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Development of a northern Australian squid fishery

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94/017 Development of a northern Australian squid fishery

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OBJECTIVES:

1. To document the known distribution and seasonal abundance of squid (*Photololigo* species) and northern calamary (*Sepioteuthis lessoniana*);
2. To investigate species composition, seasonal size composition and basic life history characteristics (life span, location of spawning grounds, spawning season, reproductive biology) of existing and potentially commercially important northern Australian squid resources;
3. To undertake gear assessment / experimental fishing for squid using jigs under lights, lift nets and purpose designed squid trawls off southern and central Queensland in collaboration with commercial fishers;
4. To assess the relative seasonal catch rates of squid at selected locations off southern and central Queensland in collaboration with commercial fishers.

NON TECHNICAL SUMMARY:

Squid are an increasing component in the reported byproduct of commercial prawn and finfish trawlers in northern Australian shelf waters and interest has been shown by Queensland and Northern Territory fishers in developing target fisheries for squid using jigs. In general, squid caught on jigs or in lift or other surround nets are of higher quality, larger size and, on overseas markets, fetch a much higher price than squid caught by trawling.

In support of developing squid jig fisheries and to provide management advice, this project aimed to consolidate and enhance our knowledge of their fisheries biology and suitable fishing methods for inshore squid in northern Australian waters.

Objective 1 In northern Australian waters, five squid species of the family Loliginidae are of commercial interest. The most abundant and widespread in mid shelf waters from northern New South Wales to the Northwest Shelf is slender squid. No clear seasonal peaks in abundance were evident in reported trawl byproduct off the Queensland east coast although catches tended to be higher in the Northern and Kimberley Prawn Fisheries from August to November. Broad squid is restricted to nearshore coastal waters from Sydney to at least Shark Bay, Western Australia and is more abundant in southern Queensland in summer. Northern calamary or tiger squid is a byproduct of coastal net fisheries, particularly in winter and is caught by recreational anglers using trolled jigs (southern Queensland). It is widespread in both shallow inshore and deeper reef waters from Brisbane to Geraldton, WA, but offshore, is nowhere as abundant as slender squid.

Objective 2 Squid byproduct from commercial trawl and research catches off Queensland, the Gulf of Carpentaria and the Kimberleys (limited samples) revealed that although different species favoured particular habitats or depth zones, catches in many areas consisted of more than one squid species.

Slender and broad squid reach 40 cm ML (500g) and 20 cm ML (160g) respectively, have short life spans (oldest recorded slender squid was 254 days) and individuals are highly variable in length at the same age. Length at reproductive maturity was also highly variable. Temperate loliginid squid (off South Africa, California, Falklands) are reported to die after a single spawning period lasting at most a few weeks. By contrast, mature female northern Australian squid were present in most months of the year in areas sampled regularly (Moreton Bay - broad squid and off Bundaberg - slender squid).

Although no comprehensive surveys could be undertaken in inshore waters, spawning grounds of northern calamary were identified off southern and central Queensland from interviews with fishers. Slender squid spawning grounds were identified only in the western Gulf of Carpentaria and off the Kimberleys. No major spawning grounds for broad squid were identified in Moreton Bay or inshore

waters elsewhere despite historically intense commercial and research trawling.

Objective 3 Active involvement of commercial fishers in the gear assessment and preliminary resource assessment had been planned. Unanticipated, ongoing delays in obtaining authorizations from the Queensland Fisheries Management Authority occurred and Queensland commercial fishers could not be actively involved in gear trials and exploratory fishing as proposed. As a result the project was unable to achieve its goals to the extent planned.

Trials of jigging machines and hand jigs could only be undertaken from a DPI research vessel off southern Queensland when vessel availability and weather conditions suited. These trials were undertaken in April and July 1995 and showed slender and broad squid could be caught by machine jig in both midshelf waters off Mooloolaba and inshore waters of Moreton Bay. Catch rates could not be extrapolated from these limited data to a commercial operation. Small but significant jig catches (70 kg in ten hours) of potentially high value slender squid were taken from a commercial prawn trawler off southern Queensland in February 1997.

Objective 4 It is recognized that commercial logbook data for squid byproduct reflects predominantly effort in the primary fishery (prawn or finfish). Despite this, analysis of logbook catches was presented to provide an indication of seasonal availability of squid resources in northern Australia.

Commercial trawl catches of broad squid in Moreton Bay showed strong seasonality whereas squid byproduct from prawn trawling elsewhere off the Queensland east coast was low and variable throughout the year. Squid byproduct in the Northern Prawn Fishery generally peaked in early spring when squid were targeted in some areas. Commercial catches of northern calamary from the inshore net fishery off southern Queensland peaked in the winter months. Catches in the Taiwanese trawl fishery in the Arafura Sea from 1978-82 peaked between spring and autumn.

Without the involvement of commercial fishers and with the limited availability of the only DPI research vessel, relative seasonal catch rates using jigs could not be determined. Research trawls off Mooloolaba showed high seasonal and annual variability in squid catches. This was less so for broad squid in Moreton Bay where abundance was generally higher from spring to autumn from research trawl data collected in 1982-84.

Conclusions and recommendations
This study has shown that slender squid and broad squid can be caught with both machine and hand operated jigs off the southern Queensland coast. Squid are aggregated and hence available to a commercial jig fishery in association with spawning activity. For all species and in all areas, spawning (as assessed by the presence of mature females) is likely to be occurring at some level throughout the year and population structure is complex.

In 1979, Taiwanese trawlers reported approximately 2600 tonnes of squid from the Arafura Sea sector of the Australian Fishing Zone, indicative of the potential of the squid resource off northern Australia. The reported annual squid catch from Australian vessels from this region has never exceeded 1000 t.

To enhance the development of squid jig fisheries off northern Australia, it is recommended that further assessment and monitoring to determine areas and times of squid aggregation (including specific spawning locations) be undertaken through the collection of more comprehensive squid byproduct data from existing trawl fisheries. Monitoring should also be undertaken of any developing squid jig fisheries noting the presence of mature female squid and egg capsules in catches as well as seeking better description of spawning habitats. With the recent targeting of squid using prawn trawls in spawning grounds off the Kimberleys and in the Gulf of Carpentaria, priority should be given to research into the impacts of bottom trawling on spawning activity and survival of squid eggs.

Future squid jigging trials to assess commercial potential should be undertaken from appropriately equipped vessels with good sea handling capabilities (similar to southern Japanese inshore squid jigging vessels) and focus on areas of identified squid abundance.

KEYWORDS: **inshore squid, developmental fisheries, jigging, tropical Australia, Loliginidae, *Photololigo, Sepioteuthis***

Background

Kinds of squid in Australian waters

Three main kinds of squid of existing or potential commercial interest occur in Australian waters. Several kinds of arrow squid occur in southern, deeper slope and oceanic waters (Gould's squid *Nototodarus gouldi* in continental shelf waters, Hawaiian flying squid *Nototodarus hawaiiensis* in northern slope waters, red ocean squid *Ommastrephes bartramii* in subtropical oceanic waters, yellowbacked flying squid *Sthenoteuthis oualaniensis* in tropical waters). Calamary or bigfin squid occur in shallow reef and seagrass habitats (northern calamary *Sepioteuthis lessoniana* in northern Australia and southern calamary *S. australis* in the south). Two kinds of pencil squid are abundant in northern continental shelf waters (broad squid *Photololigo etheridgei* in bays and close inshore, slender squid *Photololigo* sp. 4 in mid shelf waters). This study focuses on these two species with limited information presented for northern calamary (*Sepioteuthis lessoniana*) biology and fisheries.

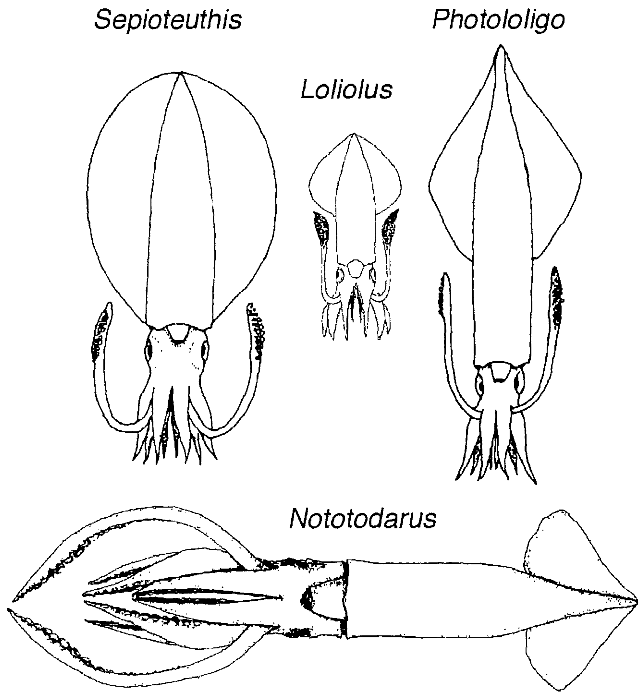


Figure 1. Common commercially important squid from shelf waters off northern Australia: pencil squid - Photololigo *spp.; northern calamary –* Sepioteuthis lessoniana*; bottle or bay squid -* Loliolus noctiluca*; and an arrow squid from tropical slope waters -* Nototodarus hawaiiensis. *[after Wormuth 1976, Okutani 1991 and Lu* et al.*, 1985]*

Arrow squid in the Bass Strait region (Gould's squid *Nototodarus gouldi*) have been the subject of small scale domestic and foreign jigging fisheries since the late 1970s with a maximum annual catch of approximately 8,000 t taken by joint venture Japanese vessels in 1979/80. Related species are the subject of major fisheries overseas (eg., Argentine flying squid *Illex argentinus* in southwest Atlantic shelf waters, up to 300,000 tonnes taken annually; Japanese common squid *Todarodes pacificus* in shelf waters of the Japan Sea and northwest Pacific, 300,000 tonnes; red squid or neon flying squid in oceanic waters of the North Pacific, 70,000 t; jumbo squid

Dosidicus gigas in oceanic waters off Peru and Chile, up to 190,000 t; Wellington flying squid *Nototodarus sloanii* in shelf waters around New Zealand, 25,000 t). They fetch the lowest prices domestically and overseas of the three kinds of squid.

Northern calamary are broadly distributed but apparently not very abundant, occurring in shallow inshore areas and out across the continental shelf in small groups as adults. By contrast, pencil squid *Photololigo* species, occur in large schools and have been reported by commercial fishers to be seasonally abundant at various locations off the northern Australian coast. Both these kinds of squid fetch considerably higher market prices than arrow squid on both the domestic and overseas markets because they are more tender than arrow squid.

Limited relevance of studies of arrow squid to northern inshore squids

Studies undertaken previously on temperate Australian squid biology, fisheries and fishing techniques are of limited relevance to development of a squid fishery in tropical and subtropical waters of northern Australia. Tropical inshore squid belong to a different group of squids (Family Loliginidae) rather than the more oceanic arrow squid (Family Ommastrephidae - *Nototodarus* spp.) which are the subject of jig and trawl fisheries off southern Australia and around New Zealand. Gear used efficiently for harvesting squid in the established southern arrow squid fisheries cannot be used unmodified for the tropical inshore squids. For example, tropical squid have softer and smaller tentacles and arms and have not been caught effectively using jigging machines rigged and operated for arrow squid during earlier trials (Dunning *et al.*, 1981). Loliginid squid are more efficiently caught in south and east Asia with smaller jigs and slower machine speeds. The basic biology of inshore squid and oceanic squid is also different (eg., likely absence of large scale migrations, possible large scale aggregations for spawning of demersal egg clusters compared to pelagic spawning in arrow squid).

Markets - import replacement, export potential?

The domestic market for cephalopods has increased over recent years with more than 9,000 tonnes of squid imported in 1998/99 (ABARE, 2000). This does not include processed cephalopod product (canned, dried or shredded), statistics for which are not reported separately from other processed product.

Overseas markets for high quality squid have opened up because of recent major reductions in the global catch (more than 300,000 tonnes of red ocean squid were taken annually by the recently banned driftnet fleets of Japan, Korea and Taiwan). In addition, catches from the jig and trawl fishery for arrow squid in the southwest Atlantic which commenced in the early 1980s and the jumbo squid jig fishery off Peru have shown significant interannual variability (Uozumi and Shiba, 1993). Hence market demand for squid from alternative sources can be quite variable.

High quality loliginid squids (as occur in Northern Territory, northern Western Australian and Queensland waters) in particular are favoured and highly priced on the Japanese and other Asian markets but are available, for example, from Japanese waters for a restricted season only, peaking in July - August. Similar squid trawled in Indian and other south east Asian waters are generally of low quality. Trial shipments to Thailand in 1993 of trawled pencil squid from

Queensland were very favourably received but the absence of information on seasonal availability and quantity of product was an impediment to this market being pursued (Bob McLean, commercial trawlerman, Yeppoon, personal communication, 1994).

The Brisbane wholesale market price for local squid has trebled since 1981 (average $1.33 per kg) with "large squid" (probably *Sepioteuthis*) selling in 1993 for up to $12.50 per kg and an average price of $4.00 per kg obtained for "medium squid" (probably *Photololigo* spp.). The wholesale average price per kilogram for fresh jigged squid (> 20 cm ML) at markets in Fukuoka, Kyusyu, southern Japan in 1994 was 2340 yen (≈$27) and for trawled squid, the monthly average price ranged from 660 to 1020 yen (≈$7.50 - $12) (H. Yamada, Seikai National Fisheries Research Laboratory, Nagasaki, personal communication, 1996)

Interest by commercial fishers

The Queensland Fisheries Management Authority (QFMA) continues to show interest in diversifying Queensland's fisheries, in part as a means of reducing effort in fully exploited trawl fisheries. After several requests from commercial fishers to undertake experimental fishing and from overseas buyers seeking high quality product, the then Queensland Fish Management Authority commenced preparation of a draft Squid Fishery Management Plan in 1993. A call for expressions of interest from Queensland commercial fishers to participate in a developing squid fishery resulted in over 35 responses, predominantly from existing commercial trawl operators. Some of these operators sought to collaborate with QDPI on this project when proposed in 1993. Following the enactment of a new Fisheries Act in Queensland in 1994, however, this process was suspended pending resolution of a new policy on exploratory and developmental fisheries.

Formal applications for participation by Queensland fishers in this project were submitted to the QFMA in October 1994 but no authorizations had been issued to allow fishers to independently operate jigging equipment by August 1996 when the field component of this project ceased.

A single fisher had a permit to fish for squid using jigs and surround nets in Northern Territory waters in 1996 and the Northern Territory Department of Primary Industries and Fisheries maintains an interest in evaluating and promoting alternative commercial harvest methods for squid.

Current reported catches

In northern Australia, pencil squid are taken primarily as a byproduct in prawn trawl fisheries and northern calamary or tiger squid in coastal set net fisheries. Since the early 1980s, some targetting of small pencil squid by domestic trawlers has been reported in Moreton Bay, especially in autumn, and elsewhere off northern Australia (eg. Shark Bay, WA; off the Bombard Shoals and north of Mornington Island and around the Vanderlin Islands in the Gulf of Carpentaria).

Because of the use in recent years of higher mouth opening nets (eg. tongue trawls, modified banana prawn trawls) and faster towing speeds, larger and better quality squid has been retained from bycatch and its market potential has been increasingly realized by commercial trawl fishers. Larger squid (of potentially higher commercial value) have been reported by Queensland trawl and reef line fishers from outside Moreton Bay and off Fraser Island, in the Swains Reefs area, off the Keppels, off Cape Flattery (eastern Cape York), off Weipa and Mornington Island in the Gulf of Carpentaria and in the northeastern Torres Strait. However, larger squid are less susceptible to capture in typical demersal prawn trawls.

Because northern Australian squid have traditionally been a byproduct rather than a target species, fishing effort and catch is typically under-reported in commercial logbooks. These existing data are hence of little value for stock identification or assessment purposes. Total catches of approximately 200 tonnes, worth in excess of $1m at the wharf, are reported annually from Queensland east coast waters. The actual catch from northern Australian waters (Qld, NT and WA) may be in excess of 1,000 tonnes. The retail value of bait squid to recreational fishers and the commercial tuna longline fleet may at least exceed the value of the commercial catch, with some of this product imported from California, New Zealand and Japan.

Collaborative studies

Increased interest in development of a squid jig fishery has also been shown by some Northern Territory fishers. The Northern Territory Fisheries Research and Development Branch submitted a complementary proposal in 1993 with a focus on harvesting and processing methods for tropical squid. However, this project did not receive funding and has not been pursued. Close liaison has been maintained with officers of NT Fisheries and with interested NT fishers in relation to gear technology and exploratory squid jigging trials.

Researchers and students at James Cook University of North Queensland have been undertaking studies of age and growth of cephalopods in Australian waters. Assistance has been provided by project staff to these studies, particularly to field collecting and laboratory analysis. Of particular interest have been ongoing studies of growth in *Sepioteuthis* spp. (southern and northern calamary) - Ms Gretta Pecl, Mr Jayson Semmens and Dr Natalie Moltschaniskyj, and statolith aging studies of pencil and bottle squid by Dr George Jackson and Mr Ross Thomas.

Need

The likely catch of squid in northern Australian waters was more than 1000 tonnes in 1995 with more than 500 tonnes reported through commercial fisheries logbooks. Fisheries managers lack even the most basic resource information to enable them to manage this developing squid fishery in various areas off northern Australian. Despite the lack of information, individual trip limits of approximately 8 -10,000 tonnes have been set by fishery managers for the squid byproduct (and target) component of demersal trawl catches in the Northern Prawn Fishery (Memorandum of Understanding between the Commonwealth of Australia and the State of Queensland with respect to the Northern Prawn Fishery, 10 February 1995).

Because tropical squid has traditionally been only a byproduct in Australian domestic fisheries and in the absence of any directed research, information is sparse on where and when squid are abundant and the size, spatial and temporal dynamics of populations / stocks. Is the resource concentrated within traditional trawl grounds or elsewhere? What are the seasonal and interannual changes in the abundance of squid in particular areas and are there regular patterns in abundance? Do tropical squid aggregate for spawning? Can these squid be caught commercially using jigs and hence fetch a higher market price? Are there any aspects of the life cycles of these species which make them vulnerable to overfishing? Will a target fishery for squid using alternative methods such as jigs or liftnets impact adversely on other recreational and commercial fisheries?

Knowledge of the species of squid present in catches from northern Australia and marketed remains largely anecdotal. Knowledge of characteristics of squid biology essential for responsible management of any developing tropical squid fishery (eg., population structure, average life span and generation time, natural mortality rates, location of spawning grounds, migrations, natural variability in abundance) remains scant.

Since this project commenced in 1994, intensive target trawling of squid in spawning aggregrations off the Kimberleys and the Vanderlin Islands in the southern Gulf of Carpentaria has occurred with catches of several hundred tonnes taken in a few weeks. Loliginid squid lay attached egg clusters on the bottom which may be destroyed by demersal trawling. The lack of knowledge of the impacts of demersal trawling even at current levels on the sustainability of the squid resource and associated local ecosystems is a matter deserving urgent consideration by fisheries managers and the industry.

Discussions with marketing staff in Queensland Department of Primary Industries and commercial seafood marketers have highlighted the need for basic information on the availability of product (especially quantities and seasonality) being obtained first as an essential prerequisite to any studies of enhancing domestic and overseas market potential and acceptability or value adding of product.

Previous studies undertaken on southern Australian arrow squid biology and resource potential are of limited use for the development and management of a fishery for inshore loliginid squid in tropical and subtropical waters of northern Australia.

Fishers want to know the most appropriate fishing methods and fishing gear to use to catch squid in northern Australian waters. Limited trials in the early 1980s indicated that gear used in the established southern Australian arrow squid fisheries (standard Japanese "surume-ika" jigging gear and high wattage, white lights) will not catch tropical inshore squid effectively (Dunning, Potter and Machida, 1981; Anonymous, 1993).

Because of concerns for the resource and returns to fishers, the currently fully exploited Queensland East Coast prawn and scallop trawl fisheries in particular are under increasing pressure to reduce effort. If a fishery for high value squid could be developed without large capital outlays to satisfy domestic demand initially, this could represent a means of diverting some of the effort away from the trawl fisheries, at least on a seasonal basis. Because squid jigging can be undertaken from vessels of various sizes, existing small boat line fishers may also be interested in diversifying into squid.

Squid jigging is one of the few fishing methods which yields no bycatch and does not impact on habitat. Because it can be undertaken over rough, untrawlable bottom and generally at night, it need not conflict with existing commercial trawling operations or recreational line fishing.

Objectives

1 **Resource availability** - To document the known distribution and seasonal abundance of squid (*Photololigo* spp.) and northern calamary (*Sepioteuthis*);

2 **Biological characteristics of the resource** - To investigate species composition, seasonal size composition and basic life history characteristics (life span, location of spawning grounds, spawning season, reproductive biology) of existing and potentially commercially important northern Australian squid resources;

3 **Improved harvesting techniques** - To undertake gear assessment / experimental fishing for squid using jigs under lights, lift nets and purpose designed squid trawls off southern and central Queensland in collaboration with commercial fishers;

4 **Preliminary resource assessment** - To assess the relative seasonal catch rates of squid at selected locations off southern and central Queensland in collaboration with commercial fishers.

Methods

Biological studies

Details of the squid samples analysed for this project are provided in Table 1 below. Additional data obtained previously during extensive research trawl sampling in Moreton Bay in 1982-84 (Michael Potter, Glen Smith, QDPI Southern Fisheries Centre, Deception Bay, personal communication) was also analysed for this study.

Representative byproduct samples were purchased from selected commercial trawl fishers direct or wholesalers at Bundaberg and Mooloolaba. Some samples were also obtained from commercial and recreational fishers in Moreton Bay, from trawling off the Kimberleys, the southwestern Gulf of Carpentaria and Torres Strait.

For all samples, squid were identified to the lowest possible taxon based on published and unpublished descriptions. Starch gel electrophoresis with silver stain used as a general protein stain (Keenan and Shaklee, 1985) was undertaken on representative subsamples of catches to confirm identifications made from morphological characters. Squid were measured (dorsal mantle length - ML- see figure below), sex and reproductive condition determined (development of the testis and spermatophoric complex and presence of mature spermatophores in males; development of the ovary, oviducal glands and nidamental glands and presence of mature eggs in the oviducts in females).

Statoliths (calcareous structures in balance organs in the heads of squid - equivalent to otoliths in teleost fish) were removed from a representative sample of squid for each sex over the size range for selected locations / times and stored dry by the project team. These statoliths were prepared and counts of growth rings made by Mr Ross Thomas and Dr George Jackson of James Cook University of North Queensland. These counts were used to infer age for the squid, assuming one ring is formed each day for the species being examined. This has been experimentally shown from studies of captive animals by Dr Jackson to be true for *Photololigo etheridgei* (referred to as *Loligo chinensis* - Jackson, 1990b) and is assumed for the other *Photololigo* spp. A more detailed analysis than is presented in this report is continuing and the publication of future results in the scientific literature is planned.

While it is easy to separate northern calamary or tiger squid (*Sepioteuthis lessoniana*) from pencil squid (*Photololigo* spp.) based on body shape, fishers are unlikely to be able to separate the species of pencil squid in the field. The identification to the species level of *Photololigo* spp. less than 50 mm ML by scientific staff in the laboratory remains problematical. Even for larger specimens, some individuals of the species pairs, *Photololigo* sp. 4 - *P. etheridgei* and *P.* sp.1 - *P.* sp. 2 remain difficult to separate on the basis of external and internal morphological characters alone. Extensive starch gel electrophoresis with silver stain used as a general protein stain was found to be necessary to confirm species identifications in many samples during this study.

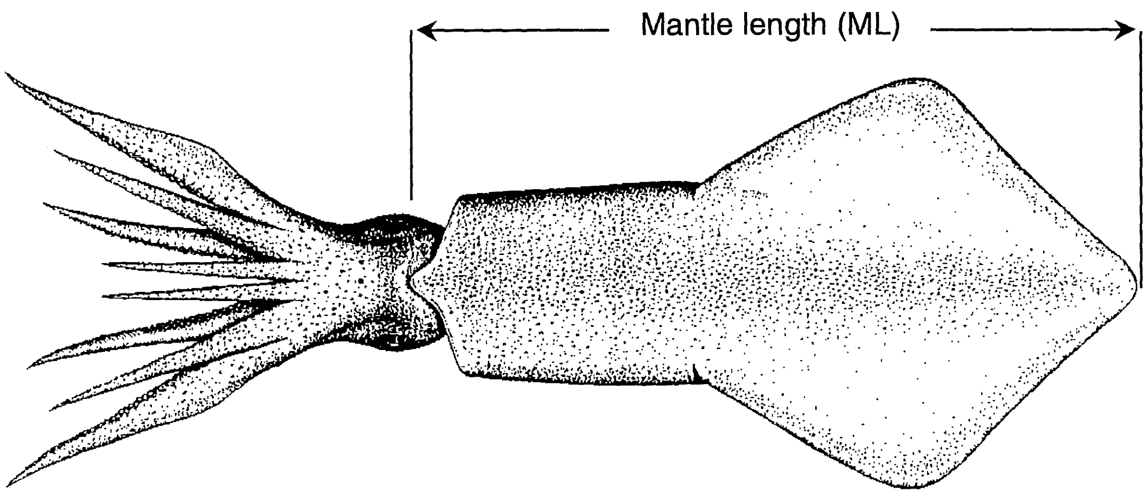


Figure 2. A generalized squid showing the standard length measurement, mantle length (ML).

Table 1. Squid samples examined for this study.

Location	Date	Source	Gear used	Slender squid	Broad squid	Northern calamary	Others	Total
Gold Coast	Mar 96	Commercial trawler	Prawn trawl	99				99
Moreton Bay	6 April 95	QDPI Research vessel	Machine and hand jigs		44			44
	July 95	Recreational fishers	Hand jigs		16			16
	Aug 95	Commercial trawler	Prawn trawl		319			319
	Nov 95	Commercial trawler	Prawn trawl		260			260
Mooloolaba region	Mar 95	QDPI survey (commercial vessel)	Squid trawl	4019		2	543	4564
	Apr 95	Commercial trawler	Fish trawl	40		3		43
	May 95	Commercial trawler	Fish trawl	22				22
	Jun 95	Commercial trawler	Fish trawl	145		2		147
	Jul 95	Commercial trawler	Fish trawl	63				63
	3-5 July 95	QDPI Research vessel	Machine and hand jigs	25				25
	Sept 95	Commercial trawler	Prawn trawl	5			3	8
	Oct 95	Commercial trawler	Fish & prawn trawl	225			8	233
	Nov 95	QDPI survey (commercial vessel)	Squid trawl	1475	2	1	259	1737
	Nov 95	Commercial trawler	Prawn trawl	45				45
	Jan 96	Commercial trawler	Prawn trawl	270	110	11		391
	Feb 96	Commercial trawler	Prawn trawl	151	12		1	164
	Mar 96	QDPI Survey (commercial vessel)	Squid trawl	870	521	6	27	1424
Bundaberg region	15 March 94	QDPI Research trawler	Prawn trawl	4	3			7
	Sept 94	Commercial trawler	Prawn trawl	176				176
	Oct 94	Commercial trawler	Prawn trawl	304				304
	Nov 94	Commercial trawler	Prawn trawl	563				563
	Dec 94	Commercial trawler	Prawn trawl	52				52
	Jan 95	Commercial trawler	Prawn trawl	116			11	127
	18Feb 95	Commercial trawler	Prawn trawl		286		3	289
	22Feb 95	Commercial trawler	Prawn trawl		310		1	311
	April 95	Commercial trawler	Prawn trawl	191		1	4	196
	23 May 95	Commercial trawler	Prawn trawl		689			689
	May 95	Commercial trawler	Prawn trawl	149		2	4	155
	Jun 95	Commercial trawler	Prawn trawl	231			9	240
	Jul 95	Commercial trawler	Prawn trawl	773			1	774
	Aug 95	Commercial trawler	Prawn trawl	697			2	699
	Oct 95	Commercial trawler	Prawn trawl	170			9	179
	Jan 96	Commercial trawler	Prawn trawl	197			8	205
	Mar 96	Commercial trawler	Prawn trawl	7	37		7	51
	Apr 96	Commercial trawler	Prawn trawl	102			4	106
	May 96	Commercial trawler	Prawn trawl		24			24
	Jun 96	Commercial trawler	Prawn trawl		308			308
								0
Swain Reefs	May 95	Commercial trawler	Prawn trawl	82				82
	Jun 95	Commercial trawler	Prawn trawl	97			4	101
	Jul 95	Commercial trawler	Prawn trawl	321			1	322
	Aug 95	Commercial trawler	Prawn trawl	114			1	115
	Sep 95	Commercial trawler	Prawn trawl	141			2	143
Cairns	Jan 96	QDPI Research trawler	Prawn trawl	37	218	1	11	267
East of Cape York	Jan-93	CSIRO Research trawler	Fish trawl	958	15	64	60	1097
	Mar-Apr 93	CSIRO survey (commercial vessel)	Prawn trawl	655	239	34	116	1044
	May-Jun 93	CSIRO survey (commercial vessel)	Prawn trawl	3	6	11	75	95
	Mar-Apr 94	CSIRO survey (commercial vessel)	Prawn trawl	51	5	60	27	143
	Oct-Nov 94	CSIRO survey (commercial vessel)	Prawn trawl	12		70	35	117
Torres Strait	Mar 96	Commercial trawler	Prawn trawl	20	5			25
Gulf of Carpentaria	Feb 97	CSIRO Research trawler	Fish trawl	215	54	16	360	645
Kimberleys, WA	Aug 95	Commercial trawler	Prawn trawl	136				136
Townsville	Mar-Apr 96	James Cook University Research trawler	Prawn trawl	11	194			205
				Slender squid	**Broad squid**	**Northern calamary**	**Others**	**Total**
			All samples	**14039**	**3677**	**284**	**1596**	**19596**

** The category "Others" includes other squid such as the smaller pencil squid species (*Photololigo* sp. 1 & 2), arrow squid (*Nototodarus hawaiiensis* and *N. gouldi*, *Todarodes pacificus pusillus*), dumpling squid (including *Euprymna* cf. *tasmanica*, *Sepioloidea lineolata*), cuttlefish (*Sepia* spp. and *Metasepia pfefferi* and octopus (*Octopus* spp. and *Eledone palari*).

Gear trials and assessment

Jigging

For the jigging trials, two 24 volt jigging machines purchased from Japan (Towa Denki Co. Ltd) were installed on the port and starboard side amidships of the QDPI vessel *Warrego*. This vessel is a Millman West Australian cray boat design. The double drum reel machines are fully automatic, with adjustable digital controls for setting jigging pattern, speed and depth.

Following a review of published details of small vessel squid fishing gear arrangements used overseas (see Appendix 2), jig line arrangements similar to that used successfully in major commercial fisheries for loliginid squid species in Japanese waters (shiro-ika or kensaki-ika *Photololigo edulis,* yari-ika *Heterololigo bleekeri*) were used (eg., size, colour and type of jigs, material and gauge of main line, line lengths between jigs). Each drum reel held 100m of clear 0.9mm monofilament line, the last 20 metres with cylindrical inline jigs spaced 1 metre apart between brass swivels. The jigs used were a mixture of 7 cm long, soft plastic, flexible jigs and 6 cm hard plastic jigs with two tiers of 16 barbless hooks each (0.9 mm diameter wire). Various colours and luminous white plastic jigs were trialled. The two jig lines were tied together using three-way brass swivels approximately 2m above a pair of 900g torpedo shaped lead weights to allow retrieval if one line tangled or was broken. Outriggers (retaining nets) of 1 metre in length were used. These consisted of outboard rollers and retaining nets which are attached to the vessel's gunwhales adjacent to the drums during jigging operations.

Figure 3. Jigging machines and hand spools with outriggers mounted on QDPI's research vessel, Warrego.

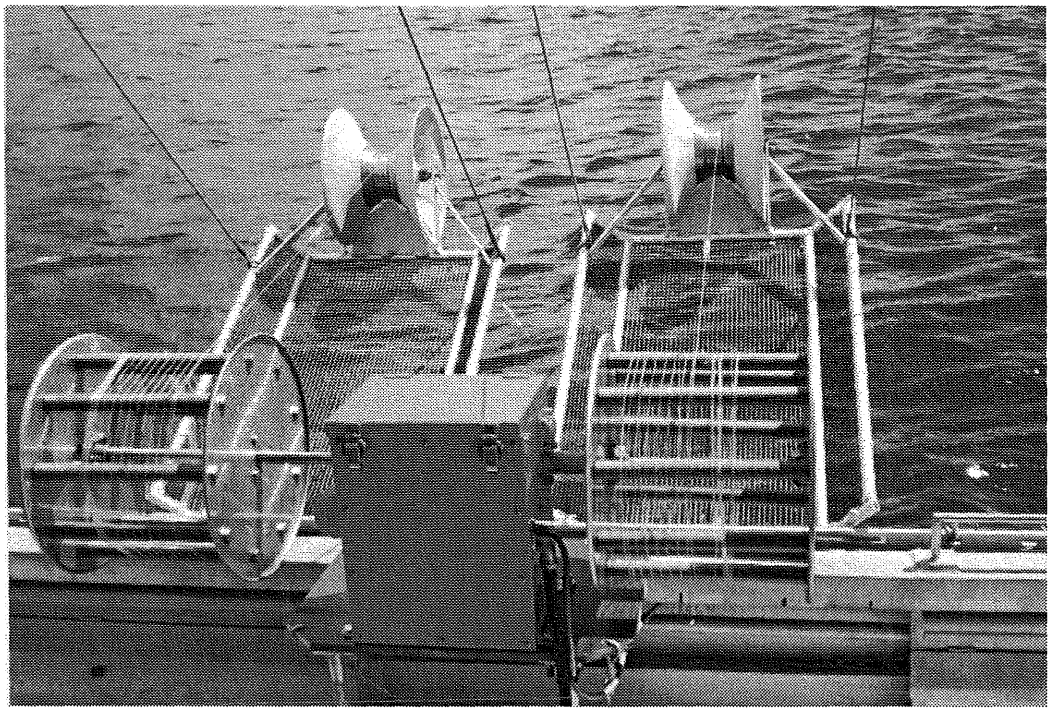


Figure 4. Close up of the variable speed, 24 volt jigging machines with independent outriggers.

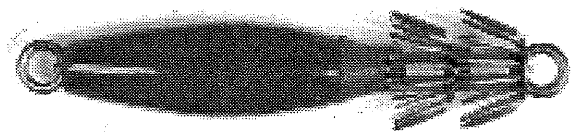


Figure 5. Typical machine jig used for inshore squid in this study (shown at near actual size).

Hand jigging was undertaken using locally manufactured, aluminium manual drum reels with outboard rollers and mounted on the vessel's stern. These reels were fitted with similar gear to the machine jiggers.

Commercially available prawn-shaped, surface trolling jigs were used also as single jigs on hand held lines. Similarly designed jigs are used by artisanal and commercial fishers for catching mainly *Sepioteuthis* elsewhere in Southeast Asia and southern Japan.

Figure 6. Typical design of a prawn-shaped trolling jig, lead weight under the head and a double row of barbless hooks trailling (the upper colour is either red or green with dark stripes) - after Hamabe et al., 1982.

Lights for attracting squid during jigging operations at night were installed 2.5 metres above the deck on the *Warrego* in a paired arrangement (three a side) to create a shadow boundary where the jig lines entered the water. As this vessel has a 24 volt electrical system, light capacity was limited to six, 120 watt white lights.

A parachute anchor (approximately 10 m diameter) was deployed near the surface during jigging operations but the research vessel still displayed some roll in moderate swell conditions and made jig line tangles a likelihood. Jigging was trialled in wind conditions exceeding 15kts but this was unsuccessful as the vessel was blown beam to the swell, negating the benefits of the parachute anchor.

These trials have shown that a small jigging vessel of light construction needs to have its superstructure aft to balance the effects of the parachute anchor and would benefit from a spanker sail on the stern. Vessels used successfully off southern Japan (10-15 m length) in the *Photololigo edulis / Todarodes pacificus* inshore jig fishery and shown in Appendix 4 to this report have this design.

Trawling

For surveys off southern Queensland, an 18 fathom high lift demersal trawl net (approximate mouth width of 78ft and height > 12ft) was constructed for the purpose of targeting squid.

It was a modified fish trawl net designed for use by a vessel of at least 350 HP and preferably set up for fish trawl operations with bridles and sweeps. Mesh size was 4.5 inches in the wings and 2.25 inches in the body. Floats rated to at least 300 m were attached to the headrope to increase the headrope height. The net was designed to be towed at 3.5 knots or faster.

A 9 fathom Florida Flyer prawn trawl was used from the Department's research trawler *Gwendoline May* for the survey off Cairns in March 1996 (approximate mouth width of 35 ft) as the vessel could not be rigged without significant cost to tow the larger squid trawl.

Commercial prawn trawlers from which byproduct samples were obtained towed triple rigged prawn trawls with total effective mouth widths between 70 ft (inshore waters) and 120 ft (offshore king prawn grounds).

Resource assessment and commercial fisheries logbook data

A preliminary resource assessment using a purpose designed squid trawl was undertaken using chartered commercial vessels off Mooloolaba and on one occasion, Yeppoon, to assess species composition, size composition, relative seasonal catch rates and biomass and obtain further biological data. A high-lift banana prawn trawl was also used during a resource survey undertaken off Cairns in January 1996.

Preliminary estimates of squid biomass off Mooloolaba were calculated using swept-area methods from research trawl catch data. Because jig catches were small, catch rates (kg / machine hours) were not recorded during experimental gear trials; rather total catches only in numbers of squid were recorded and length measurements made.

Reported squid catch data from the QFMA's Queensland Fisheries Information System (QFISH) for catches for the Queensland east coast and from the Australian Fisheries Management Authority (AFMA) for the Northern Prawn Fishery were examined. Squid catch was not differentiated between target and incidental / byproduct in these logbook data nor was time of day reported uniformly (squid are more available to trawling during the day). Therefore it was not possible to standardize and allocate effort to squid with any confidence. A detailed analysis of CPUE (catch per unit effort) data was not undertaken for this study. It must be recognized that squid catches reported in these fishery logbook data and any analysis presented here largely reflect effort in the primary fishery (prawns or trawl whiting, inshore finfish netting). However, they provide the best available indication of the spatial and temporal variability in squid resources of these regions.

With the same limitations recognized above for domestic logbook data, historical Taiwanese trawl catch data from northern Australia (1978-1982) published in annual reports of the Demersal Fish Research Center, National Taiwan University and from the radio reports available in AFMA's Australian Fishing Zone Information System (AFZIS) (1980-1982) were reviewed and analysed. These data sets provide another indication of seasonality and the potential of the northern Australian squid resource.

Changes from the original proposal

At the same time as this project commenced, surveys of fishers at ports throughout Queensland were being undertaken by other QDPI researchers as part of a trawl bycatch exclusion (TED) project and, rather than undertake independent surveys, squid project staff assisted in some of these surveys in late 1994. Anecdotal squid catch and other information was gathered and this opportunity was also taken to confirm the level of currrent reporting and encourage fishers to record squid byproduct as part of their normal logbook reporting activities.

In parallel with this study in 1995, CSIRO Division of Fisheries staff at Cleveland undertook a brief review and audit of the reported squid catch in the Northern Prawn Fishery and adjacent areas. QDPI researchers provided assistance during this desk study which highlighted the inconsistent and sometimes poor logbook reporting of squid byproduct which has occurred recently.

Ms Margot Sachse of Australian Fisheries Management Authority advised that byproduct / bycatch reporting in the Northern Prawn Fishery became compulsory in 1995 so no specific logbook liaison activities with trawl fishers in this area were undertaken as part of this project. Continued contact was however maintained with some of the prawn trawler operators targetting squid using trawls off the Kimberleys and processors in Darwin in an effort to obtain better information on the nature of the squid aggregations being fished (temporal and spatial characteristics, interannual variability, presence of egg capsules). Samples of squid from commercial vessels were also obtained in 1995 and from target trawling in the southwest Gulf of Carpentaria in 1996 to assess the species composition and reproductive condition of the squid. Liaison was also maintained with Northern Territory fishers with an interest in developmental squid jigging although up until January 1997, little exploratory fishing had occurred.

Information to assist fishers with squid identification was published in the Queensland Commercial Fisherman's Organization magazine, *Professional Fisherman* in November 1997 while similar information was provided to Brian Taylor, NPF Liaison Officer at CSIRO Cleveland for distribution to interested NPF fishers.

A field guide to Australian cephalopods (squid, octopus and cuttlefish) of commercial importance was prepared for fishers by Dr Vicki Wadley of CSIRO Marine Research, Hobart and the senior author and an excerpt published in *Australian Fisheries* in June 1995. The guide was published in September 1998 and is available to fishers from the Centre for Food Technology in Brisbane (see Appendix 3).

The senior author contributed to a technical guide to the identification of cephalopods of the Western Central Pacific (including northeastern Australia) published by FAO in 1998 (Carpenter & Niem, 1998).

Due to the delays experienced in obtaining permits from the QFMA to allow the independent use of squid jigs by commercial fishers and the sale without replacement of the Department's Brisbane-based research trawler in late 1994, the gear assessment and preliminary resource assessment components of this project were significantly reduced and efforts reallocated to other components of the study. Despite continued assurances by QFMA officers between 1994 and 1996 that resolution was near, the expeditious issue of permits to allow developmental squid jigging was not forthcoming. Commercial fishers who had previously offered to collaborate became frustrated and could not have been expected to modify their vessels to facilitate the fitting of jigging machines purchased as part of this project. Assessment of squid jigging was undertaken only from the Department's smaller research vessel and no collaborative machine or hand jigging from commercial vessels was undertaken prior to August 1996 and the end of field component of this project.

Trialling of lift-nets could not be undertaken during this project. Subsequent to the initial submission of the project proposal, local public controversy arose regarding issue of authorizations by the QFMA for a developmental pilchard lift-net fishery off southern Queensland during 1995 and 1996. Hence, no experimental lift netting could be undertaken from commercial vessels during this project and the small research vessel available to the project was not suitable for squid lift-netting in offshore waters.

In early 1997, after completion of the field component of this project, the QFMA issued permits to three vessels to allow developmental squid jigging in southern Queensland waters. One operator fishing north of Mooloolaba in southern Queensland has taken small but promising catches of large slender squid (several kg per hour) and also small oceanic squid (red ocean squid *Ommastrephes bartramii* and yellow-back squid *Sthenoteuthis oualaniensis*). One fisher had planned to shift his operations from his current trawler to a smaller, purpose built, jigging vessel for squid jigging fishing operations in 1998/99. The developmental fishery continues to be monitored by the QFMA and the senior author.

Detailed Results

Objective 1 - Squid distribution and seasonal abundance

Most squid of commercial interest from tropical continental shelf regions belong to the cephalopod family Loliginidae. Squid of this family are distributed throughout tropical and temperate continental shelf waters of the world's oceans and are the subject of major fisheries in southeast Asia, off southern Japan, off South Africa and in the southwest South Atlantic Ocean.

The six squid "species" commonly caught by recreational and commercial fishers in tropical Australian continental shelf waters are the northern calamary or tiger squid (*Sepioteuthis lessoniana*, the bay or bottle squid *Loliolus noctiluca*, the broad squid *Photololigo etheridgei*, and three unnamed pencil squid species *Photololigo* sp. 1, sp. 2 and sp 4 (of Yeatman, 1993). New South Wales Fisheries researchers (Graham *et al.*, 1993) have introduced the name "slender squid" for Yeatman 's *Photololigo* sp. 4. The southern calamary, *Sepioteuthis australis*, is also taken in small quantities as occasional byproduct in demersal trawls off southern Queensland in deeper continental shelf waters (> 50m) together with arrow squid (*Nototodarus gouldi* and *N. hawaiiensis*).

The bottle squid reaches less than 10 cm body length at maturity and, while caught in small quantities by estuarine beam trawling in southern Queensland and northern New South Wales and marketted locally as bait, is not considered to offer fishery development potential. Its distribution was reviewed by Lu *et al* (1985) and no additional information on its biology is reported here.

Because of the limited knowledge of the life history and ecology of tropical cephalopod species in Australian waters, the literature was reviewed in an attempt to synthesize the available biological data on the same and similar species elsewhere in the tropical Indo-Pacific. In addition, anecdotal information from fishers was sought on squid abundance together with information on the presence of squid egg masses in catches, indicative of spawning location and time.

Tropical inshore squids of the Indo-Pacific : a review of the fisheries biology and ecology of major species outside Australian waters.

A growing number of studies have been undertaken on the biology of cool and warm temperate loliginids (Araya and Ishii, 1974; Augustyn, 1990; Hixon, 1983; Summers 1971; Tinbergen and Verwey 1945; Pierce *et al.*, 1994; Guerra and Rocha, 1994) and general life history patterns are known (Boyle, Pierce and Hastie, 1994). However our knowledge of tropical species is poor (eg., Arocha, 1986; Gophar, 1989; Hernando and Flores, 1981; Natsukari and Tashiro, 1991) and indeed some fundamental differences in details have been reported between tropical and temperate loliginids (e.g. La Roe 1971 for *Sepioteuthis*). It is likely that growth rates in the wild are significantly higher and life spans shorter in tropical species (Jackson and Choat, 1992). Species diversity among loliginids is higher in tropical areas, eg. five species off Malaysia (Ashirin and Ibrahim , 1992), whereas in temperate waters, often a single species dominates commercial catches, eg., *Loligo opalescens* off California, Hixon, 1983; *Loligo forbesi* around the United Kingdom, Arnold 1979).

Studies to date have shown that in general, loliginid squid grow rapidly, are probably short lived and do not survive spawning. Egg clusters are laid attached to the bottom and the hatchlings appear 20 to 40 days later (dependent on ambient water temperature) as virtual replicas of the adults.

Tropical species may have extended spawning seasons (Hixon, 1980) and hence a complex population structure. Significant seasonal migrations are suspected for temperate loliginids apparently correlated with spawning and water temperature/salinity changes (Natsukari and Tashiro, 1991). Whether this also occurs in the perhaps more homogeneous tropical environment remains unknown.

Loliginid squid are important elements of food webs elsewhere (Amaratunga, 1983; Morejohn *et al.*, 1978) and perhaps occupy similar trophic positions to smaller carangids and scombrids. Crustaceans such as penaeid prawns are a common component of the diets of smaller loliginid squids elsewhere (Oommen, 1977). Cephalopods are a major component in the diets of carcharhinid sharks off northern Australia (Stevens and McLoughlin, 1991).

The six common squid "species" commonly taken by recreational and commercial fishers in tropical Australian continental shelf waters are *Sepioteuthis lessoniana*, *Loliolus noctiluca*, *Photololigo etheridgei*, and three unnamed species *Photololigo* sp. 1, sp. 2 and sp 4 (of Yeatman and Benzie, 1991). The taxonomic status of the *Photololigo* species in northern Australian waters is currently under more detailed investigation by the senior author in collaboration with Dr C C Lu, previously of the Museum of Victoria and now of National Chung Hsing University, Taichung, Taiwan.

Species reviews

Sepioteuthis lessoniana Lesson, 1830 (Synonym - *S. arctipinnis* Gould, 1852)

The bigfin reef or oval squid, *Sepioteuthis lessoniana* (called aori-ika in Japan and daai mei yau yue around Hong Kong) is a tropical loliginid which occurs throughout the Indo-Pacific from Japan to Australia and from Hawaii to the east coast of Africa (Voss 1963; Okutani 1980; Voss and Williamson 1971; Lu and Tait 1983). In Australian waters, *S. lessoniana* (called northern calamary or tiger squid locally) has been recorded from Houtman's Abrolhos in Western Australia to Moreton Bay in southern Queensland (Winstanley *et al.* 1983, Lu and Tait 1983). This species is common in coastal environments varying from seagrass to coral reefs and has been caught in depths to 100m.

Around Hong Kong, maximum size of males exceeded that of females, 360 mm (1.8 kg) and 300 mm ML (1.3 kg) respectively (Voss and Williamson 1971) while off southern Japan, males reached in excess of 420 mm and females, 340 mm (Ueta and Jo, 1989). Males from southern India reach sexual maturity at approximately 100 mm ML (range of 68-113 mm) while females larger than 130 mm were all mature. The spawning season extends from January to June in southern India (spring-summer) (Rao 1954) and from mid-June to late August in temperate, southern Japanese waters (Segawa 1987). In tropical waters around Okinawa, spawning occurs from January to September (Tsuchiya, 1981).

Adult *S. lessoniana* feed principally on teleost fishes with prawns and crabs also contributing significantly to the diet (Silas, Satyanarayana Rao *et al.* 1985; Silas, Sarvesan *et al.* 1985). Cannibalism has also been observed in this species (Rao,1954).

Rao (1954) assessed growth in *S. lessoniana* from Palk Bay in southern India by following the progression of modes in size frequency distributions with time. Inherent complexity in population size structure caused by an extended spawning season dictates that for this method to be effective large and frequently collected samples are necessary. These were unavailable to Rao. Growth estimates of 3 to 8 mm ML per month were obtained for squid 20 to 200 mm ML and longevity was estimated at 2 to 3 years. Similar longevity was estimated by Silas *et al* (1982) based on length frequency data.

However, Choe (1966) found that growth rates in experimental tanks were in excess of 30 mm per month for Japanese *S. lessoniana* reared from eggs and fed on mysids and small fishes. He concluded that *S. lessoniana* could be reared to 350-400 g (~200 mm ML) in approximately 110 days. Jackson and Choat (1992) aged specimens from northern Australian waters of 200 mm ML at ~150 days based on statolith growth rings.

Segawa (1987) noted that a single mature female between 200 and 250 mm ML will lay from 500 - 1000 eggs in one spawning. *S. lessoniana* lays finger-like attached egg capsules in clusters in shallow water, sometimes on floating or attached seaweeds. Up to 50 capsules are produced at a single laying, each containing between 2 and 10 eggs (Choe, 1966; Rao, 1954). Silas *et al.* (1982) found that egg capsules from southern India averaged 6-7 eggs. This is a small number compared with representatives of the genus *Loligo* where up to 200 smaller eggs can be found in a single capsule (Fields 1965). In contrast to *Sepioteuthis sepioidea* from the Caribbean, stimulus to spawning by other females is apparently provided by the presence of other egg clusters in an area (La Roe, 1971) and large communal egg clusters have often been observed (Rao 1954).

Alagarswami (1966) found that hatching occurred after 15 days at 27° to 29°C while Choe (1966) found hatching in aquaria required 25 to 28 days at 23.5° to 24.0°C. Segawa (1987) concluded that 20-30°C is the optimum temperature range for successful development. The hatchlings, with mantle lengths between 4 and 8 mm, are small replicas of the adults and immediately begin an independent life.

Photololigo edulis (Hoyle, 1885) - Synonyms -*Loligo kensaki*, *Doryteuthis kensaki*

In contrast to *Sepioteuthis*, *P. edulis* is a slender loliginid squid (called shiro-ika or kensaki-ika around Japan). This species has been reported from coastal waters of central and southern Japan, around Taiwan, Hong Kong and the Philippines, in the Gulf of Thailand and Indonesia and (Voss and Williamson 1971; Okutani, 1980; Shin 1982; Gophar, 1989; Natsukari and Tashiro, 1991). Reports of this species off northern Australia (Dunning,1982; Lu and Phillips, 1985) are likely to be of *Photololigo* sp. 1 and sp. 2 of Yeatman and Benzie (1994) which show some morphological characters in common with *P. edulis* but have been shown by recent biochemical genetics studies to be separate species. *Photololigo edulis* was not present in northern Australian material collected for that study nor has it been reported subsequently.

The species is apparently represented throughout its range by a complex of populations or seasonal forms spawning in different seasons and reaching maturity at different sizes. Previously, *P. edulis* was considered to consist of two subspecies around Japan (viz., *L. edulis budo*, Wakiya and Ishikawa, 1921, *L. edulis kensaki* Wakiya and Ishikawa, 1921), but these have not been shown to have any differences distinguishable by biochemical techniques (Natsukari and Tashiro 1991).

Off Hong Kong, larger males *P. edulis* attain mantle lengths of up to 40 cm and this species is common in bottom depths from 30-170 m (Voss and Williamson 1971). On the Pacific coast off southern Honshu, Japan, the size distribution of juveniles suggests that at least four spawning peaks occur during the period May to October, spring to autumn (Okutani *et al.* 1975).

The life span and growth rate of this species in temperate waters have been estimated from statolith rings as up to 350 days and 5 mm per day (Natsukari and Tashiro, 1991).

Egg capsules similar to those of S. *lessoniana* are spawned in groups of several hundred, each "mop" measuring approximately 50 cm in diameter. Each capsule contains up to 200 small eggs. According to Natsukari (1976) these masses are separated from each other by distances of more than 1.5 m and have been observed in depths of 30-40 m on sandy, featureless bottoms in the Japan Sea. Spawning in these waters takes place during spring and summer. On the Pacific coast off southern Honshu, Japan, abundance of juveniles suggests that at least four spawning peaks occur during the period May to October (Okutani *et al.* 1975) and it is suggested that newly hatched larvae have a mantle length of 5 to 6 mm.

Photololigo chinensis (Gray, 1849) Synonyms - *Loligo formosana, ?Loligo (Doryteuthis) singhalensis, Loligo chinensis*

Photololigo chinensis has been reported from off the southern Japanese islands (to 28°N), Taiwan (Wu 1987) and Thailand (Supongpan 1984), China, Hong Kong, the Philippines, Malaysia, Indonesia, India and Ceylon (Voss and Williamson 1971; Gophar, 1989; Natsukari and Tashiro 1991; Ashirin and Ibrahim, 1992). This species has been reported This species is known as tor yau yue in Hong Kong.

Natsukari and Okutani (1975) synonymized the Australian *Loligo etheridgei* Berry, 1918 with *P. chinensis*. *Loligo chinensis* has been reported from off northern Australia (Winstanley *et al.*, 1981; Dunning, 1982; Roper *et al.*, 1984; Lu and Phillips 1985). However, a recent genetics study (Yeatman, 1993) has shown the Australian species to be different from *P. chinensis* from southeast Asia.

P. chinensis is a typical slender loliginid squid and is distinguished from *P. edulis* by the sharp conical teeth on the distal portions of the arm suckers and the nearly straight posterior margin of the fins (Natsukari and Tashiro 1991). *P. chinensis* commonly reaches 350 mm ML around Taiwan (Wu 1987). Voss and Williamson (1971) recorded the largest male and female from Hong Kong waters at 490 mm (1 kg) and 310 mm (0.8 kg) respectively while the maximum size reported off the east coast of Malaysia by Ashirin and Ibrahim (1992) was 410 mm ML. Off Hong Kong, *P. chinensis* is most common in bottom depths of 30-120 m.

In the Gulf of Thailand, Ratana-anan (1979) found female *P. chinensis* outnumbered males by 1.69 : 1. Mature females were present in all months except September and represented, on average, 20.62% of the females examined by Ratana-anan (1979). In a subsequent study of *P. chinensis* in the Gulf of Thailand, Chottiyaputta (1990) found spawning peaks from March to June and from August to November with the smallest mature males from 105 mm ML and females from 100 mm ML.

Spawning occurs over soft bottoms (sand, sandy mud and muddy sand) in the Gulf of Thailand with small juveniles more abundant in depths of 30-50m (Chottiyaputta, 1993). Annuar (1984) found the proportion of mature squid present in catches from eastern peninsular Malaysia was at a maximum on or near full moons while spent squid were more abundant near new moon.

Although Wu (1987) examined the relationships between the weights of the various components of the reproductive systems of male and female *P. chinensis* from Taiwan Strait, he provided no information on the relationship between mantle length and reproductive maturity. He noted that while males reached maturity in July and August (mid-summer), mature females were not evident in trawl catches until September.

Photololigo duvauceli Orbigny, 1848 Synonyms - *Loligo indica* Pfeffer, 1884, *Loligo oshmai* Sasaki, 1929

The Indian squid, *P. duvauceli*, (called chin sui yau yue around Hong Kong) occurs from Taiwan to Indonesia and westward to east Africa in depths up to 170m, commonly in depths up to 80m (Silas *et al.*, 1982; Gophar, 1989; Chotiyaputta, 1993). The species is distinguished from the partially sympatric *P. chinensis* and *P. edulis* by the presence of square, plate-like teeth on the arm suckers, approximately equal sized suckers on the medial manus of the club and Arm III and the fins extending not more than 50% of the mantle length.

Largest specimens reported are a male of 365 mm and a female of 230 mm ML (Nair *et al.*, 1992; Rao, 1988).

Various authors have assessed the longevity of the species from modal progression as at least two years for 200 mm ML animals and up to six years (Kasim, 1985; Silas *et al.*, 1985) but direct aging from statoliths has not been reported. (The likely overestimation of longevity of squid from modal progression has been discussed previously.)

In Indian waters, Silas *et al.* (1985) reported a sex ratio overall of unity but this varied with location and season. Mature females were present in all months in both the Gulf of Thailand (Chotiyaputta, 1990; 1993) and in Indian waters (Rao, 1988; Silas *et al.*, 1985). Spawning peaks were identified in the Gulf of Thailand from January to May and September to November (Chotiyaputta, 1990) and variable with location off India (Silas *et al.*, 1985). Sunilkumar (1993) reported spawning aggregations in the Arabian Sea in September - October and Rao (1988) concluded from the size distribution of eggs in the ovary that females of *P. duvauceli* are catastrophic (single event) spawners.

Spawning occurs on soft bottoms (sand, sandy mud and muddy sand) in the Gulf of Thailand in depths more than 20m (Chottiyaputta, 1993).

The smallest mature males reported were 80 mm ML and females 70 mm ML in the Gulf of Thailand (Chotiyaputta, 1990) and 50 mm ML for both males and females off the east coast of India, with larger sizes of first maturity off the west coast (Silas *et al.*, 1985).

Photololigo duvauceli preys on crustaceans, fish and other squid (Oommen, 1977) while it forms part of the diet of small tunas off India.

Summary of general biological characteristics from studies elsewhere

Tropical loliginid squid have the following life history characteristics:

- despite some greater estimates from size frequency data, more recent examination of growth rings on statoliths indicates that they are short-lived, perhaps less than six months for some smaller species of commercial importance;
- parts of the squid population of any species are mature and females spawn throughout much of the year; individuals may spawn over extended periods (weeks to months?);
- spawning events may be related to lunar phase;
- loliginid squid lay attached eggs demersally;
- some species appear to aggregate to spawn;
- there is no evidence of directed long distance migrations although there are indications of inshore migration for spawning;
- diet shifts from primarily crustaceans to primarily fish and sometimes other cephalopods with growth;
- species may be sympatric with overlapping feeding and spawning grounds and spawning seasons.

Distribution of squid in northern Australian waters

Anecdotal information from Queensland fishers

Commercial fishers were interviewed in the major Queensland fishing ports of Brisbane, Mooloolaba, Yeppoon, Bowen, Mackay, Townsville and Cairns. Because squid is a bycatch and byproduct in predominantly prawn fisheries, little detailed information was kept by fishers and although many caught, retained and sold small quantities of squid, it was often stated that catch data was rarely recorded in logbooks.

Even the main groups of squid species (pencil squid and calamary) were not separated by many of the fishers. Squid were generally noted as present in variable quantities in the dawn and dusk shots throughout the year (predominantly night time trawling is undertaken for prawns) and in higher abundance in catches on full moon. Off north Queensland, fishers reported greater abundance of pencil squid in late summer and autumn while higher catches were reported in winter off southern Queensland.

When shown photographs of squid eggs, several fishers remembered seeing them in trawl catches but few details of where or when were generally available. One fisher recalled seeing eggs probably of *Photololigo* in inshore waters off Weipa when prawn trawling more than 10 years ago. Eggs of *Sepioteuthis* were reported from inside the Pompey Hardline reefs in 50-60 m in mid 1996 and collected in large quantities from scallop trawl areas off the northwestern tip of Fraser Island in November and December 1994. They were also collected by crabbers (attached to pots) in channels in the northern entrance to Moreton Bay in late February 1995.

Fishers trawling for squid in a spawning aggregation in approximately 40m depth off the Kimberleys, WA, in 1995 reported that the squid were clumped both by day and night but occurred closer to the bottom by day.

Specific information provided by Queensland east coast fishers is detailed in the table below.

Where and when squid have been caught :

Townsville interviews:

Groote Eylandt (October, November).
South of the Yangala wreck in 36-40m.
Cape Upstart (Nov/Dec).
Open waters 23-27m.
Around islands of Princess Charlotte Bay March and April especially if a wet year.
Middle of Princess Charlotte Bay.
Near Margaret Bay (April-May) in 34m.
Most common March and April.
Calamary common around headlands.

Near Cape Flattery and behind Cape Cleveland (Feb-April).
Palm Island. 14nm off Electra Headland and reef.
Palm Passage (April-May).
Near Palm Island, Orpheus Island and 23 fathoms.
80nm east of Cairns.
Between Cape Flattery to Cape Bedford (Feb-March).
Good catches off Cooktown.
Most squid caught in trawls on full moon.

Bowen interviews:

Rodds Bay - Fairway bouy.
Cape Upstart.
On full moon.
Not much in local area.

Between St Bees and Keswick Islands.
Gladstone in close when fishing for bananas.
Northern Calamary - reefs of Bunker Group.

Mackay interviews:

Near the wharf at Hay Point
6 miles NW Prudhoe Island.

Armstrongs Beach (Feb-Mar - small squid)

Yeppoon interviews:

Inshore Rosslyn Bay.

During banana prawn season.

Mooloolaba interviews:

Off Cape Moreton in winter (deep).
Off Mooloolaba 60-80 fathoms.
Off Mooloolaba in mornings.

Calamary - 6 inches - 60-100 fathom in winter.
30 miles offshore.
Pencil squid - 6-7inches - deepwater in winter, shallow in summer.

Where and when egg capsules have been identified in trawl catches:

Off Townsville, the Brook Islands in 40m.
In deeper waters ~50m.
Off Townsville and around the reefs in 50m.

Inside the Pompey Hardline Reefs in 50-60 m
Near 'Eden' and 'Fahey' Reefs.

Information on distribution from research studies

Broad squid

Photololigo etheridgei Berry, 1918 (=*Photololigo* sp. 3 of Yeatman and Benzie, 1994; *Photololigo* cf. *chinensis* (east coast form) of Dunning *et al.*, 1994; *Loligo chinensis* of Jackson, 1990b, 1993)

Squid samples examined during this study confirmed the occurrence of *P. etheridgei* in inshore waters from central New South Wales (Port Stephens - 33°S) to the Gulf of Carpentaria.

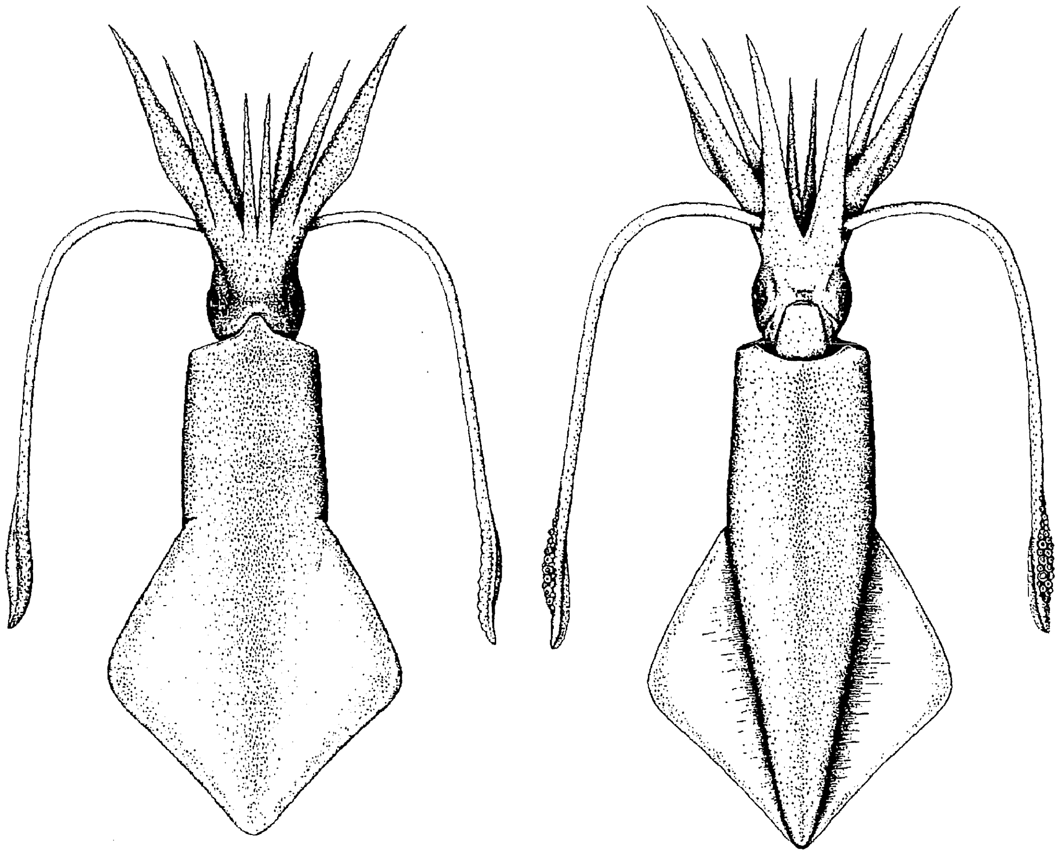


*Figure 7. Broad squid (*Photololigo etheridgei*) from Yeatman, 1993.*

P. etheridgei was the only *Photololigo* species present in commercial and research trawl catches and experimental jigs catches in Moreton Bay, southern Queensland. Off Mooloolaba and Yeppoon, this species was more abundant in research trawls undertaken in depths of less than 20 m in all sampling periods (March 1995, November 1995, March 1996), replaced in deeper waters by slender squid. Commercial trawl byproduct samples from inshore waters off Bundaberg (< 20 m depth) were entirely this species while samples from the adjacent eastern king prawn grounds (depths of > 100 m) were exclusively slender squid. Off Cairns, *P. etheridgei* numerically dominated research trawl and jig catches in waters of less than 20 m depth adjacent to the coast but was replaced by slender squid and *Sepioteuthis lessoniana* in reef waters eastward of the inshore coastal "lagoon".

Slender squid

Photololigo sp. 4 of Yeatman 1993 (=*Loligo chinensis* of Yeatman and Benzie, 1993; *Photololigo chinensis* of Yeatman and Benzie, 1994; *Photololigo* cf. *chinensis* (northern form) of Dunning *et al.*, 1994)

Photololigo sp.4 or slender squid was the most abundant species in surveys and commercial catches examined during this study. It occurred in samples taken during this study from off the Gold Coast to the Kimberleys and was the most abundant squid species in waters depths greater than 20m in all regions. Graham *et al.* (1993) reported slender squid in demersal prawn trawl catches from New South Wales midshelf waters as far south as 33°S. Yeatman and Benzie (1993) found that off the Northwest Shelf, this species was replaced in depths greater than 100 m by *Photololigo* sp. 1.

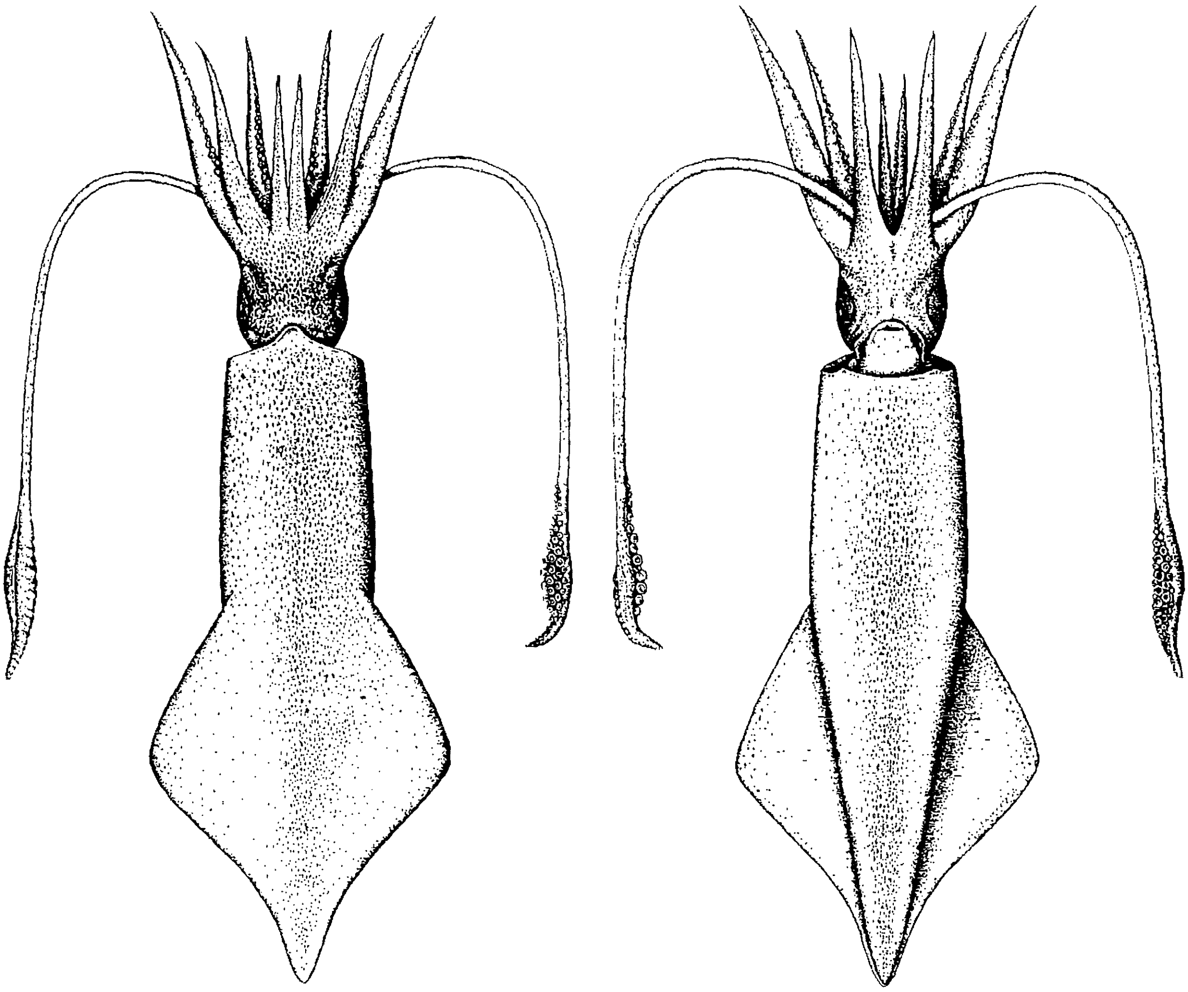


*Figure 8. Slender squid (*Photololigo *sp. 4) from Yeatman, 1993.*

Northern calamary or tiger squid

Sepioteuthis lessoniana Lesson, 1830 (= *Sepioteuthis arctipinnis* Gould, 1852)

Sepioteuthis lessoniana (known elsewhere as bigfin reef or oval squid) is a tropical squid which occurs throughout the Indo-Pacific from Japan to Australia and from Hawaii to the east coast of Africa (Lu and Tait 1983). In Australian waters, *S. lessoniana* has been reported previously from Houtman's Abrolhos in Western Australia to Moreton Bay in southern Queensland (Winstanley *et al.* 1983, Lu and Tait 1983). This species is common in coastal environments varying from subtidal seagrass to coral reefs and has been caught in depths to 100m.

During this study, northern calamary were present in trawl and stake net samples from Moreton Bay, nearshore waters off Mooloolaba and Bundaberg and were taken on jigs and in scoop nets near reefs off Cairns (only a single specimen was taken in 6 days of trawling). This species was also caught in trawls across the shelf and in reefal areas off the eastern coast of Cape York where it was third in abundance to broad squid and slender squid overall.

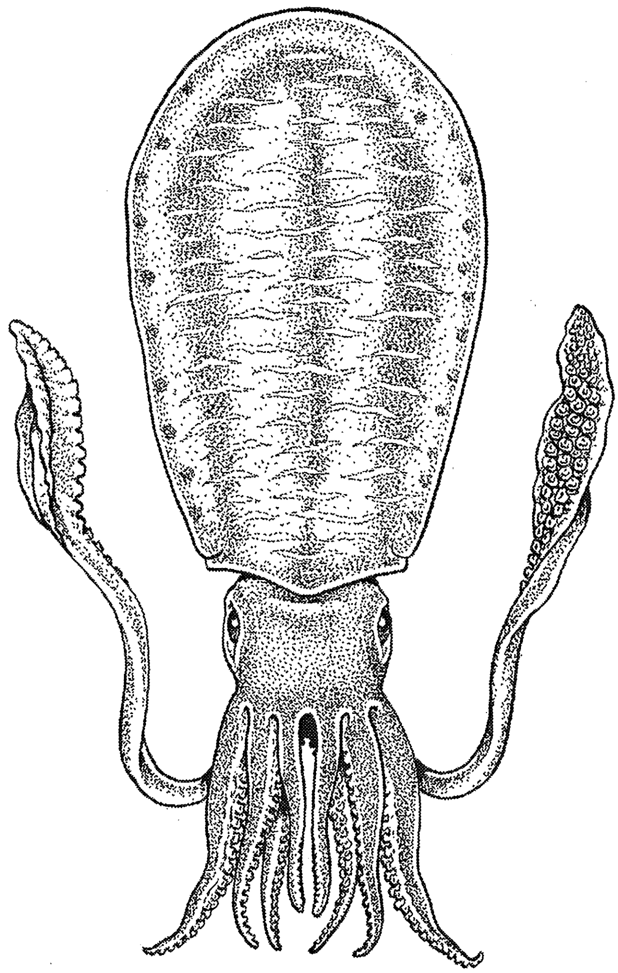


Figure 9. Sepioteuthis lessoniana

Photololigo sp. 1 of Yeatman, 1993

(=*Loligo* sp.1 of Yeatman and Benzie, 1993 and *Loligo edulis* [in part] of Dunning, 1982 and Lu and Phillips, 1985)

Photololigo sp. 1 is a small maturing species (<120 mm ML) with a distribution limited to deeper northern Australian waters (>100m) of the Northwest Shelf and eastwards to the Arafura Sea (135°E) (Yeatman, 1993; Yeatman and Benzie, 1994). This species was not present in squid samples examined during this study from midshelf waters off the Kimberleys, the Gulf of Carpentaria and the east coast of Queensland.

Few details of the biology of *Photololigo* sp. 1 have been published. Size at age and reproductive maturity were reported by Jackson and Yeatman (1996) who found the age of mature females varied between 90 and 160 days (50 - 120 mm ML).

Photololigo sp. 2 of Yeatman, 1993

(=*Loligo* sp.2 of Yeatman and Benzie 1993 and *Loligo edulis* [in part] of Dunning, 1982 and Lu and Phillips, 1985; *Photololigo* cf. *edulis* of Dunning *et al.*, 1994)

Yeatman and Benzie (1994) reported *Photololigo* sp. 2 from the Timor Sea, Arafura Sea and Gulf of Carpentaria, in some localities in the Timor Sea occurring in catches with *Photololigo* sp.1 and in the Arafura Sea and Gulf of Carpentaria, co-occurring with slender squid (*Photololigo* sp. 4). Dunning *et al.* (1994) reported this species from throughout the Gulf of Carpentaria occurring in many CSIRO research trawl catches together with slender squid.

During this study, *Photololigo* sp. 2 was caught in the Gulf of Carpentaria during January 1997 in depths of 32 to 40 m and did not occur where catches of broad squid were taken. It was again caught with slender squid at some stations. *Photololigo* sp. 2 was not present in trawl catches from midshelf waters off the Kimberleys or in samples from extensive research trawling off the Queensland east coast by DPI and CSIRO.

This species is common among squid catches from parts of the Northern Prawn Fishery area and may be confused by researchers and fishers with juveniles of the larger maturing slender squid (*Photololigo* sp 4). Maturity stage (females generally mature at ≤ 80 mm, males ≤ 60 mm) is a useful character to assist in separating this species from broad and slender squid where they co-occur.

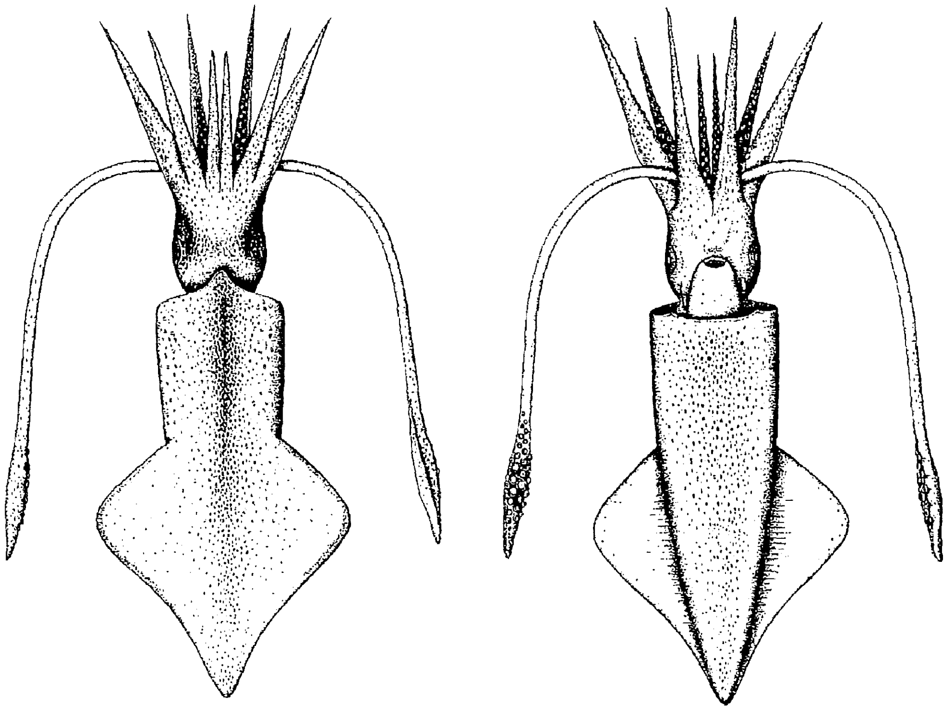


Figure 10. Photololigo *sp. 1 from Yeatman, 1993.*

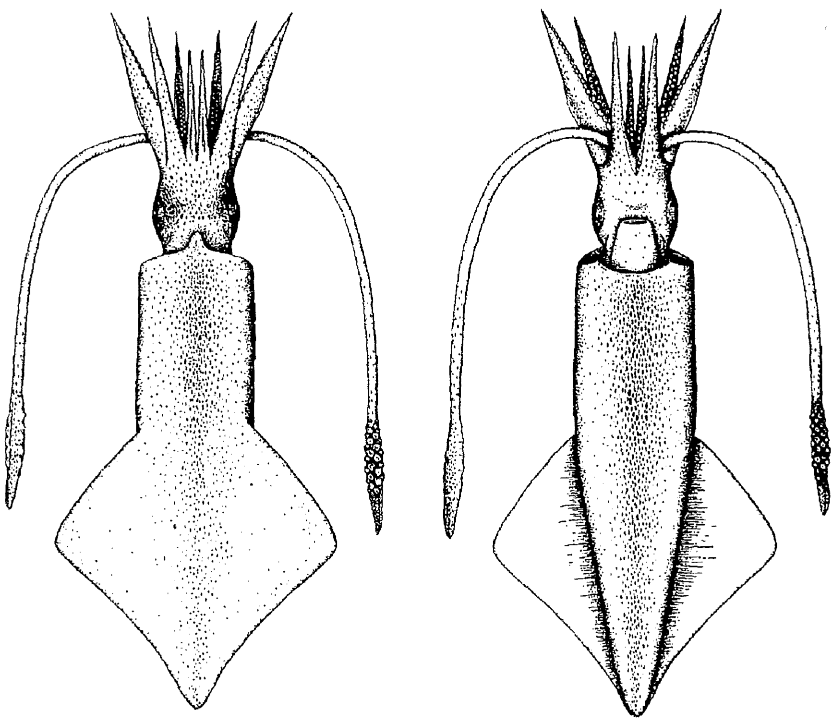


Figure 11. Photololigo *sp. 2 from Yeatman, 1993.*

Geographic distribution of domestic squid catch from logbook records

The distribution of total annual squid catch across northern Australia for 1995 (from AFMA NPF logbooks) and off the Queensland east coast for 1995 and 1997 (from QFMA East Coast trawl logbooks) by one degree latitude / longitude grids is shown in Figures 12 and 13. High seasonal catches of squid (a reported maximum of more than 400 tonnes in 1993) have also been taken regularly outside the NPF area in Western Australia off the Kimberleys and may not have been reported through the NPF logbook system (Fiona Manson, CSIRO Marine Research, pers. comm.,1996).

On the basis of research surveys undertaken previously (M Potter, G Smith, I Halliday, R Quinn, D Smallwood, all of Southern Fisheries Centre, DPI, personal communications) and during this study, it is likely that squid reported from inshore net catches from southern Queensland consist primarily of northern calamary and otter trawl catches in Moreton Bay are almost exclusively broad squid. Squid reported from otter trawl catches in midshelf waters off southern Queensland (south of 24°S) are likely to be primarily slender squid on the basis of research catches during this project.

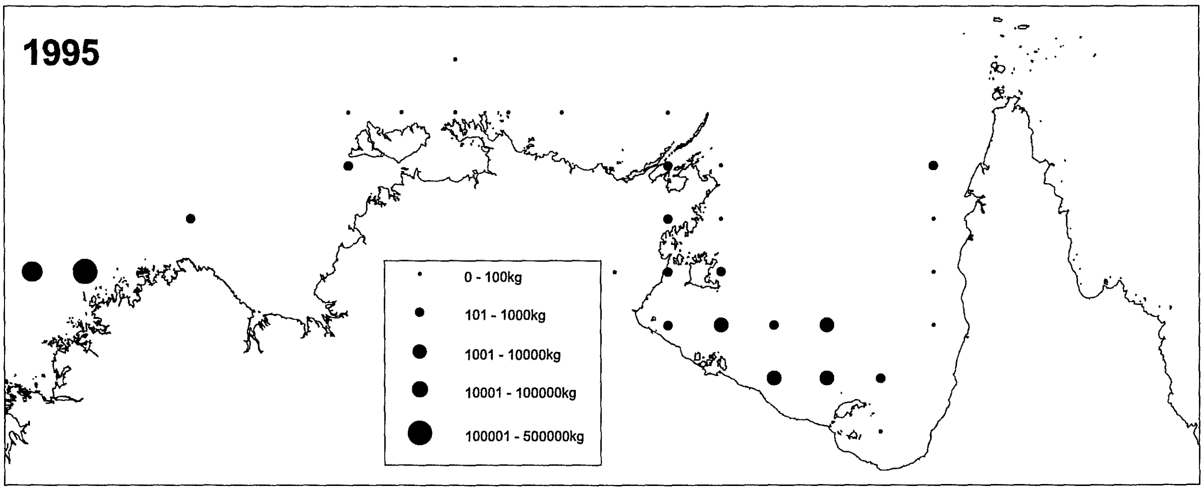


Figure 12. Reported catches of squid from Northern Prawn Fishery logbook data, 1995 (Source: AFMA commercial fishers logbooks; coastline data : AUSLIG © Commonwealth of Australia).

In the Gulf of Carpentaria and Northern Prawn Fishery area, commercial trawl catches are likely to be mixtures of *Photololigo* sp 2, broad squid, slender squid and rarely northern calamary but if they reflect research trawl catches from previous summer research surveys, slender squid is by far the most abundant species (Dunning *et al.,* 1994 reported as "*Photololigo* cf. *chinensis* northern form"). Further west in the Kimberley Prawn Fishery and off the Northwest Shelf, mid-shelf catches are likely to be dominated by slender squid with some northern calamary while in deeper water catches (>100 m), the smaller *Photololigo* sp. 1 is the more abundant loliginid squid.

Catches off the Queensland east coast are a mixture of predominantly broad squid with some northern calamary in inshore waters and slender squid in midshelf and deeper waters. At depths greater than 150m, arrow squid (*Nototodarus* spp.) are also included in commercial prawn trawling byproduct but are rarely a large component.

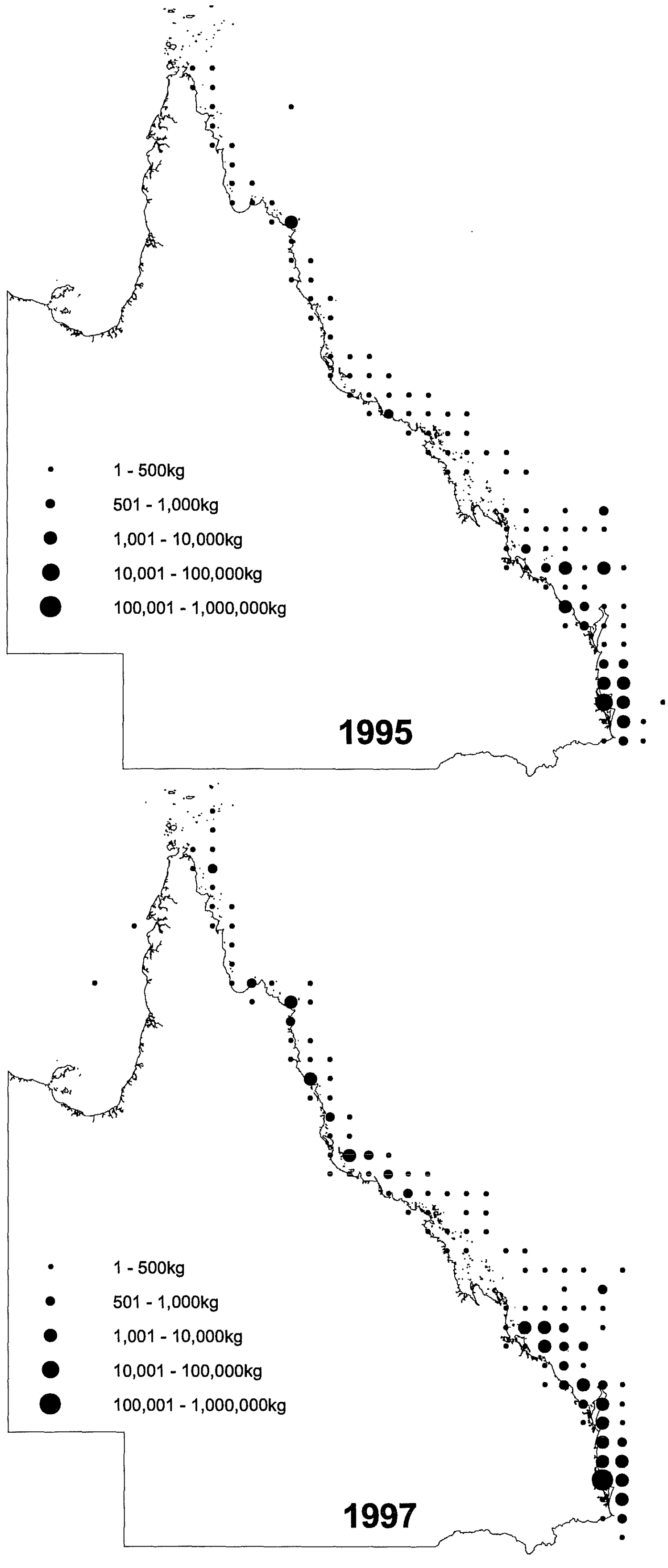


Figure 13. Reported catches of squid byproduct from Queensland East Coast trawl fishery logbooks, 1995 and 1997 (Source: QFMA commercial fishers logbooks; coastline data : AUSLIG © Commonwealth of Australia)

Taiwanese trawl catches of squid from off northern Australia

From 1971 to the early 1980's, an intensive Taiwanese pair trawl fishery operated off the northern Australian coast (Edwards, 1983). Reported catch data from this fishery provide an indication of the size of the squid resource at that time and also of temporal (monthly and interannual) variability in catches.

Published reports are available on the squid catch and total effort in this fishery at three monthly intervals and for each half degree square although in some years as few as 15% of logbooks were recovered by the Taiwan Fisheries Bureau from the vessels (Demersal Fish Research Center, National Taiwan University, 1979; 1980). With the declaration of the 320 km Australian Fishing Zone in 1979, this fishery continued as a licensed foreign fishery outside the Gulf of Carpentaria and these vessels were required to provide daily radio reports of catch and effort and complete daily logbooks. Radio report and logbook data from the Australian Fishing Zone Information System (AFZIS) were analysed for the period January 1980 to December 1982.

The distribution of Taiwanese annual trawl catch data for the NPF region by half degree squares for 1978 and 1979 (from published Taiwanese records) and for 1980 - 1982 from AFMA logbooks is presented in Figures 14 and 15.

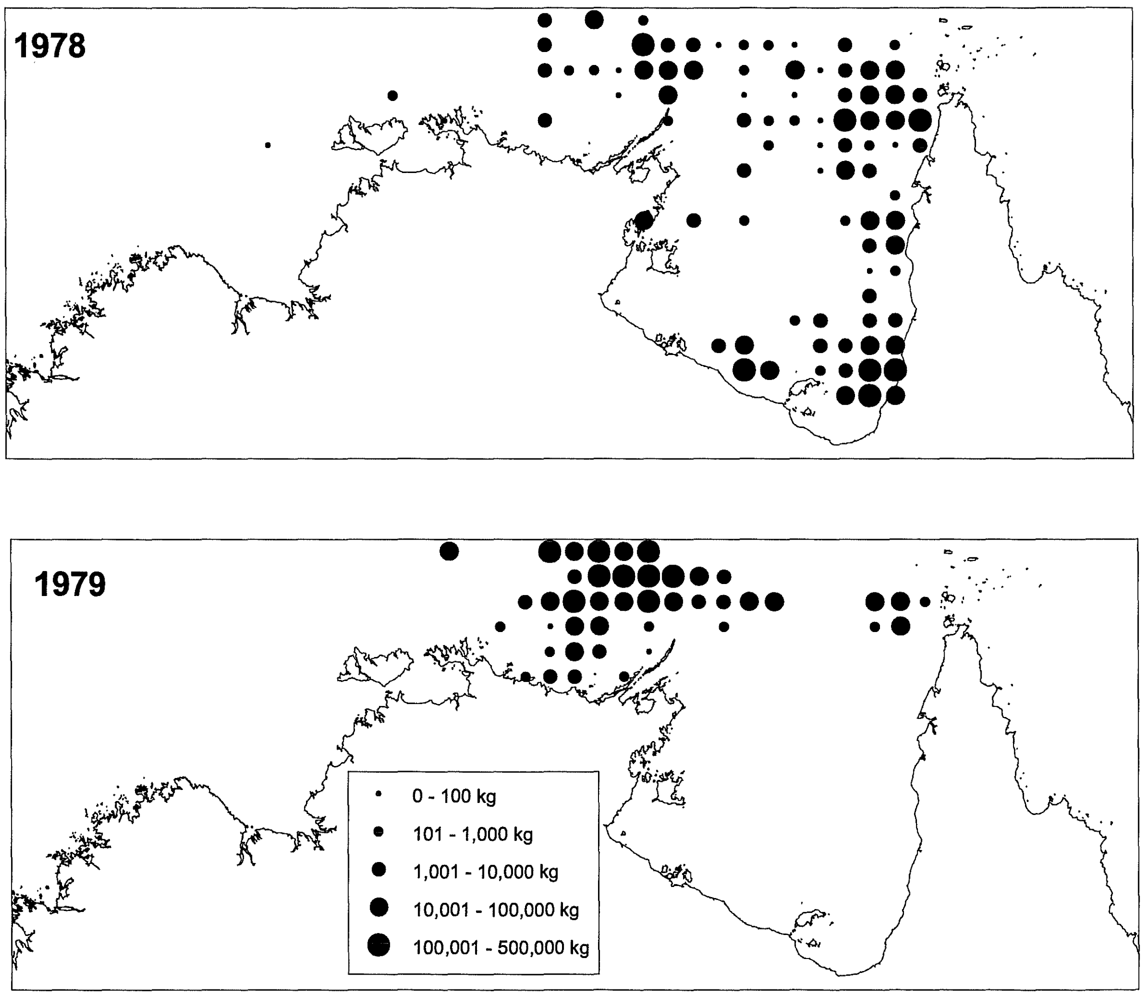


Figure 14. Reported Taiwanese trawl catches from northern Australia, 1978-79 (Demersal Fish Research Center, National Taiwan University, 1979; 1980).

It should be noted that trawl effort was not evenly spread throughout northern Australia over any of these periods and that pomfret (*Apolectus niger /Psenopsis humerosis*) and squid were target species in the Arafura region (Edwards, 1983). The level of target squid fishing and any increase in targetting over the years of the fishery or on a seasonal basis remain undocumented. Because of the difficulty in assigning effort to nontarget species, only total catch and not catch per unit effort (cpue) data are presented here.

These data show that high squid catches were taken from the area east of 132°E (the Arafura Sea region) while catches on the Northwest Shelf and Timor Sea were much lower in all years. The published Taiwanese catch reports for 1978/79 and earlier show a major squid fishing ground extending from the Wessels Islands northward to around the Aru Islands west of Irian Jaya (6°S, 134°E).

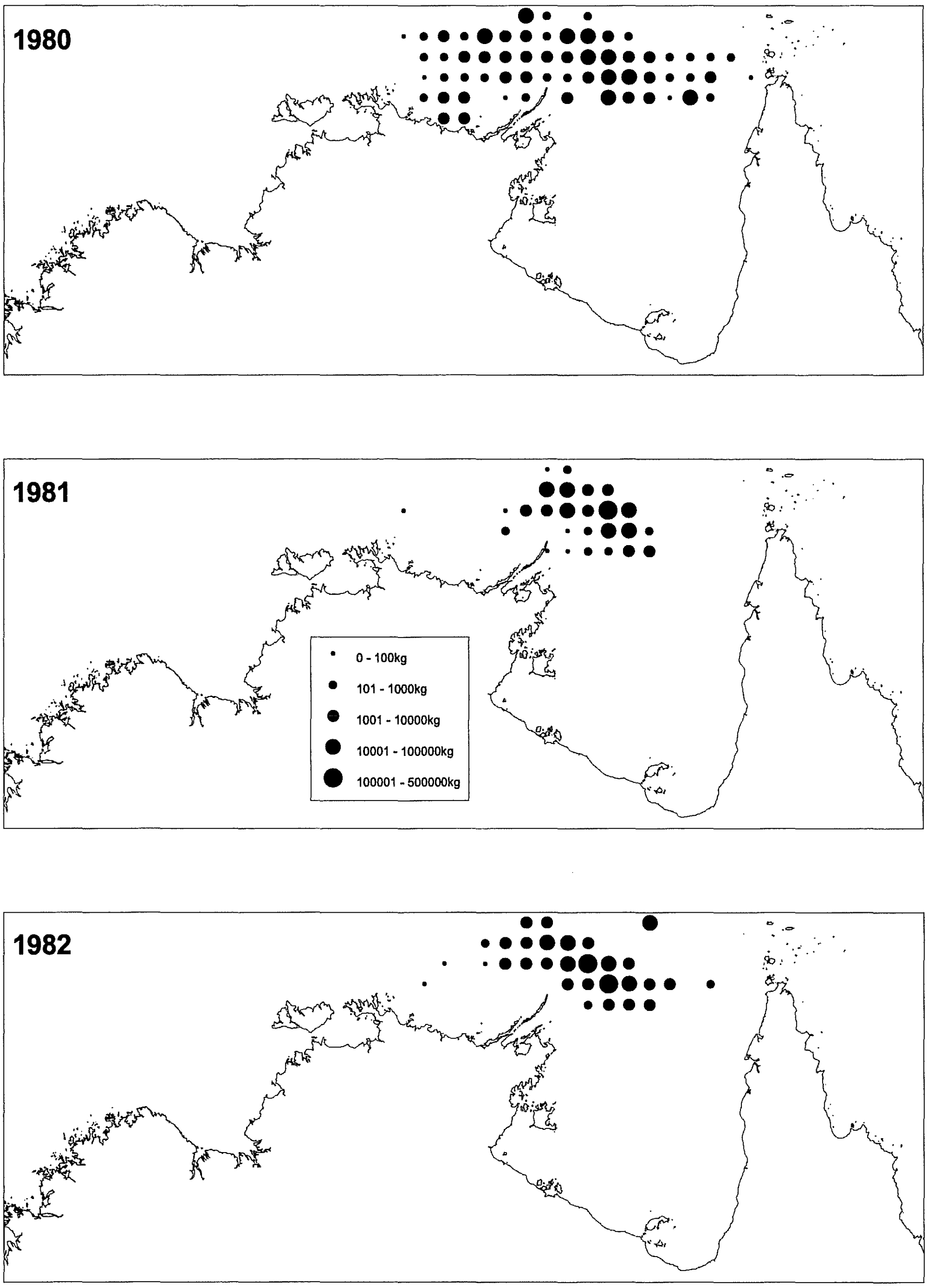


Figure 15. Squid catches reported by Taiwanese trawlers, 1980-82 from Australian Fisheries Service (now AFMA) Australian Fishing Zone Information System daily radio reports (coastline data; AUSLUG © Commonwelath of Australia).

Interannual and seasonal variability in recent domestic catches

Loliginid squid are diel vertical migrators, occurring close to the bottom during daylight hours and moving up through the water column during darkness. Hence they are more successfully caught in demersal trawls during the day. Prawn trawling, the major commercial fishing activity reporting squid, occurs predominantly at night off northern Australia.

In areas where target trawling for squid occurs (Moreton Bay, the Kimberleys and in the Gulf of Carpentaria), such fishing is often only seasonal for a variety of reasons (e.g., availability of higher value prawns, daylight commercial fishing closures) and reported squid catches at other times are not necessarily a good indicator of the availability of squid.

Several researchers have noted that byproduct reporting through the existing Queensland and Northern Prawn Fishery / Kimberley Prawn Fishery commercial fishery logbook programmes underestimates real landings, in some cases significantly. A comparison of the reported catches of squid in the NPF with commercial marketting information was undertaken by CSIRO Division of Fisheries (Fiona Manson, pers comm.,1996) with input from this study team. The CSIRO study concluded that NPF reporting levels were variable between vessels and times/areas and averaged only about 40% of the probable real catch with a range of 0-75%. It was concluded that reporting levels for the Kimberleys region of Western Australia outside the NPF also may have been as low as 33% of the actual catch.

Queensland east coast commercial catches

While recognizing the limitations of squid catch information reported in logbooks, an analysis of commercial fishers logbook data from selected higher catch areas off the Queensland east coast was undertaken for 1991 - 1995 to provide some indication of relative seasonal availability of the major squid species.

It should be noted that approximately 80% of the reported Queensland east coast catch is taken in Moreton Bay in southern Queensland. There, catchability of broad squid in demersal trawls is determined by the extent of squid concentration in clearer oceanic waters in the eastern bay resulting from freshwater runoff from the Brisbane River according to local fishers who target squid. Poor rains result in squid being broadly distributed throughout the bay and catch rates being lower. Hence the timing and intensity of the summer rainy season in the adjacent catchment may have a large influence on annual commercial trawl catches of broad squid.

Seasonal changes in the inshore set net catches of northern calamary for the Sandy Straits - Tin Can Bay area and for Moreton Bay in southern Queensland are shown in Figures 17 and 18. Catches were higher from autumn to late spring in both areas although squid were caught all year round. It is unknown whether seasonality of catches is representative of availability of squid or more a reflection of increased net fishing effort for the target species, mullet, whiting and bream, whose abundance peaks in the winter months.

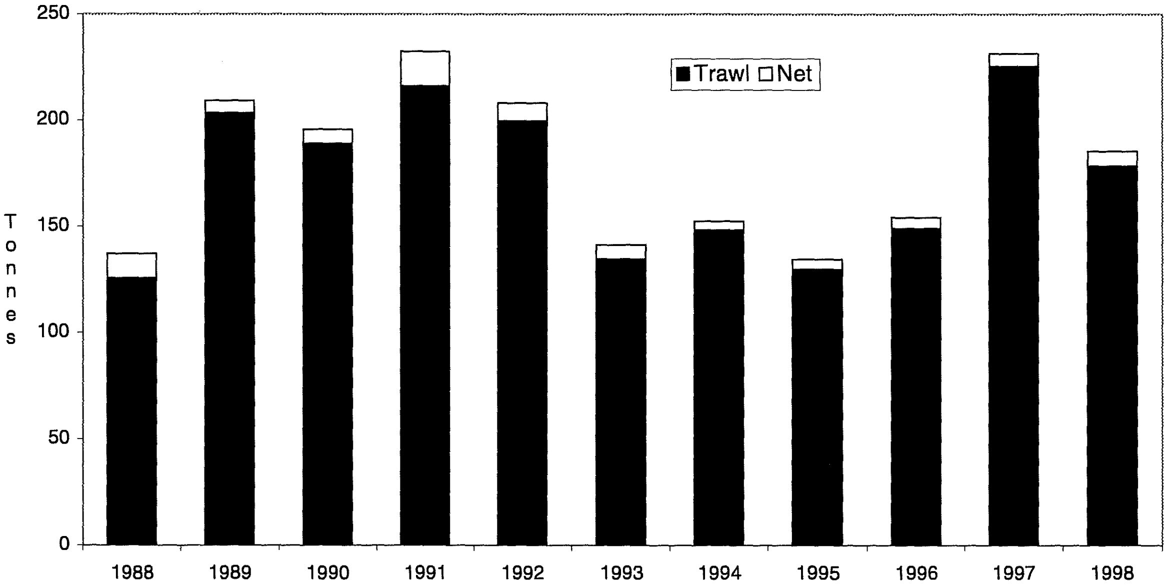


Figure 16. Total reported squid byproduct in inshore set net, prawn and scallop trawl catches from the Queensland east coast, 1988-98 (source: QFMA commercial fishers logbooks).

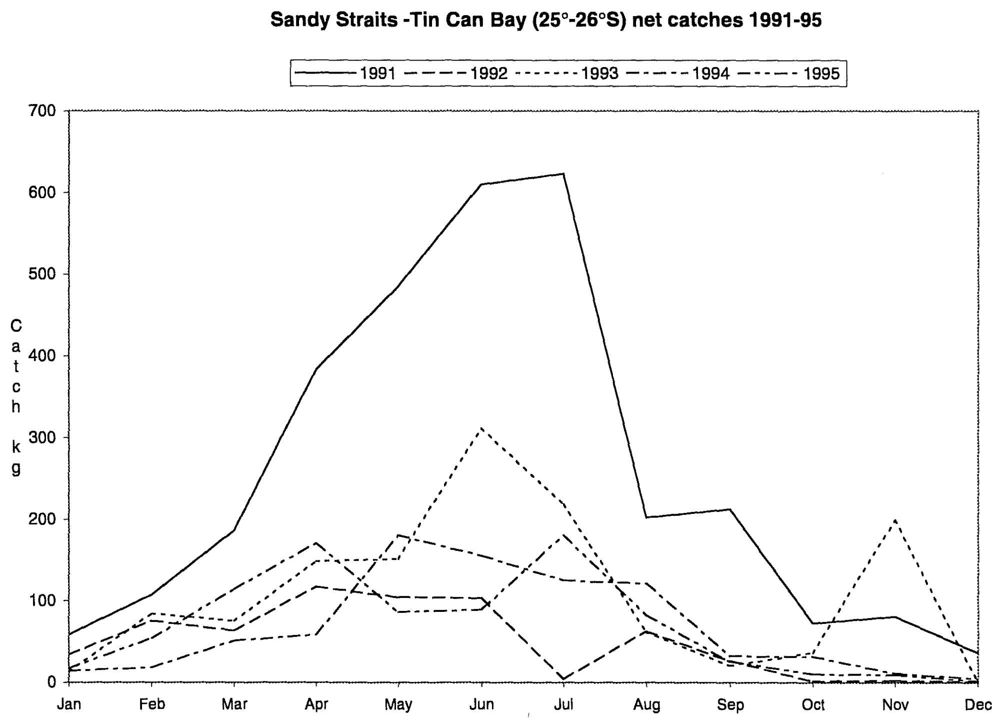


Figure 17. Reported northern calamary catches from set nets in Sandy Straits - Tin Can Bay 1991-95 (source: QFMA commercial fishers logbooks).

Broad squid catches from trawlers in Moreton Bay (Figure 19) were higher from mid-summer to autumn although the much lower broad squid catches from inshore waters off Bundaberg and slender squid catches from the offshore king prawn grounds off Bundaberg and off southern Queensland were variable and showed no clear yearly seasonal patterns. In 1995, higher catches were reported in the summer - autumn months.

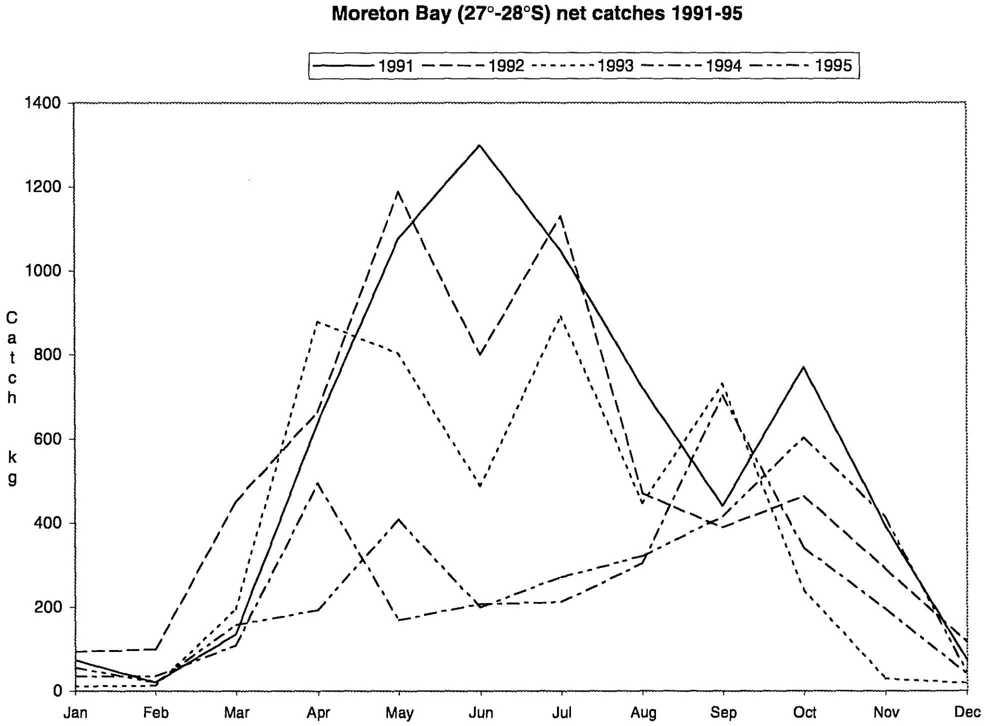


Figure 18. Reported northern calamary catches from set nets in Moreton Bay, 1991-95 (source: QFMA commercial fishers logbooks).

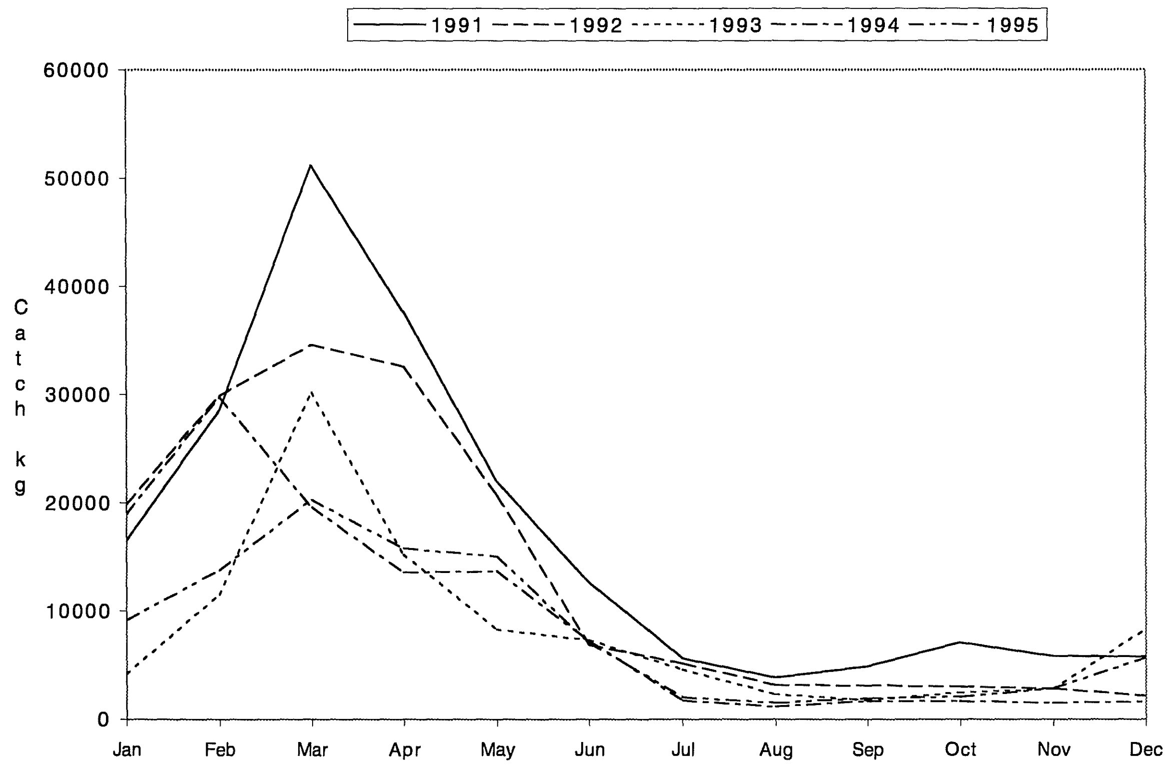


Figure 19. Seasonal changes in the reported broad squid catches from commercial trawlers in Moreton Bay, 1991-95 (source: QFMA commercial fishers logbooks).

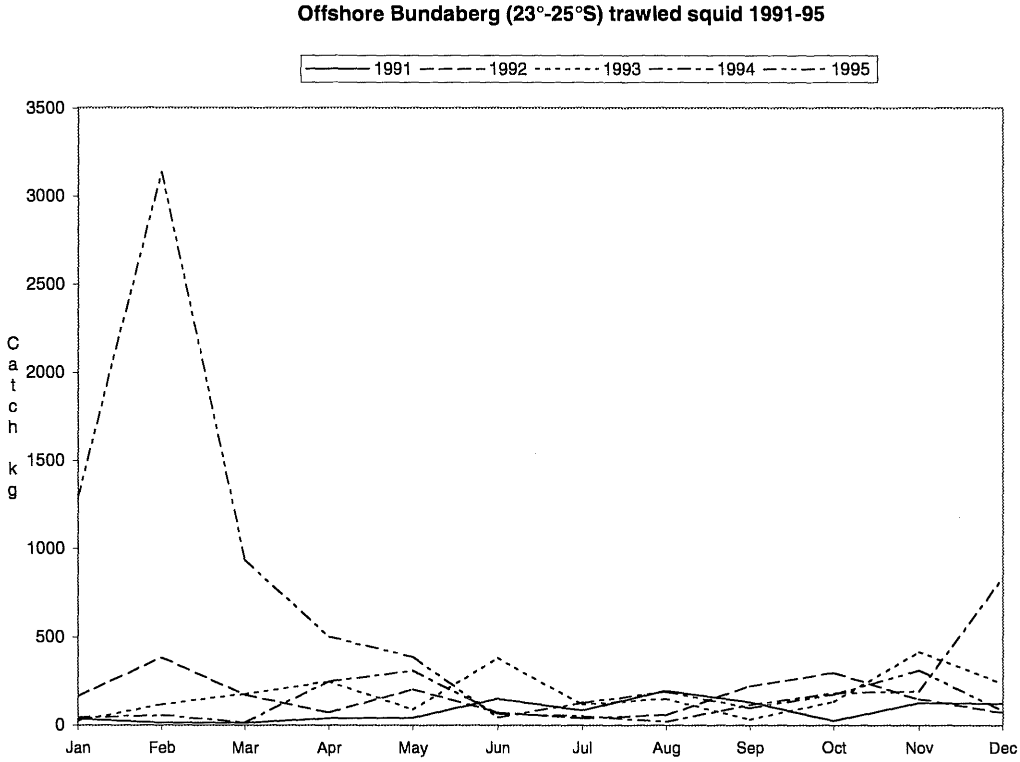


Figure 20. Seasonal changes in reported squid catches from trawlers in the deepwater king prawn grounds off southern Queensland (23°-25°S), 1991-95 (source: QFMA commercial fishers logbooks).

In contrast to the recent commercial catch information (Figure 19), trends shown in data from research trawl surveys in Moreton Bay between 1982 and 1984 did not show the same distinct seasonality at any of the ten stations regularly sampled (catches at three representative stations are shown in Figure 21). While catches were generally higher in the summer months, relatively high squid catches were also made in spring and late winter at some sites.

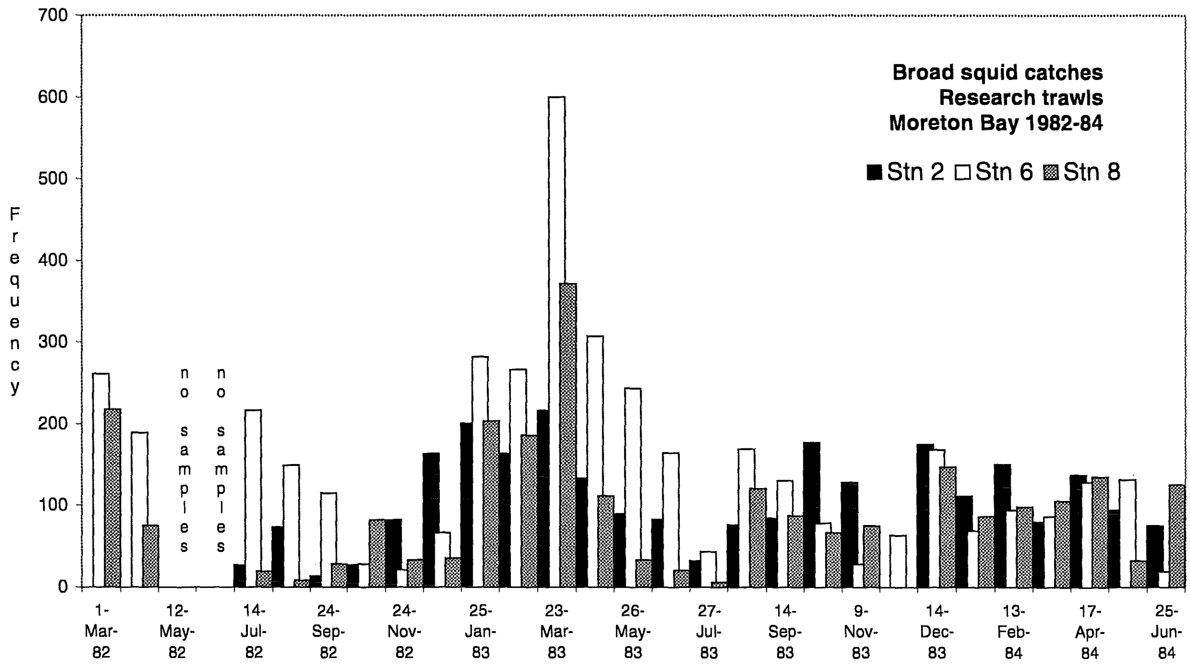


Figure 21. Broad squid catches from research trawls at selected stations in Moreton Bay, 1982-84 (Station 2 - 27°19'S 153°18.25'E; station 6 - 27°11.5'S 153°12.5'E; station 8 - 27°12'S 153°08'E).

Research trawling off Mooloolaba

Trawl surveys using a purpose designed squid trawl were conducted in three depth zones off Mooloolaba, southern Queensland in March 1995 (autumn), November 1995 (early summer) and March 1996. Average estimated biomass within each depth zone for each survey is shown in Figure 22. No clear seasonal trends (autumn vs late spring) are apparent in these data with a shift in the relative abundance of squid in each depth zone on each survey.

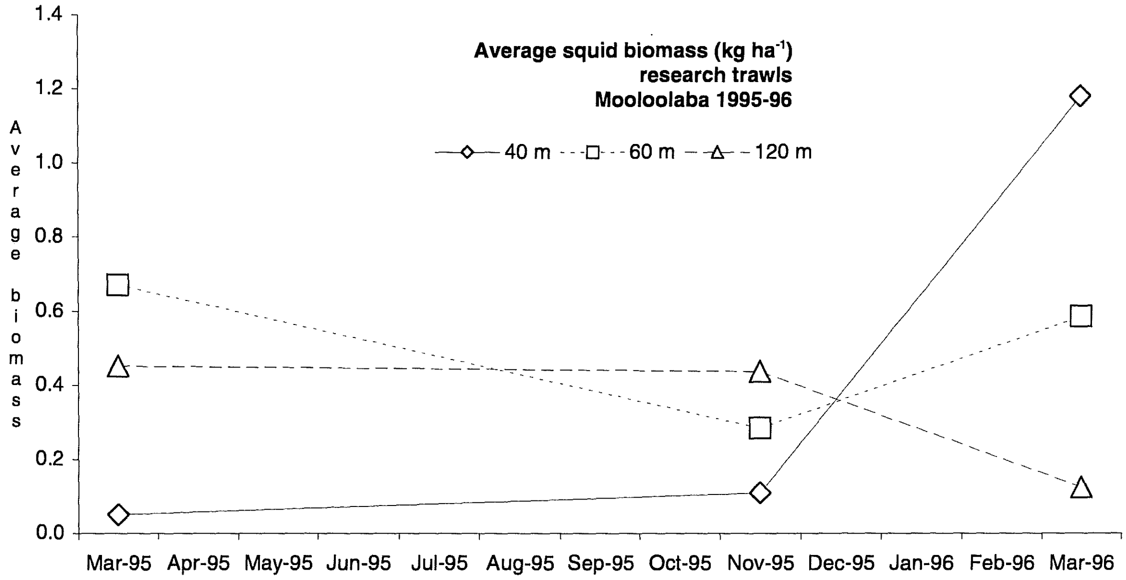


Figure 22. Average squid biomass from research trawling off Mooloolaba, 1995/96.

Domestic catches from the Northern Prawn Fishery area

Reported annual squid catches from the NPF (Figure 23) have been highly variable with marked increases in 1994 and 1995 but it should be noted that no attempt has been made to look at CPUE data because squid is primarily an incidental byproduct in this fishery. Further, prior to 1995, reporting of squid catches had not been compulsory.

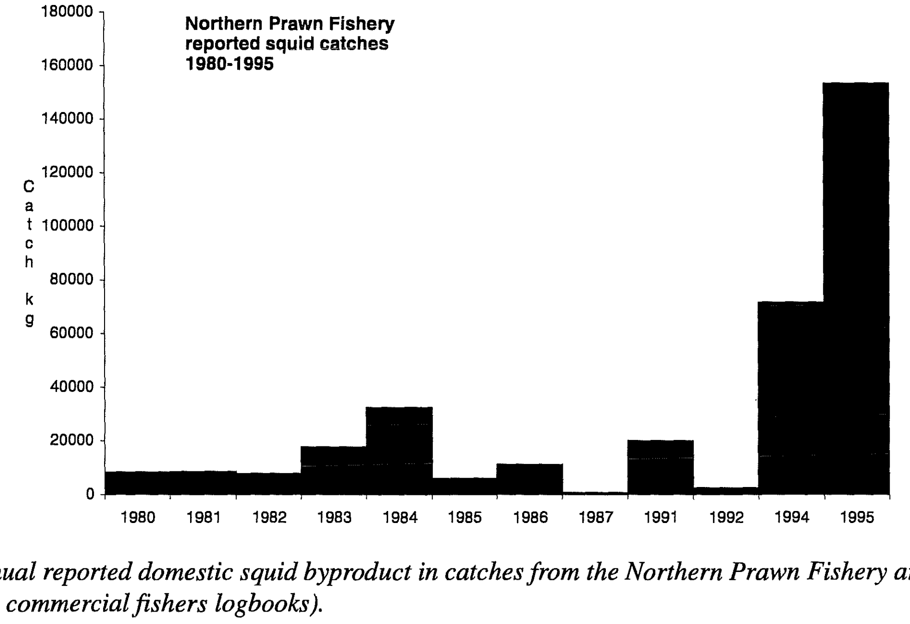


Figure 23. Annual reported domestic squid byproduct in catches from the Northern Prawn Fishery area, 1980-95 (source: AFMA commercial fishers logbooks).

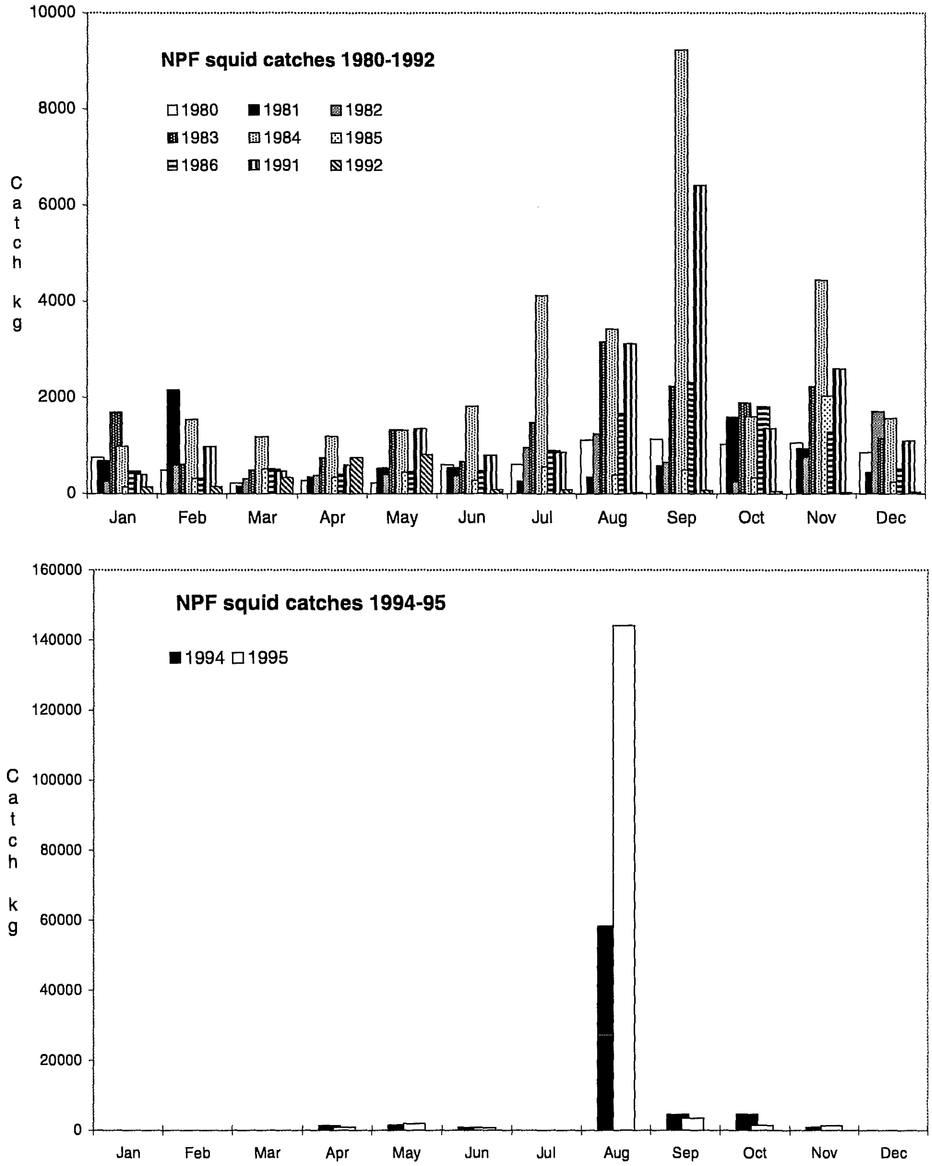


Figure 24. Seasonal changes in the reported squid catch from the Northern Prawn Fishery, 1980-1995 (source: AFMA commercial fishers logbooks).

Available data indicate greater abundance of squid from July to December in all years with highest catches reported in August and September (Figure 24). However, clarification of the extent to which this apparent seasonality reflects actual squid abundance requires further fishery independent sampling.

Seasonal changes in Taiwanese trawl catches of squid from northern Australia

Reported annual squid catches from Taiwanese vessels fishing in the Australian Fishing Zone east of 132°E reached a maximum of 2600 tonnes in 1979 (Figure 25). Highest catch rates in 1978 (when fishing was reported also from the Gulf of Carpentaria) were taken from April - September while in 1979, high catches extended through to December. Monthly catch and total effort for 1980-1982 are shown below and indicate a shift from later in the year in 1980 to earlier in the calender year in 1981 and 1982. There is no evidence from this short data set of annual periodicity in high catch rates in this area with periods between high catches of six to nine months.

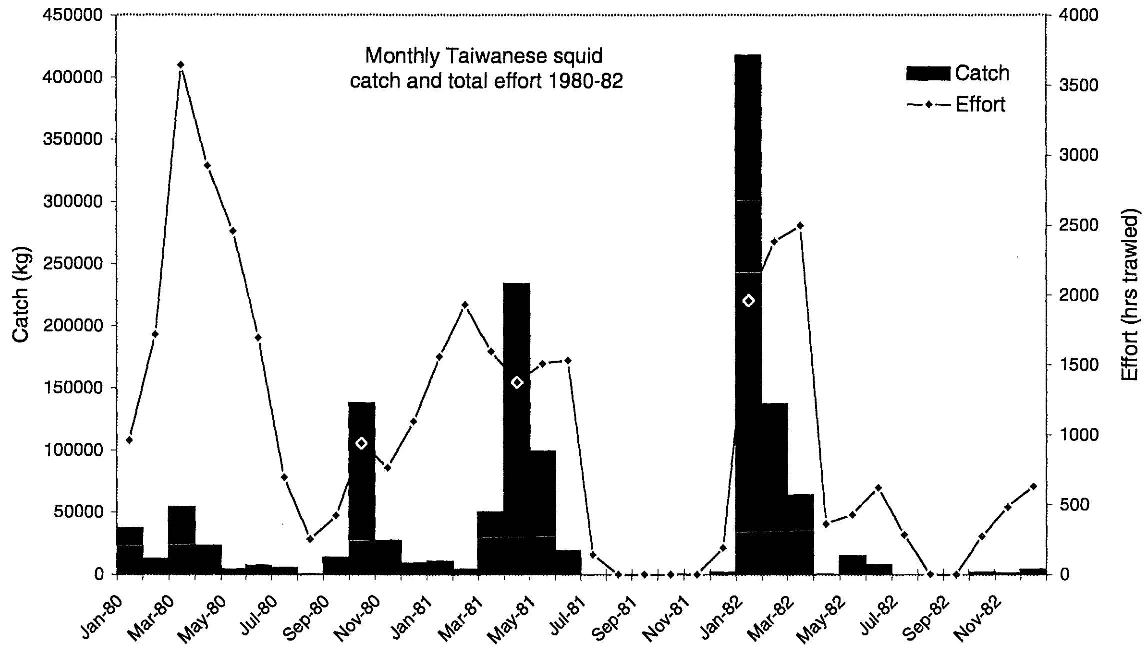


Figure 25. Monthly Taiwanese trawl squid catches and total reported effort, 1980-82 (Demersal Fish Research Center, National Taiwan University, 1981-83.

Objective 2 - Biological characteristics of the resource - species composition, seasonal size composition and basic life history characteristics

Species composition of catches

Moreton Bay, southern Queensland (≈27° 15'S)

Commercial and research trawl and jig catches in Moreton Bay were dominated numerically by broad squid with very small numbers of bay or bottle squid (*Loliolus noctiluca*) also trawled in shallower locations (<10 m depth). Slender squid were not present in any samples from Moreton Bay examined for this study.

Northern calamary or tiger squid were the primary squid component of commercial and research set netting and beach seining in shallow coastal areas, with bay squid again representing a very small component in some fine mesh net research samples in areas adjacent to mangroves.

Mooloolaba, southern Queensland (≈26° 30'S)

Five squid species of commercial interest were represented in squid trawl catches from the QDPI surveys in shelf waters off Mooloolaba in 1995/96. The relative abundance of these species overall, in each survey and by depth zone is shown below.

Species	Mar 95	Nov 95	Mar 96	Abundance overall (%)
Broad squid (*Photololigo etheridgei*)	0	2	521	8.22
Slender squid (*Photololigo* sp. 4)	4019	931	870	91.48
Northern calamary (*Sepioteuthis lessoniana*)	1	1	5	0.11
Southern calamary (*Sepioteuthis australis*)	1	0	1	0.03
Gould's arrow squid (*Nototodarus gouldi*)	1	4	5	0.16

Species	Shallow (30-40m)	Mid-shelf (50-70m)	Deep (100m+)
Broad squid	519	4	0
Slender squid	141	3037	2520
Northern calamary	2	5	0
Southern calamary	0	0	2
Gould's arrow squid	0	0	10

Information obtained from commercial catches and research surveys showed some differences in the proportions of broad and slender squid (*Photololigo etheridgei* and *P.* sp. 4) in inshore samples. However, it should be noted that trawl sites were not identical between surveys and it is apparent that these squid occur in schools, not evenly distributed on the trawl grounds.

Off Cairns (≈17°S)

Squid catches from a research survey using prawn trawls and hand jigs across the shelf south-east of Cairns in March 1996 included northern calamary, slender squid, broad squid and bay squid. The relative abundance of these in relation to bottom depth is shown below as numbers of squid caught.

Species	Shallow coastal (< 15 m)	Mid shelf reef (25-50m)	Deep (>100m)
Broad squid	152	66	0
Bay squid (*Loliolus noctiluca*)	3	0	0
Slender squid	16	21	3
Northern calamary	0	1	0

East of Cape York (≈11°S, 143°E)

Catches from the CSIRO / QDPI trawl surveys off eastern Cape York during 1993 and 1994 included three squid species of commercial interest, northern calamary, slender squid and broad squid. The relative abundance in subsamples of these species overall together with their abundance at each station in relation to bottom depth is shown in Figure 26.

Species	Abundance overall (numbers)
Broad squid	274
Slender squid	1722
Northern calamary	242

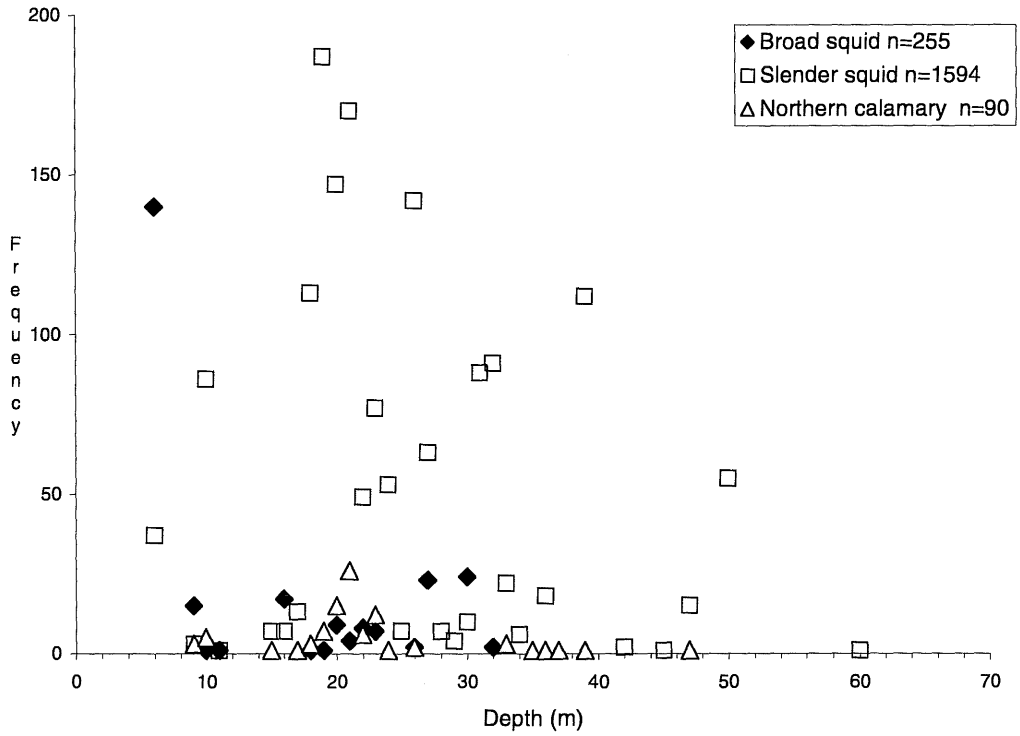


Figure 26. Abundance of broad squid, slender squid and northern calamary with trawl depth east of Cape York 1993/94

Gulf of Carpentaria

Previous CSIRO surveys identified four squid species of commercial interest from the Gulf of Carpentaria (Dunning *et al.*, 1994) and samples examined for this study did not add to this list. The overall proportion of the various species present in trawl samples taken from various regions in the Gulf of Carpentaria in February 1997 is compared with previous results below. It should be noted that sites within this area trawled for each of these surveys were not identical.

Species	1990 survey	1991 survey	1997 survey
Broad squid (*Photololigo etheridgei*)	0	145	53
Slender squid (*Photololigo* sp. 4)	634	1066	208
Northern calamary (*Sepioteuthis lessoniana*)	1	100	16
Photololigo sp. 2	268	312	11

Squid samples taken as byproduct by a commercial prawn trawler north of the Vanderlin Islands (15°S, 137°E) in August 1996 consisted entirely of slender squid (*Photololigo* sp 4) including recently laid egg capsules and fully mature female squid.

Off the Kimberleys, Western Australia

A sample of 136 squid from target squid trawling (2 minute shots in 45-50m at approximately 14°S 125°E, August 1995) consisted entirely of slender squid. In samples examined by Yeatman and Benzie (1994) from trawl catches in this region, *Photololigo* sp.1, *P.* sp 2 and broad squid were also present, the first restricted to waters deeper than 100m and the last to near coastal waters.

Size composition of catches

Broad squid in Moreton Bay - research trawl catches

The size composition of trawled broad squid from DPI research surveys between March 1982 and June 1984 was examined. A comparison for males and females overall is shown in Figure 27. Males reached larger sizes (25 cm) than females in these samples (17 cm ML).

There was little variation between years in the overall size distribution of squid catches. A few larger male squid (20-25 cm ML) were present in 1984 only while the modal length of males and females varied but not significantly between years.

Monthly size distributions of male and female squid from the ten sampling stations combined are shown in Figure 28. Comparisons of catches showed the presence of small squid (< 7 cm ML) in most monthly samples. There are indications during some periods of progression of modal size classes, perhaps representing growth in the dominant size classes (eg., Aug-Sep-Oct 1982, Feb-Mar-Apr 1983). In general, these monthly data show the continuous presence of small squid and multiple modes, indicating that recruitment to these trawled populations is occurring throughout the year at some level and that spawning of broad squid is not restricted to a single discrete season in this region.

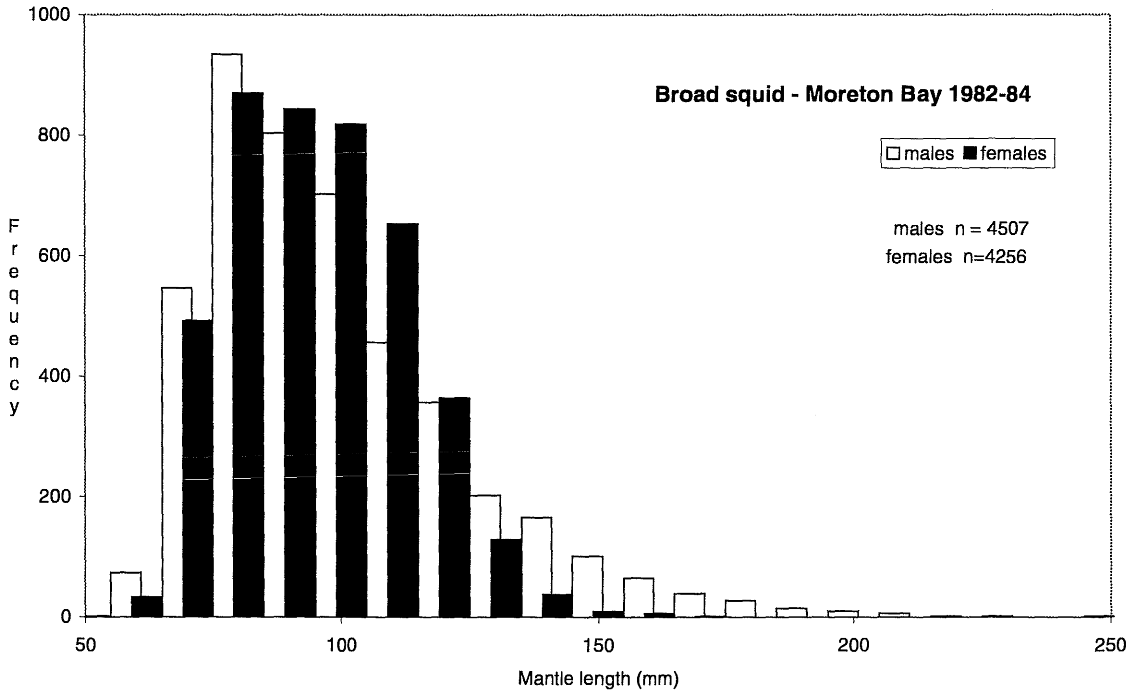


Figure 27. Overall mantle length distribution for broad squid from research trawls, Moreton Bay 1982-84.

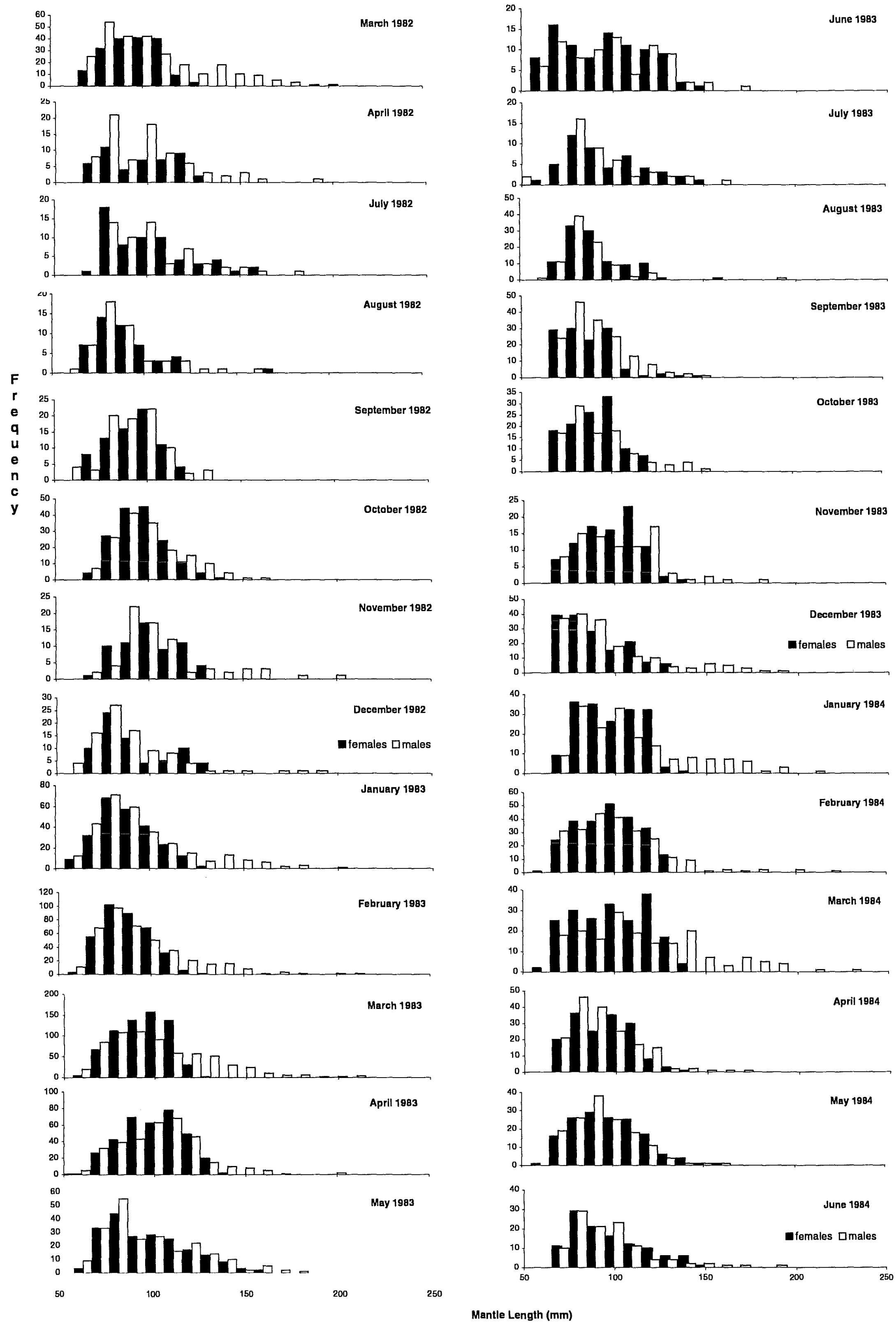


Figure 28. Size distribution of broad squid from Moreton Bay research trawling, 1982-84.

Broad squid off Mooloolaba - research trawl catches

Broad squid were only abundant in the shallow inshore trawl catches in March 1996 from the Mooloolaba research surveys. The size distribution is shown in Figure 29 and a similar modal size for both males and females is apparent.

Broad squid from off Mooloolaba had a larger modal size than samples collected in Moreton Bay in 1982-84 (≈ 130 mm cf. ≈ 80 mm in Moreton Bay) but it should be noted that the nets used in the surveys had different wing and cod end mesh sizes and were towed at different speeds (recent surveys towed larger mesh nets faster). The maximum size of squid caught in both research surveys was the same, 250 mm ML (both males).

Broad squid off Bundaberg - commercial trawl catches

The size distribution of broad squid caught as byproduct of inshore prawn trawling off Bundaberg is shown in Figure 30. As for other areas, the modal size of males and females was similar and a broad size range of both sexes was evident in most samples. There is evidence of more than one mode in samples from February 1995, March, May and June 1996 and there is little evidence of progression of modes in these samples, indicative of extended recruitment to these populations.

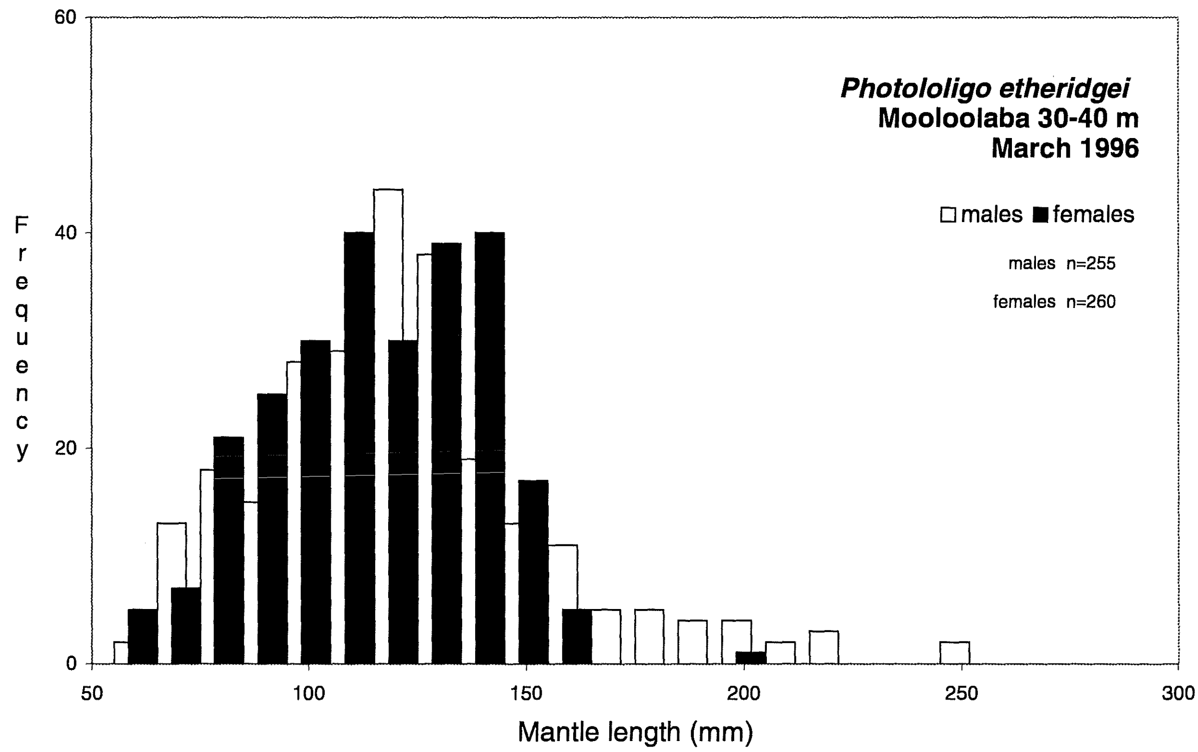


Figure 29. Size distribution of broad squid from inshore waters off Mooloolaba, March 1996.

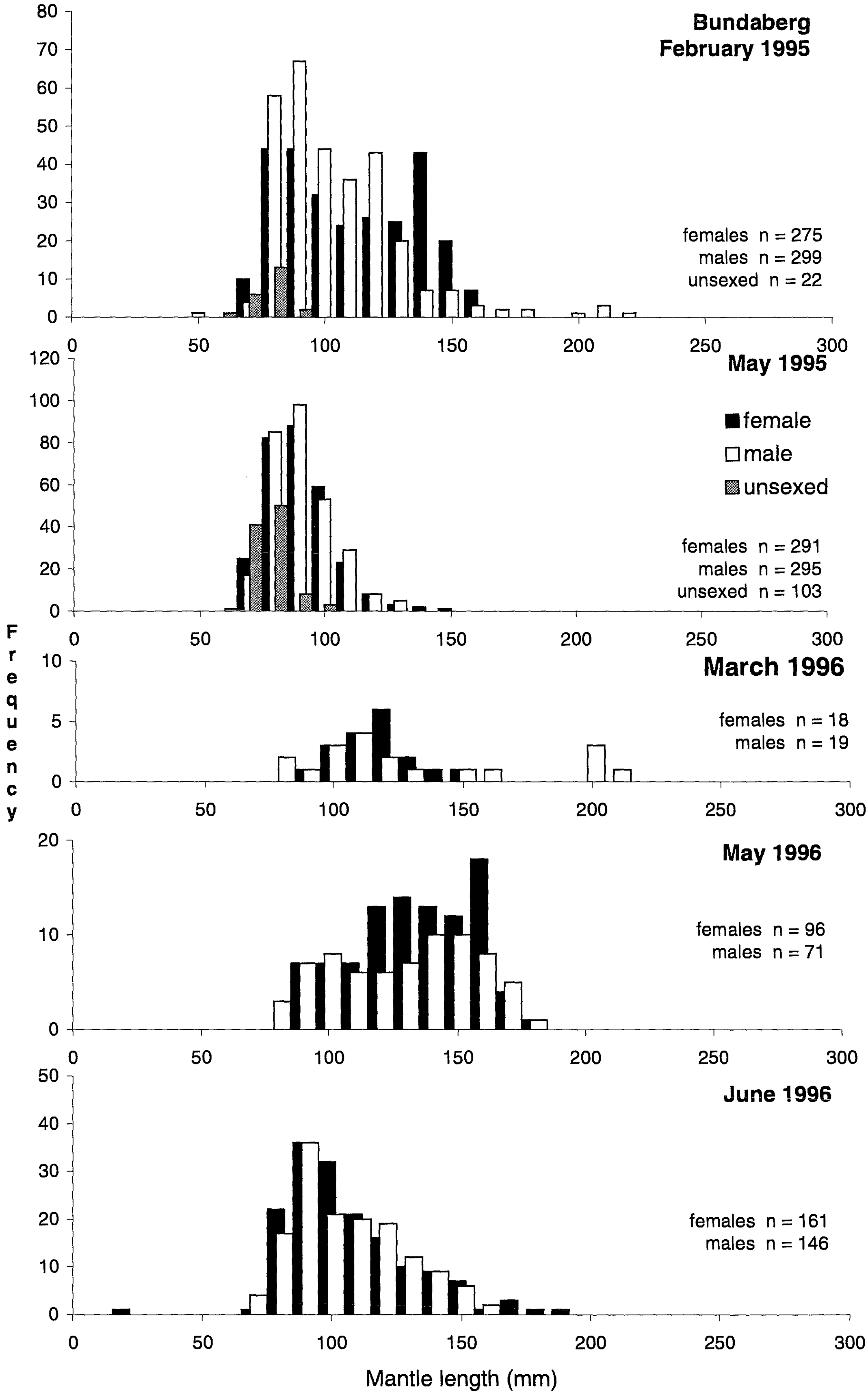


Figure 30. Size distribution of broad squid from inshore commercial prawn trawling off Bundaberg, 1995-96.

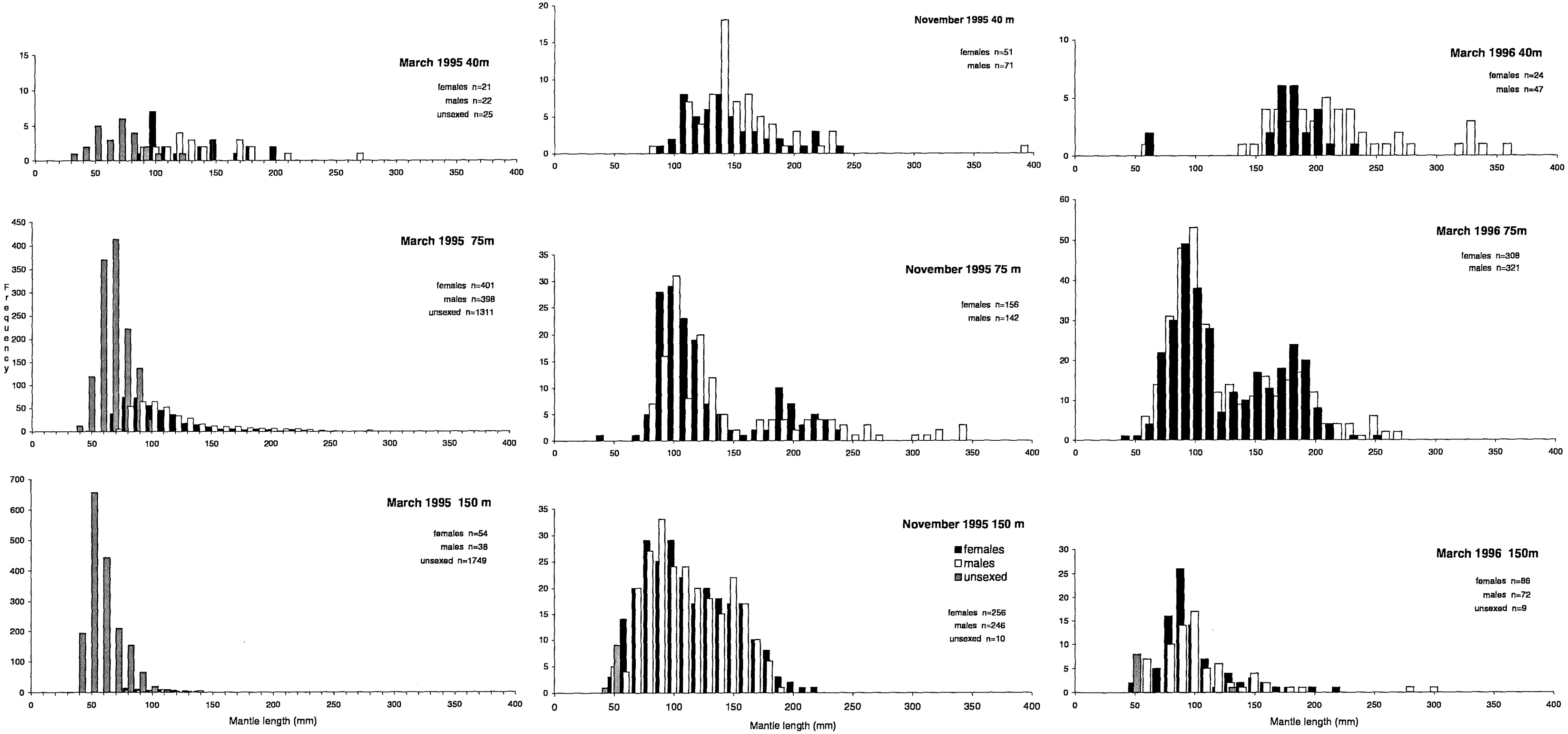


Figure 31. Size distribution of slender squid from off Mooloolaba by survey and depth zone, 1995-1996.

Slender squid off Mooloolaba - research trawl catches

Size composition of catches from the three surveys off Mooloolaba were examined for the three different depth zones (shallow - 40m, midshelf - 75m and deep - 150m) for slender squid for all surveys (March 1995, November 1995 and March 1996 (Figure 31).

In all depth zones at all times, the catch consisted of a relatively broad size range of both males and female squid suggesting that recruitment to these populations is not limited to a single short period. The mid-shelf samples from both November 1995 and March 1996 show an indication of at least two size classes of females and three of males while at least two different size classes are evidentfor both sexes in the deep water samples in November 1995.

Among the three depth zones, small squid (≤ 75 mm ML) represented the highest proportion of the catch in deep water in all surveys. They were present across the shelf in all depth zones in March 1995 but present in abundance only in deep water in November 1995. In March 1996, few slender squid less than 75 mm were caught at any station. Larger squid (≥ 200 mm ML) were present in shallow and midshelf waters and in only very small numbers in deep water in all surveys.

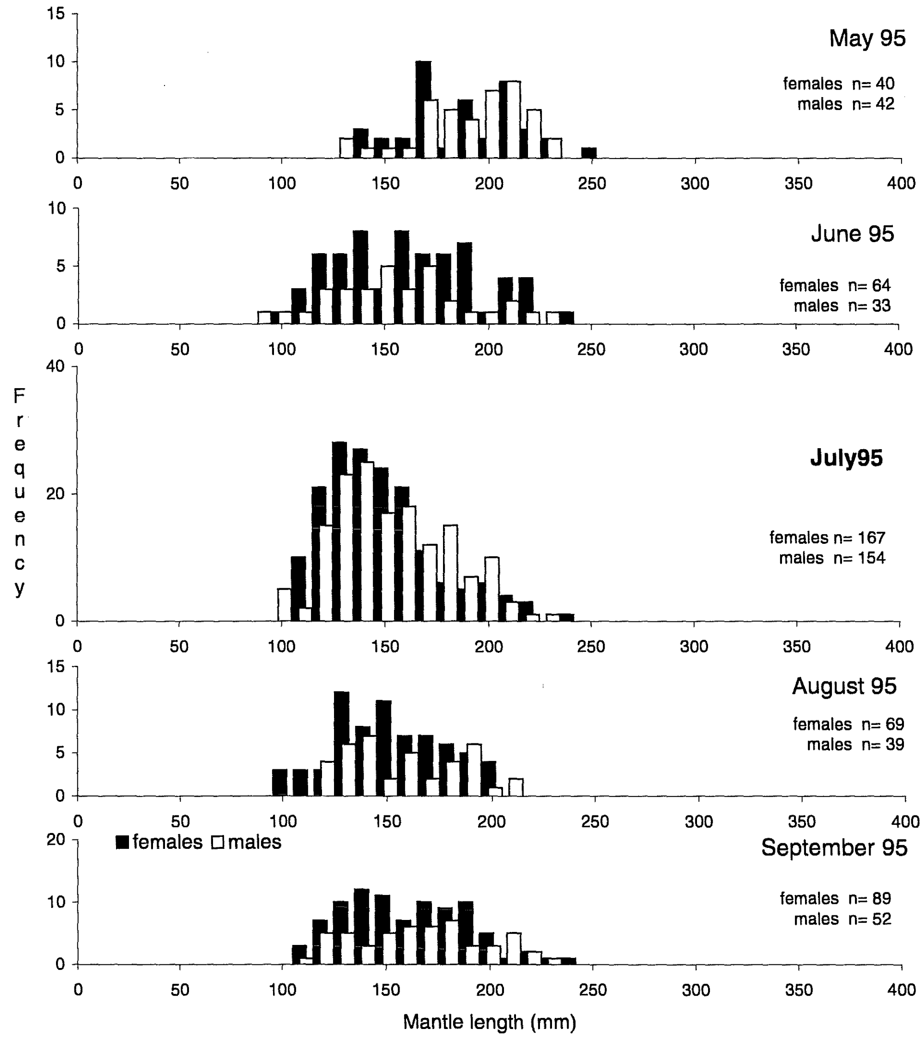


Figure 32. Size distribution of slender squid from commercial prawn and fish trawling off Mooloolaba, 1995-96.

Slender squid off Mooloolaba - commercial trawl catches

The size distribution of squid byproduct from commercial prawn and fish trawling off Mooloolaba is shown in Figure 32. A broad size range of slender squid of both sexes was present in most samples. Females larger than 200 mm ML and males larger than 250 mm ML (assumed to be mature squid) were present in all samples except June 1995. For only a few pairs of months, is there any evidence of clear progression of a single or even a few dominant modes suggesting that the population in this region at any time consists of a complex of cohorts resulting from extended spawning.

Slender squid off Bundaberg - commercial prawn trawl catches

Figure 33 shows the size distribution of slender squid byproduct from commercial prawn trawling off Bundaberg. A relatively broad size range of squid of both sexes was present in most samples with more than one size cohort generally evident. There is evidence of a progression of the major mode between September 1994 and January 1995 with another cohort appearing in catches from December 1994. As for other regions, these data suggest a complex population structure with extended spawning of slender squid populations in this region.

Slender squid off Yeppoon - research trawl survey

A research survey was conducted off Yeppoon in November 1995 using the purpose built squid trawl in similar depth zones to the surveys off Mooloolaba. Catches from all but the deep stations were small but provide an indication of the population size structure at the time. Size distribution of the catches is shown in Figure 34 and at least two major size classes are evident in thefemale squid from 150m. As found from the research data from off Mooloolaba, small slender squid are only present in the deep water samples while the largest slender squid represent a higher proportion of the catch at shallow sites.

Slender squid from the Swain Reefs - commercial prawn trawls

Squid byproduct from commercial prawn trawling in deep water off the southern Swain Reefs was examined and the monthly size distribution of slender squid males and females is shown in Figure 35. As for samples from off Mooloolaba and Bundaberg, a relatively broad size range of squid of both sexes was present in most samples. No clear progression of modes in the size distribution is evident in these samples. A complex population structure is evident in each of these time periods. It is noted that small squid < 100 mm ML were not present in any samples from this region, despite being present in samples from deep water off Bundaberg in these same months. Small sample sizes from the Swains limit any direct comparisons of the slender squid population structure between these areas.

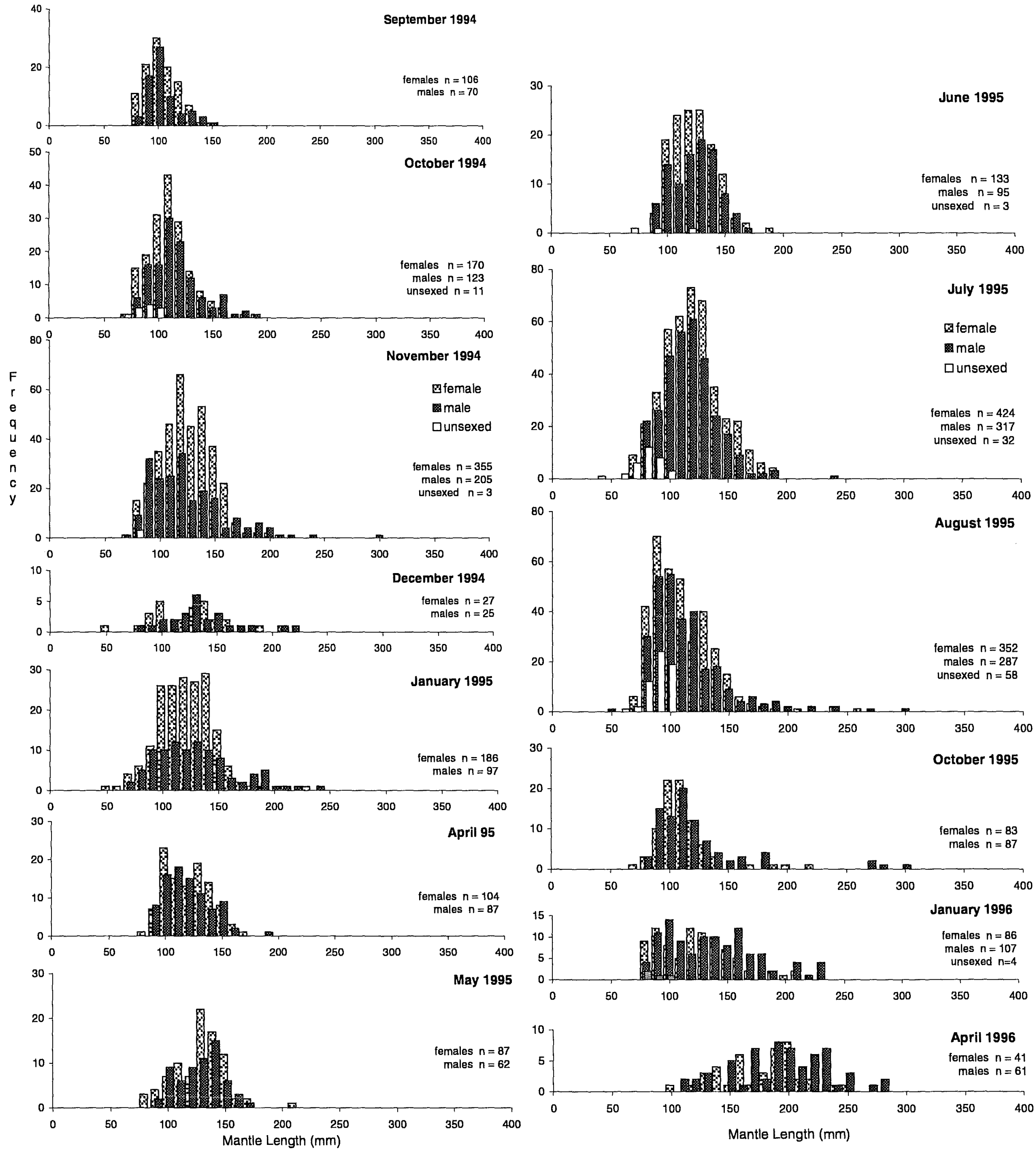


Figure 33. Size distribution of slender squid from prawn trawling off Bundaberg, 1994-96.

Slender and broad squid from the research survey off Cairns, January 1996

Squid were caught using a standard commercial prawn trawl and the small catches reveal little of the population structure in this location at this time. A broad size range of slender squid and broad squid were present (Figures 36, 37).

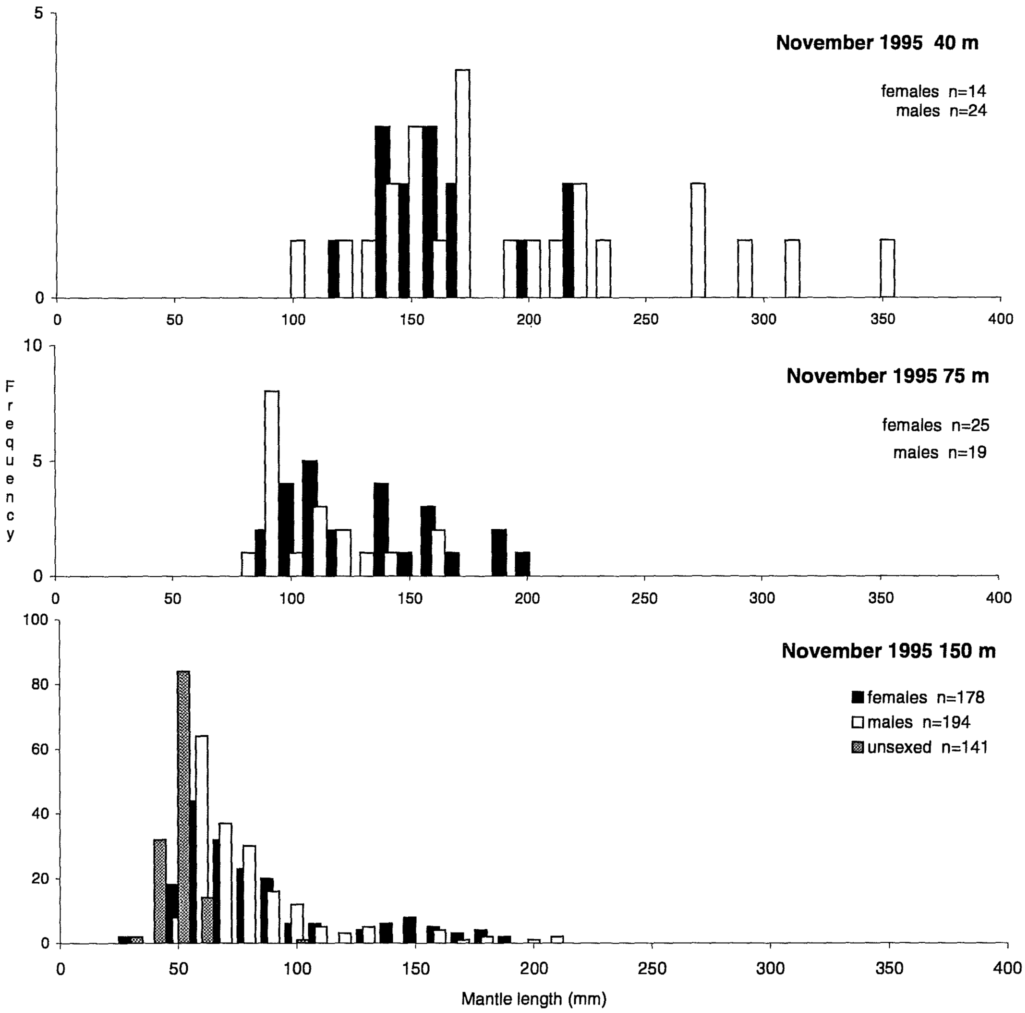


Figure 34. Size distribution of slender squid by depth zone, research trawling off Yeppoon, November 1995.

Slender and broad squid from research surveys, east of Cape York, 1993-94

The mantle length distribution of slender squid caught during 1993 in the CSIRO / DPI Effects of Trawling project (Poiner *et al.*, 1998) off the east of Cape York covers a broad range for both males and females (Figure 38). At least two size classes of both males and females are evident in what is a complex population structure. The maximum size of squid caught was somewhat less (270 mm compared to 390 mm ML) than from fish trawls off southern Queensland but prawn trawls towed at slower speed were used in the Cape York surveys. The overall size distribution of slender squid in both sampling periods off Cape York was similar.

The overall size distribution of slender squid caught east of Cape York between January 1993 and October 1994 is shown in Figure 39 together with the overall distribution for broad squid caught in much smaller numbers over this same period. Of note is that male slender squid reach larger sizes than females while for broad squid in this region (as elsewhere), there is little difference in maximum or modal size between the sexes. The modal size of broad squid is similar to that observed for catches of this species taken in research trawls off Mooloolaba in March 1996 although broad squid caught east of Cape York had slightly smaller maximum sizes (200 mm cf 250 mm ML).

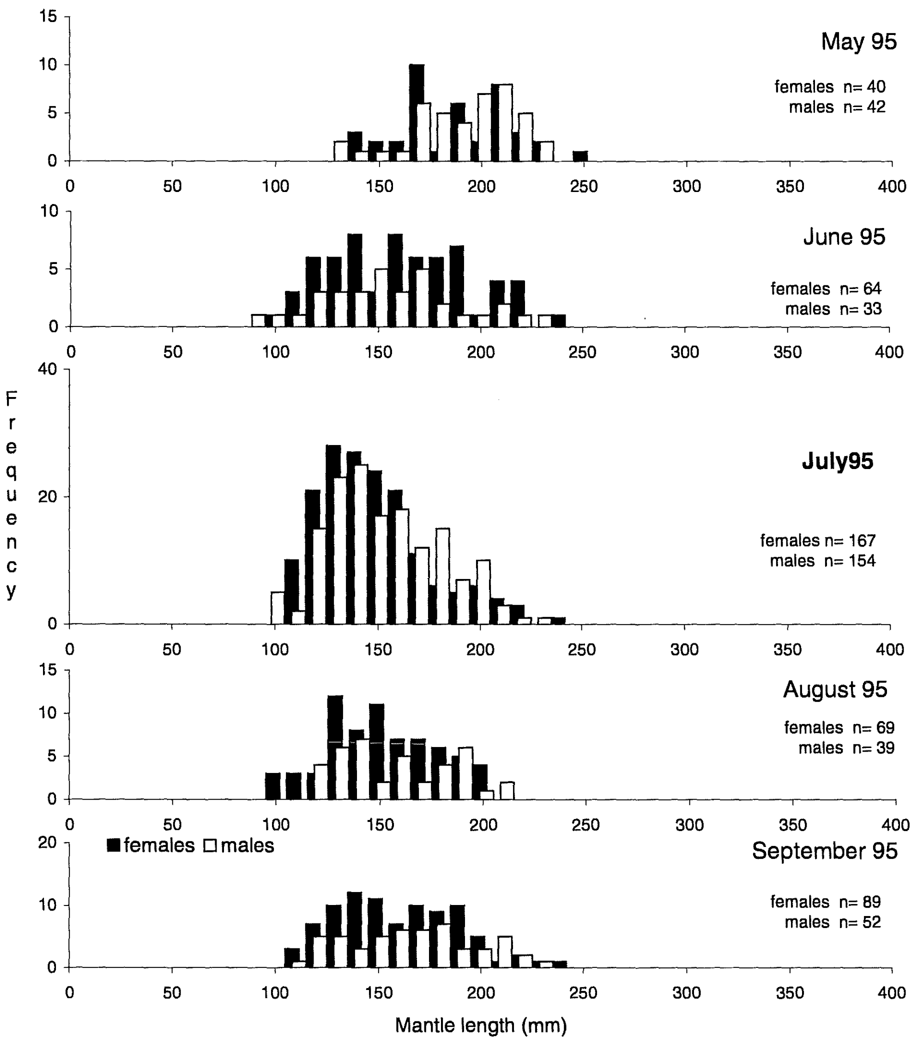


Figure 35. Size distribution of slender squid from commercial prawn trawling off the Swain Reefs, 1995.

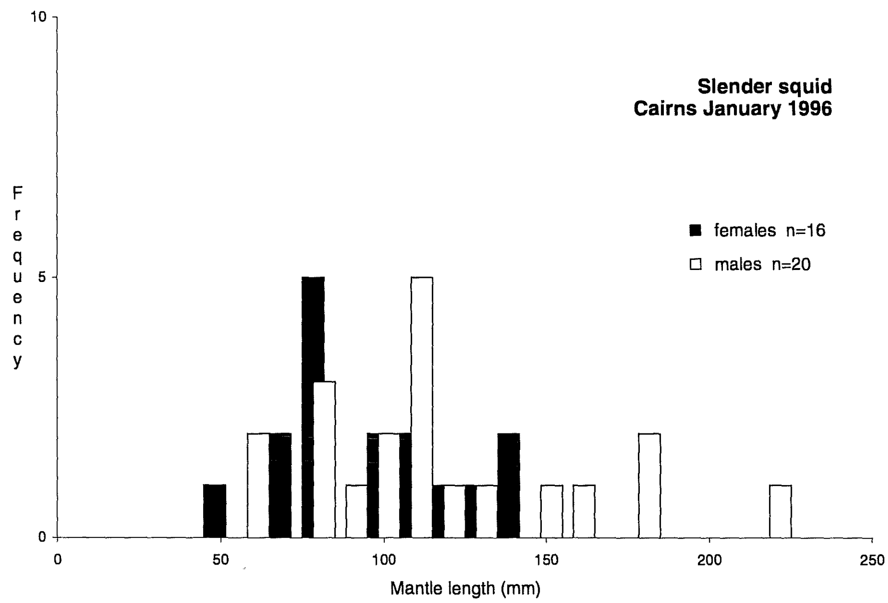


Figure 36. Size distribution of slender squid from research trawling southeast of Cairns, January 1996.

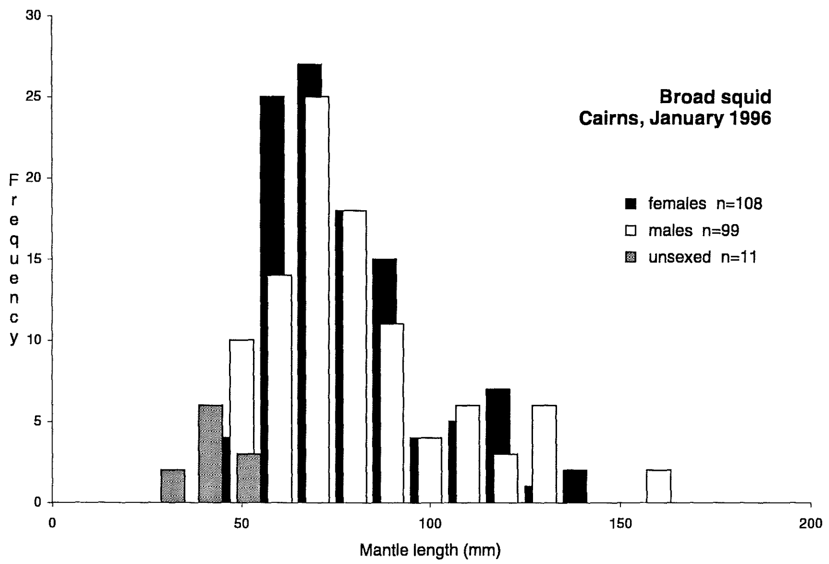


Figure 37. Size distribution of broad squid from research trawling southeast of Cairns, January 1996.

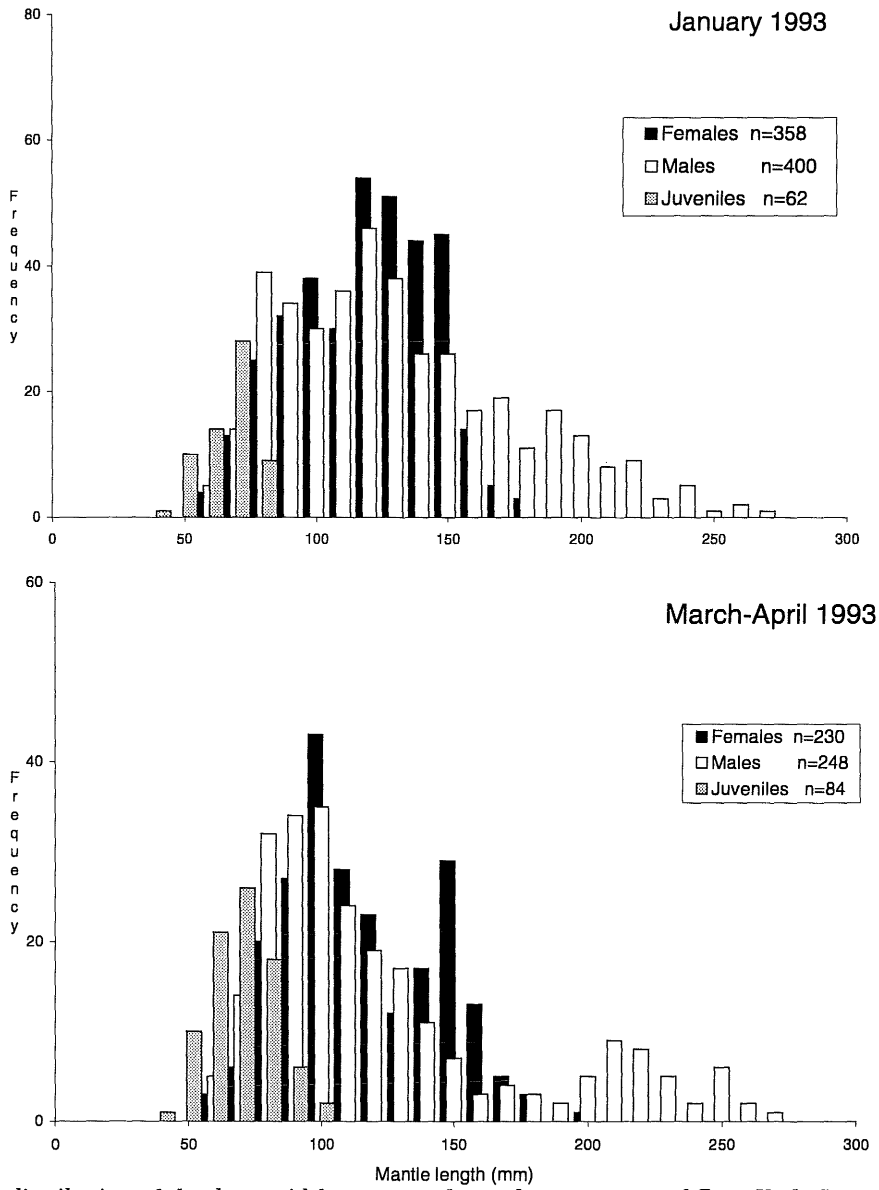


Figure 38. Size distribution of slender squid from research trawl surveys east of Cape York, January and April 1993.

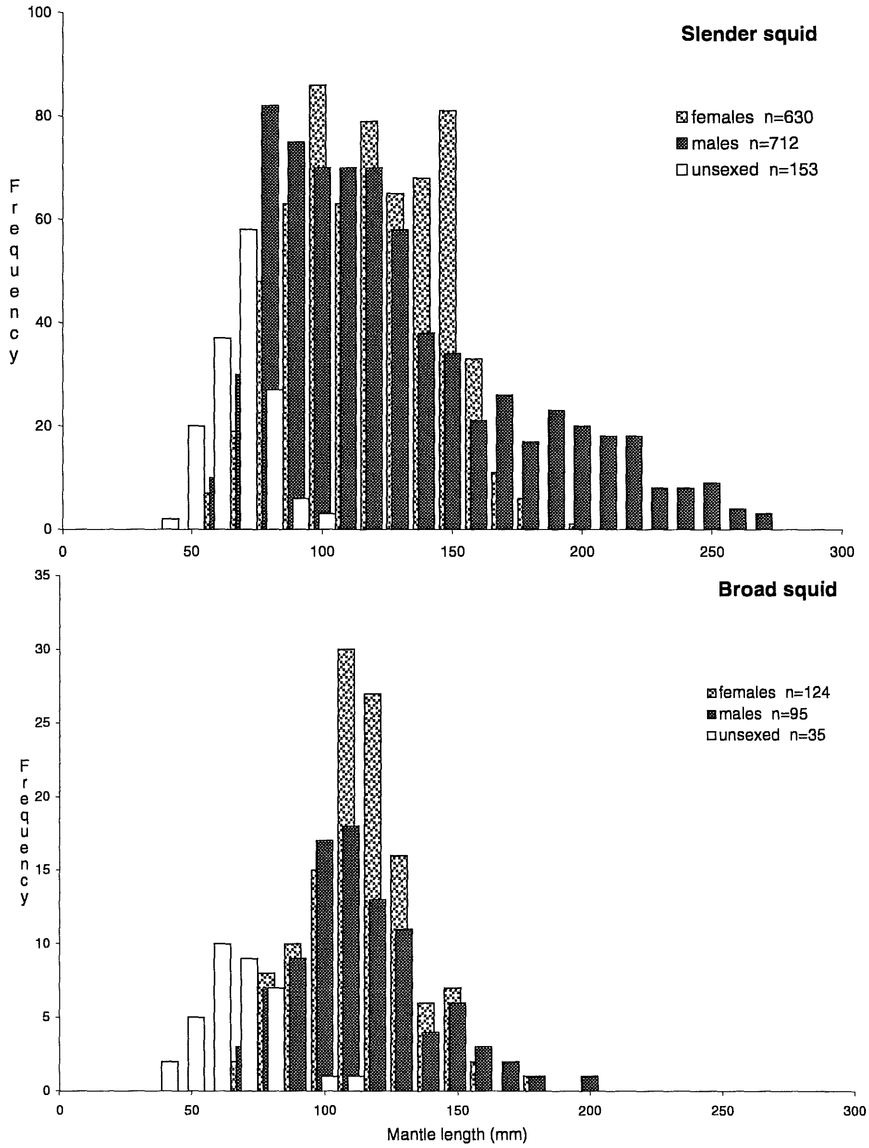


Figure 39. Comparison of the size distribution of slender and broad squid from east of Cape York, all trawl surveys 1993-1994.

Northern calamary from research surveys, east of Cape York, 1993-94

The overall size distribution of northern calamary caught east of Cape York between January 1993 and October 1994 is shown in Figure 40 and, as for slender and broad squid, a broad size rangeand complex population structure was evident in this area. No comparable size distribution information from trawl catches off the southern Queensland coast is available (very small sample sizes) but the size range evident here was similar to that observed in trawl catches from the northeast Gulf of Carpentaria in 1991 (Dunning *et al.*, 1994).

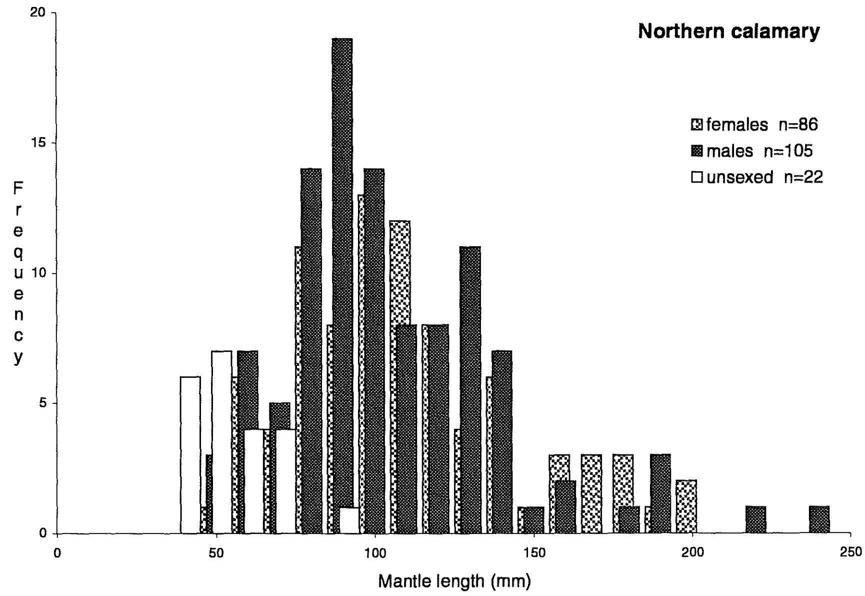


Figure 40. Size distribution of northern calamary, east of Cape York, 1993-94.

Age and size of broad and slender squid

A preliminary assessment of the age of broad squid and slender squid from southern Queensland (Moreton Bay, off Mooloolaba and Bundaberg) was undertaken in collaboration with Dr George Jackson of James Cook University. A plot of the counts of statolith growth rings versus mantle length of squid is shown in Figure 41. This preliminary analysis shows high variability in size at age for both species, and suggests that size is not a reliable indicator of age for these squid species in northern Australian waters.

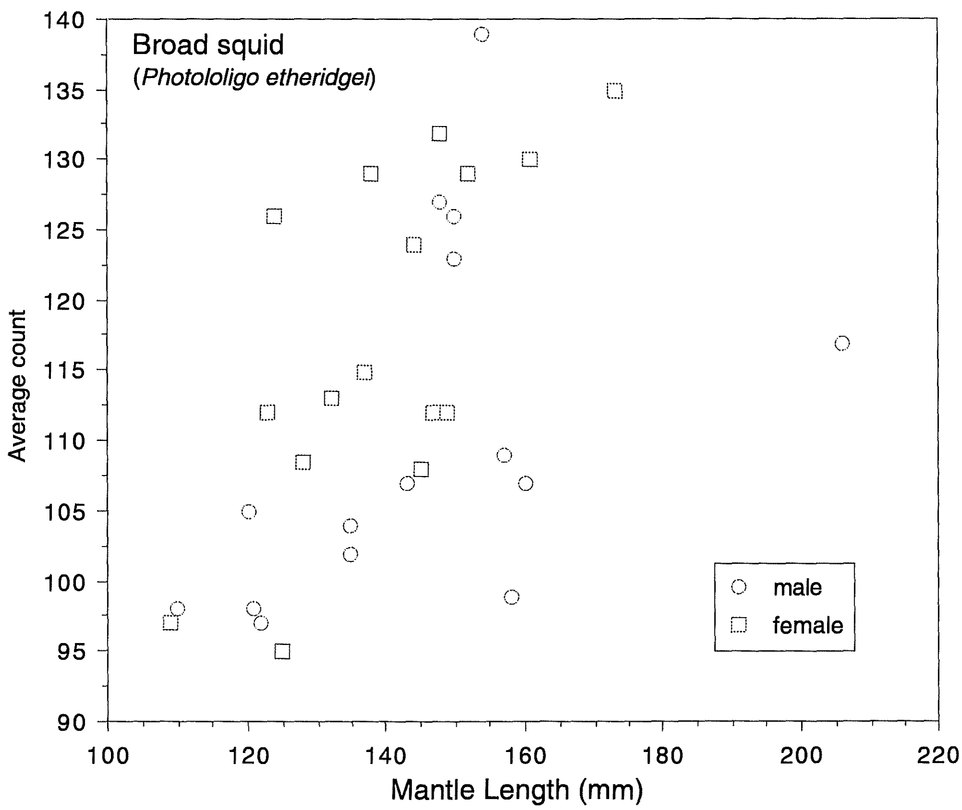


Figure 41. Average counts of assumed daily rings in statoliths of broad squid compared to mantle length from various samples off the east coast.

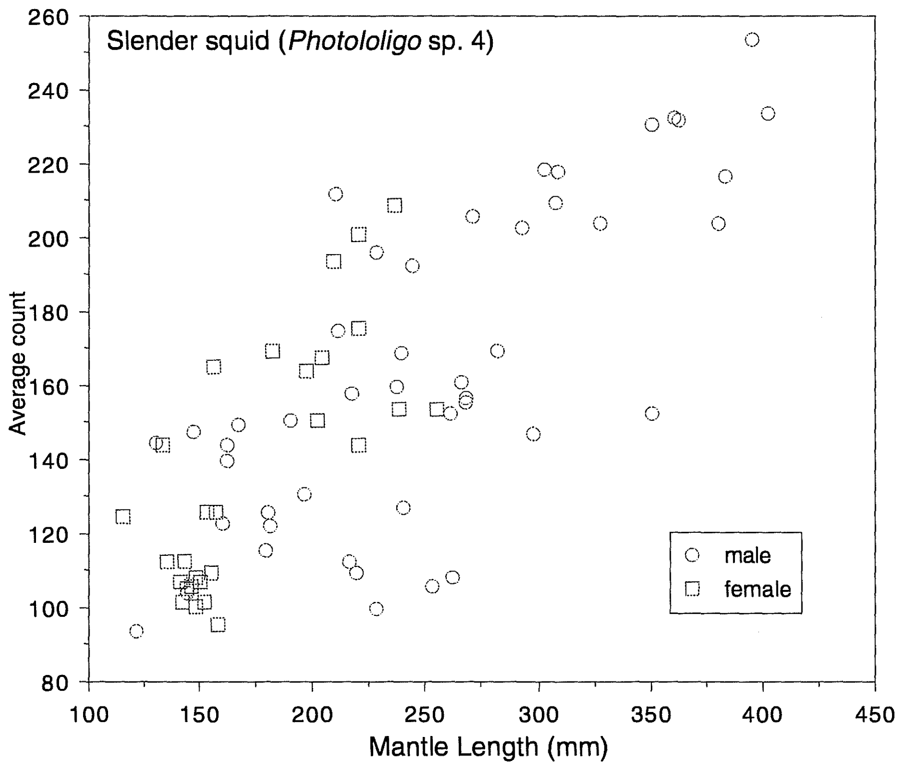


Figure 42. Average counts of assumed daily growth rings in statoliths of slender squid compared to mantle length from the east coast.

The largest slender squid, a male of 402 mm ML caught in February 1997 off Mooloolaba, was 234 days old; the largest female slender squid, 255 mm ML caught off Bundaberg in August 1995, was 154 days old. The oldest slender squid examined were caught off Mooloolaba in February 1997, a 395 mm ML male 254 days old, and off Bundaberg in April 1996, a 236 mm female 209 days old.

A 206 mm male broad squid caught in nearshore waters off Bundaberg in March 1996 was 117 days old with the largest female, 173 mm ML, caught off Bundaberg in June 1996, 135 days old. The oldest male broad squid examined was 154 mm ML and 139 days old while the largest female described above was also the oldest female.

Further collaborative studies with Dr George Jackson, now of the University of Tasmania, are planned to assess seasonal and geographic variability in size at age for males and females of both species, building on this preliminary work with examination of additional statoliths.

Reproductive condition and spawning season

Broad squid in Moreton Bay

Recorded reproductive condition of squid sampled during monthly trawl surveys of Moreton Bay between June 1983 and June 1984 for females and March 1982 and June 1984 for males was analysed for this study. The overall proportion of mature females and males in the samples is shown in Figure 43.

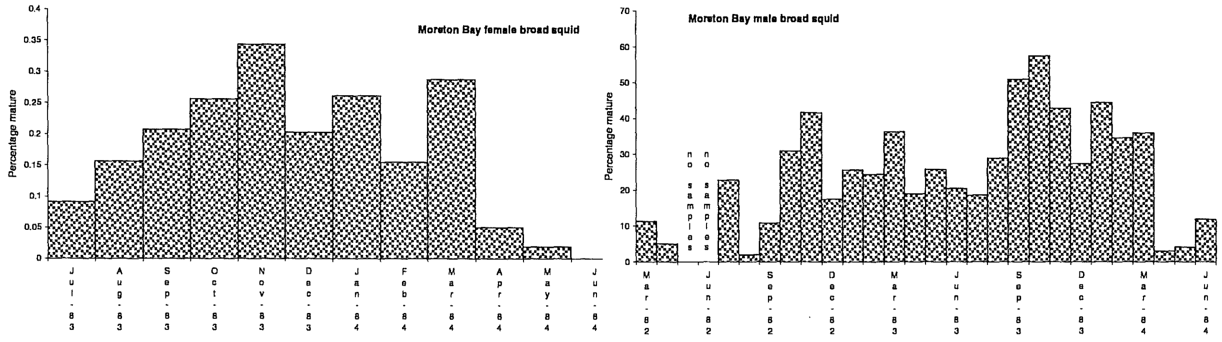


Figure 43. Monthly proportion of mature female and male broad squid in research trawl catches, Moreton Bay 1982-84.

Although mature females were present in all months except June 1984, they represented a higher proportion of the catch between September and March with a peak in November (34% of females caught).

Hatching dates for broad squid in Moreton Bay have been extrapolated from the preliminary statolith aging results (see Figure 44). They indicate adults caught together in Moreton Bay in early April 1995 were spawned between late November and late December 1994. Note that the earlier spawned animals show slower growth rates than those which hatched later.

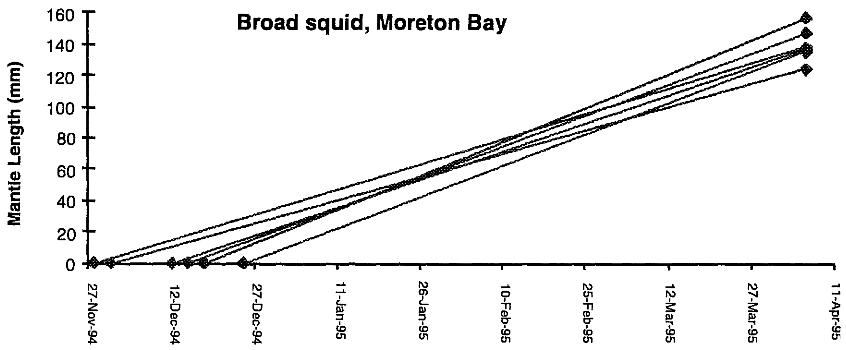


Figure 44. Estimated hatching dates for broad squid from samples taken from Moreton Bay, April 1995.

No egg clusters attributable to this species have been reported from Moreton Bay by commercial fishers or have been identified during research surveys in both shallow and deeper areas in the Bay. Given the high level of trawling activity which has occurred in the region, the absence of reports of broad squid eggs may indicate that spawning of this species is occurring only outside the Bay.

Slender squid off Mooloolaba

The proportions of mature female slender squid present in catches (commercial and DPI research survey) from off Mooloolaba are shown below. Samples were not available for all months and it should be noted that samples in some months were very small and may not have been representative of the population present.

DATE	Apr-95	Jun-95	Jul-95	Sep-95	Oct-95	Nov-95	Jan-96
% females mature	72	14	11	33	42	79	54
Sample size	18	64	27	3	118	29	199

Maturity stage with respect to mantle length was examined for slender squid from commercial and research catches off Mooloolaba. Females reach maturity (Stage 4) from about 100 mm ML and males from about 80 mm ML. However, it should be noted that some females as large as 225 mm ML and males as large as 150 mm ML were still immature.

Hatching dates for slender squid off Mooloolaba have been extrapolated from preliminary statolith aging results (Figure 45). They indicate that hatching was occurring in this region between February and October and variable average growth rates among individuals are evident.

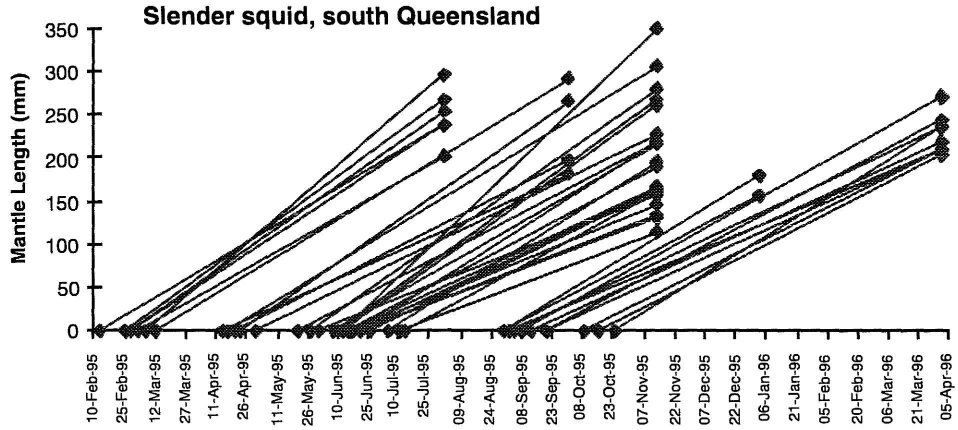


Figure 45. Estimated hatching dates for slender squid caught off Mooloolaba, southern Queensland.

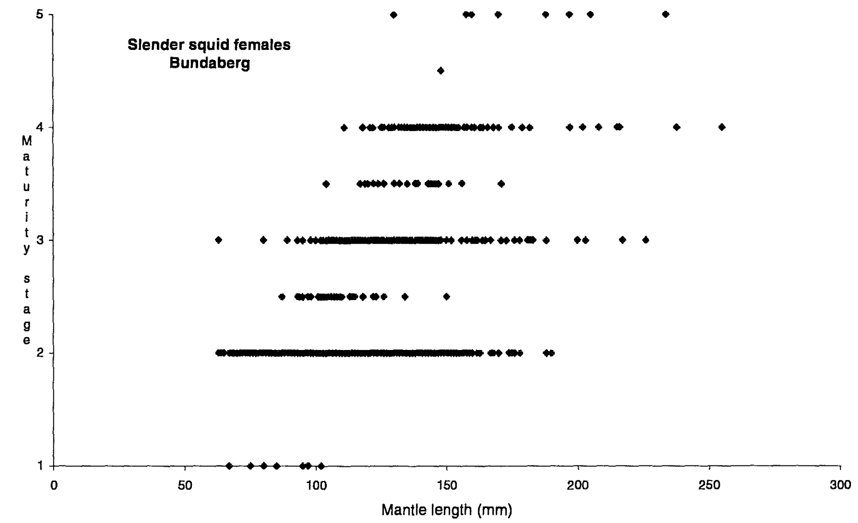
Slender squid off Bundaberg

The proportions of mature female slender squid present in commercial prawn trawl catches from the eastern king prawn grounds off Bundaberg are shown below. Samples were only available for some months and it should be noted that some samples were small and may not have been representative of the population present. These data suggest that some slender squid were spawning throughout much of the year in this region.

DATE	Mar-94	Sep-94	Oct-94	Nov-94	Dec-94	Jan-95	Apr-95	May-95	Jun-95	Jul-95	Aug-95	Oct-95	Mar-96
% females mature	43	0	5	12	7	0	0	0	0	1	9	6	25
Sample size	7	106	170	355	27	71	104	87	133	424	352	253	4

A similar assessment of the maturity stage of female slender squid caught in commercial prawn trawls off the Swains Reefs during part of this period (May - September 1995) revealed no fully mature females in this region.

Maturity stage with respect to mantle length was examined for slender squid from commercial catches off Bundaberg. Figure 46 shows that females reach maturity (Stage 4) from about 110 mm ML and males from about 80 mm ML. However, it should be noted that some females as large as 230 mm ML and males as large as 190 mm ML were still immature.



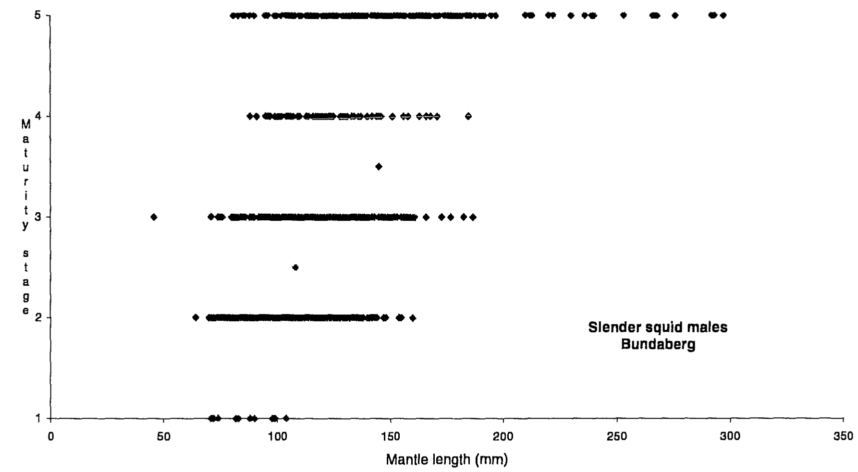


Figure 46. Maturity stage relative to mantle length of slender squid trawled off Bundaberg.

Slender squid east of Cape York

Maturity stage with respect to mantle length was examined for slender squid from research surveys east of Cape York. Females reach maturity (Stage 4) from about 100 mm ML and males from about 90 mm ML. However, it should be noted that some females as large as 160 mm and males as large as 170 mm ML were still immature.

Estimated hatching dates for slender squid caught off eastern Cape York in 1993 are shown in Figure 47. These data show some spawning was occurring in this region between November and February and that individual growth rates are quite variable.

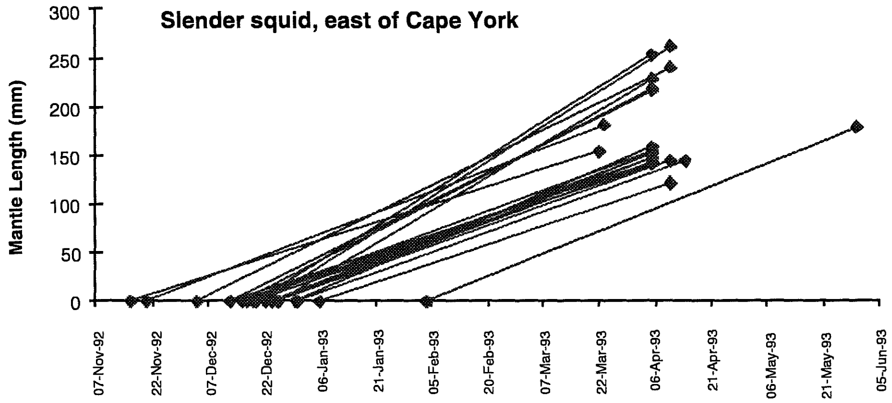


Figure 47. Estimated hatching dates of slender squid trawled east of Cape York, 1993.

Broad squid from inshore waters off Bundaberg

The proportions of mature female broad squid present in commercial prawn trawl catches from nearshore waters off Bundaberg are shown below. It should be noted that samples in some months were very small and may not have been representative of the population present.

These data indicate that some broad squid were spawning in summer and midwinter in this region.

Date	Feb-95	May-95	Mar-96	May-96	Jun-96
% mature females	39	0	78	0	4
Sample size	275	291	18	13	161

Maturity stage with respect to mantle length was examined for broad squid commercial catches from inshore waters near Bundaberg. Figure 48a&b show that females reach maturity (Stage 4) from about 100 mm ML and males from about 90 mm ML. However, it should be noted that some females as large as 160 mm and males as large as 170 mm ML were still immature.

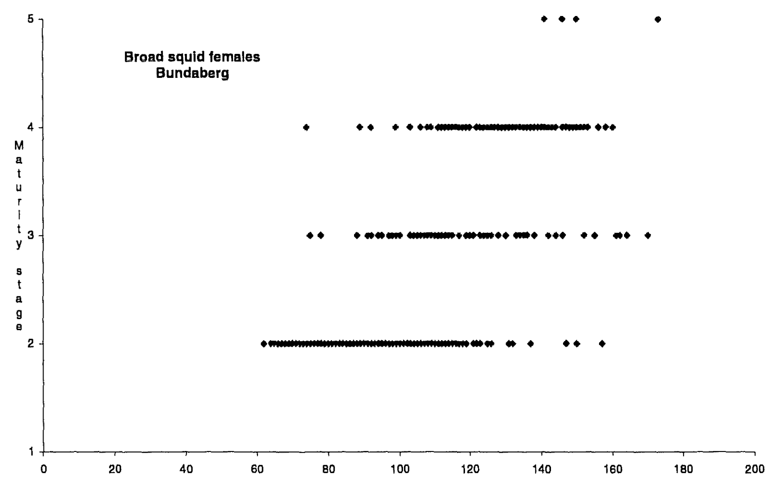


Figure 48a. Maturity stage relative to mantle length, female broad squid trawled off Bundaberg.

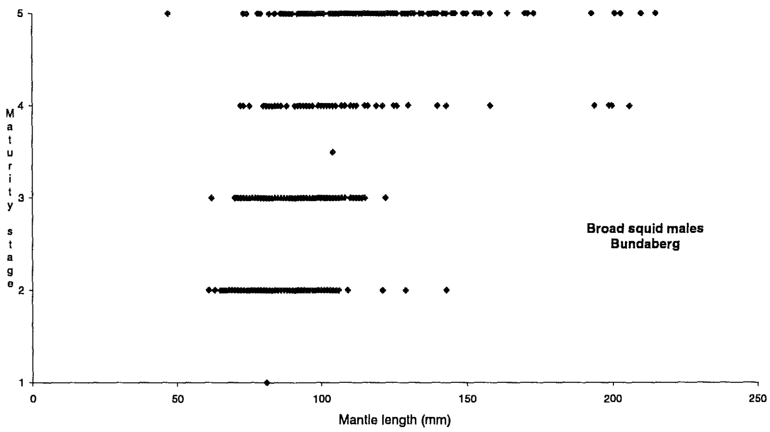


Figure 48b. Maturity stage relative to mantle length, male broad squid trawled off Bundaberg.

Estimated hatching dates for broad squid caught off Bundaberg in January, March and June 1996 are shown in Figure 49. These data show some spawning was occurring in this region from August through to November 1995 and from late January to late February 1996.

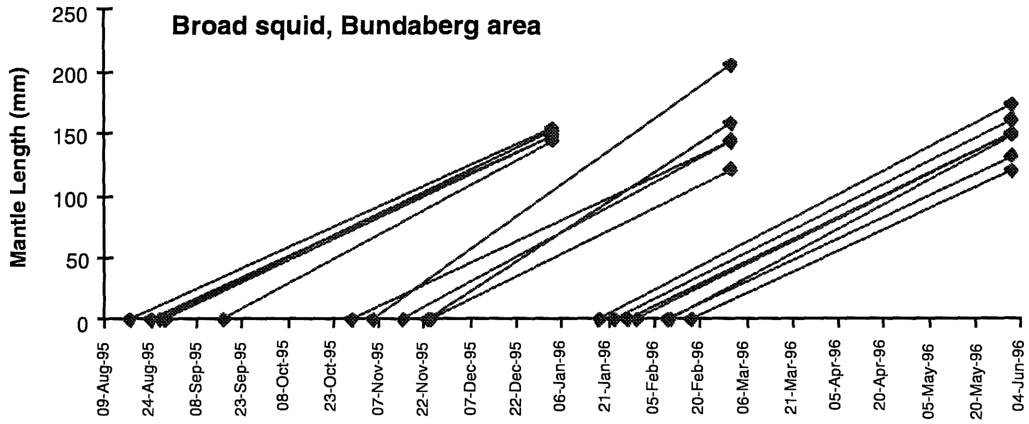


Figure 49. Estimated hatching dates of broad squid trawled off Bundaberg, 1995-96.

Broad squid east of Cape York

Maturity stage with respect to mantle length was examined for broad squid from CSIRO / DPI research surveys east of Cape York. Figure 50 shows that females reach maturity (Stage 4) from about 90 mm ML and males from a similar size. However, it should be noted that some females as large as 130 mm and males as large as 145 mm ML were still immature.

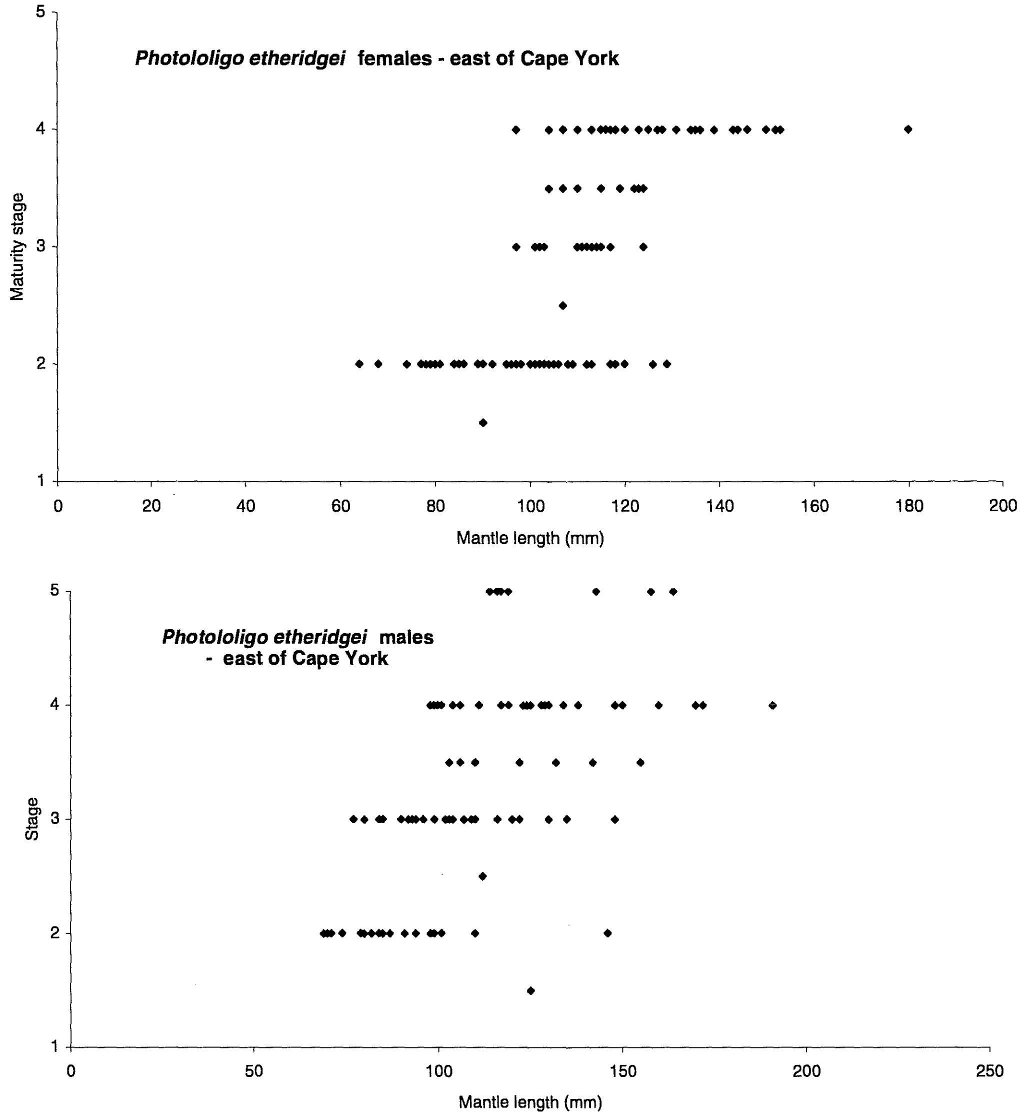


Figure 50. Maturity stage relative to mantle length for male broad squid trawled east of Cape York, 1993-94.

Hatching dates for broad squid caught off the east coast of Cape York in April 1993 are shown in Figure 51. These data indicate that these squid were spawned during December and early January 1992 and also suggest that individual growth rate among these squid is quite variable.

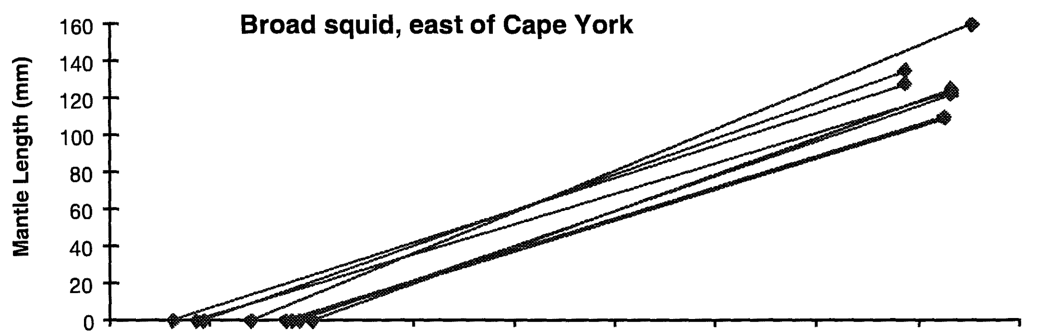


Figure 51. Estimated hatching dates of broad squid trawled east of Cape York, 1993.

Northern calamary east of Cape York

Maturity stage with respect to mantle length was examined for northern calamary from research surveys east of Cape York in 1993 . Figure 52 shows that females reach maturity (Stage 4) as small as 70 mm ML and males from a similar size. However, it should be noted that some females as large as 160 mm and males as large as 125 mm ML were still immature.

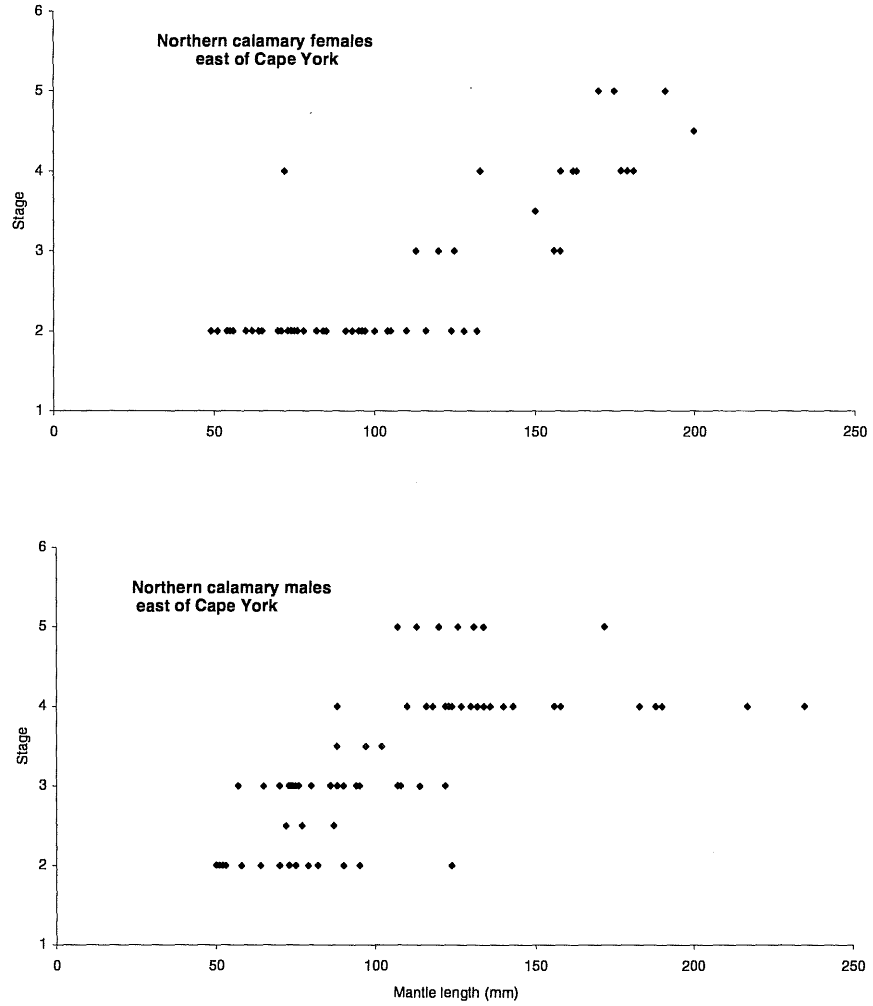


Figure 52. Maturity stage relative to mantle length for northern calamary trawled east of Cape York, 1993-94.

Spawning location

During this study, no eggs of slender or broad squid were collected from commercial or research samples from off the Queensland east coast. Eggs were reported by commercial fishers interviewed during the study but in the absence of samples it is uncertain whether they were pencil squid (*Photololigo* spp.) or northern calamary eggs. The absence of pencil squid eggs of either species, given the high level of prawn and fish trawling activity in east coast waters may indicate that spawning is occurring in rough, untrawlable areas such as around coral or rocky reefs and not in traditional prawn and whiting trawl grounds in this region.

In the Gulf of Carpentaria, eggs of slender squid were caught in prawn trawls north of the Vanderlin Islands in August 1996 and September 1997. In August and September between 1993 and 1995 off the Kimberleys, spawning aggregations of slender squid were targetted using trawls on sandy bottom in 40 m of water. Additional spawning aggregations of pencil squid (species not determined) have been reported regularly by prawn trawlermen in October and November off the Bombard Shoals in the western Gulf of Carpentaria.

Spawning represents a time when loliginid squid are aggregated and hence more available for commercial harvest by all methods including jigging and lift netting. Indeed, spawning areas and times are the focus of apparently sustainable jig fisheries for loliginid squids elsewhere (eg., South Africa for chokka squid - *Loligo reynaudi*, southern Japan for kensaki-ika - *Photololigo edulis*).

However, the impacts on spawning success of continued and expanded use of fishing methods which may destroy egg masses (such as demersal trawling) need to be assessed in northern Australia if exploitation levels for squid resources are to be increased sustainably. In Japan and South Africa, mechanized trawling is not permitted inknown spawning grounds because of presumed adverse impacts on egg masses and also on the continued aggregation of squid arriving in the area from elsewhere for spawning.

Objective 3 - Improved harvesting techniques - To undertake gear assessment and experimental fishing

A major objective of this project was to undertake gear assessment / experimental fishing for squid using jigs under lights, lift nets and make comparisons with purpose designed squid trawls off southern and central Queensland in collaboration with commercial fishers. Because of unanticipated administrative delays with the Queensland Fisheries Management Authority in relation to the issue of exploratory fishing permits, collaborative jigging trials and trawl gear comparisons with commercial fishers could not be undertaken during the study. Neither was there an opportunity for fishers to undertake independent exploratory jigging over the course of the project and hence provide the anticipated feedback to the project team on geographic and seasonal distribution of squid. This information had been expected to provide a guide for our own jigging trials by suggesting times and places when squid were aggregating and enhance the value of our research trials.

Nevertheless, trials with hand and machine jigging gear were carried out from the DPI research vessel *Warrego* in Moreton Bay and off Mooloolaba in southern Queensland. The planned direct comparisons between jig catches and squid trawl catches from off Mooloolaba (same location / sampling period) could not be made because of weather conditions restricting jigging operations (wind speeds of > 15 kts) and other commitments of the jigging research vessel and chartered commerical trawler. Squid byproduct from a commercial fish trawler however was obtained for the same period and from a similar area as the jigging trials and size and species composition compared with experimental jig catches.

Jigging for squid similar to those found in northern Australia (the swordfin squid - shiro-ika or kensaki-ika *Photololigo edulis*) using machines was observed first-hand on board commercial jigging vessels in inshore waters off Kyusyu, southern Japan in July 1996. Details of the types of vessels and gear used, fishing methods and some aspects of marketing of inshore loliginid squid off southern Japan are provided in Appendix 4 to this report.

Moreton Bay Trials

Preliminary trials were conducted to set up the jigging gear on the DPI research vessel *Warrego* in Moreton Bay over two nights in April 1995. Jigging was undertaken at a location near where trawlers were targeting squid during daylight hours of the same day. Average water depth was 17 metres.

Broad squid (*Photololigo etheridgei*) were successfully caught on the jigging machines, manual reels and surface trolled jigs. Mean mantle length for squid caught on all jigging techniques combined was 13 cm. As trial operations were limited to a few hours each night, catch rates from different gear types or variations during these trials were not compared quantitatively.

The size distribution of squid jigged during the trial is shown in Figure 53.

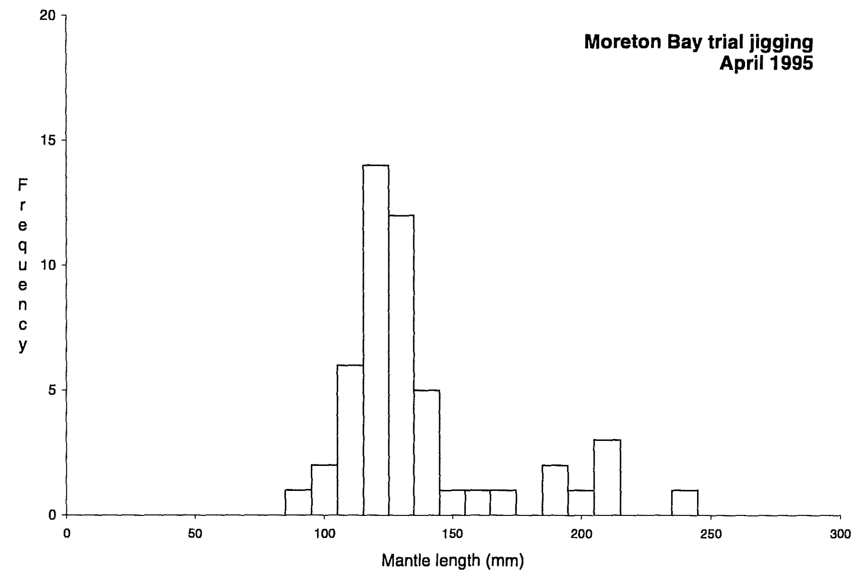


Figure 53. Size distribution of slender squid jigged in Moreton Bay, April 1995.

Mooloolaba Trials

A trail to assess jigging operations in open waters (up to 80 metres depth) from the DPI research vessel *Warrego* was conducted off Mooloolaba in July 1995. This trial was not targetted at sites of known squid concentration as few squid had been reported by fish and prawn trawlers in this region in the week immediately prior to the operation. Jigging machines and surface trolled hand jigs were used.

Slender squid (*Photololigo* sp. 4) was successfully caught by both techniques and was the only species caught. Catch rates from the two jigging machines combined were low: up to one squid every ten minutes (≈ 0.5 kg machine hr^{-1}). The mantle length frequency distribution of the jigged squid was similar to that of a sample of trawl caught squid taken from a commercial demersal fish trawler operating in the same area at the same time. The trawl catch did include some larger squid. As expected, the jigged squid were of notably higher quality than the trawled sample with far less skin and mantle damage.

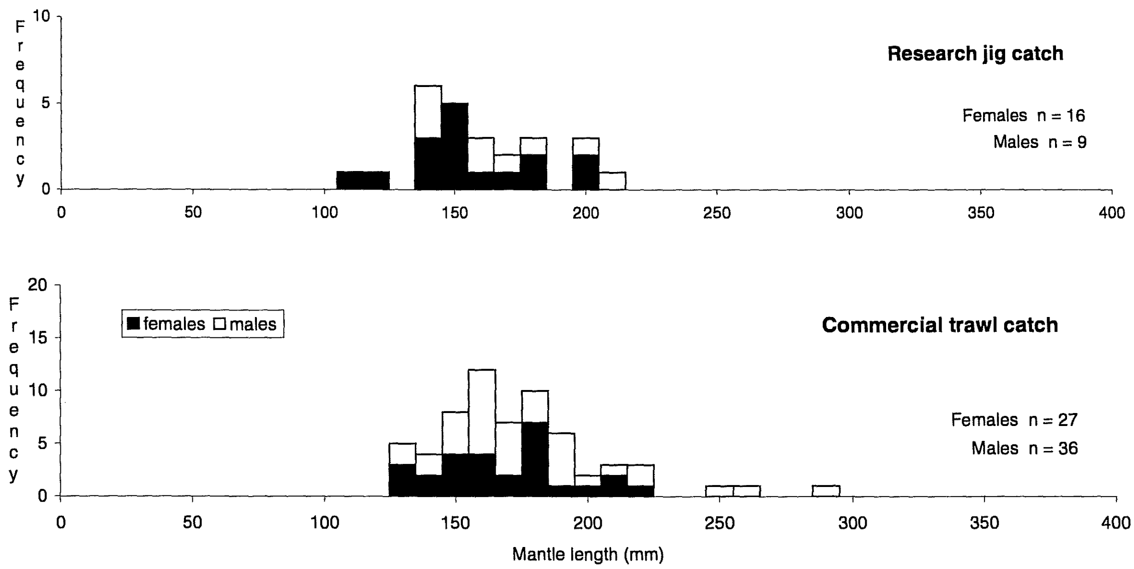


Figure 54. Size distribution of slender squid jigged and trawled off Mooloolaba, July 1995.

Commercial vessel trials

Because of extended and unanticipated delays with the issue of permits by the Queensland Fisheries Management Authority, jigging trials from commercial vessels could not be conducted during the field component of this project. However, jigging by one commercial operator in February 1997 was monitored. Four double jigging machines had been fitted to the aft deck of a commercial prawn/ fish trawler and jigging was trialled where bottom depths varied between 750 m + and 16 m off southern Queensland between Yeppoon and Southport. Fishing duration varied between 1 and 10 hours and the largest single session's catch of 70 kg of slender squid was made in 48 m of water over a 10 hour operation. Small catches of red ocean squid (*Ommastrephes bartramii*) and yellow backed squid (*Sthenoteuthis oualaniensis*) were also made in oceanic waters (Tony Pinzone, Mooloolaba, pers. comm., 1997).

Comparison with jigging trials elsewhere in southeast Asia

Few reports of experimental squid jigging in shelf waters of the tropical Indo-West Pacific have been published. In most countries (eg., Thailand, India, Malaysia, Indonesia), squid jigging using handlines is an artisanal fishing method and is still continued without any mechanization. Off southern Japan and Taiwan, the use of mechanical jiggers to catch loliginid squid has been a recent evolution from hand jigging since the 1960s and published references to comparative catch rates in exploratory fishing surveys could not be found in the English language literature.

Handlines were used in a preliminary study in the Gulf of Thailand (near Phuket) in February 1980 (Shibata *et al.,* 1980) and small catches of "*Loligo formosana*" between 7 and 23 cm ML were made from a 10 gross tonne research vessel. The total catch over three nights where bottom depths varied from 20 - 28 m was 199 squid (mean size 139 mm, estimated weight 12 kg). Approximately 3 KW of above deck lighting was used. The larger male squid were noted to have been attracted first to the boat (approximately 7-8 pm) with smaller females being caught from 9 pm.

Objective 4 - Preliminary resource assessment - Assessment of relative seasonal squid catch rates

With the expectation from discussions with fishers while developing this project that up to 12 commercial fishers would be undertaking collaborative, exploratory squid jigging with the project team, it was planned to assess the relative seasonal catch rates from trial jigging at selected locations off the southern and central Queensland coasts. Because commercial fishers were not authorized by the Queensland Fisheries Management Authority to use jigging apparatus prior to 1997 (after the project's field component had concluded), an assessment of relative seasonal catch rates from trial commercial jigging could not be undertaken during the project.

The activities of the single active participant in the Queensland developmental squid jig fishery which commenced in January 1997 continue to be incidental to his normal fish and prawn trawling activities and to date have not provided any conclusive information on seasonal squid catch rates in any area. According to NT Fisheries researchers, limited fishing has been undertaken by the one fisher licenced to jig in Northern Territory waters and few squid have been reported to the end of 1997 (additional permits have been issued subsequently - Ray Clarke, NT Fisheries, pers. comm., 1999).

To provide some fishery independent information on seasonal catch rates for squid, an assessment of relative catch rates off Mooloolaba, southern Queensland, was made using the research trawl data discussed previously.

Trawl surveys using a purpose designed squid trawl were conducted in three depth zones off Mooloolaba, southern Queensland in March 1995 (autumn), November 1995 (early summer) and March 1996. Average estimated biomass within each depth stratum for each survey in kilograms per hectare was calculated using a simple swept area expansion method and is shown in Figure 55. The minimum and maximum catch rates, highlighting the high variability, are shown in the table below. No consistent seasonal trends (autumn vs late spring) either within depth zones or among depth zones between surveys are apparent in these data.

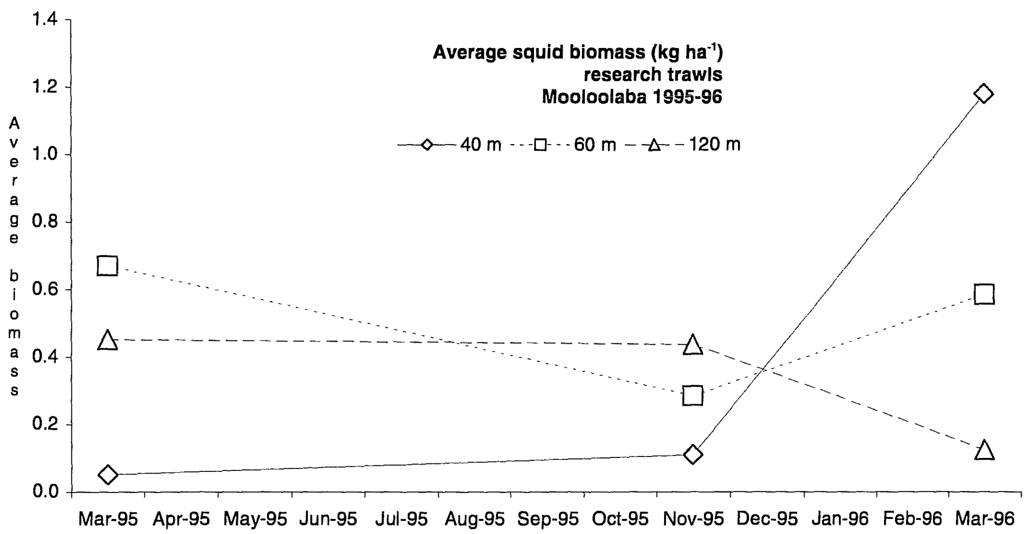


Figure 55. Average squid biomass from research trawls off Mooloolaba, southern Queensland, 1995-1996.

Survey	Mar-95			Nov-95			Mar-96		
Depth zone	40m	60m	120m	40m	60m	120m	40m	60m	120m
Average kg/ha	0.05	0.67	0.45	0.11	0.28	0.44	1.18	0.59	0.12
Minimum	0.00	0.21	0.00	0.02	0.06	0.03	0.00	0.10	0.00
Maximum	0.11	1.44	1.29	0.25	0.88	1.52	9.73	1.78	0.37
Number of tows	8	8	6	14	13	14	13	11	9

Trends in trawl bycatch data presented earlier (See Objective 1) for the area off Bundaberg and for the Northern Prawn Fishery area provide an indication that larger jig catches might be taken in these regions during the summer - autumn months and in spring respectively.

The research trawling in Moreton Bay undertaken from 1982-84 was discussed earlier and indicates that broad squid are present in the Bay throughout the year but higher trawl catches were made in the summer - autumn months, perhaps reflecting a higher degree of aggregation of squid in trawlable grounds at these times.

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Benefits

This project has shown that inshore squid off northern Australia can be caught on mechanical jigging machines. The study has provided current and potential northern Australian squid fishers with information on characteristics of squid jigging vessels, gear and techniques which are appropriate for the larger tropical inshore squid (*Photololigo* spp.). A summary of the characteristics and operation of other non-trawl gear used in southeast Asia for similar species has also been presented and may have application here in sheltered waters.

The distribution and relative abundance of the major species has been further clarified and available information on their seasonal and geographic abundance gained from research and commercial trawl catch data has been synthesized. This information can be used by fishers to assist in determining appropriate areas for further development of any jig fishery in northern Australia.

Basic life history characteristics of the major species including size at maturity and longevity have been clarified for various locations across northern Australia, together with some information on population structure to assist in any future detailed stock assessment.

The results of this project provide a framework for future squid fisheries research in northern Australian waters and highlight some of the characteristics of this cephalopod resource to guide the choice of future resource assessment and fisheries management strategies for these species.

Further developments

Gear technology

This study has shown that, at least off southern Queensland, broad and slender squid can be caught on both hand and machine jigs with jigs smaller than those generally used for arrow squid off southern Australia. Catch rates which can be achieved when fishing from a commercial vessel on confirmed squid aggregations (such as occur on spawning grounds) could not be assessed during this project and should be conducted in the future.

Additional trials fishing on squid aggregations with different colours and sized jigs under various lighting regimes (colours and intensity) would also be beneficial to any developing fishery. Future gear development and any exploratory surveys should use a more appropriate squid jigging platform, ideally a 12-15 m vessel with aft superstructure (similar in design to Japanese small jiggers) and 4-6 jigging machines.

Resource assessment and monitoring

Information obtained from the existing trawl fleets and logbooks cannot be used to provide a detailed assessment of the extent of the squid resource because squid are not generally the target species. When they are targetted in the NPF and Kimberley Prawn Fishery for example, it is when prawn catches are low. In other areas, temporal, geographic and seasonal closures for prawn fisheries also need to be taken into account in interpreting any logbook byproduct data. However, improving the reporting levels of squid byproduct could at least provide a better estimate of the current catch of these species in the context of sustainable management of the multispecies trawl fisheries of northern Australia.

Through encouragement of target fishing by closely monitored developmental jig fisheries, further information on geographic and seasonal abundance of squid for stock assesment purposes could be obtained. Available information suggests that the northern Australian squid resource remains underutilized and that production and returns from the resource could be enhanced.

Squid caught on jigs fetch considerably higher prices than trawl caught squid. Apparently sustainable jig fisheries for loliginid squid operate near spawning grounds off southern Japan and off South Africa. It is recommended that documentation of the location of squid spawning grounds be introduced as a means of identifying additional areas for jig fishery expansion. This could be undertaken through liaison with trawl fishers as part of existing logbook, bycatch monitoring and fishery observer programs

Catch data obtained from any developing squid fishery should include not only species, location and line hours fished per night but also some estimate of average squid size (numbers per standard carton?), bottom depth and sea surface temperature.

Recommended priority fisheries research

Basic characteristics of the life cycles of tropical loliginid squids have become better known in the last five years with increased research effort. This project has provided confirmation of the short life spans, highly variable growth rates and size at maturity in slender and broad squid. Further research is required to clarify the duration of spawning and hence provide estimates of fecundity of individual mature female squid for any population modelling.

More detailed studies of the habitat preferences of various life stages of the more abundant squid species and the locations of spawning grounds may provide indicators of likely areas and times of abundance of squid, useful for any developing jig fishery.

No information is available on stock discrimination in the squid resource. Previous preliminary genetic studies have not shown any variability in slender or broad squid indicative of stock separation across northern Australia but more sensitive DNA studies may reveal details of population structure. The level of movement and migration in northern Australian squid remains unknown.

Since 1993, target demersal trawling for squid has been occurring on spawning grounds off the Kimberleys and in the Gulf of Carpentaria and regulations in the Northern Prawn Fishery management plan were amended in 1995 making squid an authorized target species rather than an incidental species. Loliginid squid lay demersally attached egg capsules, potentially vulnerable to physical damage from trawling. Aggregating behaviour for mating and egg laying around spawning grounds may be interrupted by trawling and whether squid will then move elsewhere to sub-optimal areas to lay eggs is unknown. Demersal trawling in known spawning grounds for loliginid squid off southern Japan and South Africa is not allowed under current management regimes. As a priority, research should be undertaken to confirm that impacts from demersal trawling are not adversely effecting the ecological sustainability of the resource in northern Australian waters.

Further, if spawning grounds for any species are not widespread but restricted to only a few areas and times off northern Australia, the implementation of demersal trawling closures (seasonal or geographic) may be appropriate to conserve the squid resource.

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Project Officer - Kate Yeomans (June 1995 -August 1996)

Appendix 2 Harvesting inshore tropical squids - a review of gear and techniques.

In 1990, the global catch of cephalopods reached 2.3 million tonnes, with squids representing approximately 75% of this total. Squid from tropical regions totalled approximately 120,000 tonnes, only 7% of the total squid catch (FAO, 1992). Voss (1973) estimated that the squid resource of tropical waters of the Indo-west Pacific continental shelf could be as high as 500,000 tonnes. Together with the cephalopods of the tropical western Atlantic, FAO (1989) considers that the cephalopod resources of the Indo-west Pacific region could sustain increased exploitation. If the squid catches of tropical waters of the Gulf of Thailand, the south China Sea and India are indicative of the resource potential in northern Australian shelf waters, significant increases in domestic catches may be possible.

Most squid of tropical continental shelf regions belong to the cephalopod family Loliginidae (Figure A1). The species of squid commercially taken in the major tropical regions together with their marketting and common names are listed by region in Table 1.

The majority of the commercial catch of tropical squids is taken in developing countries of southeast Asia and central America, primarily as the byproduct of demersal trawling for crustaceans and finfish, with limited target fishing for squid (Gulf of Mexico - Voss, 1973; Venezuela - Arocha 1989; Gulf of Aden - Roper *et al.*, 1984; India - Silas *et al.*, 1985; Nair *et al.*, 1992; Thailand - Chottiyaputta, 1991; Malaysia - Abu Talib and Mahyam, 1986; South China Sea - Chan and Karim, 1986; Hong Kong - Chin, 1982). Around Indonesia and the Philippines, squid are again a component of mixed species lift-net fisheries with little targetting (Indonesia - Bambang Sudjoko, 1987; Philippines - Hernando and Flores, 1981). Squid are also a small byproduct of pelagic purse seining in Indian waters (Sunilkumar Mohamed, 1993).

In excess of 500 tonnes of loliginid squid was taken as byproduct in the Northern Prawn Fishery area off the Northern Territory in 1988 (Pender *et al.*, 1992) and squid were an important component of the Taiwanese trawl fishery in the Arafura Sea-Gulf of Carpentaria region particularly in the late 1970s with more than 1000 tonnes taken annually (Edwards, 1983; Dunning *et al.*, 1994). The squid byproduct and target component of the prawn trawl fishery in Moreton Bay, southern Queensland, amounts to more than 100 tonnes annually, with most taken between October and March (Dunning, 1982; 1997).

The Japanese and Spanish are the principal importers of cephalopod products and these markets differentiate product on the basis of species, size, presentation and product preservation state (ie., fresh, frozen, frequency of defrosting). Higher prices are paid for loliginid squids than for ommastrephids (the arrow squid such as *Nototodarus gouldi* and *Illex argentinus* of cooler temperate waters) and jigged or liftnetted squid fetch higher prices than trawl caught squid because of their better condition and generally larger size (Supongpan, 1988; ADB/INFOFISH, 1992).

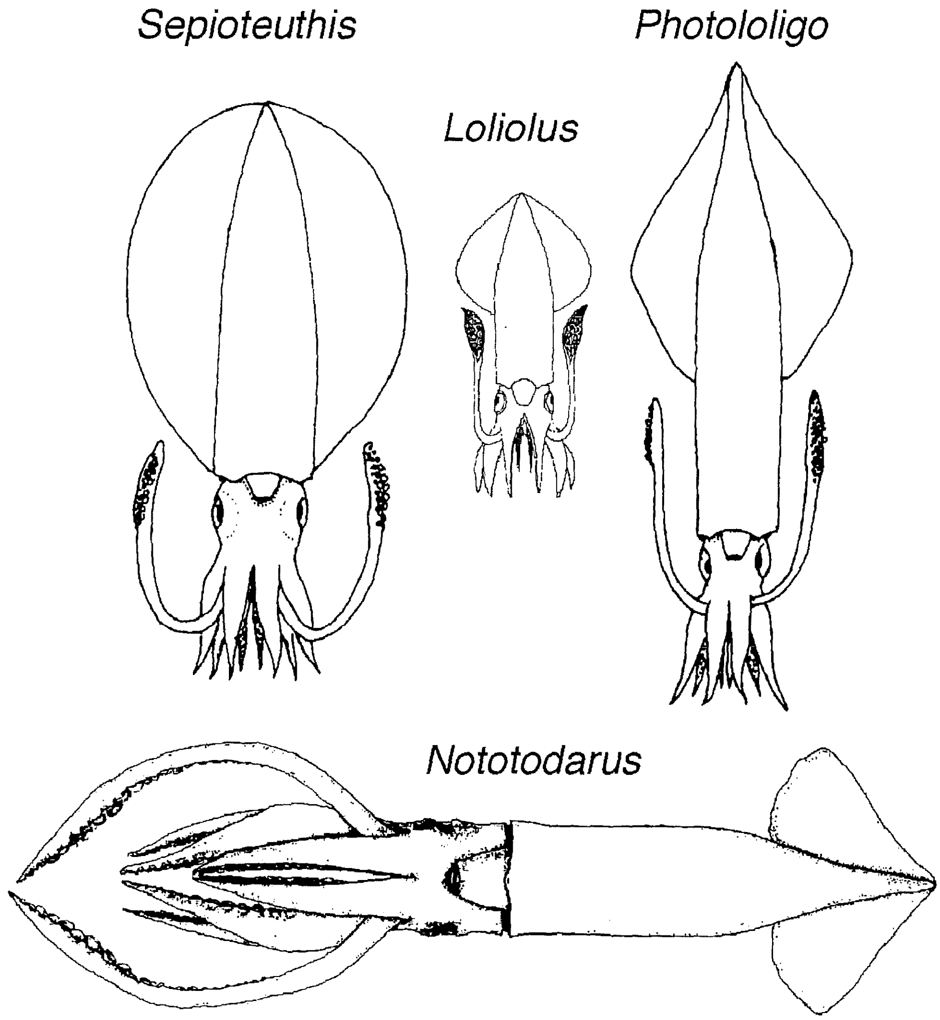


Figure A1. Inshore squid of the family Loliginidae together with an oceanic arrow squid Nototodarus *-family Ommastrephidae. Note the major difference in body shape between* Sepioteuthis *and* Photololigo, *the former mimicking the body shape (and in some respects, the behaviour) of a cuttlefish. (After Okutani, 1991; Wormuth, 1976).*

While supplies of loliginid squid from Thailand and India continue to come predominantly from trawlers (Chottiyaputta, 1991; Nair *et al.*, 1992), an export opportunity may exist for Australian fishers not only to replace squid imports into Australia but to also exploit the export market particularly in Japan, Spain and Korea for high quality product. Fishers will need to make use of "resource friendly" capture methods such as jigging or liftnetting or better semi-pelagic trawl design. These methods also have the advantage of being very selective for squid and do not impact on non-target species, benthic fauna and habitat.

Specialized commercial squid fishing gear and methods have developed from artisanal squid fishing in Japan and developing countries of southeast Asia. In addition, particular modifications to demersal fish trawls have been suggested in the literature to make them more efficient at catching squid. These gears and techniques, specifically as they are used in tropical regions, are the subject of this review.

Table A1. Tropical inshore squid of commercial importance or potential by region. Species occurring in northern Australian shelf waters are indicated *

Eastern Atlantic

Loligo vulgaris Lamarck, 1798 : European squid (FAO), kalmar or calamar (Spain, Algeria, Morocco)
Loligo forbesi Steenstrup, 1856 : lula (Azores), veined squid (FAO)

Northern Indian Ocean

Photololigo (Doryteuthis) singhalensis (Ortmann, 1891) : Long barrel squid (FAO), cheung woo chak (China)
Photololigo (Doryteuthis) sibogae Adam, 1954 : Siboga squid (FAO), cumi-kecil (Indonesia / Lombok)

Indo-west Pacific

**Sepioteuthis lessoniana* (Lesson, 1830) : aori-ika (Japan), bigfin reef squid (FAO)
Photololigo chinensis (Gray, 1849) : tor yau yue (China), hira kensaki ika (Japan), pusit (Philippines), mitre squid (FAO) , cumi-tebal (Indonesia / Lombok)
**Photololigo etheridgei* (Berry, 1918) : pencil squid, broad squid (Australia)
Photololigo edulis (Hoyle, 1885) : swordtip squid (FAO), kensaki-ika (Japan, India), tor yau yue (China), cumi-jamak (Indonesia / Lombok)
Photololigo duvauceli (Orbigny, 1848) : Indian squid (FAO), chin sui yau yue (China), pusit (Philippines)
**Photololigo* sp. 1 of Yeatman & Benzie, 1993 ["*edulis*" like squid]
**Photololigo* sp. 2 of Yeatman & Benzie, 1993 ["*edulis*" like squid]
**Photololigo* sp. 4 of Yeatman & Benzie, 1993 : slender squid (Australia) ["*chinensis*" like squid]
**Photololigo* n.sp. of Lu, Dunning and Yeatman, in prep.
**Loliolus noctiluca* Lu, Roper and Tait, 1985 : bottle squid (Australia)
Loliolus sumatrensis (Orbigny, 1835) :
Loliolus affinis Steenstrup, 1856

Caribbean region and western Atlantic

Sepioteuthis sepioidea (Blainville, 1823) : Caribbean reef squid (FAO)
Loligo pealei Lesueur, 1821 : amerikakensaki ika (Japan), common squid, longfinned squid (USA), longfin inshore squid, common squid (FAO)
Loligo (Doryteuthis) plei (Blainville, 1823) : arrow squid (USA), slender inshore squid (FAO)
Lolliguncula brevis (Blainville, 1823) : brief squid (USA)
Loligo surinamensis (Voss, 1974) : Surinam squid (FAO)

Jigging

Squid jigs, lures with clusters of typically barbless hooks, have been used traditionally to take inshore squids in SE Asia for hundreds of years. They are of two main types: trolling jigs shaped like prawns or fish used primarily to take cuttlefish and the broadfin reef squid (*Sepioteuthis lessoniana*) and cylindrical jigs (sometimes baited) used for other loliginids and used vertically (Tomiyama and Hibiya, 1978; Hernando and Flores, 1981; Saharuddin *et al.*, 1990).

While traditionally, trolling jigs (Figure A2) were carved from wood, the bodies of these (like the cylindrical jigs) are now made also from plastics. The colours preferred by traditional fishers for trolling jigs are greenish to blueish above and white below while size and shape (ie. shrimp or fish) vary with location . The total length of the jigs is between 14 and 18 cm around southern Japan and 12 to 14 cm around the Philippines and Indonesia (Shibata *et al.*, 1990).

Figure A2. Squid trolling jig from around southern Japan (After Hamabe et al., 1982).

Around the Philippines, the cylindrical type jigs are either used with a lead weight forming the shaft or baited with a whole fish (Figure A3). Only a single cylindrical jig per line is used (Hernando and Flores, 1981) although each fisher may set at least three or four troll lines with trolling jigs.

Cylindrical jigs with plastic bodies or formed from lead weights and wrapped with cloth or baited (Figure A4) are used by both commercial and recreational fishers off southern Japan to take kensaki-ika (*Photololigo edulis*), a squid very similar to the large pencil squid of northern Australia. Fishing occurs either during the day or at night under lights. Approximately 2-4 incandescent squid attracting lamps of 1-2 kW each are used on 8-14m boats (Yajima and Mitsugi, 1976; Tomiyama and Hibiya, 1978; Natsukari and Tashiro, 1991).

Jigs may be used singly on poles (Figure A5) and are typically used near the surface on 1.5 -2 m of line. Other handlines use a combination of a floating jig attached to the mainline with 50 cm of line and a lead jig on the end of the line about 1 m below (Figure A6). In deeper water, hand operated reels with multiple jigs approximately 1 m apart are used (Figure A7).

A variety of cylindrical jig types used on handlines proved successful at catching *Photololigo chinensis* of up to 230 mm ML during a preliminary trial in the Gulf of Thailand (Shibata *et al* ., 1980).

The main jigging season for kensaki-ika off southern Japan is June - July (midsummer) with a second peak in catch rates in October-November. Only recently has jigging for tropical loliginid squid using automatic jigging machines (Figure A8) commenced off southern Japan, although no catch rate information is available (Natsukari and Tashiro, 1991).

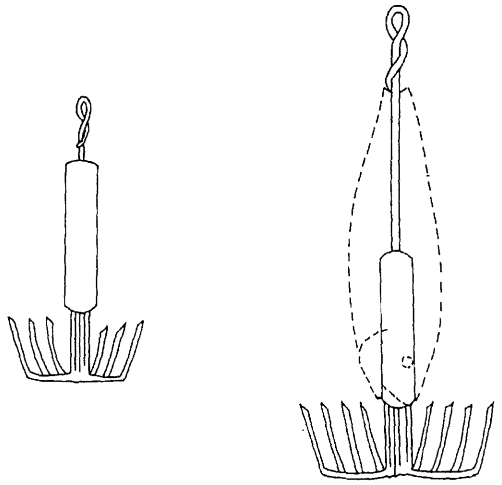


Figure A3. Unbaited and baited cylindrical jigs used around the Philippines (After Hernando and Flores, 1981).

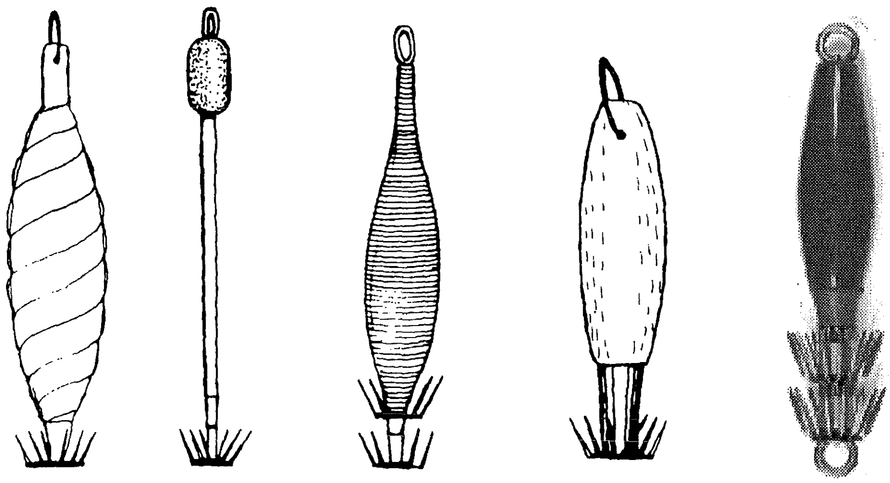


Figure A4. Traditional Japanese squid jigs together with a modern in-line jig (After Yajima and Mitsugi, 1976).

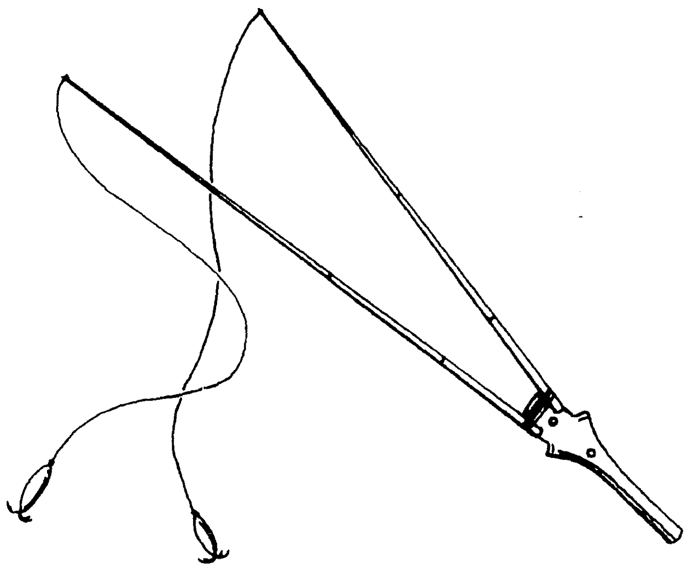


Figure A5. Traditional Japanese pole and line jigging gear (After Yajima and Mitsugi, 1976).

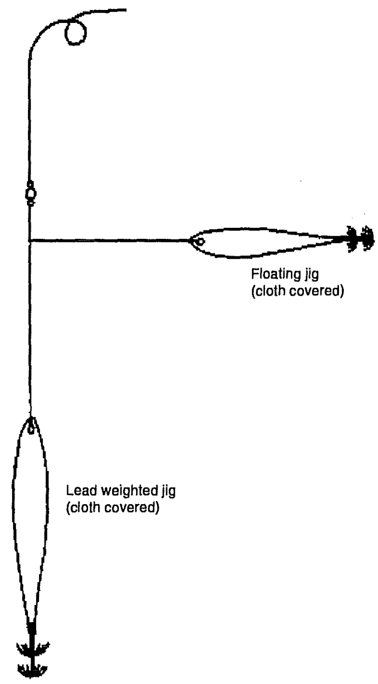


Figure A6. Typical southern Japanese hand held jig arrangement for fishing for kensaki-ika (Photololigo edulis*) (After Natsukari and Tashiro, 1991).*

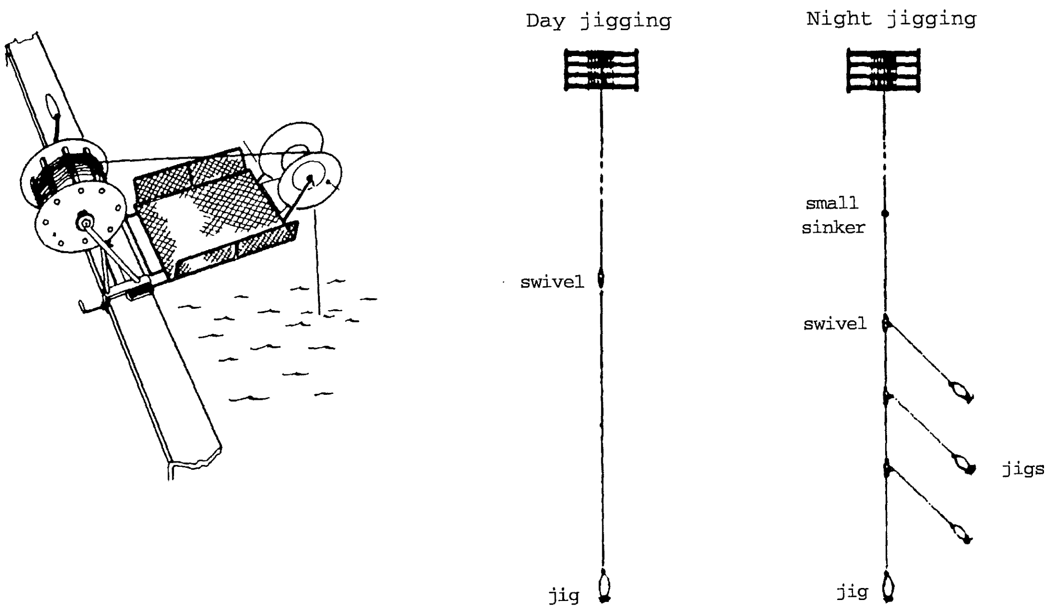


Figure A7. An example of a squid hand reel arrangement with jig lines (After Hamabe et al., 1982).

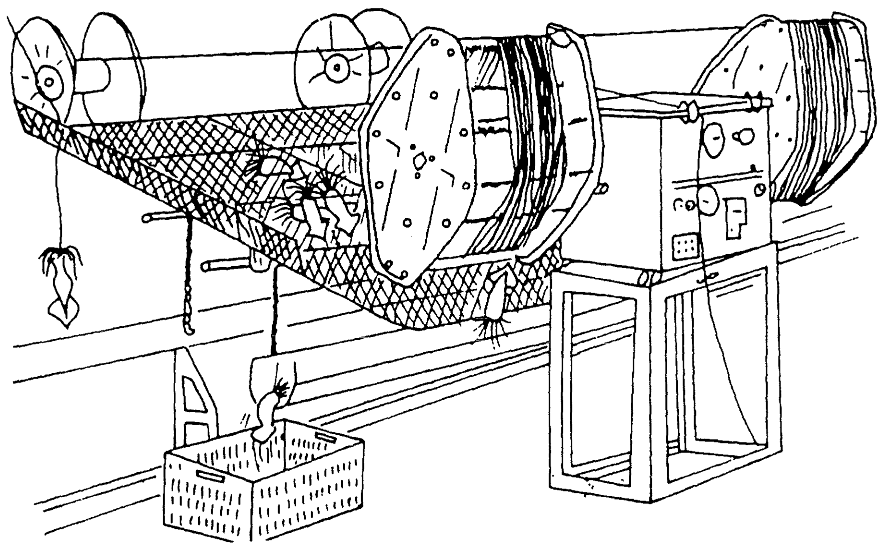


Figure A8. Example of a double spooled automatic squid jigging machine (After Hamabe et al., 1982).

In Southeast Asian countries, night time jigging using artificial light attraction tends to be undertaken during the darker phases of the moon. In contrast, trolling jigs are used to best effect around full moon.

Little information is available on the best light attraction regime to optimize the night time jig catch of tropical squid species. Chyn and Lee (1994) have assessed the behaviour of *Photololigo* *edulis* (swordtip squid) to various coloured and white lights and found that if the light intensity was too high, squid moved away from the light source. This also happened at too low a light intensity. In their experiments, 25 lux proved the optimal aggregating intensity. In addition, they found that blue and green light were up to twice as effective at aggregating swordtip squid as white light and better penetrated deeper water. Red and yellow light was most effective at aggregating squid already at the surface around the light source.

Lift nets and cast nets

In the Gulf of Thailand, dip nets, cast nets and box nets account for more than 20,000 tonnes of loliginid squids annually (Chottiyaputta, 1991). All methods involve the use of lights to attract and concentrate squid although the capture net design and its setting and recovery technique varies. Larger vessels (>8 m long) tend to use stick-held cast nets and stick-held box nets. These vessels typically carry from 3-7 crew depending on the level of automation of winches etc. Examples of vessels and gears are illustrated in Figure A9.

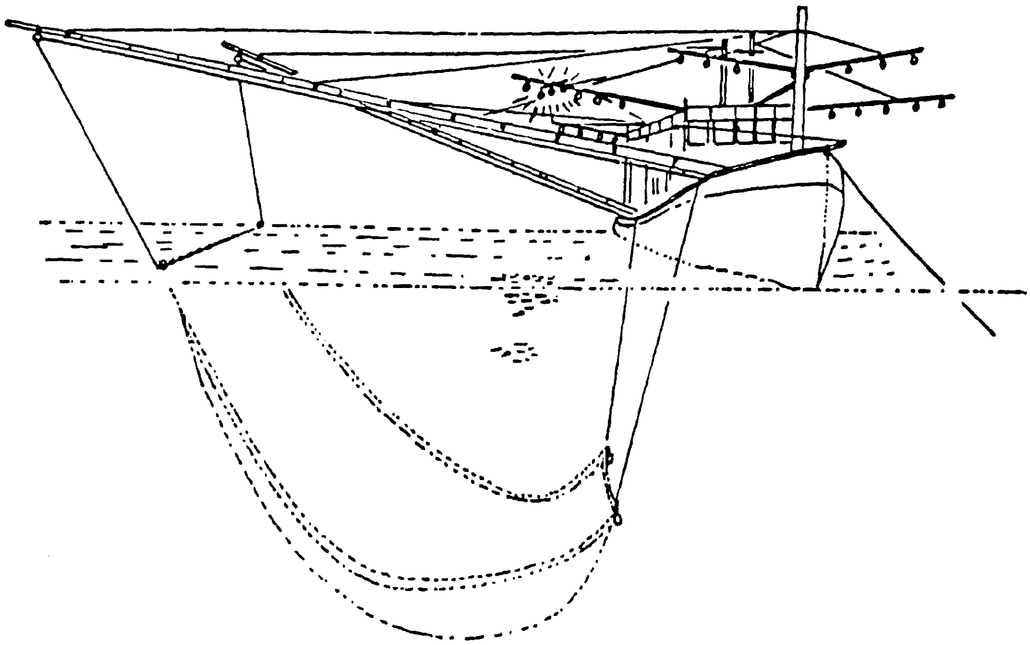
The light attraction technique is the same for all nets. Incandescent lamps of 500 w or greater and some red or green lamps are fixed to bamboo poles protruding from both sides of the vessel. Fishing is usually undertaken from the 3rd or 4th day after full moon to the 8th or 9th day after new moon. All lights are turned on after sunset and when squid appear around the vessel, the net is set for operation and lights on the side away from the net are switched off. When the squid have concentrated on the net side, the intensity of the lamps is reduced (and often only a red lamp left on) to bring the squid to the surface. Then the net is either lifted (pulled or pushed) in the case of the dip net (Figure A10) or dropped and pursed in the case of the cast and box nets and the catch rapidly retrieved.The stick-held box net, the most recent design, is considered to be more efficient than the others. It is derived from the cast net design which is conical. The box net can be set to surround the squid school more rapidly because of the reduced water resistance of the mesh panels and increased weighting of the bottom edges (up to 70 kg in the lines and 5 kg corner sinkers) (Boongerd and Chitrapong, 1986; Matsunaga, 1989).

Lift nets are operated several (10-20) times in a night with a typical box net operation taking 8-10 minutes. Catches from Thai stick-held cast nets may reach 100 kg per set with the average 5-20 kg. According to Supongpan (1988), cast nets and dip nets catch squid over a broad size range (*Photololigo chinensis* 6 - 39 cm mantle length, *P. duvauceli* 4 - 25 cm mantle length).

Trawling

As mentioned in the introduction, the majority of the the global tropical squid catch is taken as the byproduct of demersal trawling. In general, no specially designed trawl gear is used in tropical regions (Voss, 1973; Chin, 1982; Silas *et al.*, 1985; Chan and Karim, 1986; Abu Talib and Mahyam, 1986; Arocha 1989; Chottiyaputta, 1991; Nair *et al.*, 1992).

Because loliginid squid tend to be closer to the bottom during the day and move throughout the water column at night (, higher catches from demersal trawling are made during the day (Matsuoka *et al.*, 1992). Trawl nets specifically designed for catching squid have been developed for use in temperate regions, usually from vessels of 1000 hp or greater (Engel, 1976; Koyama, 1976). Goudey (1987) described a design for a semi-pelagic net with a head rope height of up to



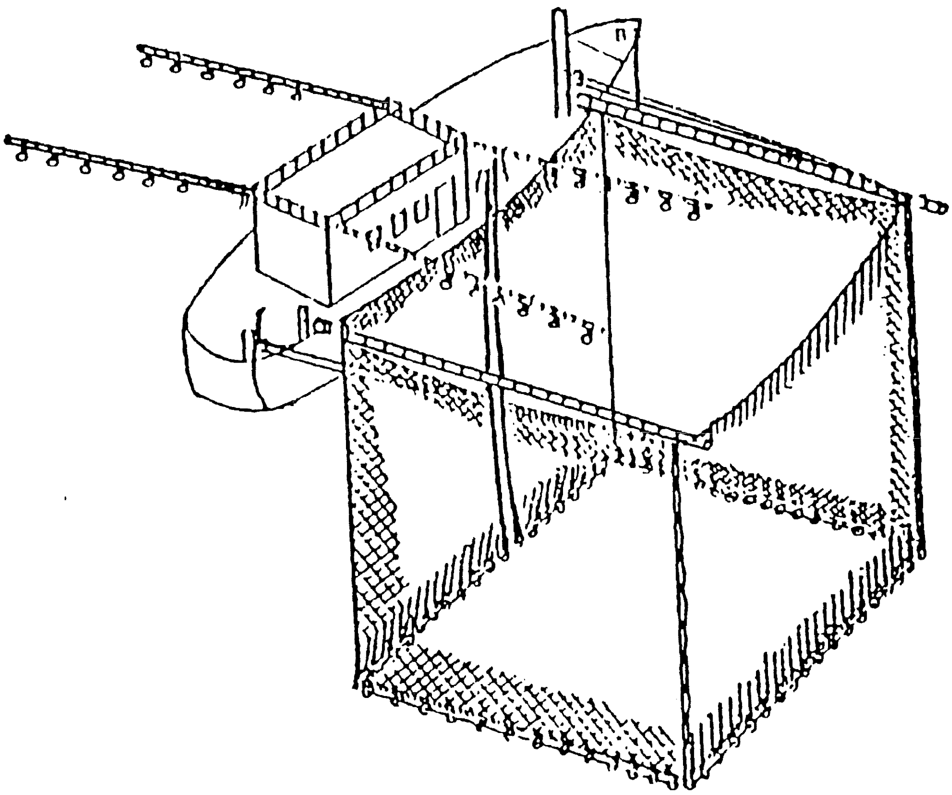


Figure A9. Typical Thai stick-held dip net (above) and box net vessels (After Boongerd and Chitrapong, 1986).

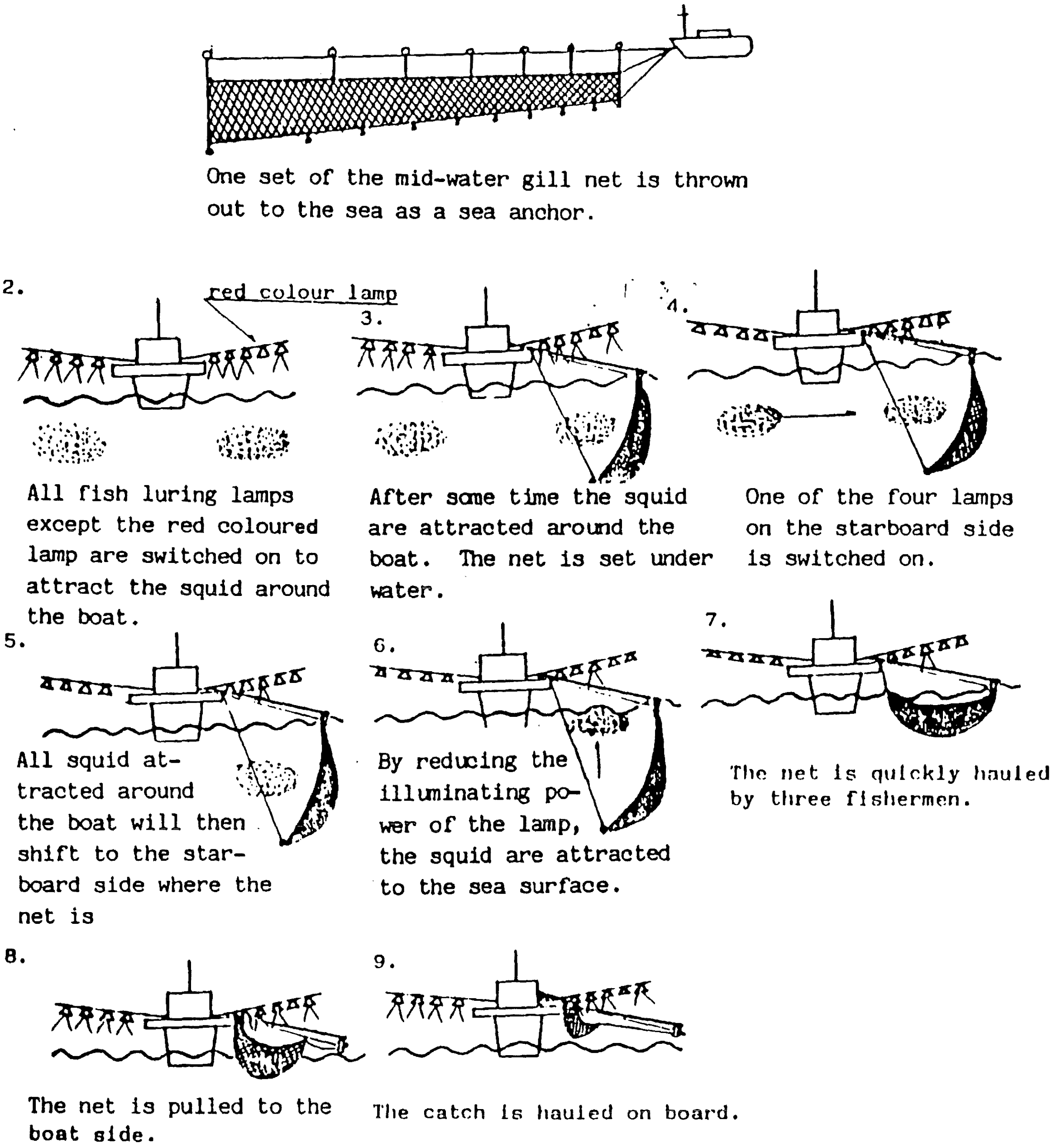


Figure A10. The operation of a typical Thai stick-held dipnet for squid (After Matsunaga, 1989).

10 m when towed at about 3.5 kts from a vessel of 450 hp but catches taken from this net have not been reported in the literature.

The basic characteristics of a trawl net suitable for catching squid appear to be that it is preferably a balloon or semi-pelagic design with a high mouth opening, can be towed at > 3.5 knots and, to maintain squid quality, is made of less abrasive material, particularly in the codend. It is not believed that squid "herd" in response to warps or large mesh wings (Blott, 1980; Amos, 1983). Brewer and Eayrs (1984) have modified a standard wing trawl to fish in semi-pelagic mode to reduce demersal bycatch and gear of this type may be appropriate to trawling for tropical loliginid squid during the daytime if the species present here are not "hard" on the bottom.

Traps

Traps are used in small scale fishing operations to take bigfin reef squid (*Sepioteuthis lessoniana*) (and also cuttlefish) in the Gulf of Thailand and around southern Japan (Boongerd and Chitrapong, 1986; Tomiyama and Hibiya, 1978). The traditional Thai squid trap is made of 1.3 to 2.5 cm diameter wooden poles, about 1-1.2 m long, 55-80 cm wide and 50-65 cm high. The entrance to the trap is nearly 40 cm at its widest and the narrowest point, 8 cm. The trap is covered in polyethylene mesh (approximately 5 cm) and coconut leaves. Traps are attached to floats and set in midwater at least 2 m off the bottom with the mouth facing vertically as shown in Figure A11. Traditionally, traps were set inshore (bottom depth 4-5 m) in Thai waters but recently trap fishing at depths of up to 40 m has occurred (Chottiyaputta, 1991).

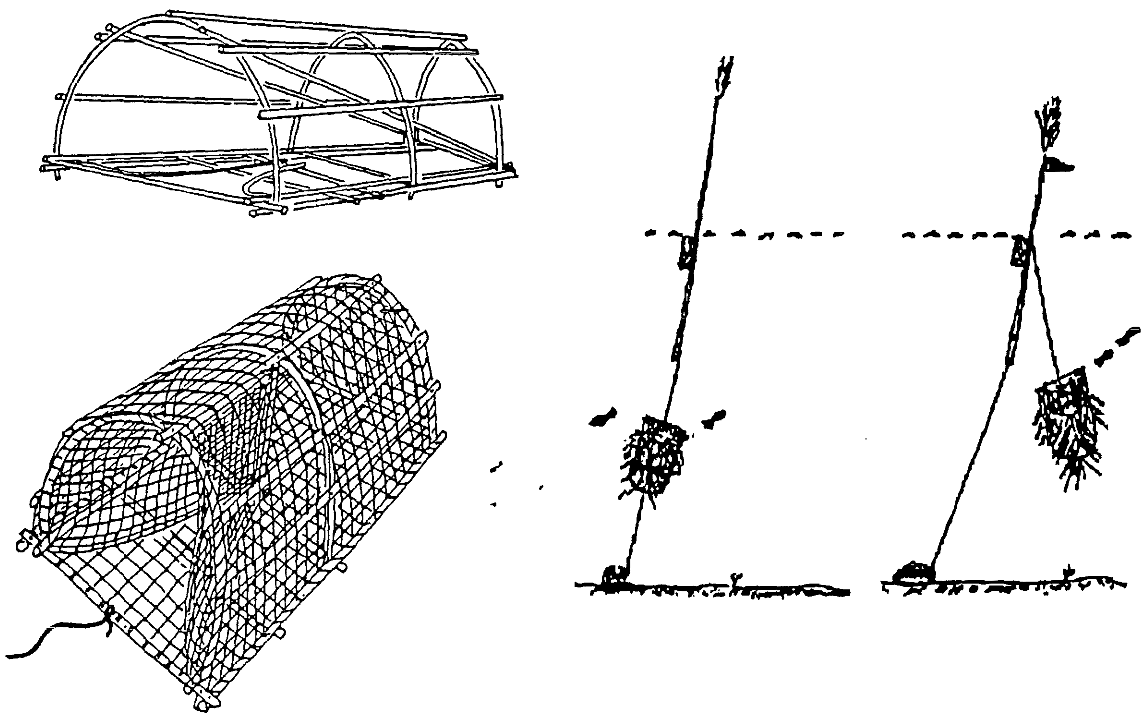


Figure A11. Typical Gulf of Thailand squid traps to catch broadfin reef squid (Sepioteuthis lessoniana) (After Boongerd and Chitrapong, 1986).

Other gears

S. lessoniana is also taken as a bycatch in "tunnel nets", walls of fine mesh netting set along and at right angles to the mangrove shoreline used to take flathead, bream and whiting, in bays off southern Queensland during the falling night tide (Winstanley, Potter and Caton, 1983).

In addition to their importance as byproduct of trawl fisheries around India, Indian squid (*Photololigo duvauceli*) are also caught as bycatch in purse seines used to take pelagic fish (eg., Indian mackerel) between September and October. Catches of up to 50 kg per set may be taken (Sunilkumar Mohamed, 1993).

Purse seine nets designed to catch temperate loliginid squids have been trialled without immediate success off the northeast coast of the United States (Taber, 1976).

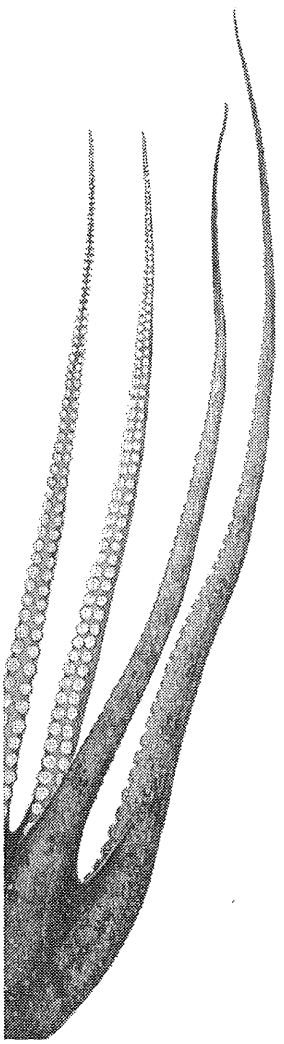
Conclusions

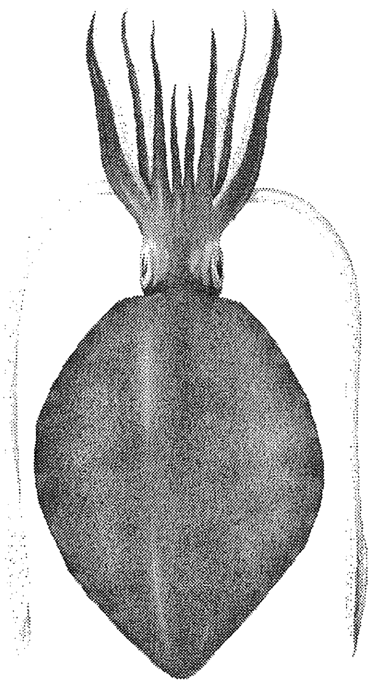
Squid jigging and lift netting are successful elsewhere for catching loliginid squid (*Photololigo* spp.) similar to those occurring in northern Australian waters. Traps are successful at catching *Sepioteuthis* elsewhere in Southeast Asia. These methods produce squid of higher quality (though smaller quantity) than those taken by trawling operations. Whether these methods, perhaps with enhanced mechanization or refinement, are economically viable for Australian fishers depends principally on two factors, the availability of the resource and market acceptance of high quality squid at a higher price than currently paid for trawl-caught squid.

Appendix 3 Field guide to Australian cephalopods

Cephalopods

of Commercial Importance in Australian Fisheries





By Victoria Wadley and Malcolm Dunning

Illustrations by Roger Swainston and Georgina Davis

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Available from Bev Austin, Centre for Food Technology, DPI, 19 Hercules Street, Hamilton Qld 4007 tel. (07) 3406 8617

Appendix 4 Coastal squid fisheries - Report on a trip to Kyusyu, Japan, 12-16 July 1996 by Malcolm Dunning.

Background to the visit

Squid in Queensland waters are one of the few fisheries resources identified as potentially supporting increased exploitation. Under the recent Offshore Constitutional Settlement with the Commonwealth, Queensland (through the Queensland Fisheries Management Authority) has fisheries management responsibility for all east coast squid resources adjacent and for squid taken by gear other than demersal trawl in Queensland waters of the Gulf of Carpentaria.

Reported landings of squid from domestic prawn trawlers in east coast waters alone total approximately 200 tonnes annually and it has been suggested by marketers that the reported catch is less than 1/3 of the actual landed catch. The value of the reported east coast trawl byproduct alone is estimated at >$1m.

Unlike arrow squid resources of southern Australian continental shelf waters, northern inshore squid that occur in Queensalnd waters are among the highest value cephalopods on Asian markets. These species are readily accepted on the domestic market where in excess of 5,000 tonnes of squid have been imported annually in recent years (much of this, arrow squid from New Zealand).

The Queensland Fisheries Management Authority received applications from fishers to participate in a developmental squid fishery in 1994 and three permits were issued in late 1996. Northern Territory Department of Primary Industry and Fisheries has also issued approvals for developmental squid jigging. Such fisheries targetting high quality squid using selective, environmentally sensitive gear such as jigs and with proper post harvest handling have the potential to not only replace imports with local product but also establish an export market for northern Australian squid.

If properly monitored and linked to appropriate research programme, developmental fisheries provide the opportunity to assess the extent of squid resources and assess their sustainability under various harvest levels.

Objectives of the study visit

- to assess squid fishing gear arrangements on inshore vessels and fishing techniques off southern Japan with a view to their applicability in a northern Australian developmental squid fishery
- to discuss squid resource assessment techniques with Japanese squid fisheries biologists
- visit fish markets to observe market presentation and wholesale pricing of squid species similar to those available in Queensland waters

Itinerary

12-13 July 1996 Fukuoka, Kyusyu, southern Japan - at sea off Nogita for the morning on a commercial squid jigging (taru-nagashi) vessel

13-14 July 1996 Iki Island (Katsumoto port) - visit to fisheries cooperative, at sea overnight on a commercial squid jigging vessel, observing the wholesale market

15 July 1996 Nagasaki - visit to fishing port / fish markets (East China Sea trawler landings)

16 July 1996 Regional workshop on squid resources hosted by Seikai National Fisheries Research Institute, Nagasaki. Presented overview of northern Australian squid resources and fisheries.

Inshore squid fishing

Squid are a major component of the commercial and recreational fisheries catch off Kyusyu in southern Japan, particularly around the cities of Fukuoka and Nagasaki. The major inshore species is *Photololigo edulis* (shiro-ika or kensaki-ika) (Figure B1), a species very similar to one of the common mid-shelf squid species found off Queensland. Spawning grounds where squid aggregate at particular times of the year are found just off the coast in this region. *Photololigo edulis* is distributed from southern Japan to Thailand and through the Indonesian archipelago but not in Australian waters.

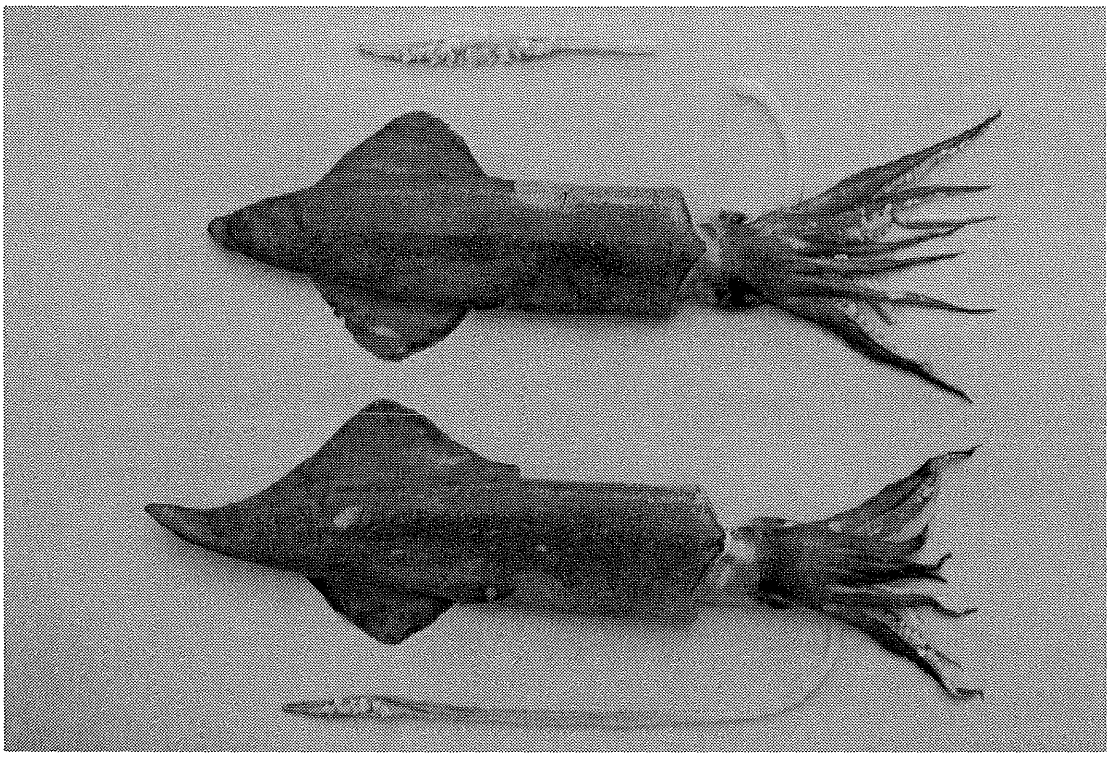

Figure B1. Photololigo edulis, *the main inshore squid species off southern Japan (Photograph by Julia Yeatman).*

Annual catches of this species by Japanese vessels around southern Japan and in the East China Sea total about 30,000 tonnes (Figure B2). The species is also harvested by Chinese and Korean vessels although catches by these nations are unavailable. While the catch of kensaki-ika is relatively small in terms of the Japanese domestic catch of the main species, Japanese common squid or surume-ika (*Todarodes pacificus*) which amounts to about 150,000 tonnes annually, kensaki-ika is among the highest valued species in Japan with wholesale prices at least five times that of surume-ika.

Fisheries biological research into this species in the East China Sea is undertaken by the Fisheries Agency of Japan through Seikai National Fisheries Research Institute in Nagasaki and in coastal waters by Prefectural (or State government) institutes throughout Kyusyu and southern Honshu .

While they are taken in deeper offshore waters in the Japan Sea and East China Sea by trawl primarily, kensaki-ika are caught also in inshore waters using jigs under lights at night, either machine or hand operated. Catches from shallow coastal waters represent about half the total catch.

Recently a new method of daytime squid fishing using jig lines attached to floats (or "barrel flowing") has been developed using one-man operated small vessels and this new fishery is tightly regulated. There are approximately 100 taru-nagashi vessels operating in the Fukuoka area.

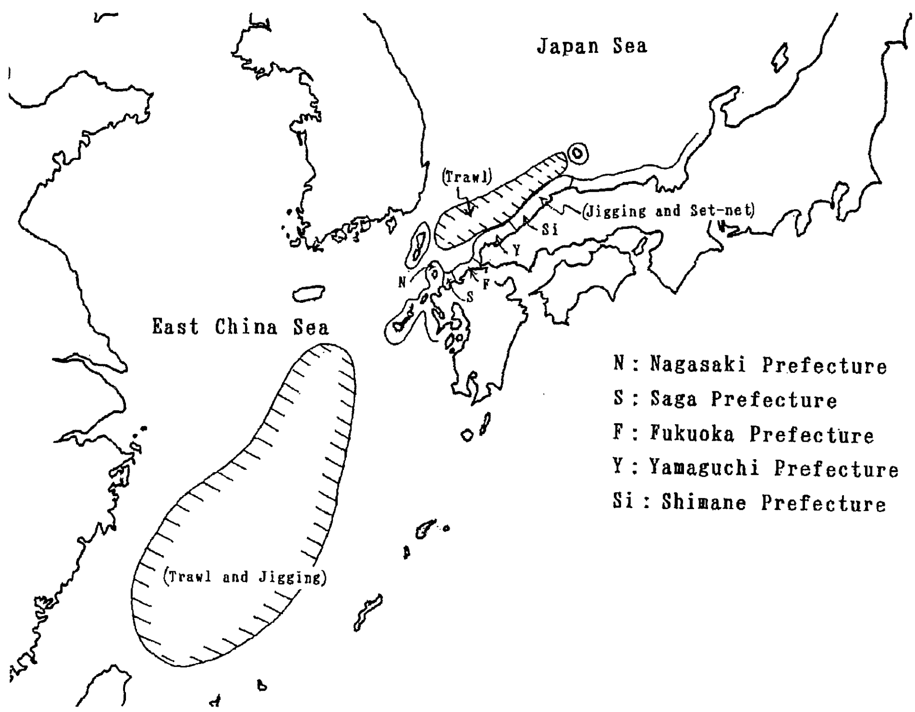

Figure B2. Distribution of fishing grounds for Photololigo edulis *off southern Japan.*

Daytime squid fishing off Nogita (near Fukuoka)

I was provided with the opportunity to go on board a taru-nagashi vessel for the morning of 13 July 1996, accompanied by my Japanese host, Mr Harumi Yamada from Seikai National Fisheries Research Institute (SNFRI) and also Mr Hiroyuki Hamada of Chikuzenkai Laboratory, Fukuoka Fisheries and Marine Technology Research Center, Fukuoka.

Japanese fishing vessels are described in terms of their carrying capacity rather than length and the vessel we boarded was a 5 tonne class vessel, approximately 12 m in length with flowthrough seawaters tanks under the forward deck for holding the catch alive. The vessel was powered by a 300 HP motor giving it a top speed in excess of 25 knots and was operated by one fisherman.

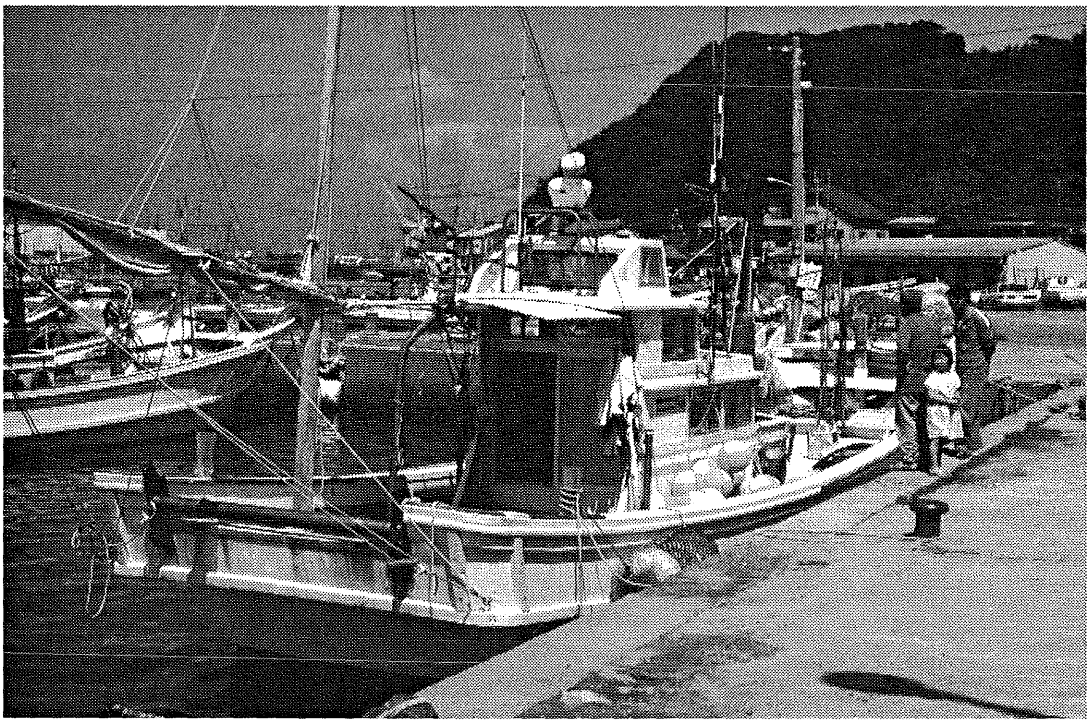

Figure B3. The taru-nagashi fishing vessel at Nogita port near Fukuoka.

Figure B4. *A smaller (3-4 tonne) taru-nagashi fishing vessel at sea off Nogita.*

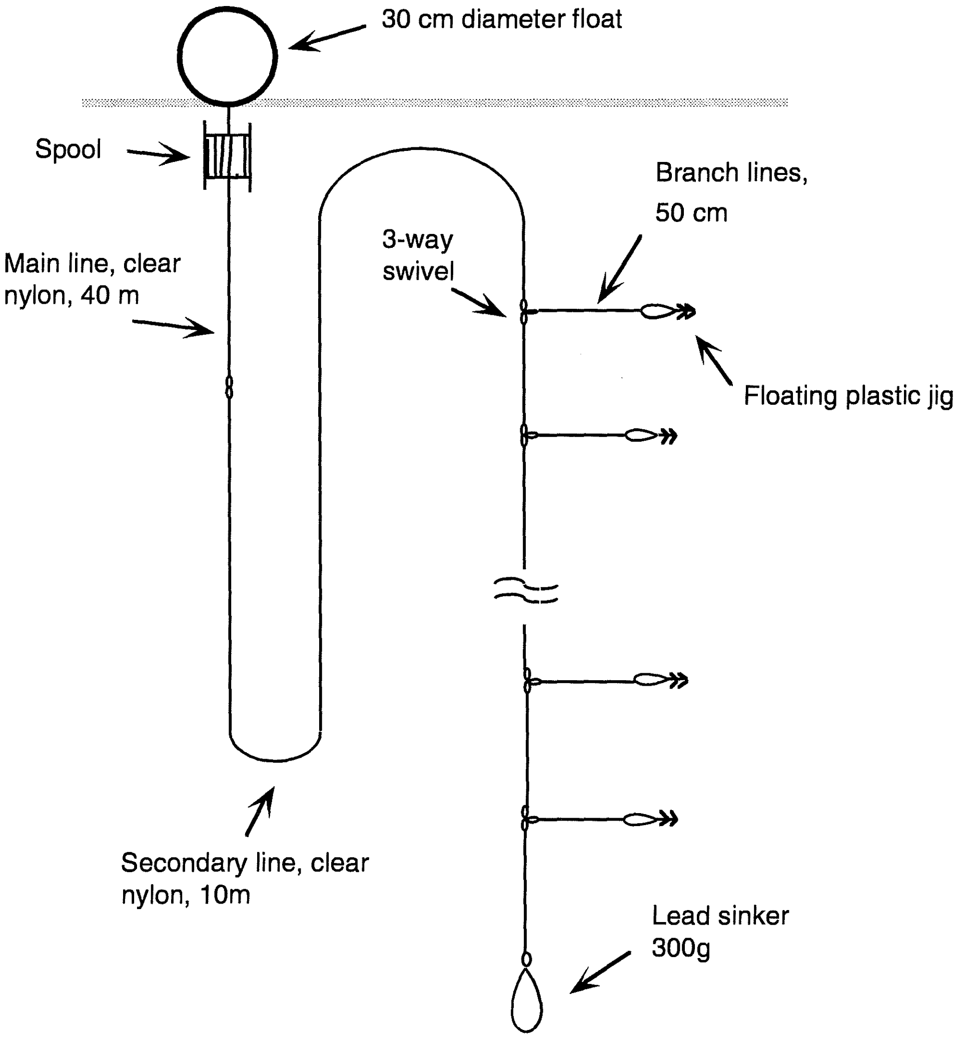

Figure B5. *Typical taru-nagashi fishing gear as used off northern Kyusyu.*

A diagram of the jig lines used is shown in Figure B5. Each vessel is permitted up to 18 floats, each with one jigline. These weighted jig lines may have up to 10-12 floating plastic jigs attached, depending on the water depth of the operation. On this day when we were fishing in mid summer in about 40 m, only five jigs were used on each line. The line is set so the weight is about 1 m off the bottom. During the autumn months, squid move further offshore and fishing occurs in water depths as much as 100m with more jigs used.

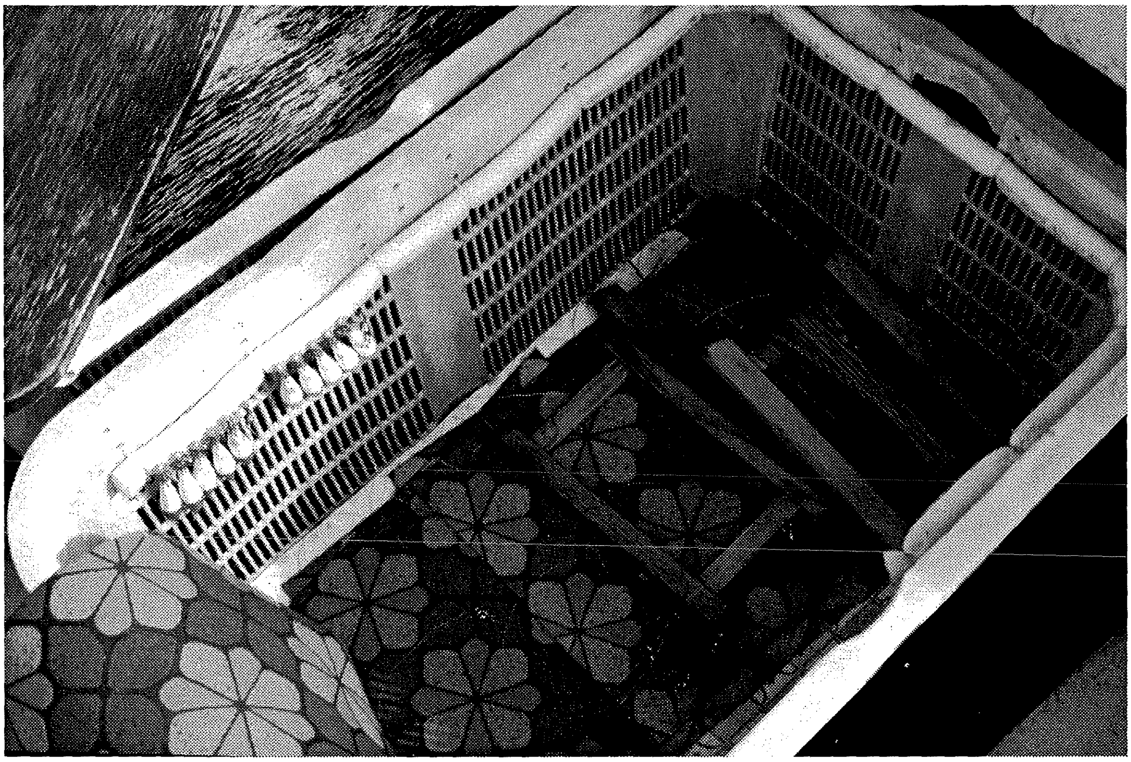

Figure B6. Jigs (left) and lines coiled in a basket ready to be set.

Figure B7. Line of jig floats as set from the vessel (retrieving the lines).

Each fisher has his own marking for the floats. According to government regulation, these must be set in a straight line. Lines are set quickly and the boat is then returned to the start of the line and hauling commences. Jigs are left in the water for only about 10-15 minutes (never more than about 30-40 minutes) because any jigged squid are quickly eaten by predatory fish and other squid. A small line-hauler manufactured locally is used to bring in the main line with the shorter section of jigs hauled by hand.

Typically, fishing commences at dawn and catches decline later in the morning. Larger squid are usually taken in the earlier sets. Vessels return to port before midday and the live animals are removed from the holds, graded by size and laid on trays of ice. The product is put into local cold store for marketing the next morning.

Figure B8. Line hauler in operation

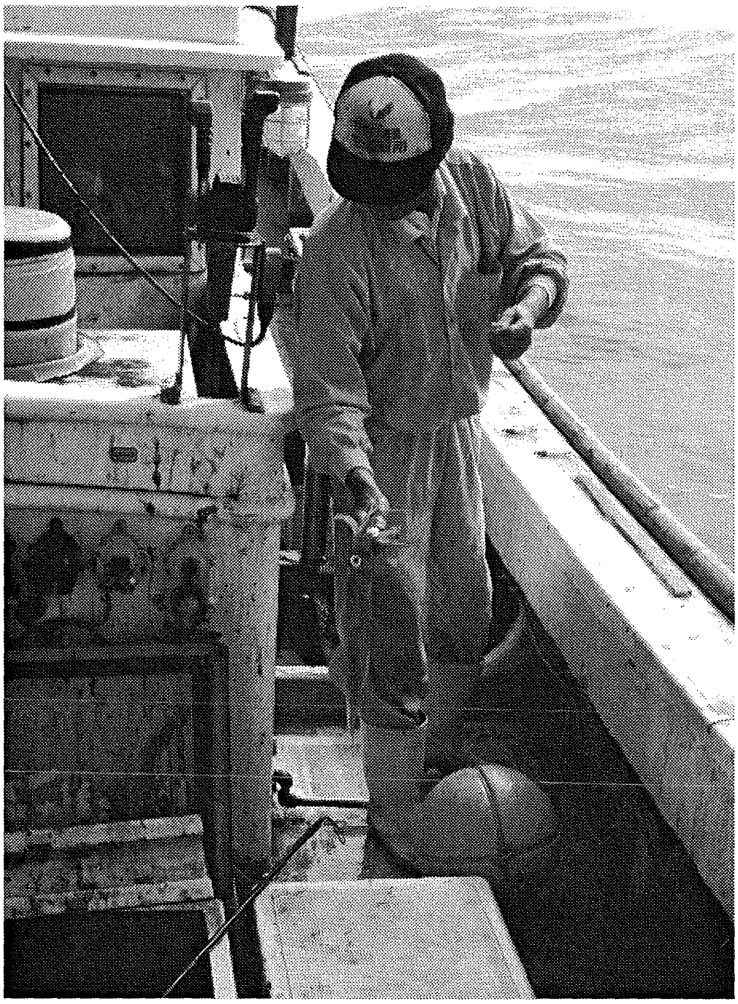

Figure B9. Large male P. edulis *being brought on board*

Figure B10. Squid catch after removal from live tanks on board.

Night jigging under lights off Katsumoto (Iki Island)

On the invitation of Mr Masatoki Tashiro of Nagasaki Prefectural Institute of Fisheries and accompanied by Mr Yamada and also Dr Kozo Kitani, Fisheries Oceanographer, of SNFRI, I was able to go on board a commercial 7 tonne jigging vessel in Katsumoto Port on Iki Island off the coast near Fukuoka.

Katsumoto Port is the one of the largest squid fishing ports in southern Japan with over 700 vessels ranging in size from 3-5 tonne inshore vessels to 300 tonne ocean going vessels. There are more than 250 vessels of the 5-10 tonne class in the Port, operated usually by one or two fishers.

The vessel on which we went to sea was operated by one fisher and carried six double spooled automatic jigging machines (other vessels of similar size carry up to eight machines). The vessel was equipped to fish deeper offshore waters as well (for Japanese common squid) and carried halogen and fluorescent lamps with a total wattage of in excess of 45 kW. The fisher was one of the best fishers in the Port and had made large catches over the previous nights. He held the local record for the largest single night's catch of 200 cases of kansaki-ika (approximately 1200kg and worth in excess of AU$6,000).

The fisher advised that he would be taking us to an inshore area where squid had been caught recently but not to a higher catch area as this was too far from port for a one night trip and subject to rougher seas. Sea surface temperature in the region was about 21°C. The area we chose to fish was in the midst of many other vessels with varying lighting and including both machine jiggers and hand jiggers only (at least 250 squid boats were out fishing that night). A sea anchor of about 10m diameter was set just on dusk at a location within about 2 km of shore. By agreement among the fishers when fishing in inshore waters, only 3 lights were turned on (about 9kW).

Jigs used were soft hollow plastic with double rings of barbs, this fisher preferring green and blue jigs for *Photololigo edulis.* The jigs were attached about 1m apart and a 300g weight attached to the bottom of each of the pairs of lines on each machine. Lines were connected together just above the weight as is standard practice. Both the mainline and lines between jigs were clear monofilament - no wire was used.

To test for the presence of squid, two jigs were used on a hand reel with a small weight (100g). When squid were caught, all six of the machines were started. Fishing was undertaken in about 75m depth with jigs fishing to 57 m. The catch was almost exclusively kensaki-ika with only about ten surume-ika caught and not retained.

Figure B11. Night jigging vessel in Katsumoto port, Iki Island

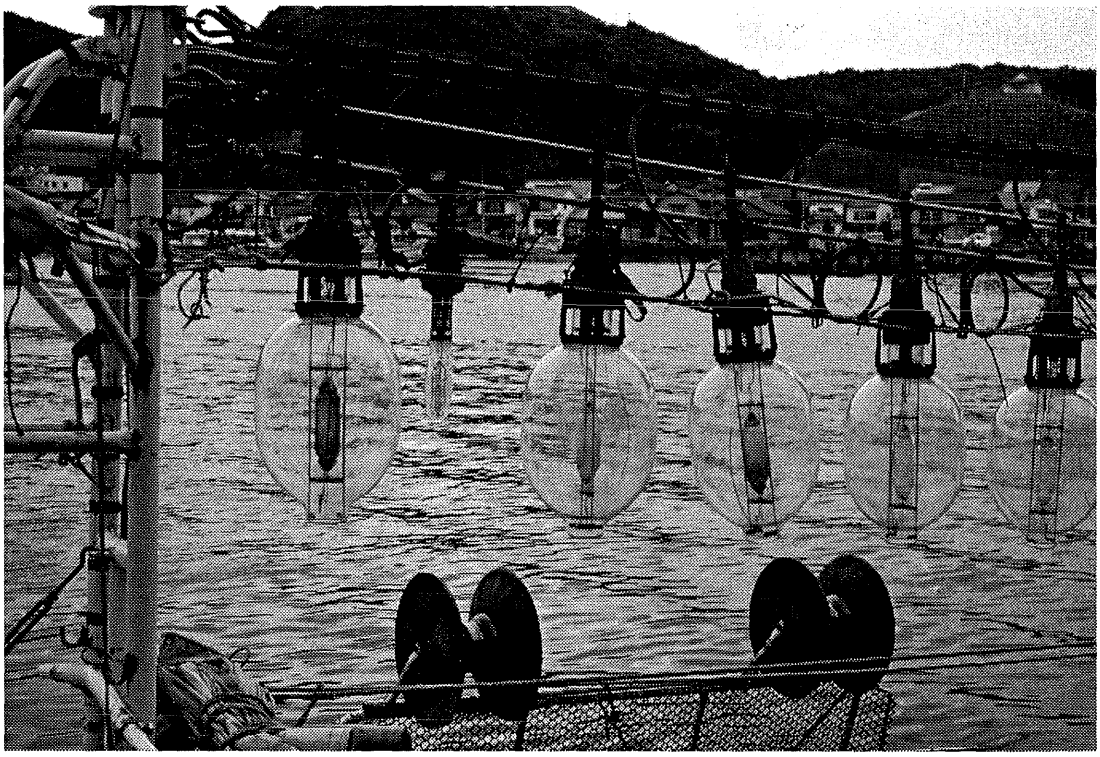

Figure B12. Fluorescent and halogen bulbs (3-5 kW).

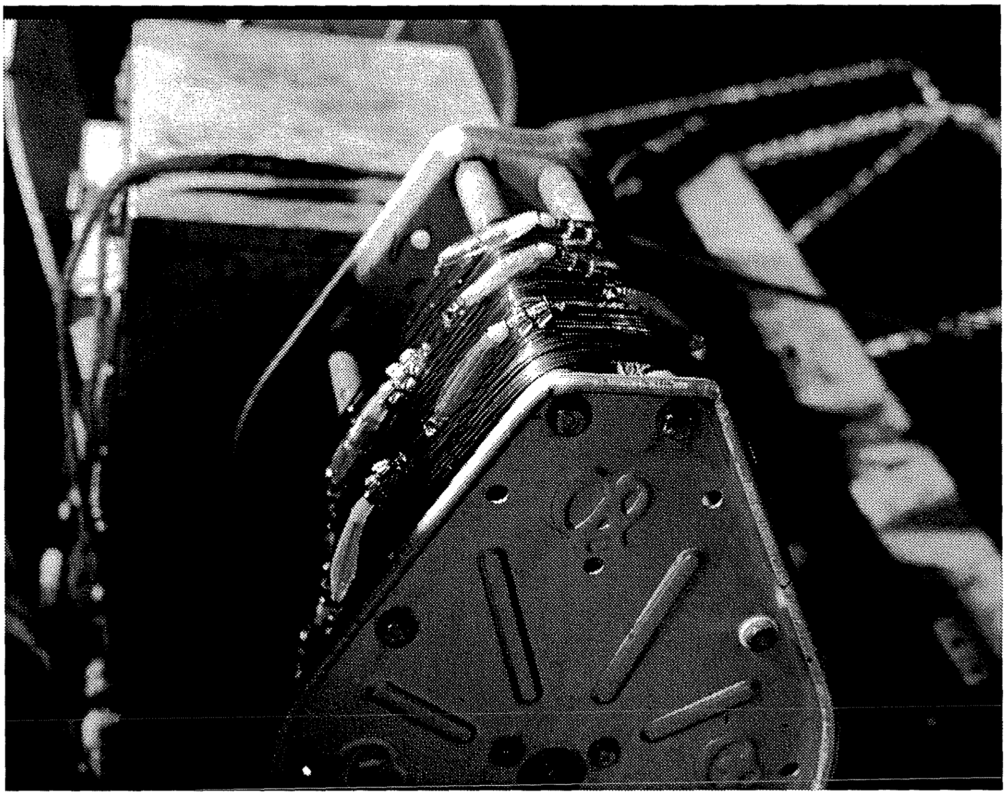

Figure B13. Squid jigs on the jigging machine spools

Squid were graded and packed onto ice in styrofoam trays. Presentation was all important and the ice was carefully flattened into the trays before squid were laid on top. Larger squid (200 mm ML +) were packed in a single layer with about 12-15 squid per box. Jigs caught squid from about 100 mm ML although some of the smaller squid were not retained.

Catch rates were low according to the fisherman and we took only 13 boxes for the night. Fishing stopped at about 02:00 and we arrived back at port at about 04:00. The boat travelled at up to 20 knots. Catch was landed at the cooperative market with a steady flow of other boats.

Selling at the market started at 05:00 and kensaki-ika dominated the product with several thousand cases offered. A variety of other fish species including yellowtail kingfish (*Seriola* sp.) and bonito were also available in small quantities and usually kept alive until just before sale.

Cases of squid are offered for sale as packed on the boats, ie., chilled product on ice. One day the week before, more than 5000 cases had been landed and sold, a record for the port. Fishers were not happy though as the unit price had dropped considerably.

Most buyers at this cooperative represent wholesalers from Osaka with most of the product then trucked chilled from the market to Osaka (a large regular vehicular ferry runs from Iki Island to the mainland). Product is then retailed in Osaka as fresh squid. A few buyers came from local restuarants and seafood retailers.

A few cases of aori-ika (broad finned reef squid - *Sepioteuthis lessoniana*) about 250 mm ML were also offered for sale at approximately AU$20 per squid. It is assumed these were caught in coastal set nets or using trolled jigs at the surface in inshore waters. This species also occurs in Queensland coastal and coral reef waters (known locally as northern calamary or tiger squid), although it is only lightly exploited mainly as byproduct of set net fisheries at present.

*Figure B15. Kensaki-ika (*P. edulis*) packed in ice trays.*

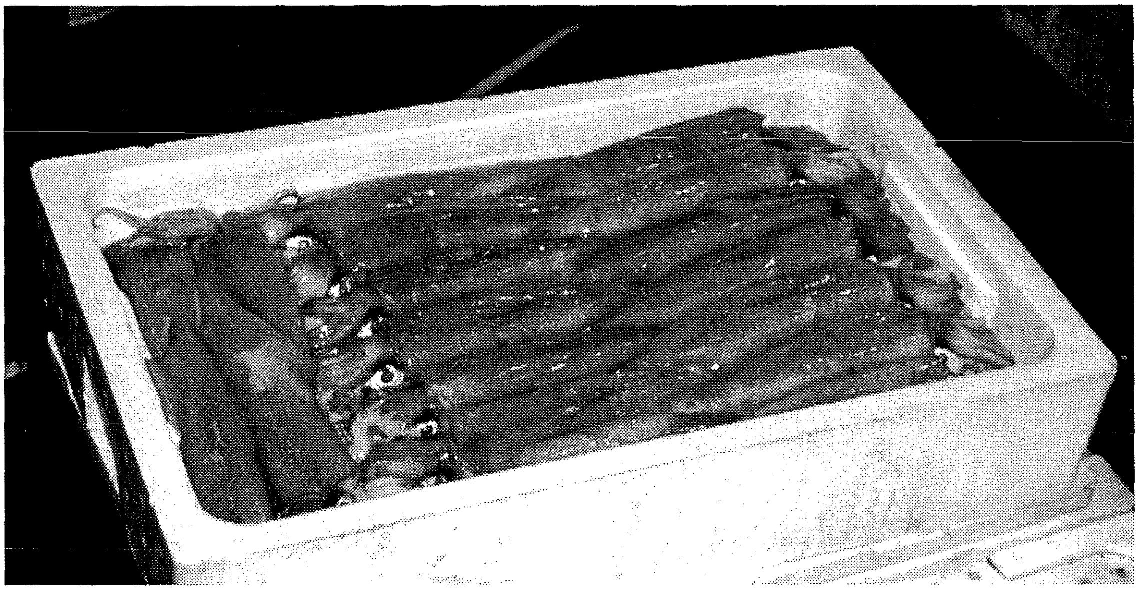

*Figure B15. Kensaki-ika (*P. edulis*) ready for sale at the markets.*

*Figure B16. Aori-ika (*Sepioteuthis lessoniana*) on ice at the wholesale market at Katsumoto Port (note use of plastic wrap to maintain freshness).*

Points of relevance to the development of a northern Australian squid fishery:

- Machine jigging is highly effective for squid very similar to those found off northern Australia. Kensaki -ika is very highly prized in Japan and fetches among the highest prices of all squid species (lower only than aori-ika and some forms of the oceanic squid, *Thysanoteuthis rhombus* or sodi-ika).

- Japanese vessels used for inshore jigging and taru-nagashi fishing all have their superstructures aft providing a large open foredeck for jigging machines, seawater or ice holds or for gear handling. Duplicated engine and steering controls are mounted on the outside of the wheelhouse at the rear of the foredeck. The rearward superstructure also acts as an effective yaw stabilizer when the vessels are hanging on parachute anchors as used during jigging operations. Spanker sails are also used in some conditions. Typical northern Australian otter trawlers and crabbing vessels have forward wheelhouses and may be unsuitable for jigging operations where yaw needs to be minimized.

Round table discussion of squid biology, Nagasaki, 16 July 1996.

This meeting was organized by Mr Harumi Yamada, the fisheries biologist at SNFRI working on kensaki-ika trawl fisheries in the East China Sea. The list of attendees is provided below. The meeting brought together all local prefectural, university and national fisheries institute biologists working on squid to review recent progress made in their respective studies and provided me with an excellent opportunity to obtain the most up to date information on squid fisheries research.

The meeting also addressed the issue of the biological appropriateness of a quota or Total Allowable Catch (TAC) for squid which is being considered by the Japanese Government. In addition to the difficulties inherent in allocating TACs to short lived (annual) species such as squids with high interannual variability, the participants also discussed the difficulties in enforcing any quota on Japanese fishers only in a multinational fishery. The squid trawl resource in the East China Sea is harvested by Japanese, Korean and Chinese vessels and no national fisheries jurisdictional boundaries or resource allocation systems have been agreed in the area.

Currently the fisheries (night jigging, taru-nagashi and trawl) are managed through input controls only - specifically controls by the various prefectures on the number of vessels allowed to operate in the various fisheries.

I presented a brief overview of the distribution of squid species in Queensland and northern Australia, their contribution as byproduct and seasonally as target species in the existing northern trawl fisheries and their possible resource potential. Copies of other papers presented at the meeting are available from the senior author.

Points of relevance to the development of a northern Australian squid fishery:

- The Japanese Government monitors annual variability in kensaki-ika stock size in the East China Sea through fishery independent trawl biomass surveys. Acoustic surveys are showing promise also in the estimation of biomass. Cohort analysis of monthly catch data collected in the many ports has also been used in estimation of squid stock size.

- Spawning of kensaki-ika occurs year-round in Kyusyu waters at some level with a peak in mid summer.

- While spawning grounds are found in many coastal areas around Kyusyu, some areas are especially recognized as sites. Jigging apparently is allowed in all areas, but mechanized trawling is not permitted in known spawning areas. I understand enforcement of this (and most regulations) comes from the fishers cooperatives themselves rather than from government agencies.

- Considerable interest was shown at the low price accepted by Queensland fishers for high quality trawl squid and wonder at why squid jigging isn't undertaken in northern Australia.

- Commercial whole life cycle culture of aori-ika is being conducted (?successfully) on a small scale by Saga Prefectural Sea Farming Centre.

Japanese participants at a round table discussion on kensaki-ika (*Photololigo edulis*) - Seikai National Fisheries Research Institute, Nagasaki, 16 July 1996.

Professor Yutaka Natsukari, Faculty of Fisheries, Nagasaki University, Bunkyou-cho, Nagasaki 852, JAPAN

Mr. Tatsuji Tameishi, Oceanographic Research Division, Shimane Prefectual Experimental Station, 25-1 Setogashima-cho, Hamada 697, JAPAN

Mr. Tomokichi Kobayashi, Fisheries Division, Yamaguchi Prefectual Open-sea Fisheries Experimental Station, 2861-3 Senzaki, Nagato 759-41, JAPAN

Mr. Toshiteru Watanabe, Fisheries Division, Yamaguchi Prefectual Open-sea Fisheries Experimental Station, 2861-3 Senzaki, Nagato 759-41, JAPAN

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Dr. Masaya Katoh, Resources Management Division, SNFRI

Mr. Yoshinobu Konishi, Resources Management Division, SNFRI

Mr. Takeo Kurihara, Resources Management Division, SNFRI

Mr. Harumi Yamada, Resources Management Division, SNFRI

Dr. Muneharu Tokimura, Resources Management Division, SNFRI

Dr Masanobu Matsuoka, Resources Management Division, SNFRI

Dr. Kouzou Kitani, Manager of Division, Fisheries Oceanography Division, SNFRI

Dr. Shigeru Shirai, Research Planning and Coordination Division, SNFRI