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REVIEW OF CEPHALOPOD RESOURCES IN THE EASTERN NORTH PACIFIC

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Resource Ecology and Fisheries Management Division
and
Marine Mammals Division

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NOTICE

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CONTENTS

1. PURPOSE OF THE REVIEW

Most of the traditional fishery resources of the oceans are extensively exploited. As a result, standing stocks and catch per unit effort of many species are declining. The principal under-exploited resources of the world oceans are squids, some offshore pelagic nonschooling fish species, and Antarctic krill. The potential of the squid resource is considered larger than that of krill, squid resources occur nearer to major exploiting and consuming nations than krill, and some species are already utilized as human food and considered to be delicacies. Some squid species, occurring periodically off coasts in near-surface layers, are already heavily exploited (e.g., Todarodes pacificus off Japan). However, the fishing industry is turning now to the large offshore squid resources. A typical example for picturing the size of the squid resources is the computation that sperm whales consume a minimum of 300 million tons of squids (not all suitable for human food) annually. Although some information is available on a few exploited squid species, little detailed knowledge and data is available on the offshore squids of the eastern North Pacific in respect to the magnitude and distribution of the resource. Therefore, this review is brief, encyclopedic in form, and written to nonspecialists. The review calls attention to the potential of squid resources in the northeast Pacific and the need to obtain more information through field surveys and ecosystem evaluation.

2. PRESENT FISHERY AND PROJECTED FUTURE DEMAND FOR SQUIDS AND OTHER CEPHALOPODS

2.1 Cephalopods used by man and notes on their ecology.

Cephalopods are soft-bodied invertebrates from the phylum Mollusca. Those utilized by man include members of the orders Octopoda (octopuses), Teuthoidea (squids), and Sepioidea (cuttlefishes).

Octopuses are eight-armed cephalopods, mostly benthic (bottom living), although there are a few edible and abundant nektonic (free swimming) species.

Squids are 10-armed cephalopods, nektonic, and mostly living in the open ocean; only a few species return to spawn in shallower water (e.g., Loligo opalescens off California). Many species live in relatively deep water (200 to 2,000 m). Squids inhabiting the surface layers (down to about 300 m) and caught by man in the North Pacific include members of the families: Ommastrepidae (e.g., Todarodes pacificus, the principal squid species caught off Japan); Loliginidae (e.g., Loligo opalescens off California); Gonatidae (also called boreal squids), abundant in higher latitudes (north of lat. 50°N) over deep ocean in intermediate layers (100 to 400 m) (e.g., Berryteuthis magister, an important food item for sperm whales in the North Pacific); and Onychoteuthidae.

Cuttlefishes are short-bodied, 10-armed cephalopods with internal cuttlebone. They are neritic (living on the continental shelf, mainly on the bottom, and feeding on bottom-associated organisms).

Squids vary in size (length) from a few centimeters to 10 meters (arms extended), weighing from a few grams to one ton. Most squids are, however, between 10 cm and 1 m long. Growth rate of squids is fast--about 15% of length per month. Some squids have only 1 year lifespan (e.g., Todarodes pacificus), although most species have several years' lifespan, maturing usually in the second year.

Nektonic squids form schools. The speed of the oceanic squid is faster than that of many fish, and because they are able to sustain high speeds, they are seldom caught in midwater trawls.

Squids occur at wide range of depths. They require higher salinity water (>30 $^{o}/_{oo}$) and do not occur in coastal waters of low salinity.

Some squid species that live near the surface undertake long seasonal migrations in large schools--toward the north in spring and back to the south in autumn. Most species undertake diurnal vertical migrations toward the surface in the evening and back into deep water in the morning. Organisms of the deep scattering layers in the oceans consist mainly of squids.

2.2 Uses, present fishery, and expected future developments

Uses - Cephalopods (squids, octopuses, and cuttlefishes) are considered a delicacy among sea foods in south European countries, Japan, and in some other far eastern countries. They are a high protein, low fat food. Squids are usually eaten fried, but lately have been used in chowders (instead of clams). In the U.S. they

are marketed as a human food in the large coastal cities. Squid and octopus find a ready market in California where recently squid steaks (prepared from mantles of larger, tropical squids imported from Japan) are becoming popular in San Francisco, Monterey, and San Diego. Most of the California catch of Loligo squid is used for bait.

Catches - The worldwide catch of cephalopods is about 1 million tons, most of which is caught by Japan and the Mediterranean countries (Spain, Italy). The Japanese cephalopod catch comprised nearly 8% of the total fish catch a few years ago. This catch has, however, declined due to the decline of Todarodes pacificus resources. The total world catch of octopuses is about 120,000 tons (mostly by Japan and Spain).

About 10,000 tons of squids (Loligo opalescens) are caught annually off California. The only other recent attempts to initiate cephalopod fisheries in the northeast Pacific are a few Japanese experimental attempts off California (mainly research oriented) and in the southern Bering Sea (for Paraoctopus and Gonatidae).

Catching methods - Benthic octopuses are caught mainly with bottom trawls and with pots. Cuttlefishes are caught with trawls, with set nets, and by angling.

Loligoid squids are caught during spawning seasons with a variety of gear, such as seines, trawls, lampara nets, and by jigging.

Ommastrepid squids (such as Todarodes sp) and other open ocean squids are caught mainly by jigging. A net fishery is also a possibility for catching large, migrating schools of squids moving in near-surface layers. Midwater trawling for squids is not effective due to the squids ability to evade trawls.

Expected future developments - The degree of exploitation and utilization of squid resources in the future depends on five conditions and developments:

1. Development of efficient catching methods and gear for open ocean squids. The efficiency of the present catching method by jigging is low and squids are therefore an expensive delicacy. Midwater trawls are inefficient for the catching of squids. Fast setline gillnets with preset depth (pressure) floats might be a possible future deep ocean squid fishing method. Self-propelled, fast submersibles might be another future method.

2. Increased demands for squids in present squid-consuming countries (Japan, Mediterranean countries, Taiwan, Korea, etc.). Additional demand and markets already exist in these countries, but demands might arise if prices can be lowered (catching methods made more efficient). Due to the declining catches of Todarodes sp off Japan, this country is already intensively exploring the possibilities of expansion of their squid fisheries to other coastal areas where traditional methods and gear can be used, and to offshore areas.

3. Creation of taste, demand, and markets in the United States. This task would require considerable marketing propaganda, especially as the palatability of squids depends largely on the way (method) of preparation. It might be hastened if some fast food chains start to sell "calamari e camberi" (fried squids and shrimp).

4. Effects of demand (and supply) of other sea food (fish). As the world limit of harvesting of traditional fisheries resources will be reached in a few years, and as catches from many traditional fishing areas are already declining (North Atlantic), the increased demand for seafood might be supplemented gradually by squids.

5. Sports fishery. Jigging for squids can be considered as a sports fishing activity. Its further development might be accelerated if salmon (and some other popular sport fishing species) catches in coastal waters are regulated; if larger vessels are used in the sports fishery (more seaworthy "party boats"), and if the taste for squids is developed in coastal communities.

3. SQUIDS IN MARINE ECOSYSTEM

3.1 Squids as food source for fish and mammals

Oceanic squids are a major food item for some of the Odontocetes, (toothed whales), e.g., sperm whales; pinnipeds, e.g., fur seals; and larger pelagic fish, e.g., salmon. Most of the quantitative knowledge on oceanic squids originates from the food studies of the marine mammals and fish.

The largest consumer of squids in the oceans is the sperm whale. About 90% of its food consists of oceanic squids. Unfortunately the estimates of the numbers of sperm whales, their size, and food requirements vary considerably in literature from one source to another. We might attempt a conservative estimate of squids consumed in the North Pacific with the following numbers: number of sperm whales 150,000; average weight 15 tons (i.e., total biomass in the North Pacific would be 2.250×10^6 tons); average food requirement 4% body weight daily, of which 90% (3.6% body weight daily) are squids. Thus the North Pacific sperm whales would consume conservatively about 30 million tons of squids annually. Clarke's (1977) conservative estimate of squids consumed by sperm shales on a worldwide basis is 320 million tons.

Squid species identified from the stomachs of sperm whales taken near the Aleutian Islands, and in the Bering Sea and Gulf of Alaska are listed in Table 1.

Nearly all pelagic marine mammals (e.g., Dall porpoise and fur seals) feed to some extent on squids which are available in near-surface layers. Table 2 lists cephalopods identified from the stomachs of fur seals taken off California, Oregon, Washington, and Alaska. Smaller squids are eaten by all larger pelagic fish (e.g., tunas, salmons, pomfrets) and even by some species of marine birds (e.g., sooty shearwaters). The marine ecosystem in the North Pacific consumes about 220 million tons of squids as food annually.

Table 1.--Squids identified from the stomachs of sperm whales from the Bering Sea and Gulf of Alaska.

Cephalopoda	Aleutian area and Bering Sea	Gulf of Alaska
Family Gonatidae		
Gonatopsis borealis	2	
Berryteuthis (Gonatus) magister	1,2	1
Gonatus fabricii	2	
Gonatus fabricii var separata	2	
Gonatopsis makko	1	
Family Octopoteuthidae		
Octopteuthis longipetra	2	
Family Onychoteuthidae		
Moroteuthis robustus	1,2	1
Onychoteuthis (banksii) borealijaponicus	2	
Family Histioteuthidae	2	
Stigmateuthis	1	
Meleagroteuthis separata	2	
Family Architeuthidae		
Architeuthis japonica	2	
Family Chiroteuthidae		
Chiroteuthis veranyi	2	
Family Mastigoteuthidae		
Mastigoteuthis sp	1	
Family Cranchidae		
Taonius pavo	1,2	
Galiteuthis armata	1,2	
Cristalloteuthis behringiana	2	
Family Ommastrephidae		
Todarodes (sloaneipacificus) pacificus	2	
Ommastrephes bartrami	2	
Order Octopoda		
Octopus sp.	2	

1 Data from Okutani and Nemoto (1964).

2 Data from Kodolov (1970).

Table 2.--Cephalopods identified in the stomach contents of northern fur seals (Callorhinus ursinus) collected during pelagic fur seal investigations 1958-1974.

Year	Location 1/	Family, genus, species: Loligo opalescens	Abraliopsis sp	Octopoteuthis sp	Other Gonatidae	Gonatus fabricii	Gonatus sp	Berryteuthis magister	Gonatopsis borealis	Onychoteuthis borealijaponicus	Moroteuthis robusta	Chiroteuthis sp	Unidentified squid
1958	CA	x				x				x			x
	OR	x								x			x
	WA												
	AK(SE,GA, WA,BS)												x
1959	CA	x					x			x			x
	OR	x					x			x			x
	WA	x					x			x			x
1960	AK				x	x		x	x				
1961	CA	x	x		x				x	x			x
	OR	x			x								x
	WA	x			x				x	x			x
	BC	x			x			x					x
1962	AK(WA,UP, BS)				x	x		x	x				x
1963	AK(BS)				x	x		x	x				
1964	CA	x			x	x				x			x
	OR	x			x	x				x			x
	WA	x			x	x		x	x				x
	AK(BS)				x	x		x	x				
1965	CA	x	x		x	x		x	x	x	x		x
	WA	x			x	x							x
1966	CA	x	x		x	x				x	x		x
1967	WA	x			x	x				x			
1968	WA	x			x	x		x		x		x	x
	AK(GA,BS, WA)				x	x		x	x				x
1969	WA	x	x		x		x			x			x
1970	WA	x	x		x		x	x	x	x	x	x	x
1971	WA	x	x		x		x		x	x		x	x
1972	WA	x	x	x	x		x	x	x	x	x	x	x
1973	AK(BS)				x		x	x	x				x
1974	AK(BS)				x		x	x	x				x

1/ SE=southeast, GA=Gulf of Alaska, WA=western Alaska, UP=Unimak Pass, BS=Bering Sea, CA= California, OR=Oregon, WA=Washington,AK=Alaska, BC=British Columbia.

Many squid species migrate seasonally in large schools in a north-south direction. These seasonally migrating squid schools are followed by fish, marine mammals, and birds.

3.2 Diet of squids

Small (juvenile) squids (and other small, juvenile cephalopods) feed on crustaceans, mainly on planktonic euphausids. However, adult squids are the most militant inhabitants of the seas, attacking larger prey than themselves. Some squid species are also venomous. All squids, longer than about 20 cm, feed exclusively on pelagic fish (e.g., Pacific saury, Cololabris saira, and other myctophids) and on other smaller cephalopods. Cannibalism is common in squids. Large squids (Architeuthidae) can overpower even large tunas. Squid attack marks are often found on tunas and salmons. It has been speculated that the inter-annual variation of abundance of squids might materially affect the fluctuations of the abundance of pelagic fish, especially small species (saury, sardines, etc.).

4. PRESENT STATE OF KNOWLEDGE OF CEPHALOPOD RESOURCES IN THE EASTERN NORTH PACIFIC

4.1 Octopuses

There are several species of octopuses along the west coast of the United States which are suitable for a specialized, small boat fishery and are presently being taken incidentally in the trawl fishery. Some of these incidentally taken octopuses are marketed in coastal cities; however, other domestic markets must be developed or export to Japan or to the Mediterranean countries organized before these species can be caught commercially.

Demersal species of octopus of the genus Octopus are found over the continental shelf and slope from southern California waters northward into the Bering Sea. The members of this genus are all potentially valuable for human consumption and presently command premium prices when brought in by trawlers. Octopus sp are frequently identified in the stomach contents of sperm whales taken near the Aleutian Islands and regularly occur in trawler catches in the Bering Sea.

4.2 Squids

Loliginid squids (Loligo opalescens) are presently taken commercially off California during their spawning season (about 10,000 tons annually). The spawning occurs over the continental shelf,often in coastal waters. Considerable year to year variations in abundance of this species has been observed. The species is underutilized and considerably more can be taken if export markets and domestic uses are developed. However, the stock of Loliginid squids is considerably smaller than their open ocean relatives of the families, Ommastrophidae, Onychoteuthidae, and Gonatidae.

Relatively little is known about the numbers of oceanic squids in the eastern North Pacific Ocean. Large numbers of Ommastrepids are found in areas of the tuna purse seine fishery and one species, Dosidicus gigas, periodically ranges north into California coastal waters as far as Monterey Bay. This species and Symplectoteuthis sp may be potentially important from about Lat 34°N south to 0°. From about Lat 32°N and northward, Onychoteuthids and Gonatids occur with Onychoteuthis borealijaponicus probably more abundant off California

than the Gonatids; and several species of Gonatids are more abundant from Washington northward into the Bering Sea. Squids of these two families are fairly abundant in surface waters at night and could form the basis of important fisheries along with the only Loliginid squid, Loligo opalescens, of the eastern North Pacific, which ranges over the continental shelf from Baja California northward to Vancouver Island.

All species mentioned have been caught in experimental drift gill nets, are attracted to lights, and may be caught by jigging.

Another Onychoteuthid, Moroteuthis robusta, the largest member of the family and primarily demersal in habit, forms an important part of the food of sperm whales in the eastern North Pacific. Its remains have been identified from the stomachs of sperm whales taken off San Francisco, British Columbia, and the Aleutian Islands and is occasionally taken by trawlers. Unfortunately, it is not considered desirable by the public and presently is of little value in the market.

5. RECOMMENDATIONS FOR CEPHALOPOD RESOURCE ASSESSMENT AND RESEARCH

Although a considerable amount of basic biological research has been carried out on octopuses, their abundance and general ecology (distribution within depth and type of bottom, and migrations) is very little known and requires additional studies for ascertaining the fisheries potential of these animals.

Some basic biological research has been carried out on the Loliginid squid Loligo opalescens; however, we do not know yet the magnitude of

the resource off California, nor do we know the magnitude and reasons for year-to-year fluctuations of abundance of this species, or the reasons for year-to-year variation in peak spawning timing.

Research on the open ocean squid resource is nearly nonexistent in the United States. The following list of research subjects has been arranged by priorities.

1. Development of efficient methods of capture, first for exploratory fishery and research purposes, later for commercial fishery.

2. Sonar surveys (high frequency sonar), combined with exploratory fishing to determine squid distribution and abundance (including school depths, school sizes, vertical migrations, and seasonal movements and areas of concentration along oceanic boundaries).

3. Determination of seasonal north-south migrations (migration routes, times, speeds of movement of schools, shoreward migrations, relations to seasonal migrations of other marine biota - mammals, fish, birds).

4. Determination of life span of species, spawning area and times, rate of growth determination.

5. Determination of year-to-year variation of abundance and the effects of these variations on marine ecosystem at large.

6. Development and export and domestic markets.

The research could be directed toward species which might become subject to a commercial fishery in the near future. It seems obvious that squids will become a very important marine food resource in the near future.

6. MAJOR REFERENCES

Akimushkin, I.D.

1963. Golovonogie mollyuski morei SSSR (Cephalopods of the seas of the U.S.S.R.). Izd. Akad. Nauk, Moscow. In Russian. (Transl. by Israel Prog. Sci.Transl., 1965., avail. Natl. Tech. Inf. Serv., Springfield, Va., as TT65-50013, 223 p.)

Berzin, A.A.

1971. Kashalot (The sperm whale). Izd. "Pishchevaya Promyshlennost," Moscow. In Russian. (Transl. by Israel Prog. Sci. Transl., 1972., avail. Natl. Tech. Inf. Serv., Springfield, Va., as TT71-50152, 394 p.)

Clarke, M.R.

1966. A review of the systematics and ecology of oceanic squids. In F. S. Russell (editor), Advances in marine biology. Vol. 4, p. 91-300. Academic Press, Inc., London and New York.

1977. Beaks, nets and numbers. In M. Nixon and J. B. Messenger (editors), The biology of cephalopods, p. 89-126. Academic Press, Inc., London and New York.

Kodolov, L.S.

1970. O. kalmarakh v Beringovom more (Squids of the Bering Sea). Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 70 (Izv. Tikhookean. Naucho-issled. Rybn. Khoz. Okeanogr. 72):162-165. In Russian. (Transl. by Israel Prog. Sci. Transl., 1972, p. 157-160 in P. A. Moiseev (editor), Soviet fisheries investigations in the northeastern Pacific, Part 5, avail. Natl. Tech. Inf. Serv., Springfield, Va., as TT71-50127.)

Nixon, M., and J. B. Messenger (editors).

1977. The biology of cephalopods. Academic Press, Inc., London and New York, 615 p.

Okutani, T.

1977. Stock assessment of cephalopod resources fished by Japan. Food Agric. Organ. U.N., FAO Fish. Tech. Paper 173, 62 p.

Okutani, T., and T. Nemoto.

1964. Squids as the food of sperm whales in the Bering Sea and Alaskan Gulf. Sci. Rep. Whales Res. Inst. 18, p. 111-122 plus 5 plates.

Rathjen, W.F.

1973. Northwest Atlantic squids. Mar. Fish. Rev. 35(12):20-26.

Roper, C.F.E., and R.E. Young.

1975. Vertical distribution of pelagic cephalopods. Smithsonian Contrib. Zool. 209.