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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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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 (<u>Atheresthes stomias</u>)	Mar-Ott 1983-84	Outer shelf, slope	65-200+	825
Pacific cod (<u>Gadus macrocephalus</u>)	Sep-Jan 1983-84	Middle-outer shelf, slope	50-200+	184
Flathead sole (<u>Hippoglossoides elassodon</u>)	Jun-Sep 1984	Middle-outer shelf	45-125	271
Walleye pollock (<u>Theragra chalcogramma</u>)	Jul-Jun 1981-83	Middle-outer shelf, Aleutian Basin	45-200+	3098
Yellowfin sole (<u>Limanda aspera</u>)	Feb-Aug 1984	Inner-outer shelf	45-125	1058
				<u>5436</u>

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

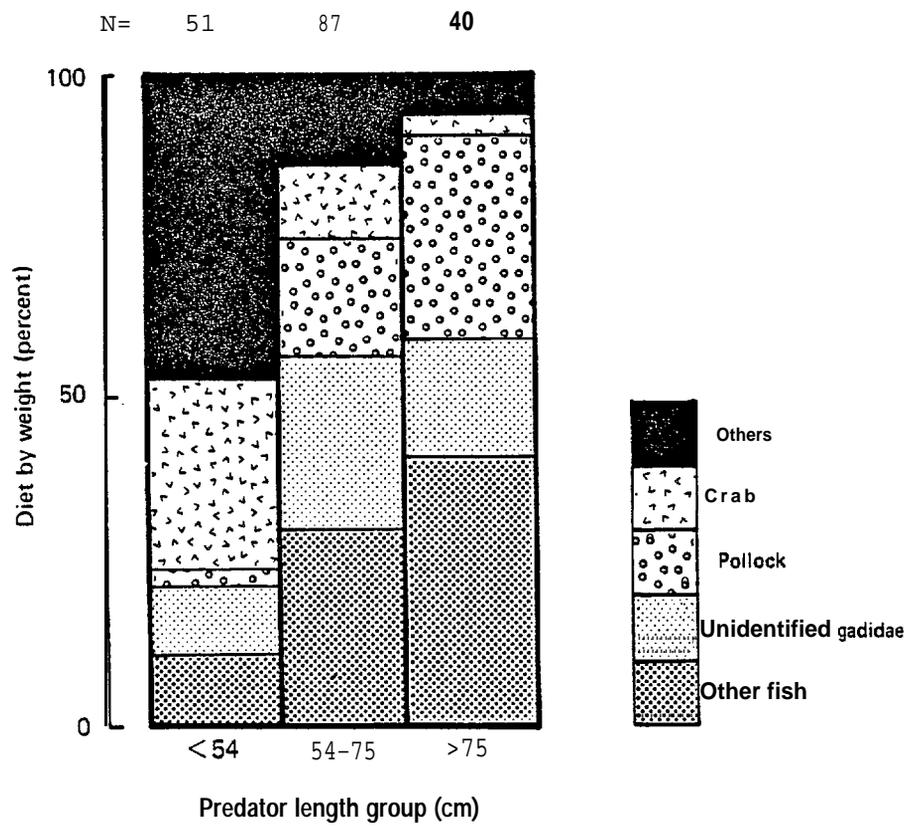


Figure 1.--Percentages by weight of main food items consumed by cod sampled in autumn and winter in the eastern Bering Sea.

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

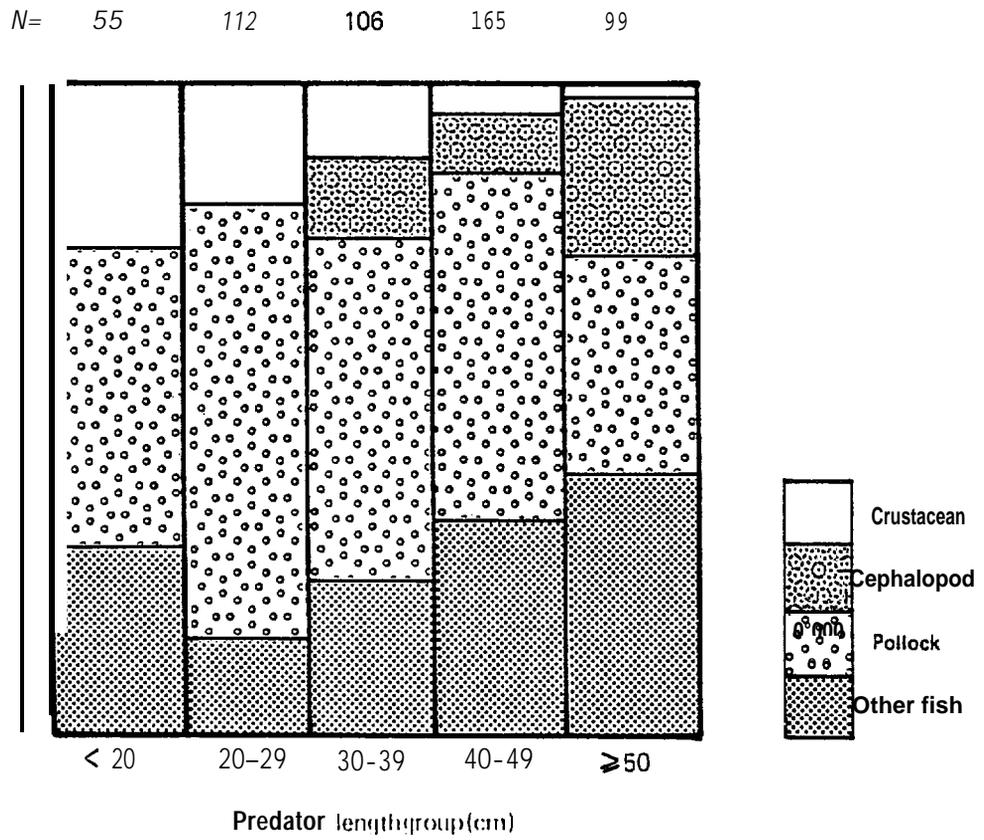


Figure 2.--Percentages by weight of main food items consumed by arrowtooth flounder sampled in spring, summer, and autumn in the eastern Bering Sea.

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, echinuroids, and molluscs**. Fish formed from 0-22% of the diet by weight, the major portion of which was **pollock**.

Mite'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.

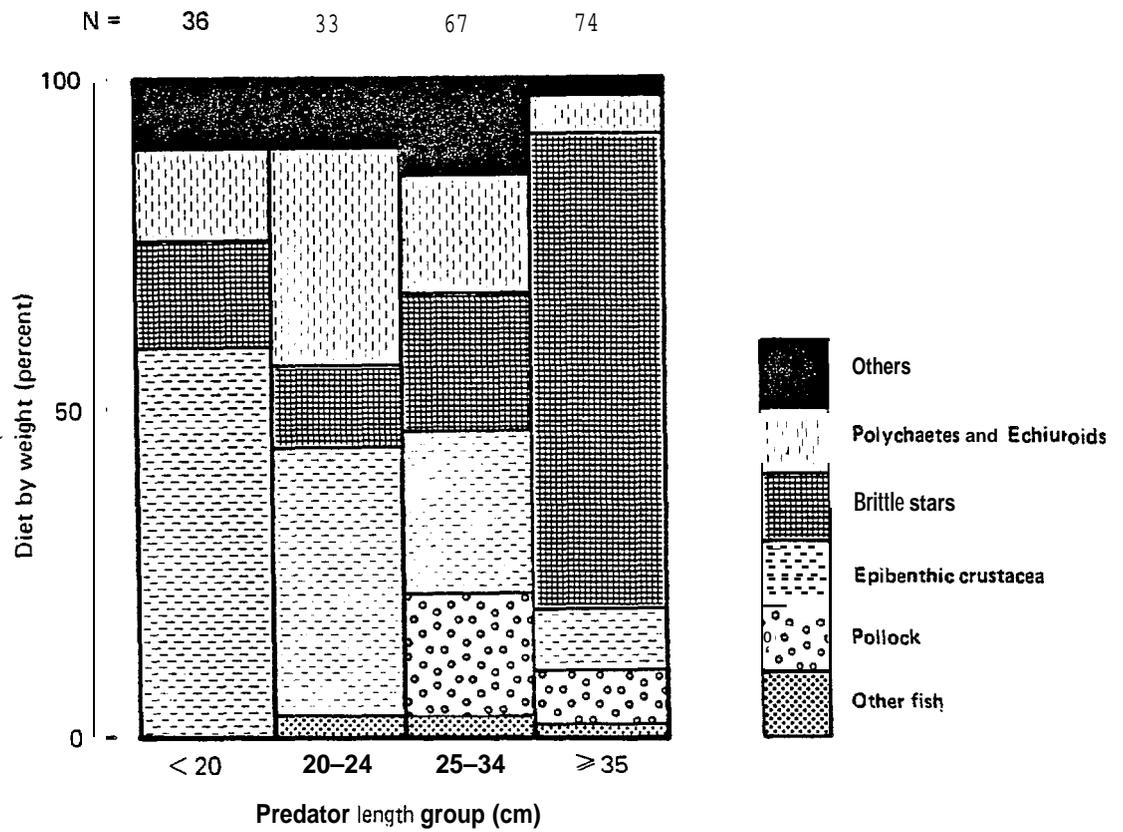


Figure 3 .--Percentages by weight of main food items consumed by flathead sole sampled in summer in the eastern Bering Sea.

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 its 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. AU 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./ Stem.	% No.	Mean wt./ Stem. (g)	% Wt.	IRI
Thecosomata	16.8	6.8	2	0.02	<1	42
<u>Calanus cristatus</u>	14.9	19.5	6	0.11	2	117
<u>Calanus</u> sp.	10.7	34.5	11	0.06	1	128
Calanoida (unident.)	23.8	54.1	17	0.12	2	457
<u>Parathemisto</u> sp.	25.6	5.5	2	0.02	<1	52
<u>Thysanoessa inermis</u>	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
<u>Theragra chalcogramma</u>	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) <i>Limanda limanda</i>	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 201-300 mm 301+ mm	Wakabayashi, 1974	Su	Bering Sea	polychaetes, amphipods, echiuroids. polychaetes, bivalves, echiuroids, gadids, osmerids, amphipods. Mostly bivalves and echiuroids.
Adults	Skalkin, 1963	Sp, Su	SW of Cape Newe nham	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, pars. 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 items 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)
Smelts	Manzer, 1969	Su	British Columbia	48% copepods , 24% fish, 14% larvaceans , 5% decapods , 4% insects, 3% amphipods .
Smelts	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 pteropods.

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; switching 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

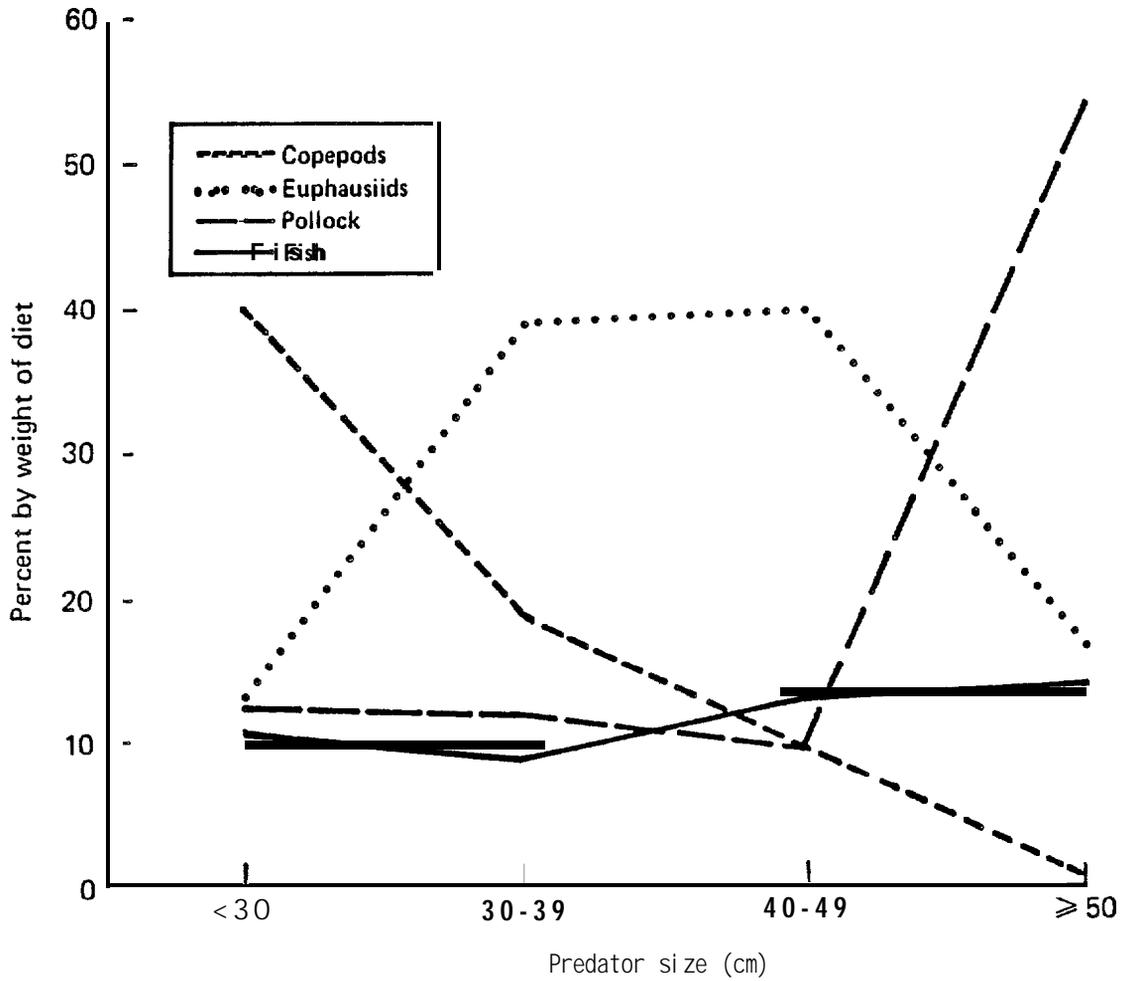


Figure 4. Percent by weight of major prey categories in the diet of pollock, by fish size. ("Fish" refers to all fish prey which was not positively identified as pollock.)

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 **NWAF** 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 smelts and adults. Smelts 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 zoea, 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 northeast 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 northeast 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 **plaice** 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 **NWAF** 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, crustaceans, 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's 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 **occurring** 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 main 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 smelts have been found with empty stomachs. Feeding seems to have commenced though, by the time smelts 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 cited 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 is 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

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