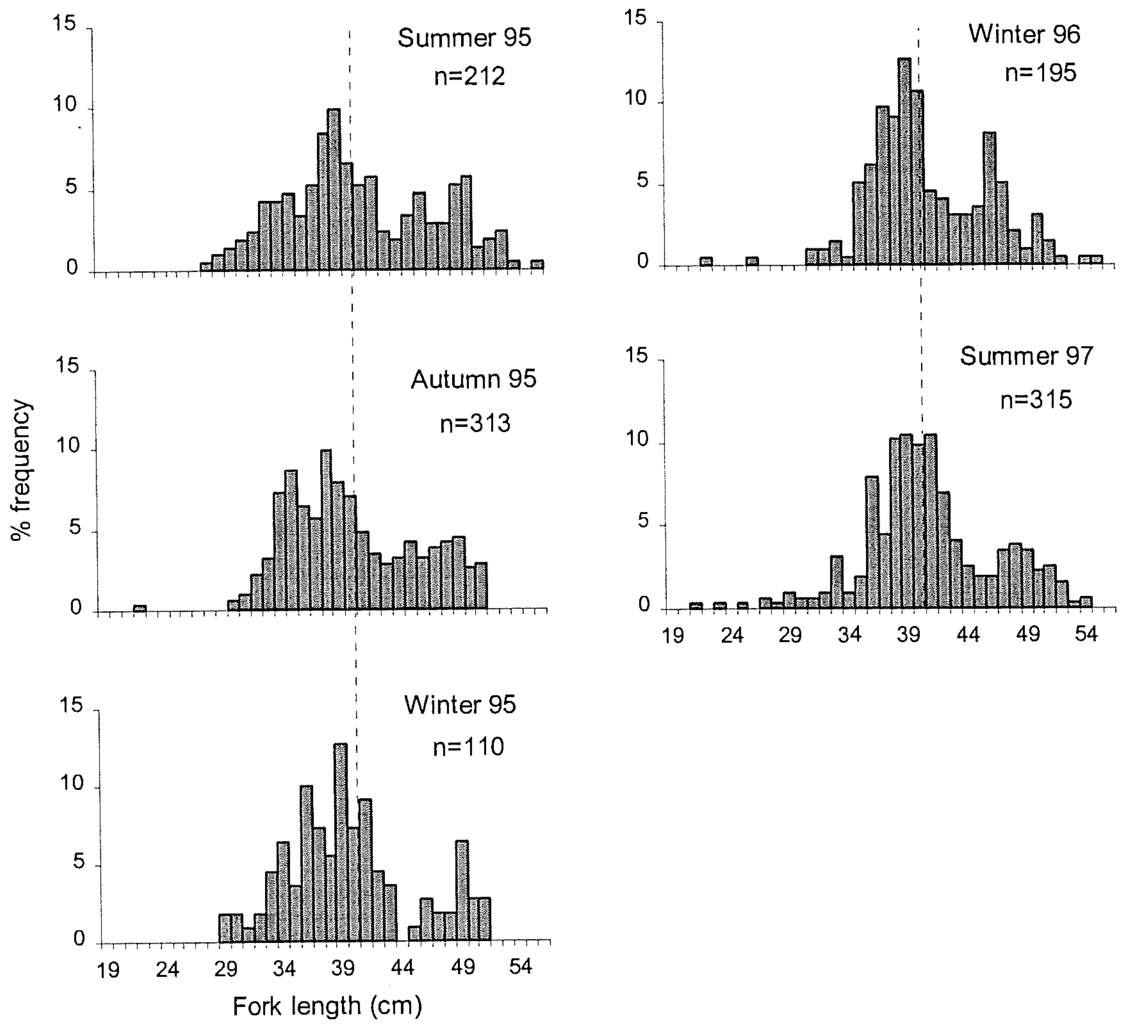


Fig. 6.5. Length frequency of banded morwong from St. Helens by season

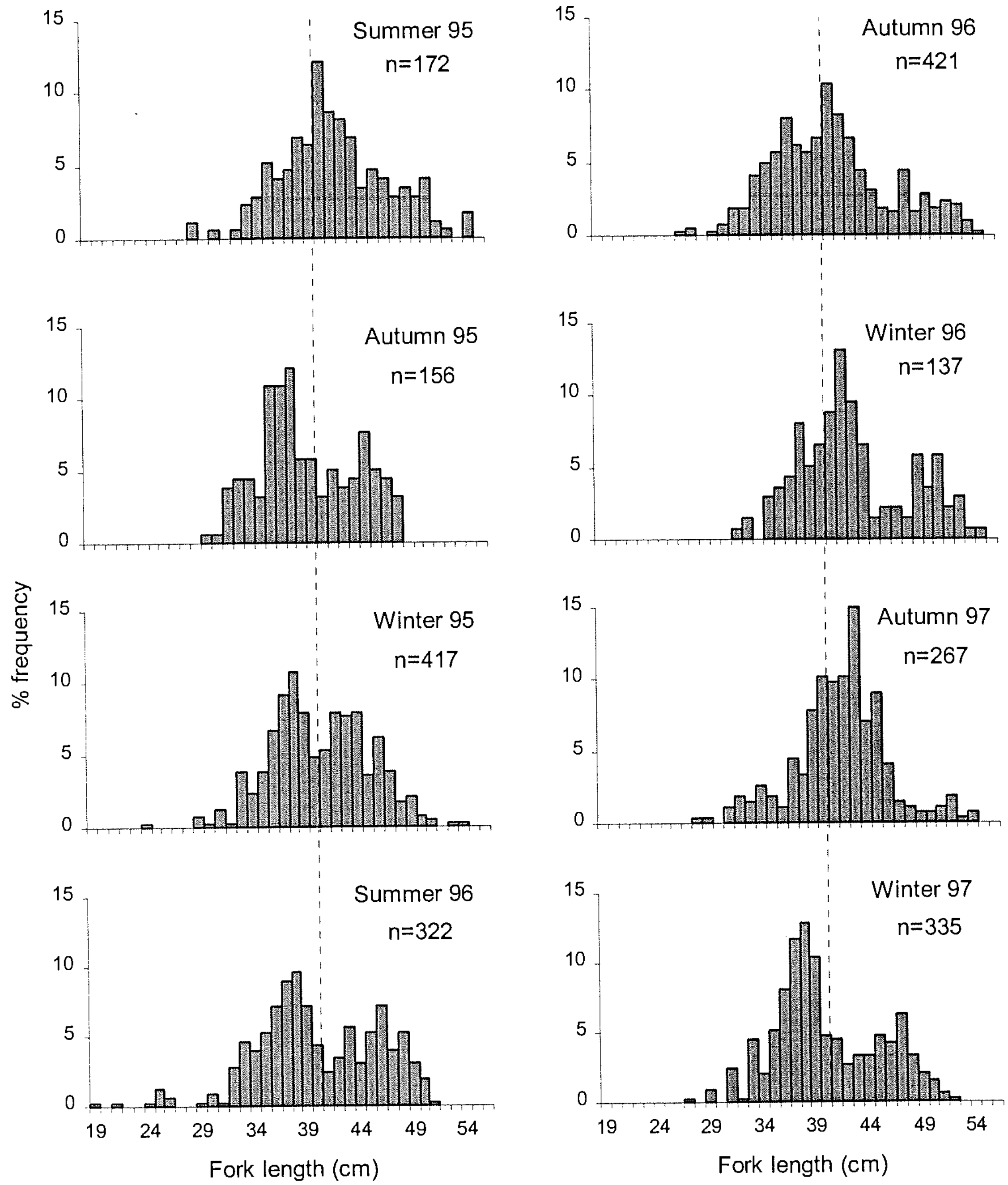


Fig. 6.6. Length frequency of banded morwong from Bicheno by season

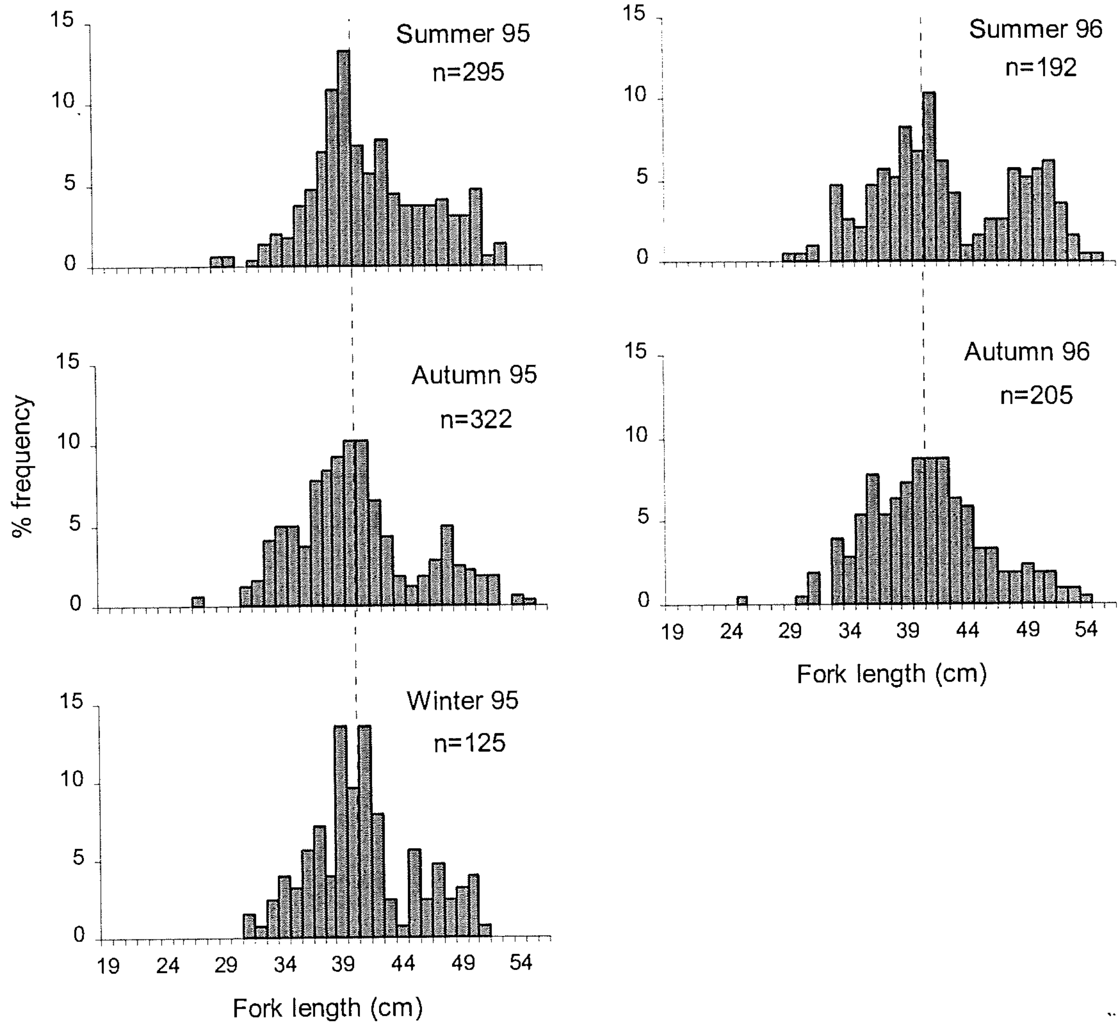


Fig. 6.7. Length frequency of banded morwong from Maria Island by season

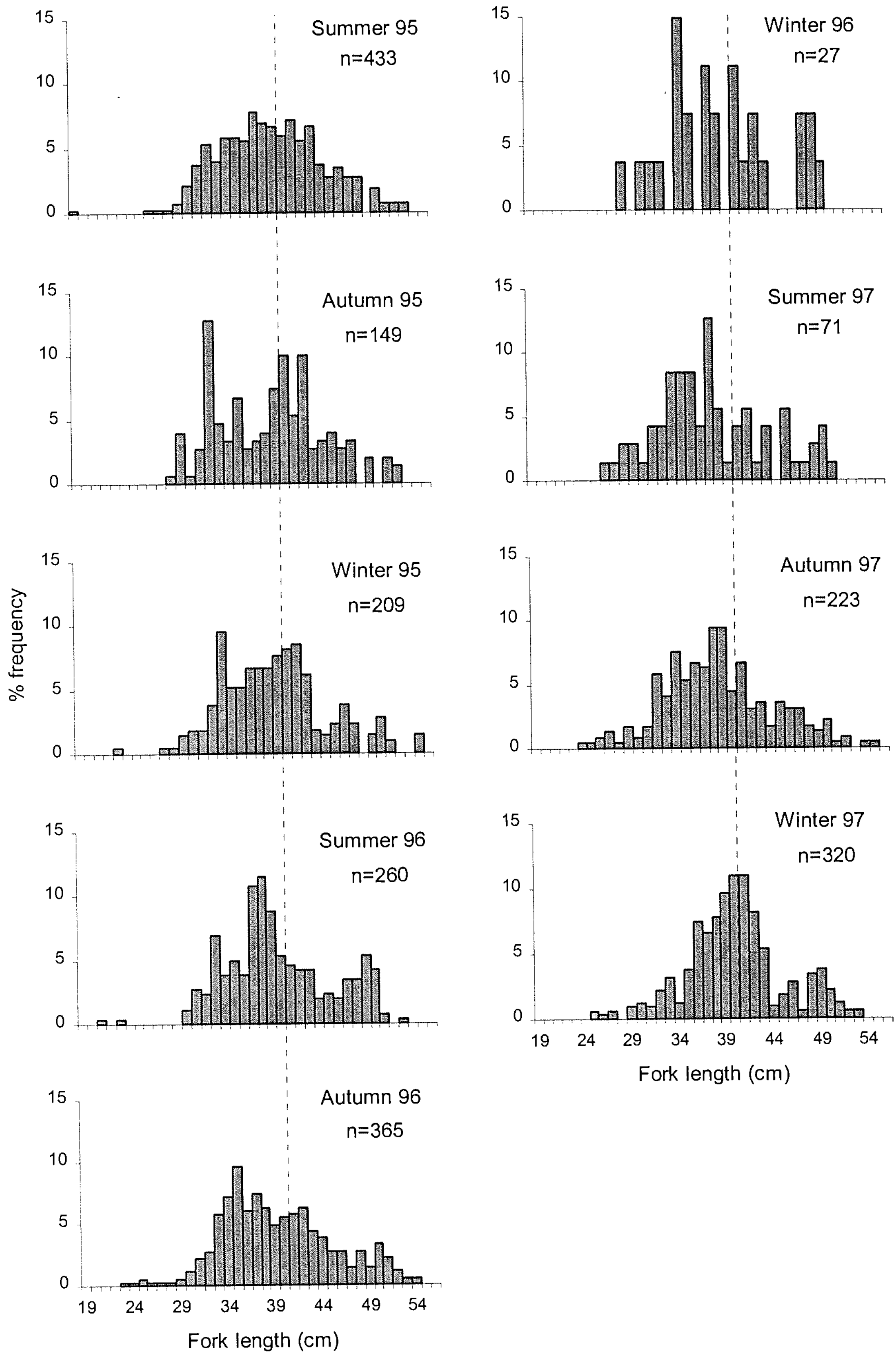


Fig. 6.8. Length frequency of banded morwong from Tasman Peninsula by season

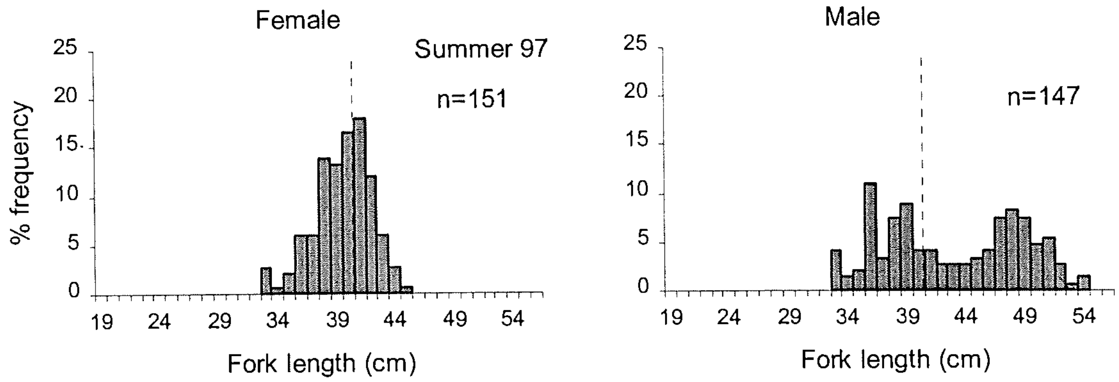


Fig. 6.9. Length frequency of banded morwong from St. Helens by sex, Summer 97

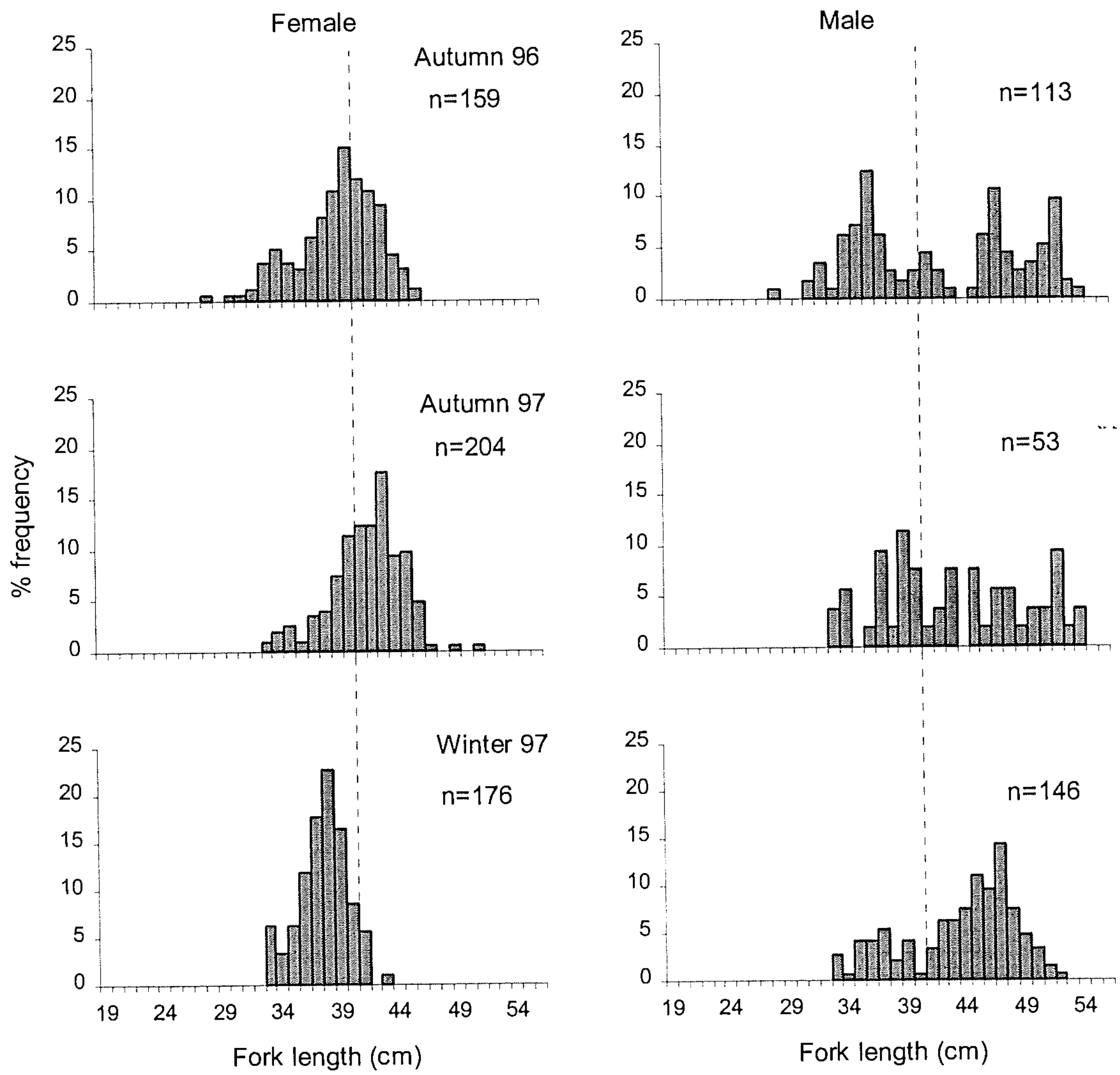


Fig. 6.10. Length frequency of banded morwong from Bicheno by sex and season
(Note that Autumn 96 sample was sexed in the laboratory, therefore fish < 33 cm FL are represented)

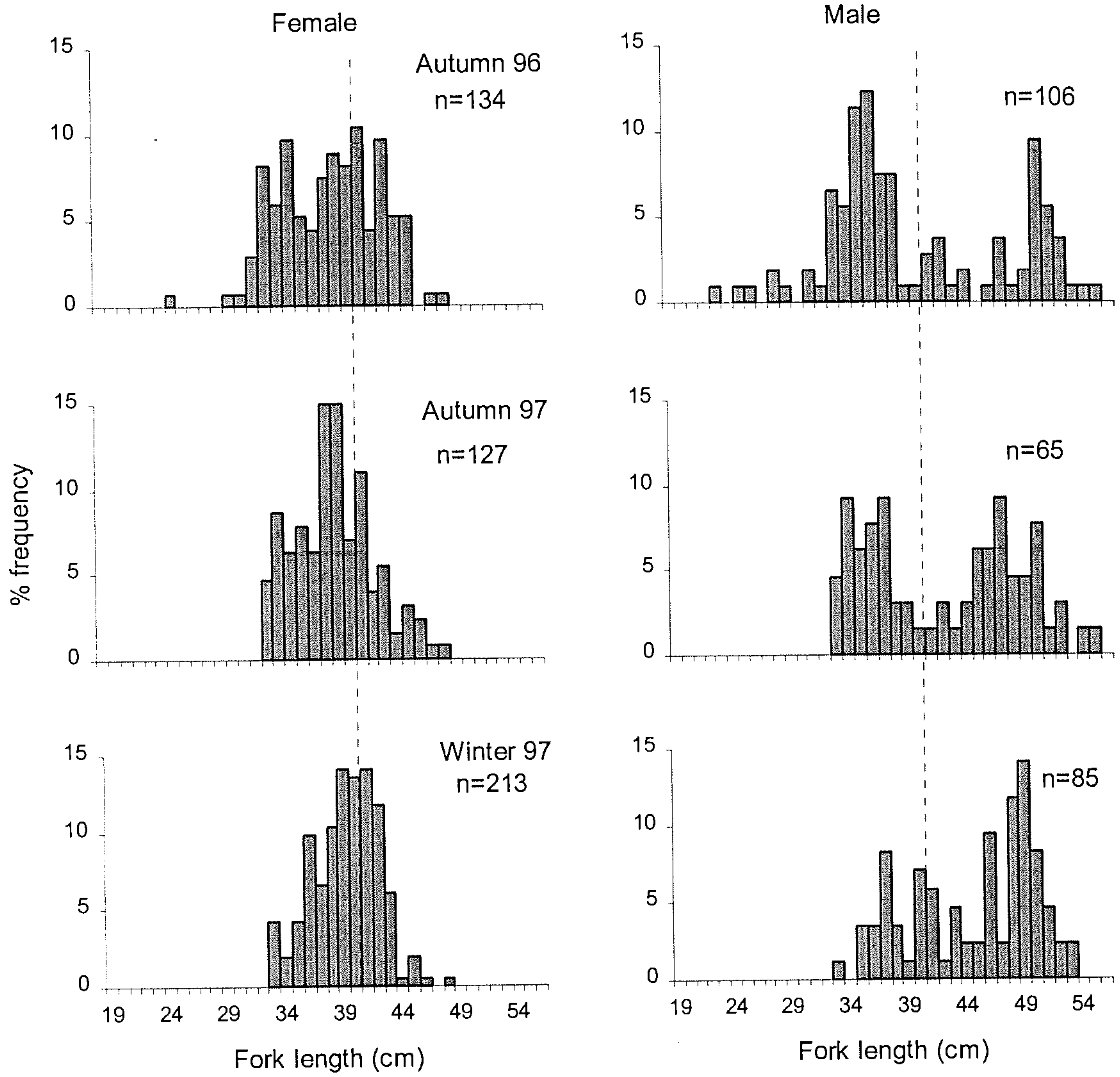


Fig. 6.11. Length frequency of banded morwong from Tasman Peninsula by sex and season (Note that Autumn 96 sample was sexed in the laboratory, therefore fish < 33 cm FL are represented)

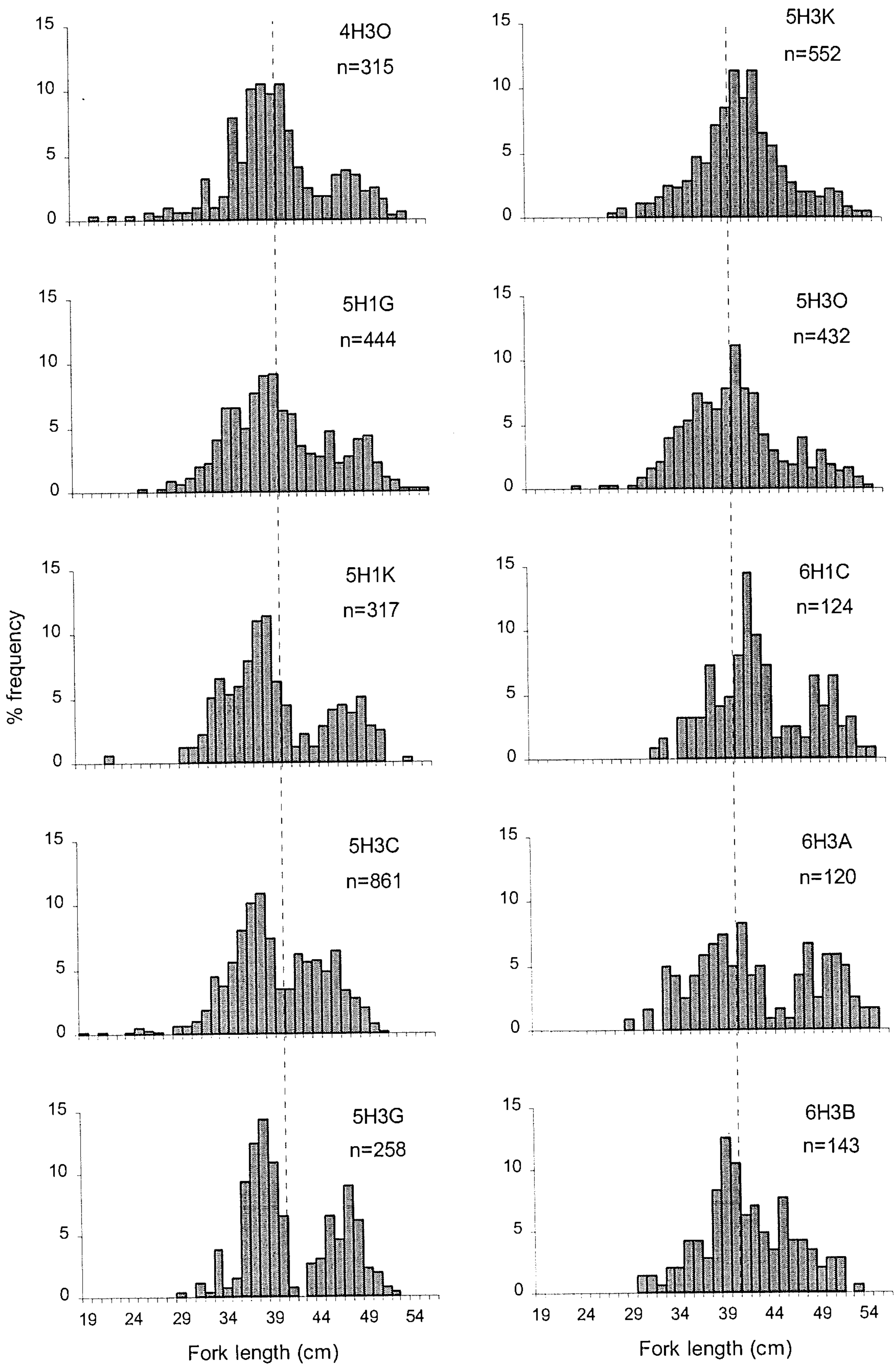


Fig. 6.12. Length frequency of banded morwong by 1/8 degree fishing block (blocks arranged from top to bottom and left to right represent blocks running North to South on the east coast of Tasmania)

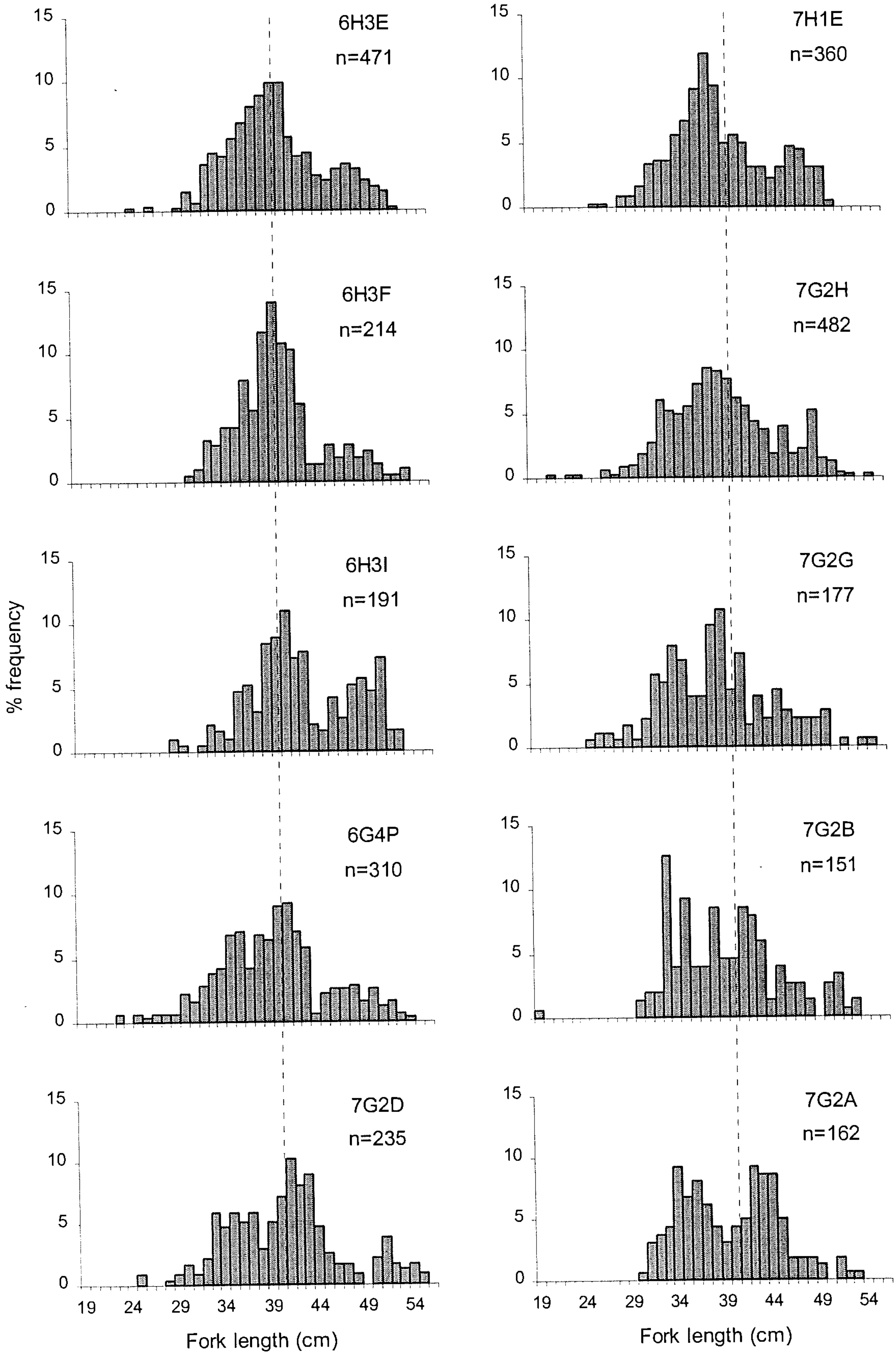


Fig. 6.12 (continued) Length frequency of banded morwong by 1/8 degree fishing block (blocks arranged from top to bottom and left to right represent blocks running North to South on the east coast of Tasmania)

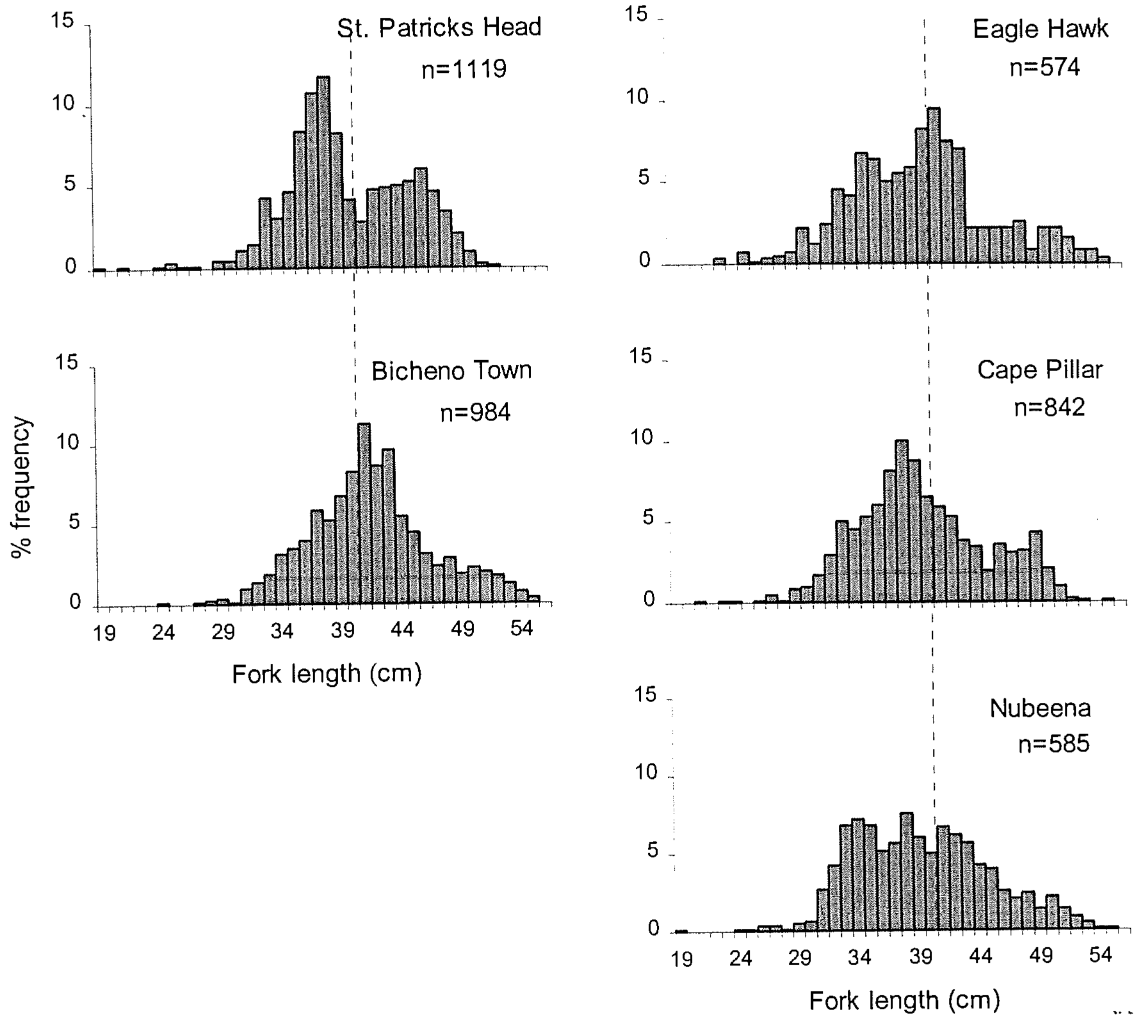


Fig. 6.13. Length frequency of banded morwong for five areas; St. Patricks Head (5H3C and 5H3G); Bicheno Town (5H3K and 5H3O); Eagle Hawk (6G4P and 7G2D); Cape Pillar (7H1E and 7G2H); and Nubeena (7G2G, 7G2F, 7G2B and 7G2A)

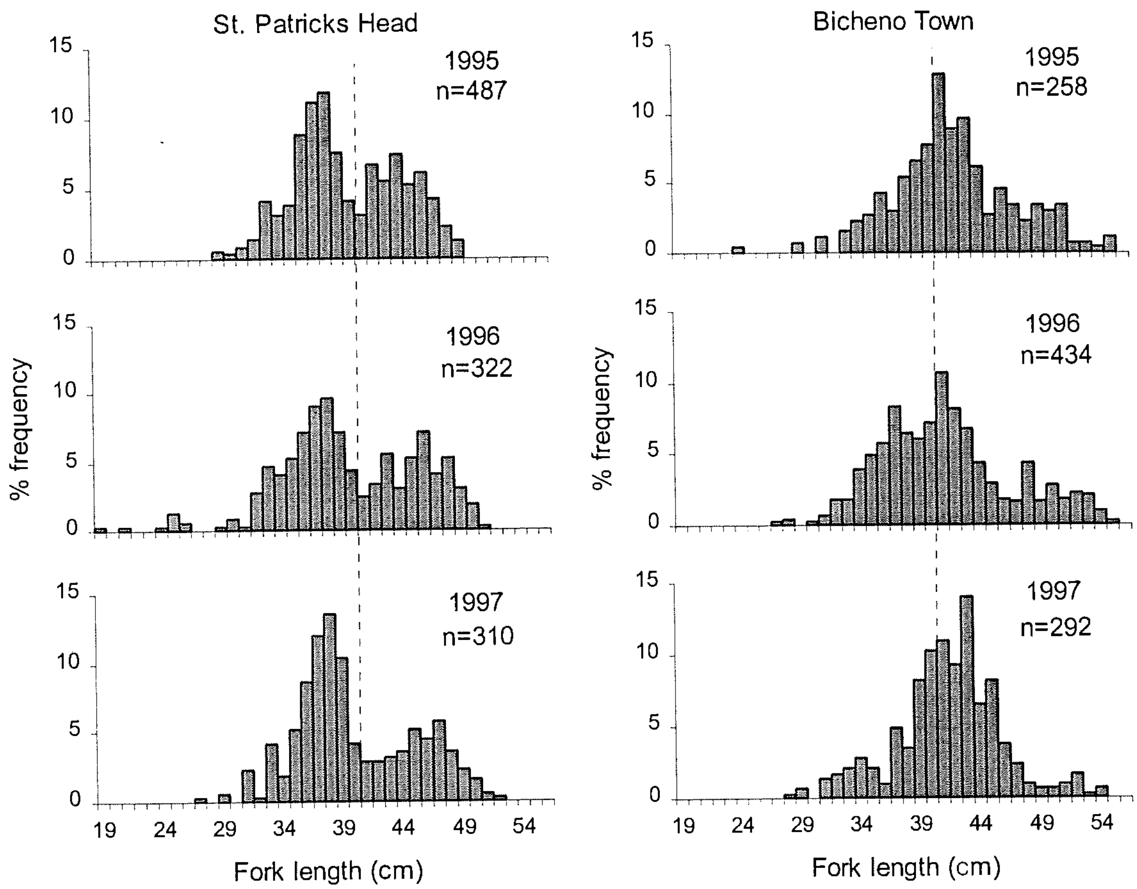


Fig. 6.14. Length frequency of banded morwong for St. Patricks Head and Bicheno Town by year.

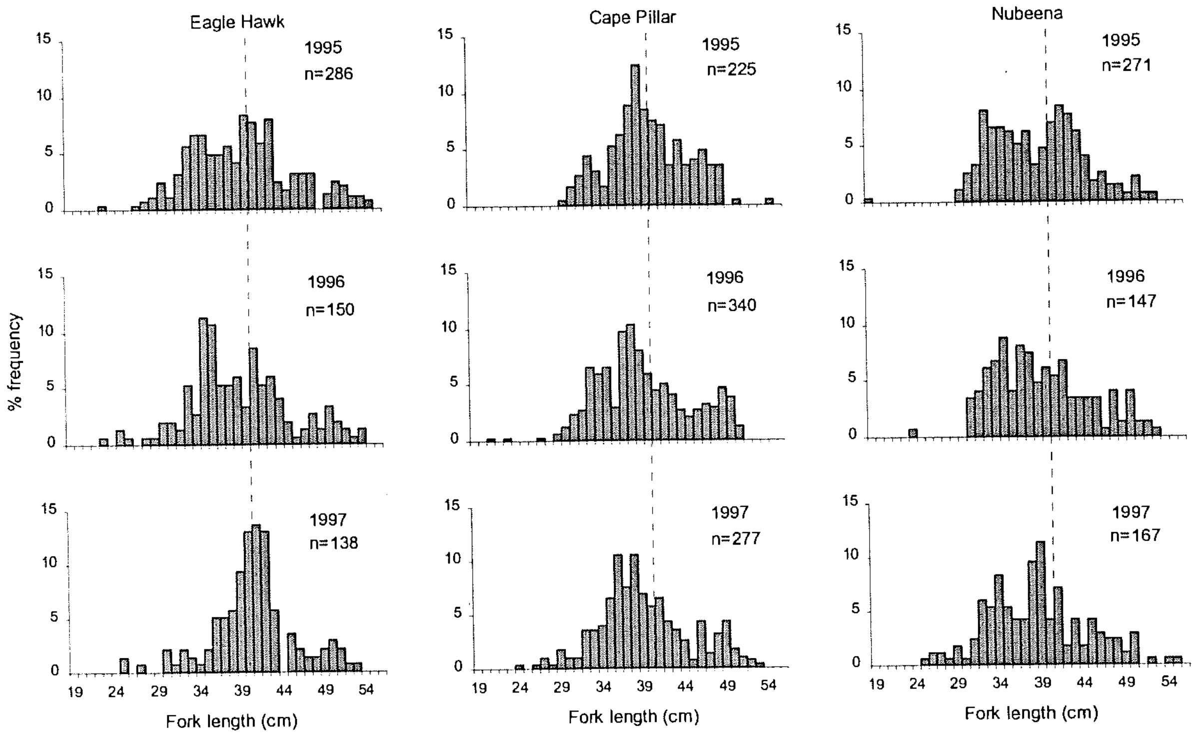


Fig. 6.15. Length frequency of banded morwong for Eagle Hawk, Cape Pillar and Nubeena by year

6.2 Mesh selectivity

Effort

Gillnets of five different mesh sizes were set on rocky reefs at 219 stations around the coastline of the Tasman Peninsula and North Bruny Island, representing 1095 individual net deployments. In the shallow, medium and deep depth strata, 80, 82 and 57 stations were deployed, respectively. Set times ranged between 1 and 7 h with the average fishing time being 3.3 ± 0.9 h. Effort for each mesh size, by season and depth strata, is shown in Table 6.4.

Catch

In the mesh selectivity trials, a total of 46 fish species were caught in depths between 2 and 28 m. However, 15 of these species were represented by a single individual. Species diversity

Table 6.4. Effort (100 m net h) for each mesh size by season and depth strata. The number of stations (*n*) deployed in each season in each depth strata is shown in italics

Depth strata	Mesh size (mm)	Season 'Winter' 95	Summer 96	Autumn 96	'Winter' 96	Summer 97	Autumn 97	Total
Shallow (0 - 9 m)	*n*	*23*	*18*	*12*	*11*	*6*	*10*	*80*
	89	18.8	16.5	9.9	13.2	7.0	9.0	74.5
	105	19.1	17.6	10.5	13.8	7.3	9.6	78.0
	114	19.3	17.1	10.4	13.0	7.2	8.9	75.9
	130	20.0	17.7	10.9	13.9	7.5	9.5	79.5
	133	21.1	18.5	11.4	14.9	7.8	9.9	83.5
	Total	98.3	87.3	53.1	68.9	36.8	46.9	391.3
Medium (10 - 19 m)	*n*	*20*	*23*	*12*	*11*	*7*	*9*	*82*
	89	15.4	20.9	10.4	12.4	7.4	7.9	74.4
	105	17.0	22.3	10.8	12.9	7.7	8.2	78.8
	114	16.2	21.5	10.5	12.7	7.6	8.2	76.8
	130	17.2	22.7	11.1	13.3	7.9	8.3	80.6
	133	18.4	24.4	11.6	14.2	8.4	9.0	86.1
	Total	84.2	111.8	54.5	65.5	39.0	41.6	396.6
Deep (20 - 29 m)	*n*	*4*	*20*	*7*	*13*	*7*	*10*	*57*
	89	3.3	15.8	6.8	13.4	7.2	8.4	54.9
	105	3.0	16.9	7.4	13.2	7.9	9.0	57.3
	114	2.9	15.6	7.1	13.9	7.5	8.5	55.6
	130	3.6	16.7	6.5	14.7	6.7	9.0	57.3
	133	3.8	17.1	9.0	15.6	9.5	9.4	64.5
	Total	16.6	82.1	36.8	70.9	38.8	44.3	289.5
Total	*n*	*47*	*61*	*31*	*35*	*20*	*29*	*219*
	Total	199.1	281.2	144.4	205.3	114.6	132.8	1077.4

tended to decrease with increasing mesh size, the 89 mm net catching almost twice the number of species as the two largest mesh sizes. The 89 mm mesh had the highest number of exclusive species, more than double the number for any of the larger mesh sizes (Table 6.5). These exclusive species were generally the smaller reef fish, such as barber perch (*Caesioperca rasor*), real bastard trumpeter (*Mendosoma lineatum*), silverbelly (*Parequula melbournensis*) and senator wrasse (*Pictilabrus laticlavius*) (Table 6.6) that pass through the larger sized meshes.

The total catch of each species, by weight and number, and effort expended for each mesh size during the selectivity study is presented in Table 6.6. For mesh sizes between 89 and 130 mm, the total CPUE, by weight and number, decreased as mesh size increased. CPUE in the 133 mm mesh was higher than in the 130 mm mesh, but lower than for the other mesh sizes. Higher catches of banded morwong and draughtboard shark caught in the 133 mm mesh accounted for the slightly increased CPUE.

In each of the mesh sizes trialed the same 10 species (the six species of leatherjacket were pooled into a single species group) accounted for over 93% of the total catch, by weight and number. The contribution of these 10 species, by weight and number, to the catch for each mesh size is presented in Table 6.7. The three commercial species, banded morwong, striped trumpeter and bastard trumpeter, and one non-commercial species, marble fish, clearly dominated the catch in all mesh sizes.

CPUE

As expected, the catch of each species in the research gillnets was characterised by large numbers of zero catches, a medium number of catches where one or two individuals were captured per net and a small number of nets in which the catch was relatively large. This is largely a result of the patchy distribution and/or schooling behaviour of the rocky reef species and their behaviour in relation to the passive fishing gear. As a consequence, standard

Table 6.5. Total number of fish species recorded for each mesh size, the number of species represented by a single individual and the number of species exclusive to each mesh size

Mesh size (mm)	No. species	Single individuals of a species	No. of species exclusive
89	31	9	8
105	25	9	3
114	26	5	2
130	17	7	3
133	17	7	2
Total	46	15	

Table 6.6. Total catch of each species, by weight and number, and effort in each mesh size

	weight (kg)					number				
Mesh size (mm)	89	105	114	130	133	89	105	114	130	133
Draughtboard shark	19.2	38.0	106.0	22.6	176.3	5	10	30	7	51
Orange spotted catshark		1.7					1			
White spotted dogfish		4.5					1			
Southern conger eel	3.1					1				
Red cod	14.0	9.1	7.9	3.5	1.1	18	9	6	2	1
Silver dory	1.3	0.7	1.3	0.3	0.2	11	4	4	1	1
Common seadragon				0.1					1	
Red gurnard perch	0.5		1.9		1.3	2		2		1
Ruddy gurnard perch		0.5			0.9		1			1
Sand flathead			0.8		0.5			2		1
Butterfly perch	1.4	0.5				5	1			
Barber perch	3.6					12				
Jack mackerel	0.6		0.2		0.5	1		1		2
Silverbelly	0.2					2				
Red mullet	0.3					1				
Common bullseye	1.1		0.6			4		2		
Silver drummer				3.0					1	
Old wife	0.3					1				
Long snouted boarfish		1.6		0.9	4.7		3		1	6
Marble fish	320.3	463.5	452.9	329.0	274.7	175	251	234	145	113
Magpie perch	0.7	0.5				2	1			
Jackass morwong	12.6	7.9	1.6			37	17	3		
Banded morwong	58.7	101.9	158.8	108.5	316.5	54	85	134	81	210
Striped trumpeter	258.9	153.4	62.5	2.3		396	196	74	3	
Bastard trumpeter	189.4	124.3	69.4	15.7	7.4	407	210	93	18	10
Real bastard trumpeter	1.6					4				
Blue throated wrasse	81.8	28.8	17.9	3.4		146	30	16	3	
Senator wrasse	0.2					1				
Purple wrasse	101.2	23.3	8.3	0.5	2.2	197	35	14	1	5
Rosy wrasse			0.3					1		
Herring cale	23.5	1.1	0.7			26	1	1		
Common stargazer			1.5					1		
Crested weedfish	0.3					1				
Blue warehou	22.4	32.9	19.5	3.6		37	34	16	5	
Leatherjackets	22.3	12.2	4.2	0.7	0.8	70	31	9	1	1
Shaw's cowfish		0.1	0.4	0.1			1	2	1	
Globe fish					1.5					1
Octopus		5.0	8.8		6.0		1	3		2
Blacklip abalone		0.4					1			
Crabs	0.5	0.3	0.4	0.9	0.5	3	2	2	3	2
Southern rock lobster	0.6	3.1	2.1	3.4	1.0	1	4	3	4	2
Total	1140	1025	928	498	796	1620	935	653	278	410
Effort (100 m net h)	203.8	214.0	208.2	217.3	234.1	203.8	214.0	208.2	217.3	234.1
CPUE (per 100 m net h)	5.59	4.79	4.46	2.29	3.40	7.95	4.37	3.14	1.28	1.75

deviation (and standard error) of CPUE was always relatively large. Fig. 6.16 to 6.19 show CPUE, by weight and number, by mesh size and season for the four major species captured. Error bars have been omitted from graphical representation of CPUE since they do not aid in discerning trends.

Analysis of variance of CPUE and mean length

Analysis of variance was used to test for the effects of mesh size, depth and season on CPUE and mean fork length of banded morwong, striped trumpeter, bastard trumpeter and marble fish. In order to satisfy the assumptions of ANOVA, that the data is normally distributed and that variances are heterogeneous, it was necessary to log transform CPUE [ln(CPUE+1)]. Length data satisfied the assumptions of ANOVA and transformation was not required.

The results of ANOVA for the four species are given in Table 6.8. For the two trumpeter species, only three mesh sizes (89, 105 and 114 mm) were included in the model, as very few fish were caught in the larger mesh sizes. For all species, the three way interaction for fork length was not be tested due to very few fish in some mesh sizes, depths, and/or seasons.

Banded morwong

For banded morwong, mesh size and season were highly significant factors on CPUE, by both weight and number. CPUE by weight and number was highest in all seasons in the 133 mm mesh (the mesh size closest to that used in the commercial fishery). The 114 mm mesh tended to have the next highest catch rate. The number captured in the 130 mm mesh was less than expected, being substantially lower than in the 133 mm mesh. For this species it is likely that factors such as twine diameter affect catches more than mesh size, with banded morwong presumably *bouncing* off meshes with a relatively large twine diameter. CPUE was generally lowest in the smallest mesh size.

Table 6.7. Percentage catch, by weight and number, of the 10 dominant species for each mesh size

	Weight (%)					number (%)				
Mesh size (mm)	89	105	114	130	133	89	105	114	130	133
Draughtboard shark	1.7	3.7	11.4	4.5	22.1	0.3	1.1	4.6	2.5	12.4
Red cod	1.2	0.9	0.9	0.7	0.1	1.1	1.0	0.9	0.7	0.2
Marble fish	28.1	46.2	48.8	66.0	34.5	10.8	27.4	35.8	52.2	27.6
Banded morwong	5.1	9.9	17.1	21.8	39.8	3.3	9.1	20.5	29.1	51.2
Striped trumpeter	22.7	15.0	6.7	0.5		24.4	21.0	11.3	1.1	
Bastard trumpeter	16.6	12.1	7.5	3.1	0.9	25.1	22.5	14.2	6.5	2.4
Blue throated wrasse	7.2	2.8	1.9	0.7		9.0	3.2	2.5	1.1	
Purple wrasse	8.9	2.3	0.9	0.1	0.3	12.2	3.7	2.1	0.4	1.2
Blue warehou	2.0	3.2	2.1	0.7		2.3	3.6	2.5	1.8	
Leatherjackets	2.0	1.2	0.5	0.1	0.1	4.3	3.3	1.4	0.4	0.2
Others	4.6	2.7	2.2	1.7	2.1	7.1	4.2	4.1	4.3	4.6

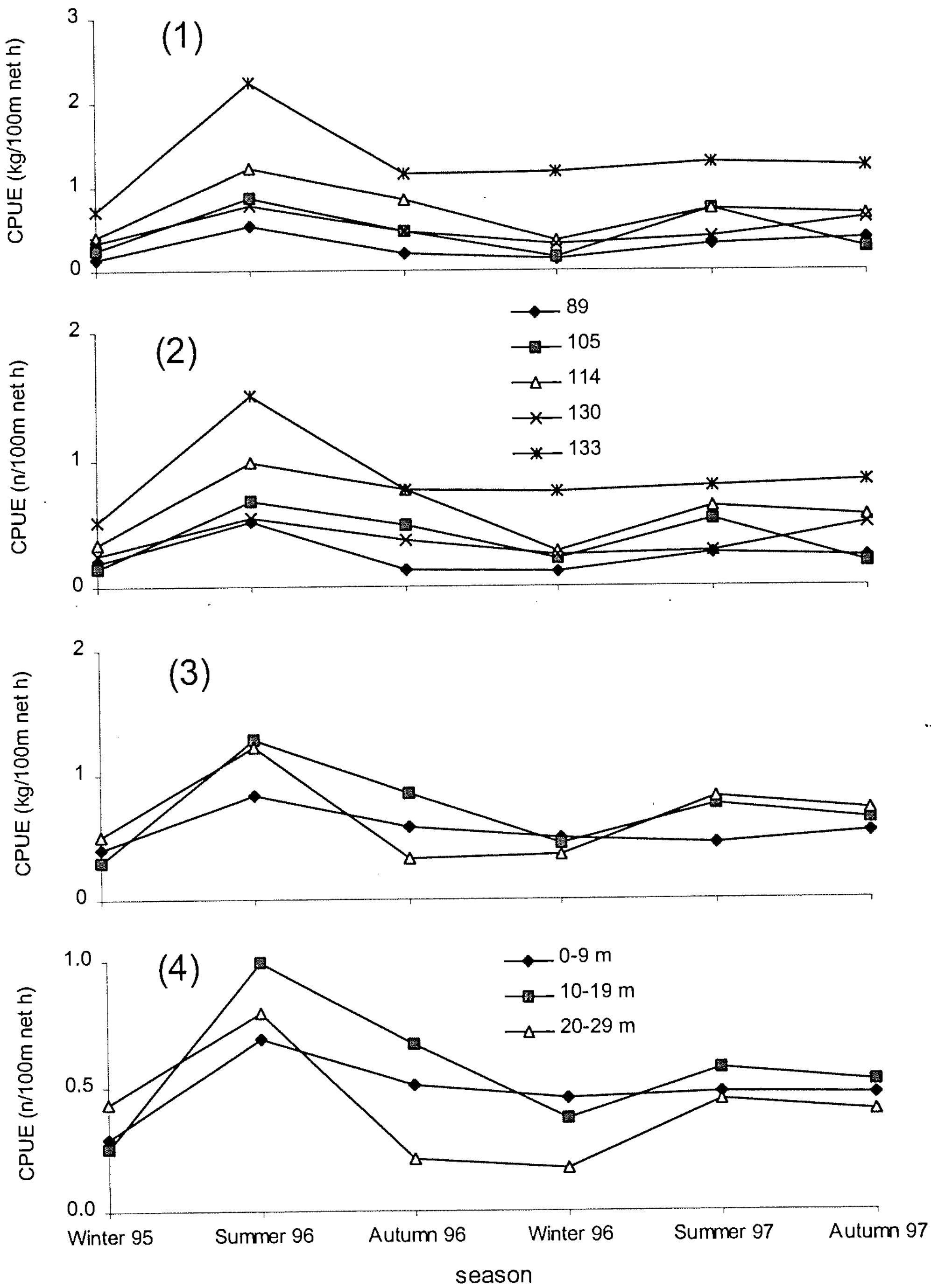


Fig 6.16. Mean CPUE per 100 m net h of banded morwong by weight (1) and number (2) in five mesh sizes by season and by weight (3) and number (4) in three depth strata by season

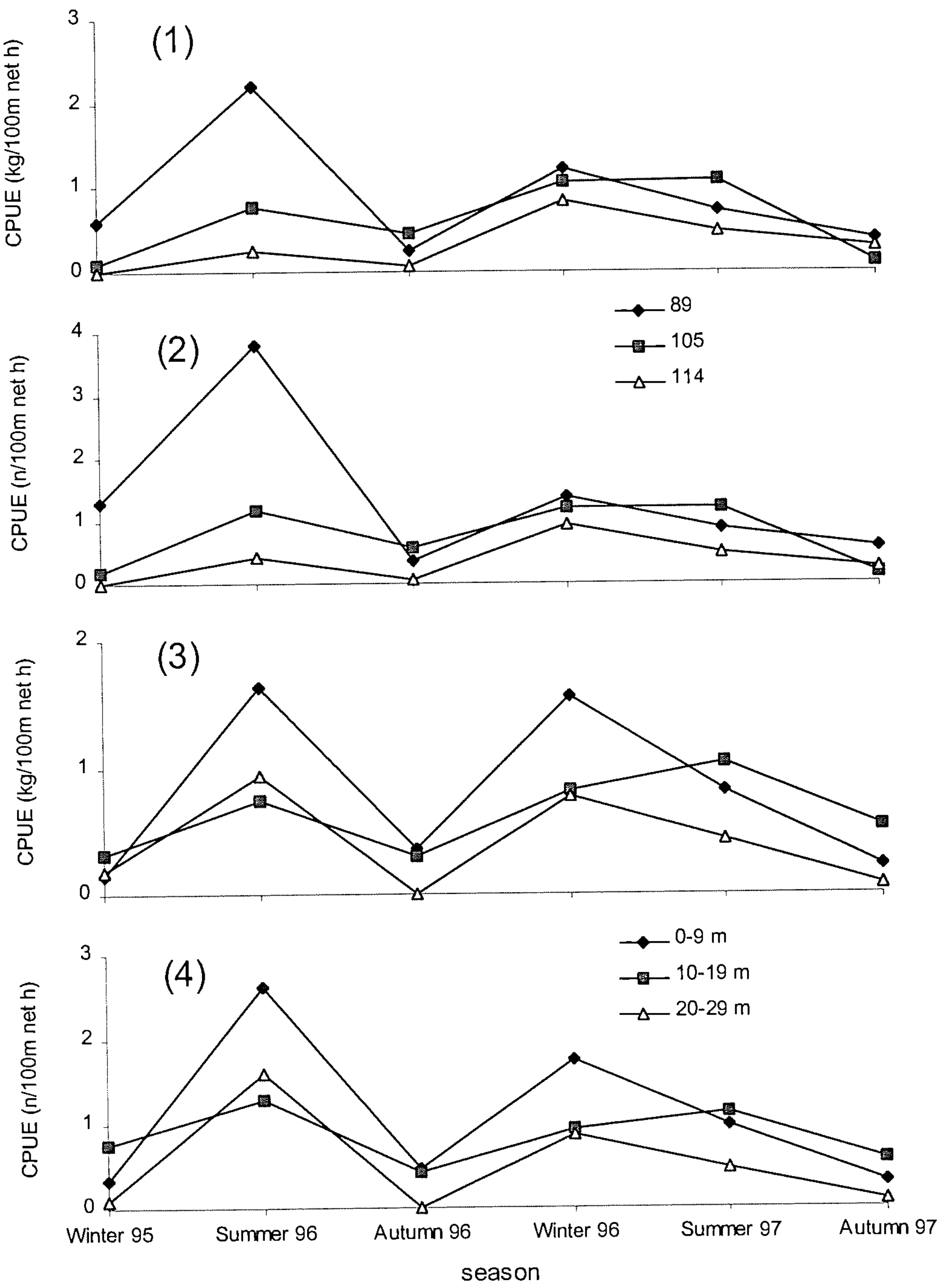


Fig 6.17. Mean CPUE per 100 m net h of striped trumpeter by weight (1) and number (2) in three mesh sizes by season and by weight (3) and number (4) in three depth strata by season

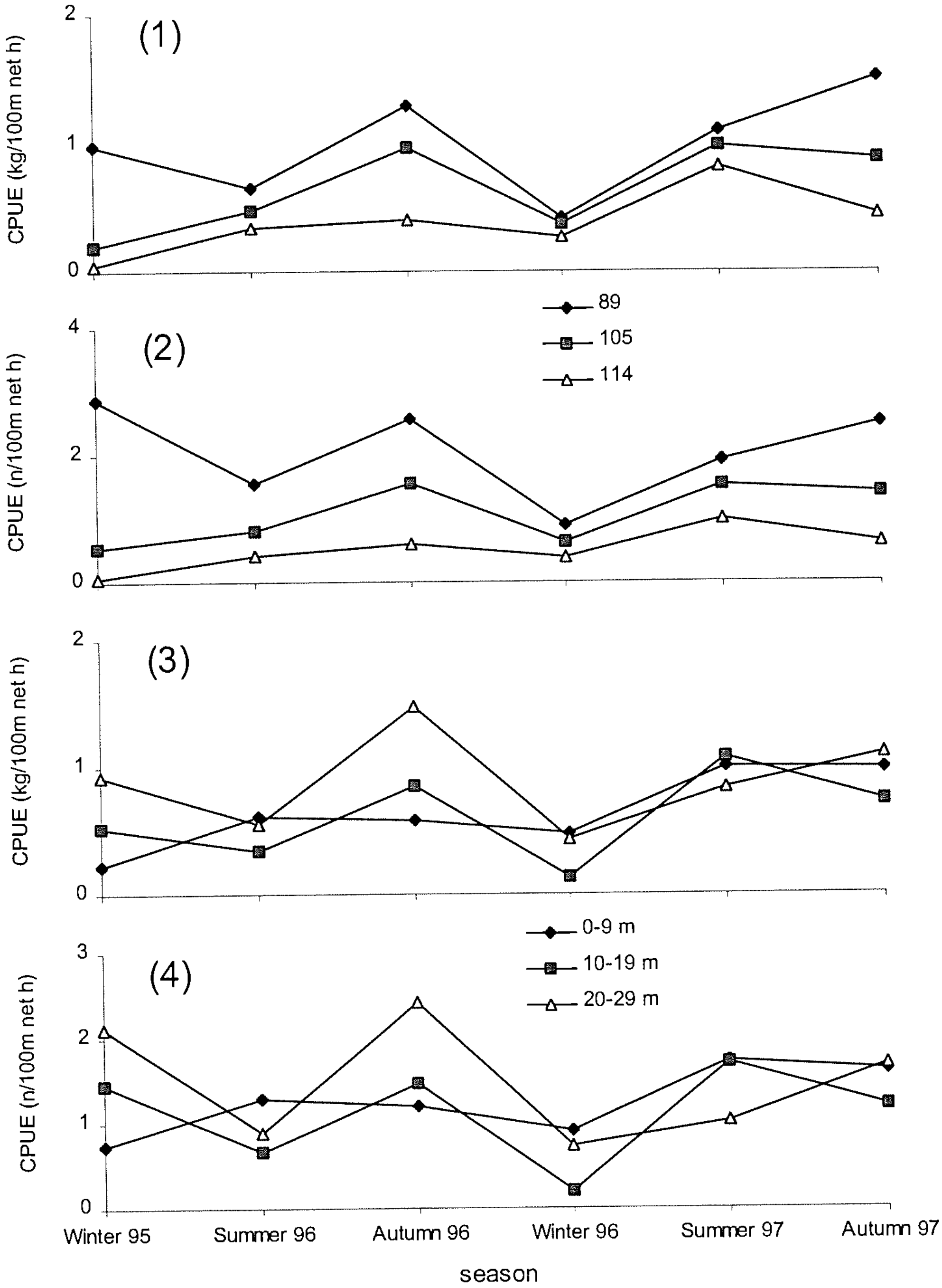


Fig 6.18. Mean CPUE per 100 m net h of bastard trumpeter by weight (1) and number (2) in three mesh sizes by season and by weight (3) and number (4) in three depth strata by season

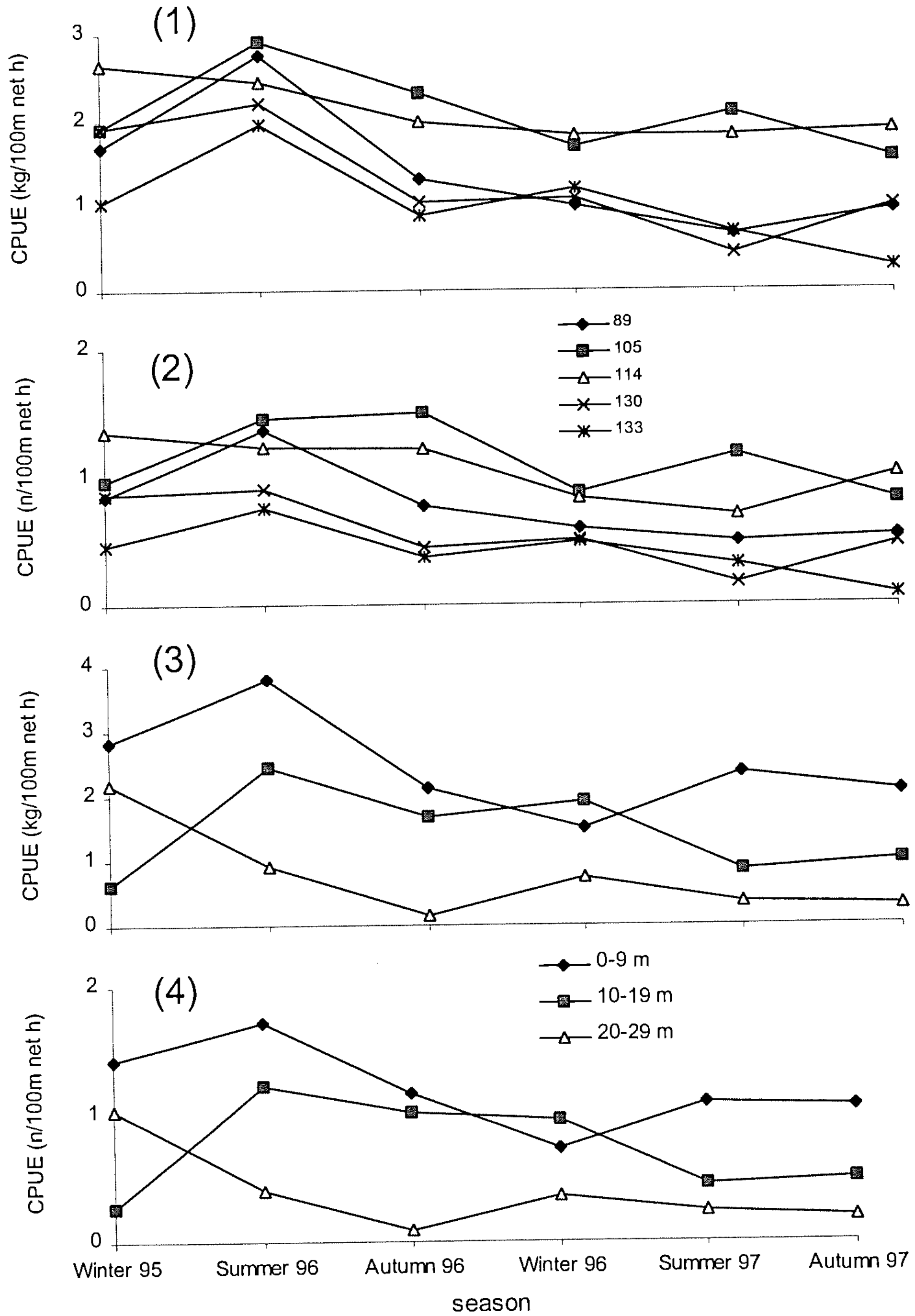


Fig 6.19. Mean CPUE per 100 m net h of marble fish by weight (1) and number (2) in five mesh sizes by season and by weight (3) and number (4) in three depth strata by season

Table 6.8. Probability values (*P*) derived from the three factor ANOVA on CPUE data and mean fork length for four species of rocky reef fish

		Banded morwong (α=0.05)			
		ln(CPUE+1) (wt)	ln(CPUE+1) (n)	fork length	
Factor	d.f.	*P*	*P*	d.f.	*P*
Mesh size (A)	4	<0.001	<0.001	4	<0.001
Depth strata (B)	2	0.175	<0.025	2	<0.001
Season (C)	5	<0.001	<0.001	5	0.935
A x B	8	0.303	0.137	8	0.122
A x C	20	0.858	0.689	20	0.169
B x C	10	0.261	0.297	10	0.398
A x B x C	40	0.993	0.980		
Residual	1005			513	

		Striped trumpeter (α=0.05)			
		ln (CPUE+1) (wt)	ln (CPUE+1) (n)	fork length	
Factor	d.f.	*P*	*P*	d.f.	*P*
Mesh size (A)	2	<0.001	<0.001	2	<0.001
Depth strata (B)	2	0.345	0.253	2	0.712
Season (C)	5	<0.001	<0.001	5	<0.001
A x B	4	0.533	0.357	4	<0.01
A x C	10	0.395	0.300	8	<0.001
B x C	10	0.968	0.989	7	0.216
A x B x C	20	0.237	0.340		
Residual	603			647	

		Bastard trumpeter (α=0.05)			
		ln(CPUE+1) (wt)	ln (CPUE+1) (n)	fork length	
Factor	d.f.	*P*	*P*	d.f.	*P*
Mesh size (A)	2	<0.001	<0.001	2	<0.001
Depth strata (B)	2	0.075	0.154	2	<0.001
Season (C)	5	<0.001	<0.001	5	<0.001
A x B	4	0.455	0.454	4	0.380
A x C	10	0.152	0.073	10	<0.025
B x C	10	0.211	0.125	10	0.245
A x B x C	20	0.660	0.754		
Residual	603			681	

		Marble fish (α=0.05)			
		ln(CPUE+1) (wt)	ln (CPUE+1) (n)	fork length	
Factor	d.f.	*P*	*P*	d.f.	*P*
Mesh size (A)	4	<0.001	<0.001	4	<0.001
Depth strata (B)	2	<0.001	<0.001	2	0.358
Season (C)	5	<0.001	<0.001	2	<0.001
A x B	8	0.453	0.474	8	0.256
A x C	20	0.970	0.953	8	0.722
B x C	10	<0.05	<0.05	3	0.176
A x B x C	40	0.595	0.584		
Residual	1005			606	

Depth strata had a significant effect on CPUE by number, tending to be highest in the 10 - 19 m strata, but was not significant in terms of weight. Although CPUE by number was comparatively low in the deep strata, it tended to be closer to that for the shallow strata. This is largely a reflection of size structuring, with larger fish occurring in deeper water. Mesh size and depth were both highly significant factors on mean length.

Striped trumpeter

For striped trumpeter, mesh size and season were highly significant factors on CPUE, by both weight and number. CPUE was consistently lower in the largest mesh size. In the first two seasons of the study, CPUE was much higher in the 89 mm mesh than in the other mesh sizes. This was due to the impact of the strong 1993 cohort (refer section 6.5) which was a size that was selected for by the 89 mm mesh (approx. 28 cm in Winter 95), but not the other two mesh sizes at that time. As the cohort increased in size, catches tended to increase in the 105 and 114 mm mesh and decline in the 89 mm mesh. Mesh size and season were both highly significant factors on mean length. There was a highly significant interaction effect on mean length between mesh size and season and a significant interaction between mesh size and depth.

Bastard trumpeter

For bastard trumpeter, mesh size and season were highly significant factors on CPUE, by both weight and number. In all seasons, CPUE was highest in the 89 mm mesh and lowest in the 114 mm mesh, reflecting a response to the population size structure which was dominated by small fish throughout the study. Mesh size, depth strata and season all had a highly significant effect on mean length. There was an interaction effect between mesh size and season on mean length.

Marble fish

For marble fish, mesh size, depth strata and season had highly significant effects on CPUE, by both weight and number. CPUE was generally highest in the 105 and 114 mm mesh nets and lowest in the two larger mesh sizes. There was a strong tendency for CPUE to be greatest in the shallow depth statum. There was a significant interaction effect between depth and season on CPUE by weight and number. Mesh size and season both had a highly significant effect on mean length.

Banded morwong mesh selectivities

A total of 563 banded morwong were captured over the 219 stations. For each mesh size, effort and numbers of banded morwong in each 30 mm length class are shown in Table 6.9.

Analysis of variance showed highly significant depth and seasonal effects on catch rates and highly significant depth effects on mean length of banded morwong. Season, however, was not a significant factor on mean length (refer Table 6.8). In an attempt to remove possible effort effects within each season, effort and the numbers of banded morwong in each size class have been adjusted for seasonal differences in effort by mesh size and depth strata. Effort and catches were adjusted by applying a weighting factor determined by the highest amount of effort of a single mesh size in a given depth strata for that season. For example, catches in winter 95 were adjusted as if 21.1 100 m net h had been deployed for each mesh size and strata, *i.e.* the same effort as the 133 mm mesh in the shallow stratum (refer Table 6.4). Effort adjustment factors are shown in Table 6.10. The adjusted number of banded morwong in each length class and adjusted effort by mesh size are shown in Table 6.11.

As large banded morwong are entangled in all mesh sizes, including those in which they can not be gilled or wedged, the resulting length frequencies for each mesh size are skewed to the right. Therefore, when calculating selectivities, the gamma distribution is a suitable model. Application of the maximum likelihood estimation procedure to adjusted catches for all 5 mesh sizes resulted in large residuals and variability in selectivity estimates. It appeared that the 130 mm mesh net had a lower fishing power than the other nets and when this mesh size was removed from the analysis a much better fit of the model was achieved. Parameter estimates are

$\theta_1 = 2.672$ $\theta_2 = 5019.6$ Log likelihood = -7.6644

Estimated relative selectivities and calculated values of α and β are shown in Table 6.12 and predicted catches from the fitted model are presented in Table 6.13.

Table 6.9. Numbers of captured banded morwong and effort for each mesh size

Length class (mm)	Mid-length (mm)	Number in nets of mesh size (mm) 89	105	114	130	133	Total
200-229	214.5	6					6
230-259	244.5	8	1	1		1	11
260-289	274.5	2	13	3	1		19
290-319	304.5		11	23	1	1	36
320-349	334.5	6	14	26	10	18	74
350-379	364.5	8	9	27	27	42	113
380-409	394.5	6	13	24	14	52	109
410-439	424.5	9	6	9	8	37	69
440-469	454.5	4	4	6	7	21	42
470-499	484.5	3	9	9	2	26	49
500-529	514.5	1	5	6	7	13	32
530-559	544.5	1	1		1		3
Total		54	86	134	78	211	563
Effort (100m net h)		203.8	214.0	208.2	217.3	234.1	1077.4

Table 6.10. Effort adjustment factors for each mesh size by depth strata for each season. The adjusted effort (*A.E.*) (100 m net h) is shown in italics

Depth strata	Mesh size (mm)	Season 'Winter' 95	Summer 96	Autumn 96	'Winter' 96	Summer 97	Autumn 97	*Total A.E.*
Shallow (0 - 9 m)	89	1.12	1.48	1.17	1.18	1.35	1.09	*92.1*
	105	1.10	1.39	1.10	1.13	1.29	1.03	*92.1*
	114	1.10	1.43	1.12	1.20	1.32	1.10	*92.1*
	130	1.06	1.38	1.07	1.12	1.26	1.04	*92.1*
	133	1.00	1.32	1.02	1.05	1.22	1.00	*92.1*
	Total A.E.	*105.5*	*122.0*	*58.0*	*78.0*	*47.5*	*49.5*	*460.5*
Medium (10 - 19 m)	89	1.37	1.17	1.11	1.26	1.28	1.24	*92.1*
	105	1.24	1.10	1.07	1.22	1.23	1.21	*92.1*
	114	1.30	1.13	1.10	1.23	1.25	1.20	*92.1*
	130	1.23	1.07	1.04	1.17	1.20	1.19	*92.1*
	133	1.15	1.00	1.00	1.10	1.13	1.09	*92.1*
	Total A.E.	*105.5*	*122.0*	*58.0*	*78.0*	*47.5*	*49.5*	*460.5*
Deep (20 - 29 m)	89	6.36	1.54	1.71	1.17	1.31	1.18	*92.1*
	105	7.15	1.45	1.58	1.18	1.20	1.10	*92.1*
	114	7.16	1.57	1.63	1.13	1.27	1.16	*92.1*
	130	5.90	1.46	1.77	1.06	1.41	1.09	*92.1*
	133	5.58	1.42	1.29	1.00	1.00	1.05	*92.1*
	Total A.E.	*105.5*	*122.0*	*58.0*	*78.0*	*47.5*	*49.5*	*460.5*
Total	*Total A.E.*	*316.5*	*366.0*	*174.0*	*234.0*	*142.5*	*148.5*	*1381.5*

Table 6.11. Adjusted numbers of banded morwong and adjusted effort (*A.E*) for each mesh size

Length class (mm)	Mid-length (mm)	Number in nets of mesh size (mm) 89	105	114	130	133	Total
200-229	214.5	7.9					7.9
230-259	244.5	10.6	1.1	1.1		1.0	13.8
260-289	274.5	2.5	15.6	3.9	1.0		23.1
290-319	304.5		13.1	33.9	1.1	1.3	49.4
320-349	334.5	8.1	16.4	32.1	11.8	20.3	88.8
350-379	364.5	10.1	10.6	40.1	30.6	47.4	138.7
380-409	394.5	7.6	15.3	30.8	21.8	58.9	134.5
410-439	424.5	11.6	7.3	11.2	9.6	40.7	80.5
440-469	454.5	5.5	4.6	6.8	7.9	23.8	48.7
470-499	484.5	3.5	11.0	12.3	2.2	29.8	58.8
500-529	514.5	1.2	5.6	8.0	8.0	14.0	36.8
530-559	544.5	1.5	1.2		1.1		3.8
Total		70.1	101.9	180.3	95.2	237.2	684.8
A.E. (100m net h)		*276.3*	*276.3*	*276.3*	*276.3*	*276.3*	*1381.5*

Estimated selectivity functions are illustrated in Fig. 6.20. The residuals (Fig. 6.21) indicate a very good fit for the 133 mm mesh, the mesh used in the commercial fishery, but a poorer fit was achieved for the smaller mesh sizes. Population length frequency distributions, predicted from fitting estimated selectivities to catches from the four mesh sizes, indicated a large proportion of the population to be greater than 45 cm (Fig. 6.22). This suggests that in commercial nets, larger fish (*i.e.* males) are under-represented in catches. By contrast, catches of females more closely reflect the predicted population structure indicating that commercial nets are effectively selecting for all sizes of females (Fig. 6.23). Predictions of low numbers of banded morwong smaller than 30 cm suggests that either fish below this size are considerably less vulnerable to all mesh sizes or that few small fish had recruited to the rocky reefs prior to the study. However, it is recognised that errors in predicted catches are likely to be greatest at the extremes of the selectivity curves, *i.e.* in the smaller and larger size classes.

Table 6.12. Estimated relative selectivities and α and β values for 89 to 133 mm mesh gillnets

Length class (mm)	Mid-length (mm)	Selectivity for nets of mesh size (mm)			
		89	105	114	133
200-229	214.5	0.94	0.58	0.34	0.06
230-259	244.5	1.00	0.86	0.65	0.20
260-289	274.5	0.88	1.00	0.90	0.45
290-319	304.5	0.67	0.94	1.00	0.74
320-349	334.5	0.45	0.76	0.92	0.95
350-379	364.5	0.28	0.54	0.72	0.99
380-409	394.5	0.16	0.34	0.49	0.86
410-439	424.5	0.08	0.19	0.30	0.65
440-469	454.5	0.04	0.10	0.17	0.42
470-499	484.5	0.02	0.05	0.09	0.25
500-529	514.5	0.01	0.02	0.04	0.13
530-559	544.5	0.00	0.01	0.02	0.06
	α	12.19	16.62	19.44	26.12
	β	19.51	16.88	15.67	13.60

Table 6.13. Predicted catches for 89 to 133 mm mesh gillnets

Length class (mm)	Mid-length (mm)	Predicted catch in net of mesh size (mm)			
		89	105	114	133
200-229	214.5	3.9	2.4	1.4	0.2
230-259	244.5	5.1	4.4	3.3	1.0
260-289	274.5	6.0	6.8	6.2	3.1
290-319	304.5	9.6	13.6	14.4	10.7
320-349	334.5	11.2	19.0	22.9	23.8
350-379	364.5	11.8	23.0	30.8	42.5
380-409	394.5	9.5	20.6	30.0	52.6
410-439	424.5	4.7	11.2	17.5	37.4
440-469	454.5	2.2	5.6	9.3	23.5
470-499	484.5	2.7	7.0	12.0	34.9
500-529	514.5	1.2	3.2	5.7	18.6
530-559	544.5	0.1	0.3	0.5	1.8

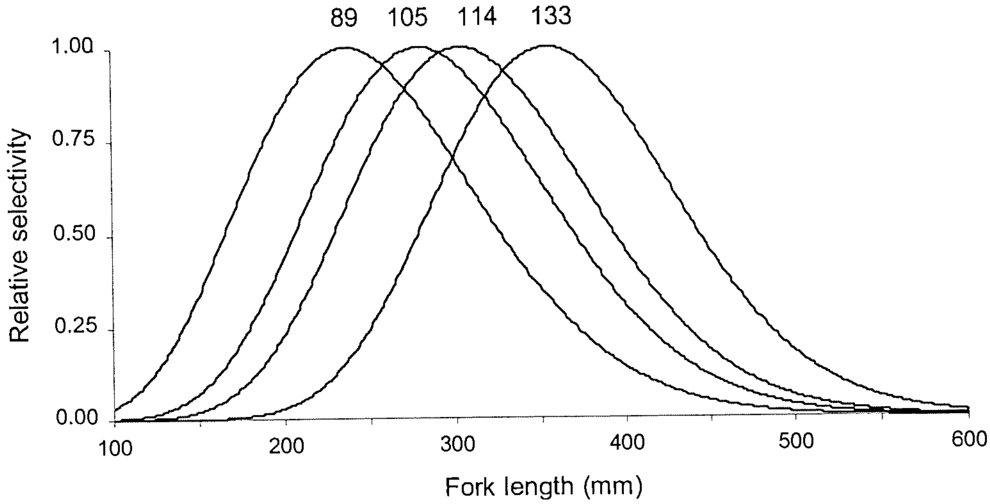


Figure 6.20. Estimated relative selectivities as a function of length for banded morwong for 89 -133 mm mesh gillnets (labelled 89-133).

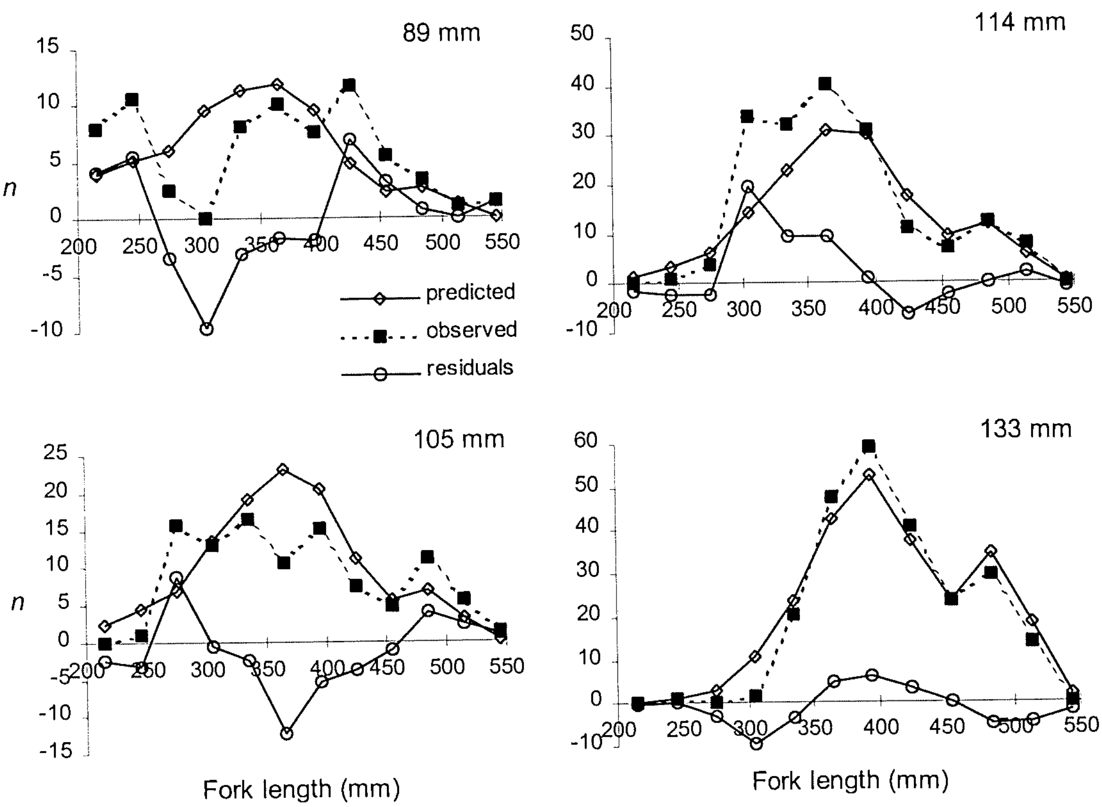


Figure 6.21. Observed and predicted catches of banded morwong and residuals in each mesh size

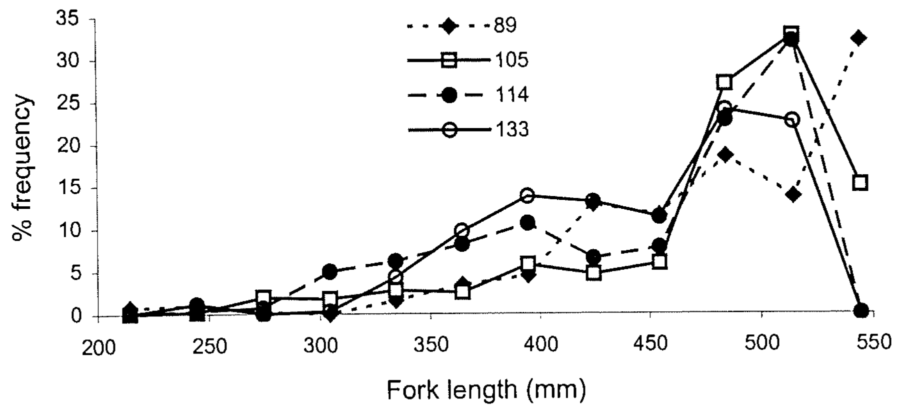


Figure 6.22. Predicted population length frequency distributions from fitting estimated selectivities to observed catches of experimental gillnets of four mesh sizes

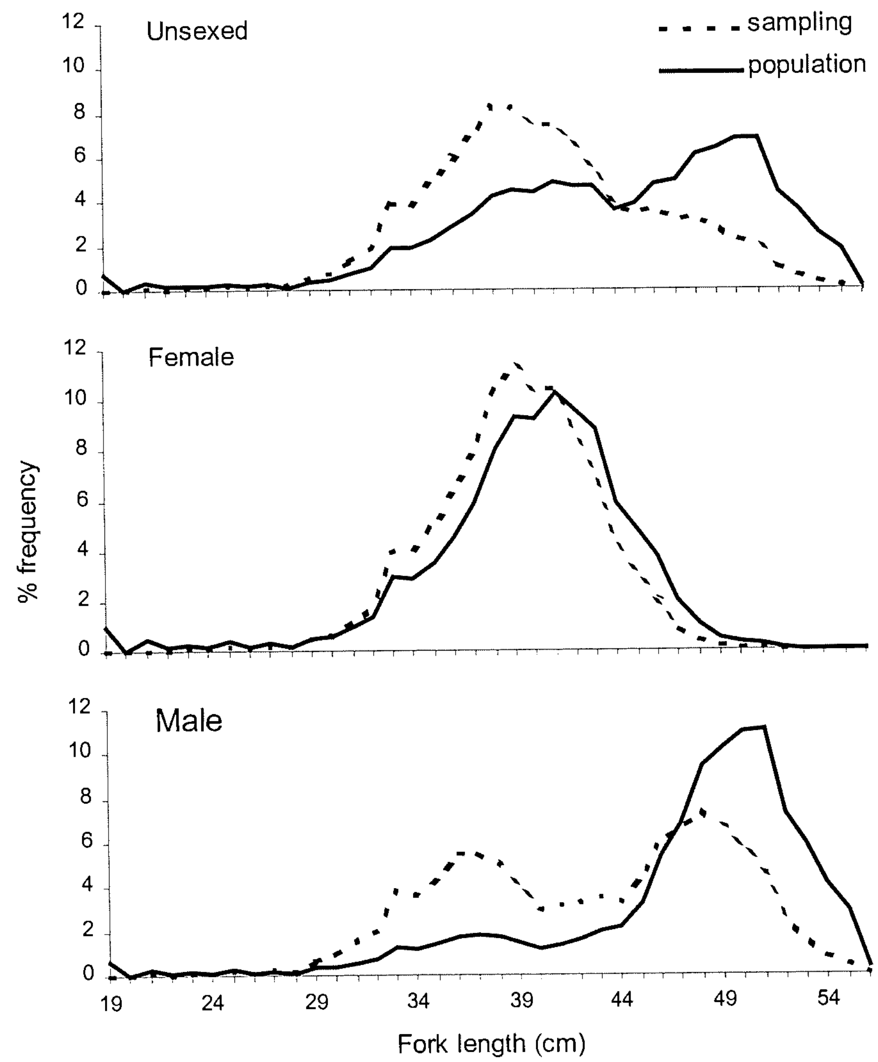


Figure 6.23. Length frequency distribution of banded morwong by sex from commercial catch sampling, Dec 94-Nov 97, and length frequency of predicted population (after adjustment for selectivity of 133mm mesh)

Other species

The mean length of striped trumpeter and bastard trumpeter, including those captured in the 64 mm, increased with increasing mesh size (Fig. 6.24 and 6.25). Length specific selectivity coefficients were not determined for either species since an assumption of the model, that is, that the size structure of the population being sampled does not change during sampling, was not valid. Length frequencies of both trumpeter species were in fact strongly influenced by a single cohort that increased in mean length over the course of the study. Striped trumpeter grew from approximately 19 cm to 42 cm and bastard trumpeter cohort from approximately 19 cm to 32 cm (see section 6.5).

Given the influence of these cohort, length frequency distributions for each mesh size were strongly influenced by the timing and frequency of sampling in relation to the growth of each species. For example, low numbers of striped trumpeter were captured when the strong cohort was between 20 to 25 cm and 30 to 32 cm, resulting in multi-modal distributions which are in fact a reflection of the growth in a single cohort. In contrast, low numbers of bastard trumpeter were recorded only in the 20 to 25 cm length range and distributions have a single mode for the 89 and 105 mm meshes. The distribution of bastard trumpeter in the 89 mm mesh was right skewed, suggesting that the majority of size classes vulnerable to that mesh size were sampled. In contrast, the distribution in the 105 mm mesh was skewed to the left, suggesting that larger bastard trumpeter were under-represented in catches in this mesh size and, hence, also in the 114 mm mesh.

The total length of blue throated and purple wrasse from all gillnet deployments also increased with increasing mesh size (Fig. 6.26). Length specific selectivity coefficients were not determined because, with the exception in the 89 mm mesh, the number of wrasse captured was low. Length frequency distributions for wrasse in the 64 and 89 mm mesh nets were typically right skewed, suggesting sampling of all size classes selected for by these mesh sizes. The large number of wrasse captured in the two smaller mesh sizes, relative to the larger mesh sizes, would suggest that the size structure of the wrasse population is dominated by fish smaller than 32 cm TL.

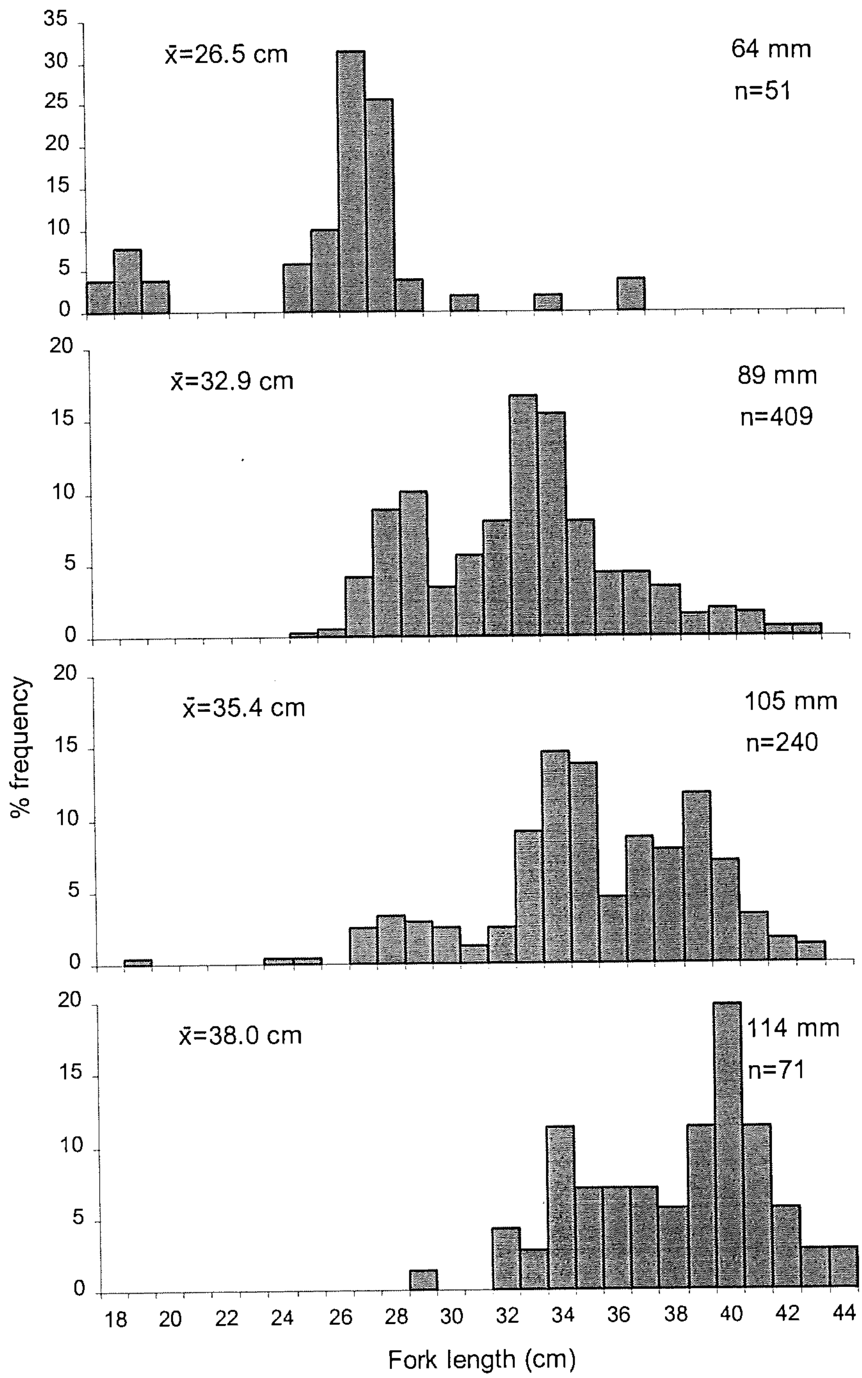


Fig. 6.24. Percentage length frequency of striped trumpeter caught in experimental gillnets. Note scale is different for 64 mm mesh.

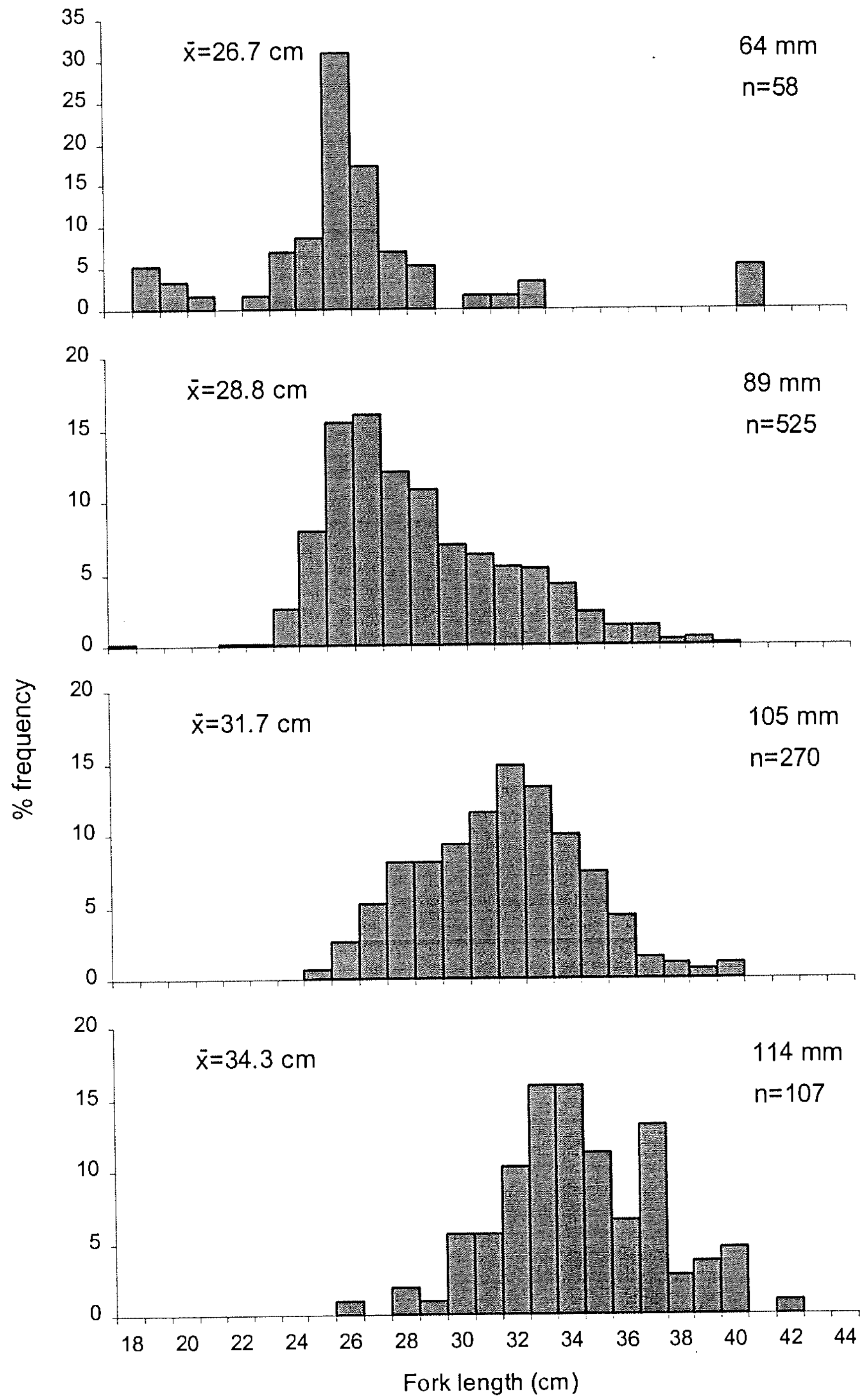


Fig. 6.25. Percentage length frequency of bastard trumpeter caught in experimental gillnets. Note scale is different for 64 mm mesh.

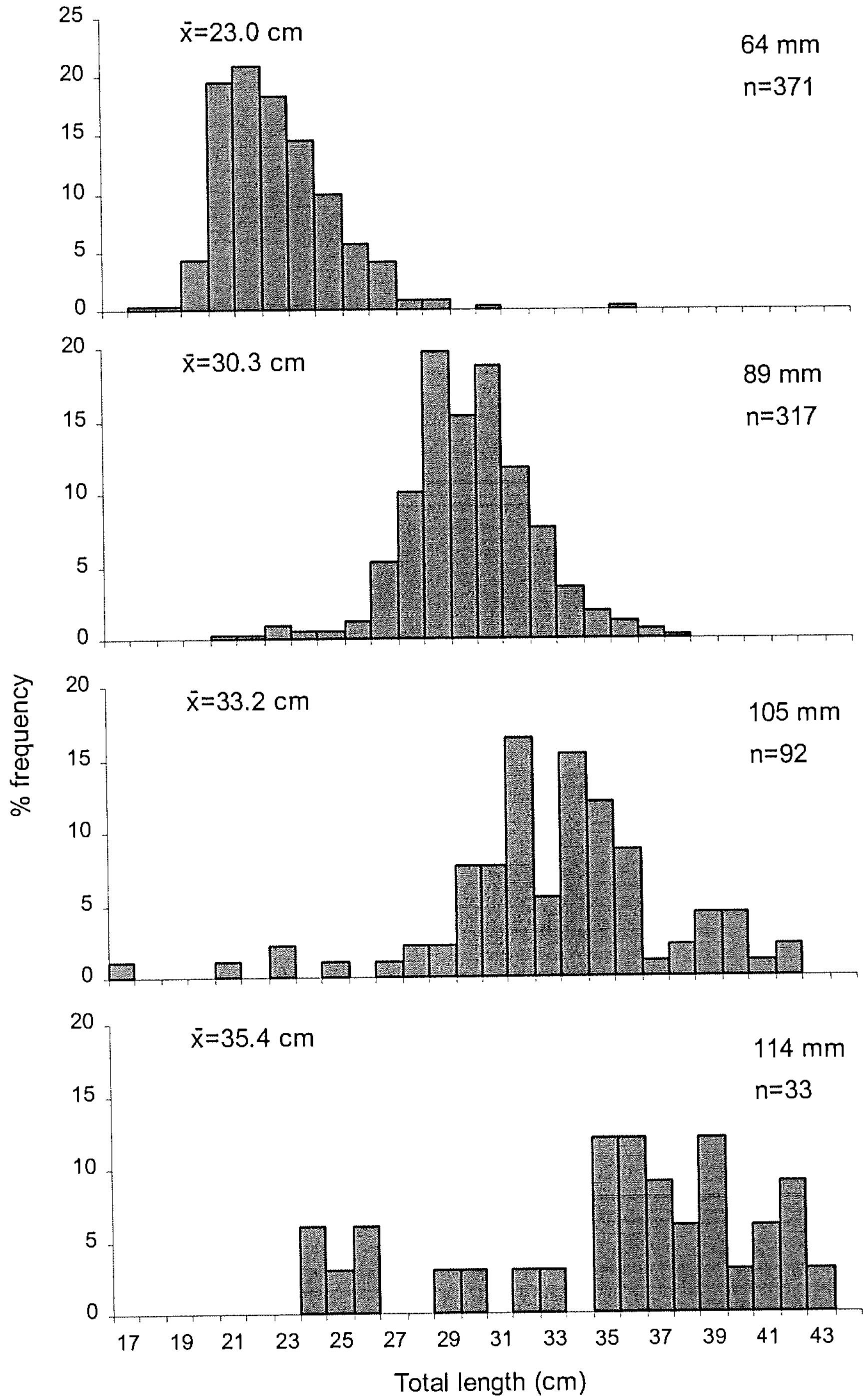


Fig. 6.26. Percentage length frequency of blue throat and purple wrasse caught in experimental gillnets. Note scale is different for 64 mm mesh.

6.3 Comparison of marine reserve and adjacent exploited reefs

During the marine reserve study, 132 net deployments (representing 156.8 100 m net h) were set in the marine reserve and 129 net deployments (representing 173.7 100 m net h) were set on adjacent exploited reefs. A total of 20 species were caught, of which 17 were caught in the reserve and 14 in the exploited areas (Table 6.14). Banded morwong dominated catches in both the marine reserve and the adjacent exploited areas, overall accounting for 76% of the catch by number and 74% by weight in each area. The only other species to comprise over 4% of the catch by both number and weight in the two areas were marble fish and long-snouted boarfish. Draughtboard shark also comprised over 4% of the catch by weight in the exploited area. Catches of all other species were very low, the only other species where greater than 10 individuals were captured were blue-throated wrasse and southern rock lobster. The low diversity of species captured in both areas reflects the selectivity of the gillnets (133 and 140 mm mesh) used in this study (refer Table 6.5).

In the reserve, the total catch per unit effort for all species combined, and for banded morwong alone, by number and weight, was almost double that for the exploited area. In each

Table 6.14. Catch and CPUE, by number and weight, of all species captured inside the Governor Island marine reserve (Res) and in adjacent exploited areas (Expl)

	number (*n*)		weight (kg)		CPUE (*n* / 100 m net h)		CPUE (kg / 100 m net h)	
Species	Res	Expl	Res	Expl	Res	Expl	Res	Expl
Draughtboard shark	6	13	21.7	42.3	0.04	0.07	0.14	0.24
Whitley's skate		1		0.3		0.01		0.01
Banded stingaree	1		0.5		0.01		0.01	
Red cod	3		6.5		0.02		0.04	
Silver dory	4	1	1.1	0.2	0.03	0.01	0.01	0.01
Barber perch	1		0.2		0.01		0.01	
Long snouted boarfish	34	18	53.2	26.6	0.22	0.10	0.34	0.15
Marble fish	43	18	108.4	47.4	0.27	0.10	0.69	0.27
Jackass morwong	2		2.6		0.01		0.02	
Banded morwong	468	275	752.1	448.6	2.98	1.58	4.80	2.58
Bastard trumpeter	7	3	6.3	4.2	0.04	0.02	0.04	0.02
Blue throated wrasse	15	7	24.5	13.6	0.10	0.04	0.16	0.08
Purple wrasse	8	7	4.9	5.3	0.05	0.04	0.03	0.03
Herring cale	7	4	4.8	3.2	0.04	0.02	0.03	0.02
Blue warehou		3		4.2		0.02		0.02
Toothbrush leatherjacket	1		0.4		0.01		0.01	
Velvet leatherjacket	3	2	3.3	1.1	0.02	0.01	0.02	0.01
Gunns leatherjacket		1		1		0.01		0.01
Crab sp.	1		0.3		0.01		0.01	
Southern rock lobster	12	6	19.6	6.8	0.08	0.03	0.13	0.04
Total	616	359	1010.4	604.8	3.93	2.07	6.44	3.48

of the months surveyed, banded morwong CPUE was greater inside the marine reserve than in outside (Table 6.15). Commercial catch sampling in blocks 5H3K and 5H3O (these blocks include the exploited reef areas sampled in this study) during the same period yielded CPUE values slightly lower than those for research fishing. Commercial monitoring CPUEs, by number and weight, were 1.34 and 1.96 per 100 m net h, respectively, compared to 1.58 and 2.58 per 100 m net h during research fishing in the exploited areas. This confirmed that research fishing was at least as effective as commercial fishing.

The size structure of banded morwong from the marine reserve and adjacent reefs was generally similar, with the exception of the relative importance of fish in the 42 cm size class (Fig 6.27). The population within the reserve has a dominant mode at 42 cm whereas the exploited population has relatively low numbers of 42 cm fish. This distinctive pattern was most pronounced in the large February 97 sample (n=240) but was also consistent within each area, even when this sample was removed from the data.

Both sexes have dominant modes at 42 cm within the reserve but low numbers within this size class in the exploited area (Fig 6.28). The prominent 41 cm and 43 cm size classes seen in the exploited area were predominantly females, with very few males at either 42 or 43 cm. The length frequency of banded morwong from commercial samples from blocks 5H3K and 5H30 (refer Fig. 6.13 Bicheno Town area) exhibited a similar distribution to the exploited area with peaks at 41 and 43 cm and a slight trough, although not as pronounced as during research fishing, at 42 cm.

There was no difference in the percentage of banded morwong within the legal size range between areas, with 68% of numbers being between 33 and 43 cm in both the reserve and exploited reef area. Mean weights for the two areas were also similar (approx. 1.6 kg).

Table 6.15. Effort and CPUE of banded morwong inside the Governor Island marine reserve (Res) and in adjacent exploited areas (Expl)

Month	Deployments (n)		Effort (100 m net h)		CPUE (n / 100 m net h)		CPUE (kg / 100 m net h)	
	Res	Expl	Res	Expl	Res	Expl	Res	Expl
Mar 96	18	18	27.7	31.7	4.95	2.37	7.69	3.43
Oct 96	41	37	41.7	43.4	1.24	0.35	1.88	0.54
Feb 97	20	20	21.3	25.6	5.92	4.45	10.11	8.17
Apr 97	12	12	16.4	18.6	4.45	1.51	6.67	2.19
May 97	29	30	34.6	38.2	1.39	0.73	2.32	1.25
Dec 97	12	12	15.2	16.3	2.11	0.92	3.65	1.16
Total	132	129	156.8	173.7	2.98	1.58	4.80	2.58

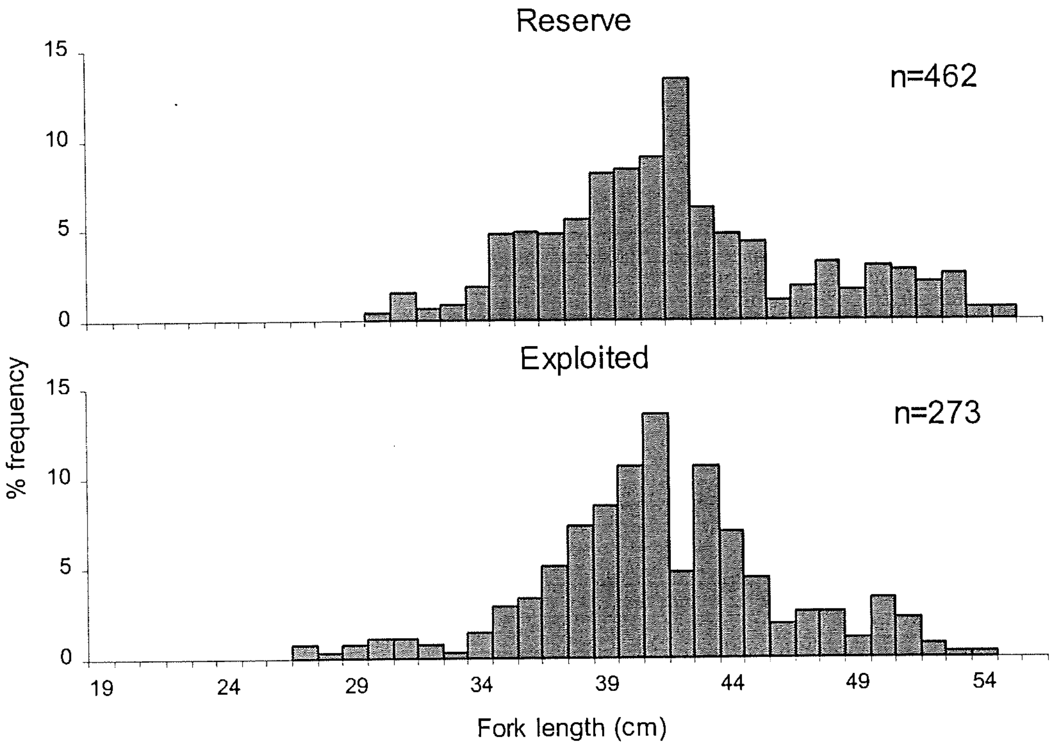


Fig 6.27. Length frequency of banded morwong from the Governor Island marine reserve (above) and adjacent exploited reef areas (below)

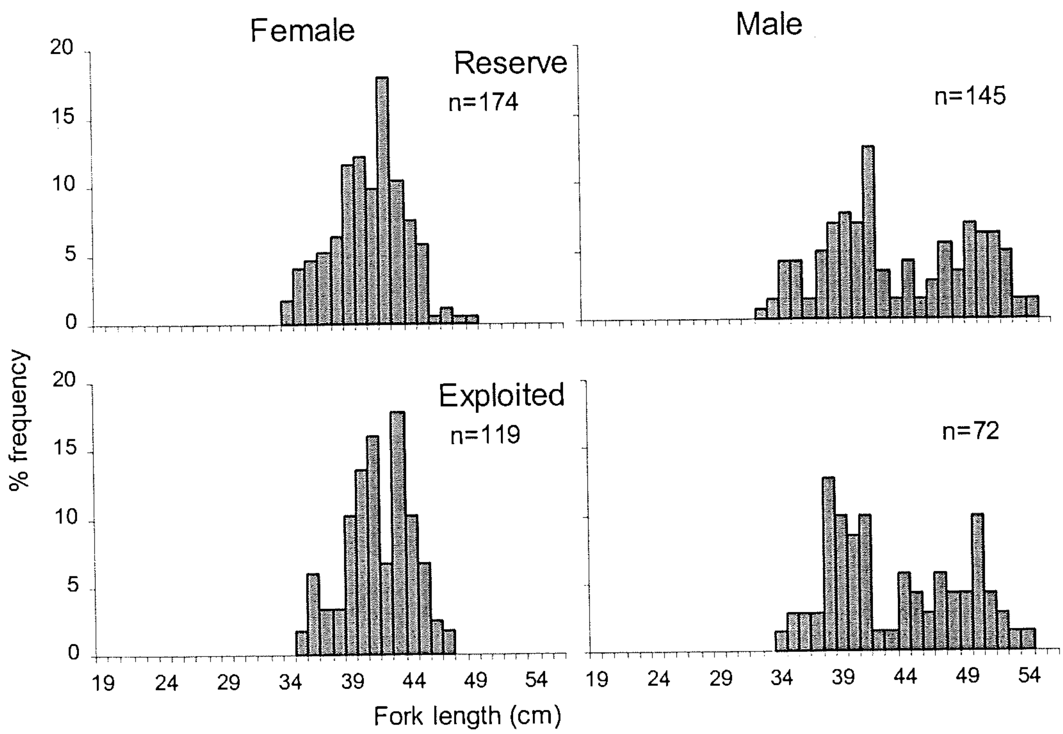


Fig 6.28. Length frequency of banded morwong from the Governor Island marine reserve and adjacent exploited population, by sex.

Table 6.16 shows the results of the tag-recapture experiment within the marine reserve. A total of 400 banded morwong were tagged within the reserve and 272 banded morwong were tagged in the exploited area, with 36 and 6 recaptures during research fishing in each area, respectively. No movement of fish was observed between the two areas and no banded morwong tagged within the reserve were reported captured by commercial or recreational fishers. Only one fish tagged outside of the reserve was reported captured by a recreational fisher. The size of the banded morwong stock in the Bicheno marine reserve available to the fishing gear, based on the Ricker tag-recapture model, was estimated at approximately 3370 individuals (95% CL 2210 - 4540). However, due to the assumptions implicit in the calculation, little confidence can be attributed to the estimate.

Table 6.16. Tag recapture data and estimates of banded morwong stock size (available to fishing gear) for the Governor Island marine reserve

Date	Catch	New tags	Total tagged	Recaptures	Estimated stock size
22/03/96	70	70	70		
23/03/96	66	66	136		
14/10/96	10	8	144	2	720
15/10/96	31	30	174	1	5394
17/10/96	1	1	175		
21/10/96	4	4	179		
22/10/96	7	7	186		
24/02/97	30	26	212	4	1590
25/02/97	78	71	283	5	4415
26/02/97	18	17	300	1	5400
15/04/97	50	47	347	3	5783
16/04/97	23	18	365	5	1679
19/05/97	10	6	371	4	928
20/05/97	18	11	382	6	1146
21/05/97	20	18	400	2	4000
16/12/97	13	0	400	1	5200
17/12/97	18	0	400	2	3600
Total	467		400	36	-

6.4 *Tagging and movement*

Banded morwong

A total of 7552 banded morwong were tagged off the east coast of Tasmania. Of these, 1954 were double tagged and 1367 were injected with OTC. By January 1998, 693 recaptures (plus 44 multiple recaptures), representing 9.2% of the number tagged, had been reported. The majority of fish were tagged in either the St. Helens or the Tasman Peninsula regions and most recaptures were reported from these regions. Based on recapture rates, there is an indication that the level of reporting recaptures varied between regions, with 12.6% of the number tagged in the St. Helens region being reported as recaptures, compared with just 3.3% for the Bicheno region, despite the Bicheno area being subject to the heaviest fishing pressure (Table 6.17).

Since commercial fishers also participated in the tagging program, a greater proportion of fish outside of the maximum legal size range, than are represented in catches, were tagged (Fig. 6.29). Not suprisingly therefore, the size distribution of recaptures is biased towards the small and large size classes (Fig. 6.29). The smallest banded morwong that was recaptured was 28 cm (*c.f.* 16 cm for the smallest tagged) reflecting length selectivity of mesh sizes used in the commercial fishery, although tag induced mortality may be higher in smaller banded morwong and may also be a contributing factor.

Table 6.17. Banded morwong tag-recapture data for regions of east coast Tasmania

Region	Total tagged	Recaptures	% reported as recaptures
St. Helens	2227	280	12.6
Bicheno*	929	31	3.3
Maria Island	819	69	8.3
Tasman Peninsula	3178	252	7.9

* excluding Governor Island marine reserve

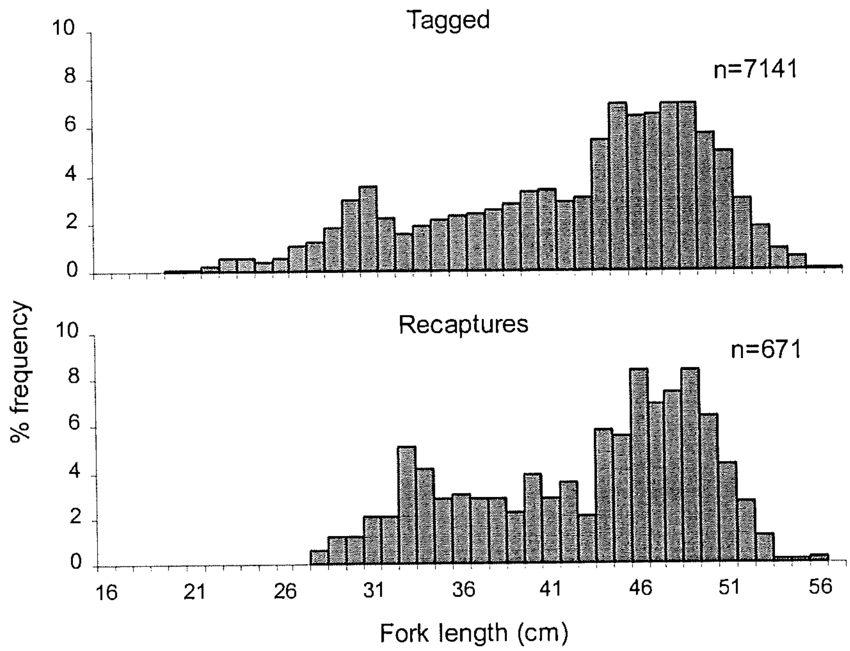


Fig. 6.29. Length frequency of banded morwong tagged (top) and recaptured (bottom) from east coast Tasmania

Of the recaptures, 140 had been injected with OTC, representing 10.2% of the number injected with OTC. Of the double tagged banded morwong, 196 were recaptured, representing 10.1% of the number double tagged. Only one tag was reported in 36 recaptures that had been double tagged, representing 18% of double tagged recaptures.

The time at liberty ranged between 1 and 998 days and averaged 238 days for all recaptures. There was no obvious or consistent trend between the average distance moved and the time at liberty (Fig. 6.30). When examined by 5 cm length classes (Table 6.18) there was no evidence to indicate that the distance moved differed with the size.

Of the banded morwong recaptured, 78 % were recaptured within 2 km of the site of release and 92% were within 5 km (Fig 6.31). Less than 4% were recorded as being recaptured greater than 10 km from the tagging site. The maximum distance moved was 41.7 km, with an average distance moved of 2.0 km. For recaptures where both the original tagging location and the recapture location had been recorded by researchers (n=114), distances moved ranged between 0 and 8.7 km, the average distance moved being just 0.9 km. Position information supplied by industry or recreational fishers tended to be less precise in terms of location than that obtained by researchers and probably accounts for the overall greater distance moved (*i.e.* 2 km). Movements that were greater that 5 km are shown for each region in Figs. 6.32 - 6.35. Where fish had been sexed, the average distance moved by females (n=56) and males (n=59) was 0.63 km and 0.65 km, respectively.

Interestingly, in May 1996, 110 banded morwong captured by a commercial fisher in the St. Helens region were tagged by researchers and released *on mass* at the St. Helens Point boat ramp (the fisher had no market for the fish at the time and suggested tagging them as he was going to release them). The habitat around the boat ramp consists of rocky reef to one side and soft, sandy bottom towards the entrance of Georges Bay on the other. Recaptures (n=19) of these banded morwong occurred after 27 to 497 days at liberty and ranged between 1.6 km and 14.2 km from the release location. The average distance moved was 5.6 km. Some recaptures occurred on rocky reef areas separated from the tagging location by soft bottom habitat, indicating that banded morwong are capable of moving between separate individual areas of reef.

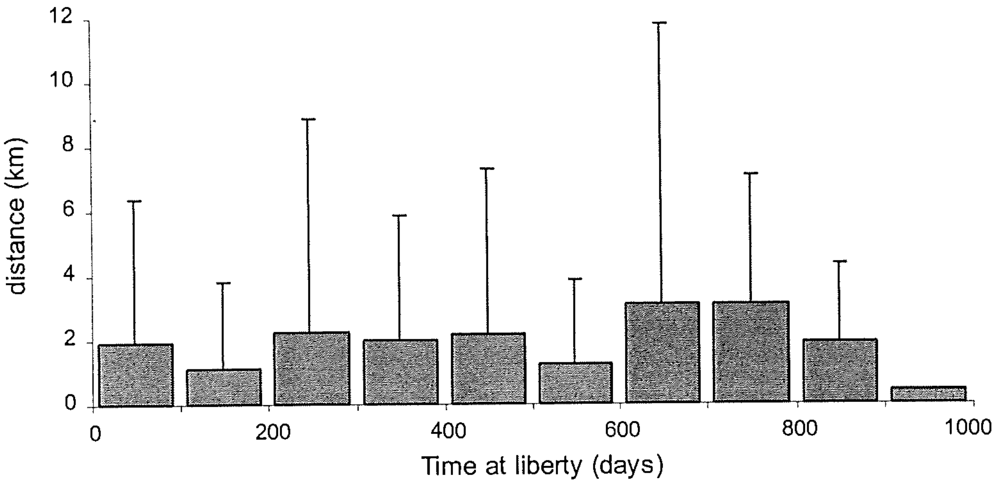


Fig. 6.30 Average distances moved by time for recaptured banded morwong. Error bars (1s.d.) are shown where n>1.

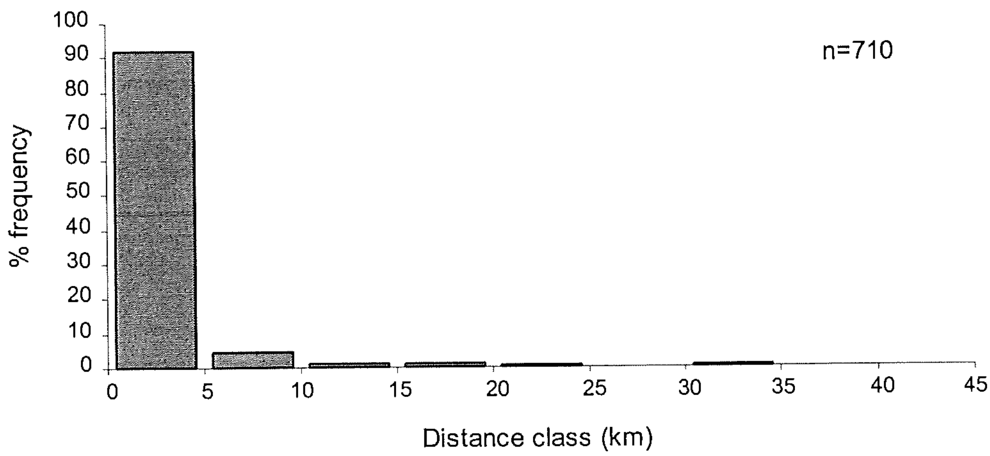


Fig. 6.31 Percentage frequency of distances moved by recaptured banded morwong, by 5 km distance classes

Table 6.18. Distance of recaptured banded morwong from tagging site, by length class

	Movement (km)			*n*
Length class (cm)	Average	Minimum	Maximum	
25.0 - 29.9	1.9	0.0	7.6	12
30.0 - 34.9	1.8	0.0	41.7	96
35.0 - 39.9	1.8	0.0	23.1	84
40.0 - 44.9	1.8	0.0	34.6	114
45.0 - 49.9	2.2	0.0	39.9	244
50.0 - 54.9	2.0	0.0	33.4	99
55.0 - 59.9	0.8	0.0	1.5	2
size unknown	2.5	0.0	17.2	59
Total	2.0	0.0	41.7	710

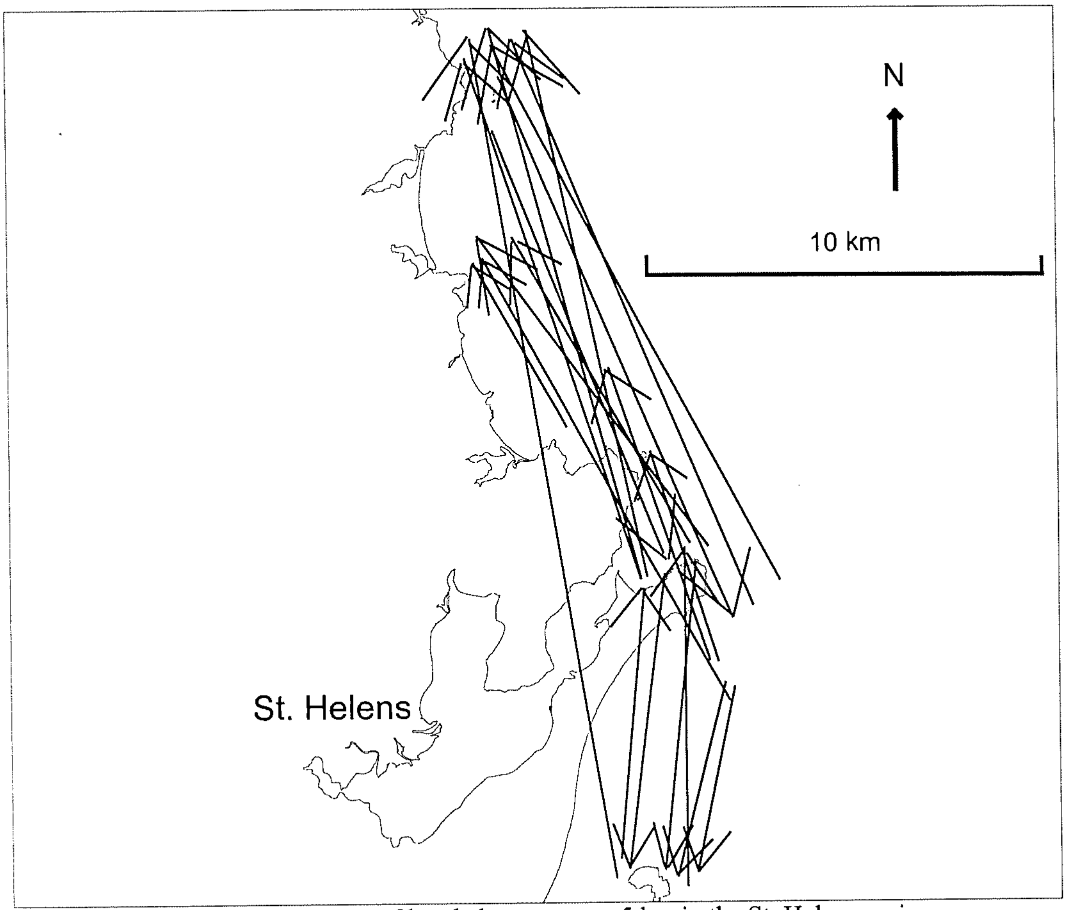


Fig. 6.32 Movement of banded morwong > 5 km in the St. Helens region

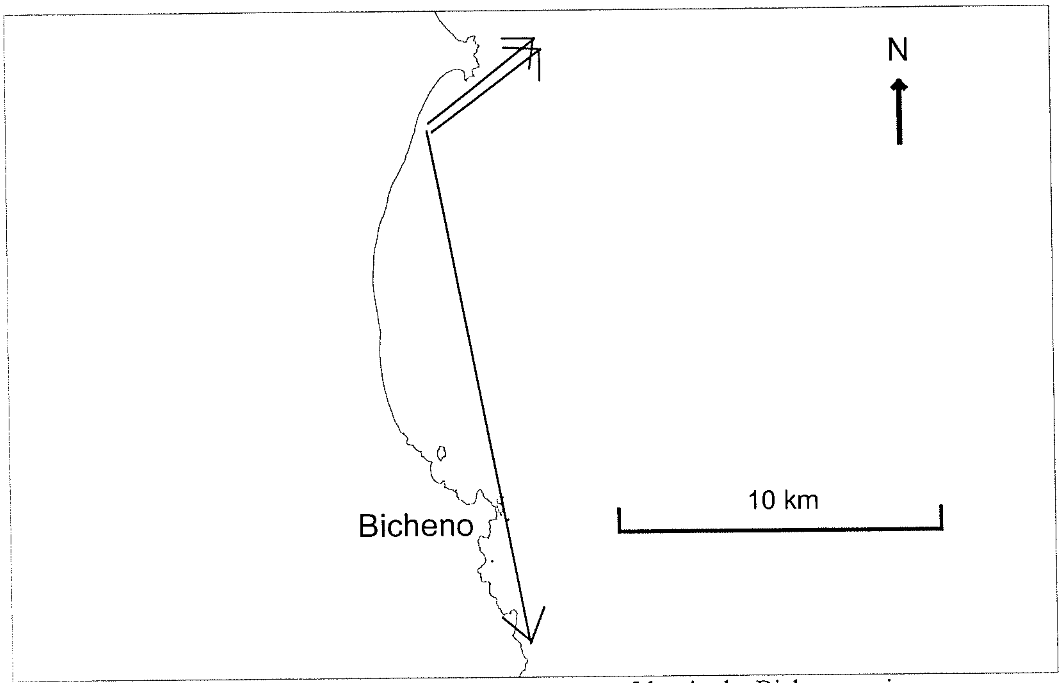


Fig. 6.33 Movement of banded morwong > 5 km in the Bicheno region

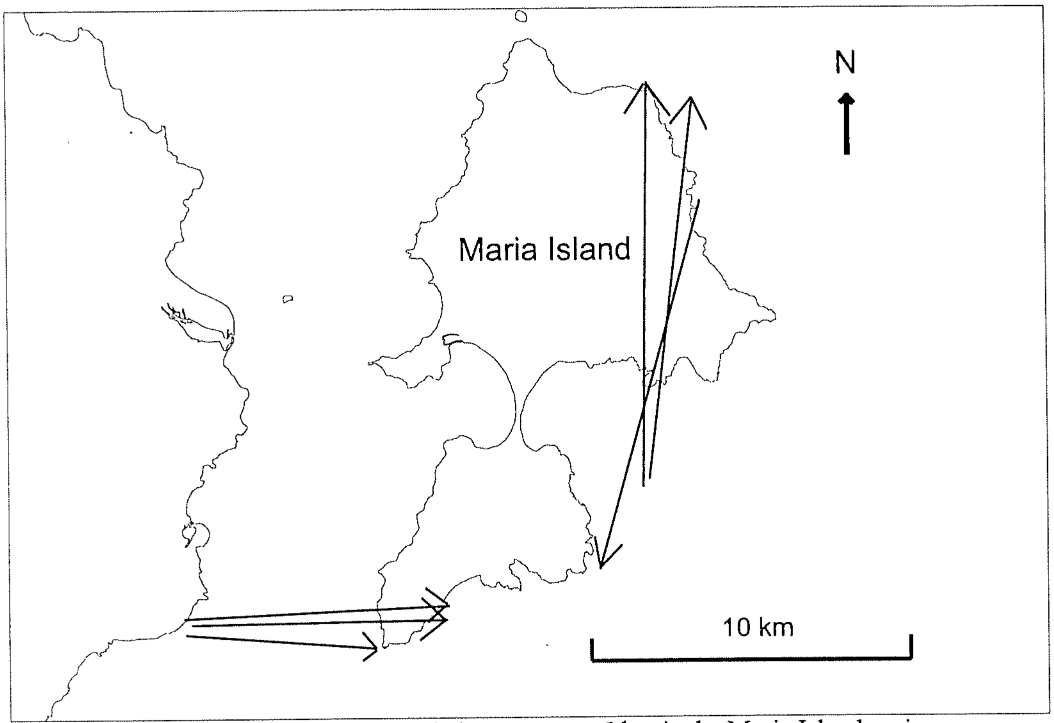


Fig. 6.34 Movement of banded morwong > 5 km in the Maria Island region

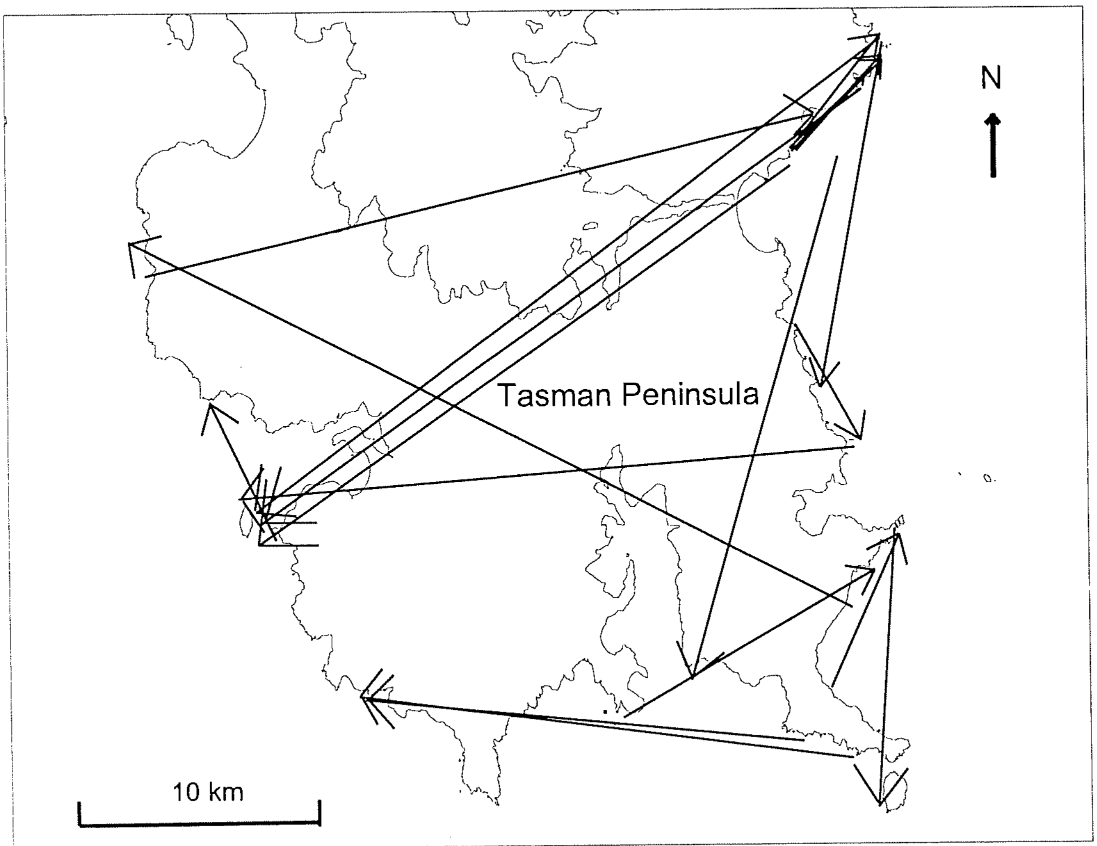


Fig. 6.35 Movement of banded morwong > 5 km in the Tasman Peninsula region

Striped trumpeter

A total of 535 striped trumpeter were tagged during the study, 102 of which were double tagged. By January 1998, 39 recaptures, representing 7.3% of the number tagged had been reported. The length frequency distribution of tagged fish was multi-modal, reflecting growth in a single cohort and the timing of tagging, whereas recaptures were predominantly greater than 37 cm, largely reflecting length based selectivity of gillnets and hooks used by commercial and recreational fishers (Fig. 6.36). Of the recaptures, 9 were double tagged fish, representing 8.8% of the number double tagged, and tag loss was reported in 3 recaptures, representing 33% of double tagged recaptures.

Overall, 74% of striped trumpeter were recaptured within 5 km of the tagging site (Fig 6.37). The maximum distance moved was 25.5 km with an average distance moved of 4.5 km. Time at liberty ranged from between 76 and 763 days and averaged 296 days. The average distance moved tended to increase as the time at liberty increased, although sample sizes were limited (Fig. 6.38). The distance that recaptured striped trumpeter had moved from the site of release was examined by 5 cm size classes and was greatest in the 45.0 - 49.9 cm size class, although sample sizes are generally low (Table 6.19). Insufficient recaptures were sexed to determine whether the distance moved was influenced by sex. Movements that were greater than 5 km are shown in Fig. 6.39. No pattern was observed in the movement of striped trumpeter, although interestingly two individuals (42 and 45 cm) were captured offshore on deeper water reefs.

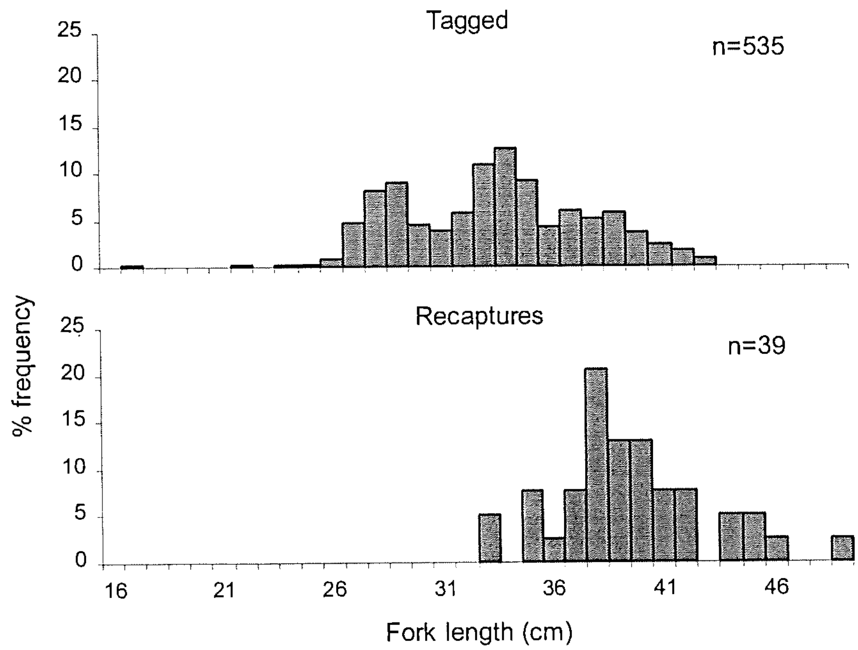


Fig. 6.36. Length frequency of striped trumpeter tagged (top) and recaptured (bottom)

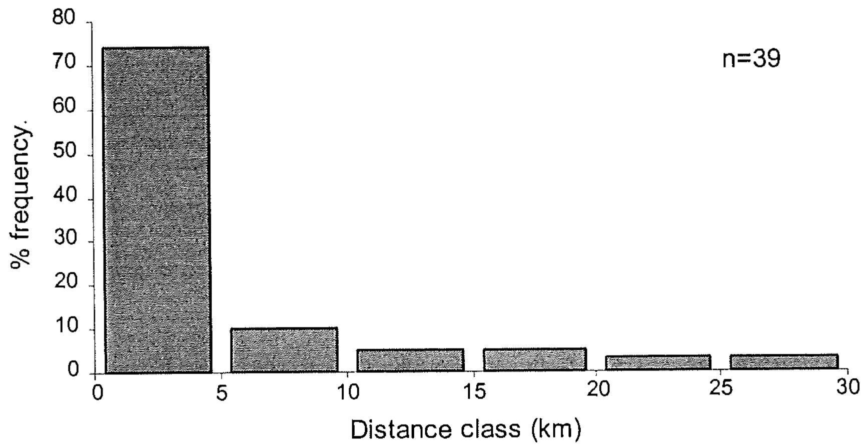


Fig. 6.37 Percentage frequency of distances moved by recaptured striped trumpeter, by 5 km distance classes

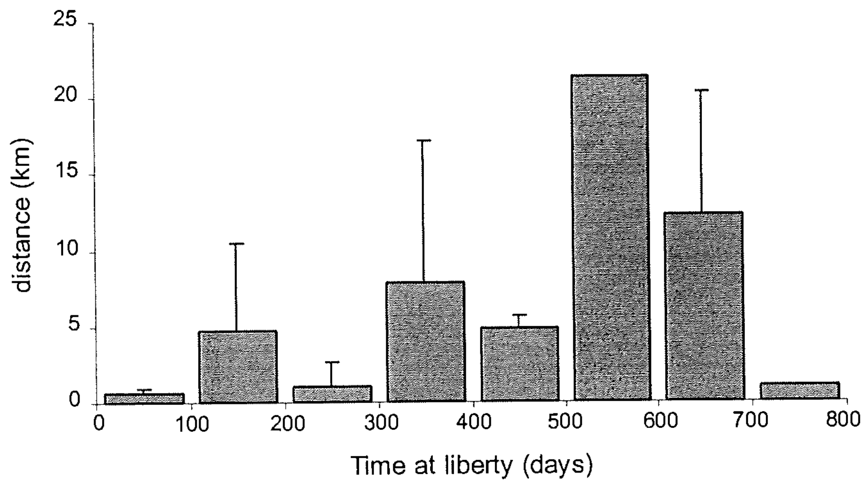


Fig. 6.38 Average distances moved by time for recaptured striped trumpeter. Error bars (1 s.d.) are shown where n>1.

Table 6.19. Distance moved by recaptured striped trumpeter, by length class

		Movement (km)		*n*
Length class (cm)	Average	Minimum	Maximum	
30.0 - 34.9	3.9	3.9	3.9	2
35.0 - 39.9	4.2	0.4	25.5	20
40.0 - 44.9	2.9	0.0	11.7	13
45.0 - 49.9	11.7	1.0	21.4	4
Total	4.5	0.0	25.5	39

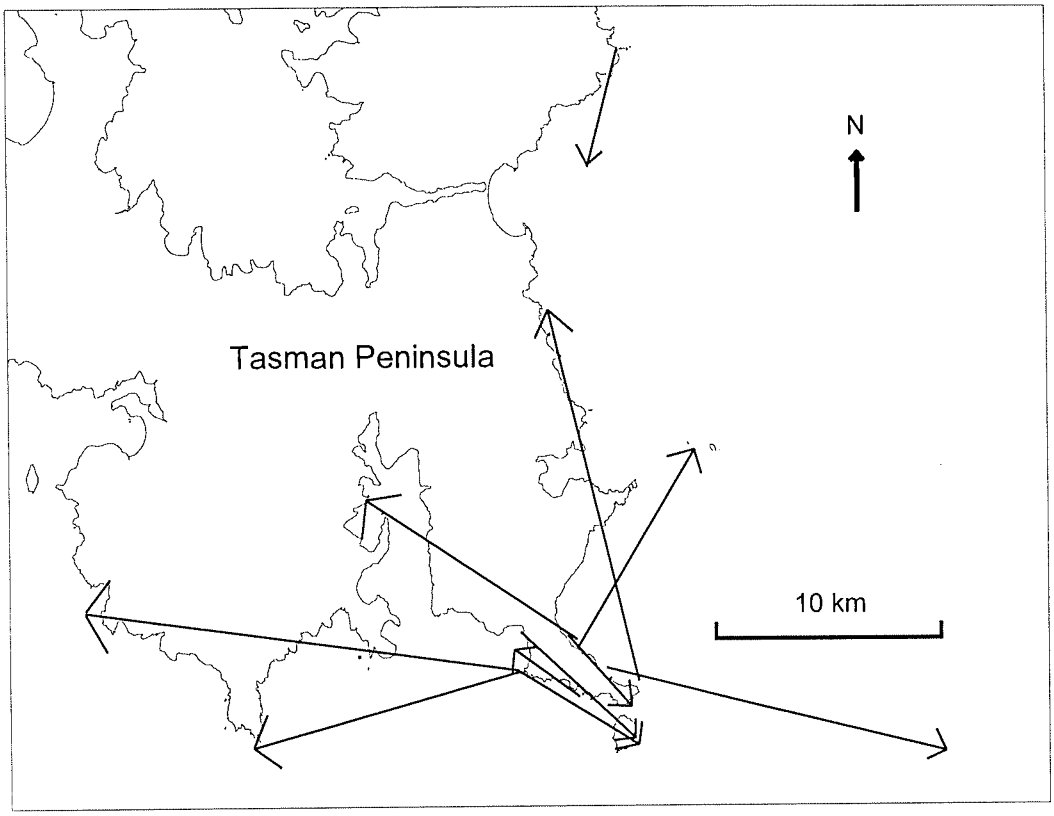


Fig. 6.39. Movement of striped trumpeter where distance moved is ≥ 5 km

Bastard trumpeter

A total of 1122 bastard trumpeter were tagged, of which 705 were double tagged and 752 injected with OTC. By January 1998, 73 recaptures had been reported, representing a recapture rate of 6.5%. The length frequency distribution of tagged fish was multi-modal, largely reflecting the selectivity characteristics of the 89 and 105 mm mesh nets (Fig. 6.40). The distribution of bastard trumpeter recaptures had modes at 31, 33 and 35 cm, reflecting a length conversion from '12, 13 and 14 inches', respectively; recreational fishers tending to describe length of recaptures in imperial measurements. Of the bastard trumpeter recaptured, 51 had been injected with OTC, representing 6.8% of the number injected with OTC and 54 were double-tagged, representing 7.7% of the number double tagged. Tag loss was reported in just 4 fish, representing 7.4% of double tagged recaptures.

Overall, 72% of bastard trumpeter were recaptured within 5 km of the tagging site and 88% within 10 km (Fig 6.41). The maximum distance moved was 143.5 km with an average distance moved of 6.9 km. Time at liberty ranged from between 1 and 758 days and averaged 256 days. There was no obvious trend between average distance moved and time at liberty (Fig. 6.42). The distance that recaptured bastard trumpeter had moved from the site of release was examined by 5 cm size classes and was greatest in the 40.0 - 44.9 cm size class (Table 6.20). However, this result was heavily influenced by a single fish which moved over 140 km. Insufficient recaptures were sexed to determine whether the distance moved was influenced by sex.

Movements of 5 to 30 km are shown in Fig. 6.43. The data suggests that there was a general movement of tagged fish from the southern entrance of Port Arthur into the embayment and from Monroes Bight into Fortescue Bay. However, interpretation of this data is complicated by the distribution and intensity of fishing effort, especially recreational gillnetting which is known to be high in Port Arthur and Fortescue Bay. Movements that were greater than 30 km are shown in Fig. 6.44. No bastard trumpeter were recaptured in offshore waters but this may reflect low effort targeting this species in these areas.

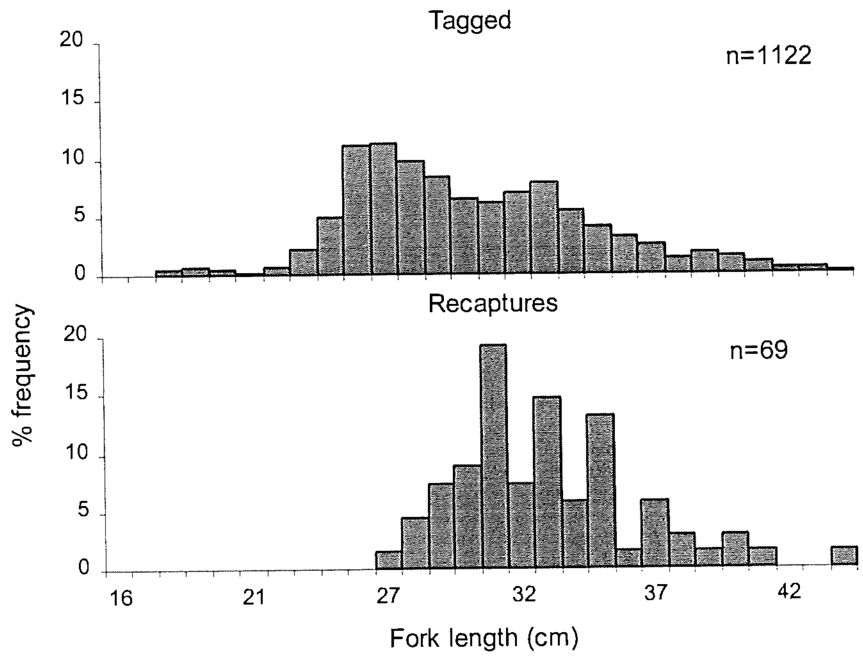


Fig. 6.40. Length frequency of bastard trumpeter tagged (top) and recaptured (bottom)

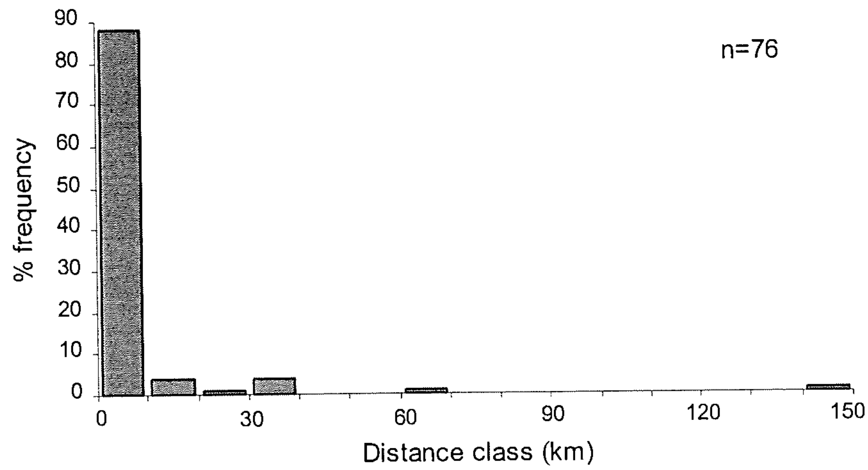


Fig. 6.41 Percentage frequency of distances moved by recaptured bastard trumpeter, by 10 km distance classes

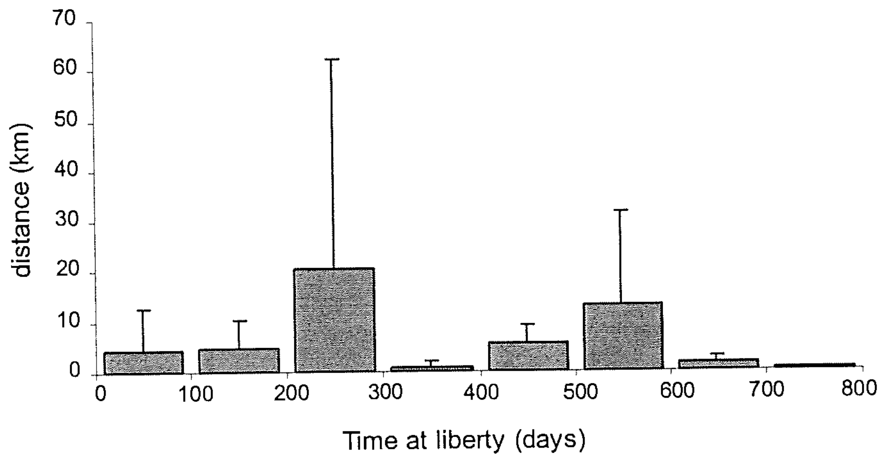


Fig. 6.42. Average distances moved by time for recaptured bastard trumpeter. Error bars (1s.d.) are shown where n>1.

Table 6.20. Distance moved by recaptured bastard trumpeter, by length class

	Movement (km)			*n*
Length class (cm)	Average	Minimum	Maximum	
25.0 - 29.9	4.6	0.2	11.5	9
30.0 - 34.9	5.3	0.0	38.9	38
35.0 - 39.9	2.0	0.0	7.8	17
40.0 - 44.9	37.5	1.1	143.5	4
size unknown	12.1	0.0	62.4	8
Total	6.9	0.0	143.5	76

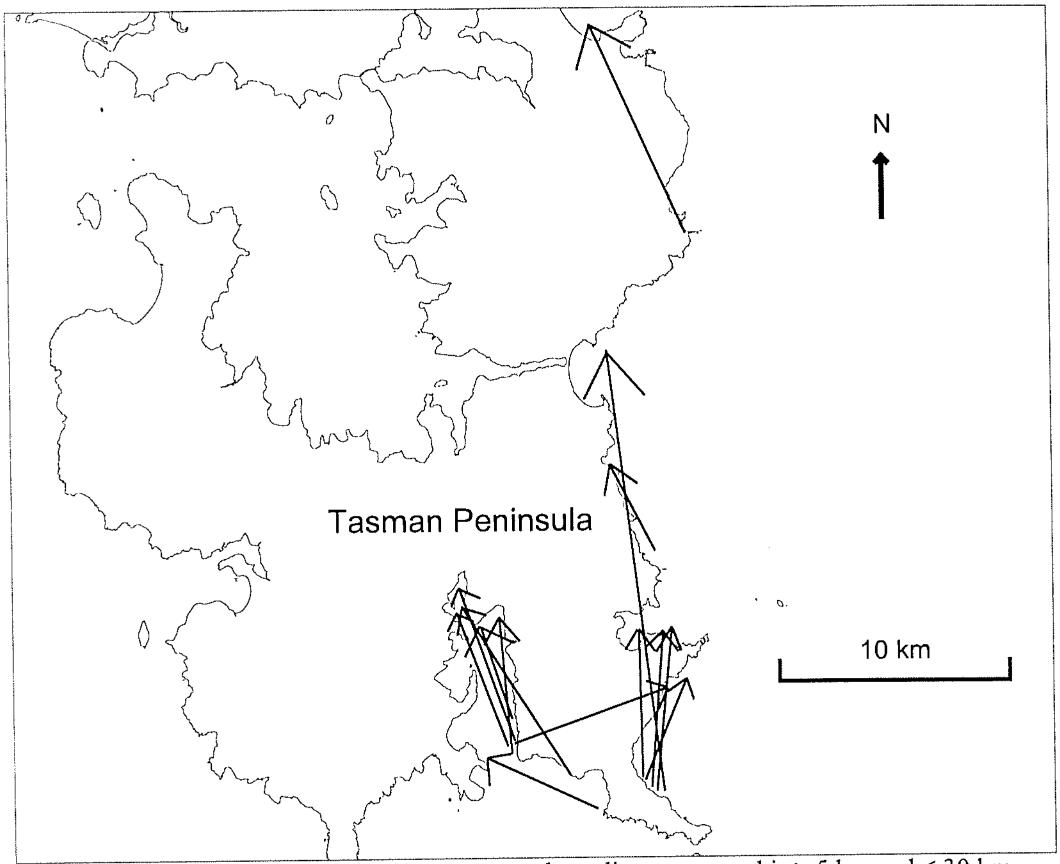


Fig. 6.43. Movement of bastard trumpeter where distance moved is > 5 km and ≤ 30 km

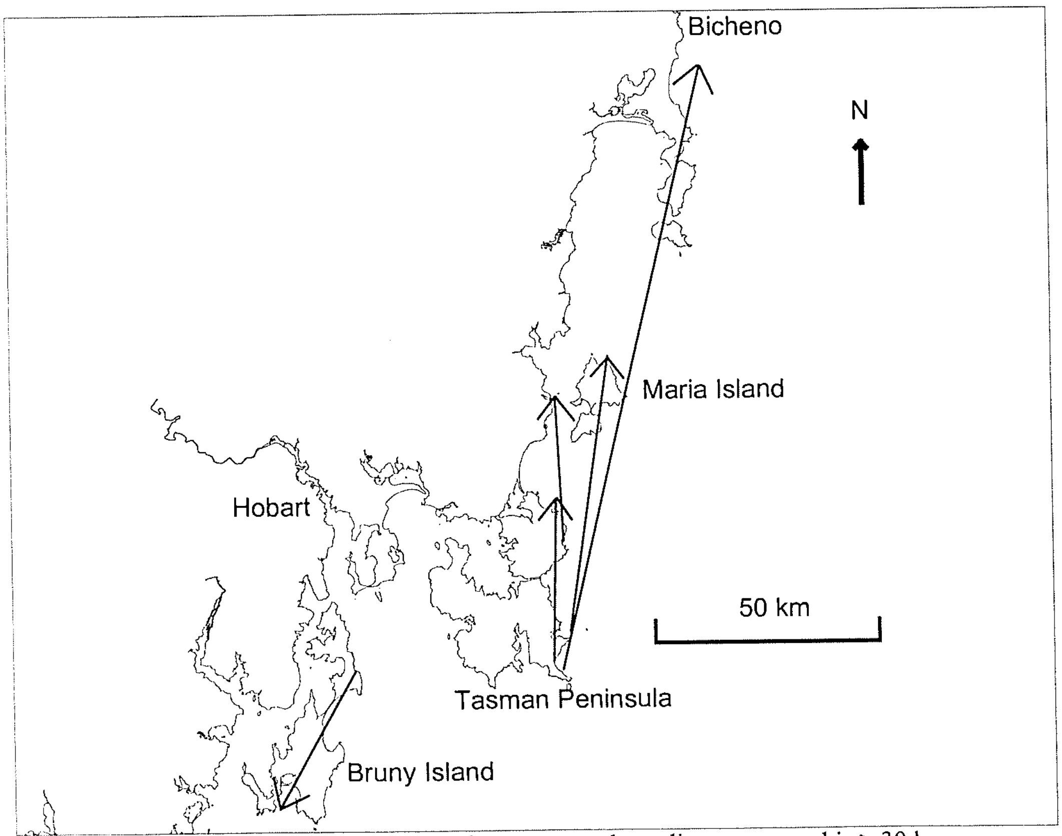


Fig. 6.44. Movement of bastard trumpeter where distance moved is > 30 km

6.5 Age and growth

Banded morwong

Morphometric relationships

The constants *a* and *b* in the length-weight relationship (Eqn. 7) for banded morwong are shown in Table 6.21. There were significant differences in the relationships between males and spawning females ($P<0.001$), males and non-spawning females ($P<0.01$) and between spawning and non-spawning females ($P<0.001$), indicating that both sex and gonad development (in females) influences the length-weight relationship. This result is not unexpected given that developed ovaries can account for up to 20% of body weight during spawning (refer section 6.6). The length-weight relationships for spawning females were not significantly different between Bicheno and the Tasman Peninsula region. By contrast, there was a significant area effect ($P<0.001$) on the length-weight relationship for males, with males of a given length heavier on average from Bicheno than from the Tasman Peninsula.

Parameters of the total length-fork length equation (Eqn. 6) for banded morwong were a = 1.080, b = 1.0678 (n=481, r^2=0.988), where length is measured in millimetres.

Table 6.21 Length-weight relationships of banded morwong. *a* and *b* are constants in the equation $W=aL^b$ (L in cm and W in g); r^2=coefficient of determination; *n*=sample size

	a	*b*	r^2	*n*
All - pooled	0.03494	2.8807	0.959	995
Females - spawning	0.03292	2.9020	0.963	639
Females - non - spawning	0.03714	2.8465	0.934	116
Males - pooled	0.03012	2.9118	0.981	356
Males-Bicheno	0.03179	2.9009	0.982	175
Males-Tasman Peninsula	0.03093	2.9009	0.982	181

Ageing

When viewed under transmitted light, most sectioned banded morwong otoliths display a relatively large central opaque area which extends outwards from around the primordium to the region designated as the first annuli. The optical properties of the otolith around the first 1 to 4 annuli are often inconsistent. The narrower, winter zones are opaque in some parts and translucent in others. However, these zones are easily distinguished relative to adjacent zones by their narrow width and the distinct scalloping that occurs where the annuli meet the distal surface of the otolith (Fig. 6.45). After the first 4 annuli, the structure of the otolith is unambiguous consisting of narrow opaque zones alternating with relatively broader translucent zones.

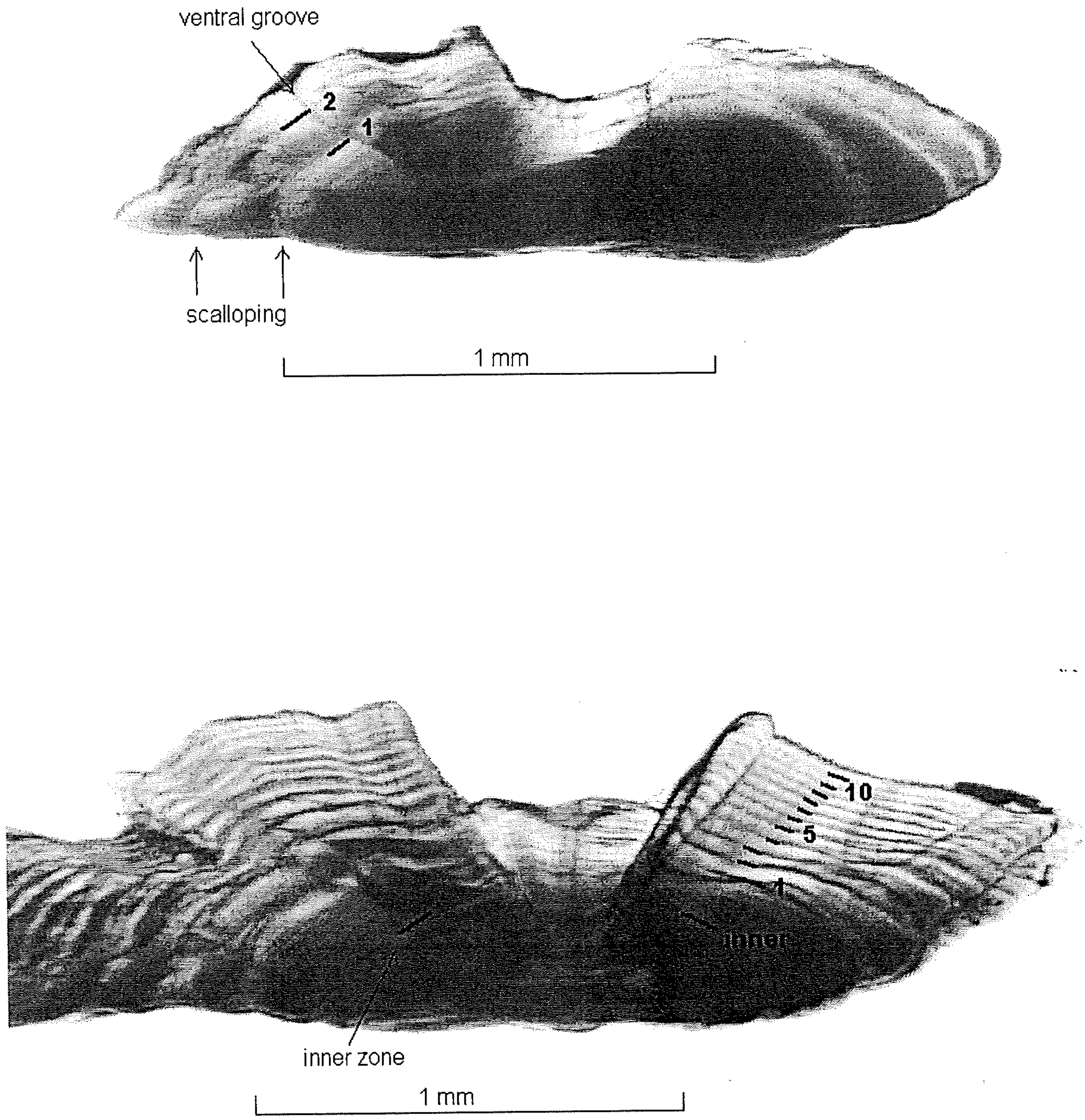


Fig. 6.45 Sections of banded morwong otoliths showing scalloping on distal surface, the ventral groove and 2 annuli (top), and, the inner zone and 11 annuli (bottom)

Since otoliths used to determine length at age data were all collected in March and April it was assumed that the last zone was always translucent, representing summer growth. Therefore opaque regions on the very edge of a section otolith were interpreted as being an artefact of sectioning and not the commencement of another annuli.

A translucent zone, termed the *inner zone*, was visible within the central opaque area on a small proportion (5.5%) of sectioned otoliths and usually where the central opaque area is more translucent, possibly due to section thickness. This inner zone cannot be confused with the first annuli since, unlike the first annuli, the inner zone does not touch or form scalloping on the distal surface of the otolith but instead forms an ellipse around the primordium. The mean and standard deviation of the distance from the primordium to the inner zone and the first and second annuli are 334 ± 24 µm (n=12), 606 ± 55 µm (n=456) and 730 ± 64 µm (n=449), respectively, which are all significantly different (P<0.001). The first annuli was interpreted to represent the beginning of the second winter. Therefore, for samples collected during March and April, an age class of 2+ is assigned when a single annuli is counted on the otolith, 3+ for 2 annuli, 4+ for 3 annuli, and so on.

In terms of ageing accuracy, no bias in readings was detected for either the primary or secondary reader and agreement between readers was very high. The distribution of differences for second readings (initial reading minus second reading) had a mode of 0 for both the main and secondary reader (Fig. 6.46) with 60% of readings being identical for the main reader and 53% for the secondary reader. Most differences between readings occurred in older otoliths. The index of APE was 0.97% for the main reader and 1.27% for the secondary reader. The main reader tended to estimate slightly lower ages for the second reading whereas estimated ages of the secondary reader were slightly higher than the initial reading by the main reader.

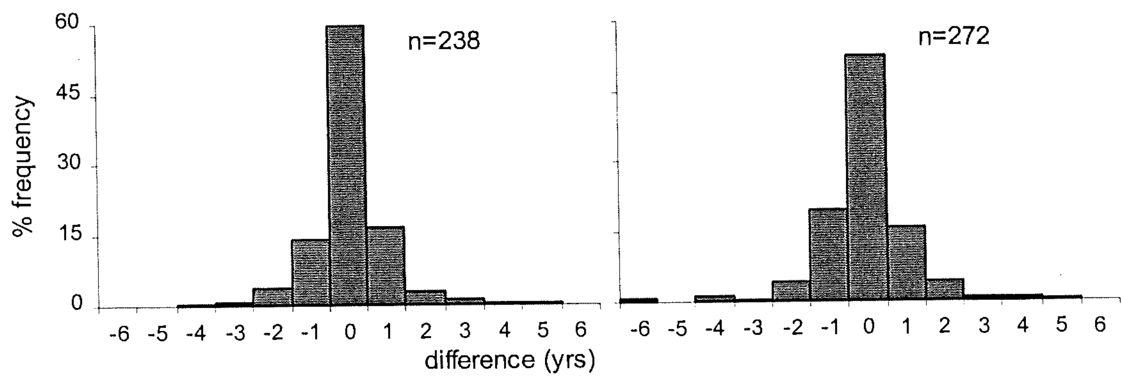


Fig.6.46. Distribution of differences in estimated ages for second readings of banded morwong otoliths by the main reader (left) and a second reader (right).

Validation

Otoliths were obtained from 94 banded morwong that had been injected with OTC between 43 and 731 days prior to recapture. One banded morwong was recaptured after exactly two years at liberty and 25 were recaptured after at least one year. Otolith sections from 71 fish that had been injected with OTC between 204 and 731 days prior to recapture were viewed under blue-violet light. Fluorescent marks were observed in 22 (31%) of the otoliths. Specimens in which a clear fluorescent mark was visible ranged in estimated age from 4 to 62 years and all were recaptured after at least one year at liberty. The position of the OTC mark in relation to the opaque and translucent zones indicated that annuli are formed not more than once a year, in both small and large otoliths of both sexes (Fig. 6.47). The translucent zone is predominantly formed in summer, between January and April. All fish showing a fluorescent mark that were tagged outside of these months showed a mark coincident with the opaque zone, indicating that otolith growth is minimal during this time. The single recapture that was at liberty for exactly two years was tagged in January 1995 and recaptured in January 1997. The position of the fluorescent mark was clearly visible just on the outside of the second-most outer opaque zone (winter 1994 growth) that was visible. Presumably the margin of the otolith consisted of a narrow, opaque zone representing winter growth in 1996 (and possibly the start of another translucent zone) but this could not be confirmed on the section. Because of the difficulty of interpreting the structure at the very margin of sectioned banded morwong otoliths it will be necessary to examine recaptures at liberty for greater than 2 years before conclusively showing that annuli are formed annually (*c.f.* not more than once a year, as above). No fluorescent marks were observed in 64% of specimens at liberty for greater than one year, indicating that the rate of incorporation of OTC into the banded morwong otolith is low at dosages of 50 mg/kg.

Length at age

The mean length at age for banded morwong, by sex and region, is shown in Table 6.22. For female banded morwong, age estimates ranged from 2 yrs for a 25.8 cm fish to 86 yrs for a 46.8 cm fish. The largest female was 49.6 cm and was aged at 47 yrs. Age estimates for male banded morwong ranged from 2 yrs for a 23.9 cm fish to 81 yrs for a 52.8 cm fish. The largest male was 55.2 cm and was aged at 62 yrs. Age length keys for the combined 1996 and 1997 samples, for females and males, are shown in Tables 6.23 and 6.24.

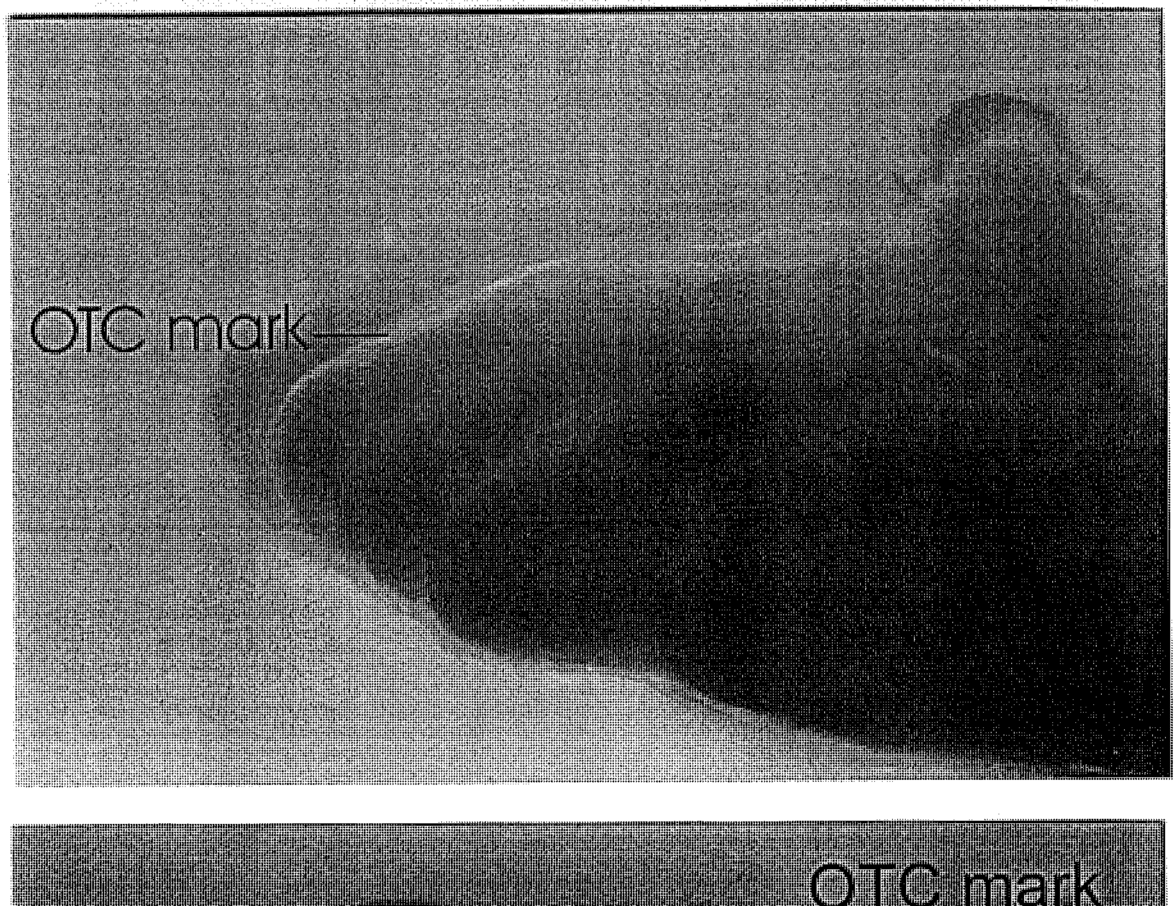


Fig. 6.47. Oxytetracycline mark in otolith from fish aged 5 years (top), at liberty for 424 days tagged May 96 and recaptured August 97, and aged 25 years (bottom), at liberty for 560 days tagged Nov 95 and recaptured May 97

Table 6.22. Mean length (cm) at age (yrs) for banded morwong by sex and by region. Standard deviation of mean length (s.d) and sample size (*n*) are shown.

	Female									Male								
	All regions			Bicheno			Tasman			All regions			Bicheno			Tasman		
Age (yrs)	L	s.d.	*n*	L	s.d.	*n*	L	s.d.	*n*	L	s.d.	*n*	L	s.d.	*n*	L	s.d.	*n*
2	25.80		1				25.80		1	25.90	1.70	4	28.00		1	25.20	1.18	3
3	29.53	2.01	9	31.07	1.51	6	26.47	0.90	3	31.37	2.26	16	32.72	1.31	10	29.12	1.57	6
4	33.56	1.77	45	34.27	1.60	24	32.75	2.16	21	34.29	1.82	38	34.75	1.60	25	33.42	1.95	13
5	34.88	2.13	55	35.78	2.04	11	34.66	1.64	44	36.38	1.73	83	37.52	1.20	29	35.77	1.67	54
6	35.96	2.79	26	37.25	1.69	13	34.67	1.72	13	37.49	2.51	26	40.06	1.70	10	35.89	1.29	16
7	35.22	2.85	9	37.08	1.49	4	33.74	2.77	5	39.60	1.89	11	39.88	2.26	6	39.26	1.51	5
8	37.18	1.29	12	37.18	1.47	7	36.32	1.35	5	42.53	2.31	12	43.10	2.53	4	42.54	2.38	8
9	37.15	1.46	17	37.97	1.39	6	36.71	1.85	11	42.53	1.67	12	43.10	2.03	5	42.13	1.38	7
10	39.12	1.70	10	40.50	1.06	4	38.20	0.78	6	44.55	2.80	6	45.10	2.74	5	41.80		1
11	39.23	1.80	10	39.73	1.16	8	37.25	2.62	2	47.00	2.80	8	47.20	3.05	5	46.67	2.93	3
12	40.19	2.34	10	41.52	1.39	5	38.86	0.95	5	46.57	1.00	9	47.38	0.39	4	45.92	0.84	5
13	39.10	1.12	9	40.00	2.23	6	37.30	1.47	3	47.60	2.19	12	47.97	2.04	9	46.50	2.72	3
14	40.41	1.43	8	40.42	1.20	6	40.40	1.27	2	47.37	2.65	7	51.50		1	46.68	2.11	6
15	40.85	1.71	11	41.20	1.49	8	39.90	0.78	3	49.38	2.72	4	50.00	2.95	3	47.50		1
16	40.62	1.41	9	41.52	1.16	6	38.83	1.07	3	49.69	2.25	9	49.51	2.49	7	50.30	1.56	2
17	39.78	2.09	17	40.07	1.06	9	39.46	1.74	8	49.13	2.46	4	50.17	1.59	3	46.00		1
18	40.13	1.28	23	40.86	1.80	14	39.01	2.11	9	49.80	1.96	8	50.38	1.35	5	48.83	2.75	3
19	40.64	2.33	18	40.91	1.34	7	40.47	1.27	11	50.30	2.22	6	50.97	3.10	3	49.63	1.19	3
20-24	41.14	2.18	53	42.03	1.95	29	40.07	1.99	24	50.36	1.79	22	50.40	1.83	5	50.35	1.83	17
25-29	41.51	1.96	53	41.81	1.83	34	40.97	2.12	19	50.70	2.02	12	50.12	2.49	5	51.11	1.69	7
30-34	42.27	2.41	44	42.28	2.14	22	42.27	2.70	22	51.09	3.36	11	50.89	2.76	8	51.63	5.40	3
35-39	42.57	2.15	32	42.72	2.23	23	42.19	1.98	9	50.43	1.81	6	50.28	2.29	4	50.75	0.49	2
40-44	42.87	1.49	38	42.92	1.46	28	42.73	1.66	10	49.23	3.10	7	49.00	3.33	6	50.60		1
45-49	43.88	2.46	20	44.85	1.83	13	42.07	2.58	7	54.20		1	54.20		1			
50-54	43.36	2.68	20	43.21	2.55	15	43.80	3.34	5									
55-59	43.51	1.63	26	43.64	1.60	19	43.14	1.79	7	49.40	3.76	3	45.50		1	51.35	2.33	2
60-64	43.84	2.26	11	44.16	1.64	8	42.97	3.82	3	55.20		1				55.20		1
65-69	42.65	1.50	6	42.65	1.79	4	42.65	3.04	2	50.30	1.69	3	50.40	2.26	2	50.10		1
70-74	44.12	2.66	10	44.68	2.86	6	43.28	2.45	4									
75-79	44.03	2.05	3	42.90	0.85	2	46.30		1									
80-84	43.13	2.80	3	39.90		1	44.75	0.21	2	51.55	1.77	2	51.55	1.77	2			
85-90	46.35	0.64	2	46.35	0.64	2												

Table 6.23. Age length key for female banded morwong

	age (yrs)																															
length (cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89
25	0.50	0.50																														
26																																
27		1.00																														
28		1.00																														
29			1.00																													
30		0.17	0.67			0.17																										
31		0.43	0.29	0.14		0.14																										
32		0.06	0.28	0.50	0.17																											
33			0.52	0.30	0.13	0.04																										
34			0.42	0.35	0.04	0.04	0.04	0.12																								
35			0.17	0.43	0.17	0.03	0.03	0.07		0.03		0.03					0.03															
36			0.05	0.52	0.14	0.05	0.14	0.10																								
37			0.08	0.05	0.16	0.03	0.08	0.03	0.05	0.03	0.03	0.05			0.03	0.08	0.03		0.14	0.05	0.03			0.03	0.03							
38				0.04	0.09	0.04	0.06	0.15	0.04	0.02	0.02	0.02			0.02	0.04	0.09	0.02	0.09	0.11	0.06	0.06			0.02							
39				0.02	0.02		0.02	0.04	0.06	0.06	0.06	0.02	0.08	0.06	0.02	0.06	0.09	0.08	0.11	0.09	0.08	0.02	0.02								0.02	
40									0.01	0.04	0.03	0.01	0.01	0.05	0.01	0.08	0.05	0.11	0.14	0.11	0.07	0.05	0.05	0.01	0.03	0.04	0.01	0.03	0.03			
41									0.03	0.02	0.03		0.05	0.02	0.05	0.05	0.05	0.03	0.16	0.10	0.13	0.08	0.08	0.02	0.02	0.05	0.03		0.02			
42												0.04		0.04	0.04		0.06	0.04	0.08	0.27	0.12	0.04	0.15	0.02	0.02	0.04	0.00	0.02	0.02	0.02		
43														0.02			0.03	0.02	0.14	0.15	0.09	0.09	0.14	0.06	0.08	0.11	0.05	0.02		0.02		
44											0.02								0.06	0.02	0.11	0.13	0.17	0.17	0.06	0.11	0.04	0.04	0.02		0.04	
45																			0.04	0.04	0.21	0.18	0.11	0.07	0.07	0.21			0.04			0.04
46																			0.09	0.09					0.18		0.18		0.27	0.09		0.09
47																								0.25	0.25		0.25		0.25			
48																					1.00											
49																								1.00								

Table 6.24. Age length key for male banded morwong

	age (yrs)																															
length (cm)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89
23	1.00																															
24																																
25	1.00																															
26	0.50	0.50																														
27																																
28	0.33	0.67																														
29		1.00																														
30			1.00																													
31		0.44	0.56																													
32		0.45	0.27	0.27																												
33			0.45	0.45	0.09																											
34		0.05	0.50	0.35	0.10																											
35		0.04	0.25	0.50	0.21																											
36			0.10	0.77	0.10	0.03																										
37			0.10	0.62	0.19	0.10																										
38			0.06	0.65	0.12	0.12	0.06																									
39				0.75	0.13	0.13																										
40					0.56	0.11	0.22	0.11																								
41					0.08	0.25	0.08	0.50	0.08																							
42					0.11	0.11	0.44	0.11	0.22																							
43							0.50	0.25		0.25																						
44								0.29		0.14	0.14	0.29	0.14																			
45								0.10	0.10	0.10	0.10		0.20								0.20		0.10		0.10							
46							0.07			0.14	0.14	0.14		0.07	0.07	0.07			0.07	0.07			0.14									
47							0.04		0.08	0.04	0.21	0.17	0.04	0.04	0.04		0.08	0.04	0.13		0.04	0.04										
48												0.13	0.13		0.13	0.13	0.13	0.13		0.13							0.13					
49												0.09			0.27			0.09	0.09	0.18		0.09			0.09						0.09	
50										0.05		0.05		0.05		0.05	0.09		0.41	0.09		0.05	0.09				0.05			0.05		
51													0.06		0.06	0.06	0.12	0.12	0.24	0.18	0.06	0.06	0.06									
52										0.06		0.06		0.06	0.06		0.06		0.24		0.24	0.12					0.06			0.06		
53															0.13			0.13		0.38	0.13		0.13		0.13							
54																					0.50			0.50								
55																					0.50					0.50						

Fig. 6.48 shows length at age data and fitted von Bertalanffy growth curves for female and male banded morwong from both regions combined. The difference in growth patterns between the sexes is obvious. ARSS (Eqn. 9) (Chen *et. al.* 1992) showed significant differences in growth curves between females and males (P<0.001) and significant differences between regions for each sex (P<0.001). Table 6.25 shows the calculated von Bertalanffy parameters and their standard errors for each sex, by region and for regions combined. Males grow to larger sizes and at a faster rate than females. L_∞ values were 43.2 cm for females and 51.2 cm for males, values for each sex being very similar for the regions. However, the parameter K was greater for both females and males from the Bicheno region, indicating that banded morwong grow faster towards L_∞ in the Bicheno region compared with the Tasman Peninsula region.

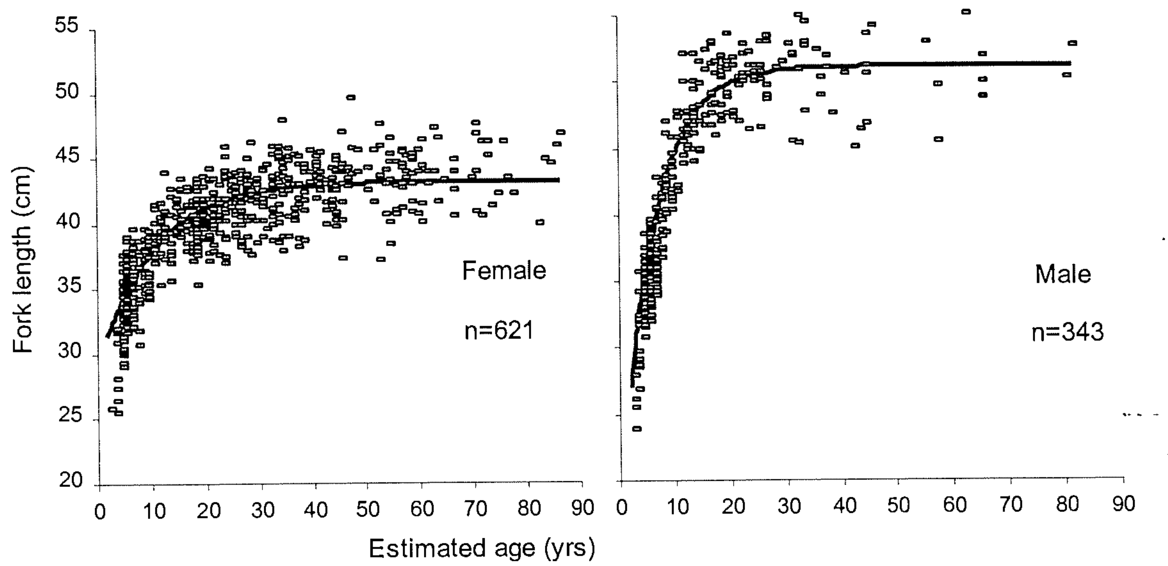


Fig. 6.48. Length at age data and fitted von Bertalanffy growth curves for female and male banded morwong

Table 6.25. von Bertalanffy growth parameters and their standard errors (in parenthesis) of banded morwong by sex and region from otolith ring counts

		$L\infty$ (cm)		K		t_0		n
Female	All	43.2	(0.2)	0.098	(0.007)	-11.3	(1.1)	621
	Bicheno	43.2	(0.2)	0.113	(0.010)	-10.0	(1.3)	350
	Tasman	43.1	(0.4)	0.082	(0.009)	-13.7	(1.9)	271
Male	All	51.2	(0.3)	0.161	(0.008)	-2.7	(0.3)	343
	Bicheno	50.9	(0.3)	0.178	(0.012)	-2.5	(0.4)	169
	Tasman	51.6	(0.4)	0.149	(0.009)	-2.8	(0.4)	174

Plots of fork length against otolith weight for both sexes show a non-linear relationship with the otolith continuing to increase in mass while growth occurs asymptotically (Fig. 6.49). Plots of otolith weight against estimated age for both sexes indicate a slight curvi-linear relationship, the relationship appearing curved in very young age classes (Fig. 6.50). Residuals in otolith weight-age plots increased with age for both sexes, the lack of linearity presumably due to changes in growth rates of both somatic and otolith growth.

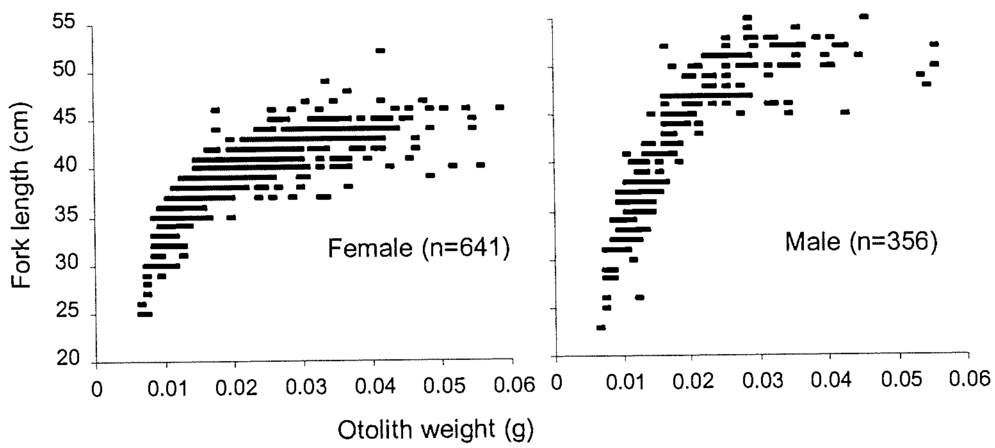


Fig. 6.49. Fork length versus otolith weight for banded morwong

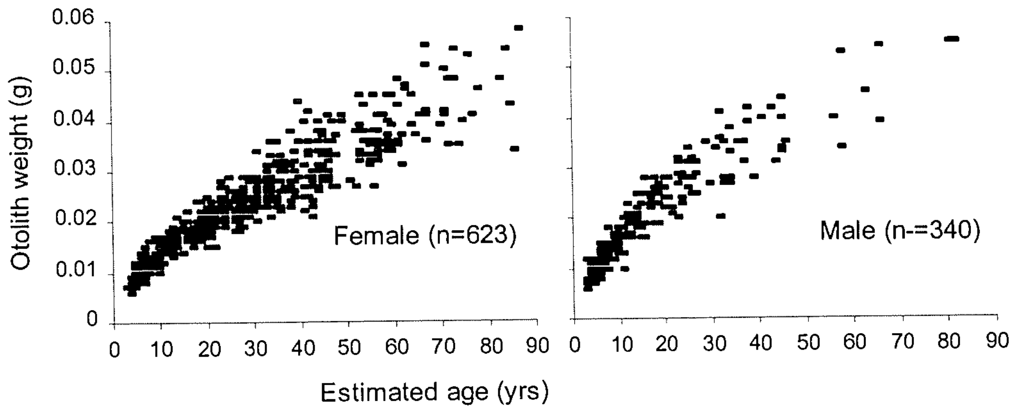


Fig. 6.50. Otolith weight versus age for banded morwong

Tag-recapture

A total of 142 banded morwong where the sex was known (49 female and 93 male; all recaptures ≥ 48 cm were considered to be male) were recaptured greater than 200 days after tagging. These recaptures were included in analysis of growth from tag-recapture data. The von Bertalanffy parameters and their standard errors, in parentheses, derived from Fabens parameterisation of tag recapture data, were 41.6 cm (1.14) and 0.134 (0.032) for females and 55.2 cm (1.64) and 0.092 (0.017) for L_∞ and K, respectively. For females, L_∞ was estimated to be considerably lower than the maximum size presumably because the number of recaptures in the larger size classes, where sex was known, was low. In contrast, L_∞ for males was close to the maximum size because all recaptures ≥ 48 cm were consider to be male resulting in a large number of recaptures that were near the maximum size for males. Von Bertalanffy parameters are, however, generally similar to those determined through examination of otoliths, but the standard errors are comparatively large when compared with otolith ageing.

Mortality

The age frequency distributions for the aged sample, the derived age frequency distributions from commercial catch sampling (based on length at age keys), and for the population after adjusting for selectivity (using mesh selectivity co-efficients for 133 mm mesh) are shown in Fig. 6.51. Regression lines were fitted to the natural logarithm of the frequency of each age class and were used to determine total mortality (Z). Estimated of Z for females were 0.026 (r^2=0.34) for the aged sample, 0.040 (r^2=0.50) from the commercial sample and 0.025 (r^2=0.31) from the population. For male banded morwong, total mortality was estimated as 0.064 (r^2=0.56) for the aged sample and 0.069 (r^2=0.53) from the commercial sample. However, a negative value of Z, -0.01, and a very low correlation coefficient (r^2=0.04) was obtained when the sample was adjusted for the effects of mesh selectivity.

Estimates of Z for lightly exploited stocks (actually an estimate of M, as $F \cong 0$) derived from the equation $\log_e Z = 1.46 - 1.01 \log_e t_{max}$ (Hoenig 1983), where t_{max} is the maximum age in years, gave values of 0.048 for females and 0.051 for males, where the maximum age for females and males is 86 and 81 years, respectively.

The age structure of the population suggests that approximately 1% of the virgin population (A_{max}) reaches an age of about 77 years for females and 65 years for males. Estimates of instantaneous natural mortality (M) derived from the equation $M = \log_e 100/A_{max}$ (Sparre *et. al.* 1989) were 0.059 for females and 0.071 for males.

Each of the above analyses suggest that natural mortality for banded morwong is very low and is probably around 0.05.

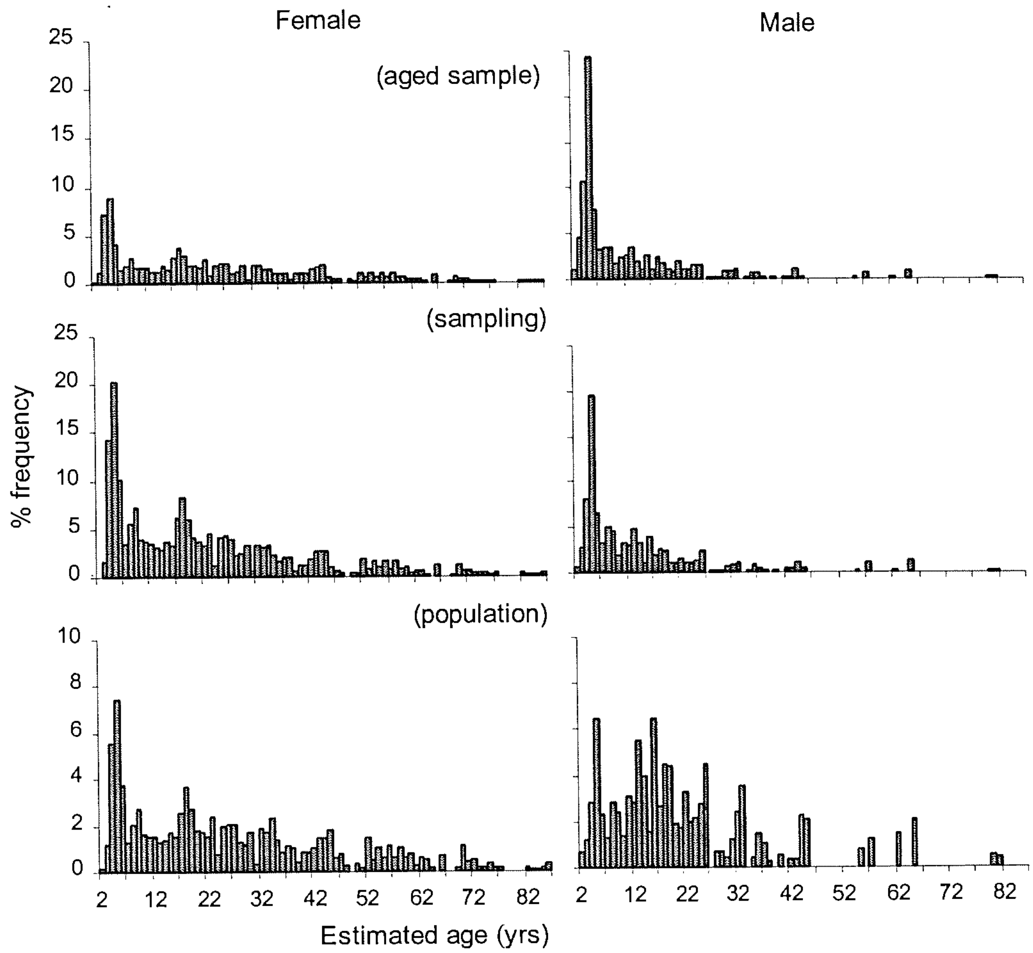


Fig. 6.51 Age frequency distribution of female and male banded morwong from east coast Tasmania for aged sample (top), commercial sampling (middle) and for the population after applying mesh selectivity co-efficients (bottom).

Trumpeters

Morphometric relationships

Parameters of the length-weight relationship (Eqn. 7) for striped trumpeter (≤ 45 cm) were calculated to be, $a = 0.0341$, $b = 2.7718$ ($n = 235$, $r^2 = 0.981$) and for bastard trumpeter (≤ 45 cm) the parameters were $a = 0.0112$, $b = 3.1419$ ($n = 194$, $r^2 = 0.957$).

Parameters of the total length-fork length equation (Eqn. 6) for striped trumpeter were $a = -7.84$, $b = 1.1322$ ($n = 134$, $r^2 = 0.970$) and for bastard trumpeter were $a = -3.37$, $b = 1.1589$ ($n = 96$, $r^2 = 0.996$).

Cohorts

During summer 1995, large recruitment pulses of both trumpeters were detected in gillnet sampling on inshore rocky reefs in south-eastern Tasmanian waters. It was assumed that cohorts were fish spawned in 1993, based on the results of growth observed in larval rearing trials of striped trumpeter (D. Morehead unpublished data). For striped trumpeter, there was very limited evidence of fish from older cohorts in the inshore catches throughout the survey period, although younger cohort (1994) was evident by late 1996 (Fig. 6.52). By contrast, a number of bastard trumpeter cohorts were represented in catches during the surveys (Fig. 6.53).

Growth of the 1993 cohort of either species was clearly evident over the study period (Fig. 6.52 and 6.53). The majority of growth occurred during the warmer period of each year between November and April, with little growth apparent between May and October.

Both species had a mean length of 19 cm in January 1995 (1.3 years old, based on a nominal birthdate of October 1993).

Growth in the striped trumpeter cohort was rapid, the mean length being 28 cm in May 1995 (1.7 years), 29 cm in November 1995 (2.1 years) and 38 cm in November 1996 (3.1 years). The cohort was still detectable, with a mean length of approximately 42 cm, in October 1997 (4 years). Another recruitment pulse of striped trumpeter, representing the 1994 cohort, was detected in 1996. Isolated specimens of this cohort were captured in May 1996 at approximately 27 cm and the cohort had a mean length of 30 cm in November 1996 (2.1 years) (*c.f.* 29 cm for the 1993 cohort in November 1995). The 1994 cohort was not detected earlier (*c.f.* Jan 1995 for the 1993 cohort) because the 64 mm mesh was not used after May 1995 and striped trumpeter below approximately 27 cm are not susceptible to capture in the 89 mm mesh, the smallest mesh size routinely used throughout the study (refer Fig. 6.24).

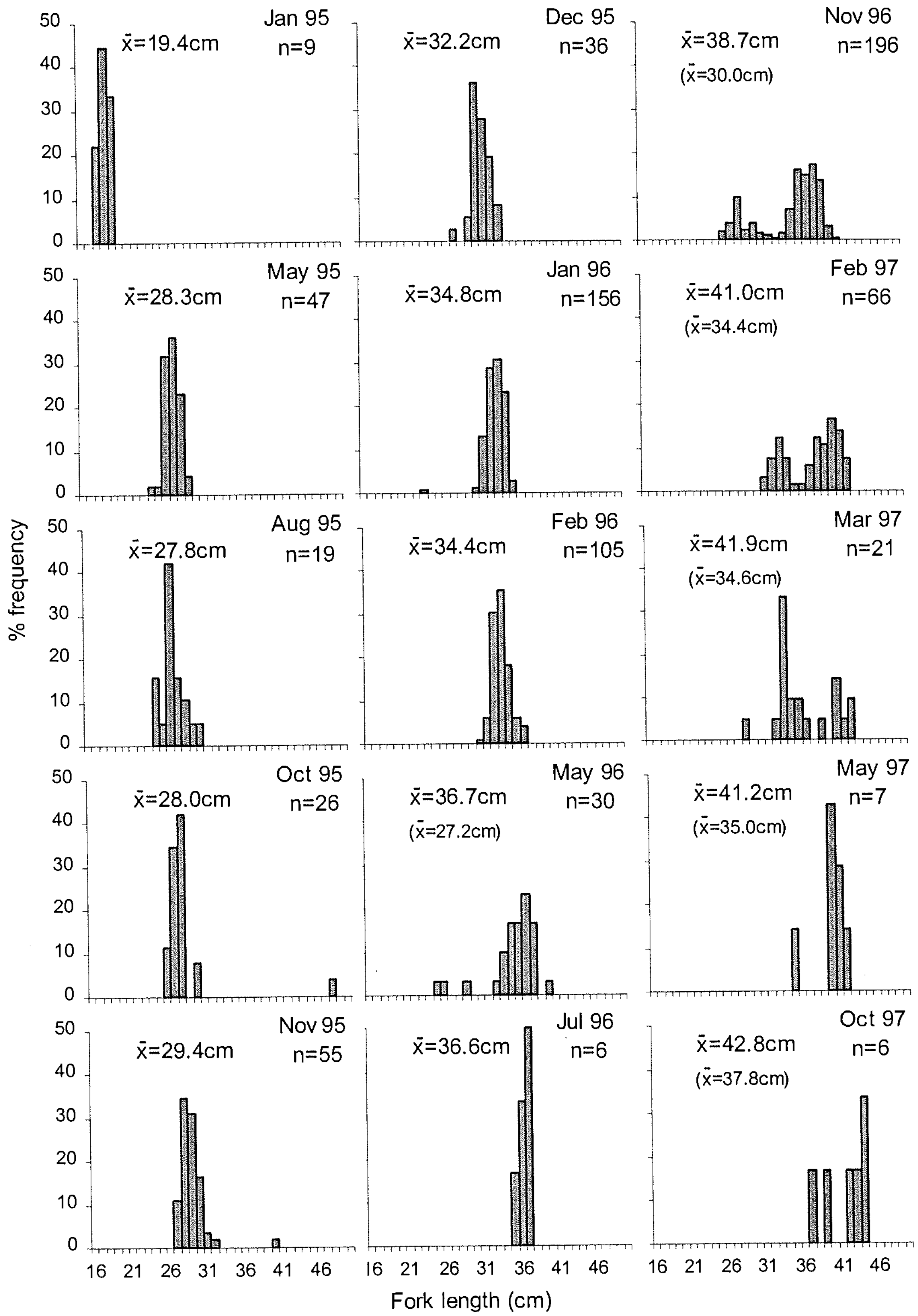


Fig. 6.52 Length frequency histogram of striped trumpeter by month from mesh selectivity study in south-eastern Tasmania. The mean length (cm) of the 1993 cohort is shown and the mean length of the 1994 cohort, May 96 onwards, is shown in parenthesis.

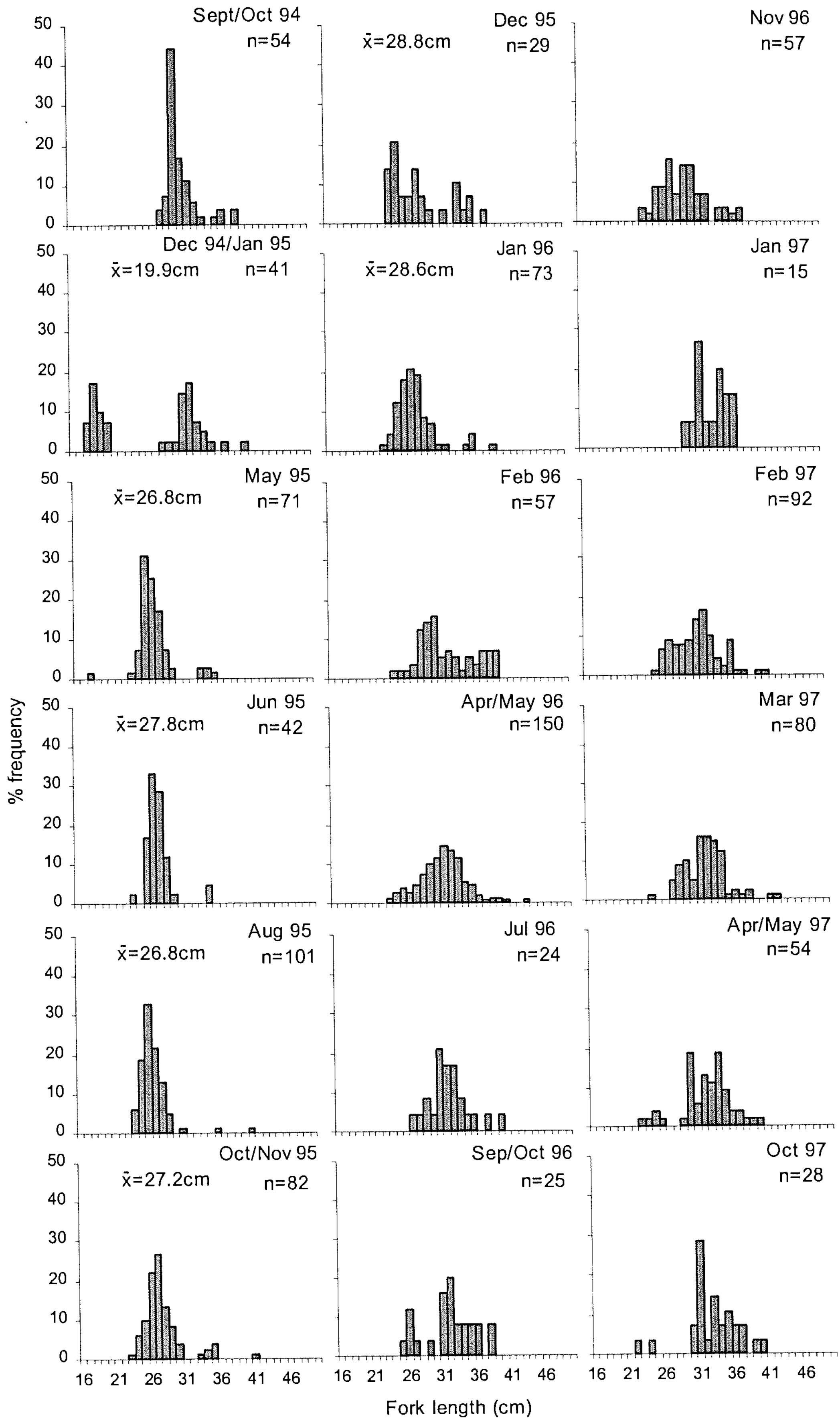


Fig. 6.53. Length frequency histogram of bastard trumpeter by month from mesh selectivity study

Observed growth rates were supported by tag-recapture data from these cohorts.

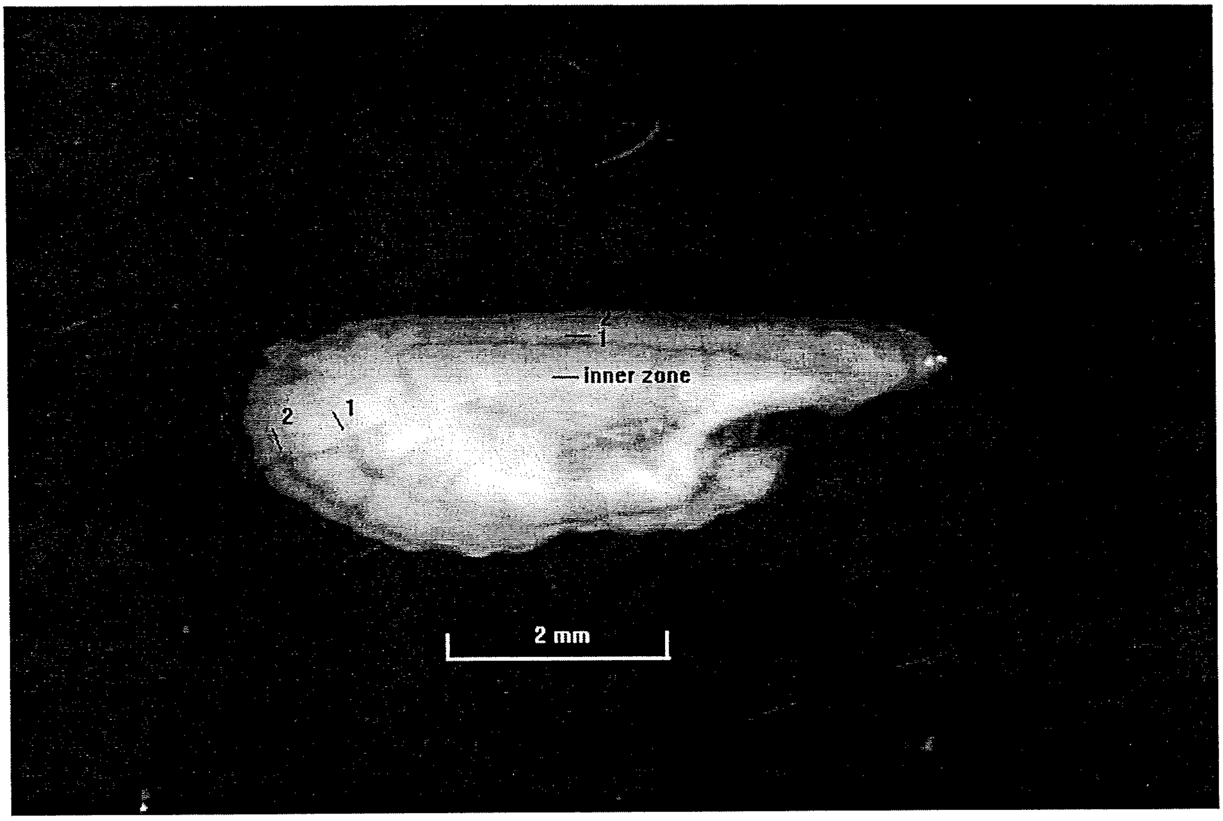
Initial growth of the 1993 bastard trumpeter cohort was rapid, attaining a mean length of 26 cm in May 1995 (1.7 years), 27 cm in October/November 1995 (2 years), and 28 cm in January 1996 (2.3 years). By April/May 1996, the modal length was 32 cm but by this time the cohort was merging with other age classes and was not readily be distinguishable based on modal analysis.

Tag-recaptures from the 1993 bastard trumpeter cohort had mean lengths of 33 cm (*n*=7) in March 1996 (2.5 years) and 34 cm (*n*=2) in March 1997 (3.5 years). One fish recaptured from the 1993 cohort was 40 cm in length by December 1997 (4.2 years) and another 37 cm by January 1998 (4.3 years). It is recognised that fish size will be skewed towards individuals that are selected for by the mesh sizes used in the inshore fishery, with slower growing fish being available to capture for a greater period than faster growing individuals.

Otoliths

Whole striped trumpeter and bastard trumpeter otoliths are very similar in general appearance, being ovate in shape (Fig. 6.54). When viewed under reflected light, trumpeter otoliths show a relatively large central opaque area that extends outwards from around the region of the primordium to the zone that is designated as the first annuli. The structure of the otolith after the first annuli consists of concentric (except at the excisural notch) narrow translucent zones alternating with relatively broader opaque zones. In otoliths of both species, where only the first 1 or 2 annuli are discernible, the first annuli are generally easiest to see on the ventral side of the otolith and the second annuli are easiest to see on either the rostrum or the ventral side. In otoliths where more than 2 annuli are discernible, the outer annuli are generally clearest on the rostrum or posterior end.

An inner translucent zone was visible within the central opaque area on 45 (18%) of whole striped trumpeter otoliths and 105 (59%) of whole bastard trumpeter otoliths. The distances from the primordium to the inner, the first and the second annuli, measured on the ventral side of the dorso-ventral axis, were significantly different ($P<0.001$) in both species. For striped trumpeter, the mean and standard deviation of the distances from the primordium to the inner zone, first and second annuli were 553 ± 60 μm (*n*=45), 858 ± 51 μm (*n*=216) and 1077 ± 75 μm (*n*=38), respectively. For bastard trumpeter, the equivalent distances were 576 ± 59 μm (*n*=105), 903 ± 79 μm (*n*=131) and 1155 ± 97 μm (*n*=46). Therefore the position of the first annuli and the inner zone should not be confused for either species. The inner zone was interpreted to represent either growth that occurred in the first winter of the fishes life (during



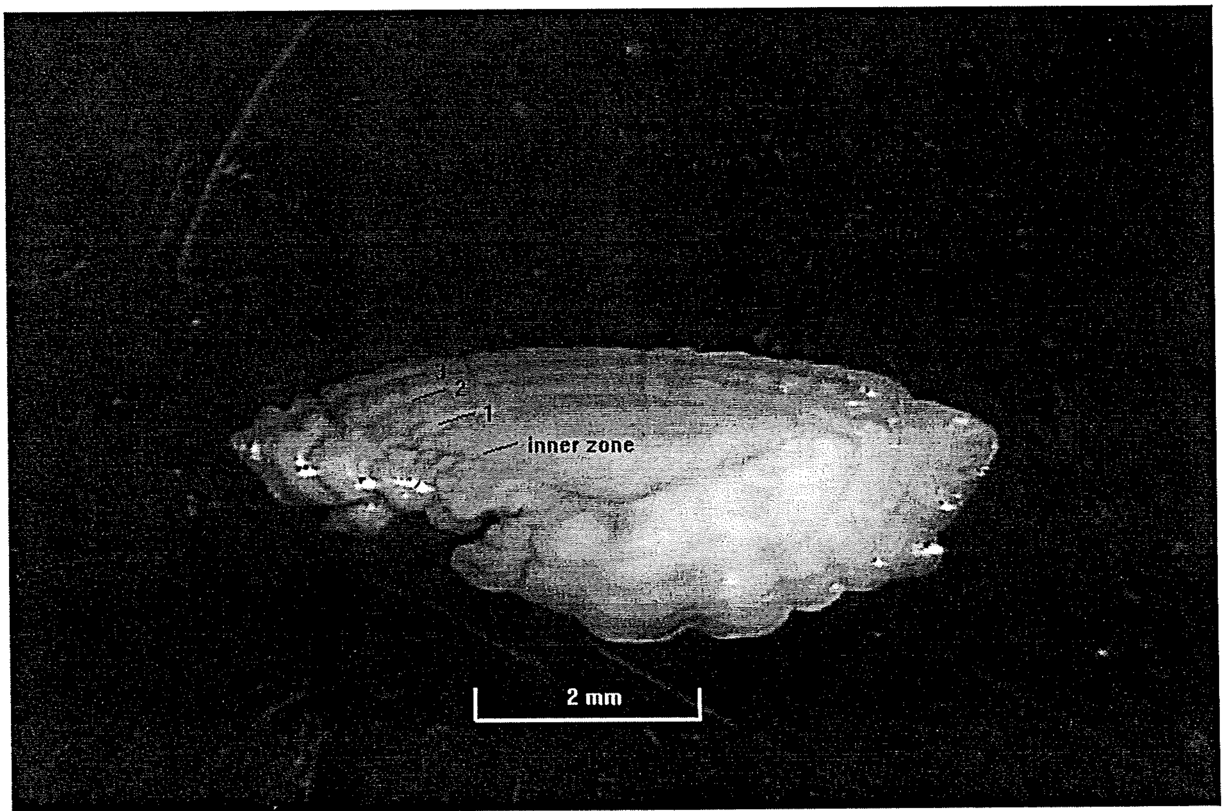


Fig. 6.54. Whole otolith from a striped trumpeter showing inner zone and 2 annuli (top) and from a bastard trumpeter showing inner zone and 3 annuli (bottom)

the pelagic larval stage), or a settlement mark, and the first annuli represents the end of the second winter. Therefore, for fish aged from whole otoliths, an age class of 1+ is assigned when there is no annuli or only the inner zone counted on the otolith, 2+ for 1 annuli, 3+ for 2 annuli and so on.

For whole striped trumpeter otoliths, ageing criteria was applied similarly between readers and agreement in estimated ages was reasonably high. The distribution of differences for second readings had a mode of 0 for both readers (Fig. 6.55) with 89% of readings being identical for the main reader and 70% for the secondary reader. The index of APE was 1.78% for the main reader and 3.94% for the secondary reader. Secondary readings by the main reader were not skewed toward either side of the mode whereas estimated ages of the secondary reader tended to be higher than the initial reading by the main reader.

Agreement between readers was lower for whole bastard trumpeter otoliths than for striped trumpeter. The distribution of differences for bastard trumpeter had a mode of 0 (Fig. 6.55) for both readers with 64% of readings being identical for the main reader and 61% for the secondary reader. The index of APE was 4.11% for the main reader and 4.00% for the secondary reader. The main reader tended to estimate lower ages on the second reading whereas differences in readings for the secondary reader were not skewed toward either side of the mode. These comparisons indicate that the incremental structure of whole otoliths is easier to interpret for striped trumpeter than for bastard trumpeter.

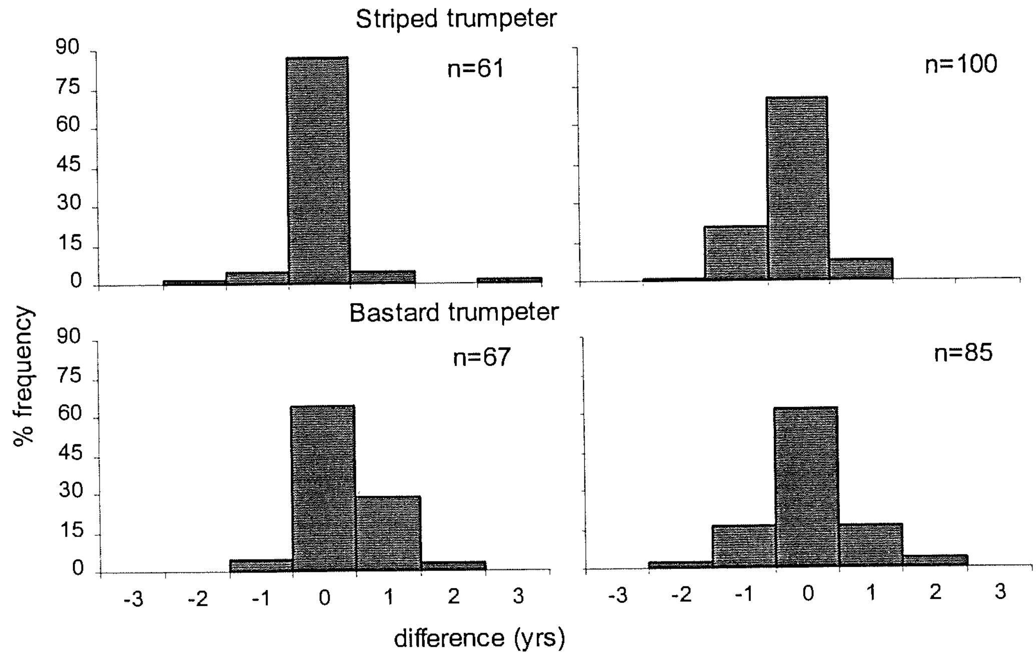


Fig.6.55. Distribution of differences in estimated ages for second readings of whole otoliths of striped trumpeter (top) and bastard trumpeter (bottom) by the main reader (left) and a second reader (right).

Sectioned otoliths from juveniles of both species were difficult to interpret. When viewed under transmitted light, otoliths generally show a relatively large central opaque area that extends outwards from around the region of the primordium (Fig. 6.56 and 6.57). However, the optical properties can be inconsistent (probably due to section thickness) and the central area may be translucent instead. Similar to banded morwong, the winter zones before the first 1 to 3 annuli are more readily distinguished by their narrow width, relative to adjacent zones, than their optical properties. In the small number of otoliths examined from larger specimens of both trumpeter species the structure of the otolith was unambiguous after the first 3 annuli, consisting of narrow opaque zones alternating with relatively broader translucent zones (Fig. 6.56 and 6.57).

Both readers gave lower estimates of age for juvenile striped trumpeter from transverse sections compared to the whole otolith age estimate of the main reader. Only 55% of readings were identical for the main reader and 52% for the secondary reader with both readers ageing 40% of otoliths one year less than the whole age estimate (Fig. 6.58). The index of APE between whole and section readings was 4.73% for the main reader and 5.78% for the secondary reader.

Age estimates for juvenile bastard trumpeter from transverse sections did not compare well with whole otolith age estimate of the main reader. Only 48% of readings were identical for the main reader and 49% for the secondary reader. The main reader did not skew readings to either side of the mode but the secondary reader tended to ascribe higher ages with 33% of otoliths age one year more than the whole age estimate (Fig. 6.58). The index of APE between whole and section readings was 7.76% for the main reader and 7.01% for the secondary reader.

Validation

Otoliths were obtained from 22 bastard trumpeter that had been injected with OTC between 5 and 563 days prior to recapture. Of the recaptures, 18 were recaptured after at least 100 days at liberty and 8 after at least one year. Sections from 18 otoliths that were injected with OTC, between 122 and 563 days prior to recapture, were observed under blue violet light and fluorescent marks were observed in 12 (67%). Specimens in which a fluorescent mark was visible ranged in estimated age from 2 to 4 years. The position of the OTC mark in relation to the opaque and translucent zones indicated that annuli are formed once a year, during winter, and that new translucent (summer) growth commences in about August (Fig. 6.59).

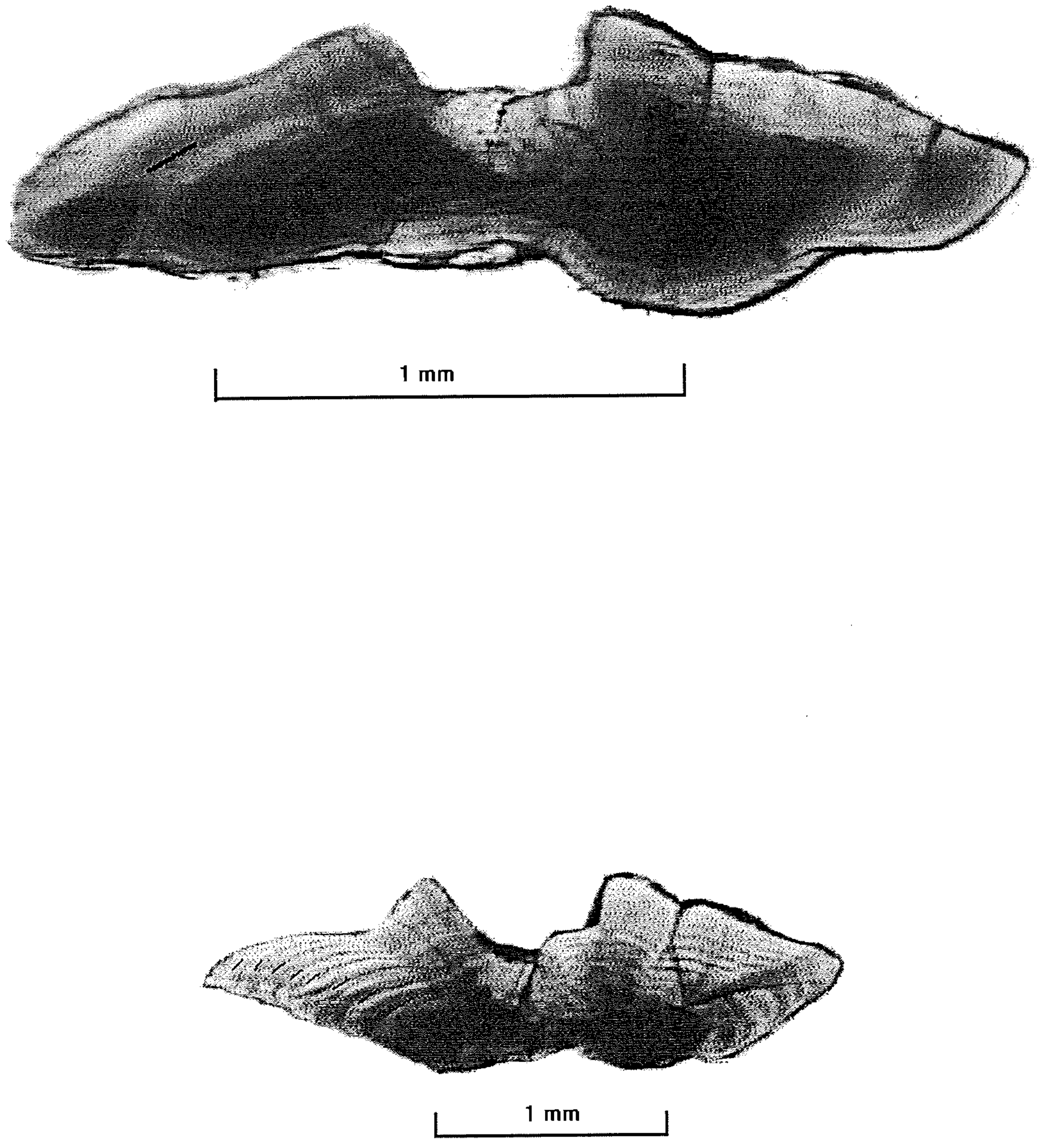


Fig. 6.56. Sections of striped trumpeter otoliths showing 1 annuli (top) and 8 annuli (bottom)

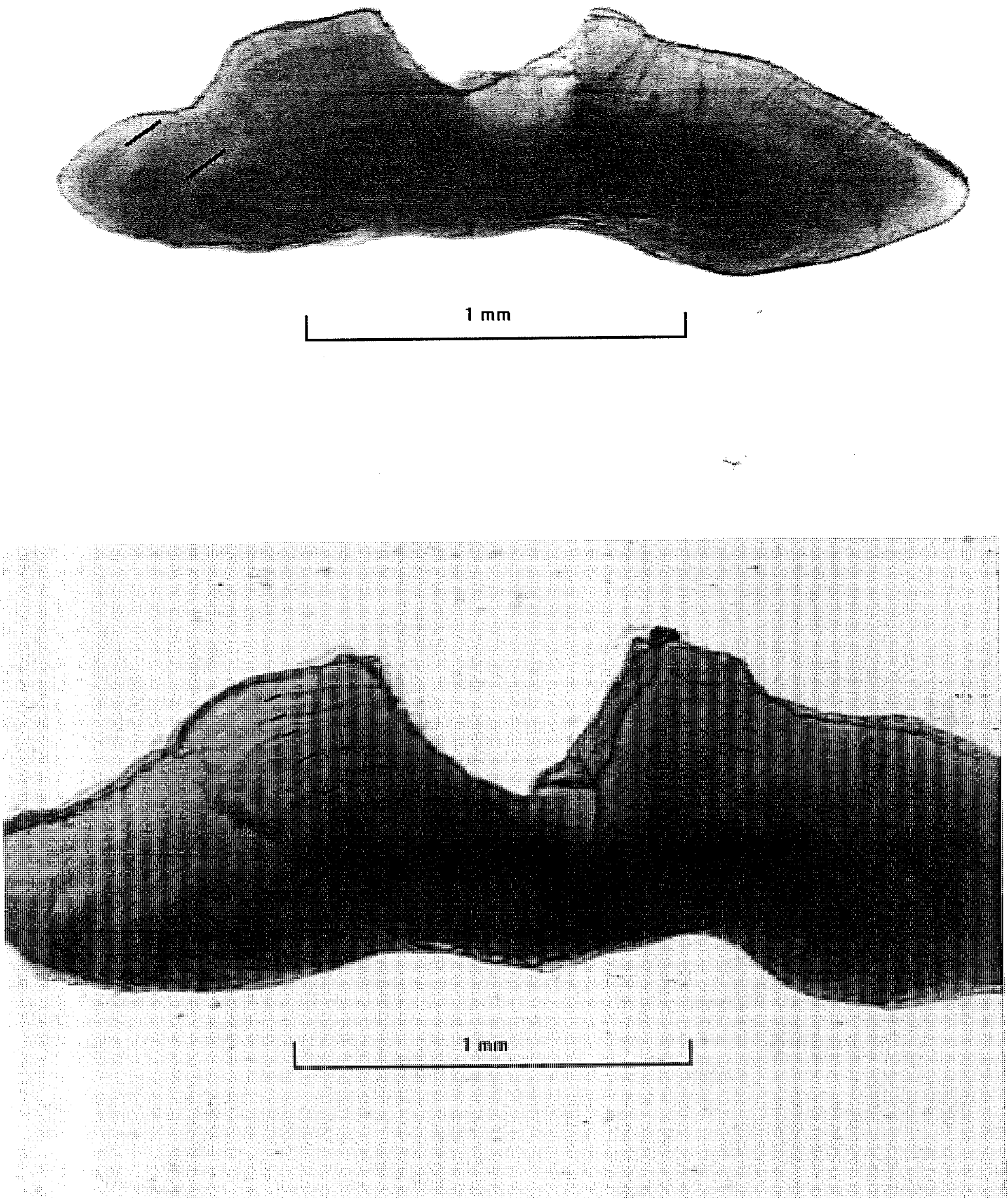


Fig. 6.57. Sections of bastard trumpeter otoliths showing 2 annuli (top) and 5 annuli (bottom)

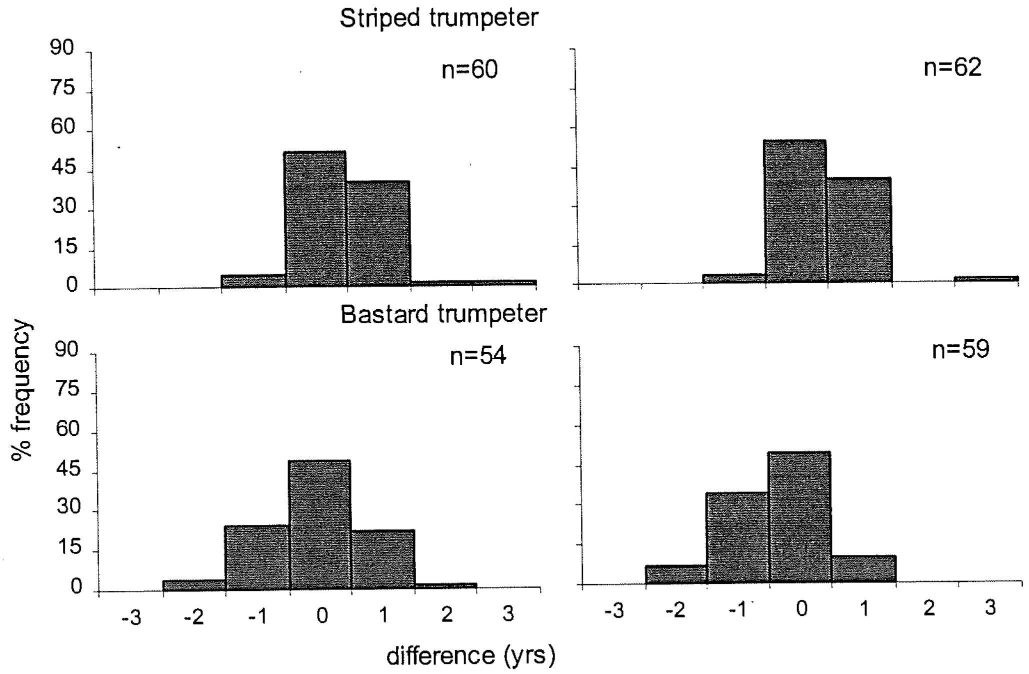


Fig.6.58. Distribution of differences in estimated ages for striped trumpeter (top) and bastard trumpeter (bottom) from whole otoliths and ground otoliths, by the main reader (left) and a second reader (right)

Length at age

The von Bertalanffy growth parameters and their standard errors (in parentheses) for striped trumpeter from length at age data (length at age was determined by assigning a decimal age to all specimens ≤ 45 cm, based on whether they were from the 1993 or 1994 cohort, and from sectioned otoliths in specimens > 45 cm) were 73.7 cm (8.2), 0.188 (0.006) and -0.89 (0.07) for L_∞, K, and t_0, respectively. For bastard trumpeter, the corresponding parameters (length at age was determined from whole otoliths in specimens ≤ 45 cm and from sectioned otoliths in specimens > 45 cm) were 59.4 cm (4.4), 0.144 (0.031) and -2.9 (0.60). Fig 6.60 shows the length at age data and fitted von Bertalanffy growth curves for striped trumpeter and bastard trumpeter.

Fig. 6.59. Oxytetracycline mark in otolith from bastard trumpeter aged 3 years, at liberty for 536 days tagged August 95 and recaptured February 97

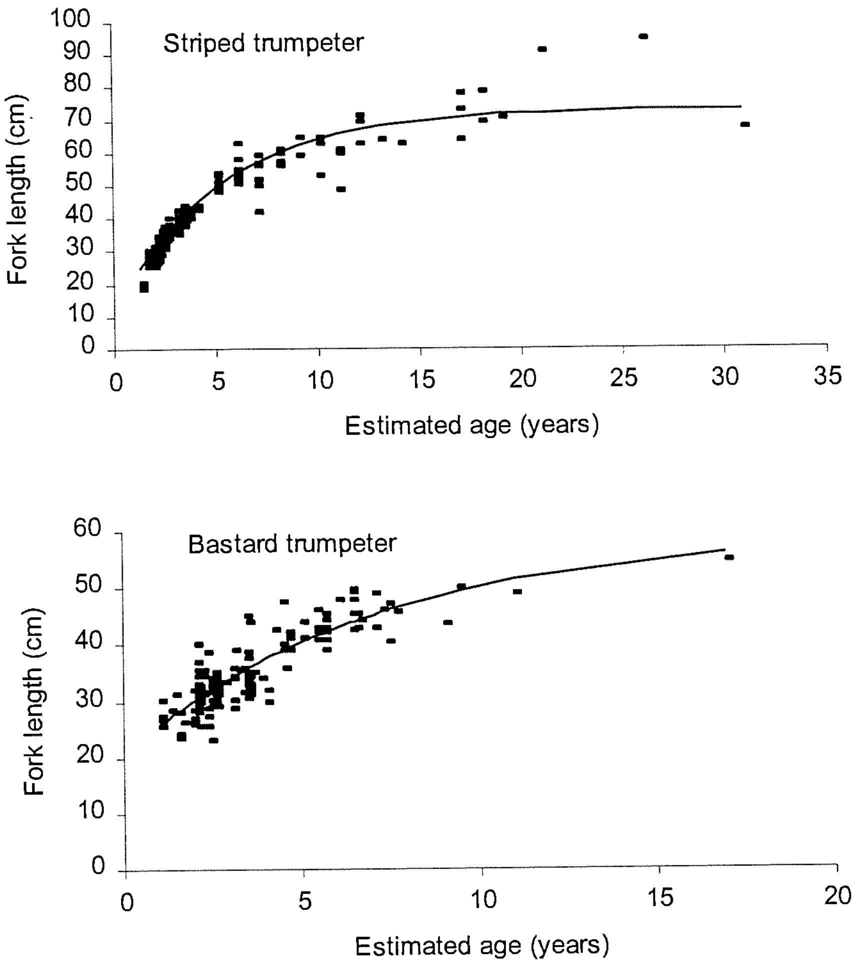


Fig. 6.60 von Bertalanffy growth curves for striped trumpeter (top) and bastard trumpeter (bottom)

Tag-recapture

A total of 30 striped trumpeter and 42 bastard trumpeter were recaptured greater than 200 days after tagging. These recaptures have been included in the analysis of growth from tag-recapture data. The von Bertalanffy parameters and their standard errors (in parentheses) for striped trumpeter, derived from Fabens parameterisation of tag recapture data, were 73.8 cm (16.2) and 0.193 (0.087) for L_∞ and K, respectively. For bastard trumpeter the parameters were 52.8 cm (12.8) and 0.251 (0.154), respectively.

Estimates of growth parameters vary greatly, as can be seen from the large standard errors, and should therefore be treated with caution. Because recapture growth data was derived solely from juvenile fish, estimates of K will tend to be larger, and L_∞ smaller, than would be expected for the whole population. Future recaptures of larger fish should result in increasing estimates of L_∞, although annual growth rates will be increasingly smoothed due to recapture times being greater than 1 year.

6.6 Reproductive biology

Banded morwong

Sex determination

In the laboratory, the McCormick morphometric method was not used to estimate the sex of banded morwong less than 30 cm FL because the features described to differentiate between sexes were not considered to be developed in fish of this size. Similarly, the biopsy probe method was not used on fish below this size because it was considered that the opening of the cloaca would not be sufficiently enlarged in females to allow the insertion of the biopsy probe.

Using the McCormick method, sex was successfully predicted at greater than 50% at approximately 31 cm for females and 35 cm for males. Therefore, we found McCormicks method was no better than a random guess at determining sex in fish below these sizes (Fig. 6.61). The success of sex prediction using this method was only greater than 85% once females had reached approximately 44 cm and males 47 cm. It was therefore concluded that the method was unsuitable for sexing live banded morwong in the field during commercial catch sampling or research fishing. In contrast, the biopsy method was close to 100% accurate in predicting sex at ≥ 31 cm for both sexes (Fig. 6.61).

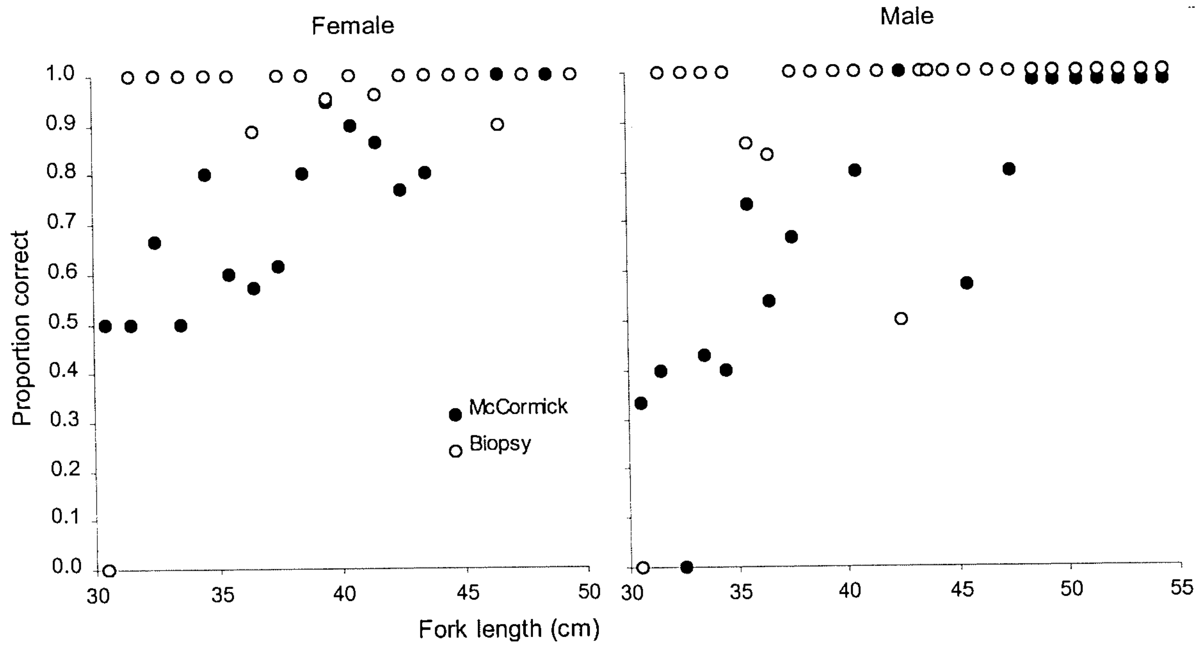


Fig 6.61. Proportion of female (left) and male (right) banded morwong sexed correctly using the visual method of McCormick and the biopsy method

Sex determination was undertaken on samples obtained during the spawning season when, presumably, penetration of the biopsy into the cloaca would be easiest. However, ovary tissue samples were also successfully obtained using the biopsy probe outside of the spawning season, from banded morwong as small as 33 cm. These results suggest that the biopsy probe method is a highly suitable procedure for sexing banded morwong (≥ 33 cm) at all times of the year.

Size at maturity

Sexual maturity in female banded morwong commences at between 30 and 32 cm, equivalent to 4 to 5 years of age. The smallest (and youngest) mature female examined was 30 cm (four years old). Length at 50 % maturity was 32.4 cm although sample sizes were small below 32 cm(Fig. 6.62). Almost all fish were mature at about 37 cm, or eight years of age. The parameters *A* and *B* of the logistic equation for maturation (Eqn. 4) are -13.77 and 0.0428, respectively, when fork length is measured in mm.

The parameters *a* and *b* of the power equation (Eqn. 5) describing the length-gonad weight relationship, for specimens where the gonad is stage 4, are 1.325×10^{-9} and 4.1489, respectively (r^2=0.39) (Fig 6.63). Table 6.23 shows GSI values (gonad weight as a percentage of body weight) for female banded morwong during the spawning season.

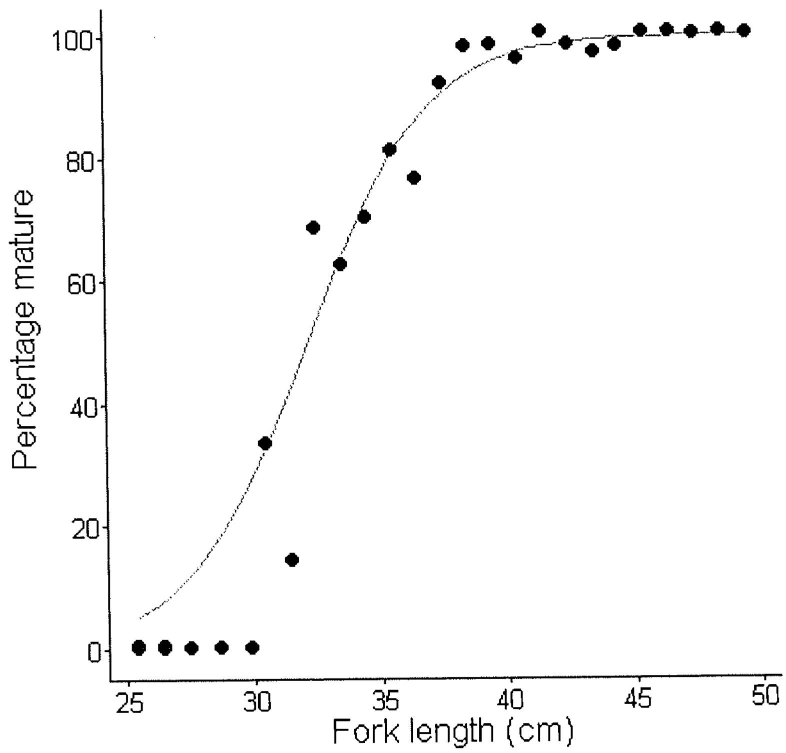


Fig 6.62. Logistic maturation curve for female banded morwong showing percentage mature, by length (cm)

Sexual maturity in male banded morwong could not be determined macroscopically. Unlike in the ovaries, there is no obvious change in the appearance and size of the testes during the spawning season. Male GSI values were comparatively low and did not changing markedly over time. In fact, the heaviest gonad weighed from a male was only 14.3 g from a 53 cm and 3.7 kg fish, equivalent to a GSI of 0.4.

Oocyte development

Microscopic examination of whole oocytes from biopsy samples revealed 6 distinct oocytes types, distinguished on the basis of macroscopic appearance, optical qualities, and morphometrics (Table 6.24). Mean oocyte diameter peaked between late February and early May, the highest value occurring in the first half of March (Fig. 6.64). Gonad maturation occurred quickly with oocyte diameters increasing dramatically in the second half of February, from around 200 to 700 μm. The relatively large standard deviation during late February demonstrates the heterogeneity in oocyte development between individuals early in the spawning season. Oocyte diameter declined gradually from early March to early May and

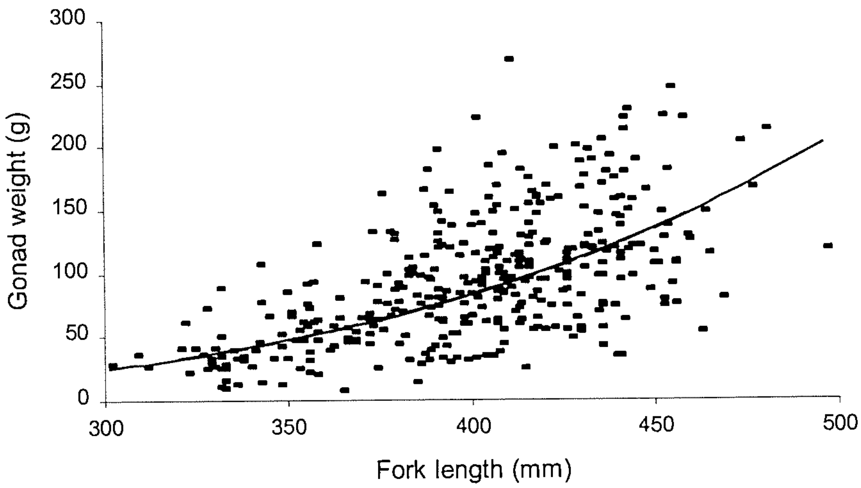


Fig. 6.63. Relationship between fork length and gonad weight. Fitted curve is shown.

Table 6.23. GSI values for female banded morwong during the spawning season, by gonad stage

Stage	*n*	GSI (mean ± s.d.)	Range
2	15	0.78 ± 0.18	0.5 - 1.1
3	49	2.65 ± 2.09	0.6 - 9.0
4	372	6.31 ± 2.49	0.8 - 16.3
5	149	7.93 ± 3.11	2.1 - 19.8
6	19	6.94 ± 2.06	3.2 - 10.1

was significantly lower by late May. In mature ovaries, both immature and mature oocytes were present, supporting the observation of McCormick (1986) that banded morwong are serial spawners.

For each whole gonad sample examined microscopically the most advanced oocyte type was the same in the anterior, middle and posterior region of the gonad. For samples where the most advanced oocyte type was either yolk 1 or yolk 2 there was no significant difference, at the 0.05 level of significance, in the mean diameter of the most advanced oocytes between regions of the gonad. However, in two of the eight samples where the most advance oocytes were ripe, there was a significant difference in the mean diameter between regions of the gonad. In one sample the mean diameter in the anterior region was different ($P < 0.05$)

Table 6.24. Female banded morwong maturity stages based on macroscopic examination and oocyte diameter

Oocyte	Appearence	Diameter ± 1s.d.(μm)	Maturity	Stage
Oogonia	Translucent, small spherical/ellipsoid	66 ± 22	Immature	2
Cortical alveoli	Translucent, cytoplasm just visible, spherical	206 ± 59		3
Yolk 1	Totally opaque, spherical	284 ± 50		3
Yolk 2	Opaque with yolk surrounded by translucent vitelline border, spherical	535 ± 44	Mature	4
Ripe	Translucent except for oil droplet, spherical	871 ± 34		5 - 6
Atretic	Totally opaque and/or small regions of translucence, non-spherical with crenellated edges	385 ± 128		

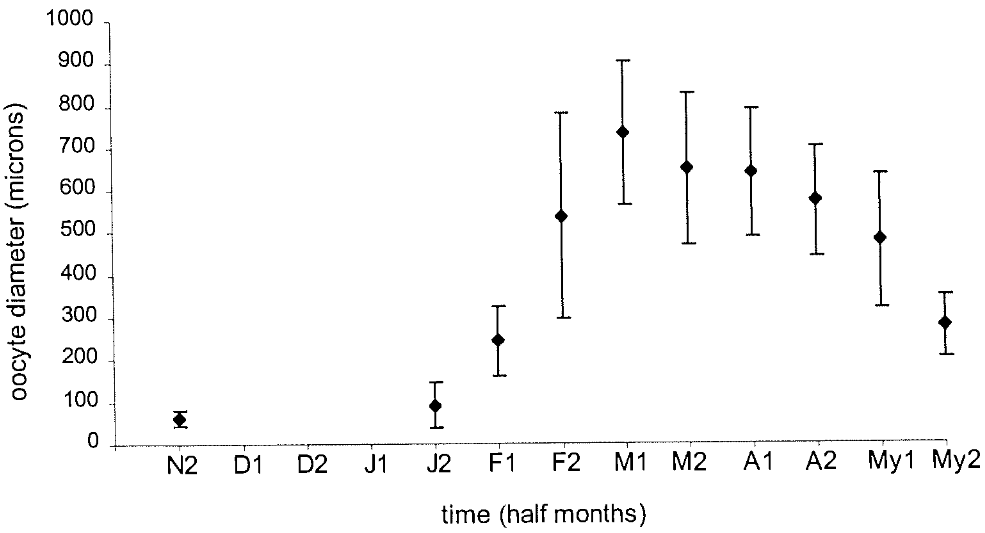


Fig.6.64. Mean diameter of 10 most advanced oocytes pooled from each gonad biopsy of female banded morwong from Tasman Peninsula, Nov 96 (N2) to May 97 (My2). Error bars are 1 s.d

whereas in the other the mean diameter in the mid section was different ($P < 0.001$) from the other two regions. Therefore, the region of the gonad in which a biopsy sample is taken will not affect classification of the most advance stage of oocyte development, but in some ripe individuals the mean oocyte diameter may be slightly affected.

Trumpeters

All striped trumpeter and bastard trumpeter retained from inshore waters, from the mesh selectivity trial and as tag recaptures, were immature. These data indicate that maturity occurs at sizes greater than 45 cm and ages greater than 4 years in both species (mature bastard trumpeter, collected from deep water reefs in eastern Bass Strait, were examined).

6.7 *Yield per recruit and egg per recruit analyses*

Yield per recruit relationships for female and male banded morwong are shown in Fig 6.65. These graphical representations show yield at various levels of F between 0.1 and 1.0 and for three possible estimates of M; 0.025, 0.05, and 0.10. For each of the individual scenarios, the potential yield for a given length class is reasonably constant across all values of F, except for when F is low (< 0.2). Therefore, setting of a minimum size limit to maximise yield is relatively insensitive to fishing pressure.

For both sexes, the length at maximum YPR increases as M decreases. Therefore, the lower the rate of natural mortality the higher the minimum size limit necessary to maximise yield. The difference in growth rates and maximum sizes between females and males can be seen clearly in the estimates of optimum potential yield. Using $M = 0.05$ as an example, it can be seen that for the slower growing and smaller females over 90% of yield could be achieved, at most values of F, by harvesting at a minimum size of between approximately 31 and 38 cm. However, for males at $M = 0.05$, over 90% of yield is achieved by harvesting at a minimum size of between approximately 40 and 47 cm. For each value of M there is little overlap of 90% yield between sexes. Therefore, the setting of a minimum size limit for banded morwong based solely on yield, will be a compromise of maximising yield for each of the sexes. At $M = 0.05$ and $F \geq 0.2$, a minimum size limit of between 36 and 38 cm would result in 90 to 99% yield for females and 80 to 90% yield for males.

YPR relationships for male banded morwong, to test for the effect of maximum size limits, are shown for minimum size limits of 36 and 37 cm and the same levels of F and estimates of M used above (Fig. 6.66). In order to maximise yield in each scenario, the required maximum size limits become higher as estimates of M decrease. Generally, the maximum size limit can be lower as F increases. Using $M = 0.05$ and $F \geq 0.2$, as an example, it can be seen that for both the 36 and 37 cm minimum size limits over 70% of potential yield is achieved at a maximum size limit of 47 cm or larger. Yield per recruit analyses to test for maximum size limits were not conducted for female banded morwong because L_∞ for females is identical to the current maximum of size of 43 cm. Therefore, theoretically, yield will be maximised at any size above this length.

Egg per recruit relationships are shown for the same scenarios of M and F used for YPR analyses (Fig. 6.67). It is worth noting that the model recognises that egg production occurs at lengths above L_∞ and that the proportion of egg production above L_∞ is greater as estimates of M decrease. As with potential yield from the YPR analyses, for each individual scenario the percentage of virgin egg production for a given length class is reasonably constant across all values of F, except for when F is low (< 0.2). Therefore, the setting of a minimum size limit to maximise virgin egg production is relatively insensitive to fishing pressure. However, estimates of virgin egg production are larger for a given length class as estimates of M increase. For example at $F \geq 0.2$, a minimum size limit of between 36 and 38 cm would maintain between 12 and 35% of virgin egg production if $M = 0.05$ but 26 to 59% if $M = 0.10$.

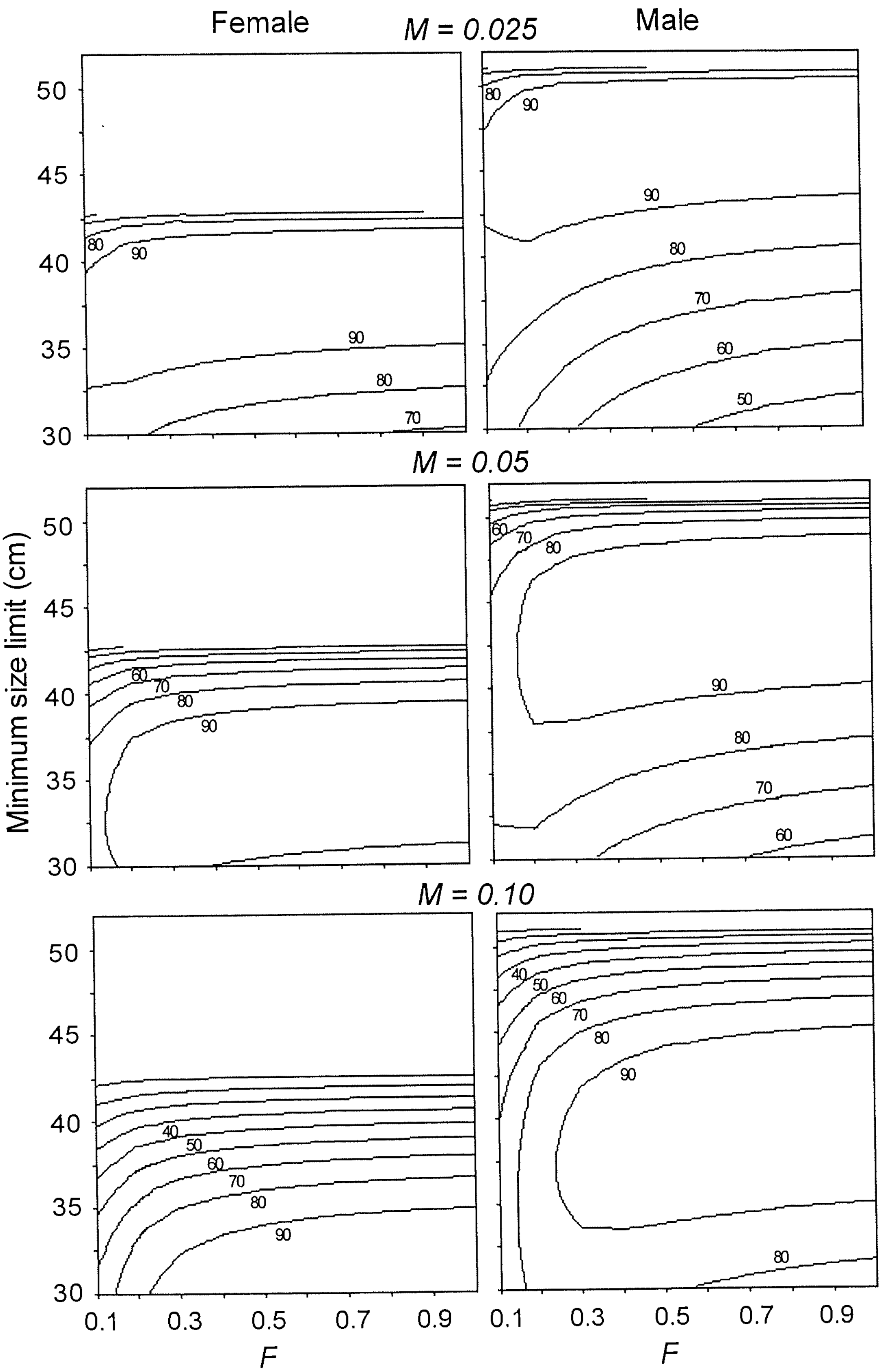


Fig. 6.65. Yield per recruit contour diagram for banded morwong, by sex, for three estimates of natural mortality

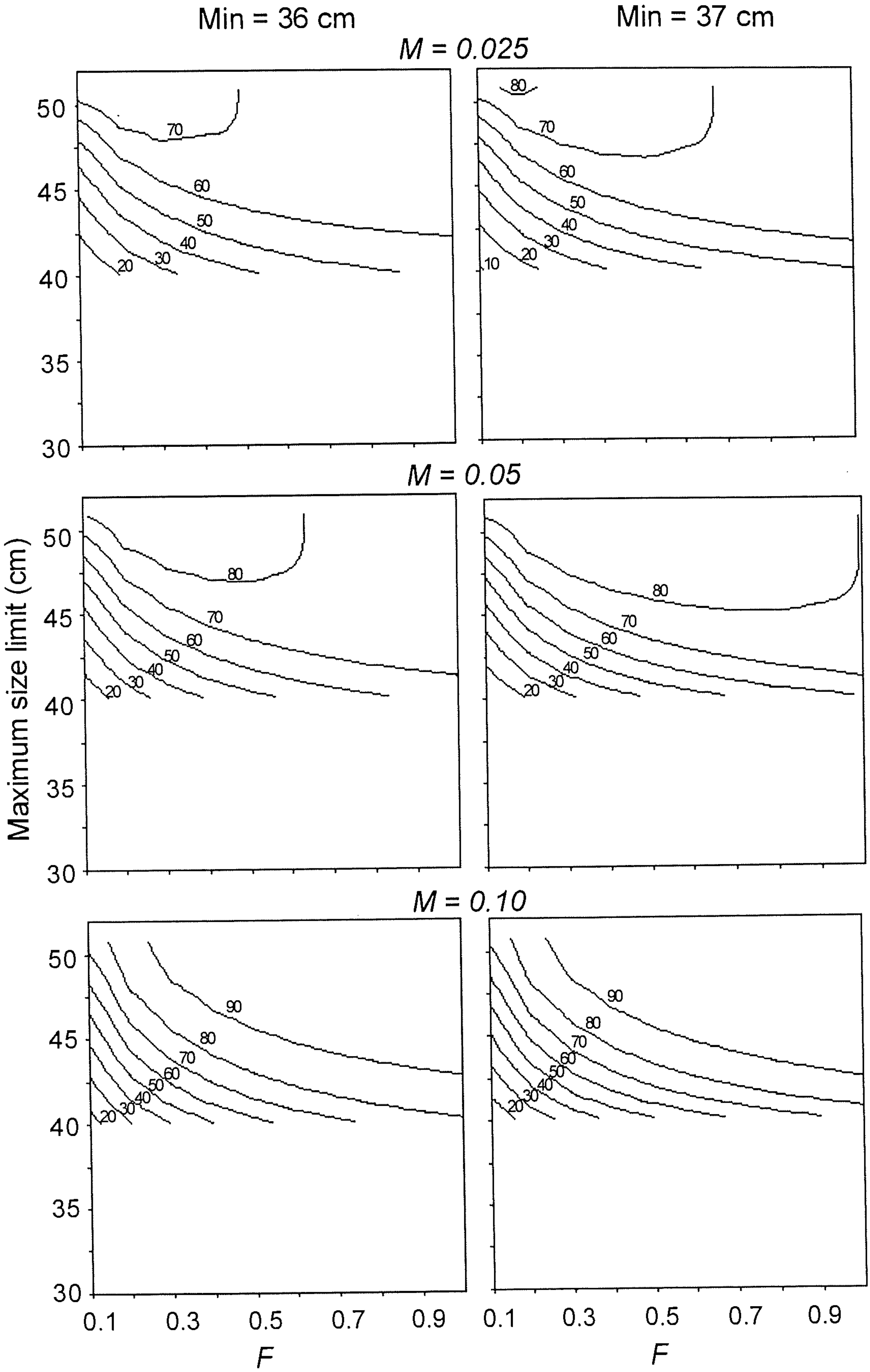


Fig. 6.66. Yield per recruit contour diagram for male banded morwong for two minimum size limits, 36 and 37 cm, and for three estimates of natural mortality

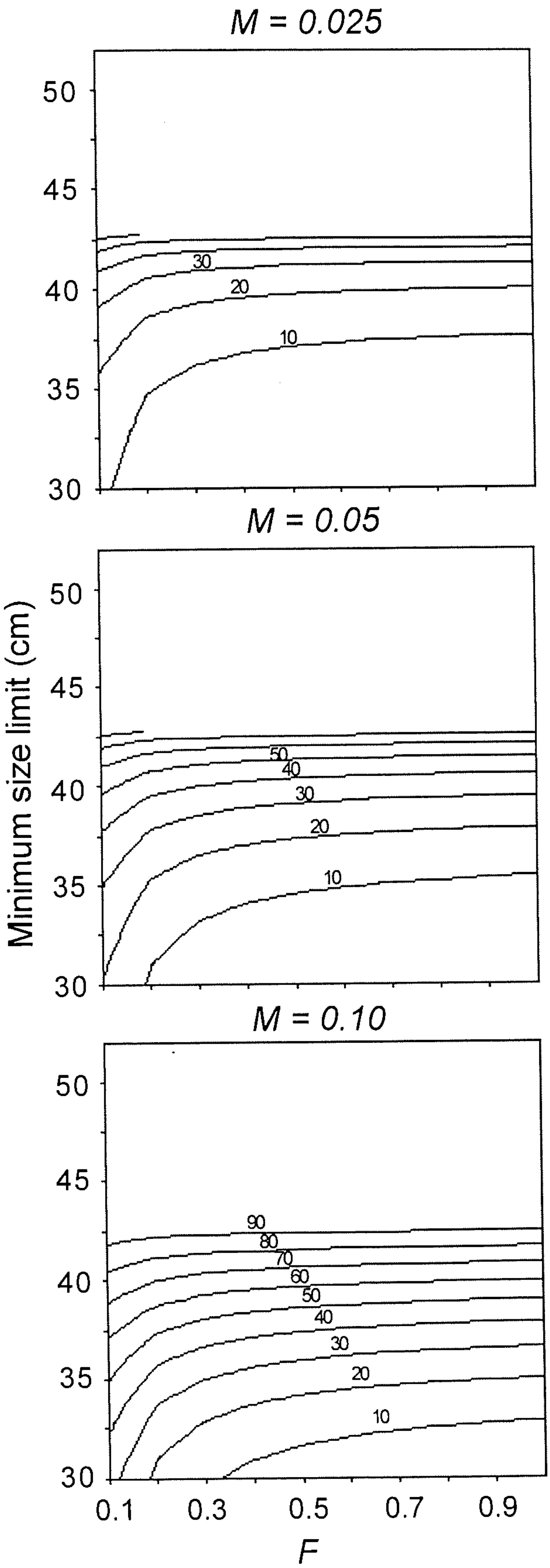


Fig. 6.67 Egg per recruit contour diagram for banded morwong for three estimates of natural mortality

7 DISCUSSION AND CONCLUSIONS

7.1 *Commercial catch sampling*

Commercial catch sampling is, obviously, restricted to areas where commercial fishing occurs and by the cooperation of commercial fishers. During the course of this study several of the more active and cooperative banded morwong fishers altered their level of participation in the fishery, or shifted effort to different regions on a seasonal basis. As such, it proved neither practical nor feasible to undertake seasonal catch sampling in all regions (*i.e.* St. Helens, Bicheno, Maria Island and the Tasman Peninsula), as originally proposed in the sampling design. As a consequence, by the second half of the study period sampling was concentrated on two of the original four sampling regions; Bicheno and the Tasman Peninsula. These two regions were chosen because both had historically high catches (refer Fig. 2.2), they represented the northern and southern areas of the fishery and were fished in all seasons by active fishers.

Generally, the length of net carried and the length of individual nets reflect the preferred fishing practices of individual banded morwong fishers, the size of vessel and the method used to haul the gear. Fishers hauling by hand are physically limited by the length of net that can be lifted in a day. However, by using relatively short nets (averaging 55 m in length) they are able to target areas very close to the shore, such as gulches and bommies, that are not available to fishers deploying longer nets from a net reel. Fishers utilising net reels are restricted to targeting more open rocky reef areas slightly further offshore.

The size of mesh used in the fishery was relatively consistent over the three years of the study. By the time commercial catch sampling had commenced, fishers had more or less determined that a mesh size of between 130 and 140 mm, with a fine twine diameter, was best for capturing banded morwong within the target size range and that the by-catch of unwanted species was less than in smaller mesh sizes. Our mesh selectivity study supported these observations, with CPUE highest for banded morwong, optimum selection of fish within the legal size range and the highest percentage of the target species in the total catch occurring in the 133 mm mesh.

Nets with a fine twine diameter set on rocky reefs are, however, susceptible to damage from the hard substrate and from entanglement with bull kelp (*Durvillaea antarctica*) and ascidian tunicates (*Pyura gibbosa*). This, combined with the practice of cutting the mesh to remove fish unharmed from nets, results in a large turnover in net bunt. The actual mesh size being deployed by an operator is more often a reflection of the availability of either 133 or 140 mm net bunt from manufacturers and suppliers, rather than a conscious decision to 'experiment' with slightly different mesh sizes.

On the east and south-eastern coast of Tasmania, inshore rocky reefs tend to drop off rapidly from the shoreline into depths of greater than 10 m and then extend out from the coast to a depth of 20 to 30 m before the substrate becomes sand. The mesh selectivity study demonstrated that CPUE of banded morwong (within the targeted size range) was generally highest in the 10 - 19 m depth stratum. In addition, because CPUE of marble fish was generally highest in the 0 - 9 m depth stratum, the catch of this unwanted species can be effectively reduced by fishing in depths greater than about 10 m. Gear damage is also reduced in depths greater than 10 m with nets largely out of any surge effect caused by swell which causes problems of entanglement, especially with bull kelp. Therefore, fishers tend to operate in 10 to 20 m depths for a number of reasons including higher catch rates, reduced by-catch and reduced damage to gear.

Overall, by-catch is minimal in the banded morwong fishery, with the target species dominating the catch in all regions sampled (approx. 60% of the catch by number and weight). When discards, especially non-commercial species, are taken into account banded morwong comprise a much greater proportion of the retained catch. This high degree of targeting by commercial fishers and low level of by-catch are supported by commercial logbook data where, in 80% of all fishing days between 1995 and 1997 in which banded morwong was reported in catches, the species comprised over 70% of the retained catch for the day (Lyle 1998).

The large mesh sizes used in the banded morwong fishery effectively ensure that few of the smaller reef species (*e.g.* wrasse, leatherjackets, trumpeters, herring cale etc.) are captured. This was confirmed by the mesh selectivity study, where few, if any, of these smaller species were captured in the 133 mm mesh size, compared to relatively high catches in the smaller mesh sizes. Short soak times, averaging 3 h per net, also ensure that unwanted species can be returned to the water alive and with a good chance of survival. This is especially true for robust species such as banded morwong (outside the legal size limit), marble fish and draughtboard shark which were observed to be generally undamaged when removed from meshes and actively swam away upon release.

Generally, there are significant targeted fisheries for the other species captured as by-catch in the banded morwong fishery. For instance, blue-throated and purple wrasse are taken in a line and trap fishery for the live fish market and bastard trumpeter are targeted (in conjunction with blue warehou) by commercial and recreational gillnet fishers. Long-snouted boarfish are taken as a by-catch from shark netting and leatherjackets are taken as a by-catch in line, gillnet and trap fisheries. Given this, and the observation that the most discards are usually released alive, increases in gillnet effort targeting banded morwong are not likely to have significant direct impacts on the populations of other rocky reef species, with the possible exception of long-snouted boarfish.

Between 1990 and 1996, the annual reported catch of long-snouted boarfish was approximately 10 t, half of which was taken in shark nets and half from the general gillnet fishery (including that for banded morwong). Reported catches increased slightly with the commencement of the banded morwong fishery, from 11.6 t in 1992 to a high of 13.7 t in 1994, but declined to 6.7 t in 1996 (Lennon 1998). There is very little biological information available for long-snouted boarfish and size composition data is limited to that obtained during this study. In an effort to reduce the catch of small specimens of this species, a minimum size limit of 45 cm TL has been adopted in the Fisheries (Scalefish) Rules 1998, which take effect from November 1998.

As an index of banded morwong abundance, trends in CPUE obtained from commercial catch sampling during this study should be treated with caution, especially as they are based on relatively few samples in each region. At the commencement of the monitoring program the fishery was in an exploratory stage, particularly at the St. Helens and Bicheno regions. Fishers targeted largely unexploited stocks in these two regions in early 1995 and some relatively high CPUE values were recorded (*e.g.* Bicheno Summer 95 and St. Helens Autumn 95). As the fishery has developed, CPUE has decreased and stabilised. CPUE tends to be higher in the summer and autumn seasons, presumably reflecting increased catchability of banded morwong at this time of the year. However, occasional high catches are taken at other times of the year (*eg*. St.Helens Winter 96), possibly as fishers target new fishing areas. For these reasons, it will be important to account for the effects of season or targeting 'unfished' areas, if CPUE is to be effective as an index of abundance for banded morwong.

In the Tasman Peninsula region, where fishing for banded morwong has occurred over a greater period of time than the northern regions, CPUE is relatively constant over all seasons (1.04 to 1.75 kg/100 m net h). CPUE was also relatively constant for this species in the 133 mm mesh nets deployed in the mesh selectivity study conducted at the Tasman Peninsula (1.16 to 1.28 kg/100 m net h for the last four seasons surveyed). Although CPUE has remained relatively stable, it is unclear whether this indicates that current catch levels have not impacted significantly on the stocks in the area or that fishing is simply serially depleting the virgin biomass, which is not yet reflected by changes in CPUE. However, if a consistent fall in CPUE below these levels occurred it would suggest that overfishing is occurring in this region.

It is worth noting that although CPUE is generally lower in the Tasman Peninsula than in other regions, effort remains reasonably high. The convoluted coastline in this area is no doubt a contributing factor, as it offers some protection from wind and swell from most directions, allowing fishing to occur when it would not be viable in other regions.

Estimates of CPUE for banded morwong *retained* for the entire fishery, from logbook data for the 1995/96 and 1996/97 years, are approximately 1.2 kg/100 m net h (J. Lyle, in preparation). This value is slightly higher than estimates obtained from commercial catch sampling (0.91 kg/100 m net h) but compares favourably, considering that catch sampling did not cover the entire range of the fishery during this period and that fishers are required to provide estimates on a daily basis of the weight of banded morwong retained, the total length of net deployed and soak times. Impression in logbook data for this fishery is most likely to come from estimates of effort, as fishers generally record an estimate of the amount of net lifted during the day and the average soak time for all nets deployed. Estimates of weight retained are likely to be more accurate because most fishers keep a tally of the number of fish retained each day and multiply this by an estimate of average weight per fish (generally 1.1 to 1.3 kg). Alternatively, the catch may be unloaded and weighed at the end of a fishing day, resulting in very accurate values in logbook data of the daily landed weight.

Small scale spatial and temporal variability in size and sex structure is a feature of the commercial banded morwong catch. Such variability can not readily be explained by possible impacts of fishing or gear selectivity. Rather, results imply that structuring of the banded morwong population, based on size, occurs at a small spatial scale (*e.g.* individual rocky reef areas). In some situations, commercial fishers have recognised spatial structuring and report that individual rocky reef areas are characterised by different size classes of banded morwong (*e.g.* the fish at St.Patricks Head are 'smaller' than those at Bicheno Town). In addition, changes in behaviour may occur during spawning, affecting the temporal catchability of either sex or size classes. These observations are supported to some extent by length frequency distributions obtained during commercial catch sampling.

Newman *et. al.* (1997) found that for Lutjanidae, Lethrinidae and Serranidae populations on the Great Barrier Reef, determining the appropriate spatial scale of sampling was required to ensure that the effects of smaller scale spatial differences were not confounded when larger scale comparisons were made. Similarly, our data indicate that sampling of the size and sex structure of the banded morwong population needs to be undertaken at a fine spatial scale.

Future monitoring of the banded morwong fishery that aims to detect changes in the population structure and catch rates will, therefore, need to be considered at the scale of the individual reef areas. In practice, this degree of sampling intensity may be difficult to achieve in a fishery of this size because of the dependence on the prevailing weather and sea conditions when deciding on a fishing location and the propensity of individual fishers to seasonally target different regions.

Gillnets with mesh sizes of 133 and 140 mm that were used in research fishing (*e.g.* the mesh selectivity study, *ad hoc* sampling) were constructed similarly to those used in the commercial banded morwong fishery. During research fishing, these nets were deployed in a similar fashion to the commercial fishery and catch rates comparable with those achieved by commercial fishers were attained. Therefore, considering the problems of commercial catch sampling in achieving adequate spatial resolution, it is feasible that future assessment of banded morwong be conducted more effectively (but not necessarily more cost effectively) by fishery independent surveys, than through a commercial catch sampling program.

7.2 Mesh selectivity

This study has provided detailed data on the effects of mesh size on catches of rocky reef fishes in south-eastern Tasmanian waters. The total number of species captured was low, reflecting the limited diversity of species that are susceptible to the mesh sizes trialed in this study. The dominant species in the catch in all mesh sizes, by both weight and number, were banded morwong. Species of secondary importance include bastard trumpeter, striped trumpeter and marble fish. Given its relatively large size, averaging 3.4 kg, draughtboard shark was also a significant contributor to the catch by weight.

There were proportionally more blue-throat and purple wrasse caught in the 89 mm mesh than in the larger mesh sizes. This reflects the size structure of both wrasse species, the populations being comprised predominantly of fish smaller than those selected for by the mesh sizes used by commercial and recreational fishers, although 89 mm mesh can be used off the north coast of Tasmania and mullet nets (60 to 70 mm mesh) can be used by recreational fishers. In general though, the impact of gillnet fishing on wrasse populations is likely to be limited for mesh sizes greater than or equal to 105 mm, especially when compared to the catch taken by commercial line and trap fishing. In the case of the large mesh sizes used in the banded morwong fishery, by-catch of wrasse would appear to be minimal.

Non-banded morwong targeted commercial and recreational gillnet catches (which target slightly different areas, *e.g.* at the edges of reefs, and use different mesh types to the banded morwong fishery, *i.e.* 100 - 115 mm for recreationals and 115 - 130 mm for commercials) are strongly influenced by the availability of two of the main target species; bastard trumpeter, which are subject to recruitment variability, and blue warehou, a migratory species that moves into south-eastern Tasmanian waters during summer and autumn. In this study, catches reflected a large recruitment pulse of bastard trumpeter (1993 cohort) during the research program and the relatively scarcity of blue warehou. In addition to bastard trumpeter, an exceptionally large number of juvenile striped trumpeter (1993 cohort and, to a lesser extent, 1994 cohort) recruited to the study area. Anecdotal evidence from fishers with a long-term involvement in the fishery suggested that the 1993 cohort of striped trumpeter was unprecedented in size for at least the previous two decades. In fact, many fishers reported catching no juvenile striped trumpeter on inshore reefs for many years prior to this event. The dominance of the two trumpeter species in the catch, and the lack of blue warehou, suggests that when these three species are absent or in low numbers around rocky reefs, gillnet catches will be low and dominated by species such as marble fish, banded morwong and, to a lesser extent, wrasse and leatherjackets.

The 89 mm mesh size captured the highest diversity of species. Although it is illegal to use this mesh size in southern and eastern Tasmanian waters, 19 commercial fishers are endorsed to use mesh sizes between 75 and 100 mm known as 'small mesh nets' off the north coast, which are used to target species such as small blue warehou and short-finned pike (*Sphyraena novaehollandiae*) (Murphy 1994). In addition, licensed recreational fishers are able to use mesh sizes of between 60 mm and 70 mm, known as a 'mullet net'. However, with the commencement of the new Scalefish Management Plan mullet nets may only be deployed on sandy substrate, because of their potentially damaging effect on small reef fishes. To determine the catch in mullet nets set on rocky reefs, this study included a 64 mm mesh size in the original sampling design and the 64 mm mesh was trialed prior to the commencement of this project. However, because of the extremely large numbers of small fish such as wrasse, barber perch (*Caesioperca rasor*), trumpeters and herring cale (*Odax cyanomelas*) that were captured, it was decided not to continue using the 64 mm mesh. These small fish were generally in poor condition and could not be released alive, even though set durations were short (< 3 h). Although the 64 mm mesh was not used extensively, the quantity of smaller species that were commonly taken in the 89 mm net, particularly wrasse, herring cale and leatherjackets, highlights the problem of small mesh gillnets (< 100 mm mesh) set on rocky reefs.

CPUE for banded morwong was highest in the 133 mm mesh followed by the 114 mm mesh. The fact that CPUE for the 130 mm mesh was lower than might have been expected is likely to be more a function of twine diameter than mesh size. Both the 133 and 114 mm mesh sizes have a narrow twine diameter (0.38 mm) whereas the 130 mm mesh, which is commonly used to target blue warehou, is a heavier twine (0.60 mm), giving rise to the possibility that banded morwong 'bounce' off the net or are able to 'detect' the heavier gauge mesh.

The selectivity of 114 mm mesh nets towards banded morwong is of some significance given that a move to 115 mm (4 ½ ") as a minimum mesh size for the entire fishery (recreational and commercial) has been flagged in an attempt to increase the size of target species, particularly trumpeters, and reduce the catch of smaller target and non-target species (Anon 1998). A shift to this minimum size could lead to an increase in the by-catch of banded morwong when targeting trumpeters and warehous around rocky reef areas.

Banded morwong selectivities

Gillnet selectivities were determined for banded morwong for four mesh sizes of gillnet ranging between 89 and 133 mm (3 ½ to 5 ¼ "). Large residuals were observed when the 130 mm mesh was included in estimates of relative selectivities, supporting the observation that factors other than mesh size (*i.e.* twine diameter) influenced catches of this species.

Low numbers of banded morwong below 30 cm in length were captured in all mesh sizes, despite having girth measurements that would make them vulnerable to capture in the 89 and 105 mm mesh sizes. Leum and Choat (1980) observed that smaller banded morwong are less mobile than larger fish and thus may be less likely to encounter and be captured in gillnets. Alternatively, low numbers of fish captured below this size may reflect the low abundance of small fish in the population. McCormick (1989a) reported large recruitment variability in banded morwong in New Zealand (only one large recruitment occurring over a 10 year period). Given the length at age, low levels of recruitment in the 3 to 4 years prior to sampling would be necessary to produce low numbers of fish below 30 cm in the population.

Relative selectivities for banded morwong in the 133 mm were highest between 32 and 38 cm. Although not included in the mesh selectivity study, it is likely that the highest relative selectivities for the other common mesh size used in the fishery (140 mm) are similar, but slightly larger, than in the 133 mm mesh. Therefore, in terms of the initial minimum and maximum size limits for banded morwong(33 - 43 cm) the widely used mesh sizes were quite appropriate in maximising returns. With the introduction of new minimum and maximum size limits (36 and 46 cm, respectively) in July 1998, fishers using 133 mm mesh will possibly handle more fish below the minimum size at the expense of capturing fish at the upper end of the size limits. A fishery wide move towards 140 mm mesh can be expected in order to compensate for these management changes.

Selectivities applied to catches from four mesh sizes indicate that a greater proportion of the population are larger than 45 cm than are observed in commercial catch sampling or research fishing. By applying selectivity coefficients, it is apparent that in commercial catches the number of banded morwong between 30 to 44 cm are over-estimated while fish over 45 cm are significantly under-estimated. For females, observed length frequency data closely reflect the population size structure but males are over-represented below, and substantially under-represented above, 47 cm. The adjusted population structure is strongly bi-modal with a dominant mode at 37-43 cm and a secondary mode at 46-51 cm.

The bimodal size structure of the selectivity adjusted population can be explained by considering life history characteristics of banded morwong. The mode of smaller fish (35 - 45 cm) is primarily due to an accumulation of females in this size range. Female growth is very slow post maturity and, being long lived, reflects the accumulation of a large number of year classes (possibly up to 80). The mode of larger fish (45 and 55 cm) is a consequence of the relatively faster initial growth of males (for the first 10 - 12 years) and subsequent accumulation of a large number of year classes. (Interestingly, in the bi-modal distribution determined for the population, the first mode peaks at 43 cm and the second at 51 cm, lengths that correspond to the L_∞ values determined for female and male banded morwong, respectively, from length at age data).

The accumulation of a large number of age classes has implications if changes in the size structure of the population are used to monitor the effects of fishing, especially if recruitment levels are relatively low. Changes in the size structure can be expected to be small, at least until a significant proportion of the virgin biomass is removed.

Hamely (1975) emphasised that mesh selectivities will be influenced by the probability of individual size classes of fish being captured. For banded morwong, catchability may be influenced by seasonality and by structuring of the population by depth (Leum and Choat 1980, McCormick 1989a). A search of the literature, however, found no studies where minimising, or adjusting for, the effects of changes in population distribution or CPUE, by depth and/or season, were considered. In this study, sampling was stratified by depth and catch data weighted for differences in effort between mesh sizes and depth strata, within seasons. Selectivities were then determined from the adjusted data. In comparison, selectivities determined from non-adjusted data (but not show in results) were found to be almost identical to those from the adjusted data. This suggests that the stratified design, in which differences in levels of effort between mesh size within each depth strata were minimised, reduced the possibility of errors in determining mesh selectivity in a species that is size structured by depth.

Trumpeters and other species

The 105 mm mesh is the closest in dimensions to both the proposed new minimum mesh size of 108 mm (4 ¼ ") and the current legal minimum of 100 mm for recreational and commercial fishers graball nets. In addition, a move to a minimum mesh size of 115 mm has been flagged. For both striped trumpeter and bastard trumpeter, the minimum size limit of 33 cm TL (approx. 30 cm FL for striped trumpeter and 29 cm FL for bastard trumpeter) to 35 cm TL (approx. 31.5 cm FL for striped trumpeter and 30.5 cm FL for bastard trumpeter) will be introduced in November 1998.

Striped trumpeter were first captured in significant numbers at approximately 27 cm FL in the 105 mm mesh and 32 cm FL in the 114 mm mesh (although it should be noted that due to growth in the 1993 cohort and the frequency of sampling, few samples between 30 and 32 cm FL were captured in all mesh sizes). Bastard trumpeter were first captured in significant numbers at approximately 26 cm FL in the 105 mm mesh and 30 cm FL in the 114 mm mesh. A move to 115 mm as a minimum mesh size is clearly justified if minimum mesh sizes are to be consistent with minimum size limits for both trumpeter species (at least in relation to size at first capture). By contrast, the 105 mm mesh will result in the capture of some under-sized trumpeter.

Significant numbers of wrasse were captured at approximately 30 cm in the 105 mm mesh and 35 cm in the 114 mm mesh, suggesting that the 108 mm mesh size will result in a minimal catch of under-sized wrasse (28 cm minimum size limit). By contrast, mullet nets (60 - 70 mm) and other nets below 100 mm mesh size can be expected to take large numbers of under-sized wrasse if fished on rocky reefs.

7.3 Comparison of marine reserve and adjacent exploited reef areas

Low species diversity and low catches for species other than banded morwong within both the Governor Island marine reserve and the adjacent exploited area is largely a reflection of the selectivity of the mesh sizes used.

In each of the months sampled (apart from February 1997), catch rates for banded morwong within the marine reserve were at least twice those obtained outside of the reserve. In February 1997, sampling coincided with the onset of spawning, a time when catchability of banded morwong apparently increases and catch rates were very high and similar in both areas.

Assuming that CPUE is indicative of abundance, then our results suggest that the density of banded morwong in the reserve (of those selected for by the mesh sizes used in this study) was approximately double that of the exploited area. However, differences in abundance cannot be attributed solely to fishing pressure. Comparison of a marine reserve and exploited area in NZ based on underwater census found that differences in banded morwong density could be explained equally by differences in habitat structure within each area, as by differences between the two areas (McCormick and Choat 1987) Therefore, they suggested that a comparison of size-frequency data may be of greater value than abundance data in determining differences between exploited and unexploited areas. From estimates of length (nearest 5 cm) they determined that the modal length of banded morwong was larger in the reserve than the non-reserve area. In the present study, we found no obvious difference in the both the overall and sexed length frequency distributions (nearest 1 cm) between the Governor Island marine reserve and the adjacent exploited areas. Because fishing is limited by minimum and maximum size limits (33 - 43 cm), it was envisaged that fishing would have impacted more on the intermediate size range and be reflected in differences in the proportions of banded morwong within the legal size range. This was not the case with the proportion of fish within the legal size range being very similar for the reserve and exploited areas. This suggests that either the impact of fishing on the size structure has not been of a magnitude to be detected or that there is substantial mixing between the reserve and adjacent populations, although the latter explanation seems unlikely given the results of tagging studies.

No recaptures of fish tagged in the reserve were recaptured in adjacent reef areas, suggesting that the Governor Island marine reserve offers reasonable protection for this species. Banded morwong do, however, move greater distances than that covered by the Governor Island marine reserve and it is reasonable to assume that some fish will move outside its boundaries and be susceptible to fishing. As the setting of gillnets is permitted along the boundary of the reserve, and is practiced by many local fishers, it is probable that the reserve does not offer complete protection for banded morwong or other predominantly residential species (*e.g.* wrasse, leatherjackets).

Interestingly, a large number of banded morwong in the reserve were within the 42 cm size class and a comparatively low number in this size class occurred in the adjacent exploited area (refer Fig. 6.27). Such differences cannot be explained readily in terms of the impact of fishing (a single cm size class may represent over 70 year classes). Although this observation could be an artefact of sampling, it is significant that the characteristic size structures were reasonably consistent over time and, in the exploited area, for research and commercial fishing.

7.4 Movement

Based on tagging, banded morwong appear to be largely site attached, that is, residential on a given area of reef. In terms of movement, over 90% of recaptures occurred within 5 km of the release site. Generally, this supports the observations that movement of banded morwong is limited to within reef areas (Leum and Choat 1980, McCormick 1989a). However, even allowing for occasional location recording errors, the number of fish recorded as moving greater than 10 km (4%) does suggest that some infrequent, larger-scale movements occur. The movement of fish tagged and released at the St.Helens Point boat ramp demonstrated that banded morwong will cross over soft bottom habitats between individual rocky reefs. There was no suggestion from the analysis of tagging data that distance moved was affected by fish size or time at liberty. Being largely residential on a given reef, banded morwong will be susceptible to localised depletion. While commercial and research CPUE data do not reveal any obvious trends to suggest significant declines in abundance, anecdotal reports from fishers do suggest that catch rates have declined on some individual reefs.

Although the majority of recaptures of both trumpeter species (over 70 %) occurred within 5 km of the tagging site, larger scale movements occur, with over one quarter of recaptures of both species having moved between 5 and 30 km. It appears that most juvenile bastard trumpeter remain within the same general area for extended periods (up to several years) with a few individuals being more mobile. For example, one bastard trumpeter had moved 143 km and another 62 km, with both of these recaptures occurring within less than 300 days of being tagged and released. Another bastard trumpeter moved 36 km in just 5 days.

Barrett and Edgar (1998), through bi-annual underwater census of the marine reserve at Maria Island (a narrow coastal reserve approx. 7 km in length) between 1992 and 1997, observed that bastard trumpeter showed a great degree of site fidelity and rarely moved between reefs. This conclusion was based on a dramatic increase in the number of bastard trumpeter during their study and the continued presence of large numbers of bastard trumpeter (that were observed to increase in size) throughout the remainder of the study. However, our tagging data suggests that although a large proportion of the fish seen during each underwater census may have been the same individuals, some mixing between areas would be expected.

Juvenile striped trumpeter movements did not tend to be as large as those observed for bastard trumpeter, though there was evidence to suggest that distances travelled increases in fish over 45 cm. Importantly, two recaptures were taken from deep water offshore rocky reefs. The movement of fish over 45 cm would tend to support data from the commercial fishery for striped trumpeter which shows fish entering the deep water offshore fishery (100-300 m depths) at approximately 45 cm (Hutchinson 1993, J. Lyle unpublished data). It is likely that future recaptures of striped trumpeter will occur on deep water reefs, further supporting the general movement of striped trumpeter from the shallow inshore reefs to deep offshore areas as they grow. The only known reports of adult bastard trumpeter have been from deep water reefs such as in eastern Bass Strait (Jeremy Lyle, unpublished data), where they are taken as bycatch in a gillnet fishery for blue warehou, suggesting that there may also be an offshore movement with growth in this species.

Large scale movement of adult striped trumpeter has been reported from tagged fish that escaped from sea cages in North-West Bay, near Hobart, in 1992 (Arthur Ritar pers. comms.). Several recaptures have been reported from commercial fishers operating on deep water reefs in the vicinity of St.Helens, Bicheno and off the Tasman Peninsula.

7.5 Age and growth

Banded morwong

This study has determined age and growth parameters for banded morwong, from two regions on the east coast of Tasmania.

McCormick (1986) described the internal structure of broken and burnt banded morwong otoliths from New Zealand as consisting of alternating concentric layers of hyaline and opaque material, in which the hyaline zones were narrower than the opaque zones. The width of the opaque zones became relatively narrow and constant after the sixth or seventh zone. Using marginal increment analysis, he validated that an opaque and hyaline zone was laid down annually for at least the first three years. The pattern of zonation was not validated past this age but, by assuming an annual pattern, it was determined that males grew faster than females, and that both sexes reached a maximum age of approximately 60 years.

The present study describes a similar structure for banded morwong otoliths from Tasmania, as those from New Zealand. In sectioned otoliths viewed under transmitted light, the narrow opaque zones and broader translucent zones correspond to the hyaline and opaque zones, respectively, for otoliths that were broken and burnt. Importantly, our study validated the incremental structure, for both sexes and in both small and large otoliths, through the use of oxytetracyline to mark the otolith. Maximum ages for banded morwong in Tasmania, over 85 years for females and over 80 years for males, were much greater than those obtained from New Zealand (*c.f.* 60 yrs). By validating the incremental structure of sectioned otoliths, we are confident in our estimates of maximum age and growth parameters from length at age data.

The position of the fluorescent OTC mark, in relation to the translucent and opaque zones, suggests that the translucent zone is formed predominantly in summer, between January and April. In all fish that were tagged between May and December, the position of the fluorescent mark was almost coincident with the opaque zone, suggesting that little or no growth occurs during these months.

Female growth is rapid for the first 5 - 6 years, until about 35 cm, and then slows dramatically, whereas for males, growth is rapid for the first 10 - 12 years, until about 45 cm, before slowing dramatically. The maximum sizes recorded in this study were 51 cm for females and 56 cm for males.

The maximum size for banded morwong observed in this study is much smaller than that reported by Last *et. al.* (1983) for the species in Tasmania (*i.e.* approx. 100 cm total length. However, we examined the preserved head of the specimen on which this maximum size was based and found that it was in fact a dusky morwong (*Dactylophora nignicans*) and not a banded morwong. The head was also examined by Peter Last who confirmed our identification. Therefore, the maximum size of banded morwong in Tasmania is likely to be approximately 60 cm TL, not 100 cm as generally cited in the literature.

For each sex, the average maximum size (the von Bertalanffy parameter, L_∞) was almost identical in the Bicheno and Tasman Peninsula regions but differences in the rate of growth (K) towards L_∞ were found between regions. Fish of both sexes grew faster in Bicheno than those in the Tasman Peninsula, indicating regional differences in growth over a relatively small scale. In addition, males from Bicheno were slightly heavier at a given length than those from the Tasman Peninsula but no regional differences were found in the length-weight relationship for females. Differences in growth parameters between regions, however, were not considered large enough to warrant different harvest strategies between regions.

Compared with many other temperate reef species, age and growth characteristics in banded morwong are unusual in that the species is very long lived (>80 years) and males grow significantly faster and to larger sizes than females, a situation that is the reverse of what is seen in most other species. Within the Family Cheilodactylidae, jackass morwong (*Nemadactylus macropterus*) females grow slower and to a slightly larger maximum size than males, both sexes reaching a similar maximum age of approximately 40 years (Morison, A 1996; A. Jordan unpublished data). In red morwong (*Cheilodactylus fuscus*), maximum age estimates of approximately 27 years were obtained from unsexed specimens (A. Smith unpublished data) and males grow to a larger maximum size than females (Schroeder *et. al* 1994).

Growth characteristics of banded morwong have important implications in the assessment of the fishery. Differences in growth rates between sexes means that any minimum size limits that apply will by necessity represent a comprise, if an objective of adopting a minimum size regulation is to maximise yield (see section 6.7)

As would be expected for a long lived species, estimates of natural mortality were low. Estimates of M based on maximum ages (Hoenig 1983, Sparre *et. al.* 1989) were in the range of 0.05 to 0.07 for either sex (for Hoenigs' equation, Z was substituted for M, as an assumption of the equation is that $F = 0$). Estimates of Z ($Z = F + M$) from catch curve analysis were in the range of 0.02 to 0.04 for females and 0.06 to 0.07 for males. In fact, when adjusted for mesh selectivity, a negative estimate for Z was obtained for males indicating that in this case catch curve analysis may not be a valid means of estimating mortality, even where mesh selectivity is taken into account. Further, since estimates of M and Z that are within similar ranges, the impact of fishing (*i.e* F) can not be detected from catch curve analysis.

Trumpeters

The extremely large recruitment of striped trumpeter from the 1993 cohort provided a unique opportunity to assess growth in juveniles of this species. Larval rearing trials provided the basis for confidently assigning a year class to the recruitment pulse (David Morehead unpublished data). The initial lack of other year classes and the rapid growth of the cohort enabled its progression to be monitored for the entire study, growing from 19 cm (1.3 yrs) in January 1995 to 42 cm (4.0 years) in October 1997. The subsequent 1994 cohort, allowed for comparison of length at age between the two year classes. The rapid growth in juveniles of this species, and similar growth rates for the cohorts allowed an age class to be confidently assigned to most individuals captured inshore, based on length and the time of capture

Coincidentally, a large recruitment pulse of bastard trumpeter was also observed in coastal waters in early 1995. Because of similarity in the length of this and the striped trumpeter cohort when first observed in January 1995, it was assumed that bastard trumpeter were also from the 1993 cohort. However, unlike striped trumpeter, growth slowed significantly at approximately 2 to 2 ½ years of age and after this time age in this species could not be assigned confidently, simply on the basis of length and time of capture.

The incremental structure on whole striped trumpeter otoliths was generally easier to interpret than for whole bastard trumpeter otoliths. As such, estimates of age from whole striped trumpeter otoliths were more consistent within and between individual readers than whole bastard trumpeter otoliths. Sectioned otoliths from both species were found to be difficult to interpret with annuli being more difficult to discern than in whole otoliths. Notwithstanding the difficulty in interpreting the position of annuli in sectioned otoliths from juvenile bastard trumpeter, where an OTC mark was visible on a sectioned otolith its position suggested that the increments interpreted as annuli were formed once a year.

Harries and Lake (1995) found that no 'growth check' was added to scales of bastard trumpeter in the first year and therefore calculated ages based on the number of growth checks counted plus one year. Similarly, this study found that an annuli was generally not apparent in the first winter for bastard trumpeter and striped trumpeter, in both whole and sectioned otoliths, and therefore one year was added to the number of annuli counted when assigning an age class.

Preliminary estimates of age and growth parameters for the two trumpeter species were obtained from length at age and from tag-recapture data. For striped trumpeter, although estimates of L_∞ and K were similar for the two methods, the estimates of maximum length were significantly less than those recorded from the commercial fishery (approx. 120 cm TL) (Hutchinson 1993). For bastard trumpeter, estimates of L_∞ were larger, and K lower, from length at age data when compared with tag-recaptures. Estimates of maximum length from tag-recapture data were similar to those obtained by Harries and Lake (1985) whereas L_∞ estimates from length at age data were similar to the maximum size recorded for the species in Australia (Last *et al.* 1983).

Most specimens used in calculating these parameters were small, juvenile fish from inshore waters and do not adequately represent larger mature fish. In order to determine appropriate harvest strategies for these species, there is a need to sample across the full size range by including the offshore fishery. However, even without robust estimates of growth parameters, the current harvest strategy that allows for the capture of large numbers of immature fish in the inshore commercial and recreational gillnet fishery must be seen as questionable.

7.6 Reproductive biology

The reproductive biology of banded morwong in Tasmania was similar to that described from New Zealand (McCormick 1986). Both studies found that banded morwong is a serial spawner. The minimum size at maturity in females was slightly smaller in New Zealand, but this observation may be in part due to the selective nature of the gillnets used as sampling gear in our study. Fish were collected by diving in the New Zealand study. Maturity in males of this species can only be accurately determined through histological examination (McCormick 1986) and was not conducted in this study. Both studies found that the peak spawning period is in autumn. However, it is unlikely that McCormick (1986) examined females that were running ripe, describing the diameter of mature eggs as being 567.8 ± 111 μm. This diameter approximates our observations of fully yolked eggs (535 ± 44 μm) but is much smaller than that measured for hydrated ripe eggs (871 ± 34 μm). The large standard deviation in egg diameter described by McCormick (1986) may be due to the grouping of several mature stages of oocytes which would have included some hydrated and some smaller eggs.

This study has demonstrated that progression in the spawning cycle can be monitored non-destructively through the use of the biopsy probe. The appearance and mean diameter of 6 oocytes types has been described. Mean oocyte diameter was used as an indicator of the timing of peak spawning activity and the appearance of oocytes was used to determine maturity. In ripe fish, the region of the gonad from which the biopsy sample was obtained may slightly affect the index of average oocyte diameter but the large difference in the diameter of vitellagenic and ripe oocytes means that the peak spawning time will always be obvious. In 1997, the peak spawning activity in the Tasman Peninsula region occurred between late February and early May, therefore the closed season from March to April inclusive coincided with the majority of peak spawning activity.

7.7 *Yield per recruit and egg per recruit analyses*

This study determined estimates of population parameters for banded morwong that are necessary to conduct YPR and EPR analyses to determine appropriate legal size limits. Management recommendations from these analyses were based on the assumption of values for M of 0.05 and for F of ≥ 0.2.

Management of the banded morwong fishery based solely on the objective of maximising yield could be achieved with a minimum size limit of between 36 and 38 cm. However, if additional management objectives are to provide some protection of larger male fish (size at maturity of males being unknown) and levels of egg production then YPRmax and EPR analyses need to be considered. YPRmax analyses for males were conducted for minimum size limits of 36 and 37 cm which were considered (after the EPR analyses) to be the only two alternatives that would be acceptable to *both* management and industry. For each of these minimum sizes, management based solely on the objective of obtaining greater than 70% potential yield in weight could be achieved with a maximum size limit of greater 47 cm. However, a maximum size limit of this size would result in males being available to the fishery for three to four years longer than under the original 33 to 43 cm size limit. Because the maximum size limit is designed to offer protection to larger male fish, this was considered an unacceptable increase in fishing pressure on males.

Based on an approximation of the length-fecundity relationship, EPR analyses showed that the original minimum size limit of 33 cm would maintain just 4 to 13% of virgin egg production. Management based on the objective of maintaining at least 20% virgin egg production could be achieved with a minimum size limit of 38 cm.

On the basis of YPR and EPR analyses (plus considerations of the impact on catch rates and economic returns) the minimum and maximum size limits for banded morwong have been raised from 33 to 36 cm FL and 43 to 46 cm FL, respectively.

8 BENEFITS

This study has produced considerable data on the size, sex and age structure of banded morwong populations from east coast Tasmanian waters. Spatial structuring in size structure composition have been identified, indicating that future commercial catch sampling will need to be conducted at a small scale in order to detect changes in size structure due to fishing or for the assessment of biological trigger points.. The selectivity of mesh nets used in the commercial banded morwong fishery has been determined and applied to correct length frequency and age frequency data obtained from catch sampling. Growth parameters and mortality estimates, necessary to conduct yield per recruit and egg per recruit analyses (and thus appropriate minimum and maximum size limits) were determined. Protocols used to age banded morwong were validated through the use of fluorochemical markers further supporting the growth parameters determined for this species. Levels of by-catch were quantified for the banded morwong fishery and showed that this fishery has little direct impact on species other than the target species.

The input of information derived during this project into the management plan process, resulted in the general recognition that the biological characteristics of the species made it susceptible to overfishing, resulting in the introduction of a new Fishing Licence (Banded morwong).

A non-destructive methodology was developed in the use of a biopsy probe to determine sex and maturity data for high value fish in live fish fisheries. For banded morwong, reproductive data determined using the biopsy probe proved suitable in the assessment of the timing of spawning season closures of the fishery. This technique also has applications in the assessment of other live fish fisheries, in non-destructive sampling of finfish populations in marine reserves and in tagging studies where sex at time of tagging would improve the utility of recapture data.

Catch and CPUE of inshore rocky reef fishes and size selectivity characteristics of striped trumpeter, bastard trumpeter and wrasse were described in experimental gillnets of five mesh sizes. This data is of considerable use to resource managers in evaluating the appropriateness of mesh sizes and size limits in the inshore scalefish fishery.

Movement of banded morwong, striped trumpeter and bastard trumpeter was described. This data is of substantial use in determining the appropriate size of marine reserves designed to offer short and long-term protect these three species.

9 INTELLECTUAL PROPERTY

No commercial intellectual property arose from this work

10 FURTHER DEVELOPMENT

This project has assessed the impact of gillnet fishing on inshore temperate reef fishes in south-eastern Tasmanian waters. However, due to the major focus of the research being on the banded morwong fishery, all catch data refers only to daytime fishing where set times were relatively short. There is a need to assess the catch of gillnets, particularly in relation to the mortality of undersized or unwanted species, when deployed in overnight fishing. In addition, the impact of gillnet fishing in other areas, such as soft bottom habitats and in the north of the State, needs to be quantified so that resource managers can introduce universal regulations on gillnet fishing in Tasmania.

In relation to the live fish fishery, the effect of trap and line fishing on wrasse populations is unknown. The impact of size limits and different fishing gears requires assessment.

There is a paucity of information regarding the offshore fisheries for striped trumpeter and bastard trumpeter. Basic size and age composition data is needed in order to determine harvest strategies appropriate for these species. The study has shown that recruitment for both trumpeter species is highly variable. Further development could be undertaken in the establishment of a monitoring program that provides a pre-recruit index of trumpeter abundance that would be used in the interpretation of catch and effort information obtained from logbook data.

11 STAFF

Dr. Jeremy Lyle	Principal Investigator
Mr Ray Murphy	Project Research Officer
Mr Tim Debnam	Technical Officer
Mr Bob Kennedy	Population Dynamicist
Mr David Campbell	Technical Officer
Mr Carl Waterworth	Technical Officer

All staff were DPIF, Tasmania. Ray Murphy was externally funded

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13 DISTRIBUTION

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Tasmanian Department of Primary Industry, Water and Environment
GPO Box 192B
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Tasmanian Fishing Industry Council
P.O. Box 878
Sandy Bay TAS 7006

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PO Box 332
Somerset TAS 7322

Marine and Freshwater Resources Institute
PO Box 114 Queenscliff
Victoria 3225

Central Ageing Facility
Marine and Freshwater Resources Institute
PO Box 114 Queenscliff
Victoria 3225

Victorian Fisheries Research Advisory Committee
33 Stephens St
Nth Balwyn VIC 3104

New South Wales Fisheries
202 Nicholson Pde
Cronulla NSW 2230

NSW Advisory Council on Fisheries Research
202 Nicholson Pde
Cronulla NSW 2230

Australian Institute of Marine Science
PMB No. 3, Townsville MC,
QLD 4810

CSIRO Division of Marine Research
GPO Box 1538
Hobart TAS 7001

15 APPENDICES

Appendix A. List of common names, taxonomic names and CSIRO identification code for species caught during the inshore reef fish gillnetting project

Family	Common name	Scientific name	CSIRO code
Heterodontidae	Port Jackson shark	*Heterodontus portusjacksoni*	007001
Scyliorhinidae	Draughtboard shark	*Cephaloscyllium laticeps*	015001
	Orange spotted catshark	*Asymbolus sp.D*	015024
Squalidae	White spotted dogfish	*Squalus acanthias*	020008
Rajidae	Skates		031000
	Whitley's skate	*Raja whitleyi*	031006
Urolophidae	Banded stingaree	*Urolophus cruciatus*	038002
	Sparsely spotted stingaree	*Urolphus paucimaculatus*	038004
Myliobatidae	Eagle ray	*Myliobatis australis*	039001
Congridae	Southern conger eel	*Conger verreauxi*	067007
Moridae	Bearded rock cod	*Pseudophycis barbatus*	224003
	Red cod	*Psuedophycis bachus*	224006
Zeidae	Silver dory	*Cyttus australis*	264002
Syngnathidae	Common seadragon	*Phyllopteryx taeniolatus*	282002
Scorpaenidae	Red gurnard perch	*Helicolenus percoides*	287001
	Ruddy gurnard perch	*Neobastes scorpaenoides*	287005
	Thetis fish	*Neobastes thetidus*	287006
Pataecidae	Red velvet fish	*Gnathanacanthus goetzeei*	292002
Platycephalidae	Sand flathead	*Platycephalus bassensis*	296003
Serranidae	Butterfly perch	*Caesioperca lepidoptera*	311002
	Barber perch	*Caesioperca rasor*	311003
Apogonidae	Long-finned pike	*Dinolestes lewini*	327002
Carangidae	Jack mackerel	*Trachurus declivus*	337002
	Silver trevally	*Pseudocaranx dentex*	337062
Gerreidae	Silverbelly	*Parequula melbournensis*	349001
Mullidae	Red mullet	*Upeneichthys lineatus*	355001
Pempheridae	Common bullseye	*Pempheris multiradiatus*	357001
Girellidae	Silver drummer	*Kyphosus sydneyanus*	361001
	Luderick	*Girella tricuspidata*	361007
	Sweep	*Scorpis lineolatus*	361009
Enoplisidae	Old wife	*Enoplosus armatus*	366001
Pentacerotidae	Long snouted boarfish	*Pentaceropsis recurvirostris*	367003
Aplodactylidae	Marble fish	*Aplodactylus arctidens*	376001
Cheilodactylidae	Magpie perch	*Cheilodactylus nigripes*	377001
	Grey morwong	*Nemadactylus douglasi*	377002
	Jackass morwong	*Nemadactylus macropterus*	377003
	Dusky morwong	*Dactylophora nignicans*	377005
	Banded morwong	*Cheilodactylus spectabilis*	377006
Latridae	Striped trumpeter	*Latris lineata*	378001
	Bastard trumpeter	*Latridopsis forsteri*	378002
	Real bastard trumpeter	*Mendosoma lineatum*	378004
Muglidae	Yellow eye mullet	*Aldrichetta forsteri*	381001
Labridae	Blue throated wrasse	*Notolabrus tetricus*	384003
	Senator wrasse	*Pictilabrus laticlavius*	384020
	Purple wrasse	*Notolabrus fucicola*	384021
	Rosy wrasse	*Pseudolabrus psittaculus*	384023

Appendix A. cont.

Family	Common name	Scientific name	CSIRO code
Odacidae	Herring cale	*Odax cyanomelas*	385001
Uranoscopidae	Common stargazer	*Kathetostoma laeve*	400003
Clinidae	Crested weedfish	*Cristiceps australis*	416007
Centrolophidae	Blue warehou	*Seriolella brama*	445005
Monocanthidae	Toothbrush leatherjacket	*Acanthaluteres vittiger*	465002
	Mosiac leatherjacket	*Eubalichthys mosaicus*	465003
	Velvet leatherjacket	*Parika scaber*	465005
	Brown striped leatherjacket	*Meuschenia australis*	465008
	Gunn's leatherjacket	*Eubalichthys gunnii*	465034
	Six spined leatherjacket	*Meuschenia freycineti*	465036
Aracanidae	Shaw's cowfish	*Aracana aurita*	466003
Diodontidae	Globe fish	*Diodon nichthemerus*	469001
Octopodidae	Octopus		601000
Haliotidae	Blacklip abalone	*Haliotus rubra*	662001
Grapsidae	Crabs		702000
Palinuridae	Southern rock lobster	*Jasus edwardsii*	703014