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Proceedings of the Squid Workshop

October 1981

PROCEEDINGS OF THE SQUID WORKSHOP

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INTRODUCTION

In recent years there has been a growing interest by the domestic fishing industry in the potential for a squid fishery in the northeastern Pacific Ocean. This is attributable to several factors, including:

(1) A growing realization in the scientific community that squid may represent a large part of the biomass in the marine ecosystem.

(2) A general decline in abundance of some presently exploited fish stocks, coupled with a recent decline of prices.

(3) An increasing demand in Japan and other western Pacific rim countries for squid, coupled with a decline in Japanese domestic squid production.

There are, at this time, several government-sponsored and private experimental squid fishing ventures in progress or planned for the near future in the northeastern Pacific Ocean. To help meet increasing constituent demand for information on squid and to more fully understand the role of squid in the marine ecosystem, the National Marine Fisheries Service's (NMFS) Northwest and Alaska Fisheries Center (NWAFC) sponsored a Squid Workshop on 19 and 20 March 1981. The workshop focused summarizing on current knowledge of the distribution, seasonal abundance, commercial utilization, and ecosystem role of squids in the northeastern Pacific Ocean.

19 March 1981 (Thursday)

9:00 to 9:10 a.m.

Dr. Murray Hayes, NWAFC

Dr. Hayes welcomed participants to the Workshop and presented the opening comments. He suggested focusing on two aspects of squid research:

(1) The importance of squid in the ecosystem both as predators and as prey organisms.

(2) Commercial potential and management considerations for squid in the northeastern Pacific Ocean and Bering Sea.

He requested that the workshop address the need for NWAFC involvement in squid research.

9:10 to 9:45 a.m.

Mr. Warren Rathjen, NMFS, Gloucester, Massachusetts

Mr. Rathjen presented a summary of the Cephalopod Workshop[1], held in Melbourne, Australia, the week previous to this meeting. The Workshop was, to a large degree, a response to a rapidly developing international squid fishery in Australian and New Zealand waters. He stated that the potential commercial squid catch in Australian waters is estimated to be between 20,000 and 50,000 metric tons (t) annually and that commercial estimates for the New Zealand squid catch ranges from 80 to 140 thousand t per year. A comprehensive writeup of presentations made at Melbourne is in preparation and should soon be available from the Victorian Institute of Marine Sciences. During discussion with other participants, Mr. Rathjen brought up the following points regarding capture of squid:

1/ Biology and Resource Potential of Cephalopods, sponsored by the National Museum of Victoria and the Victorian Institute of Marine Sciences, 9-13 March 1981, Melbourne, Australia.

(1) Jigging: Jigging has proven very successful off New Zealand with up to 25 t of squid being taken by one vessel per night. Halogen lamps are replacing incandescent lamps in the Japanese jig fishery and terminal lights on the jigging gear sometimes improve effectiveness.

(2) Trawling: Trawl surveys are being used for assessment of *Nototodarus sloani*. In the northwestern Atlantic, some squid (*Loligo pealei*) tend to lead well in trawls while others (*Illex illecebrosus*) appear to attempt to escape as evidenced by a high enmeshing rate in the wings of the trawl.

10:25 to 11:15 a.m.

Dr. William Pearcy and Ms. Kathy Jefferts, Oregon State University, Corvallis

Ms. Jefferts began by listing various sources of her squid data. Three main sources mentioned were Oregon State University (OSU) data 1960-1980; NWAFC rockfish cruises, 1977-1980, from southern California to Unimak Pass; and BROWN BEAR cruise data, 1957-1960, in the Gulf of Alaska and Bering Sea. The OSU data come mainly from off the Oregon coast west, in some cases, to Hawaii. Gear used for collection ranged from Isaacs Kidd Midwater Trawls to Nor'eastern Bottom Trawls and Cobb Pelagic Trawls. Over 40,000 squid were examined during her graduate work at OSU.

Ms. Jefferts then reviewed the approximately 70 species of squid which she has examined. For each species covered she included such information as maximum dorsal mantle length, range of the species, spawning season and habits, and diurnal migration. Information presented is available in reports[2/] prepared for NWAFC or will soon be available in her Doctoral thesis.

2/ Jefferts, K., and W. Pearcy. 1979-1981. Distribution and biology of cephalopods from the Northeast Pacific ocean. Phases I (1/1/77-6/30/78), II (7/1/78-6/30/79) and III (7/1/79-6/30/80). Oreg. State Univ., Corvallis. Contract 03-7-208-35070 to Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Dr. Pearcy emphasized the problem of quantitative sampling for pelagic squid species. He pointed out that nearly all pelagic sampling has been done with small midwater trawls which are strongly biased for larvae and smaller squid specimens. Larger commercial type midwater and bottom trawls have been made along the continental shelf and slope and some near-shore species of squid have been captured with this gear, but a need exists for some means of quantitatively sampling pelagic squid. He noted that the quantity of squid found in stomachs of birds, fish, and marine mammals frequently indicate an abundance of squid in pelagic areas where few squid are actually caught with smaller sampling gear. Dr. Pearcy suggested using large midwater trawls with large mouth openings (100 m^2 in area) for pelagic sampling of oceanic species of squid.

In additon to suggestions for improved pelagic squid sampling, Dr. Pearcy made some comments about squid species with commercial potential. Purse seine sampling for juvenile salmonids has indicated that Loligo opalescens occur off southern Oregon at an average density of about one individual per 32 m^2 of surface area. Other species mentioned included Onychoteuthis borealijaponicus, Gonatopsis spp. and Ommastrephes bartramii, which were taken by various mesh sizes of gillnet from the Japanese research vessel Oshoro Maru. The first two species were caught from 41° to 45° N along the 175° W meridian. Ommastrephes was also taken along the 175° W meridian but was found in greatest abundance south of 41° N. All three species are thought to be available in commercial quantities in the northern North Pacific. Gillnet data from the Oshoro Maru along the 145° W meridian reflect significantly lower catches of squid compared to more westerly waters.

Dr. Pearcy presented a food web diagram which shows squid are a central figure in the oceanic food web. He pointed out that, although squid or their hard parts are fairly easy to recognize in predator's stomachs, squid stomach contents are particularly difficult to analyze because their prey animals are not usually intact. In reference to cannibalism, Dr. Summers mentioned that he has not observed it in aquaria and that squid may consume each other only when being captured in purse seines or trawls.

1:20 to 2:07 p.m.

Mr. Chris Bublitz, University of Alaska, Fairbanks

Mr. Bublitz reviewed a list of squid species which were collected during his work in the Bering Sea. Samples were obtained only from the eastern (east of Bower's Bank) Bering Sea in depths ranging from 35 to 4,000 m. Most samples were collected with plankton tows or ring nets from the Japanese research vessel *Oshoro Maru*. Some specimens were taken from other available vessels such as the National Oceanic and Atmospheric Administration (NOAA) ship *Miller Freeman* which made some large midwater trawl sets during a 1980 winter cruise to the Bering Sea. He pointed out that, although his original intent had been to do an ecological study on Bering Sea squid, the lack of adequate species descriptions necessitated a systematics type study first.

Each species covered was described in detail in both larval and post-larval stages. Key identifying features such as sucker patterns on tentacles were described and illustrated on slides. Mr. Bublitz noted that he may have discovered one previously undescribed species of the genus *Gonatus*. Charts showing seasons and locations where each species was collected were presented as part of each account.

It was noted that larval and post-larval stages of *Berryteuthis magister* were found in abundance in 1977 and 1979 but very few were collected during 1978. This apparent even-odd year fluctuation in abundance was discussed further by Dr. Nishiyama in reference to salmon stomach content data.

2:07 to 3:10 p.m.

Dr. Taivo Laevastu, NWAFC

Dr. Laevastu spoke about the role of squid in the North Pacific ecosystem as determined, either directly or indirectly, from his work in developing a computerized ecosystem model. Squid were treated as a general group and not by species. He noted that his model is based on the rate of change of each component's biomass. Factors affecting biomass include recruitment, growth, and mortality (disease, senescence, and predation). The main predators on squid are thought to be marine mammals, birds, cod, sablefish, rockfish, salmon, and albacore.

The best data available on quantity of squid consumed are from marine mammal stomach analyses. Two species of marine mammals known to prey heavily on squid are sperm whale and fur seal. Fortunately, considerable seasonal distribution and dietary information are available for both of these marine mammals from commercial harvest data and from Pelagic Fur Seal Investigation reports of the NWAFC National Marine Mammal Laboratory, Seattle, Washington. Based on sperm whale consumption, Dr. Laevastu estimates that squid biomass in the North Pacific alone amounts to a minimum of 400 million t (see Table 1). Several participants observed that the estimate given by Clarke (1966)[3/] was probably an underestimate given several of the assumed values in the derivation.

Dr. Laevastu noted that, although they are voracious predators, very little quantitative information is available for food habits of squid. Young squid are known to consume euphausiids and other macroplankton; larger squid are known to prey upon small fishes such as capelin and myctophids, but their rate of consumption of each prey species is not known.

3/ Clarke, M.R. 1966. A Review of the Systematics and Ecology of Oceanic Squids, Adv. Mar. Biol. 4:91-300.

Laevastu also gave some results from ecosystem simulations in respect to squid. The ecosystem internal consumption of squid in the eastern Bering Sea and in the Aleutian region is 3.0 million t, which is of the same order of magnitude as the consumption of zooplankton (3.3 million t), benthos (2.3 million t), and finfish (2.6 million t). Lowering or increasing of squid biomass in the above-mentioned region by 25% would cause a 100,000 t change of equilibrium biomass of herring (or increase-decrease of 11,500 t of herring catch annually)[4/]. The effects of the increase-decrease of squid biomass in the Aleutian region and western Gulf of Alaska on the biomasses of walleye pollock and capelin are shown on Figures 1 and 2, as revealed by ecosystem simulation model PROBUB.

In summing up, Dr. Laevastu emphasized a need for more information on the seasonal abundance and migratory habits of squid and more quantitative information about squid both as predators and prey. Dr. Laevastu presented plans for a small, high speed midwater trawl (Figure 3) which he felt would be helpful in providing quantitative samples of squid. Dr. William Aron noted that results from a study by Richard Barkley indicate that a large, slow, midwater trawl might be more effective at sampling squid[5/].

<u>3:10 to 4:05 p.m.</u>

Mr. Clifford Fiscus, Briar, Washington

Mr. Fiscus presented information on the trophic relationship of marine mammals and squid in the North Pacific and reviewed squid catch data from the NWAFC High Seas Drift Gillnet sampling program which was carried out in the

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4/ Laevastu, T., and F. Favorite. 1980. Fluctuations in Pacific herring stocks in the eastern Bering Sea as revealed by an ecosystem model (DYNUMES III). Rapp. P.-V. Réun. Cons. Int. Explor. Mer 177:445-459.

5/ Barkley, R. A. 1964. The theoretical effectiveness of towed-net samplers as related to sampler size and to swimming speed of organisms. J. Cons. Int. Explor. Mer 29(2):146-157.

Table 1.--Estimation of consumption of squid by sperm whale in the North Pacific Ocean.

175,000[1] harvestable sperm whale in the North Pacific

30 metric tons (t) mean weight

= 5.25 million t biomass

5%[2] body weight daily, food requirement (BWD)

= 18.25 times body weight annually

= 95.81 million t total food consumption

Food composition:

85%[3] squid

15% fish

Annual consumption by sperm whale in North Pacific

= 81.4 million t squid

14.4 million t fish

Assuming F_{max} 20%[4], the minimum biomass of squid in the North Pacific is 400 million ton.

1/ This is a minimum estimate (Int. Whaling Comm. Spec. Issue 2, 1980). The total number of sperm whale in the North Pacific is estimated for 1977 as: females 411,000 to 525,000; males 376,000 to 474,000.

2/ The food consumption of whales is estimated in literature to 4 to 6% BWD. The minimum estimate is 2.5% BWD.

3/ Some estimates give up to 95% squid.

4/ This "fishing coefficient" of squid by sperm whale is probably too high; it corresponds roughly to F of pelagic fish.

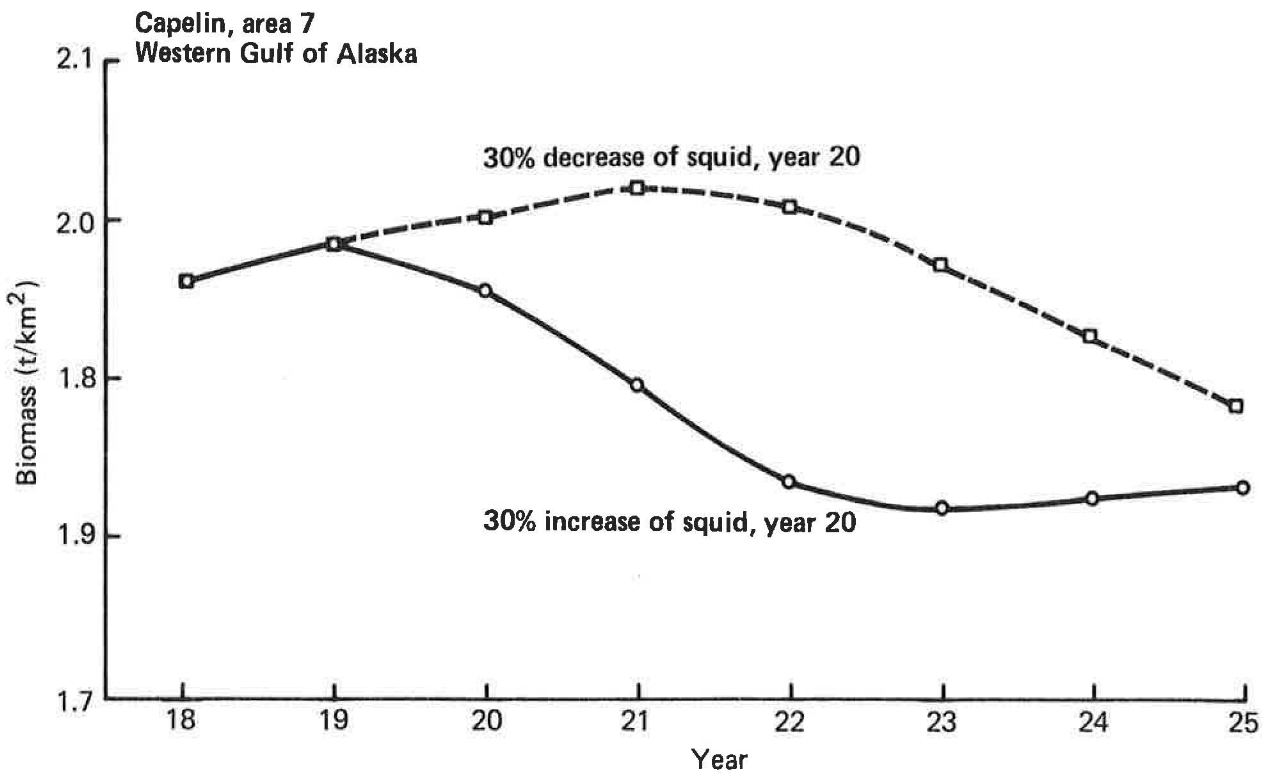

Figure 1 -- Computer predicted variation of capelin density in response to a 30% variation of squid density in the western Gulf of Alaska (Laevastu).

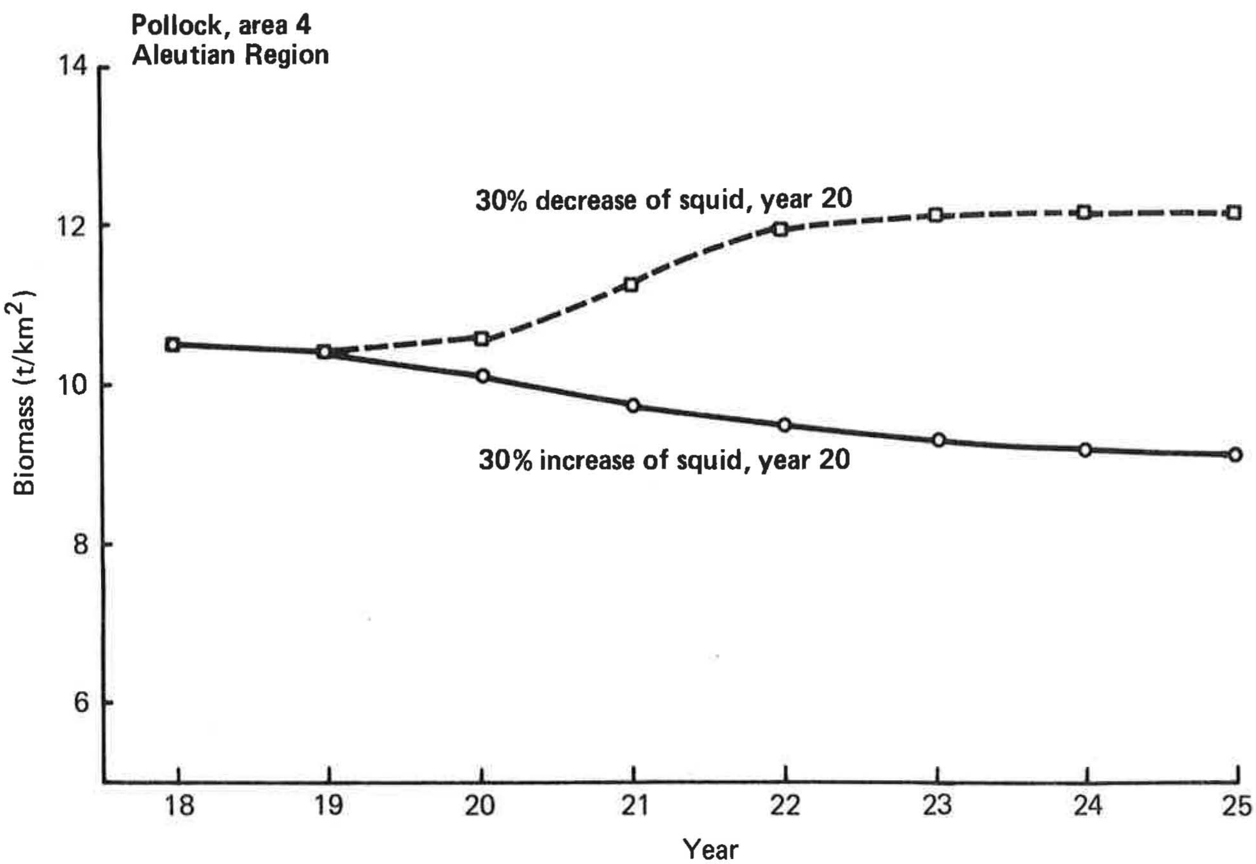

Figure 2 -- Computer predicted variation of pollock density in response to a 30% variation of squid density in the Aleutian region (Laevastu).

Fast, aimable midwater sampling trawl
Scale 1:20 (cm)

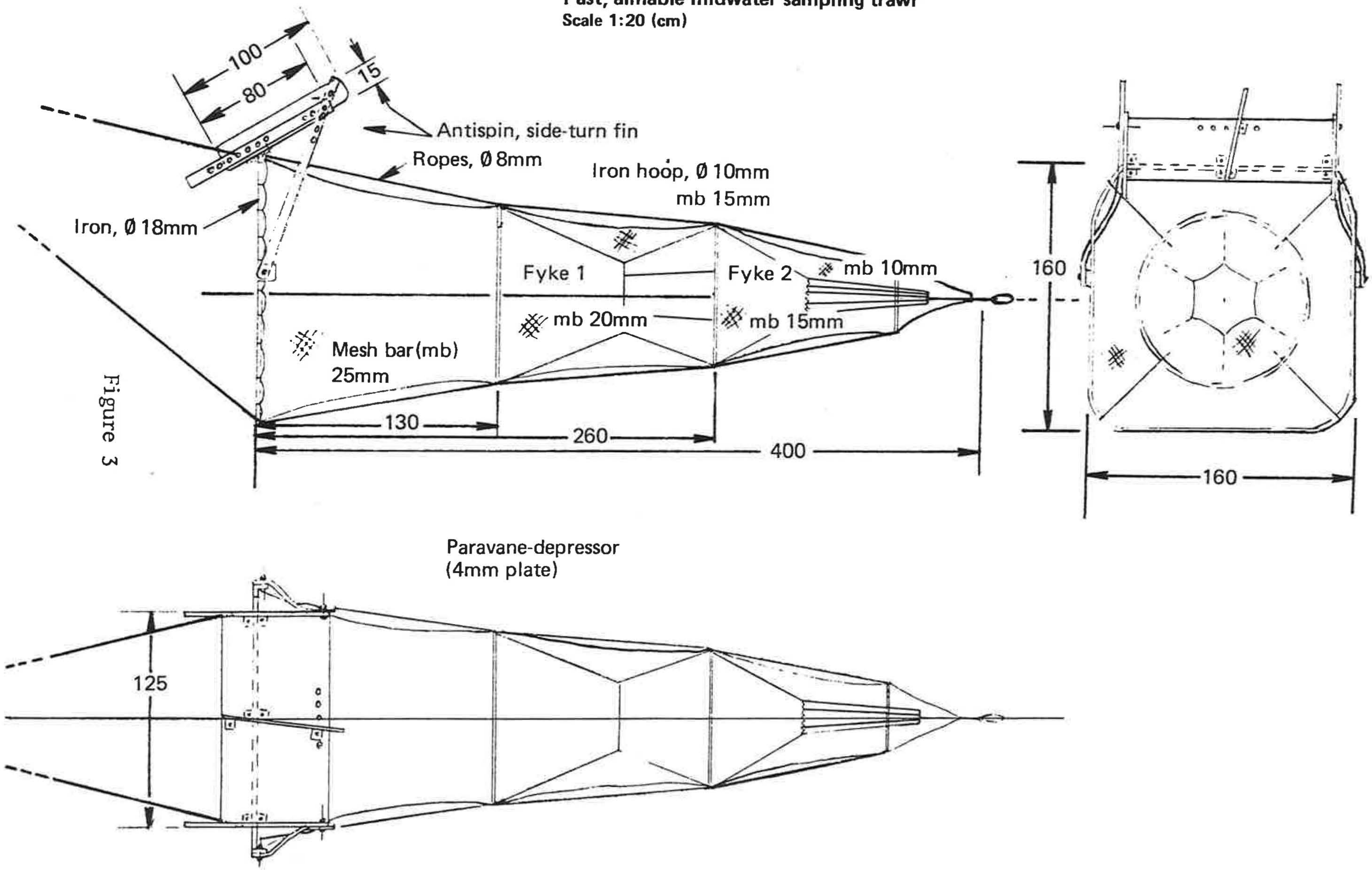

Figure 3

North Pacific from 1955 through 1974. He restricted his presentation to species of squid which might be of commercial importance. These were: Loligo opalescens, Symplectoteuthis oualaniensis, Dosidicus gigas, Ommastrephes bartramii, Onychoteuthis borealijaponicus, Berryteuthis magister, and members of the family Gonatidae. Mr. Fiscus distributed copies of an unpublished draft of a paper on squid data from Pelagic Fur Seal Investigations. He also distributed a NWAFC Processed Report which related to his topic (Laevastu and Fiscus 1978[6/]) and mentioned two other reports (Antonelis and Fiscus 1980[7/]; Kajimura et al. 1980[8/]).

In reference to marine mammal stomach content data, Mr. Fiscus noted that cephalopods must frequently be identified from beaks alone, which remain in the stomach for an undetermined length of time after the soft parts are digested. He discussed difficulties with "beaks only" work and noted that identifications from beaks can be made fairly reliably for some species such as L. opalescens but, in other cases such as with Gonatids, only the family can be readily determined. Most of the data presented by Mr. Fiscus came from Pelagic Fur Seal Investigations which were carried out between 1958 and 1972. He presented charts of sampling locations and times which indicated that most samples were taken along the continental slope. Limits on different species'

6/ Laevastu, T., and C.Fiscus. 1978. Review of cephalopod resources in the eastern North Pacific. Processed Rep., 15 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle Wash. 98112.

7/ Antonelis, G.A., Jr., and C.H. Fiscus. 1980. The pinnipeds of the California Current. Calif. Coop. Oceanic Fish. Invest. Rep. 21:68-78.

8/ Kajimura, H., C.H. Fiscus, and R.K. Stroud. 1980. Food of the Pacific white-sided dolphin, Lagenorhynchus obliquidens, Dall's porpoise, Phocoenoides dalli, and northern fur seal, Callorhinus ursinus, off California and Washington; with appendices on size and food of Dall's porpoise from Alaskan waters. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/NWC-2, 30 p.

range of distribution as determined from marine mammal stomach data were presented along with some thoughts on seasonality. He noted that pelagic fur seal collections were made where seal were available and that the samples strongly reflect the migrational behavior of fur seal and not, necessarily, that of squid or fish found in their stomachs. Fur seal were collected off California during winter and spring months, in the Gulf of Alaska in spring and early summer, and the Bering Sea during summer and early fall. He noted that, off California, more gonatid squid were found in small cetacean stomachs than in fur seal stomachs which contained more Loligo and Onychoteuthis. This may indicate that porpoise and dolphin probably feed at a deeper level than do fur seal. In the Gulf of Alaska and Bering Sea, fur seal stomachs contained gonatid squids.

Dr. Summers asked about information that would allow correlation of beak size with mantle length. It was pointed out that the presence of commercially valuable sized squid could be determined by examining beaks from marine mammal stomachs.

Mr. Fiscus noted that, where gonatid beaks only were found, they were listed as family Gonatidae. If fragments of the head region, buccal mass, arms, and tentacles were found, identification could be made to genus.

For the second part of his presentation, Mr. Fiscus briefly reviewed work that is being done with squid catch data from the NWAFC High Seas Salmon Research Program. This program was carried out mostly south of the Aleutian Islands and Alaska Peninsula from 1955 to 1974. Of the various gillnet mesh sizes used, 2-1/2 in to 3-1/4 in mesh seemed to catch the most squid. Species of squid captured included Ommastrephes bartramii, Gonatopsis borealis, Onychoteuthis borealijaponicus and Gonatus sp. Of those squid examined and identified, most were O. borealijaponicus. Surface temperature data which were taken in conjunction with the gillnet sampling showed a peak of squid catch between 9 and 11°C. Squid examined from two summer cruises, south of the Aleutians, showed an abundance of O. borealijaponicus which were of a commercially valuable size range. Mr. Fiscus noted that a paper on this topic was being prepared by himself and Roger Mercer of the NWAFC and would soon be available.

4:05 to 4:45 p.m.

Mr. Gerry Sanger, U.S. Fish and Wildlife Service, Anchorage, Alaska

Mr. Sanger presented material on the trophic relationship of birds and squid. He discussed a unit derived from percentage volume, percentage of number counted, and frequency of occurrence of prey items found in stomach analyses (Pinkas). This he called an index of relative importance (IRI) (Table 3). The IRI was used in his tables to show the relative importance of different prey species in the diets of different birds (Table 4).

Mr. Sanger's data were collected as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) in the Gulf of Alaska and Bering Sea from 1975 through 1978. He noted that 71% of the stomach content data were collected during the summer and that, consequently, most of his results reflect summer trends. Fifteen species of birds examined during his study had at least trace quantities of squid in their stomachs. A graph was presented which showed the depth ranges utilized by different bird species during feeding. Six species of birds which appeared to consume the most cephalopods were northern fulmar, sooty and short-tailed shearwater, fork-tailed storm petrel, thick billed murre, and tufted puffin. Mr. Sanger felt that shearwater, which are the most abundant sea birds off Alaska during summer, probably consume large quantities of cephalopods relatively far offshore and then

Table 2.--Data on squid-eating seabirds for Alaskan waters, based on birds collected 1969-71 in the Aleutian Island area, 1973-74 near the Pribilof Islands and 1975-78 in the southeastern Bering Sea and the Gulf of Alaska as part of fish and wildlife studies for the Outer Continental Shelf Environmental Assessment Program.

Bird species	Net body wt.(G)		Total length (cm)		Estimated population ($x10^3$)	Estimated biomass (t)
	N	$\overline{X}$	N	$\overline{X}$		
Northern fulmer	39	610	33	41.8	2,000	1,220
Sooty shearwater	181	842	52	45.0	14,200	11,956
Short-tailed shearwater	211	634	200	39.2	25,800	16,357
Fork-tailed stormy petrel	9	54	9	21.1	5,000	270
Northern phalarope	-	25	-	--	1,000 1/	25
Black-legged kittiwake	316	396	144	42.4	2,500	990
Red-legged kittiwake	3	429	3	43.2	250	107
Common murre	203	1,042	109	42.6	5,000	5,210
Thick-billed murre	26	1,051	26	41.8	5,000	5,255
Marbled murrelet	148	234	93	23.6	1,000 1/	234
Ancient murrelet	14	221	11	25.6	400	88
Cassin's auklet	3	202	2	22.4	600	121
Rhinoceros auklet	19	526	13	34.8	200	105
Horned puffin	46	540	40	34.0	1,500	810
Tufted puffin	441	776	208	38.0	4,000	3,104

1/ Guess

Table 3.--Relative importance of cephalopods to seabirds in Alaskan waters based on data pooled from birds collected 1969-71 in the Aleutian Islands area, 1973-74 near the Pribilof Islands, and 1975-78 in the southeastern Bering Sea and Gulf of Alaska as part of fish and wildlife studies for the Outer Continental Shelf Environmental Assessment Program. Values less than 0.1% shown as 0.0.

"Kind" of cephalopod	Importance of cephalopod to seabird species Numbers (%)	Volume (%)	Frequency of occurrence (%)	Indices of relative importance
	Northern fulmer, N = 46			
Unidentified Gonatidae	12.6	2.5	11.6	175
Unidentified Squid	58.9	60.1	81.4	9.687
TOTAL squid	71.5	62.6	81.4	10,916
	Sooty shearwater, N = 187			
Unidentified cephalopod	7.7	1.0	28.4	247
Unidentified Gonatidae	1.9	0.1	2.3	4
Onychoteuthis sp. (Squid)	0.0	0.0	0.6	1
Unidentified Squid	38.1	1.0	40.9	1,599
TOTAL squid	40.7	1.1	40.9	1,710
TOTAL Cephalopoda	47.7	2.1	40.9	2,037
	Short-tailed shearwater, N = 228			
Unidentified cephalopod	0.6	1.5	36.8	77
Gonatidae	0.0	0.0	1.0	1
Squid	0.0	0.0	0.5	1
TOTAL Cephalopoda	0.6	1.5	36.8	77
	Fork-tailed storm-petrel, N = 14			
Cephalopod	6.3	15.7	37.5	826
Squid	3.2	42.8	25.0	1,150
TOTAL Cephalopoda	9.5	58.5	37.5	2,550
	Northern phalarope, N = 7			
Cephalopoda	7.1	13.1	14.3	289
	Black-legged kittiwake, N = 328			
Cephalopoda	0.2	0.2	1.5	1
	Red-legged kittiwake, N = 3			
Cephalopoda	12.5	0.5	33.3	433
	Common murre, N = 252			
Squid	0.2	0.4	1.2	1
	Thick-billed murre, N = 63			
Cephalopoda	47.4	25.9	51.4	3,765
	Marbled murrelet, N = 158			
Cephalopoda	0.0	0.2	0.8	1

Table 3.--Continued.

"Kind" of cephalopod	Importance of cephalopod to seabird species: Numbers (%)	Volume (%)	Frequency of occurrence (%)	Indices of relative importance
	Ancient murrelet, N = 18			
Cephalopoda	0.8	0.8	6.7	11
	Cassin's auklet, N = 3			
Cephalopoda	16.7	33.3	33.3	1,667
	Rhinoceros auklet, N = 21			
Cephalopoda	6.1	1.0	6.3	44
	Horned puffin, N = 54			
Cephalopoda	8.7	0.1	2.5	22
	Tufted puffin (nestlings & subadults), N = 80			
Cephalopoda	0.4	0.5	1.7	1
Octopi	0.4	0.1	1.7	1
	Tufted puffin (adults), N = 440			
Cephalopoda	5.2	2.1	14.6	106
Squid	16.9	0.6	4.1	72

Table 4.--Comparative importance of cephalopods to seabirds in Alaskan waters based on data pooled from birds collected 1969-71 in the Aleutian Islands area, 1973-74 near the Pribilof Islands and 1975-78 in the southeastern Bering Sea and the Gulf of Alaska as part of fish and wildlife studies for Outer Continental Shelf Environmental Assessment Program. Importance levels of prey based on their indices of relative importance: 0-9 = trace (tr); 10-99 = 1; 100-999 = 2; 1,000-9,999 = 3

			Squid			
Bird species	N	Gonatidae	*Onychoteuthis* sp.	Unidentified	Cephalopod	Octopus
Northern fulmar	46	2	-	3	-	-
Sooty shearwater	187	tr	tr	3	2	-
Short-tailed shearwater	228	tr	-	tr	1	-
Fork-tailed storm petrel	14	-	-	3	2	-
Northern phalarope	7	-	-	-	2	-
Black-legged kittiwake	328	-	-	-	tr	-
Red-legged kittiwake	3	-	-	-	2	-
Common murre	252	-	-	tr	-	-
Thick-billed murre	63	-	-	-	3	-
Marbled murrelet	158	-	-	-	tr	-
Ancient murrelet	18	-	-	-	1	-
Cassin's auklet	3	-	-	-	3	-
Rhinoceros auklet	21	-	-	-	1	-
Horned puffin	54	-	-	-	1	-
Tufted puffin (nestlings and sub-adults)	80	-	-	-	tr	tr
Tufted puffin (adults)	440	-	-	1	2	-

Table 5.--Estimated consumption of cephalopods by seabirds in the Gulf of Alaska and the southeastern Bering Sea in summer (120 days).

Bird species	volume of cephalopods in diet (%)	Amount of cephalopods eaten at assumed rate of 15% of population biomass per day	
		Metric Tons[1/]	Total (%)
Northern fulmar	62.6	13,745	26.0
Sooty shearwater	2.1	4,520	8.6
Short-tailed shearwater	1.5	4,415	8.4
Fork-tailed stormy petrel	58.5	2,845	5.4
Northern phalarope	13.1	60	0.1
Black-legged kittiwake	0.2	35	0.1
Red-legged kittiwake	0.5	10	<0.1
Common murre	0.4	375	0.7
Thick-billed murre	25.9	24,500	46.4
Marbled murrelet	0.2	10	<0.1
Ancient murrelet	0.8	15	0.1
Cassin's auklet	33.3	725	1.4
Rhinoceros auklet	1.0	20	<0.1
Horned puffin	0.1	15	<0.1
Tufted puffin	2.7	1,510	2.8
	TOTAL	52,800	100

1/ Metric tons = (population biomass)(120 days)($\frac{15\%}{\text{day}}$)(% volume of cephalopods in diet).

digest them before returning to nearshore areas where they were collected. He estimated that cephalopod consumption by birds in Alaska probably amounts to a minimum of 53,000 metric tons (t) each summer (120 days) and that the majority of this is taken by birds offshore of the continental shelf (Table 5).

Mr. Sanger concluded by expressing a need for more bird sampling data in feeding areas at the actual time of feeding (night or early morning).

March 20, 1981 (Friday)

9:00 to 9:55 a.m.

Dr. Tsuneo Nishiyama, University of Alaska, Fairbanks

Dr. Nishiyama's presentation dealt with the trophic relationship of fishes and squids in the western North Pacific and Bering Sea. He quoted Mr. Bublitz' data and data from Japanese gillnet sampling. Dr. Nishiyama began by noting that squid are generalists in their feeding habits and that they will feed on almost anything they are large enough to capture. Most post-larval and sub-adult squid tend to feed on zooplankton (crustaceans) and, as they grow, shift to feeding on smaller fishes such as myctophids and capelin. Specimens of *Todarodes pacificus* were found to feed mostly on zooplankton when they were less than 20 cm (dorsal mantle length) and fed mostly on fish when larger than 20 cm. He noted that, under some conditions, several species of squid seemed to feed largely on other squid. Tables were presented which depicted rates of food consumption and daily growth rates for *Todarodes pacificus*. In reference to squid as prey items for fishes, Dr. Nishiyama noted that squid comprise a significant part of the diets of many fish including salmon, tuna, pollock, cod, and flatfishes.

He then discussed the importance of squid in the diets of different species of salmon. Coho and chinook salmon were identified as heavy squid predators and pink and sockeye salmon fed on squid to a lesser extent. Chum salmon were not found to contain any significant quantities of squid. He pointed out that coho and chinook salmon were found to feed heavily on squid only during even years, indicating that squid may occur abundantly on the salmon feeding grounds only during those years. This was based on 10 years of data from 1956 to 1966 and seemed to be supported by the collections (1977-79) of Mr. Bublitz which reflect an abundance of larval squid only during odd years. Dr. Nishiyama pointed out that he considers this part of his presentation at the workshop to be inconclusive and that he will be doing more research in this area. He also noted that, although relatively unimportant during the summer, squid appear to become an important dietary item for bottomfish during the autumn in the eastern Bering Sea.

In conclusion, Dr. Nishiyama emphasized the importance of squid in the marine ecosystem. Although important as predators of and competitors with many fish stocks, one of the most significant roles that squid play seems to be as an intermediary between zooplankton and higher trophic levels which are occupied by many commercially valuable fish species.

9:55 to 10:45 a.m.

Dr. Bill Summers, Western Washington University, Bellingham

Dr. Summers presented material on life cycles, reproduction, and growth rates of squid. His presentation began by briefly reviewing the taxonomy of cephalopods and with a description of his cultivation work with Sepiolid squid in Sweden.

Dr. Summers began describing reproduction and growth of squid. He emphasized that a major difficulty in determining growth rates of squid is that of determining their age. No clear system for aging squid exists and, though some work is being done with statoliths and beaks, most aging work involves deduction from length frequency analyses made at different times of the year. He noted that growth is dependent on availability of feed, can be very rapid because little formation of hard parts such as bones is required, and may be sexually dimorphic during maturation. Growth also seems directly related to water temperature with faster growth rates at higher temperatures. He additionally observed that, in many species, growth tends to be slower but size at maturity is larger at higher latitudes. Breeding seasons also are more dispersed at lower latitudes.

Breeding frequently peaks more than once (usually twice) each year, resulting in more than one annual cohort of young animals. Dr. Summers noted that egg mortality is generally very low and that the incubation period shows a strong, indirect relationship with temperature. The number of eggs laid range from tens to hundreds of thousands dependent upon species. The more demersal varieties of squid such as Rossia pacifica or sepiolids tend to lay a small number of large eggs producing relatively well-formed young which, immediately upon hatching, take up a demersal type of existence and do not go through a free swimming, planktonic stage. Pelagic species generally lay a large number of smaller eggs and have a planktonic larval stage. Most near-shore and bottom dwelling cephalopods were observed to anchor their egg masses to hard bottom features, whereas some oegopsid eggs have been found floating free indicating that their eggs may not be bottom anchored. Eggs have a high fat content but do not seem to suffer much, if any, predation mortality. Many species die after spawning.

In reference to feeding, Dr. Summers indicated that the squid he has reared in captivity are not particular about their feed. Feeding seems to be more size-related than anything else with the smallest squid eating very small crustaceans, shifting to larger crustacea as they grow, and finally graduating to large shrimp and fish when they attain full size. Sepiolids kept in the aquarium readily accept substitute species of crustacea when their normal prey species cannot be obtained.

10:50 to 11:30 a.m.

Mr. Warren Rathjen, NMFS, Gloucester, Massachusetts

Mr. Rathjen spoke on the developing commercial squid fishery in the northwestern Atlantic Ocean. He began by describing a recent dramatic increase of squid landings from the northwestern Atlantic, as evidenced by an increase in annual squid landings from 5,000 metric tons per year between 1970 and 1974 to over 200,000 metric tons (U.S. and Canada) in 1979. The catch consisted primarily of two species: *Loligo pealei*, which are caught with bottom trawls and pound nets, and *Illex illecebrosus*, which are caught by bottom trawling and jigging.

Trawl fishing for squid is conducted during daylight hours for both species of squid. *Loligo* are fished in southern New England during the spring and offshore during fall and winter using bottom trawls. Mesh sizes range from 150 mm (6 in) in the wings to 45 mm (1-3/4 in) in the belly and cod end. Highest catches occur around noon in 8°-12°C bottom water. Mr. Rathjen noted that there was a high incidental catch of butterfish in the *Loligo* bottom fishery. Foreign trawling for *Illex* is conducted by larger vessels from June through October each year. High rise bottom trawls towed at speeds between 3 and 4 knots produce the best catches. Catch rates for the German research trawler *Anton Dohrn* ranged from 600 to 700 kg per half hour during a 1979 research cruise. Catch rates on Spanish trawlers often run from 10 to 20 t per tow.

Jigging is another primary method of catching squid. A traditional small boat jig fishery exists in the bays and inlets of Newfoundland. *Illex* are jigged from small boats (one man) during daylight hours. One of these small boats can land 1,000-2,000 lb of *Illex* on a good day. In Canada, the greatest production in 1979 resulted from the inshore jig fishery. *Illex* are also jigged offshore by larger automated foreign vessels.

Another method of capturing squid (*Loligo*) is practiced in Nantucket Sound. This method employs pound nets which trap the squid in shallow water. Squid caught in these traps are brailed alive and delivered for processing in a very short time and are, consequently, the highest quality squid available from that area.

After reviewing the Canadian and New England squid fishery, Mr. Rathjen briefly discussed the potential for a squid fishery off the southeastern United States and the Gulf of Mexico. Four species which he identified as having possible commercial value were *Lolliguncula brevis*, *Loligo plei*, *Loligo pealei*, and *Ommastrephes pteropus*. The first three of these would probably be most accessible by trawling but further research is necessary to determine the most economically effective means of fishing *Ommastrephes*.

The last part of Mr. Rathjen's presentation dealt with processing and marketing of squid. Of the squid caught in the northwestern Atlantic, *Loligo pealei* is the most desirable, bringing an ex-vessel price of two to three times that paid for *Illex*. Most *Loligo* and many *Illex* are frozen whole in blocks for resale in Japan or southeastern Europe. Some of the *Illex* caught in Canada is air dried and shipped to Japan where it is processed further and then marketed. He observed that domestic (United States) markets for squid are not large but a domestic demand for squid could be developed by capitalizing upon its versatility as a fish or clam substitute in many popular dishes.

Development of fast sorting and processing equipment is necessary to provide competitively priced squid products to domestic markets.

Discussion and Recommendations:

Dr. Hayes: Thanked all participants for their attendance and complimented them for their presentations. He then opened the floor for discussion of requirements for further squid research in the northeastern Pacific and asked for recommendations as to how NWAFC might contribute to further research efforts.

Mr. Rathjen: Noted that the potential impact of a commercial squid fishery needs to be evaluated before large scale commercial harvesting begins. He suggested collaborating with Japanese scientists, especially in the areas of harvest technology, systematics, and the ecosystem roles of different species. He considered that, due to the volatility of world markets and the fact that there is no major dependence by U.S. fishermen on Pacific squid, it would be wise to work on developing a more reliable domestic market for squid to help buffer against international price fluctuations before any large scale squid fishery is encouraged.

Dr. Laevastu: Observed that further work is required to identify more quantitatively the role of squid in the northeastern Pacific ecosystem. He pointed out the following specific areas where more information is needed:

1) Determine quantitatively the prey composition of different squid as a function of time and maturity.
2) Look at seasonal variations of squid in the ecosystem (i.e., migration, size of squid over time, and area).
3) Determine extent and effect of cannibalism between and within different species of squid.

4) Determine how squid may affect salmon recruitment. Methods not employed for obtaining more information about squid might include requesting sounding transect records from research vessels while transiting deep water regions and sampling suspected squid concentrations using small high speed nets.

Dr. Summers: Suggested that NWAFC keep abreast of progress in the squid field by sending a representative to scientific and industry related meetings, workshops, and expositions pertaining to squid. He also encouraged NWAFC to review and publish presently held squid data and to refine methods for sampling and identifying squid as the data base continues to develop. He observed that systematics and stock identification work could be carried out using squid specimens collected incidentally to regular NWAFC fish and crab sampling programs. Additionally, he suggested that more work be done with identification of cephalopod remains found in the stomachs of predator species caught by research vessels. With regard to potential commercial exploitation, he suggested that close attention be given to variability of squid growth in response to overfishing at lower latitudes and to variability of squid recruitment with overfishing at higher latitudes.

Ms. Jefferts: Emphasized a need for more information about maturation, growth rates, and life spans of different squid species. She noted that a better understanding of the factors that influence the above aspects of squid biology would allow for more accurate predictions of stock availability. She added that a better definition of biomass with age would also be helpful in making predictions.

Mr. Bublitz: Pointed out a need for better information on squid in major current systems of the Gulf of Alaska and Bering Sea. Involvement of NWAFC could include assistance with development of better sampling gear and with collection of baseline samples of squid species from various parts of the northeastern Pacific. Such wide ranging baseline samples could help with identification of different squid stocks.

Dr. Nishiyama: Stressed the need for a long-range, year-round sampling program using larval type nets and gear for adult squid. He proposed development of an international larval sampling program utilizing research vessels of opportunity on a piggyback basis. Such a program would be relatively cheap to conduct and could produce very useful stock management data. Sampling of larger squid could be carried out using surface gillnets. Some experiments using acoustic transmitters or lights might help to increase the effectiveness of such gillnets. He also suggested conducting some experimental transplanting of commercially valuable species of squid into favorable current systems.

Mr. Sanger: Pointed out a need for sea bird collections at times and places where birds are actively feeding. Such collecting would probably result in fresher, intact samples of squid compared to those frequently collected from birds near shore. In reference to stomach samples, Mr. Sanger stressed a need for an agreed upon, standard method of preserving squid.

Mr. Fiscus: Recommended that a data search of all NWAFC research fishing records be conducted and published. The search would focus both upon squid in the catch and squid reported in stomach analyses. He also suggested that NWAFC conduct a literature search and maintain an annotated bibliography on commercial aspects of squid and fishing methodology. Dr. Hayes noted that a search is underway and an annotated bibliography will be kept up to date.

Mr. Fiscus also suggested that piggyback squid sampling be conducted from NOAA and charter research vessels using ring nets, jigs and/or gillnets as appropriate. A field identification manual (at least to family) could be prepared to assist NWAFC field personnel in classifying cephalopods collected.

In addition to NWAFC data, Mr. Fiscus suggested that a complete review of squid data held by the NWAFC National Marine Mammal Laboratory be made and temporal or spacial data gaps identified. He also suggested review of data from many transects which have been run out to Cobb Seamount by the University of Washington in recent years.

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