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Pictorial Guide to the Gill Arches of Gadids and Pleuronectids in the Eastern Bering Sea

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ABSTRACT

The structures of the gill arches of three gadids and ten pleuronectids were studied. The purpose of this study is, by using the picture of the gill arches and the pattern of the gill-rakers, to help the identification of the gadids and pleuronectids found in the stomachs of marine fishes in the eastern Bering Sea.

CONTENTS

INTRODUCTION

One purpose of the Fish Food Habits Program of the Resource Ecology and Fishery Management Division (REFM) is to estimate predation removals of commercially important prey species by predatory fish (Livingston et al. 1986). Fish stomach content data are used for this purpose to estimate 1) the proportion by weight of a particular prey species in the diet of predatory fish and 2) the mean stomach content weight by prey type (i.e., fish, crab, small invertebrates) to calculate daily ration of predatory fish. To accurately estimate the former, it is important to identify commercially important prey such as fish and crab to the species level. One major stumbling block in identifying prey to the species level using stomach content analysis is the digestion within the stomachs. The external morphological characters used for identification are usually missing.

Immunological techniques have been applied in diet analysis to identify prey species (Claver 1984); however, because it can not be applied to specimens preserved in chemicals and because the procedure is slow for a large number of samples, the traditional method of analyzing stomach contents (i.e. sorting and identifying stomach contents under the microscope) is still the preferred method.

Since hard parts (bones, otoliths, beaks etc.) are usually the remains found in highly digested stomach contents, they have been used in the identification of stomach contents (Clarke 1962, Ingrid et al. 1971 for cephalopod beaks; Eziuzo 1963, Fitch et al. 1968, Morrow 1977 for fish otoliths). When examining prey,

we found that gill arches, protected by the gill cover (operculum), are usually less digested than the external parts of the fish. Therefore, for a partially digested fish, gill arches are in relatively better shape and suitable to be used as a characteristic for prey fish identifications. Predator-prey interrelationship studies in the eastern Bering Sea ecosystem (Livingston et. al 1986; Yang and Livingston 1986; Yang and Livingston 1988) show that many commercially important fishes (e.g., Pacific cod (Gadus macrocephalus), arrowtooth flounder (Atheresthes stomias), and Greenland turbot (Reinhardtius hippoglossoides)) are mainly fish eaters. Therefore, it is our desire to identify prey fishes consumed by these predators to the species level. It is the objective of this study, by providing a pictorial guide of the gill arches from two families of eastern Bering Sea fishes, to assist in this endeavor.

MATERIALS AND METHODS

Positively identified fish species were collected in the eastern Bering Sea by scientists on board the research vessels or chartered fishing vessels during the survey cruises of the Alaska Fisheries Science Center, National Marine Fisheries Service.

At sea, fork length and haul locations of each specimen were recorded. The specimens were then preserved in 10% Formalin solution. In the lab, the first gill arch on the right side of the fish (eyed-side of flatfish) was excised and the gill-rakers were counted and recorded. The format to record the gill-raker count is: U + I + L; where U is the raker count for the upper

limb, I is the count (0 or 1) of the raker straddled in the middle between the upper limb and the lower limb, and L is the raker count for the lower limb. Photos of the first gill arches were taken for each species.

RESULTS AND DISCUSSION

Three species in Family Gadidae and ten species in Family Pleuronectidae are included in this guide. Table 1 shows the gill-raker pattern of the fish. The general pattern of the gill-raker is expressed in the following format: A~B + C~D + E~F = G~H; where A~B is the range of the raker count on the upper limb, C~D is the range of the raker count between lower limb and upper limb, E~F is the range of the raker count on the lower limb, and G~H is the range of the total raker count.

Table 2 shows the prey fish found in the stomach contents of key predator fishes in the eastern Bering Sea. This table is arranged in phylogenetic order by prey fish. For each prey fish species, the correspondent predator species and the prey size range were listed.

A total of 13 photos are presented. For each photo, there is a brief description of the occurrence of that species in the stomachs of the predator species in the eastern Bering Sea. Some remarks were also included to distinguish them from similar species by gill-rakers. Some gadids and pleuronectids were not included in this study because of the lack of sufficient information for those species.

Eleginus gracilis (Saffron cod)

Occurrence Not found in the eastern Bering Sea fish stomachs.

Remarks This species might be difficult to be distinguished from Pacific cod by gill-raker pattern. However, the distributions of these two species can help the identifications. Saffron cod is a subarctic species, they are common only in the extreme northern part of the Bering Sea whereas Pacific cod are abundant in the north Pacific.

Fish size: 132 mm SL, Magnification: 25 X

Gill-raker pattern: 2˜4+0+17˜20= 20˜24

Gadus macrocephalus (Pacific Cod)

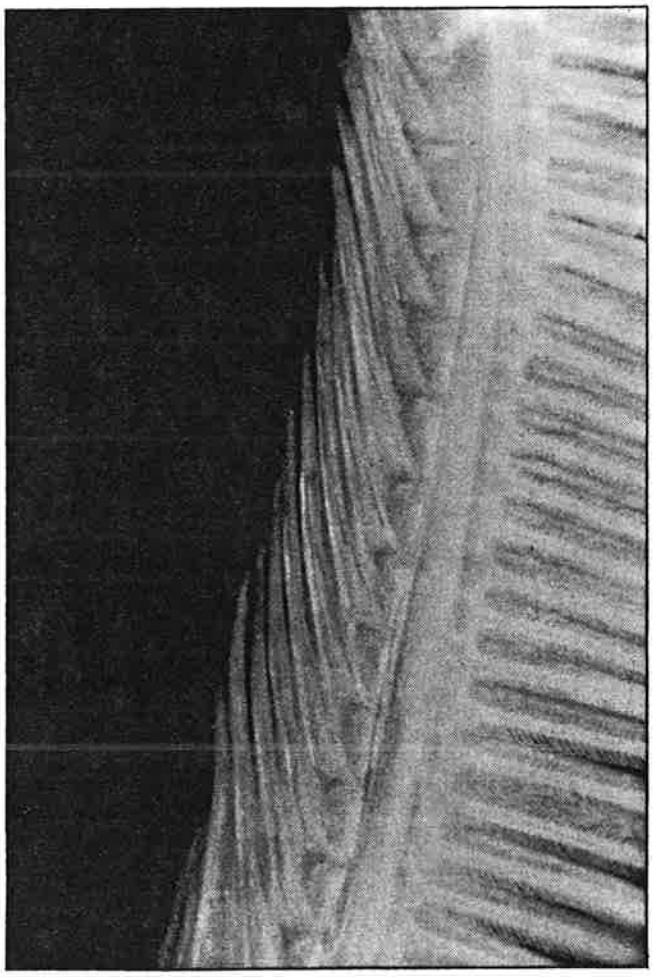
Occurrence Found in the stomachs of Pacific cod, walleye pollock, flathead sole, and Pacific halibut.

Fish size:135 mm SL, Magnification: 25 X

Gill-raker pattern: 3˜4+0˜1+17˜19= 20˜23

Theragra chalcogramma (Walleye Pollock)

Occurrence Found in the stomachs of Pacific cod, walleye pollock, arrowtooth flounder, flathead sole, yellowfin sole, rock sole, Greenland turbot, and Pacific halibut.



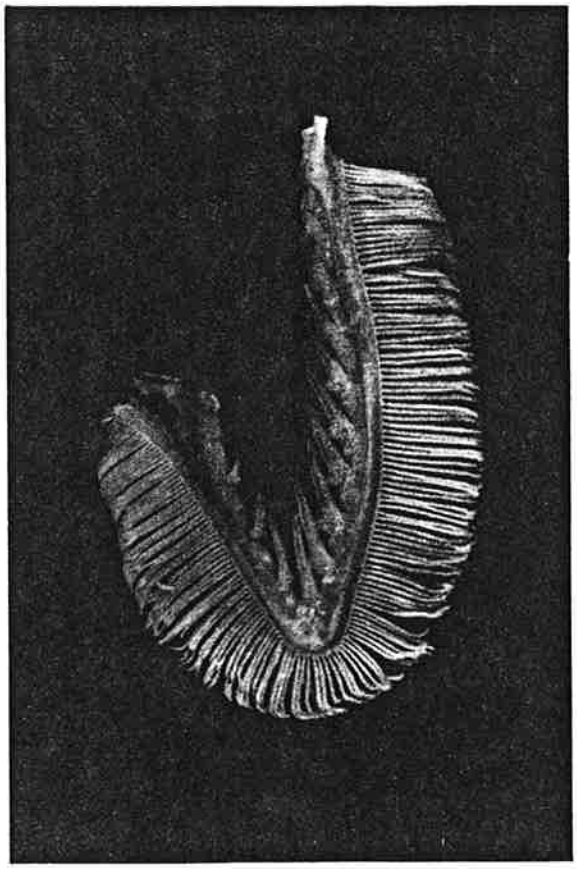
Fish size: 102 mm SL, Magnification: 50 X

Gill-raker pattern: 5˜9+0+28˜35=35˜42

Atheresthes evermanni (Kamchatka Flounder)

Occurrence Found in the stomachs of Pacific cod, walleye pollock, arrowtooth flounder, and yellowfin sole.

Remarks Kamchatka flounder is distinguished from arrowtooth flounder by having one raker (instead of two) on the upper limb of the second gill arch.



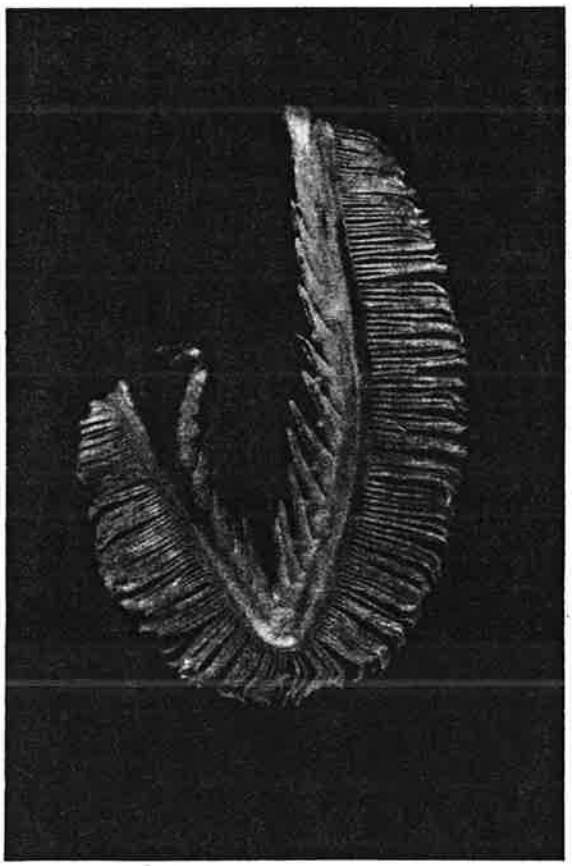
Fish size: 380 mm SL, Magnification: 1 X

Gill-raker pattern: 2˜3+0+9˜11= 11˜14

Atheresthes stomias (Arrowtooth Flounder)

Occurrence Found in the stomachs of Pacific cod, walleye pollock, arrowtooth flounder, and yellowfin sole.

Remarks Arrowtooth flounder is distinguished from Kamchatka flounder by having two (instead of one) rakers on the upper limb of the second gill arch.



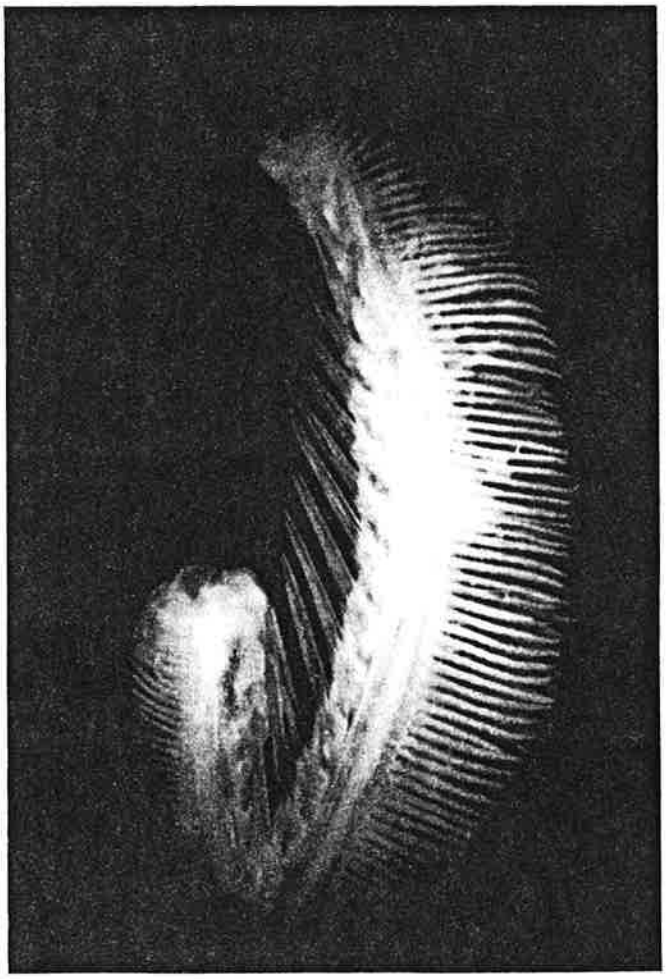
Fish size: 340 mm SL, Magnification: 1 X

Gill-raker pattern: 3˜5+0+10˜13= 13˜16

Hippoglossoides elassodon (Flathead Sole)

Occurrence Found in the stomachs of Pacific cod, walleye pollock, Kamchatka flounder, arrowtooth flounder, flathead sole, Greenland turbot, and Pacific halibut.

Remarks Flathead sole can be distinguished from Bering flounder by having more rakers on the first gill arch (Table 1).



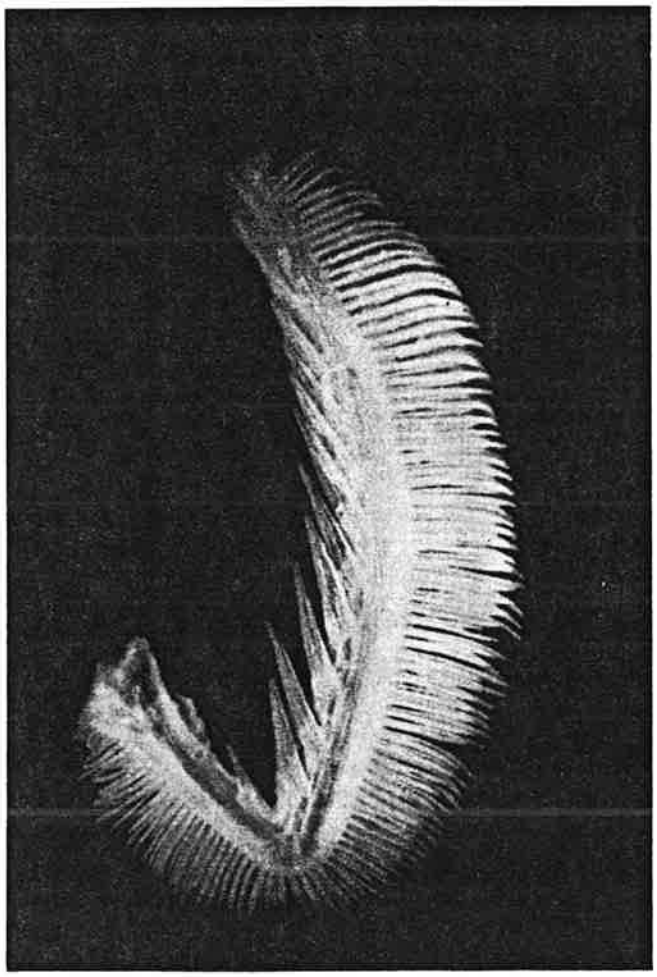
Fish size: 191 mm SL, Magnification: 10 X

Gill-raker pattern: 3˜6+0˜1+13˜18= 18˜23

Hippoglossoides robustus (Bering Flounder)

Occurrence Found in the stomachs of Pacific cod.

Remarks Bering flounder can be distinguished from flathead sole by having less rakers on the first gill arch (Table 1).



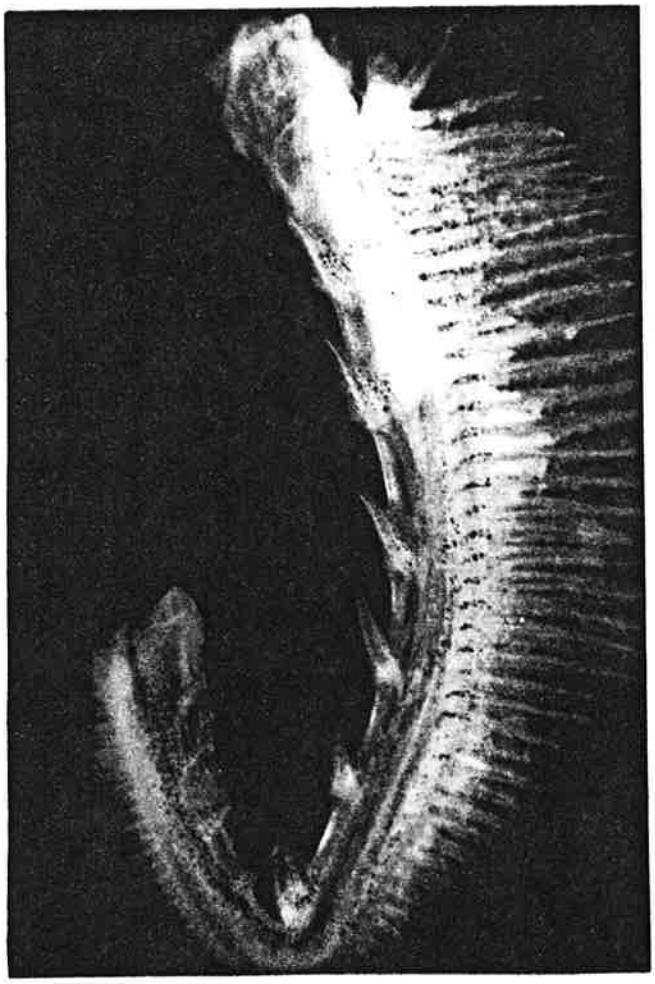
Fish size: 190 mm SL, Magnification: 10 X

Gill-raker pattern: 3+0+11˜13= 14˜16

Lepidopsetta bilineata (Rock Sole)

Occurrence Found in the stomachs of Pacific cod, walleye pollock, flathead sole, yellowfin sole, and Pacific halibut.

Remarks The shape of the gill-raker of this species is similar to that of yellowfin sole. However, rock sole has 3~4 rakers on the upper limb whereas yellowfin sole has 5~8 rakers on the upper limb (Table 1). Also, the rakers on the upper limb of rock sole are smaller than those of yellowfin sole.



Fish size: 116 mm SL, Magnification: 20 X

Gill-raker pattern: 3~4+0+6~8= 10~12

Limanda aspera (Yellowfin Sole)

Occurrence Found in the stomachs of Pacific cod, walleye pollock, and Pacific halibut.

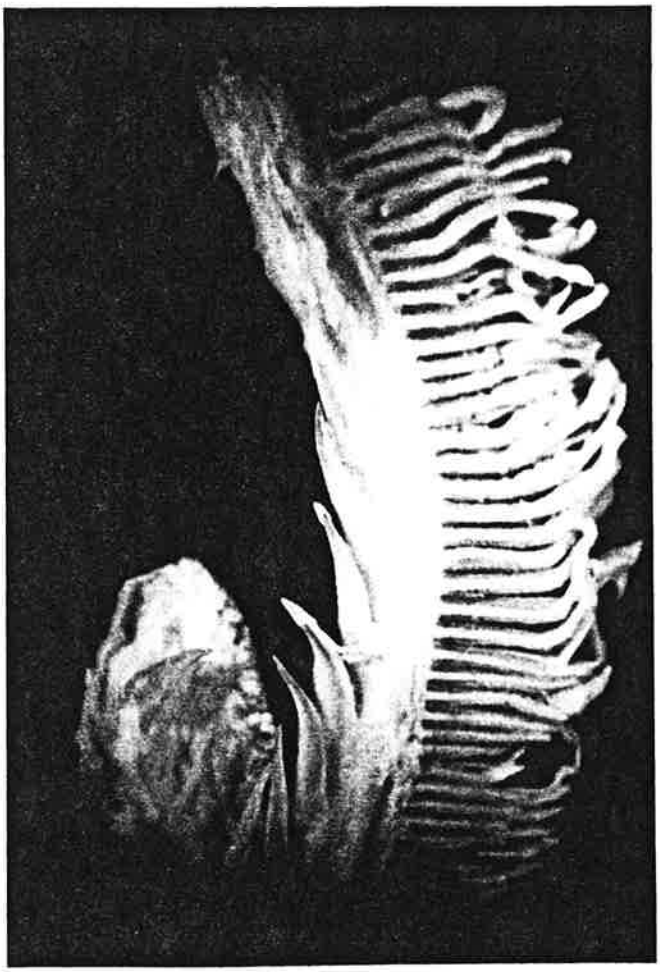
Special remarks The shape of the gill-rakers of this species is similar to that of rock sole. However, this species can be distinguished from rock sole by having more rakers (especially on the upper limb) on the first gill arch (Table 1).

Fish size: 134 mm SL, Magnification: 20 X

Gill-raker pattern: 5˜8+0+7˜10= 13˜18

Limanda proboscidea (Longhead Dab)

Occurrence Found in the stomachs of Pacific cod and Pacific halibut.



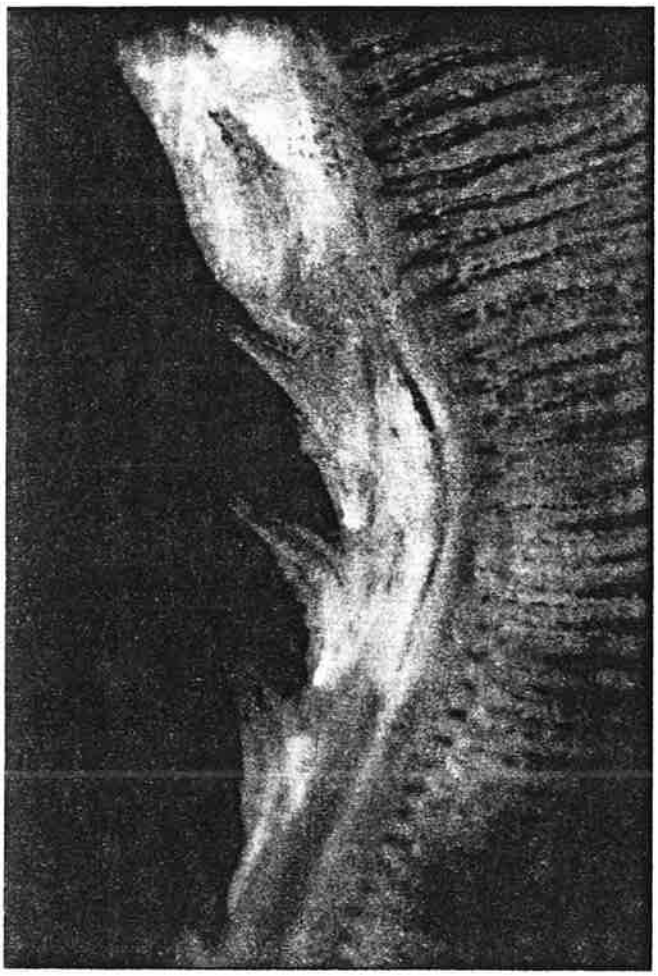
Fish size: 265 mm SL, Magnification: 10 X

Gill-raker pattern: 5+0˜1+9˜10= 14˜16

Pleuronectes quadrituberculatus (Alaska Plaice)

Occurrence Found in the stomachs of flathead sole.

Remarks This species (along with Pacific halibut) has the least number of gill-rakers in the Family Pleuronectidae.



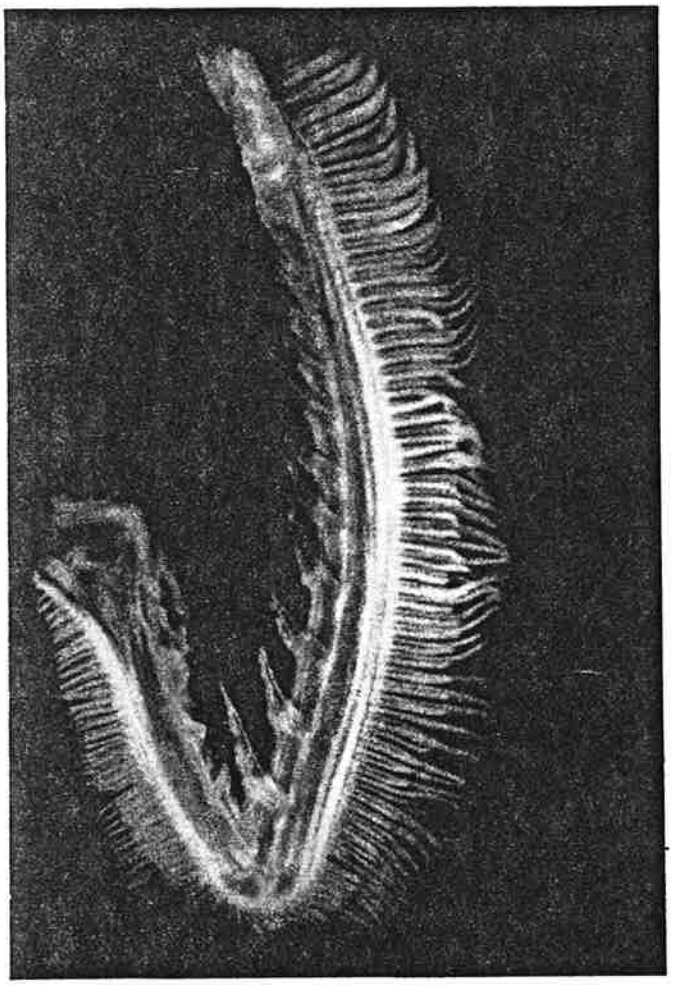
Fish size: 144 mm SL, Magnification: 25 X

Gill-raker pattern: 3+0+5˜7= 8˜10

Reinhardtius hippoglossoides (Greenland Turbot)

Occurrence Found in the stomachs of yellowfin sole and Greenland turbot.

Remarks Though the shape and number of gill rakers of this species is similar to that of the arrowtooth flounder, this species can be distinguished from arrowtooth flounder by having more gill-rakers on the first gill arch and by not having knob-like structure on the left side of the gill-raker.



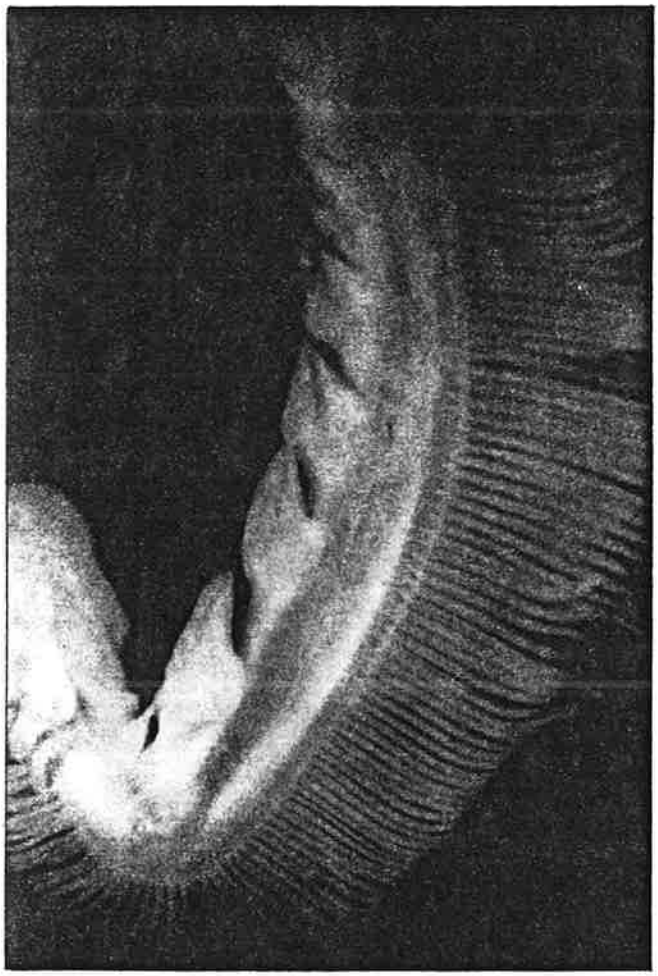
Fish size: 80 mm SL, Magnification: 25 X

Gill-raker pattern: 4˜5+0+13˜14= 17˜19

Hippoglossus stenolepis (Pacific Halibut)

Occurrence Found in the stomachs of Pacific cod and yellowfin sole.

Remarks This species, like Alaska plaice, also has the least number of gill-rakers in the Family Pleuronectidae. However, these two can be distinguished from each other by the shape of the rakers. Alaska plaice has more slender shaped rakers and Pacific halibut has shorter and stouter rakers.



Fish size: 200 mm SL, Magnification: 16 X

Gill-raker pattern: 1˜2+0+7˜8= 8˜10

Table 1.--Gill-raker (first gill arch) patterns of the gadids and pleuronectids in the eastern Bering Sea. N is the number of specimens examined, (-) indicates no data.

Species name	Gill-raker pattern	Fish Size (cm)	N
Eleginus gracilis (Saffron cod)	2˜ 4+0 +17˜20= 20˜24	11˜18	33
Gadus macrocephalus (Pacific cod)	3˜ 4+0˜1+17˜19= 20˜23	5˜16	26
Theragra chalcogramma (Walleye pollock)	5˜ 7+0 +28˜35= 35˜42	6˜22	27
Atheresthes evermanni (Kamchatka flounder)	2˜ 3+0 + 9˜11= 11˜14	(-)	81
Atheresthes stomias (Arrowtooth flounder)	3˜ 5+0 +10˜13= 13˜16	(-)	170
Hippoglossoides elassodon (Flathead sole)	3˜ 6+0˜1+13˜18= 18˜23	6˜20	13
Hippoglossoides robustus (Bering flounder)	3 +0 +11˜13= 14˜16	19˜21	10
Lepidopsetta bilineata (Rock sole)	3˜ 4+0 + 6˜ 8= 10˜12	6˜26	21
Limanda aspera (Yellowfin sole)	5˜ 8+0 + 7˜10= 13˜18	5˜23	19
Limanda proboscidea (Longhead dab)	5 +0˜1+ 9˜10= 14˜16	13˜27	3
Pleuronectes quadrituberculatus (Alaska plaice)	3 +0 + 5˜ 7= 8˜10	14˜32	8
Reinhardtius hippoglossoides (Greenland turbot)	4˜ 5+0 +13˜14= 17˜19	8˜39	15
Hippoglossus stenolepis (Pacific halibut)	1˜ 2+0 + 7˜ 8= 8˜10	16˜49	4

Table 2.--List of fishes identified from the stomach contents of key predator fishes in the eastern Bering Sea including information of prey sizes consumed.

Fish prey species	Predator species	Prey size (mm)
Family Clupeidae		
Clupea harengus pallasi (Pacific herring)	Pacific cod	25-280
	Walleye pollock	63-190
	Arrowtooth flounder	160-283
	Greenland turbot	210-300
	Pacific halibut	200-260
Family Osmeridae		
Malotus villosus (Capelin)	Pacific cod	53-139
	Arrowtooth flounder	140-140
	Flathead sole	101-149
Osmerus mordax (Rainbow smelt)	Walleye pollock	98- 98
Thaleichthys pacificus (Eulachon)	Pacific cod	116-205
Family Bathylagidae		
Bathylagus stilbius (Calif. smoothtongue)	Greenland turbot	85-110
Family Myctophidae		
Stenobrachius leucopsarus (Northern lampfish)	Walleye pollock	43- 92
	Greenland turbot	60- 60
Family Gadidae		
Gadus macrocephalus (Pacific cod)	Pacific cod	350-453
	Walleye pollock	44-104
	Flathead sole	13- 90
	Pacific halibut	85-300
Theragra chalcogramma (Walleye pollock)	Pacific cod	8-570
	Walleye pollock	10-310
	Arrowtooth flounder	19-360
	Flathead sole	23-170
	Yellowfin sole	4-104
	Greenland turbot	22-440
	Pacific halibut	35-530

Table 2.--Continued.

Fish prey species	Predator species	Prey size (mm)
Family Zoarcidae		
Lycodes brevipes (Shortfin eelpout)	Pacific cod	16-334
	Arrowtooth flounder	90-265
	Flathead sole	52- 74
	Pacific halibut	60-135
Lycodes diapterus (Black eelpout)	Arrowtooth flounder	230-332
	Greenland turbot	210-210
Lycodes palearis (Wattled eelpout)	Pacific cod	26-310
	Arrowtooth flounder	233-233
	Greenland turbot	315-315
Family Macrouridae		
Coryphenoides filifer (rattail)	Greenland turbot	180-180
Family Scorpaenidae		
Sebastes sp. (rockfish)	Flathead sole	30- 60
	Yellowfin sole	21- 21
Family Hexagrammidae		
Hexagrammos stelleri (White-spotted greenling)	Pacific cod	160-183
Pleurogrammus monopterygius (Atka mackerel)	Pacific cod	260-270
Family Icelidae		
Icelus spiniger (Thorny sculpin)	Pacific cod	31-105
	Arrowtooth flounder	65-128
	Flathead sole	53- 64
	Yellowfin sole	23- 23
	Greenland turbot	110-110

Table 2.--Continued.

Fish prey species	Predator species	Prey size (mm)
Family Cottidae		
Dasycottus setiger (Spinyhead sculpin)	Pacific cod	70-202
	Arrowtooth flounder	40- 70
	Flathead sole	58- 58
	Greenland turbot	170-170
Hemilepidotus sp. (Irish lord)	Yellowfin sole	15- 23
Hemitripterus bolini (Bigmouth sculpin)	Greenland turbot	80- 80
Family Agonidae		
Aspidophoroides bartoni (Aleutian alligatorfish)	Pacific cod	46-127
Asterotheca pentacanthus (Bigeye poacher)	Pacific cod	96-125
	Arrowtooth flounder	43- 43
Agonus acipenserinus (Sturgeon poacher)	Pacific cod	44-195
	Arrowtooth flounder	50-210
Family Cyclopteridae		
Aptocyclus ventricosus (Smooth lumpsucker)	Greenland turbot	210-210
Careproctus cypselurus (Blackfinned red snailfish)	Greenland turbot	340-340
Liparis sp. (Snailfish)	Yellowfin sole	16- 26
Family Tricodontidae		
Tricodon tricodon (Pacific sandfish)	Pacific cod	135-227
Family Bathymasteridae		
Bathymaster signatus (Searcher)	Pacific cod	265-265
	Arrowtooth flounder	56- 56
Bathymaster sp.	Flathead sole	38- 55

Table 2.--Continued.

Fish prey species	Predator species	Prey size (mm)
Family Ptilichthyidae		
Ptilichthys goodei (Quillfish)	Pacific halibut	340-420
Family Stichaeidae		
Allolumpenus hypochromus (Y-prickleback)	Walleye pollock	86- 86
Lumpenus fabricii (Slender eelblenny)	Pacific cod	61-174
Lumpenus sagitta (Snake prickleback)	Walleye pollock	160-160
Lumpenus maculatus (Daubed shanny)	Pacific cod	75-125
	Arrowtooth flounder	50-178
	Flathead sole	66-101
	Greenland turbot	71-200
Poroclinus rothrocki (Whitebarred prickleback)	Pacific cod	105-193
Lyconectes aleutensis (Dwarf wrymouth)	Pacific cod	116-174
	Flathead sole	35-190
Family Ammodytidae		
Ammodytes hexapterus (Pacific sandlance)	Pacific cod	39-402
	Walleye pollock	26-168
	Flathead sole	22- 55
	Yellowfin sole	31-111
	Pacific halibut	59-130
Family Pleuronectidae		
Atheresthes stomias (Arrowtooth flounder)	Pacific cod	30-210
	Walleye pollock	29- 50
	Arrowtooth flounder	150-150
	Yellowfin sole	34- 37
Hippoglossoides elassodon (Flathead sole)	Pacific cod	43-351
	Walleye pollock	42- 44
	Arrowtooth flounder	47-160
	Flathead sole	54- 54
	Greenland turbot	151-151
	Pacific halibut	89-180

Table 2.--Continued.

Fish prey species	Predator species	Prey size (mm)
Hippoglossoides robustus (Bering flounder)	Pacific cod	100-123
Lepidopsetta bilineata (Rock sole)	Pacific cod	30-262
	Walleye pollock	107-107
	Flathead sole	27- 75
	Yellowfin sole	12- 20
	Pacific halibut	57- 65
Limanda aspera (Yellowfin sole)	Pacific cod	23-300
	Walleye pollock	14- 14
	Pacific halibut	85-260
Limanda proboscidea (Longhead dab)	Pacific cod	94-231
	Pacific halibut	225-225
Pleuronectes quadrituberculatus (Alaska plaice)	Flathead sole	11- 11
Reinhardtius hippoglossoides (Greenland turbot)	Yellowfin sole	10- 33
Hippoglossus stenolepis (Pacific halibut)	Pacific cod	420-420
	Yellowfin sole	20- 20

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