https://doi.org/10.24199/j.mmv.1983.44.19 30 June 1983

AUSTRALIAN CEPHALOPOD RESOURCES

By R. H. Winstanley,[1] M. A. Potter[2], and A. E. Caton[3]

[1] Fisheries and Wildlife Division, 250 Victoria Parade, East Melbourne, Vic., Australia, 3002
[2] Southern Fisheries Research Centre, P.O. Box 76, Deception Bay, Qld., Australia 4508
[3] Department of Primary Industry, Fisheries Division, Canberra, A.C.T., Australia, 2600

Abstract

Australian domestic catches of cephalopods total less than 1000 tonnes per annum and comprise many species none of which is intensively fished as a target species except in extremely localised situations. Recent catches by foreign fishing vessels operating within the 200-mile Australian Fishing Zone have shown that large squid and cuttlefish stocks occur in tropical waters off northern Australia and large squid stocks occur in temperate waters off southern Australia. Modest improvements in local markets and increased local awareness of these and other cephalopod resources have led to an upsurge in experimental and exploratory fishing and biological studies.

This paper summarises the fragmentary information on the occurrence, fisheries and biology of exploited and commercially potential cephalopod resources in Australian waters.

Introduction

This paper provides an overview of the exploited Australian cephalopod resources, including a summary of the biology of species for which information is available. A number of species with potential for exploitation have also been included.

Australian cephalopod fisheries are small—the domestic catch was less than 1,000 tonnes in 1979/80—and fisheries for many species are in their infancy. Until recently most cephalopods taken by Australian fishermen were destined for the bait market. While this remains important, the proportion of squid caught for human consumption has increased considerably during the last decade. Annual consumption of squid in Australia now exceeds 2,600 tonnes, but some 70 per cent of this is imported, mostly as frozen squid tubes from south-east Asia (Anon., 1980f).

Catches by foreign fishing vessels operating in and adjacent to the 200-mile Australian Fishing Zone (AFZ) have overshadowed domestic catches in recent years. Squid jigging vessels took 3387 and 7914 tonnes of squid from south-east Australian waters in 1978/79 and 1979/80, respectively. The cuttlefish component of the catch of Taiwanese pair trawlers operating in north and north-west Australian waters is of the order of 600 tonnes annually (Demersal Fisheries Research Centre 1980). Squid is the most important component in the catches by Taiwanese pair trawlers operating in the Arafura and Timor Seas (Liu *et al.*, 1978) with a total catch of 2660 tonnes in 1979 (Demersal Fisheries Research Center 1980). However, the AFZ database (based on logbook information from feasibility and licensed foreign fishing vessels) shows that in 1980, Taiwanese pair trawlers caught a total of only 370 tonnes of squid within the AFZ.

These figures indicate that although exploitation by Australian vessels is light, there are significant squid resources in Australian waters. As a consequence of low domestic catches, until recently, investigations of squid and other cephalopod resources have been accorded relatively low priority by Australian fisheries agencies. Hence there is little published information available on most cephalopod species in Australian waters.

In this paper the available information for each species is summarised under three headings:

(i) distribution, including geographic range in Australian waters, depth range, position in water column and seasonal and diurnal variations in occurrence;
(ii) biology including fisheries biology;
(iii) exploitation including experimental fishing results.

Reference is made to ongoing studies under the appropriate sections.

No attempt is made to compare results of local studies with those of overseas work on similar species or to summarise overseas infor-

Memoirs of the National Museum Victoria, No. 44, 1983.

mation for a species when there is none for that species in local waters.

Order TEUTHOIDEA, Family LOLIGINIDAE

Members of this family are neritic or continental shelf-dwelling species. Larger species are generally of commercial value.

Four species are already exploited by Australian fishermen and are described in more detail below. Several other species have been collected in northern Australian waters, but there is very little information on their distribution and abundance. They include commercially valuable species such as *Loligo edulis* Hoyle and *Doryteuthis singhalensis* Ortman.

Loligo chinensis Gray, 1849

Distribution: L. chinensis is synonymous with *L. etheridgei*, *L. formosana* and *L. indica* (Natsukari & Okutani, 1975) and occurs in the waters off Taiwan and southern China, the Gulf of Thailand, Arafura Sea and tropical and subtropical Australian waters (Tomiyama & Hibiya, 1978); it is also widely distributed off south-eastern Australia (Macpherson & Gabriel, 1962). It inhabits the shallow waters of the continental shelf and coastal bays and inlets (e.g. Gorman & Graham, 1981b). Off the coast of southern Queensland a few specimens have been taken by jig in waters as deep as 300 m (Potter, unpubl. data).

Biology: In southern Queensland waters *L. chinensis* grows larger than 600 g and 38 cm mantle length (ML). However, males and females mature as small as 12 cm ML and mature specimens can be found in most months (Potter, unpubl. data). *L. chinensis* exhibits a behavioural characteristic observed in other loliginids (Serchuk & Rathjen, 1974), congregating near the sea floor during the day and rising in the water column after dark. Consequently, demersal trawl catches are greater during daylight hours.

The seasonal abundance and reproductive biology of *L. chinensis* in southern Queensland is currently being investigated, but there is no published information yet available.

Exploitation: Most of the domestic catch of *L. chinensis* is taken as a by-catch of prawn trawling. However, this species becomes a target species at certain times of the year in some areas such as Moreton Bay, Queensland, where the maximum size commonly trawled is about 18 cm ML and the minimum size retained is approximately 7 cm ML. Larger specimens are occasionally taken by recreational fishermen on baited jigs or lures.

Landings of this species in Moreton Bay are highest in May but the quantities landed are strongly influenced by prawn catches and squid prices, and the local markets for squid can easily become saturated causing a decline in squid landings. When prawn catches are poor, fishermen trawl for *L. chinensis* as an alternative target species. Consequently the stocks of *L. chinensis* in Moreton Bay are not considered to be fully exploited (Potter, pers. obs.).

The species composition for the squid catch taken by Taiwanese pair trawlers operating in northern Australian waters is not known. However, *L. chinensis* is known to be abundant in parts of the Gulf of Carpentaria and Torres Strait and it is believed that this species might be an important component of Taiwanese pair trawl catches in the Arafura Sea area. Total squid catches in this area in 1976 were assessed as 17 per cent of a total catch of 44,900 tonnes (Liu *et al.*, 1978) and the same authors considered that less than 10 per cent of the potential yield (for all species) is being taken from the Arafura Sea. Much of this area, however, lies outside the declared AFZ. The recorded catch within the AFZ in 1980 was only 370 tonnes (AFZ database).

Loliolus sp.

Distribution: This species is presently being described (C. C. Lu, pers. comm.). It occurs in shallow coastal and estuarine waters on the east coast of Australia from northern Queensland to southern Victoria. Specimens have been collected in rivers and creeks with salinities as low as 2.2 per cent (Potter, unpubl. data).

Biology: No published information.

Exploitation: This species is caught incidentally by prawn trawlers and because of its small size (<8 cm ML) is usually marketed in Queensland and New South Wales as bait (Potter, pers. obs.).

Sepioteuthis australis Quoy and Gaimard, 1832

Distribution: Southern calamary *S. australis* occurs in coastal waters, bays and inlets of southern Australia from southern Western Australia to New South Wales. It is usually caught in depths less than 70 m and although its occurrence in research and commercial catches suggests that it is a largely demersal species (i.e. it is seldom trolled or caught by jigging machines) it is often observed at the surface (Gorman & Graham, 1981a,c).

Biology: During late winter and spring, clusters of eggs have been found attached to algae on reefs and to seagrasses in Port Phillip Bay, Western Port and Portland Bay, Victoria (Winstanley, unpubl.). Observations in South Australian gulfs show that several females may deposit eggs in collective egg-masses attached to seagrass, ascidians and other benthic organisms at depths of 3-20 m (Smith, 1981a).

Field and aquarium studies of the biology of *S. australis* are in progress in South Australia (Smith, 1981a).

Exploitation: S. australis is caught incidentally in bays and estuaries in seine nets, gill nets and prawn trawls and, in coastal waters, in fish and prawn trawls and Danish seines. During some seasons in gulfs and bays it is the target species for commercial fishing with seine nets and baited jigs on handlines. For instance, inside the entrances to Port Phillip Bay and Western Port, Victoria, both methods are used to take *S. australis* mainly in spring; smaller catches are taken in autumn mainly in seine nets. The annual catch is in the order of 100 tonnes (Winstanley, unpubl. data). In South Australia most of the catch in autumn and winter (the most productive seasons) is taken with seine nets and most of the catch in spring and summer is taken with handlines. The 1979/80 catch was 193 tonnes (Smith, 1981b).

Sepioteuthis lessoniana Lesson, 1830

Distribution: Northern calamary, *S. lessoniana*, is widely distributed throughout the Indo-Pacific from Japan to Australia and Hawaii to the east coast of Africa (Voss & Williamson, 1971). In Australian waters it inhabits subtropical coastal waters, bays and inlets from depths of less than 1 m to in excess of 100 m.

Biology: In Moreton Bay, Queensland, eggs were obtained in September from artificial collectors in shallow water (1-3 m), and hatching commenced after approximately 35 days at 20-24°C (Potter, unpubl. data).

Exploitation: S. lessoniana is taken for human consumption. In southern Queensland it is a prime market species taken mainly by tunnel net fishermen operating in the intertidal zone in Moreton Bay and Great Sandy Strait, from April to October. Prawn trawlers operating on the continental shelf in the same region take incidental catches during the same period. In the last few years handline fishing with baited jigs and lures from bayside jetties has become more popular, but this is still a small fishery (Potter, pers. obs.).

Order TEUTHOIDEA, Family OMMASTREPHIDAE

This family comprises neritic and oceanic species: *Nototodarus gouldi* (McCoy, 1888) is the major commercial species off south-eastern Australia; *Ommastrephes bartrami* (Lesueur, 1821) and *Symplectoteuthis oualaniensis* (Lesson, 1830) both of which are commercially exploited elsewhere in the Indo-Pacific, occur in offshore waters of the AFZ (Clarke, 1966; Nesis, 1979; Dunning *et al.*, 1981) and *Todarodes filippovae* Adam, 1975 occurs in the Southern Ocean and along the southern Australian coast (Anon., 1978, 1980c; Okutani, 1980) and might represent a latent resource (Okutani, 1980).

Nototodarus gouldi (McCoy)

Distribution: Gould's squid *N. gouldi* occurs in continental shelf waters off southern Australia from Queensland to Western Australia. Although it is sometimes abundant in shallow coastal waters and estuaries, particularly in summer, the greatest numbers occur in waters 50-200 m deep. The species has been trawled from as deep as 640-825 m in the Great Australian Bight (Berry, 1918) and as deep as 485 m off New South Wales (Gorman & Graham, 1981a). Schooling behaviour and the apparent occurrence of distinct broods (see below) contribute towards the variability in

distribution and abundance with locality and season (Anon., 1978, 1980c; Harrison, in prep.).

Biology: N. gouldi regularly grows to sizes of 1200 g and 40 cm ML and females grow to larger sizes than males (Anon., 1980c).

Several size-classes of squid are present in the Bass Strait region (Anon., 1978, 1980c; O'Sullivan, 1980a; Harrison, 1979, in prep.), possibly resulting from discrete spawnings or from variable mortality of larvae and juveniles (Harrison, in prep.). The summer spawning season can be clearly defined as in 1978/79 (January-February), or indistinct as in 1979/80 (December-March) (Harrison, in prep.).

According to Harrison (*op. cit.*), during the December-April fishing season in Bass Strait, jig catches comprise: remnants of the previous autumn brood mainly in December; a late winter or spring brood, the bulk of the catch; and a summer brood, mainly in March and April.

From catch data, Harrison (in prep.) estimated that the Bass Strait spring brood in 1979/80 grew at monthly rates that varied with locality from 109 to 200 g/month. Using the mantle length-weight relationship

$$W = 0.0183 \mathrm{ML}^{3.1073} \text{ kg}$$

together with monthly modal weights he found that the relationship

$$W = 1.06\ [1\text{-}2^{-0.3(t+1)}]^3 \text{ kg } (t \text{ in months})$$

provided a useful approximation to growth during the summer-autumn fishing season. Smith (1983) calculated a similar length-weight relationship for *N. gouldi* off Victoria and South Australia in 1979/80. From studies of modal progressions, growth of 1-2 cm/month has been reported from this region (Anon., 1978; Smith, 1981a). Harrison (in prep.) considered that *N. gouldi* lives no more than one year, however there are no data on longevity.

Off south-eastern Australia between September and April most males and females bigger than 22 cm and 30 cm ML, respectively, are sexually mature (Anon., 1978, 1980c, 1980e). But off New South Wales most females bigger than 22 cm ML are mature and copulated (Gorman & Graham, 1981a, b). The male produces up to several hundred spermatophores and, during mating, transfers these into the female's buccal pouch where fertilisation occurs subsequently (Harrison, in prep.); the time elapsing between mating and fertilisation is not known.

O'Sullivan (1980a, b) showed that *N. gouldi* is an opportunistic predator feeding on planktonic crustaceans, fishes and cephalopods. As squid grow, the incidence of crustaceans in the diet decreases while the incidence of cephalopods (including *N. gouldi*) increases. Feeding occurs mainly at night and at dawn, and food passes through the digestive tract rapidly.

Predators include seals, dolphins, tunas and benthic and bathypelagic fishes, notably school shark *Galeorhinus australis* (Macleay) (Olsen, 1954). In a study of the diets of 52 fish species exploited off Victoria, Coleman and Hobday (1982) found *N. gouldi* in the diets of only eight species with the greatest occurrence of 4-6 per cent in school shark and gummy shark *Mustelus antarcticus* Gunther. They suggested that increased exploitation of squid off Victoria would be unlikely to adversely affect fin-fish populations.

Echosoundings and trawl catches indicate that *N. gouldi* congregates close to the sea floor during the day and disperses into the mid and surface waters during the night. Limited tagging studies off south-eastern Australia have shown some movements in the order of 60 n.mi. (3 days) but recapture data are too few to show systematic movements of squid schools (Anon., 1980c).

Using catch and effort data from fishing logs of feasibility fishing boats in eastern Tasmanian and Bass Strait waters, Harrison (in prep.) estimated growth parameters, catchability coefficients; total, fishing and natural mortality rates; initial population size; yields and optimum levels under various combinations of parameter values. Natural mortality (M) appeared to increase sharply about 100 days after the start of the fishing season. This increase appears to coincide with the onset of spawning. Cannibalism is suggested as a significant component of M during the first 100 days although there is no direct evidence of this.

With some exceptions or ambiguous observations, squid catch rates have usually been found to be lowest in the full moon period (Anon., 1980c, 1980d; Gorman & Graham, 1981a; Smith, 1981a).

In comparing catch rates during the seasons from 1977/78 to 1980/81, the low rates obtained in 1979/80 have been ascribed to unusual oceanographic conditions in Bass Strait characterised by the absence of a marked thermocline (Anon., 1980e; Caton, 1981), and slightly lower maximum temperatures than in the two earlier seasons (Anon., 1980e; Harrison, in prep.). Commercial catch rates are obtained in waters ranging in temperature from 14° to 18°C (Anon., 1978).

In January-March 1980 in the Great Australian Bight, demersal trawls in the depth range 95-830 m showed that *N. gouldi* was most abundant in waters 300-400 m deep, occurred in 96 per cent of all hauls at these depths and were mainly caught during the day. In waters off South Australia, and off western and southern Tasmania the species occurred in about 50 per cent of all demersal and pelagic trawls where surface temperatures were between 12° and 24°C but were most abundant where surface temperatures were between 18° and 22°C (Collins & Baron, 1981).

During the 1980/81 season in Bass Strait and off western Victoria, comparisons were made of catch rates, length frequencies and sex ratios by fishing method (automatic and hand jigging), time of day and bottom depth (Anon., 1981c). Results showed that:

(i) catch rates for females were higher than for males using both fishing techniques;
(ii) catch rates by jigging machine increased progressively through the night while those from hand jigging were fairly constant;
(iii) mean lengths of machine-jigged squid decreased during the night while those of hand-jigged squid were constant;
(iv) hand-jigged females were larger than males while machine-jigged males and females were of similar sizes;
(v) hand-jigged squid were larger than machine-jigged squid; and
(vi) squid were caught at low rates in daylight hours.

Analysis of feasibility fishing results (T. I. Walker, unpubl. data) showed that catch rates exceeded 1 tonne per night where surface temperatures were 14°-19°C (range studied 11°-20°C) and that catches were greatest at depths of 40-100 m. Kowarsky and Mobley (1982) confirmed some of the observations (i)-(vi) above.

Exploitation: With few exceptions most commercial landings of *N. gouldi* by Australian fishermen have resulted from incidental catches during demersal trawling or trolling operations. A notable exception occurred during the summer of 1972/73 in the Derwent River estuary, Tasmania, where large numbers of squid appeared and 154 tonnes were caught by boats fitted with improvised gear (Wolfe, 1972). The order of magnitude of these domestic squid landings from New South Wales, Victoria, Tasmania and South Australia is 200 tonnes annually. Most of this is caught by trawlers in New South Wales offshore waters whence reported catches of all squid (mainly *N. gouldi*) have increased from 19 tonnes in 1975/76 (Anon., 1977) to 110 tonnes in 1978/79 (Anon., 1981b).

Squid feasibility fishing conducted during 1978/79 and 1979/80 (AFZ database) showed that the magnitude of squid catches taken by jigging off south-eastern Australia might be increased to several thousand tonnes annually. In 1978/79, 19 vessels caught 3,387 tonnes from December to May, mainly in the waters off western Victoria, western Bass Strait and eastern Tasmania. During the same period of the following year, 64 vessels fished over a wider area including eastern Victoria and South Australia and caught a total of 7,914 tonnes of squid. Western Bass Strait and northern Tasmanian waters were the most productive. Feasibility fishing was also conducted off south-western Western Australia during 1979/80 by a fleet of 22 vessels. Their catch was disappointingly low (808 tonnes) in contrast to catches from south-eastern Australia.

Feasibility fishing ended in 1979/80 and because of depressed world markets for squid,

joint venture operations have not proceeded since then.

Between October and March from 1977/78 to 1980/81 a Japanese squid research vessel fitted with jigging machines conducted resource surveys and biological studies of *N. gouldi* mainly in Tasmanian and Bass Strait waters. In the last year, operations were also conducted in South Australian, Victorian, and southern Queensland waters. Catches of 46, 121, 44, and just over 80 tonnes of *N. gouldi* were taken in those successive seasons, respectively (Anon., 1978, 1980c, 1980e; Caton, 1981). These catches are not directly comparable because of differences in the amounts and localities of fishing.

Australian vessels' attempts at midwater trawling and bottom pair-trawling for *N. gouldi* have been unsuccessful (Caton, 1981). Surface, subsurface and bottom mesh netting in Bass Strait has also been unsuccessful, leading to the conclusion that mesh netting is not an appropriate fishing method for this species (Jameson, 1981).

Ommastrephes bartrami (Lesueur, 1821)

Distribution: O. bartrami, a large oceanic species known as red ocean squid, occurs in subtropical waters of the southern Pacific and in the north-western Pacific (Collins & Dunning, 1981). It has been taken in research cruises and by commercial vessels off southern Western Australia (M. Dunning, pers. comm.), in the Great Australian Bight, in eastern Bass Strait, off New South Wales (Gorman & Graham, 1981a), and off Queensland as far north as 23°42′S (Dunning *et al.*, 1981). At all of these localities it has been caught in the deeper waters of the continental shelf and beyond.

Biology: No published information for Australian waters.

Exploitation: This species is presently not exploited in Australian waters.

In April 1981 a commercial fishing boat chartered for experimental squid mesh netting caught almost 290 kg of *O. bartrami* off north-eastern Tasmania and in eastern Bass Strait (Jameson, 1981). This species was found to be better suited to capture by mesh netting than the intended target species, *N. gouldi*, and further fishing was conducted during 1982 (Anon., 1982).

Also in April 1981 the Japanese research vessel *Hoyo Maru 81* caught more than 300 kg of *O. bartrami* weighing between 100 and 3000 g using automatic jigging machines in waters more than 1000 m deep off north-eastern Tasmania. Smaller catches were also taken east of Flinders Island and in deep water off eastern Bass Strait. Later in the month catches of *O. bartrami* were taken off southern Queensland (Dunning *et al.*, 1981).

Symplectoteuthis oualaniensis (Lesson, 1830)

Distribution: S. oualaniensis is widely distributed throughout tropical oceanic waters of the Indo-Pacific from the west coast of Central America to the Cape of Good Hope and from southern Japan to Australia (Tomiyama & Hibiya, 1978).

Biology: There is no published information for Australian waters.

Exploitation: This species is exploited commercially off the Ryukyu Islands of southern Japan and off Taiwan (Okutani & Tung, 1978). It is not exploited in Australian waters but small catches were taken during a cruise of the Japanese research vessel *Hoyo Maru 81* off southern Queensland in April 1981 (Dunning *et al.*, 1981). There is no other published information on this species in Australian waters.

Order SEPIOIDEA, Family SEPIIDAE

The Australian cuttlefish fauna appears to be the richest in endemic species in the world with about 20 species (Adam & Rees, 1966; Adam 1979) but exploitation of the resources by Australian fishermen is low. A number of these species may have some potential for future exploitation if suitable export markets are developed.

Sepia pharaonis Ehrenberg, 1831

Distribution: S. pharaonis is distributed throughout the Indo-West Pacific region from the Red Sea to southern Japan. In Australian waters it occurs from Rottnest Island (Western Australia) through northern Australian waters to the Capricorn Group at the southern end of

the Great Barrier Reef (Queensland) (Adam, 1979).

Biology: There is no information available on the biology of this species in Australian waters. It is amongst the largest of the cuttlefish growing to 4 kg in weight (Tomiyama & Hibiya, 1978).

Exploitation: This cuttlefish is widely exploited by trawlers operating off the Arabian Peninsula (Okutani, 1977) and in south-east Asia (Tomiyama & Hibiya, 1978). Taiwanese pair trawlers caught approximately 600 tonnes of cuttlefish off northern Australia in 1979 (Demersal Fisheries Research Center 1980). The catch reported from within the AFZ was about 350 tonnes in 1980 (AFZ database). Approximately 90 per cent of this cuttlefish catch was *S. pharaonis* (C. C. Lu, pers. comm.).

Small quantities of this cuttlefish, caught incidentally by prawn trawlers, are occasionally sold in local markets on the east coast of Queensland (Potter, pers. obs.).

Other **Sepia** species

Distribution: Off southern Australia two *Sepia* species, *S. apama* Gray and *S. braggi* Verco are exploited commercially (Winstanley, 1981, unpubl. data). *S. apama* is the largest and most abundant and occurs over reefs, seagrass beds and open trawl ground in coastal waters and bays.

In subtropical and tropical waters a number of species are occasionally marketed including *S. chirotrema* Berry, *S. rex* Iredale and *S. elliptica* Hoyle (Potter, pers. obs.).

Biology: No published information.

Exploitation: New South Wales cuttlefish landings, mainly by trawlers, have risen from 17 tonnes in 1975/76 to 87 tonnes in 1978/79 (Anon., 1981b). Small quantities of cuttlefish are landed in other states, taken incidentally in trawls, beach seines and fish traps.

Order OCTOPODA, Family OCTOPODIDAE

Octopus in Australian waters have only been lightly exploited.

Considerable interest has been developing in recent years in the market possibilities for octopus taken incidentally in rock lobster pots and some research has been directed to investigating this potential. Domestic markets for octopus are small, but some species are suitable for export particularly to the Japanese market.

Octopus australis Hoyle, 1885

Distribution: O. australis occurs among ascidians, sponges and molluscs and in seagrass beds in bays and coastal waters off southern Australia (Macpherson & Gabriel, 1962, Winstanley, unpubl.).

Biology: Tait (1980) described some aspects of the ecology and life history of *O. australis* in Port Phillip Bay, Victoria. Females brood one group of 50-130 eggs measuring about 11 mm long, mainly during summer. Eggs are usually attached to the inside of an old mud oyster (*Ostrea angasi* Sowerby) shell, a drink can or similar object. After 100+ days the young hatch and immediately adopt a benthic existence. During their lifespan, estimated at 18-20 months, males grow to 210 g and females to 105 g. Once females commence brooding, their food intake diminishes and they usually lose weight. *O. australis* feeds mainly on isopods; the diet also includes other crustaceans, gastropods, bivalves, polychaetes and octopus.

Exploitation: This species is virtually unexploited. Trivial quantities are caught incidentally in scallop and mussel dredging and beach seining operations in Port Phillip Bay. Because of its small size and slender arms it is difficult to skin and is sold mainly for bait. Its main development potential appears to be extremely limited, for instance as bait for the longline fishery for snapper *Chrysophrys auratus* (Bloch and Schneider) (Winstanley & Kearney, 1982).

Experimental trapping in Port Phillip Bay has shown that catch rates of *O. australis* varied with trap type and locality from 0 to 52 octopus per 100 trap-lifts (Winstanley & Kearney, 1982).

Octopus flindersi Cotton, 1932

Distribution: O. flindersi occurs on coastal reefs off South Australia and Western Australia and is prominent as a predator of southern rock lobsters *Jasus novaehollandiae* Holthius especially those trapped in pots (Anon., 1981a).

Biology: No published information (apart from observation of predation on rock lobsters in pots).

Exploitation: South Australian rock lobster fishermen are keen to catch *O. flindersi* mainly to reduce predation on the highly-valued rock lobsters. Trial exports have shown that the large size and toughness of this species make it unacceptable for Japanese markets while the lack of adequate freezer-storage facilities hinders development oriented towards local or European markets (Anon., 1981a). Competition from West African trawled octopus eroded some progress made in marketing in Europe during 1982 (Winstanley, unpubl.).

Octopus pallidus Hoyle, 1885

Distribution: O. pallidus occurs off New South Wales, Victoria, Tasmania and South Australia (Macpherson & Gabriel, 1962). These authors stated that the species is often trapped in rock lobster pots and have been taken in depths as great as 366 m. However, commercial fisheries and research catch information (Winstanley, unpubl. data) suggests that *O. pallidus* is largely confined to depths less than 110 m and occurs mainly among bryzoans, sponges and ascidians suggesting that the above report may have involved misidentification.

Biology: No published information.

Exploitation: Most of the commercial landings of *O. pallidus* (mean size about 500 g) are incidental catches by inshore fish or prawn trawlers and by Danish seiners which also catch small quantities of other *Octopus* species (Winstanley, pers. obs.). The total annual catch of these species from New South Wales and Victorian waters is in the order of 160 tonnes (Anon., 1981b; Winstanley, unpubl. data).

Dix (1981) described the results of an octopus trapping survey conducted off northern Tasmania between November 1980 and August 1981. The total catch of 6.7 tonnes comprised *O. pallidus* (92 per cent, mean weight 810 g) and a larger unidentified species (mean weight 2120 g). Monthly catch rates for *O. pallidus* were highest in April (64 per 100 trap-lifts) and lowest in November (18 per 100 trap-lifts).

During 1981 and 1982, experimental trapping has been conducted in Port Phillip Bay and off the central Victorian coast. At the latter location between August 1981 and May 1982 (in depths of 35-70 m), catch rates were highest in October (44 per 100 trap-lifts) and were low (8-13 per 100 trap-lifts) during other months. During this period the mean size increased to 700 g (Winstanley, unpubl.). In Port Phillip Bay, catch rates varied with locality and trap type from 0 to 10 per 100 trap-lifts in March and April 1982 (Winstanley & Kearney, 1982).

Octopus tetricus Gould, 1852

Distribution: O. tetricus occurs off southern Western Australia and has been reported to occur off eastern Australia (Joll, 1977a). In Western Australia it inhabits coastal reefs where it is a major predator of western rock lobster *Panulirus cygnus* George trapped in pots (Joll, 1977b); it also inhabits seagrass beds such as occur in Cockburn Sound near Fremantle.

Biology: Because of its significance as a rock lobster predator and, more recently, its value as a resource with fishery potential in its own right, *O. tetricus* has been studied more than any other *Octopus* species in Australian waters. In aquaria with excess food available, *O. tetricus* grows rapidly and the daily feeding rate is a function of weight and water temperature; food intake diminishes and weight loss occurs in ageing animals (including brooding females) and there is an approximately linear relationship between growth in weight and daily feeding rate (Joll, 1977a).

Males mature at sizes of 100-150 g and females at larger sizes. After copulation spermatazoa are stored for 12-114 days before egg-laying (usually nocturnal) which occurs over several days. Eggs are laid in strings and a female weighing 2.1 kg laid approximately 150,000 eggs.

Embryonic development varies inversely with water temperatures and takes 22-36 days; hatching of 2.5 mm long larvae takes 6-28 days. During the period of embryonic development and hatching, females cease feeding and actively tend and defend their eggs then die 5-20 days after their eggs have all hatched (Joll, 1976).

Exploitation: Although Joll (1977b) estimated

the annual quantity of octopus (largely *O. tetricus*) caught by rock lobster fishermen as 138-247 tonnes, commercial landings statistics and reports (Anon., 1980b) show that virtually all of this was killed and discarded or used for bait. Experimental trapping and resource assessment work (see below) resulted in an increase in reported landings from 1 tonne in 1978/79 to 29 tonnes in 1979/80. A trial shipment of *O. tetricus* (mean live weight 0.7 kg) showed that, properly processed and frozen, this species is most acceptable to the Japanese market (Anon., 1980a). Kimura (1979) estimated that 30,000 tonnes could be caught annually from Fremantle to north of Geraldton.

Fishery development investigations off southern Western Australia have been conducted in three phases (Anon., 1980a). From March to May 1978, various fishing methods, gear types and localities were tested, then from November 1978 to March 1979, commercial feasibility fishing trials were conducted in Cockburn Sound and off Geraldton resulting in a total catch of 5 tonnes which were processed and shipped to Japan. A detailed account of this second phase of the survey (Kimura, 1979) describes the vessel, gear, methods, export considerations, market evaluations and recommendations for Australian fishermen. From December 1979 to June 1980, a full-scale commercial feasibility trial was conducted using a Japanese octopus-trapping vessel at the same localities using cylindrical traps made of PVC pipe. The results show that catch rates vary within and between seasons with means of 5.44, 9.66 and 5.31 per 100 holes (4 holes per trap) during the three phases. Best results were obtained between January and June (Anon., 1980b).

Octopus species

Distribution: One or more large *Octopus* species of uncertain identity occur on coastal reefs at depths of 0-50 m off south-eastern Australia and are reported to reach sizes of 14 kg (Winstanley, unpubl.). These are similar to *O. flindersi*.

Biology: No published information.

Exploitation: As with *O. tetricus* and *O. flindersi* these species are mainly encountered and exploited by rock lobster fishermen most of whom do not actively seek to catch them. Recently a few South Australian fishermen have experimented with traps or have modified their rock lobster pots to retain octopus and catches of up to 0.5 tonnes of 1-5 kg octopus per month have been reported from a boat fishing in shallow reefs (0-25 m) during summer in Discovery Bay, western Victoria. Low prices on local and European markets have discouraged development of a fishery for these species (Winstanley, unpubl.).

Fishermen do not discriminate between the species of octopus they land so it is difficult to estimate the degree of exploitation for each species. The total annual catch of the above *Octopus* species plus *O. flindersi* off South Australia is in the order of 100 tonnes (Anon., 1981a).

Private and government-funded investigations of capture methods and fishery potential have been conducted by fishermen in south-eastern Australia (e.g. Anon., 1981a, d). The only account of results of such work (Dix, 1981) is discussed under *O. pallidus*.

Acknowledgements

The authors are grateful to Malcolm Dunning who refereed the manuscript and made many useful suggestions.

References

ADAM, W., 1979. The Sepiidae (Cephalopoda, Decapoda) in the collections of the Western Australian Museum. *Rec. West. Aust. Mus.* 7(2): 111-212.

ADAM, W. & REES, W. J., 1966. A review of the cephalopod family Sepiidae. *Sci. Rep. John Murray Exped.* 1933-34, 11(1): 1-165.

ANONYMOUS, 1977. Report on the fisheries in New South Wales for 1975-76. Government Printer, New South Wales, 26 pp.

ANONYMOUS, 1978. Report on feasibility study on squid jigging fisheries in the south-western Pacific Ocean, 1977. *Japan Marine Fishery Resource Research Centre Report* No. 18, 163 pp.

ANONYMOUS, 1980a. A possible octopus fishing industry in Western Australia. *FINS* 13(1): 4-6.

ANONYMOUS, 1980b. Octopus survey. *FINS* 13(2): 21-22.

ANONYMOUS, 1980c. Report of feasibility study 1978 on squid jigging fisheries in the south-western Pacific Ocean. *Japan Marine Fishery Resource Research Centre Report* No. 19, 178 pp.

ANONYMOUS, 1980d. Preliminary report Tasmanian squid catch to 30 April, 1980. *FINTAS* 2(6), 10.

ANONYMOUS, 1980e. Report of the squid survey by the F.V. *Hoyo Maru 67* in south-east Australian waters 1979/80. *Japan Marine Fishery Resource Research Centre Report* No. 22, 43 pp.

ANONYMOUS, 1980f. Australian squid consumption 2600 tonnes a year; most imported. *Aust. Fish.* 39(10): 52.

ANONYMOUS, 1981a. Attempts will be made to find best way of catching octopus. *SAFIC* 5(4): 14-15.

ANONYMOUS, 1981b. Report on the fisheries in New South Wales for 1978-79. Government Printer, New South Wales, 36 pp.

ANONYMOUS, 1981c. Monitoring squid catches aboard F.V. *Hoyo Maru 81.* Fisherman's News, Fisheries and Wildlife Division, Victoria 4(1): 13.

ANONYMOUS, 1981d. Fishing industry research grants announced. *Aust. Fish.* 40(5): 4-5.

ANONYMOUS, 1982. Squid survey continues. *Professional Fishermen* 4(4): 23.

BERRY, S. S., 1918. Report on the Cephalopoda obtained by the F.I.S. *Endeavour* in the Great Australian Bight and other southern Australian localities. Biological results of the Fishing Experiments carried on by the F.I.S. *Endeavour*, 1909-14 IV(5), 203-298, Plates LIX-LXXXVIII.

CATON, A. E., 1981. *Hoyo Maru* takes good Gould's squid catches in Bass Strait Survey. *Aust. Fish.* 40(12): 22-25.

CLARKE, M. R., 1966. A review of the systematics and ecology of oceanic squids. *Adv. Mar. Biol.* 4: 91-300.

COLEMAN, N. & HOBDAY, D., 1982. Squid not vital in the diets of commercially important fish from SE Australia. *Aust. Fish.* 41(11): 6-8.

COLLINS, S. & BARON, M. P., 1981. Demersal and pelagic trawling survey of the M.T. *Denebola* in southern Australian waters, 1979/80 summer. *Tas. Fish. Res.* 24: 48 pp.

COLLINS, S. & DUNNING, M., 1981. Tasman squid studies demonstrate gillnetting effective. *Aust. Fish.* 40(8): 2-6.

DEMERSAL FISHERIES RESEARCH CENTER, 1980. Annual Report of Effort and Catch Statistics by Area on Taiwan Demersal Fish Fisheries—1979.

DIX, T. D., 1981. Octopus survey in Bass Strait. *FINTAS* 4(2): 4-7.

DUNNING, M., POTTER, M., & MACHIDA, S., 1981. *Hoyo Maru* survey shows oceanic squid could have potential. *Aust. Fish.* 40(12): 26-29.

GORMAN, T. B. & GRAHAM, H. J., 1981a. *Kapala* Cruise Report No. 68, 12 pp.

GORMAN, T. B. & GRAHAM, K. J., 1981b. *Kapala* Cruise Report No. 69, 6 pp.

GORMAN, T. B. & GRAHAM, K. J., 1981c. *Kapala* takes small but encouraging squid catches. *Aust. Fish.* 40(8): 7-10.

HARRISON, A. J., 1979. Preliminary assessment of a squid fishery off Tasmania. In: Squid Outlook Tasmania 1979/80, H. E. Rogers (Ed.), Tasmanian Fisheries Development Authority, 60 pp.

JAMESON, J., 1981. Bass Strait trials show mesh netting for red ocean squid has potential. *Aust. Fish.* 40(12): 20-29.

JOLL, L. M., 1976. Mating, egg-laying and hatching of *Octopus tetricus.* (Mollusca:Cephalopoda) in the laboratory. *Mar. Biol.* 36: 327-333.

JOLL, L. M., 1977a. Growth and food intake of *Octopus tetricus* (Mollusca:Cephalopoda) in aquaria. *Aust. J. Mar. Freshw. Res.* 28: 45-56.

JOLL, L. M., 1977b. The predation of pot-caught western rock lobster (*Panulirus longipes cygnus*) by octopus. *Dept. Fish. Wildl. West. Aust. Report* No. 29, 58 pp.

KIMURA, Y., 1979. Report on the second-phase survey for commercial harvesting of octopuses in the Western Australian waters. National Federation of Fisheries Co-operative Associations of Japan, 47 pp.

KOWARSKY, J. & MOBLEY, M. C., 1982. Effects of freezing, gear type and time of sampling on biological measurements of the arrow squid *Nototodarus gouldi* (McCoy) (Ommastrephidae). *Victorian Fish. Wildl. Div. Mar. Sci. Lab. Tech. Rep.* No. 14, 12 pp.

LIU, H. C., LAI, H. L., & YEH, S., 1978. General review of demersal fish resources in the Sunda Shelf and the Australian waters. *Acta Oceanographica Taiwanica* 8, 109-140.

MACPHERSON, J. H. & GABRIEL, C. J., 1962. Marine Molluscs of Victoria. Handbook No. 2, National Museum of Victoria, 475 pp.

NATSUKARI, Y. & OKUTANI, T., 1975. Taxonomic and morphological studies on the loliginid squids. I. Identity of *Loligo chinensis*—redescription of the type specimen and taxonomic review. *Venus* 34(3, 4): 86-91.

NESIS, K. N., 1979. Squid of the family Ommastrephidae in the Australian-New Zealand region. *Tr. Inst. Oceanol.* 106: 140-146.

OKUTANI, T., 1978. Stock assessment of cephalopod resources fished by Japan. *FAO Fish. Tech. Pap.* No. 173, 62 pp.

OKUTANI, T., 1980. Useful and latent cuttlefish and squids of the world. National Co-operative Association of Squid Processors, Tokyo, 66 pp., Revised edition.

OKUTANI, T. & TUNG, I. H., 1978. Reviews of biology of commercially important squids in Japanese and adjacent waters. I. *Symplectoteuthis oualaniensis* (Lesson). *Veliger* 21(2): 87-94.

OLSEN, A. M., 1954. The biology, migration and growth rate of the school shark *Galeorhinus australis* (Macleay) (Carcharhinidae) in south-eastern Australian waters. *Aust. J. Mar. Freshw. Res.* 10(2): 150-176.

O'SULLIVAN, D., 1980a. The food and feeding of the squid *Nototodarus gouldi* (McCoy) in Bass Strait and adjacent waters. Unpublished B.Sc. Hons. Thesis, Monash University, Victoria, 56 pp.

O'SULLIVAN, D., 1980b. Biology of Gould's squid in Bass Strait studied. *Aust. Fish.* 39(12): 18-19.

SERCHUK, F. M. & RATHJEN, W. F., 1974. Aspects of the distribution and abundance of the long-finned squid, *Loligo pealei*, between Cape Hatteras and Georges Bank. *Mar. Fish. Rev.* 36(1): 10-17.

SMITH, H., 1980. Report on SAFCHU feasibility ventures. *SAFIC* 4(1): 14-18.

SMITH, H., 1981a. Preliminary trials on egg hatching and rearing of the southern calamary (*Sepioteuthis australis*). *Aust. Mar. Sci. Assoc. Bull.* 79: 35.

SMITH, H., 1981b. The development potential of the southern calamary squid (*Sepioteuthos australis*) fishery. *SAFIC* 5 (1): 28-29.

SMITH, H. (This volume). Fishery and biology of *Nototodarus gouldi* (McCoy, 1888) in western Bass Strait.

TAIT, R. W., 1980. Aspects of the ecology and life history of *Octopus australis* Hoyle, from northern Port Phillip Bay. Unpublished B.Sc. Hons. Thesis, Monash University, Victoria, 77 pp.

TOMIYAMA, T. & HIBIYA, T. (EDS.), 1978. Fishes in Japan: Squid and Cuttlefish. Japan Marine Products Photo Materials Association, Tokyo, 162 pp.

VOSS, G. L. & WILLIAMSON, G., 1971. Cephalopods of Hong Kong. Hong Kong Government Press, Java Road, Hong Kong, 138 pp.

WINSTANLEY, R. H., 1981. Fisheries resources of Victoria's coastal and offshore waters. *Proc. Roy. Soc. Vict.* 92: 81-92.

WINSTANLEY, R. H. & KEARNEY, J., 1982. Experimental and exploratory octopus trapping in Port Phillip Bay, December 1980—April 1981. *Vict. Fish. Wildl. Div. Comm. Fish. Rep.* No. 7, 13 pp.

WOLFE, D. C., 1972. Squid fishing and the Tasmanian potential. *Tas. Fish. Res.* 6(2): 26-31.