SUMMER FOOD OF THE PACIFIC COD, *GADUS MACROCEPHALUS*, NEAR KODIAK ISLAND, ALASKA[1,2,3]

The Pacific cod, *Gadus macrocephalus* Tilesius, was the target of the earliest United States commercial fishery in the North Pacific (Buck[4]). Its fleet, organized in spring 1865 (Bean 1887), began to fish along the Alaska Peninsula and the Aleutian Islands and eventually expanded into the Bering Sea (Cobb 1916). Dwindling stocks and poor market prices ultimately resulted in the collapse of this fishery shortly after World War II (Ketchen 1961).

Growing pressures in recent years on domestic fishing stocks, in addition to increased worldwide protein demand, improved technological skills and readily available investment capital, have resulted in renewed interest in Pacific cod in the United States (Jones 1977). A bottomfish survey off the coast of Kodiak Island and throughout Shelikof Strait by the National Marine Fisheries Service in 1973 showed the Pacific cod to be one of the most abundant fishes inhabiting the area and the standing stock was conservatively estimated to be about 36,363 t (Hughes and Parks 1975). A small experimental trawl fishery for the Pacific cod and other bottom fishes has been proposed for the Kodiak region by Jones (1977).

Preliminary examination of *G. macrocephalus* stomach contents by Alaska Department of Fish and Game (ADF&G) biologist Guy C. Powell and the author during ADF&G crab investigations off Kodiak Island indicated a high frequency of occurrence of the commercially important snow crab, *Chionoecetes bairdi*. In view of the probable predation pressure on existing snow crab populations by *G. macrocephalus* and in view of the potential commercial importance of the Pacific cod, the summer food habits of this fish in the Kodiak area were examined by me. Ancillary goals included a comparison of food data from pot- and trawl-captured cod.

[1]Contribution No. 339, Institute of Marine Science, University of Alaska, Fairbanks, AK 99701.

[2]This study was partially supported under contract 03-5-022-56 between the University of Alaska and NOAA, U.S. Department of Commerce through the Outer Continental Shelf Environmental Assessment Program to which funds were provided by the Bureau of Land Management, U.S. Department of Interior.

[3]Based on a thesis submitted in partial fulfillment of the requirements for the M.S. degree, University of Alaska.

[4]Buck, E. H. 1973. Alaska and the law of the sea. National patterns and trends of fishery development on the North Pacific. Alaska Sea Grant Rep. No. 73-4, 65 p.

Methods

Specimens were taken near Kodiak Island, Alaska, (Figure 1) in conjunction with the crab-assessment studies of ADF&G and the surveys of the International Pacific Halibut Commission. Fishing gear consisted of commercial king crab pots, measuring 203 × 203 × 76 cm (inside) and weighing 340 kg; baited with chopped, frozen herring. Webbing was #72 tarred nylon thread with mesh stretched to 7.6 cm. The gear used on the halibut-survey vessels in July 1975 and July 1976 was a standard 400-mesh Eastern otter trawl (Greenwood 1958). Sampling by pots was from 26 June to 3 August 1973, 28 June to 31 July 1974, and 30 June to 27 July 1975. Stations usually consisted of 4-12 pots in a straight line, equally spaced every 0.46 km. Gear was pulled every 18-24 h except when weather conditions prolonged fishing time.

A haphazard sample of 3,933 of Pacific cod was taken from 10,857 cod caught in pots (the number sampled was contingent on the shipboard time available for analysis of stomach contents). Food items were identified to the lowest taxon practical aboard ship, and unidentifiable contents were preserved for later laboratory examination. Analysis of stomach contents was carried out using the frequency of occurrence method in which the prey organisms are expressed as the percent of stomachs containing various food items from the total number of stomachs analyzed. Cod were arbitrarily divided into 33-52 cm, 53-72 cm, and 73-92 cm size (total length) groups for analysis.

The frequency of occurrence method was also used for food data from trawl-caught Pacific cod. The stomachs of 344 cod were examined from 24 trawl stations, which were located in the same general area as the pot stations (Figure 1).

Results and Discussion

As determined from the pot data, the summer diet of *G. macrocephalus* was fishes, crabs, shrimps, and amphipods, in decreasing order of occurrence (Table 1). The most frequently occurring fish was walleye pollock, *Theragra chalcogramma*. Flatfishes (Pleuronectidae) and Pacific sand lance, *Ammodytes hexapterus*, were also frequent. Suyehiro (1942:233-236), Moiseev (1953, 1960), and Mito (1974) also reported that Pacific cod feed on these fishes.

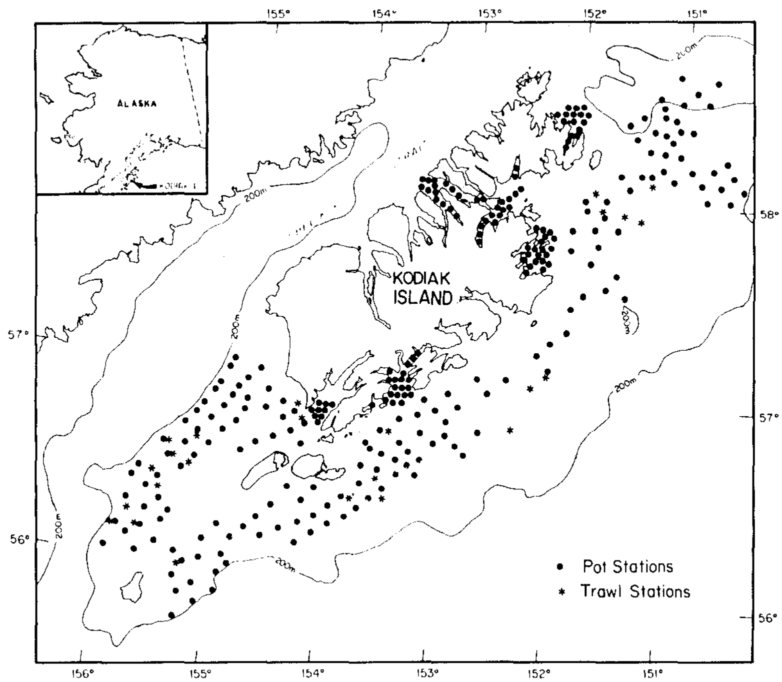

FIGURE 1.—Stations near Kodiak Island, Alaska, where Pacific cod were collected by pots and trawls during summers of 1973-75.

Crab occurrences were dominated by juvenile *C. bairdi*. Snow crabs were the single most frequently occurring food species found in Pacific cod stomachs and occurred in nearly 40% of the cod (Table 2). The average number of snow crabs occurring in cod feeding on snow crabs was 3.3 and they ranged from 1.8 to 70 mm carapace width[5] (Hilsinger et al.[6]); 78% were between 7 and 23 mm. Up to 32 crabs were found in a single cod stomach.

Chionoecetes bairdi had become important in the Alaskan and world markets with landings for Kodiak increasing from 50.3 t in 1967 to 12,400 t in 1976 (North Pacific Fishery Management Council[7]). Since juvenile snow crabs are a major item in the diet of the Pacific cod, reduction of cod stocks by the anticipated new bottomfish fishery should improve the chances for survival of young crabs. Enhanced recruitment of snow crabs to fishable stocks might result from such improved survival.

Pandalid and crangonid shrimps were important in the diet of the Pacific cod in the Kodiak area, a region where both groups are abundant in species and numbers (Ronholt 1963; Barr 1970; Feder and Jewett[8]).

Anonyx nugax may be the principal amphipod. Amphipods which were occasionally preserved from the stomach contents as well as from the perforated bait cans in the crab pots were later identified as *A. nugax*. Because of attraction to the bait, the occurrence of amphipods in stomachs of the pot-caught cod was probably artificially high.

Occurrence of food organisms in trawl-caught cod, in decreasing order was also fishes, crabs, shrimps, and amphipods (Table 3). The most common fishes were *A. hexapterus*, *T. chalcogramma*, and flatfishes. The most frequently consumed crab was *C. bairdi*. Shrimps were primarily Crangonidae.

Wilcoxon's paired-sample test indicated no significant difference ($\alpha = 0.05$) among food groups from cod caught by the two methods, or between sexes (Table 4). No sex differences were found in

[5]Females mature at about 72 mm carapace width (Hilsinger et al. see footnote 6) and males at about 110 mm carapace width (Brown and Powell 1972).

[6]Hilsinger, J. R., W. E. Donaldson, and R. T. Cooney. 1975. The Alaska snow crab, *Chionoecetes bairdi*, size and growth. Unpubl. manuscr., 38 p. Univ. Alaska Sea Grant Rep. No. 75-12 (Inst. Mar. Sci. Rep. No. 75-6).

[7]Fishery Management Plan and environmental impact statement for the tanner crab off Alaska. Sept. 23, 1977. Unpubl. manuscr., 346 p., prepared by the North Pac. Fish. Manage. Counc.

[8]Feder, H. M., and S. C. Jewett. 1977. The distribution, abundance, and diversity of the epifauna of two bays (Alitak and Ugak) of Kodiak Island, Alaska. Inst. Mar. Sci. [Univ. Alaska] Rep. R77-3, 74 p.

TABLE 1.—Frequency and percent frequency of occurrence of summer food items in stomachs of *Gadus macrocephalus* collected during 1973-75 by pots near Kodiak Island, Alaska. N = number of stomachs examined. Subtotals in parentheses.

FOOD ITEMS	1973 N=689 Freq.	1973 % Freq.	1973 subtotal	1974 N=1183 Freq.	1974 % Freq.	1974 subtotal	1975 N=2061 Freq.	1975 % Freq.	1975 subtotal	TOTAL 1973-75 N=3933 Freq.	TOTAL % Freq.	TOTAL subtotal
Coelenterata												
Hydrozoa (hydroids)	2	0.3		-	-		1	0.1		3	0.08	
Scyphozoa (jellyfishes)	-	-		-	-		1	0.1		1	0.03	
Anthozoa (anemones)	5	0.7	(1.0)	3	0.3		1	0.1	(0.3)	9	0.2	(0.31)
Annelida												
Polychaeta (segmented worms)	-	-		53	4.5		74	3.6		127	3.2	
Aphrodita sp.	15	2.1		10	0.9	(5.4)	24	1.2	(4.8)	49	1.2	(4.4)
Mollusca												
Polyplacophora (chitons)	-	-		1	0.1		-	-		1	0.03	
Pelecypoda (clams, mussels, cockles)												
Astarte polaris	-	-		1	0.1		1	0.1		2	0.05	
Chlamys sp.	-	-		-	-		1	0.1		1	0.03	
Clinocardium sp.	1	0.1		-	-		4	0.2		5	0.1	
Cyclocardia crassidens	1	0.1		1	0.1		1	0.1		3	0.08	
Cyclocardia crebricostata	1	-		1	0.1		-	-		1	0.03	
Cyclocardia sp.	-	-		-	-		2	0.1		2	0.05	
Glycymeris subobsoleta	1	0.1		-	-		-	-		1	0.03	
Hiatella arctica	1	0.1		-	-		-	-		1	0.03	
Limopsis akutanica	-	-		1	0.1		-	-		1	0.03	
Limopsis vaginatus	-	-		2	0.2		-	-		2	0.05	
Macoma brota	-	-		-	-		1	0.1		1	0.03	
Macoma calcarea	-	-		-	-		1	0.1		1	0.03	
Macoma expansa	1	0.1		-	-		-	-		1	0.03	
Macoma moesta	-	-		1	0.1		1	0.1		2	0.05	
Macoma sp.	1	0.1		1	0.1		1	0.1		3	0.08	
Modiolus sp.	-	-		-	-		2	0.1		2	0.05	
Musculus discors	-	-		-	-		1	0.1		1	0.03	
Musculus olivaceus	1	0.1		1	0.1		1	0.1		3	0.08	
Nucula tenuis	1	0.1		-	-		4	0.2		5	0.1	
Nuculana fossa	30	4.3		43	3.6		36	1.8		109	2.7	
Panomya ampla	1	0.1		-	-		-	-		1	0.03	
Patinopecten caurinus	-	-		7	0.6		5	0.2		12	0.3	
Pododesmus macroschisma	-	-		1	0.1		1	0.1		2	0.05	
Psephidia lordi	1	0.1		-	-		-	-		1	0.03	
Puncturella galeata	-	-		1	0.1		-	-		1	0.03	
Serripes groenlandicus	-	-		3	0.3		3	0.1		6	0.1	
Siliqua sloati	-	-		-	-		1	0.1		1	0.03	
Tellina nuculoides	-	-		-	-		1	0.1		1	0.03	
Velutina velutina	1	0.1		-	-		-	-		1	0.03	
Yoldia beringiana	2	0.3		-	-		5	0.2		7	0.2	
Yoldia myalis	-	-		2	0.2		-	-		2	0.05	
Yoldia thraciaeformis	-	-		1	0.1		-	-		1	0.03	
Yoldia sp.	7	1.0		4	0.3		-	-		11	0.3	
Unidentified Pelecypods	26	3.8		27	2.3		53	2.6		106	2.7	
Gastropoda (snails)												
Admete couthouyi	-	-		-	-		1	0.1		1	0.03	
Aforia circinata	-	-		-	-		1	0.1		1	0.03	
Amphissa columbiana	1	0.1		-	-		1	0.1		2	0.05	
Beringius kennicotti	-	-		-	-		1	0.1		1	0.03	
Boreotrophon pacifica	-	-		1	0.1		1	0.1		2	0.05	
Buccinum sp.	1	0.1		-	-		-	-		1	0.01	
Colus halli	-	-		-	-		2	0.1		2	0.05	
Cylichna alba	1	0.1		1	0.1		-	-		2	0.05	
Fusitriton oregonensis	1	0.1		-	-		2	0.1		3	0.08	
Margarites baxter	-	-		1	0.1		-	-		1	0.03	
Margarites obscura	-	-		1	0.1		2	0.1		3	0.08	
Margarites pupillus	-	-		-	-		1	0.1		1	0.03	
Mitrella gouldi	-	-		-	-		1	0.1		1	0.03	
Natica aleutica	1	0.1		2	0.2		-	-		3	0.08	
Natica clausa	-	-		1	0.1		-	-		1	0.03	
Natica sp.	-	-		-	-		5	0.2		5	0.1	
Neptunea sp.	1	0.1		-	-		1	0.1		2	0.05	
Polinices nanus	-	-		-	-		1	0.1		1	0.03	
Polinices pallida	2	0.3		2	0.2		3	0.2		7	0.2	
Solariella varicosa	-	-		1	0.1		-	-		1	0.03	
Tachyrhynchus sp.	-	-		1	0.1		-	-		1	0.03	
Trichotropis cancellata	1	0.1		1	0.1		3	0.2		5	0.01	
Turridae	-	-		-	-		1	0.1		1	0.03	
Unidentified gastropods	1	0.1	(11.6)	26	2.2	(11.9)	34	1.7	(10.3)	61	1.5	(10.2)
Cephalopoda												
Octopi	53	7.6		108	9.1		164	8.0		326	8.3	
Squid	-	-		1	0.1	(9.2)	-	-		-	-	
Arthropoda												
Crustacea												

TABLE 1.—Continued.

FOOD ITEMS	1973 N=689 Freq.	1973 % Freq.		1974 N=1183 Freq.	1974 % Freq.		1975 N=2061 Freq.	1975 % Freq.		TOTAL 1973–75 N=3933 Freq.	TOTAL % Freq.	
Malacostraca												
Euphausiacea (krill) and												
Mysidacea (mysids)	20	2.9		34	2.9		181	8.8		235	6.0	
Isopoda (pill bugs)	3	0.4		4	0.3		10	0.5		17	0.4	
Amphipoda (sand fleas)	192	27.8		195	16.5		407	19.8		794	20.2	
Ampelisca macrocephala	-	-		-	-		52	2.5	(22.3)	52	1.3	(21.5)
Decapoda												
Pandalidae (shrimps)	67	9.7		118	10.0		-	-		185	4.7	
Pandalus borealis	-	-		-	-		166	8.1		166	4.2	
Pandalopsis dispar	-	-		4	0.3		19	0.9		23	0.6	
Pandalus goniurus	-	-		-	-		4	0.2		4	0.1	
Pandalus hypsinotus	-	-		-	-		7	0.3		7	0.2	
Pandalus montagui tridens	-	-		-	-		8	0.4		8	0.2	
Pandalus platyceros	-	-		1	0.1		3	0.2		4	0.1	
Crangonidae (shrimps)	77	11.1		95	8.0		286	13.9		458	11.6	
Argis crassa	-	-		-	-		3	0.2		3	0.08	
Sclerocrangon boreas	-	-		-	-		5	0.2		5	0.1	
Hippolytidae												
Spirontocaris sp.	-	-		-	-		5	0.2		5	0.1	
Unidentified shrimps	131	19.0	(39.8)	82	6.9	(25.3)	171	8.3	(32.9)	384	9.8	(31.8)
Paguridae (hermit crabs)	24	3.4		21	1.8		55	2.7		100	2.5	
Elassochirus cavimanus	-	-		-	-		2	0.1		2	0.05	
Elassochirus tenuimanus	-	-		1	0.1		3	0.2		4	0.1	
Lithodidae (crabs)												
Paralithodes camtschatica	2	0.3		9	0.8		31	1.5		42	1.1	
Placetron wosnessenskii	-	-		1	0.1		2	0.1		3	0.08	
Rhinolithodes wosnessenskii	-	-		-	-		1	0.1		1	0.03	
Galatheidae (crabs)												
Munida quadrispina	-	-		-	-		1	0.1		1	0.03	
Cancridae (crabs)	-	-		1	0.1		13	0.6		14	0.4	
Cancer sp.	4	0.5		-	-		-	-		4	0.1	
Telmessus cheiragonus	1	0.1		-	-		2	0.1		3	0.08	
Pinnotheridae (pea crabs)												
Pinnixa sp.	5	0.7		36	3.0		23	1.1		64	1.6	
Majidae (spider crabs)												
Chionoecetes bairdi	281	40.7		428	36.2		735	35.6		1444	36.7	
Hyas lyratus	13	1.8		44	3.7		42	2.0		99	2.5	
Oregonia gracilis	-	-		3	0.3		6	0.3		9	0.2	
Unidentified crabs	12	1.7	(49.2)	3	0.3	(46.4)	4	0.2	(44.7)	19	0.5	(46.0)
Echinodermata												
Asteroidea (sea stars)	1	0.1		2	0.2		1	0.1		4	0.1	
Ctenodiscus crispatus	-	-		-	-		1	0.1		1	0.03	
Echinoidea (sea urchins)	1	0.1		-	-		1	0.1		2	0.05	
Holothuroidea (sea cucumbers)	2	0.3		5	0.4		10	0.5		17	0.4	
Ophiuroidea (brittle stars)	-	-		3	0.3		3	0.2		6	0.1	
Ophiura sarsi	-	-	(0.4)	-	-	(0.9)	2	0.1	(1.1)	2	0.05	(0.73)
Vertebrata												
Osteichthyes												
Clupeidae (herrings)												
Clupea harengus pallasi	6	0.8		1	0.1		2	0.1		9	0.2	
Osmeridae (smelts)	3	0.4		2	0.2		4	0.2		9	0.2	
Mallotus villosus	-	-		-	-		1	0.1		1	0.03	
Gadidae (codfishes)												
Theragra chalcogramma	12	1.7		32	2.7		109	5.3		153	3.9	
Gadus macrocephalus	7	1.0		13	0.9		3	0.2		23	0.6	
Zoarcidae (eelpouts)	29	4.2		9	0.8		7	0.3		45	1.1	
Lycodes brevipes	-	-		-	-		3	0.2		3	0.08	
Scorpaenidae (rockfishes)	1	0.1		1	0.1		-	-		2	0.05	
Hexigrammidae (greenlings)												
Pleurogrammus monopterigius	-	-		-	-		2	0.1		2	0.05	
Cottidae (bullheads)	8	1.1		27	2.3		6	0.3		41	1.0	
Dasycottus setiger	-	-		-	-		2	0.1		2	0.05	
Hemilepidotus jordani	-	-		-	-		1	0.1		1	0.03	
Gymnocanthus sp.	-	-		-	-		6	0.3		6	0.1	
Agonidae (poachers)	-	-		3	0.3		17	0.8		20	0.5	
Bathymasteridae (ronquils)												
Bathymaster signatus	-	-		1	0.1		2	0.1		3	0.05	
Trichodontidae (sandfishes)												
Trichodon trichodon	-	-		4	0.3		2	0.1		6	0.1	
Cyclopteridae (lumpsuckers)	1	0.1		1	0.1		5	0.2		7	0.2	
Pleuronectidae (flatfishes)	22	3.2		21	1.8		40	1.9		83	2.1	
Atheresthes stomias	-	-		-	-		2	0.1		2	0.05	
Hippoglossoides elassodon	-	-		-	-		12	0.6		12	0.3	
Hippoglossus stenolepis	-	-		-	-		2	0.1		2	0.05	
Ammodytidae (sand lances)												
Ammodytes hexapterus	20	2.9		20	1.7		9	0.4		49	1.2	
Stichaeidae (pricklebacks)	14	2.0		-	-		10	0.5		24	0.6	
Crypacanthodidae (wrymouths)												
Lynconectes aleutensis	9	1.3		4	0.3		4	0.2		17	0.4	
Unidentified fishes	256	37.1	(55.9)	476	40.2	(51.9)	655	31.8	(44.1)	1387	35.3	(48.2)
Stomachs empty	8	1.6		59	5.0		184	8.9		251	6.4	

TABLE 2.—The importance of the snow crab, *Chionoecetes bairdi*, in the summer diet of Pacific cod. Analysis based on specimens from pots. Crab incidence is given for total number of cod examined; incidence as a percent of feeding cod given in parentheses.

Sampling date	Cod examined (no.)	Feeding cod (%)	Incidence of crabs Number	Incidence of crabs Percent	Crabs (no.)	Average crab occurrence in cod feeding on crabs
26 June-3 August 1973	689	98.8	281	40.7 (41.3)	1,022	3.6
28 June-31 July 1974	1,183	95.0	427	36.2 (38.0)	1,033	2.4
30 June-27 July 1975	2,061	91.0	734	35.6 (39.1)	2,682	3.6
Total	3,933	93.6	1,442	36.7 (39.2)	4,737	3.3

TABLE 3.—Frequency and percent frequency of occurrence of food items in stomachs of *Gadus macrocephalus* collected July 1975 and 1976 by otter trawl near Kodiak Island, Alaska. N = number of stomachs examined. Subtotals in parentheses.

Food items	July 1975 N = 150 Freq.	% Freq.	July 1976 N = 194 Freq.	% Freq.	Total 1975-1976 N = 344 Freq.	% Freq.
Annelida						
Polychaeta	2	1.3	3	1.5	5	1.4
Mollusca						
Pelecypoda and Gastropoda	17	11.3	10	5.1	27	7.8
Cephalopoda	3	2.0	8	4.1	11	3.2
Arthropoda						
Crustacea						
Euphausiacea and Mysidacea	13	8.6	10	5.1	23	6.7
Isopoda	-	-	3	1.5	3	0.9
Amphipoda	14	9.3	15	7.7	29	8.4
Decapoda						
Pandalidae	16	10.7	24	12.4	40	11.6
Crangonidae	37	24.7	37	19.1	74	21.5
Unidentified shrimps	18	12.0 (47.4)	24	12.4 (43.9)	42	12.2 (45.3)
Majidae						
Chionoecetes bairdi	55	36.7	82	42.3	137	39.8
Unidentified crabs	13	8.7 (45.4)	23	11.9 (54.2)	36	10.5 (50.3)
Echinodermata	1	0.6	-	-	1	0.3
Vertebrata						
Osteichthyes						
Gadidae						
Theragra chalcogramma	6	4.0	7	3.6	13	3.8
Pleuronectidae	5	3.3	4	2.1	9	2.6
Ammodytidae						
Ammodytes hexapterus	20	13.3	13	6.7	33	9.6
Unidentified fishes	66	44.0 (64.6)	70	36.1 (48.5)	136	39.5 (55.5)
Stomachs empty	7	4.7	13	6.7	20	5.8

TABLE 4.—Comparison of percent frequency of occurrence of summer food groups in male and female *Gadus macrocephalus* caught by pots and trawls in the Kodiak Island area.

	Percent frequency of occurrence in:			
	Pot-caught cod		Trawl-caught cod	
Food groups	Males	Females	Males	Females
Fishes	21.8	24.2	26.3	24.8
Crabs	22.0	19.3	24.2	20.9
Shrimps	15.1	14.2	15.4	24.7
Amphipods	10.0	14.3	4.1	4.3
Gastropods and pelecypods	5.0	4.7	3.3	4.5
Cephalopods	3.6	4.7	2.3	0.9
Euphausiids and mysids	2.1	4.0	4.0	2.7
Polychaetous annelids	1.4	3.1	0.3	1.1
Echinoderms	0.4	0.4	0.1	0.2
Isopods	0.2	0.2	0.5	0.4
Empty stomachs	4.4	2.0	2.8	3.0
Stomachs examined (no.)	2,106	1,827	188	156

other studies on Gadiformes (e.g., Homans and Vladykov 1954; Wigley 1956; Powles 1958; Wigley and Theroux 1965).

A significant difference (χ^2, $\alpha = 0.05$) was found for occurrence of food groups between years for each size group (Figure 2). The only similarity was among 33-52 cm fish between 1973 and 1975 and among 73-92 cm fish between 1974 and 1975. Some trends in frequency of food groups by cod size were apparent (Figure 2). Fishes and cephalopods increased in frequency with increasing cod size over all years while amphipods and polychaete worms decreased. Daan (1973) investigated the relative size of food items (crustaceans and fishes) used by the Atlantic cod, *G. morhua*, and found

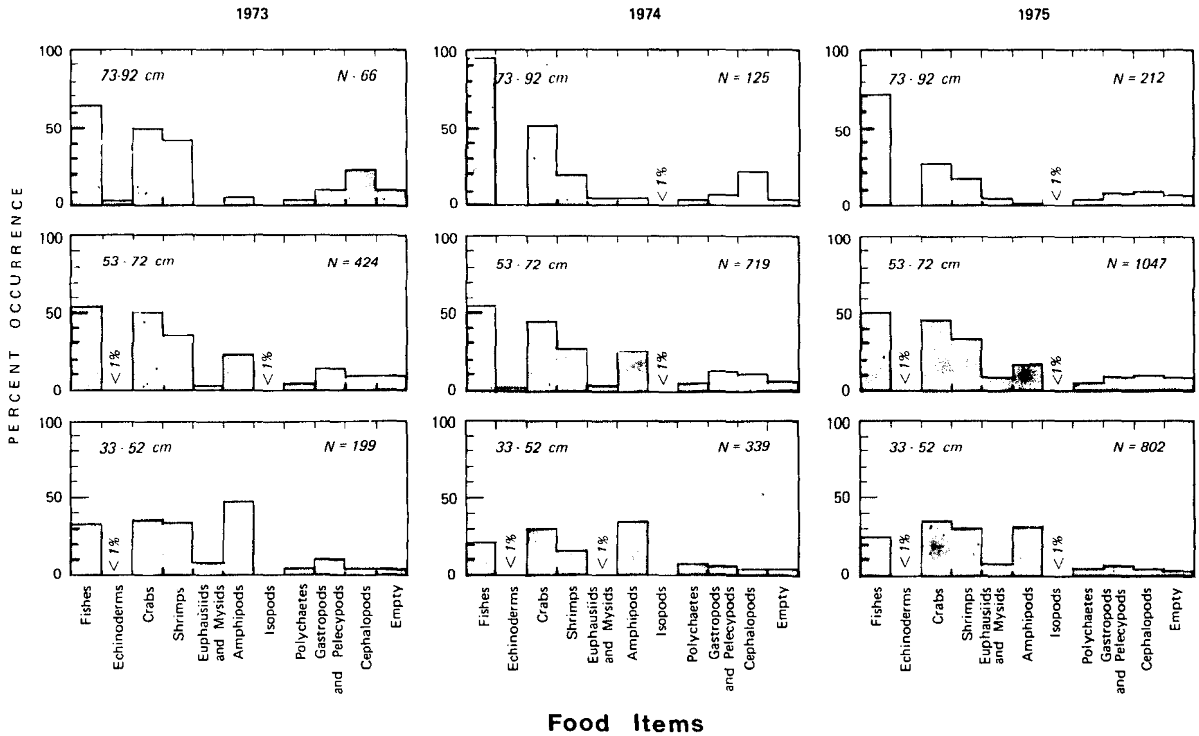

FIGURE 2.—Percent frequency of occurrence of summer food items within three size groups of pot-caught Pacific cod by year of collection—1973-75—near Kodiak Island, Alaska.

that smaller crustaceans were more commonly found in small cod while a gradual shift to a mixed diet of larger prey (primarily fishes) was noted for the larger fish. Arntz (1974) examined juvenile *G. morhua*, and found the most important food to be small crustaceans, mainly cumaceans (35.6% by weight of the total food consumed); fishes accounted for only 15.3% by weight of the total food consumed. This trend of large cod being more piscivorous than small cod has also been demonstrated by Powles (1958) and Rae (1967).

Acknowledgments

I am especially indebted to the ADF&G and Guy C. Powell for their assistance in collection of data. Special thanks to Howard M. Feder, University of Alaska, for his editing suggestions. Thanks to John R. Hilsinger, University of Alaska, for allowing me to use his Pacific cod feeding data obtained during International Pacific Halibut Commission surveys, and to George Mueller and Kenneth Vogt, both of the Marine Sorting Center, University of Alaska, for their taxonomic assistance. Mollusc identifications were made by Rae Baxter, ADF&G.

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STEPHEN C. JEWETT

Institute of Marine Science
University of Alaska
Fairbanks, AK 99701

A COMPUTER SOFTWARE SYSTEM FOR OPTIMIZING SURVEY CRUISE TRACKS[1]

Since 1972, the Southeast Fisheries Center, National Marine Fisheries Service, NOAA, has been conducting resource assessment surveys for groundfish in the northern Gulf of Mexico. Random sampling stations were selected and cruise tracks plotted by hand requiring several man-days of effort without assurance than an optimum cruise track had been chosen. Consequently, a computer routine was developed at the NMFS National Fisheries Engineering Laboratory, Bay Saint Louis, Miss., to satisfy two requirements: Generate a set of randomly selected sampling stations from a preestablished station grid and minimize the distance the vessel must travel to sample each station once. This paper presents the resultant routine, a comparison of results with actual cruises, and a discussion of other possible applications of the program.

Background

The problem of determining the optimum cruise track to sample a given set of stations can be restated as, "determining the shortest route from one point to another which allows a vessel to visit every station once." This problem is similar to one in the field of operations research generally referred to as "the traveling salesman problem." The original formulation of the problem was to minimize the time required by a traveling salesman to visit a number of cities and return home (Bellmore and Nemhauser 1968). Several algorithms have been developed which solve the problem exactly; however, computer storage and running time increase exponentially with the number of points to be visited. Because the groundfish surveys normally deal with station numbers in excess of 100, an heuristic method of solving the problem was selected. Lin and Kernighan (1973) at the Bell Telephone Laboratories (BTL) developed an approximate procedure for solving traveling salesman problems with large number of visitation points which appeared applicable to cruise track optimization.[2] The National Fisheries Engineering Laboratory obtained

[1]Contribution No. 78-19F from the Southeast Fisheries Center, National Marine Fisheries Service, NOAA, NSTL Station, MS 39529. MARMAP Contribution No. 154.

[2]To develop a feeling for the complexity of these problems, it should be noted that for a given number of stations, n, there are