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Food Habits of Bristol Bay Species Which Might Be Affected by Oil Development

A Study on the Variability in Demersal and Pelagic Food Habits

April 1985

FOOD HABITS OF BRISTOL BAY SPECIES WHICH MIGHT BE AFFECTED BY OIL DEVELOPMENT

A study on the variability in demersal and pelagic food habits

by

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Report to
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CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Simulation modeling efforts have shown that one of the consequences of oil spill events on the Bering Sea fauna is contamination of fishes via uptake of oil (Gallagher and Pola 1984). Oil uptake by fishes and invertebrates occurs through passive uptake processes (adsorption and absorption) and the ingestion of oil contaminated food. Contamination was shown to be more persistent, lasting at least two weeks longer, in fishes consuming demersal food items because of the longer residence time of weathered oil in the demersal habitat (Pola and Miyahara 1985). Laevastu and Fukuhara(1985) in their review of studies on oil sedimentation in the sea conclude that very high concentrations of oil can accumulate in the nepheloid layer near the bottom and later in sediments and may possibly persist in the sediments for years. Thus, species which utilize demersal food items are more likely to be impacted in the long-term by oil spill events than species which consume pelagic food. It becomes important to outline the existing knowledge of patterns of demersal versus pelagic habitat utilization by marine fish species to determine likelihoods of oil spill impact on these species. In order to extrapolate oil spill modelling results to other seasons or areas it is necessary to understand the variability in demersal versus pelagic food components in marine fish species by season, area, and fish size.

It is the purpose of this study to summarize data regarding the food habits of the marine fish and invertebrate species used in the BIOS (Biological Impact of an Oil Spill) Model. Differences in food habits by fish size, season, and area in the Bering Sea will be discussed particularly with reference to changes in pelagic versus demersal food habits. This should provide an indication of the likely impact on these species from oil spills occurring in different areas and times in the eastern Bering Sea. The species included in this report are sockeye salmon, Pacific herring, walleye pollock, Pacific cod, Pacific halibut, yellowfin sole, rock sole, flathead sole, arrowtooth flounder, Alaska plaice, and king and Tanner crabs. New data will be presented for walleye pollock, Pacific cod, yellowfin sole, flathead sole and arrowtooth flounder. Other evidence for food habit trends are obtained from the literature.

SAMPLE COLLECTION AND PROCESSING

Specimens were collected during 1983 and 1984 in the eastern Bering Sea by U.S. observers aboard foreign fishing vessels and by U.S. scientists aboard research vessels participating in resource assessment surveys of the area. Stomachs of Pacific cod, walleye pollock, yellowfin sole, arrowtooth flounder, and flathead sole were taken from bottom and midwater trawl samples of variable tow duration. The 5436 stomach samples which were obtained came mostly from the middle shelf to slope areas of the eastern Bering Sea in depths of 45m to 200m (Table 1).

Individual fish were first checked for signs of regurgitation, i.e., food items in mouth or gill plates or flaccid stomach and discarded if any such signs were noted. Stomachs from the remaining fish were excised and placed individually into muslin bags with a specimen label containing fish fork length, sex, and station information. All samples were preserved in a 10:1 seawater/formaldehyde mixture.

Stomachs were analyzed individually in the laboratory. Prey items were identified to the lowest practical taxon and damp weight to the

Table 1.--Stomach sampling dates, areas, and depths for five groundfish species in the eastern Bering Sea and the respective sample sizes.

Species	Sampling dates	Area	Depth interval (m)	No. stomachs
Arrowtooth flounder (*Atheresthes stomias*)	Mar-Oct 1983-84	Outer shelf, slope	65-200+	825
Pacific cod (*Gadus macrocephalus*)	Sep-Jan 1983-84	Middle-outer shelf, slope	50-200+	184
Flathead sole (*Hippoglossoides elassodon*)	Jun-Sep 1984	Middle-outer shelf	45-125	271
Walleye pollock (*Theragra chalcogramma*)	Jul-Jun 1981-83	Middle-outer shelf, Aleutian Basin	45-200+	3098
Yellowfin sole (*Limanda aspera*)	Feb-Aug 1984	Inner-outer shelf	45-125	1058
				5436

nearest milligram and number of each prey taxon were recorded. Length measurements of fish and crab prey were taken when enough remained of the items to permit measurement.

FOOD HABITS OVERVIEW OF KEY PREDATORS
General Prey Types

Pacific cod

Figure 1 shows the main categories of food consumed by Pacific cod sampled in autumn and winter in the eastern Bering Sea. Crab and fish constituted the major portion of cod's diet by weight. Most of the crab consumed was Tanner crab (*Chionoecetes* sp.) and the major fish prey was the walleye pollock . Other fish consumed were from the families Zoarcidae, Cottidae, Stichaeidae, Cyclopteridae, and Pleuronectidae. Cod also consumed a variety of invertebrates including crangonid and pandalid shrimp, anemones, squid, polychaetes, and small epibenthic crustaceans.

Other studies of Pacific cod food habits in the eastern Bering Sea produced similar results. Shimada and June (1982) sampled extensively throughout the eastern Bering Sea and discovered pollock dominated the diet by weight (28%) and other fish, Tanner crab, king crab (*Paralithodes* sp.) and shrimp were also important food items. Mito (1974) and Feder (1978) found pollock, tanner crab, and shrimp as the most predominant items in the diet of Pacific cod.

Similar prey types were consumed by cod in the Gulf of Alaska. Jewett (1978) found that pandalid shrimp occurred most frequently in the diet of cod sampled near Kodiak Island and that pollock and Tanner crab were the next most frequently occurring prey. In southeast Alaska, Clausen (1980) reported that pollock and herring constituted the bulk of

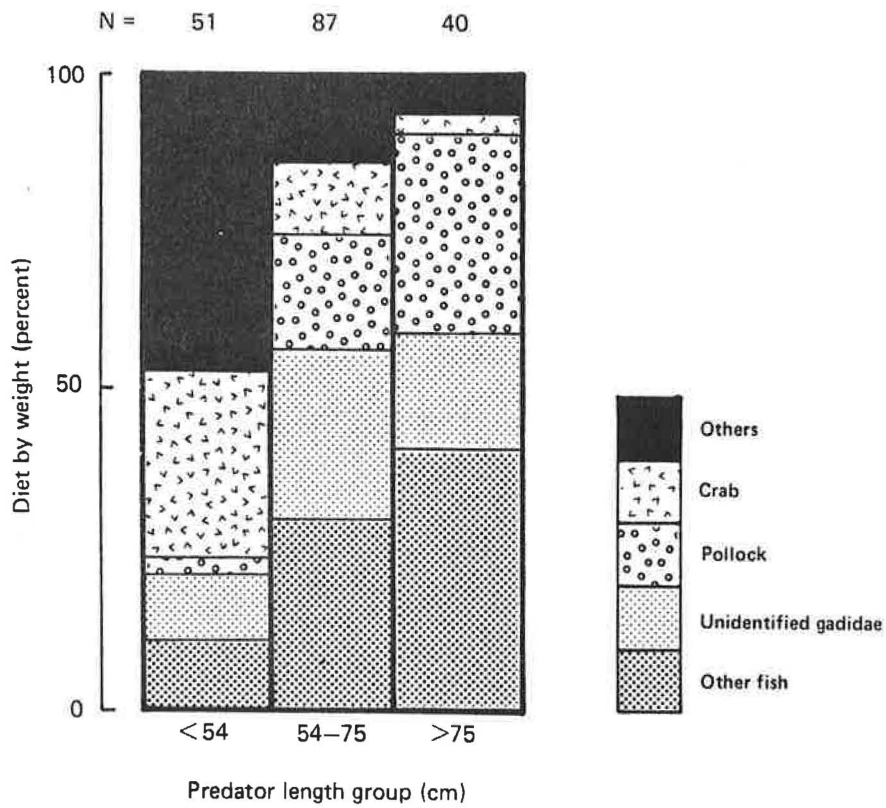

Figure 1.--Percentages by weight of main food items consumed by cod sampled in autumn and winter in the eastern Bering Sea.

cod's diet (40% by volume) and tanner crab and shrimp made up most of the remainder.

Allen (1984) summarized the feeding behavior of Pacific cod. He described cod as a benthopelagivore that is a searcher-pursuer. Results from the above studies support this observation that the main prey types of cod are benthic invertebrates and pelagic fish which requires a search and pursuit prey capturing behavior.

Arrowtooth flounder

Figure 2 shows the percentages by weight of main food items consumed by arrowtooth flounder sampled in spring through autumn in the eastern Bering Sea. Pollock dominated the diet, constituting as much as 67% by weight of prey consumed by arrowtooth flounder. Other fish were also important prey and included Zoarcidae, Macrouridae, Cottidae, Stichaeidae, Ammodytidae, and Pleuronectidae. As much as 25% by weight of the diet was squid, mainly Berryteuthis sp., and up to 26% by weight of prey consumed were crustaceans (pandalid shrimp and euphausiids).

The only other detailed analysis of arrowtooth flounder food habits in the eastern Bering Sea was performed by Mito (1974). He found flounder consuming mostly pollock (56-100% by weight) and shrimp (1-38% by weight). Smith et al. (1978) sampled arrowtooth flounder in the Gulf of Alaska and reported unidentified fish (23% by weight), pollock (10% by weight) and euphausiids (37% by weight) as the main dietary components. Off northern California, arrowtooth flounder ate mostly fish (47% by weight), the majority of which were flatfish. Also important in the diet were pandalid shrimp (38% by weight) and euphausiids (7% by weight)(Gotshall 1969).

Allen (1982) characterizes large-mouthed flatfishes with symmetrical mouths like the arrowtooth flounder as sight-feeders which are oriented

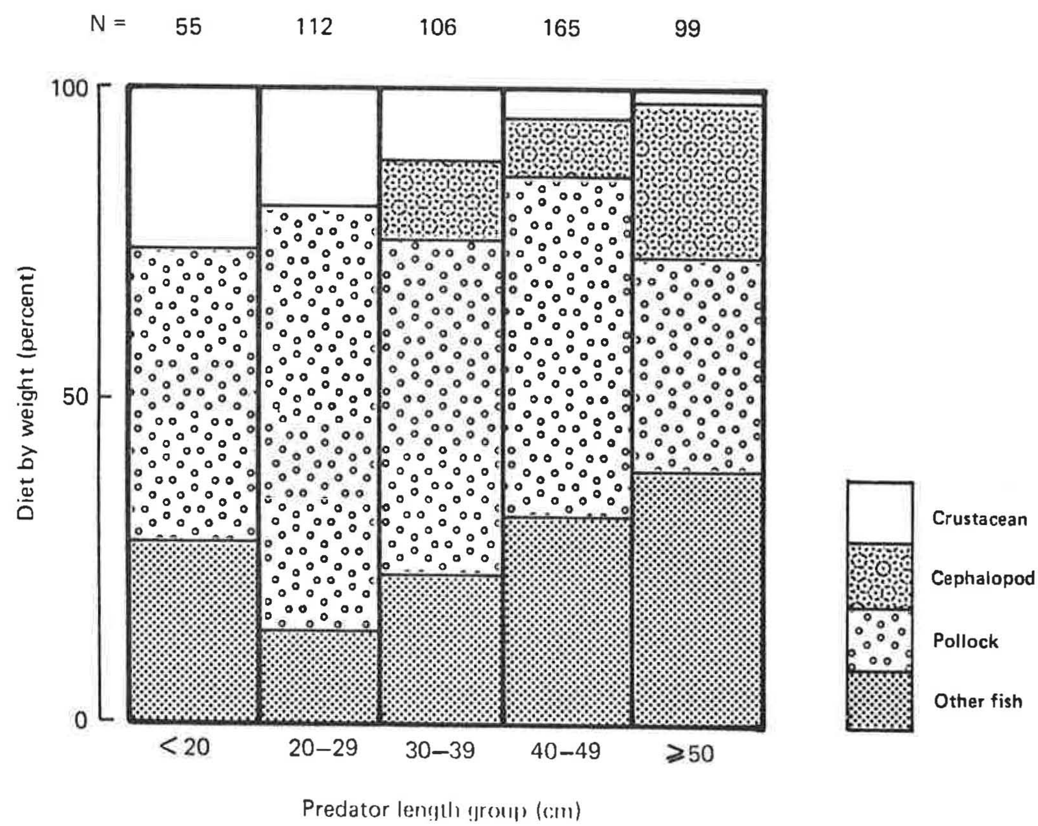

Figure 2.--Percentages by weight of main food items consumed by arrowtooth flounder sampled in spring, summer, and autumn in the eastern Bering Sea.

up in the water column when foraging for prey. The presence of pelagic fish and euphausiids or nektonic benthopelagic crustaceans such as shrimp in the arrowtooth flounder diet support these observations.

Flathead sole

Figure 3 shows the percentages by weight of main food items consumed by flathead sole sampled in summer in the eastern Bering Sea. Epibenthic crustacea, which includes shrimp and crab, constitute from 10 to 60% of the diet by weight. Brittle stars are also an important prey item forming up to 72% of the diet by weight. Other lesser important dietary components include polychaetes, echiuroids, and molluscs. Fish formed from 0-22% of the diet by weight, the major portion of which was pollock.

Mito's (1974) study of flathead sole's diet in the eastern Bering Sea classified flathead sole as a mostly benthic feeder. Ophiuroids (brittle stars) at times formed up to 98% by weight of the diet. Pandalid shrimp (up to 47% by weight), Tanner crab (up to 23% by weight) and pollock (up to 15% by weight) were the other major dietary components. Skalkin (1963) called flathead sole in the eastern Bering Sea a benthic and nektonic feeder based on its consumption of benthic brittle stars and nektonic shrimp, euphausiids, and hyperiid amphipods. Similarly, Mineva (1964) found flathead sole consuming mostly brittle stars, along with shrimp, amphipods, fishes, and molluscs. In the Gulf of Alaska, flathead sole ate euphausiids, brittle stars, pandalid shrimp and juvenile pollock (Smith et al. 1978). In the coastal waters of Washington state, Miller (1970) reported flathead sole consumed mostly fish (39% by weight) and mysids (36% by weight). Shrimp, clams, and polychaetes formed the remainder of the diet.

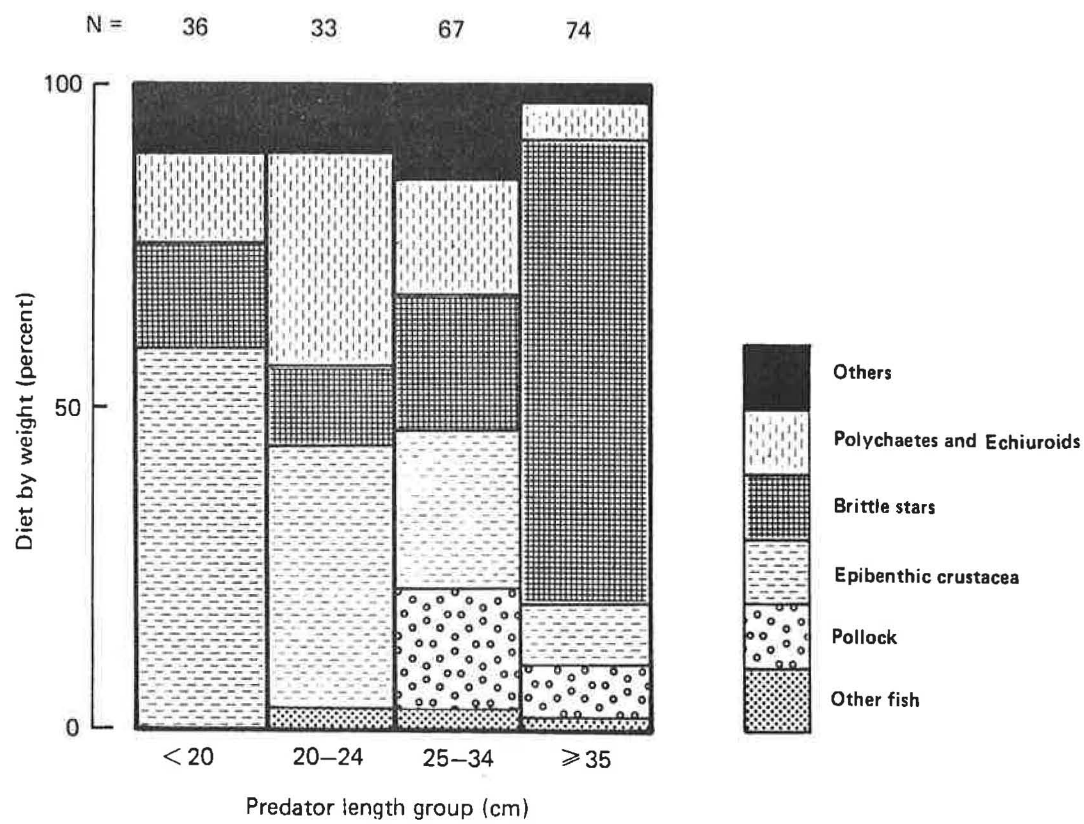

Figure 3.--Percentages by weight of main food items consumed by flathead sole sampled in summer in the eastern Bering Sea.

Allen (1984) classified flathead sole as a benthopelagivore that uses ambush, search, and pursuit techniques for food gathering. The above results support this observation in that flathead sole uses benthic and pelagic foods for prey. Some of these prey are sessile requiring searching behavior while others are more motile requiring ambush or pursuit behavior for capture.

Walleye pollock

Table 2 (from Dwyer 1984)shows the major prey items found in walleye pollock collected from the eastern Bering Sea. Euphausiids (13% by weight) and fish (48% by weight) were the main consumed prey. The major fish consumed was walleye pollock. Other prey items consumed included copepods, amphipods, and larvaceans.

Other studies have also reported juvenile pollock and euphausiids as major prey items of pollock (Takahashi and Yamaguchi 1972; Mito 1974; Bailey and Dunn 1979). Pandalid shrimp is also consumed by pollock in certain areas (Feder 1977). Allen (1984a) classifies pollock as a pelagivore which pursues it prey. The above findings substantiate this observation in that pollock consume pelagic juvenile pollock, euphausiids and copepods.

Pacific halibut

Most food habit studies on Pacific halibut show its main prey to be fish, crab, shrimp and molluscs. Fish consumed include sandlance (Smith et al. 1978), pollock (Mito 1974), and crab(Feder 1977)(mainly Tanner crab). Allen (1984b) notes that Pacific halibut feed mostly on nektonic and motile epibenthic fish. Although its life mode is benthic it obtains prey primarily from the water column and partly from the bottom. Allen (1984b) classifies halibut as an ambusher-pursuer that feeds mostly on active prey.

Table 2. Major prey items found in the stomachs of pollock collected from the eastern Bering Sea. All items which showed a percent frequency of occurrence (% F.O.)>10% are included. IRI = Index of Relative Importance (Pinkas et al. 1971)

Prey Organism	% F.O.	Mean No./ Stom.	% No.	Mean Wt./ Stom. (g)	% Wt.	IRI
Thecosomata	16.8	6.8	2	0.02	<1	42
Calanus cristatus	14.9	19.5	6	0.11	2	117
Calanus sp.	10.7	34.5	11	0.06	1	128
Calanoida (unident.)	23.8	54.1	17	0.12	2	457
Parathemisto sp.	25.6	5.5	2	0.02	<1	52
Thysanoessa inermis	17.6	7.4	2	0.21	3	95
Euphausiacea (unident.)	30.2	18.2	6	0.72	10	481
Larvacea	11.4	87.1	28	0.31	4	372
Theragra chalcogramma	10.3	0.4	<1	2.92	41	420
Osteichthyes (unident.)	13.7	0.7	<1	0.52	7	101

Alaska plaice and Rock sole

The main food item of Alaska plaice appears to be infaunal polychaetes (Skalkin 1963; Mineva 1968; Allen 1984a). Minor food items include amphipods, bivalve molluscs, shrimp, and echiuroids. Allen (1984a) classifies plaice as a benthivore which stalks and extracts prey on or associated with the bottom.

Rock sole consume similar prey types. Polychaetes, clams and brittle stars are major prey items while amphipods and even fish are minor prey items (Feder 1977; Mito 1974; Rogers et al. 1979; Smith et al. 1978). Allen (1984a) also classifies rock sole as a benthivore. He reports that rock sole is a searcherstalker which extracts and excavates for prey on the sea bottom.

Yellowfin sole

Yellowfin sole utilizes a more diverse set of prey items than Alaska plaice and rock sole. It consumed not only molluscs, polychaetes, brittle stars, and amphipods but also euphausiids, shrimp, and sand dollars. Some studies have reported fish (Feder 1977; Rogers et al. 1979; Wakabayashi 1974) and crab larvae (Haflinger 1983) as prey items (Table 3). Allen classifies yellowfin sole as a benthopelagivore which actively searches and pursues its prey.

King and Tanner crab

King crab consume mostly bivalve molluscs, echinoderms and crustaceans (McLaughlin and Hebard 1961; Feder 1977). Cunningham (1969) reports that echinoderms comprise most (49% by weight) of the adult diet while molluscs (37% by weight) form the remainder (Table 4).

Tanner crab have similar diet of which bivalves, crustaceans, and polychaetes are the main food items (Feder 1978, 1979, 1981). Fish is

Table 3. Major prey items of yellowfin sole by life history stage, season, and area.

Food Habits

Life history stage	Reference	Season	Area	Food Items (% by weight
Larvae (2-10 mm) Limanda limanda	Last, 1980	Su	North Sea	90% copepodites, 10% decapod zoea.
Juveniles	Rogers et al. 1979	Sp, Su	Kodiak I.	22% fish (cottids), 20% poly chaetes, 18% crab, 14% clams.
Adults 100-200 mm	Wakabayashi, 1974	Su	Bering Sea	polychaetes, amphipods, echiuroids.
201-300 mm				polychaetes, bivalves, echiuroids, gadids, osmerids, amphipods.
301+ mm				Mostly bivalves and echiuroids.
Adults	Skalkin, 1963	Sp, Su	SW of Cape Newenham	mysids, euphausiids (30-50 m depth) polychaetes, molluscs (50-65 m depth).

Table 4. Major prey items of king crab by life history stage, season, and area.

Food habits

Life history stage	Reference	Season	Area	Food items (% by weight)
Pelagic larvae	Incze, pers. comm.	Sp, Su	Bristol Bay	copepod nauplii, copepodites, cirripedia larvae.
Benthic juveniles	Takeuchi, 1968	Su		polychaetes, seaweed.
Adults	Cunningham, 1969	Su	Bristol Bay	49% echinoderms, 37% molluscs, 10% crustaceans, polychaetes.

also a prey item but may possibly be consumed only as dead carcasses lying on the sea bottom. Feder (1977, 1978) calls both king and Tanner crabs scavengers in describing their main food gathering behavior.

Pacific herring

Table 5 shows some of the main food items of Pacific herring; copepod eggs, copepods, algae, and euphausiids. Fish fry and amphipods are also consumed occasionally (Rumyantsev and Darda 1970). It appears herring utilize the pelagic environment exclusively for food gathering.

Sockeye salmon

Table 6 outlines the major prey consumed by sockeye salmon. Fish, copepods, and euphausiids dominate the diet. Other prey itmes include pelagic crab larvae, amphipods and pteropods. Similar to herring, sockeye salmon feeds exclusively on pelagic prey.

Size Related Feeding Trends

Pacific cod

Figure 1 also shows changes in major prey items of Pacific cod with increasing cod size. Cod appears to consume more invertebrate prey and particularly crab at smaller (<54 cm) sizes and changes to more of a fish-feeder as it grows in length. By the time cod are >75 cm in length, their diet consists mostly of fish (90% by weight).

Most other studies found identical changes in diet with cod size. Shimada and June (1982) report that the percentage of pollock by weight in cod's diet increased from about 15% in cod <45cm to up to 60% in cod >65cm in length. Mito (1974) found cod <50cm long ate more shrimp and crab while cod >50cm consumed mostly pollock. He noted that the proportion of 1+ aged pollock consumed increased with increasing cod size while the proportion of 0-age pollock decreased in the diets of larger cod. This

Table 5. Major prey items of Pacific herring by life history stage, season, and area.

Food habits

Life history stage	Reference	Season	Area	Food items (% by weight)
Larvae 9-20 mm	Wailes, 1963	Sp	British Columbia	40% invertebrate eggs, 40% diatoms, 20% copepods nauplii.
Larvae 9-20 mm	Barraclough, 1967	Sp, Su	British Columbia	90% copepod nauplii, 10% eggs and algae.
Juveniles 20-100 mm	Barraclough, 1967	Su	British Columbia	phytoplankton, copepod eggs, copepods, amphipods, larvaceans.
Adults 100+ mm	Wailes, 1963	Su, F, Sp	British Columbia	euphausiids, copepods.
Adults	Dudnik and Usol'tsev 1968	Su	Bering Sea	euphausiids, calanoid copepods, Sagitta.
Adults	Barraclough, 1967	Sp, Su	British Columbia	90% copepods, 10% amphipods, euphausiids, brachyura larvae, and invert. eggs.

Table 6. Major prey items of sockeye salmon by life history stage, season and area.

Food habits

Life history stage	Reference	Season	Area	Food items (% by weight)
Smolts	Manzer, 1969	Su	British Columbia	48% copepods, 24% fish, 14% larvaceans, 5% decapods, 4% insecta, 3% amphipods.
Smolts	Straty, 1974	Su	Bristol Bay	Sandlance larvae, euphausiid larvae, copepods, cladocera, pteropods, decapod larvae, other fish larvae, invert. eggs, insects.
Adults	Kanno and Hamai, 1971	Su	E. Bering Sea shelf	43% euphausiids, 27.7% fish, 25.1% amphipods.
Adults	Nishiyama, 1974	Su	Bristol Bay	70% euphausiids, 20% fish larvae, 10% crab zoea, amphipods and pterapods.

predator-prey size relationship was reported to be linear in that as cod size increased the maximum pollock size which was consumed increased in a linear fashion. Clausen (1980) and Jewett (1978) observed similar trends in the Gulf of Alaska. Crab and shrimp dominated in cod <50 or 60 cm while cod between 50-70 cm or 60-70 cm had a transitional diet and cod >70 cm consumed mostly fish. Thus cod have a definite change in diet with increasing size; swithching from a predominantly crustacean and other invertebrate diet to a fish dominated diet when cod reach a length of between 50 to 70 cm.

Arrowtooth flounder

Figure 2 shows trends in food items consumed by arrowtooth flounder of various size groups. No major changes occur in percentages by weight of various prey items in the diet. Cephalopod consumption appears to replace crustaceans (euphausiids and shrimp) in arrowtooth flounder of increasing length. The percentages of fish other than pollock (which are mostly deep-water fishes) increase slightly while the percentage of pollock decreases slightly with increasing arrowtooth flounder length. These trends may not be related directly to size but rather to depth of sampling; larger flounder may be captured in deeper water than smaller flounder and where squid and deep-water fish are more available.

Similar to the present study, Mito (1974) found all sizes of arrowtooth flounder consuming mostly pollock. He also noted increasing prey pollock length with increasing flounder length. The results of Shuntov (1970), Smith et al. (1978) and Mikawa (1963) are somewhat different to those above. Their studies all report increasing amounts of predation on fish and decreasing amounts of euphausiids consumed as arrowtooth flounder increase in length. Thus, it appears arrowtooth flounder are predominantly a fish feeder but at smaller sizes may consume more euphausiids and other crustaceans. The maximum size of prey fish consumed also increases with arrowtooth flounder length.

Flathead sole

Figure 3 shows the proportions of various prey items in the diet of flathead sole of different size groups. Flathead sole <25 cm appear to consume mostly epibenthic crustacea such as crab and shrimp along with polychaetes, echiuroids and brittle stars. Sole >25 cm consumed more brittle stars and pollock. The percentages of brittle stars in the diet increased from 16% by weight in sole <25 cm to 72% by weight in sole >35 cm in length.

Mito (1974) reports no clear trends in diet with flathead size. However Smith et al. (1978) note that flathead sole >30 cm in length caught in deeper waters of the Gulf of Alaska consumed mostly brittle stars while flathead sole <30 cm long captured in shallower water consumed more euphausiids. Miller (1970) stated flathead sole's diet changed from mostly mysids when sole were <18cm to shrimps when sole were 18-26 cm long and finally to fishes and clams when sole were >26cm long. Thus, there are some size-related feeding trends in flathead sole as larger sole tend to consume more fish and brittle stars than smaller sole. There might be some confounding of predator size with depth of capture, though, as larger flathead sole may be caught in deeper waters where brittle stars and juvenile pollock may be more available.

Walleye pollock

Figure 4 (from Dwyer 1984)shows the changes in major prey items consumed by pollock with increasing pollock length. Most notable is the

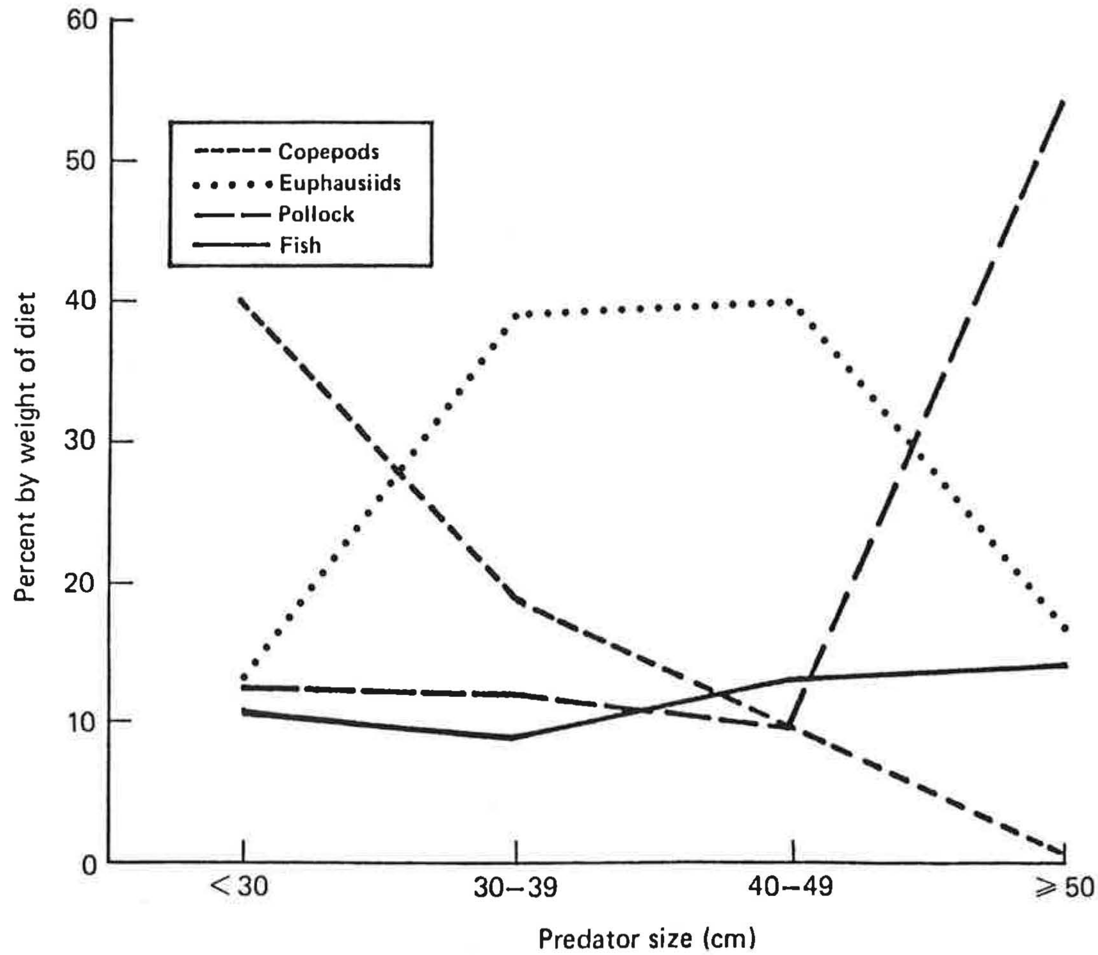

Figure 4. Percent by weight of major prey categories in the diet of pollock, by fish size. ("Fish" refers to all fish prey which was not positively identified as pollock.)

increase in cannibalism with length; small pollock (<50 cm) consume only 10% by weight of prey pollock and pollock larger than 50 cm consume mostly pollock (more than 50% by weight of the diet). There is an opposite trend in the consumption of copepods which decreases with increasing pollock length. Euphausiids are consumed mostly by pollock which are 30-49 cm long. The consumption of other fish is fairly constant over all pollock size groups (around 10% by weight of the diet).

Takahashi and Yamaguchi (1972), Mito (1974) and Bailey and Dunn (1979) found similar size related dietary trends. Pollock <50 cm consumed mostly euphausiids and copepods while pollock >50 cm consumed mostly pollock, herring, and euphausiids. Pollock in the Gulf of Alaska do not appear to cannibalize but instead consume pandalid shrimp (Feder 1977; Smith et al. 1978).

Pacific halibut

Pacific halibut also appear to change their diet with increasing size. Smith et al. (1978) found juveniles in the eastern Bering Sea had shrimp occurring in their stomachs about as frequently as fish. Novikov (1964) found crustaceans occurring in almost all (89%) stomachs of halibut <30 cm while the percent frequency of occurrence of fish increased with increasing size; from 61% in halibut 30-60cm long to 87% in halibut >90 cm long. Thus, halibut appears to switch from an epibenthic crustacean diet to a fish diet with increasing size.

Alaska plaice and Rock sole

Adult plaice appear to consume the same food items regardless of size (Skalkin 1963; Mineva 1964). Similar results have been noted for a similar species the European plaice, *Pleuronectes platessa*, which feed primarily on polychaetes and bivalves at sizes >5 cm (see Allen 1984a).

Rock sole also exhibit little change in diet with size. The dominant food of most adults is polychaetes (Mito 1974; Smith et al. 1978). Rock sole of the smaller sizes (20-30 cm) may consume more amphipods (Mito 1974) and larger rock sole include fish such as sandlance in their diet (Smith et al. 1978).

Yellowfin sole

As Table 3 shows yellowfin sole change their feeding habits with increasing size. Wakabayashi (1974) noted that juveniles <20 cm consumed polychaetes and amphipods but with increasing size also included fish and bivalves in their diet. Unpublished NWAFC data indicate, however, that at least 80% of the diet by weight for juvenile and adult yellowfin sole (14-33 cm) in Bristol Bay in spring was bivalves. Small amounts of polychaetes, echinoderms, and crustaceans were also consumed by all size classes.

King and Tanner crabs

As Table 4 shows king crab switch from consuming copepods when they are pelagic larvae to polychaetes as benthic juveniles and finally to echinoderms, molluscs, crustaceans, and polychaetes as adults. Pearson et al. (1984) found that the softs tissue contained in juvenile king crab stomachs was predominantly polychaetes, sand dollars, and clams.

Tarverdiyeva (1981) described the change in food habits with size in Tanner crab. His data show some difference in frequency of occurrence of the major prey items; molluscs, polychaetes, crustaceans, and echinoderms between Tanner crab of 24-60 mm carapace widths and 61-161 mm carapace widths. Polychaetes and decapod crustaceans occurred more frequently in larger Tanner crab while echinoderms and amphipods occurred more frequently in small crab. Feder (1978), however, shows little difference in frequency of occurrence of prey types among various sizes of Tanner crab in Cook Inlet. Crabs of all sizes consumed clams, barnacles, and pagurid crabs.

Pacific herring

Table 5 shows differences in food items consumed by herring of various sizes. It appears that juvenile herring consume smaller food items such as phytoplankton, copepod eggs, copepods and amphipods. Adults usually consume more euphausiids although copepods still remain in the diet and at times may still be predominant in the stomach contents.

Sockeye salmon

Table 6 shows differences in food consumption between sockeye smolts and adults. Smolts consume small prey such as fish larvae, invertebrate larvae and eggs, and copepods. Adults consume mostly euphausiids and fish. Small portions of the diet are composed of crab zooea, amphipods and pteropods.

EASTERN BERING SEA FOOD HABITS
Area and Season Trends

Pacific cod

The cod taken for the present study were sampled from the central (165° W longitude to 171° W longitude) and northwest (westward of 171° W longitude)regions of the eastern Bering Sea and pollock, tanner crab, and other fish were the main food items. Pollock were consumed by cod in both these areas. Shimada and June (1982) sampled during summer and found that the frequency of occurrence of pollock in cod stomachs increased from 8% in southeastern Bering Sea (eastward of 165° W longitude) to 27%

in the central area and 32% in the northwest. They also noted that the occurrence of euphausiids decreased from the southeast to the northwest and that cod consumed sandlance, flatfish, and king crab in the southeast region and pollock and Tanner crab in the central and northwest regions. Similarly, Mito (1974) in the autumn, Feder (1978) in spring and Allen (1984) sampled cod in the deeper waters (>70m) of the central region and reported pollock, Tanner crab, and shrimp as the main prey items. Thus, cod appear to have definite area trends in diet composition; more pollock and tanner crab are consumed in the central and northwest regions while other fish, king crab and euphausiids are consumed in the southeast with no real seasonal change in diet evident from any of the studies.

Arrowtooth flounder

Stomach samples from arrowtooth flounder taken for the present study were obtained around the Pribilof Islands and to the northwest of the Pribilof Islands at depths ranging from 65 m to more than 200 m. Pollock, euphausiids, cephalopods, and bathypelagic fish were the main food items. Pollock were consumed by arrowtooth flounder at virtually all shelf stations sampled and many of the slope sampling sites. Larger arrowtooth flounder were obtained mostly from foreign commercial fishing vessels which were fishing in the deeper slope waters of the northwest region so the increasing percentages of cephalopods and bathypelagic fish in the diet of larger arrowtooth flounder are probably due to the increased availability of those prey in the slope region of the eastern Bering Sea. The only other detailed study of arrowtooth flounder food habits in the eastern Bering Sea was by Mito (1974) who sampled southeast of the Pribilof Islands in waters about 200 m in depth. His study reported mostly pollock and shrimp in the stomach contents. Mikawa (1963) and Shuntov (1970) both note a decrease in stomach content of arrowtooth flounder sampled in winter. They claim arrowtooth flounder feeds mostly during summer and autumn. Thus, arrowtooth flounder also has area trends in diet as fish captured in deep slope waters consume more cephalopods and bathypelagic fishes than those captured in waters over the shelf.

Flathead sole

Flathead sole were obtained during summer from the central and northwest shelf regions of the eastern Bering Sea in depths from 45 m to 125 m for this study. The main food items were shrimp, crabs, and brittle stars. Pollock were consumed by flathead sole only at a few stations which were located northwest of the Pribilof Islands. Mito (1974) sampled the slope region in autumn just south of the Pribilof Islands and Mineva (1964) sampled flathead sole northwest of the Pribilof Islands. Both reported similar trends; brittle stars, shrimp and fish were the main dietary items. Mineva (1964) also reported that flathead sole do feed during winter but only small amounts compared to summer feeding. Skalkin (1963) noted that as sampling of flathead sole moved further inshore in the eastern Bering Sea, planktonic crustaceans such as hyperiid amphipods and euphausiids replaced brittle stars and pandalid shrimp in the diet. Thus, flathead sole appear to consume more brittle stars and fish with increasing depth and more euphausiids inshore.

Walleye pollock

Dwyer (1984) outlined seasonal and area differences in diet for walleye pollock. In spring, euphausiids and copepods were consumed by most pollock while only small amounts of prey pollock were consumed by fish >50 cm. In summer, copepods were the most dominant prey item for smaller pollock while euphausiids and prey pollock were consumed by larger pollock. Copepods disappeared from the diets in autumn and the main prey items for all pollock size groups were pollock and euphausiids. By winter, fish <30cm were consuming mostly euphausiids while pollock 30-44 cm long contained mostly fish (gadids and myctophids). The largest pollock size group (>50 cm) consumed mostly fish the majority of which was pollock. Seasonal changes in mean stomach content weights were also observed with lowest amounts in winter and highest in the summer. Some differences were observed in pollock diet among the Aleutian Basin area, the area northest of the Pribilofs, and the area southeast of the Pribilofs. Cannibalism was never observed in the Aleutian Basin. Average stomach content weight varied among areas with the southeast area having the greatest stomach content weight (1.1% of the body weight) followed by the northest area (0.7% body weight) and finally the Aleutian Basin with the lowest value of 0.4% body weight. Cannibalism was most important in the southeast region during autumn and winter and in the northwest during summer.

Pacific halibut

Novikov (1964) compared halibut's diet between the southeast and northwest regions of the eastern Bering Sea. The main difference was in the type of fish consumed; in the northwest pollock occurred most frequently in stomachs while in the southeast flatfishes such as yellowfin sole occurred more frequently. Crustaceans also occurred more frequently in the northwest than in the southeast. Intensity of feeding changed seasonally being lower in winter than in summer. Novikov (1964) also noted that young halibut continue feeding through the winter while large halibut cease feeding during this season.

Alaska plaice and Rock sole

Allen (1984a) summarized the literature on Alaska plaie and noted that seasonal changes in diet have been reported. Echinoderms were more important in spring while molluscs and polychaetes predominated in summer. Winter feeding was almost nonexistent. It was mentioned that seasonality in diet may be due to plaice's seasonal migration through different depth zones.

Rock sole also change their feeding intensity seasonally. The most intensive feeding occurs in spring and summer while feeding ceases almost completely in winter. Some seasonal changes in prey items were also noted by Allen (1984a); gammarid amphipods and crustaceans dominating spring and summer diets but polychaetes were more important in autumn. Skalkin (1963) noted changes in family of polychaetes consumed by season but it is not clear whether region of sampling also varied seasonally.

Yellowfin sole

Seasonal changes in stomach content weight occur in yellowfin sole with feeding ceasing almost completely in winter. Unpublished NWAFC data indicate frequency of occurrence of polychaetes, bivalves, sand dollard, shrimp, euphausiids, and amphipods is high in the southeast area. In the northwest, however, brittle stars occur most frequently followed by polychaetes, crustceans, and molluscs, Fadeev (1972) noted that certain areas in the Bering Sea, such as the Cape Newenham area, are poor in benthic organisms and thus yellowfin sole in those areas may consume more pelagic prey. Skalkin (1963) reports crustaceans in the diet of yellowfin sole sampled inshore (30-50 m), mostly polychaetes in waters 50-65 m, molluscs at 6580 m and brittle stars at depths greater than 75 m. Thus, there does appear to be a trend in yellowfin sole's diet with depth with more brittle stars in deep waters and crustaceans and polychaetes in shallower waters.

King and Tanner crab

There are little seasonal data available for comparison of king crab diets. Feder (1978) sampled in spring and reported bivalves occuring most frequently in the diet. McLaughlin and Hebard (1961) report a similar trend in summer.

Tanner crab diets by Bering Sea area were discussed by Tarverdiyeva (1981). In the western Bering Sea, Tanner crab consumed mostly sea urchins. He found Tanner crab consuming primarily bivalve molluscs near the Pribilof Islands. Decapods and sea urchins were the secondary foods. Further north near St. Matthew Island, polychaetes, bivalves and decapod crustaceans were all important prey items.

Data regarding seasonal changes in stomach fullness are not available for either species.

Pacific herring

Rumyantsev and Darda (1970) noted seasonal changes in stomach filling in Pacific herring. Stomach fullness was low in spring and increased to maximum values in June and July. Feeding continued into autumn but was not as vigorous as in summer. Dudnek and Usol'tsev (1964) report herring captured in the southeast area of the Bering Sea consume mostly euphausiids and copepods and that foraging continued until November.

Sockeye salmon

Kanno and Hamai (1971) report changes in sockeye salmon's diet with area. Squid was 95% of the diet by weight in the western and central

Bering Sea. Euphausiids (43% by weight), fish (28% by weight), and amphipods (25% by weight) were the amin prey items in the south and central Bering Sea. Further inshore in Bristol Bay, Nishiyama (1974) found euphausiids (70% by weight) as the dominant prey, with fish and crustaceans forming the remainder of the diet.

In the inner portion of Bristol Bay, sockeye smolts have been found with empty stomachs. Feeding seems to have commenced though, by the time smolts reach Port Moller.

DISCUSSION

The fish and crab diets reported here show a variety of trends regarding the pelagic versus demersal nature of the diet. Some of the fishes utilize strictly demersal food items as prey such as Alaska plaice and rock sole. Others such as Pacific cod and flathead sole use demersal and pelagic animals for food. Finally, most of the pelagic fishes consume only pelagic prey. Some fishes exhibited size related differences in the pelagic versus demersal nature of the diet. Fish such as cod and flathead sole feed more demersally as juveniles and switch to pelagic fishes as adults.

Seasonal trends in diet appeared mainly to be in the amount and not the type of food consumed by predators. There was general agreement among the studies cited here that fish feed most heavily in summer and autumn, almost none at all in winter, and small amounts in spring. There were area differences in prey consumed but it appeared that although different prey items were eaten the basic pelagic or demersal nature of the diet did not change. The only exception was in the Soviet literature which reports the Bering Sea to be poor in benthos in some areas (particularly

Cape Newenham) where demersally feeding fishes may consume more pelagic prey.

Since the main differences in benthic versus pelagic diets are by predator species and predator size, the diets must be categorized by the degree of demersal feeding of predators by species and size in order to speculate on the effect of oil on various fishes via uptake of benthic prey. Table 7 shows such a summarization based on the results from feeding studies cites in this paper. All species except Pacific herring and sockeye salmon have a demersal component in their diet. Juveniles of some species feed more demersally such as Pacific cod, flathead sole, Pacific halibut, and yellowfin sole. Finally, some groups feed strictly in the demersal habitat both as juveniles and adults: Alaska plaice, rock sole, and king and Tanner crabs.

Areas in the eastern Bering Sea likely to be impacted most by demersal oil fractions would be those areas where demersally feeding fish are most abundant. Walters and McPhail(1982) summarized community structure in the eastern Bering Sea and concluded the areas with the highest density of fish and invertebrates were the inner (southeast) and central shelf regions. The most abundant species in these areas are yellowfin sole, Tanner crab, king crab, Alaska plaice, rock sole and Pacific cod. These areas thus appear to be dominated by demersally feeding fishes whereas the outer shelf and sole regions contain more walleye pollock, large Pacific cod and pelagically feeding flounders such as Greenland halibut and arrowtooth flounder. There is still a high abundance of Tanner crab in these outer shelf regions though, which could suffer if weathered oil was present on the bottom.

Seasons of greatest impact via uptake of demersal food would be those seasons where feeding level (or amount of food ingested) is at its highest level. Summer is the season of greatest food intake for all the groups discussed here and autumn is next in terms of most food intake. In spring fishes feed little and winter most groups cease feeding entirely.

Thus, there are several groups of fishes and invertebrates which are strict demersal feeders both as juveniles and as adults. Areas of highest abundance of these groups in the eastern Bering Sea are the inner (southeast) and central shelf. The season of greatest feeding activity by these groups in summer. The impact of oil on the bottom would then be greatest for the demersal groups inhabiting those regions during summer.

Table 7.--Categorization of the pelagic versus demersal nature of the diets of 10 predator species groups by predator size in the eastern Bering Sea. (Predators which feed strictly pelagically = 0, predators which obtain <25% of their food from the bottom = 1, predators which obtain 25-49% of their food from the bottom = 2, predators which obtain 50-74% of their food from the bottom = 3, and predators which obtain ≥75% of their food from the bottom = 4.)

Predator	Size group	
	Juveniles	Adults
Pacific cod	4	1
Arrowtooth flounder	1	1
Flathead sole	4	3
Walleye pollock	1	1
Pacific halibut	3	1
Alaska plaice and rock sole	4	4
Yellowfin sole	4	3
King and Tanner crab	4	4
Pacific herring	0	0
Sockeye salmon	0	0

Literature Cited

Allen, M.J. 1982. Functional structure of soft-bottom fish communities of the southern California shelf. Ph.D. Thesis, Univ. California, San Diego, 577 pp.

Allen, M.J. 1984a. Functional organization of demersal fish communities of the eastern Bering Sea shelf. (Unpubl. manuscr.) NOAA, NMFS, NWAFC, 7600 Sand Point Wy., N.E, Seattle, Washington 98115.

Allen, M.J. 1984b. Niche segregation of nearshore soft-bottom fishes in a subarctic, warm-temperate, and tropical environment. (Unpubl. manuscr.). NOAA, NMFS, NWAFC, 7600 Sand Point Wy. NE, Seattle, Washington 98115. 44 pp.

Armstrong, D.A. et al. 1981. Distribution and abundance of decapod crustacean larvae in the S.E. Bering Sea with emphasis on commercial species. Ann. Rept. Env. Assess. of the Alaska Cont. Shelf V.II, pp 365-596.

Bailey, K.M. and J.R. Dunn. 1979. Spring and summer foods of walleye pollock, Theragra chalcogramma, in the eastern Bering Sea. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 77:304-308.

Barraclough, W.E. 1967. Data Record. Number, size, and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, April 25-29, 1966. Fish. Res. Board Can. MS Rep. Ser. 922, 926, 928, 940.

Clausen, D.M. 1980. Summer food of Pacific cod, Gadus macrocephalus, in coastal waters of southeastern Alaska. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 78:968-973.

Cunningham, D. 1969. A study of the food and feeding relationships of the Alaskan king crab, Paralithodes camtschatica. M.S. Thesis, San Diego State College. 78 pp.

Dudnik, Y.I. and E.A. Usol'tsev. 1968. The herrings of the eastern part of the Bering Sea. In: Soviet fisheries investigations in the northeast Pacific, Pt. II, pp 236-240. Ed: P.A. Moiseev.

Dwyer, D.A. 1984. Feeding habits and daily ration of walleye pollock (Theragra chalcogramma) in the eastern Bering Sea. M.S. Thesis, Univ. Wash. Seattle, Washington, 102 pp.

Fadeev, N.S. 1972. The fishery and biological characteristics of yellowfin soles in the eastern part of the Bering Sea. In: Soviet fisheries investigations in the northeast Pacific, Pt. V, pp 332-396. Ed: P.A. Moiseev.

Feder, H.M. 1977. The distribution, abundance, diversity, and biology of benthic organisms in the Gulf of Alaska and the Bering Sea. In: Environmental Assessment of the Alaskan Continental Shelf, Annual Reports 8:366-712. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Environ. Res. Lab., Boulder, Colo.

Feder, H.M. 1978. Distribution, abundance, community structure, and trophic relationships of the nearshore benthos of the Kodiak shelf, Cook Inlet, northeast Gulf of Alaska and the Bering Sea. In: Environmental Assessment of the Alaskan Continental Shelf, Annual Reports 4: 416-730. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Environ. Res. Lab., Boulder, Colo.

Feder, H.M. 1979. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of Cook Inlet and NEGOA. In: Environmental Assessment of the Alaskan Continental Shelf, Annual Reports 3:1-83. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Environ. Res. Lab., Boulder, Colo.

Feder, H.M. 1981. Distribution, abundance, community structure and trophic relationships of the nearshore benthos of the Kodiak continental shelf. In: Environmental Assessment of the Alaskan Continental Shelf, Final Reports, Biological Studies 9:1-255. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Off. Mar. Pollut. Assess., Juneau, Alaska.

Gallagher, A.F., Jr. and N.B. Pola. 1984. The uptake and depuration of petroleum hydrocarbons in marine species: A simulation study of the uptake and depuration of petroleum hydrocarbons and its effect on selected marine species in the Bristol Bay ecosystem. Natl. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, WA, Processed Rep. 84-16, 68 pp.

Gotshall, D.W. 1969. Stomach contents of Pacific hake and arrowtooth flounder from northern California. Calif. Fish and Game 55:75-82.

Haflinger, K.E. and C.P. Roy. 1983. Yellowfin sole predation on three commercial crab species in the southeastern Bering Sea. Unpubl. manuscr. Institute of Marine Science, University of Alaska, Fairbanks, AK 99701. 28 pp.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Can. Bull. 180.

Jewett, S.C. 1978. Summer food of the Pacific cod, Gadus macrocephalus, near Kodiak Island, Alaska. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 76:700-705.

Kanno, Y. and I. Hamai. 1971. Food of salmonid fish in the Bering Sea in summer of 1966. Bull. Fac. Fish., Hokkaido Univ. 22:107-128.

Laevastu, T. and F. Fukuhara. 1984. Quantitative determination of the effects of oil development in the Bristol Bay region on the commercial fisheries in the Bering Sea. Natl. Mar. Fish. Serv., Northwest and Alaska Fisheries Center, Seattle, WA., Processed Rep. 84-06, 73 pp.

Last, J.M. 1980. The food of twenty species of fish larvae in the west-central North Sea. Gt. Britain Ministry of Agr., Fish. and Food. Fish. Res. Tech. Rep. 60.

Manzer, J.I. 1968. Food of Pacific salmon and steelhead trout in the N.E. Pacific ocean. J. Fish. Res. Board Can. 25:1085-1089.

McLaughlin, P.A. and J.F. Hebard. 1961. Stomach contents of the Bering Sea king crab. Int. N. Pac. Fish. Comm. Bull. 5:5-8.

Mikawa, M. 1963. Karasugarei no setai. (Ecology of the lesser halibut, Reinhardtius hippoglossoides matsuurae, Jordan and Snyder.) Bull. Tohoku. Reg. Fish. Lab. 23:1-41. In Jap. (Transl. by Fish. Res. Board, Canada Transl. Ser. No. 1260.)

Miller, B.S. 1970. Food of flathead sole (Hippoglossoides elassodon) in East Sound, Orcas Island, Washington. J. Fish. Res. Board Canada 27:1661-1665.

Mineva, T.A. 1964. Materialy po biologii nekotorykh vidov Kambal vostochnoi chasti Beringova morya. (On the biology of some flatfishes in the eastern Bering Sea). Tr. Vses. Nauchno-issled. Inst. Morsk. Ryon. Khoz. Okeanogr. 49 (Izv. Tikhookean. Nauchno-Issled. Inst. Tybvn. Khoz. Okeanogr. 51): 215-224. In Russ. (Transl. by Isr. Program Sci. Transl., 1968, pp. 227-235, In: P.A. Moiseev (Editor). Soviet Fisheries Investigations in the northeast Pacific, Part 2, available U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT 67-51204).

Mito, K.I. 1974. Food relationships among benthic fish populations in the Bering Sea. M.S. Thesis, Hokkaido Univ., Hakodate, Jpn., 135 pp.

Musienko, L.N. 1968. Ichthyoplankton of the Bering Sea. In: Soviet Fisheries Investigations in the northeast Pacific, Part II:251-286. Ed: P.A. Moiseev.

Nishiyama, T. 1974. Energy requirement of Bristol Bay sockeye salmon in the central Bering Sea and Bristol Bay, pp 231-343. In: D.W. Hood and E.J. Kelley 1974 (eds.). Oceanography of the Bering Sea with emphasis on renewable resources, Occas. Publ. No. 2 - Inst. Mar. Sci., Univ. Alaska, Fairbanks.

Novikov, N.P. 1964. Osnovnye cherty biologii tikhookeanskogo belokorogo pltusa (Hippoglossus hippoglossus stenolepis Schmidt) y Beringovour more (Basic elements of the biology of the Pacific halibut (Hippoglossus hippoglossus stenolepis Schmidt) in the Bering Sea). Tr. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 49 (Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 51):167-204. In Russ. (Transl. by Isr. Program. Sci. Transl., 1968, pp 175-219. In: P.A. Moiseev (Ed.), Soviet fisheries investigations in the northeast Pacific, Part 2, available U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT 67-51204.)

Pearson, W.H., D.L. Woodruff, and B.J. Higgins. 1984. Feeding ecology of juvenile king and Tanner crab in the southeastern Bering Sea. (Unpubl. manuscr.) Battelle, Pacific Northwest Lab., Richland, WA 99352. 48 pp.

Pola, N.B., R.K. Miyahara, and A.F. Gallagher, Jr. 1985. Spatial and temporal extent of hydrocarbon contamination in marine species of Bristol Bay. NOAA, NMFS, NWAFC, 7600 Sand Point Way N.E., Seattle, WA. Proc. Rept. 85-08, 40 pp.

Rogers, D.E. et al. 1979. Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island. Ann. Rept. Env. Assess. Alaskan Cont. Shelf 4.

Rumyantsev, A.I. and M.A. Darda. 1970. Letniaia sel'd'vostochnoi chasti Beringova moria (Summer herring in the eastern Bering Sea). Tr. Vses Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 70 (Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 72):402-432. In Russ. (Transl. by Isr. Program Sci. Transl., 1972 pp. 409-441. In: P.A. Moiseev (Ed.), Soviet fisheries investigations in the northeastern Pacific, Part 5, available U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT 71-50127.)

Shimada, A. and J. June. 1982. Eastern Bering Sea Pacific cod food studies. NOAA, NMFS, NWAFC, 7600 Sand Point Wy. N.E., Seattle, Washington 98115, (unpubl.), 41 pp.

Shuntov, V.P. 1970. Sezonnoe raspredelenie chernogo i strelozubykh patusov v Beringovum more (Seasonal distribution of black and arrow-tooth halibuts in the Bering Sea). Tr. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 70 (Izv. Tikhookean, Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 72):391-401. In Russ. (Transl. by Isr. Proram Sci. Transl., 1972, pp. 397-408. In: P.A. Moiseev (Ed.), Soviet Fisheries Investigations in the Northeastern Pacific, Part 5, available U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT 71-50127.)

Simenstad, C.A. 1979. ADF&G-OCS Fish Food Habits Analysis. Ann. Rept. Env. Assess. Alaskan Cont. Shelf 4:411-440.

Skalkin, V.A. 1963. Pitanie kambal v yugo-vostochnoi chasti Beringova morya (Diet of flatfishes in the southeastern Bering Sea). Tr. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48 OIzv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 50):223-237. In Russ. (Transl. by Isr. Program Sci. Trans., 1968, pp. 235-250. In: P.A. Moiseev (Ed.) Soviet Fisheries Investigations in the Northeast Pacific, Part 1, available U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as TT 67-51203.)

Smith, G.B. 1981. The biology of walleye pollock. In: D.W. Hood and J. Calder (Eds.), The Eastern Bering Sea Shelf: Oceanography and Resources, Volume 1, pp. 527-551. U.S. Gov. Print. Off., Washington, D.C.

Smith, R.L., A.C. Paulson, and J.R. Rose. 1978. Food and feeding relationships in the benthic and demersal fishes of the Gulf of Alaska and Bering Sea. In: Environmental Assessment of the Alaskan Continental Shelf, Final Reports, Biological Studies 1:33-107. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Environ. Res. Lab., Boulder, Colo.

Straty, R.R. 1974. Ecology and behavior of juvenile sockeye salmon (Onchorynchus nerka) in Bristol Bay and the eastern Bering Sea, pp. 285-319. In: D.W. Hood and E.J. Kelley (Eds.) Oceanography of the Bering Sea with emphasis on renewable resources, Occas. Publ. No. 2. Inst. Mar. Sci. Univ. Alaska, Fairbanks.

Takahashi, Y. and H. Yamaguchi. 1972. Stock of the Alaskan pollock in the eastern Bering Sea. Bull. Jpn. Soc. Sci. Fish. 38:389-399.

Takeuchi, I. 1960. Rearing experiment of juvenile king crab (Paralithodes camtschatica) in the eastern Bering Sea-observations on molting and growth. 1968 Transl. from: Hokkaido Fish. Exp. Station, Monthly Rept. 17(12)453-460.

Tarverdiyeva, M.I. 1981. O pitanii krabov-strigunov Chionoecetes opilio i C. bairdi v Beringovum more. (On the feeding of snow crabs in the Bering Sea.) Zool. Zh. 60:991-997. (Transl. 1982 Canadian Trans. Fish. Aquat. Sci. No. 4892.)

Wailes, G.H. 1936. Food of Clupea pallasii in southern British Columbia waters. J. Biol. Board Can. 1:477-486.

Wakabayashi, K. 1974. Studies on resources of the yellowfin sole in the eastern Bering Sea. I. Biological characters. Fishery Agency of Japan, Far Seas Fisheries Research Laboratory, Shimuzu, Jpn. 77 pp.

Walters, G.E. and M.J. McPhail. 1982. An atlas of demersal fish and invertebrate community structure in the eastern Bering Sea: Part I, 1978-81. NOAA Tech. Memo. NMFS F/NWC-35.