**INTERNAL REPORT**

# TASMANIAN ARROW SQUID FISHERY – STATUS REPORT 2001

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*June 2001*

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Published by the Tasmanian Aquaculture and Fisheries Institute, University of Tasmania 2001

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## Summary

Commercial fishing for arrow squid was first explored in Tasmanian and adjacent waters by the Japanese in the late 1960's. Several periods through the 1970's and 1980's saw large scale harvesting of arrow squid stocks by foreign fishing companies, with up to 7,900 tonnes being taken in one season (1979/80) from southern Australia.

A dramatic expansion of catch and effort in the fishery in Tasmanian coastal waters occurred in 1999/2000, when about 430 tonnes were taken, primarily by automatic jig vessels. This increase in effort prompted a call for the development of a long-term management strategy for the Tasmanian arrow squid fishery. The fishery is centered off south-eastern Tasmania during the summer months. A strong seasonal pattern in catches is evident with peak catch rates occurring in December and January. In the most recent season (2000/01) catches fell to less than 40 tonnes despite considerable effort by automatic jig vessels.

Biological sampling of commercial catches commenced in 1999/2000 and continued through 2000/2001. In addition to strong inter-annual variability in the availability of squid (as evidenced by catches), the biological characteristics of the catches differed between and within seasons. In both years, catches early in the season consisted of small, immature individuals, with some evidence of modal progression in size during the season. In 1999/2000, the proportion of mature females increased as the season progressed (to February) whereas as the proportion of mature females declined over time in 2000/01. Autumn catches were almost exclusively comprised of immature animals. This was due to the influx of small animals in late December, possibly a second cohort, and the gradual disappearance of the larger animals. Bimodality in the size composition of catches was not observed in 1999/2000. Highly plastic growth rates prevent forming links between size and age.

The fishery is largely based on immature squid, the impact of taking large quantities of small, immature squid especially early in the season, as opposed to delaying the fishery to allow further growth and development, on potential yields and overall stock productivity is unknown.

Greater understanding of the growth dynamics, stock structure and reproductive biology is required to interpret both the intra and inter-annual variability observed in catches and biological characteristics. Further, as the fishery off south-eastern Tasmania is in reality a component of a larger squid fishery based off southern Australia, it will be important to consider the present findings in the context of the wider fishery and the wider squid resource.

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# 1. Stock Structure and Life History

Arrow squid (*Nototodarus gouldi*) are found throughout the shelf waters of southern Australia, from Geraldton in Western Australia to latitude 27°S in southern Queensland and including Bass Strait and Tasmania (Stewart, 1993). They are also common in New Zealand waters where they support a major fishery along with the related species, *N. sloanii*. Arrow squid are an oceanic squid but are commonly found schooling in shallow coastal and estuarine waters at certain times of the year (Winstanley *et al*., 1983). The species has, for instance, been reportedly caught at the upper tidal limits of the Derwent Estuary.

Stock structure within Australia is not known and it is unclear whether Australian and New Zealand populations constitute a single stock.

Arrow squid aggregate near the seabed during the day and disperse through the water column at night to feed (Winstanley *et al*., 1983, O'Sullivan and Cullen, 1983). Their diet consists mainly of planktonic crustaceans, fish and other squids (O'Sullivan, 1980). The main predators of arrow squid are seals, dolphins, tuna and benthic and bathypelagic fishes including school shark (Coleman and Hobday, 1982). Arrow squid are cannibalistic and this, along with other predation, is thought to comprise a significant proportion of the mortality (Harrison, 1980).

As a group, squid are generally fast growing, short-lived animals. Arrow squid are thought to live for up to 12 months. Females grow larger than males and reach 1400 g and 370 mm dorsal mantle length, males reach 1000g and 330mm (Harrison, 1980).

Based on length frequency information, early research on arrow squid in Tasmania suggested that there were at least three separate broods or cohorts a year. These were termed the winter, spring and summer broods (Harrison, 1980). More recent work based on ageing using statoliths has revealed that growth rates are highly variable in response to ecological parameters such as temperature and productivity and that length is not a reliable indicator of age.

Males store sperm in spermatophoric packages that are transferred to the female using a single modified arm called a hectocotylus. Females are mated before they mature and store the sperm packets in buccal pouches around the mouth. Eggs are fertilised as they pass the buccal mass and are transferred to a gelatinous mucous ball produced by the female (Harrison, 1980). It is not known whether the egg mass is free floating or attached to the substrate. Naturally spawned egg masses have not been identified and studied at this stage. Based on studies of other oceanic species, it is thought that fertilised eggs develop and hatch in 1 to 2 months depending on water temperature.

# 2. Fishery Background

The existence of a squid resource off southern Australia has been known for many years. The Japanese-owned Gollin Gyokuyo Fishing Company conducted a survey around Tasmania in 1969/70 for under exploited fishery resources. This survey indicated that arrow squid occurred right around the state. The same company returned in 1971/72 with a vessel equipped with 20 automatic jig machines and targeted squid commercially (Wolfe, 1972).

At the end of the season, the company left two jig machines in Tasmania that the Fisheries Division put aboard the FRV *Penghana* for fishery research and promotional purposes. Demonstrations of the equipment were held for fishermen in an attempt to generate interest in the fishery. High catch rates for fishing trials in the Derwent Estuary in December 1972, sparked a rapid gearing of boats for squid fishing in that season. Thirty vessels fished the summer of 1972/73, taking 154 tonnes in the Derwent alone (Wolfe, 1973). The total squid catch for 1972/73 was around 170 tonnes( Fig. 1). Catches then fell to less than 10 tonnes per annum as interest in the fishery waned. Catches increased again in 1979/80 to 55 tones but fell in subsequent years, remaining at less than 20 tonnes per annum through the 1980's. Poor prices and limited market opportunities appear to have been major contributors to the low catches throughout this period.

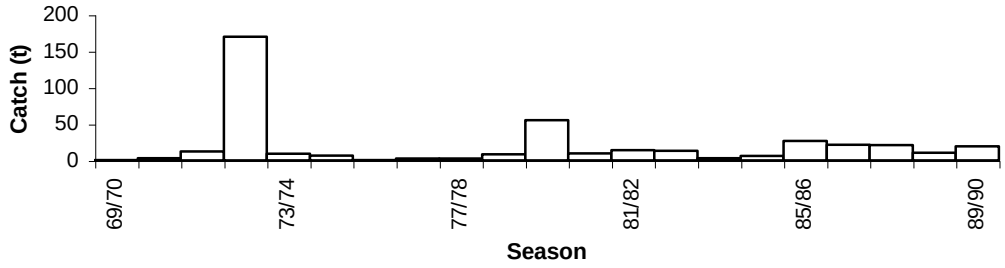


**Fig. 1.** Catches of arrow squid by season in Tasmanian waters through the 1970's and 1980's.

Fishing by foreign owned jig vessels for arrow squid was a feature of the Australian fishery in the 1970's and 1980's. Nineteen vessels from Japan caught 3400 tonnes in 1978/79 and 64 vessels caught 7900 tonnes in 1979/80 (Winstanley *et al*., 1983). Between 1983 and 1988, Taiwanese and Korean owned vessels took between 300 and 2300 tonnes per year from around Tasmania and in Bass Strait (JAMARC logbook data). There has been no foreign fishing for squid since 1988 (Fig. 2).

There have been no quantitative assessments of the size of the arrow squid resource off southern Australia. However, Harrison (1980) stated that based on measurements of primary productivity in south east Australia, it would be reasonable to expect that stocks of arrow squid in the south east zone could sustain a fishery of between 10000 and 50000 tonnes per year.

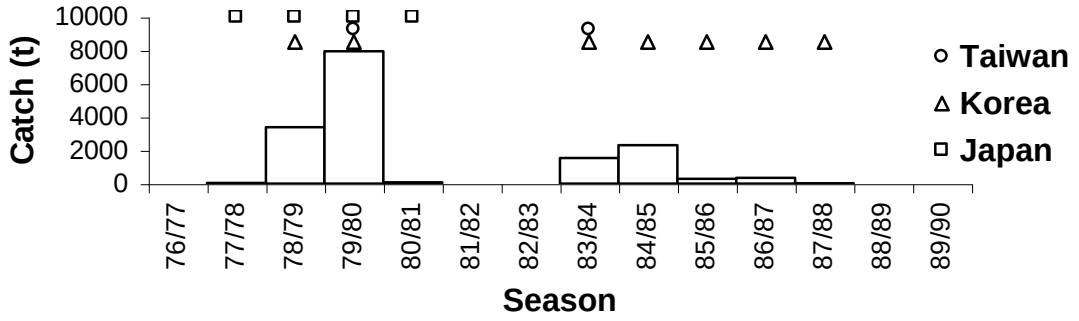


**Fig. 2.** Catches of arrow squid by foreign owned fishing vessels in Australian waters. Symbols indicate the nationality and years in which the vessels operated in Australian waters.

# 3. Commonwealth Fishery

Since the departure of foreign fishing vessels in the late 1980's there has been a growing interest in developing a domestic arrow squid fishery in Bass Strait. The fishery now targets arrow squid using jigs but there is also a significant catch (targeted and bycatch) from demersal trawling (Sturnman, 1999).

Australian light equipped jig boats began fishing in Commonwealth waters in 1986/87 with participation fluctuating between 7 and 17 vessels through to 1995. The five years between 1995/96 and 1999/2000 has seen 30 to 40 vessels participating in the Southern Squid Jig Fishery (SSJF). Catches peaked in the 1996/97 season at 2008 tonnes and have been as low as 347 tonnes in the1999/2000 season (Sturnman, 1999, AFMA logbook data) (Fig. 3).

Jig fishing is an effective way to take squid. The use of powerful lights at night attracts squid and prey species alike and creates dense aggregations. Arrow squid are aggressive and voracious feeders and readily attack jigs. Despite some issues with visual pollution from light sources, jig fishing is thought to have minimal environmental impacts with very little bycatch and physical habitat damage (Caton and McLoughlin, 1999).

The Great Australian Bight Trawl Fishery and South East (Trawl) Fishery have been operating for much longer than the SSJF. Arrow squid have traditionally been caught as bycatch of demersal trawling, however, some targeting of arrow squid aggregations now occurs. Trawl catches of arrow squid have fluctuated between 300 tonnes and 640 tonnes per year since 1985 (Fig. 3) (Sturnman, 1999).

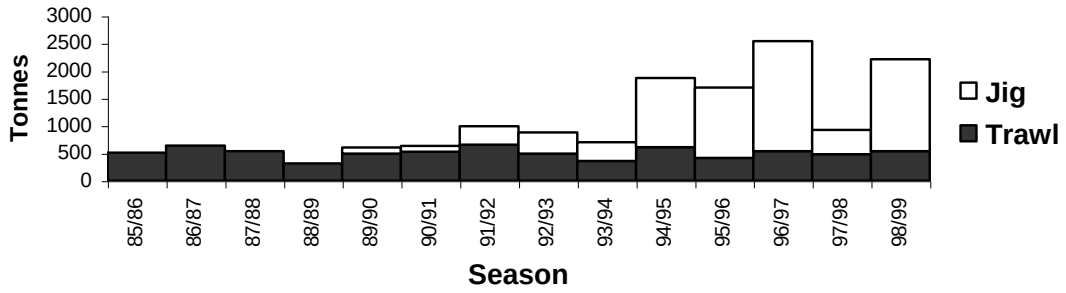


**Fig. 3.** Arrow squid jig and trawl catches in the Commonwealth fishery.

Jig catches peak at around 60 to 90 m depth (approximately 100 m is the limit of automatic jig equipment). By contrast, trawl catches of arrow squid are highest between 100 and 150 m with catches from as deep as 450 m reported (Sturnman, 1999). It is likely that this pattern reflects the depth range and intensity of fishing on trawl grounds rather than being representative of the distribution of arrow squid in south east Australian waters.

The general consistency of the trawl catches suggests that squid stocks may be more stable than has been previously suggested from jig catches. Availability of squid to the jig fishery apparently varies seasonally with dynamic environmental variables, including water temperature and the depth of the thermocline.

# 4. Tasmanian Fishery

## 4.1 Management arrangements

Under the scalefish management plan all scalefish and rock lobster licence-holders are entitled to use an unrestricted number of squid jigs. Until recently, the Tasmanian arrow squid fishery was based around diversified fishers who periodically targeted arrow squid using squid jigs operated by hand or semi-automatic fishing devices. The fishery expanded rapidly between November 1999 and February 2000, when about 400 tonnes of arrow squid were taken in State waters (mainly Storm Bay) by vessels using automatic squid jigging gear. Most of these vessels also participated in the Southern Squid Jig Fishery.

In response to the rapid increase in effort in the fishery the Tasmanian Minister for Primary Industries, Water and Environment issued a press statement in April 2000 warning fishers against investing in automatic squid jigging gear and fish attraction lamps. The Minister also made fishers aware that management arrangements for this fishing sector would be reviewed, and that catches taken after the press release date might not be taken into account in any determination of future access to the fishery. In November 2000, the Minister advised that State waters were to be closed between December 2000 and February 2001 to large-scale automatic jig operators, unless otherwise authorised by permit. About 15 arrow squid permits were issued. Long-term management of the arrow squid fishery is to be considered as part of the review of the scalefish management plan, scheduled to take effect in late 2001.

## 4.2 Recent catches

The Tasmanian arrow squid fishery targets schools that form around the coast from October through to March. The fishery saw a dramatic expansion of effort in the jig sector in 1998/99 and again in 1999/2000, with annual catches increasing from less than about 10 tonnes during the 1990's to 90 tonnes in 1998/99 and 430 tonnes in 1999/2000 (Fig. 4, Table 1). Preliminary catch data for 2000/01 indicate a sharp fall in the catch, to less than 40 tonnes. This occurred despite concerted fishing effort by a number of automatic jigging vessels. Significantly, good catches of arrow squid were reported by trawlers operating off the east coast of Tasmania during the summer and autumn period (46.5 tonnes was taken between October 2000 and April 2001- AFMA data section), suggesting that squid were present around Tasmania but not available to the jig sector.

In each of the seasons since 1998/00 the majority (about 80%) of the annual catches have been taken between December and January and predominately from Storm Bay.

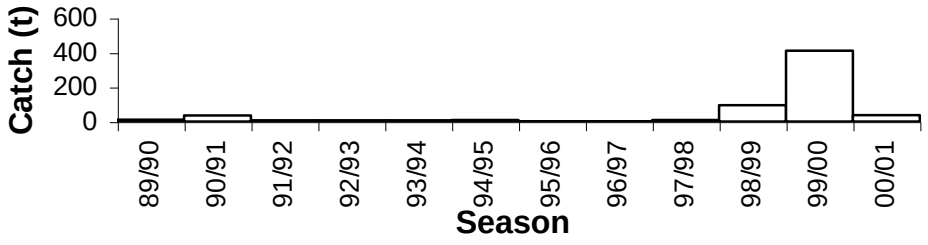


**Fig. 4.** Catch of arrow squid by season in Tasmanian waters.

**Table 1. Total arrow squid catch, squid jig catch and number of operators reporting the use of squid jigs in Tasmanian waters since 1990/91.**
Prior to 1995 squid jigging was not defined as a fishing method in the General Fishing catch return. Data for 2000/01 are preliminary.

| Fishing Season | 1990 /91 | 1991 /92 | 1992 /92 | 1993 /94 | 1994 /95 | 1995 /96 | 1996 /97 | 1997 /98 | 1998 /99 | 1999 /00 | 2000/ 01 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total catch(t)** | 37.4 | 7.2 | 7.0 | 8.1 | 8.8 | 6.3 | 11.6 | 13.1 | 94.5 | 431.1 | 36.9 |
| **Jig catch(t)** | - | - | - | - | - | 4.1 | 10.2 | 12.2 | 90.9 | 430.0 | 36.4 |
| **No. jig vessels** | - | - | - | - | - | 17 | 15 | 17 | 40 | 41 | 14 |

## 4.3 Fishing fleet

The fleet of vessels reporting arrow catches can be split into three groups based on the number of jigs used. The 'handline' category covers operators where rods or handlines with only a few jigs are used (the majority use less than 10 jigs). The 'small-scale' category covers fishers who have one or two automatic jig machines or have increased the number of jigs fished by using manual or semi automated reels. The majority of operators in this category report using less than 60 jigs. The 'large-scale' sector covers the larger boats equipped with powerful lights and up to 10 automatic jig machines and 500 jigs (the majority use over 200 jigs).

The arrow squid catch through the early to mid 1990's was attributable primarily to 'handline' and 'small-scale' operators. The 1998/99 season saw a major change in the fishery with the entry of several new jig boats and the operation of dual licensed Commonwealth jig vessels in Tasmanian waters. Six large-scale jig vessels reported some fishing in Tasmanian waters during 1998/99. This increased to 11 vessels in 1999/2000 while in 2000/01 8 vessels in this category reported fishing activity. In 1998/99 the large-scale sector accounted for over two-thirds (61 tonnes) of the total catch while in 1999/2000 this had increased to over 85% (352 tonnes) of the total. Although the other sectors were minor by comparison, there was a sharp decline in the handline catch between 1998/99 and 1999/2000 (from 27 to 10 tonnes) offset by increases in catches by small-scale operators (from 2 to 35 tonnes).

## 4.4 Marketing considerations

Logistically, the fleet has been limited in its area of operation since the catch is either stored fresh or on ice or in brine and spoils quickly. It is necessary, therefore, to fish in close proximity to the processing and storage facilities if a high quality product is to be achieved. Partly for this reason, catches in the past three seasons have been concentrated in Storm Bay and to a lesser extent off the east and north coasts of Tasmania. Industry members believe there are commercial quantities of squid spread right round the state but in many areas they remain largely under-utilised at the present time.

The world market for squid demands a product that is cheap and of high quality. Industry reports of quality problems, which have existed in Tasmania in the past, are currently being addressed (Tasmanian arrow squid management and research forum, August 2000). Arrow squid flesh discolours and loses its firm texture rapidly if it is not kept chilled and

processed soon after catching. Colour and texture are important factors in demand and sale price for fish products. One solution to the degradation of flesh quality that occurs in squid is to process and freeze the product as quickly as possible. Potentially, this could lead to on board packing and freezing in the future as is the case in the New Zealand fishery. Under such a scenario, the range of the fishery would be expected to expand to beyond grounds in close proximity to ports.

### 4.5 The 1999/2000 fishing season

The catches of arrow squid demonstrated a strong seasonal pattern, with peak catches taken between December 1999 and January 2000 (Fig. 5). Monthly catches between July and October did not exceed one tonne but increased to over 20 tonnes in November and peaked at over 180 tonnes in December and 150 tonnes in January. Landings then fell sharply in February to about 35 tonnes and then to less than 15 tonnes by March 2000. Catches for the reminder of the fishing year remained low, at less than 4 tonnes per month.

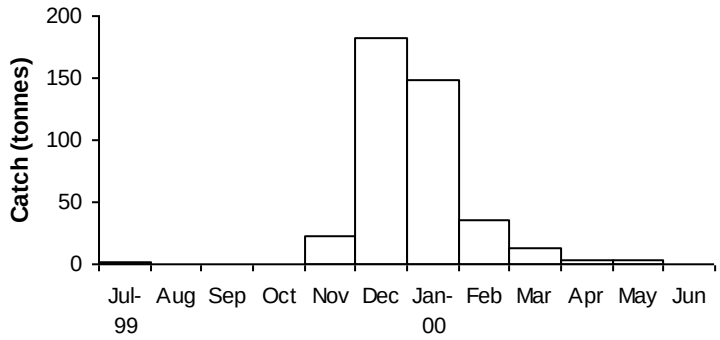


**Fig. 5.** Monthly arrow squid catches between July 1999 and June 2000 for Tasmanian waters

Approximately 90% of the 1999/2000 catch was taken from Storm Bay, with greatest concentrations of squid taken in December and January (Fig. 6). Smaller catches were also reported from Bass Strait, east of the Tamar River, and off the east coast, predominantly south of the Freycinet Peninsula. Industry reports suggested that effort and thus catches were low in Bass Strait despite an abundance of squid. The presence of large quantities of barracouta caused excessive damage and losses to fishing gear and as a consequence only limited fishing was attempted.

The vulnerability of arrow squid to squid jig fishing tends to follow a lunar cycle, with catch rates lowest around the full moon period and higher at other times. Not unexpectedly, the pattern of fishing effort has developed to mirror this, with many fishers remaining in port over the full moon period. Daily catch, effort and catch per unit effort[1] between November 1999 and March 2000 are shown in Fig. 7. The lunar periodicity of the fishery is clearly evident in these data.

Highest daily catches were taken throughout December, peaking before the full moon at the end of December. Catches declined steadily through January to March. Effort increased from November to peak levels either side of the full moon in January (i.e. late January/early February). A steady decline in effort was seen from mid-February to the

[1] In generating catch rate statistics the geometric mean has been calculated. The geometric mean approach is recommended because catch rate data tend to be log-normally distributed.

end of the season. Catch rates (CPUE) were highest early in the season (December) whereas by January and February, when effort had peaked, catch rates had declined to less than half the December levels. Biological sampling of arrow squid throughout this period indicated that at the start of the season the squid were small and generally immature (refer below). Mature females were not recorded in any numbers until February, by which time catches had dropped off markedly.

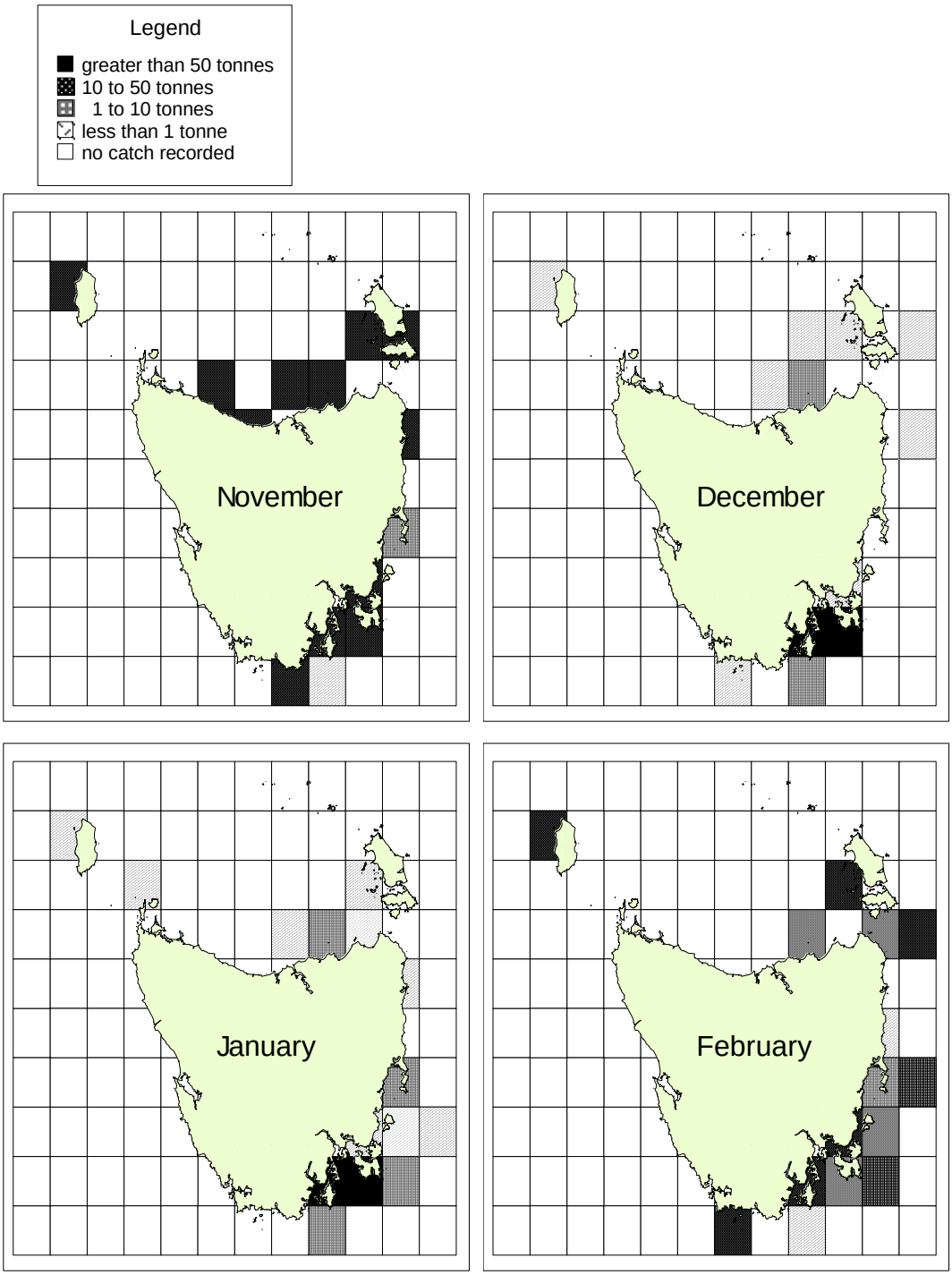


**Fig. 6.** Monthly catches of arrow squid in Tasmanian waters by half degree grid between November 1999 and February 2000.

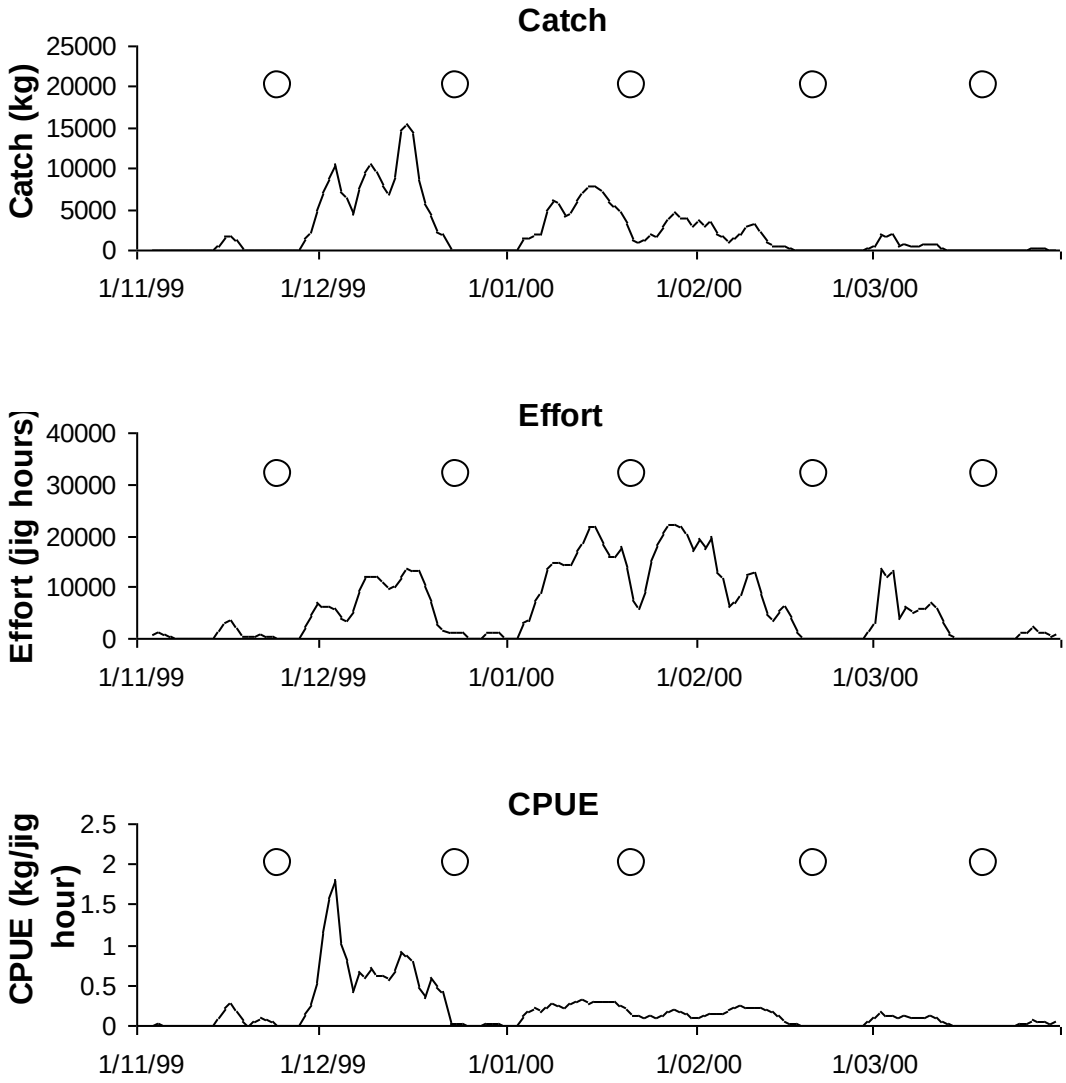


**Fig. 7.** Daily catch, effort, and CPUE for large-scale arrow squid vessels for November 1999 to March 2000. Open circles above the trendline represent full moon periods (Note, a three point running average has been applied to smooth the distribution).

## 4.6 Biological characteristics of the catch

### 4.6.1 Sampling

Samples from commercial catches and some research caught squid (from the D'Entrecasteaux Channel) were examined during the 1999/2000 season. Biological information for 1999/2000 has been provided by Belinda McGrath (Institute of Antarctic and Southern Ocean Studies) and by Ralph Mitchell (Australian Maritime College).

A more thorough sampling regime was implemented in the 2000/2001 fishing season, involving sampling the catch once every two weeks, where possible. Of particular interest were temporal changes in size structure and onset of sexual maturity for the local arrow squid population and how these results compared to the previous season.

All squid were measured to the nearest mm dorsal mantle length (DML), sexed, weighed and assigned a maturity stage according to Lipinski's universal scale (Sauer and Lipinski, 1990).

### 4.6.2 1999/2000 season

*Size composition*

In December 1999 arrow squid of 200 – 260 mm dominated the sample whereas by February 260 – 360 mm individuals were dominant (Fig. 8). In the absence of ageing information it is uncertain whether the increase in mean size from 223 to 299 mm between December and February is simply a reflection of the growth of a single cohort or due to a combination of other factors, including changes in fishing patterns (e.g. depth or areas fished). The occurrence of a small number of squid under 250 mm in February indicated that small individuals were at least present throughout the entire sampling period. The largest squid sampled was a 430 mm (about 1900 g) female[2].

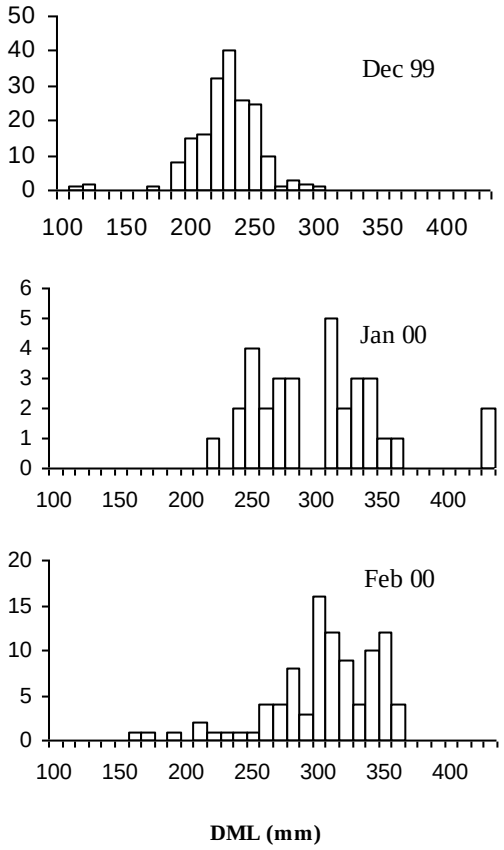


**Fig. 8.** Length frequency of arrow squid caught in Tasmanian waters in 1999/2000.

*Sex ratio and maturity*

The December sample consisted of approximately equal numbers of males and females whereas females accounted for 78 and 76% respectively of the January and February samples (Fig. 9). Given the small sample sizes in January and February it is uncertain as to whether these observations are representative of the population. Of particular

[2] The large size of this specimen suggests that it may have been the closely related species *Todarodes pacificus.*

significance was the observation that all females sampled in December were immature (based on maturity stages 1-3) (Fig. 10). In the January sample nearly 50% of the females were judged to be mature (maturity stages 4-5) with 60% mature by February. By contrast, between 80 - 100% of the males examined were mature throughout the sampling period.

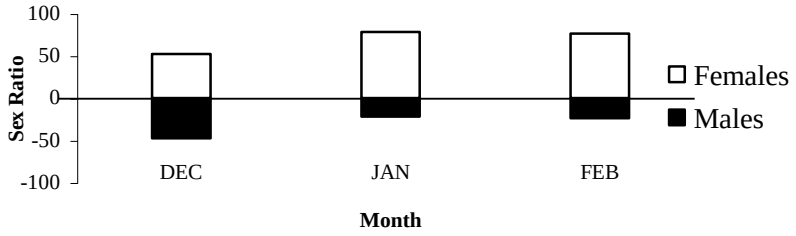


**Fig. 9.** Sex ratio of arrow squid caught in Tasmanian waters in 1999/2000.

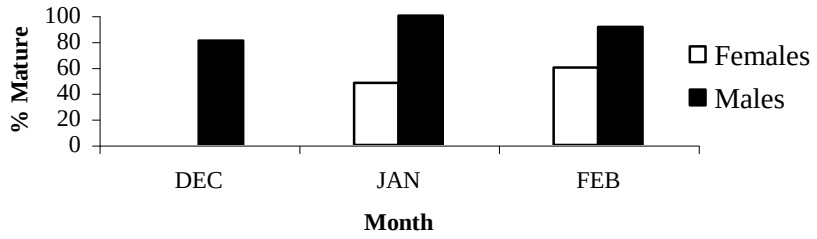


**Fig. 10.** Reproductive maturity of females and males caught in Tasmanian waters in 1999/2000

Size and maturity data for females indicated that the average size of the mature females examined was 328 mm, with the smallest mature female measuring 290 mm. However, individuals up to about 340 mm were immature. Given the degree of plasticity in individual growth rates evident in many squid species, it is unclear whether age rather than size (coupled with environmental influences) is a more important factor in determining the onset of maturity.

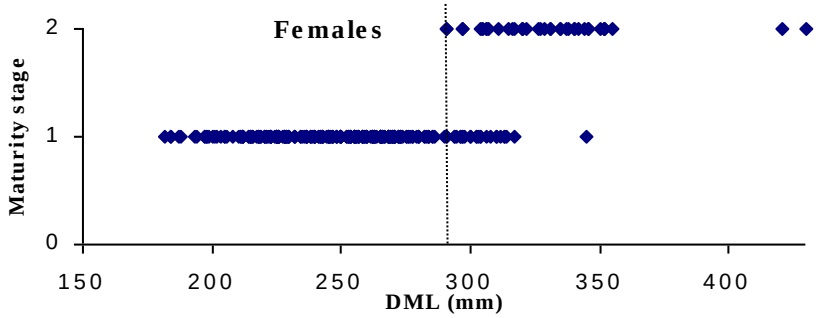


**Fig. 11.** Size (dorsal mantle length) and stage of maturity (1=Immature, 2=Mature) of female arrow squid from Tasmanian waters in 1999/2000. Dotted line indicates the smallest size at maturity.

### 4.6.3 2000/2001 season

In total 7 samples were collected from commercial catches between October 2000 and May 2001. As a result of poor and sporadic commercial catches, samples were collected opportunistically. Each sample consisted of approximately 150 squid, the majority of which were jigged from the Storm Bay region, however, there was a single sample (April) trawled from the eastern side of Maria Island.

*Size composition*

The size composition of the commercial catches initially displayed modal progression for both males and females, where the average size increased from approximately 200 mm in late October to approximately 240mm by late December (Fig. 12). In late December, however, the influx of smaller, immature animals coexisting with larger mature/maturing individuals produced a bimodal size structure (Fig. 12). This bimodality persisted until late January, with the relative quantities of the larger more mature animals slowly declining. Although it is difficult to make accurate inferences about this population structure without age-based analysis, these results suggest that a younger cohort entered the fishery during the second half of December, complimenting the gradual disappearance of the larger (older) cohort of mature squid from the fishery. Interestingly, the modal size for this 'younger' cohort remained around the 180 mm between December and January, irrespective of sex.

Unfortunately there was a 3-month period, extending from late January to late April, during which commercial samples were unable to be obtained in large enough quantities for biological investigation. However, a trawled sample collected in late April was comprised of squid largely in the 230 – 340 mm size range, with the average size males and females measuring 289 and 267 mm, respectively. The females in this trawled sample were relatively large in comparison to those collected earlier in the season but were immature, being equally composed of stage 2 and 3 animals. A jigged sample collected in May indicated a markedly different size structure to the trawl catch, with a large proportion of the individuals measuring 160 – 280 mm, but similarly was comprised of immature females. The size structure of the May sample was in fact more comparable to that observed in early December. These differences in size structure for the April and May samples may be, in part, a function of fishing method, with trawls and jigs possibly having different selectivity profiles for squid. Without ageing these samples it is unclear whether they represent the cohort of smaller squid observed during the summer or were a new cohort entering the area.

Females displayed a broader size range than males and ultimately attained larger body sizes. The largest female recorded was 364 mm (substantially smaller that the largest individual for 1999/2000) compared to 323 mm for the largest male. Both of these animals were collected from the trawled April sample. For jigged animals the females were also considerably larger than males, measuring 351 mm and 313 mm respectively.

*Comparison between years*

The bimodality in December and January was not evident in the 1999/2000 samples and in fact the modal size in December 1999 (220 - 240 mm) lay within the trough between the modes of late December 2000 sample. Although it is possible that the 1999/2000 samples were not fully representative, it is also possible that the observed differences between seasons may reflect inter-annual variability in growth rates and population structure within

the sampling area. The fact that the 2000/01 catch was almost an order of magnitude smaller that in the previous year (despite concerted fishing effort) is indicative of strong inter-annual variability in availability.

*Length weight relationship*

Length weight relationships for females and males were $W = 2E\text{-}05L^{3.0525}$ ($r^2$=0.9556) and $W = 1E\text{-}05L^{3.1487}$ ($r^2$=0.9216), respectively, where *W* is weight in grams and *L* is dorsal mantle length in millimeters (Fig. 13). The heaviest specimen examined was 1250 g.

*Sex ratio and maturity*

Females accounted for between 51-55% of the samples in each of the months examined, whereas in May where they contributed 60% of the catch numbers (Fig. 14). Examining maturity indices across the entire sampling period revealed that over half of all females from each month were immature (Fig. 15). The greatest proportion of mature females (41%) was recorded in December, with around 20% of females mature in the October and January samples. Virtually all of the females examined in April and May were immature. The proportion of males that were mature was consistently higher than for females, with between 45-56% of males mature in the October, December and January samples. In contrast to females, the highest rates of mature animals present (over 70%) occurred in the April and May samples. Declines in the proportion of mature squid for either sex between December and January were due to the influx of the smaller squid in late December and the disappearance of larger squid over this period (Fig. 12).

Results from this study indicated that males were more precocious than females, with the smallest mature male measuring 166 mm, considerably smaller than the smallest mature female that measured 230 mm (Fig. 16). Size at maturity for females collected during the 2000/2001 season was comparatively smaller than females collected from the previous fishing season (compare with Fig. 11). This may be a result of the plasticity of growth and reproduction, typical of most cephalopod species, or may be related to the fact that the previous year's sample size was relatively small.

All stage 5 mature females were mated, having spermatophores stored within their buccal membranes. Approximately 15% of stage 3 and 4 females were mated whereas all immature females displayed no evidence of mating activity (Fig. 17).

### 4.6.4 Conclusions

Biologically there were differences between years, not only in terms of catch levels but also in terms of the size structure of catches. What was consistent, however, was the observation that the bulk of the females examined were immature, especially early in the season. Interestingly, the autumn catches in 2001 were also based on immature animals. The impact of taking large quantities of small, immature squid early in the season, as opposed to delaying the fishery so to allow further growth and development, on potential yields and overall stock productivity is unknown. Greater understanding of the growth dynamics, stock structure and reproductive biology is required to interpret both the intra and inter-annual variability observed in catches and biological characteristics. Further, as the fishery off south-eastern Tasmania is in reality a component of a larger squid fishery based off southern Australia, it will be important to consider the present findings in the context of the wider fishery and the wider squid resource.

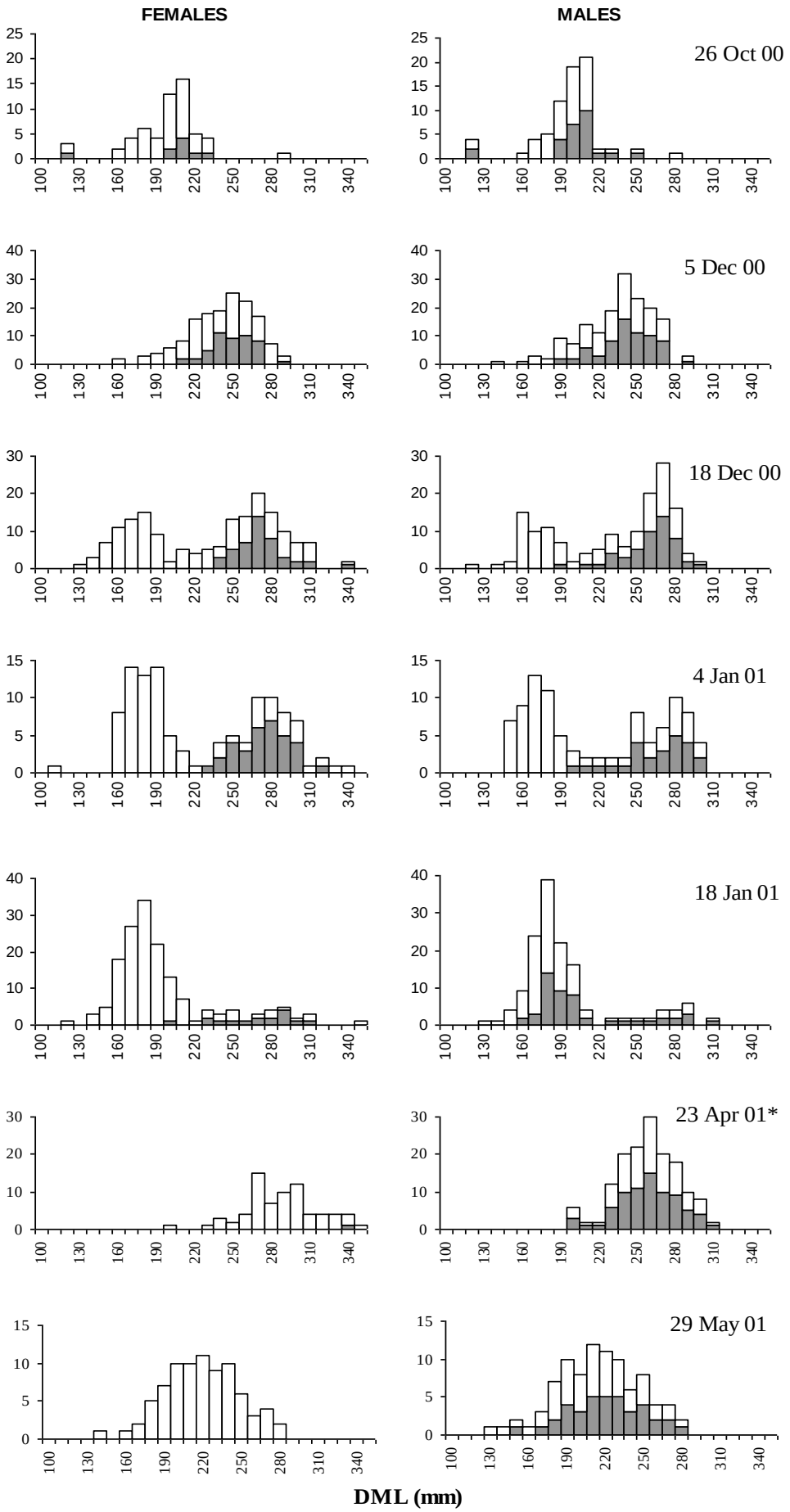


**Fig. 12.** Length frequency histograms of arrow squid caught in Tasmanian waters 2000/2001. Shaded areas represent mature (stage 4 and 5) animals, * represents trawled sample.

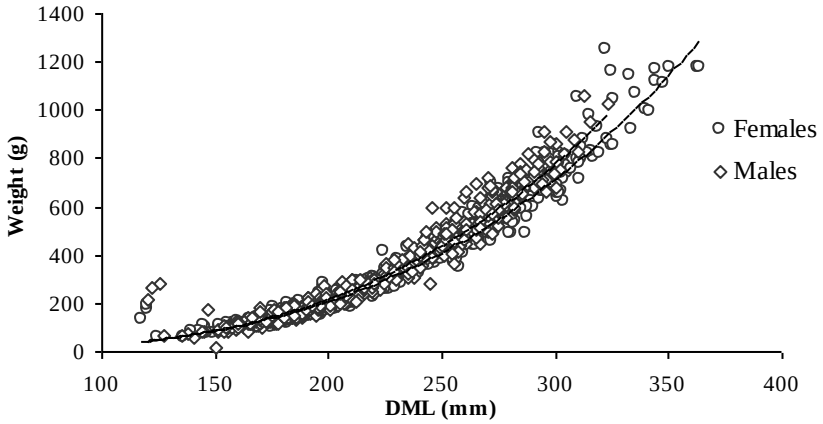


**Fig. 13.** Length weight relationship for arrow squid.

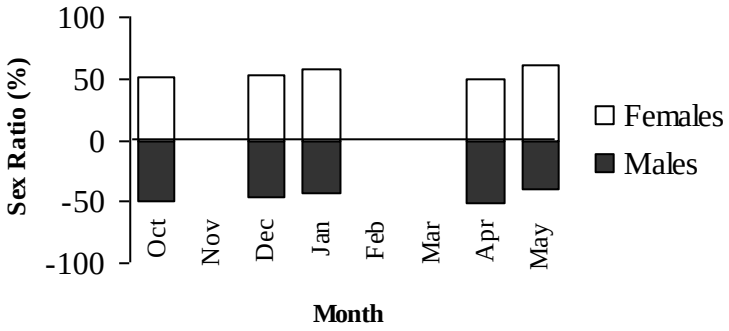


**Fig. 14.** Sex ratio of arrow squid caught in Tasmanian waters in 2000/2001.

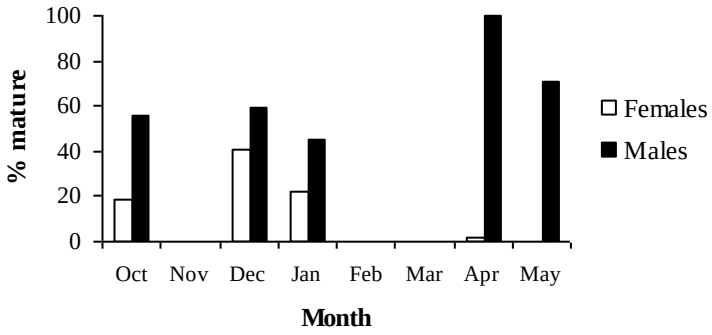


**Fig. 15.** Reproductive status of males and females caught in Tasmanian waters in 2000/2001 by month.

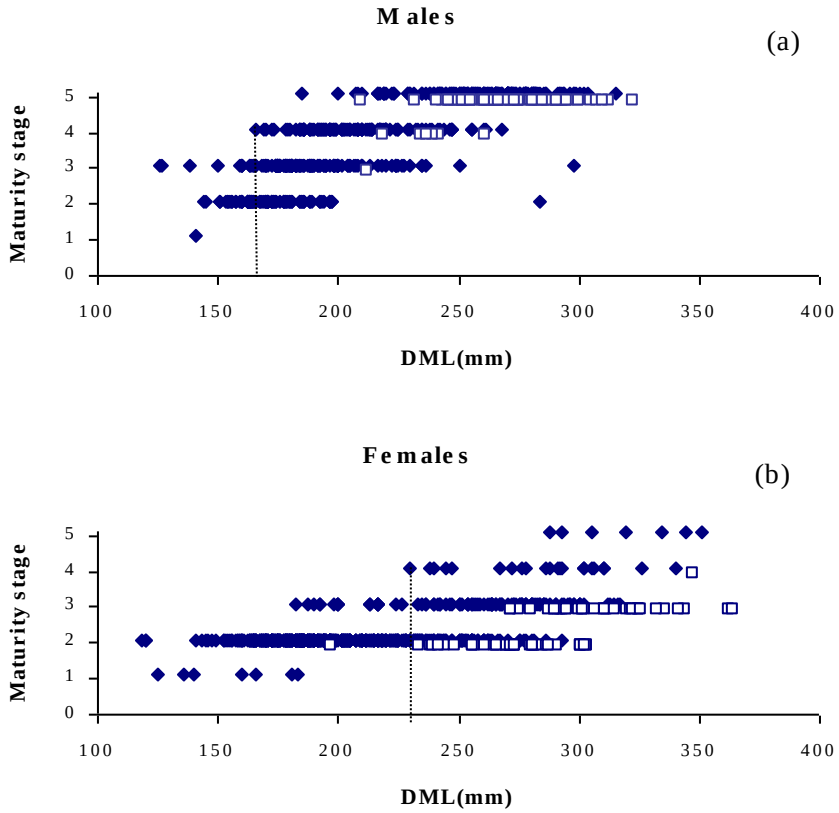


**Fig. 16.** Size at maturity for (a) male and (b) female arrow squid caught in Tasmanian waters. Stage 4 and 5 considered mature. Empty squares represent animals trawled in April sample.

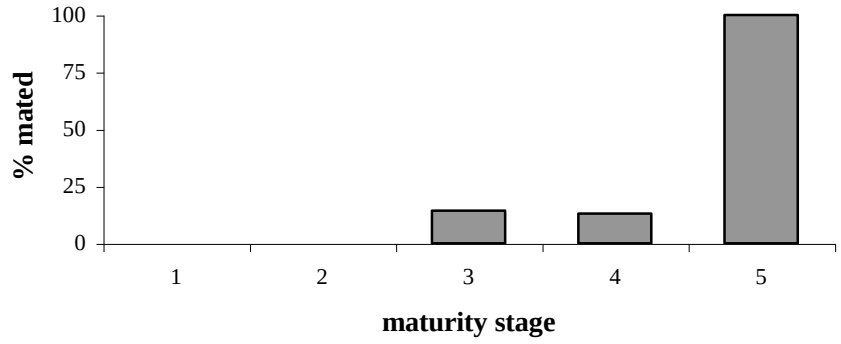


**Fig. 17.** Percentage of female arrow squid mated according to maturity stage.

## 5. Implications for Management

The sporadic nature of the arrow squid fishery in south-east Australia has been due in part, to economic viability, as dictated by world supply and demand for squid, and to fluctuations in the size of the stock available to the jig fishery. Some variation in effort may also be due to fluctuations in the performance of other south-east Australian fisheries which have the effect of forcing fishers to look to alternative species such as squid.

A significant body of latent effort exists in the Tasmanian arrow squid fishery in the form of Commonwealth automated jig boats that are increasingly looking to maximise the

length of their fishing season. Arrow squid become available to the jig fishery in Tasmania as early as November as opposed to February in Bass Strait. By fishing in Tasmanian waters, Commonwealth operators can increase the length of the season by up to 4 months. There is, therefore, an urgent need to address the issue of access by large-scale operators to the fishery. This was undertaken as an interim measure for the 2000/01 season but should be resolved within the context of the 2001 scalefish management plan review.

A number of characteristics particular to squid populations make management of such fisheries particularly difficult. The short life span means that essentially a new population has to be managed each year. Also, the extreme plasticity of growth in squid means that the more traditional use of length frequency relationships in management and assessment techniques are not valid. Ageing of individuals is a much more powerful tool for determining population dynamics. The implications of harvesting large quantities of immature squid from a relatively small area (principally Storm Bay) on potential yield and stock status are unknown. Very little is known about the population dynamics and stock structure of arrow squid in Australian waters at this stage.

Given the existence of squid fisheries in waters adjacent to Tasmania it would also be prudent to consider management of the Tasmanian fishery in the context of the wider fishery off southern Australia.

## 6. Research Needs

The need for research into arrow squid, in particular in relation to monitoring size/age structure and reproductive condition as a means of supporting management, was identified as a high research priority by the 1999 - 2004 Tasmanian Fisheries and Aquaculture Strategic Research Plan. Very little is known about the ecology and population dynamics of arrow squid populations around Tasmania. Various studies have been conducted since the early 1970's and data obtained from these studies have shown a high degree of variability in the distribution and abundance of the species between years. Recent ageing work on squids has revealed that the more traditional use of length frequency analysis may not be an appropriate way to model the populations.

Research into the life history and stock structure of arrow squid off southern Australia is being undertaken by the Institute of Antarctic and Southern Ocean Studies. A post-graduate study within TAFI to examine the dynamics of arrow squid in Tasmanian waters has also been proposed.

## 7. Acknowledgements

We gratefully acknowledge Belinda McGrath (Institute of Antarctic and Southern Ocean Studies) for assistance in sourcing many of the squid samples and for the provision of biological data, in particular during the 1999/2000 season. Ralph Mitchell (Australian Maritime College) also provided some biological material for the 1999/2000 analyses.

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