Biology of Eggs, Larvae, and Epipelagic Juveniles of Sablefish, *Anoplopoma fimbria*, in Relation to Their Potential Use in Management

ARTHUR W. KENDALL, Jr., and ANN C. MATARESE

Introduction

Sablefish, *Anoplopoma fimbria* (also known as "blackcod"), are a moderately sized (length to about 100 cm) semi-demersal fish mainly of the outer continental shelf and upper slope of the North Pacific Ocean. This fish and the skilfish, *Erilepis zonifer*, another North Pacific resident, are the only members of the cottoid family Anoplopomatidae.

Sablefish occur widely along the Asian coast from Sagami Bay north along the Japanese coast to Cape Navarin, and along the North American coast from the northeastern Bering Sea south to Baja California (Sasaki, 1985). Along the west coast of the United States sablefish have been the target of both foreign and domestic fisheries since the end of the last century where they are caught by trawl, longline, and trap. In 1973, the United States imposed regulations on foreign fisheries and initiated intense discussions on sablefish biology, assessment, and regulation (Sasaki, 1985). It appears that sablefish in the U.S. and Canadian exclusive economic zones are now fully utilized, although most of the products are exported. High levels of incidental catch of sablefish in other fisheries have forced some to cease operations before the quotas of the target species have been reached.

Although various aspects of sablefish biology and the fishery have been studied (e.g., Bell and Gharrett, 1945; Phillips, 1958; Shubnikov, 1963; Kodolov, 1968, 1976; Sasaki, 1985), until recently little was known about sablefish during their first few months of life. Knowledge of the early life history of sablefish has potential to help management of the fishery in several ways, including improving the methods for stock assessment and measurement of year-class strength. Understanding factors influencing survival of eggs and larvae may lead to early forecasts of recruitment several years before the year class enters the fishery.

New information on sablefish early life history has resulted mainly from several ichthyoplankton sampling programs from the Bering Sea to northern California and from experimental work at Oregon State University, Corvallis, and the Pacific Biological Station in Nanaimo, B.C. It is now known that sablefish spawn pelagic eggs in winter near the edge of the continental shelf. The eggs float deeper than 200 m and probably require 2-3 weeks to develop. At hatching, the larvae seem to swim immediately to the surface and grow quickly (up to 2 mm per day) as part of the neuston during spring. There is no marked transition from larvae to juvenile, but by summer the young-of-the-year fish are found at the surface in inshore waters. This paper is a review of the studies on which these conclusions are based and an evaluation of how early life history information might be used to improve management of the fishery.

ABSTRACT—Recent studies on sablefish, Anoplopoma fimbria, *early life history have shown that they spawn pelagic eggs in winter near the edge of the continental shelf. The eggs float deeper than 200 m and probably require 2-3 weeks to develop. Shortly after hatching, the larvae seem to swim to the surface and grow quickly (up to 2 mm per day) as part of the neuston during spring. There is no marked transition from larvae to juvenile, but by summer the young-of-the-year fish are found at the surface in inshore waters. This is a review of the studies on which these conclusions are based and an evaluation of how early life history information might be used to improve management of the fishery.*

The authors are with the Resource Assessment and Conservation Engineering Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

Description of Eggs and Larvae

The early life history stages of sablefish are incompletely described in the literature. Sablefish eggs have been reported mainly from deep (>200 m) plankton tows, although they have not been adequately described or illustrated (Thompson, 1941; Mason et al., 1983b). Sablefish larvae[1] larger than 9.0 mm SL and juveniles have been reported in the literature since Brock (1940) first described four postflexion larvae (21-33 mm TL) collected from surface waters off Oregon and noted their unique coloration (blue-green on the dorsal surface and silvery on the ventral surface) and the large size of the pectoral fin (about one-third the length of the body). Sablefish larvae (11.3-30.2 mm TL, n=16) collected from surface waters near the

[1]Lengths of sablefish larvae are described using one of the following body measurements: Notochord length (NL) = A straight-line measurement from snout tip to notochord tip prior to development of the caudal fin, standard length (SL) = A straight-line measurement from snout tip to posterior margin of hypural element, and total length (TL) = A straight-line measurement from most anterior point to most posterior point of the fish.

Aleutian Islands were described and illustrated by Kobayashi (1957). Ahlstrom and Stevens (1976) briefly described 443 larvae (9.0-33.0 mm SL) collected in neuston samples from off Washington and Oregon and illustrated a series of five larvae (11.7-33.0 mm SL).

Based on the occurrence of sablefish eggs in slope waters off British Columbia in plankton tows to deeper than 400 m (Mason et al., 1983a, b), we made 12 special deep-water plankton tows during March 1984 along the continental slope off the coasts of Washington, Oregon, and northern California (Table 1). These deep-water tows (mean depth = 400 m), which were designed to collect the earliest life history stages (eggs and preflexion larvae <9.0 mm SL) of sablefish, produced the eggs and newly hatched larvae that are described and illustrated here, thus completing the description of sablefish development from egg through juvenile stage. Eggs and preflexion larvae were identified by considering a combination of characters (pigment, morphology, and number of myomeres). The largest larva collected in the deep-water tows (7.6 mm NL) was similar in these characters to the smallest larva collected in neuston tows (7.1 mm NL). Larvae larger than 8.0 mm NL, collected in surface waters, were identified by comparing our specimens with the smallest specimens illustrated by Kobayashi (1957) and Ahlstrom and Stevens (1976), 11.3 mm TL and 11.7 mm SL, respectively. Specimens less than 8.0 mm NL are generally less pigmented along the lateral body surface but have a similarly elongate body and gut, 61-66 myomeres, and relatively large eyes. Embryos in late-stage eggs and newly hatched larvae were matched to this series, and although they were less pigmented they were quite similar morphologically.

Table 1.—Summary of collection data for sablefish eggs and larvae taken at deep plankton stations off Washington-Oregon in 1984.

Station	No. of eggs	No. of larvae	Latitude (°N)	Longitude (°W)	Date	Sample depth (m)
G002B	2	4	48°00.9′	125°56.0′	12 March	390
G012B	0	1	47°21.5′	125°43.0′	13 March	402
G019B	1	4	46°40.5′	124°59.0′	15 March	389
G044B	1	0	45°19.0′	124°46.0′	20 March	403
G122B	1	0	40°00.1	124°51.0′	4 April	404

Eggs

Near-spawning ovarian eggs (Fig. 1) of sablefish are translucent and 1.0-1.2 mm in diameter (Mason et al., 1983b). Mason et al. (1983b) characterized developing eggs as pelagic, 1.8-2.2 mm in diameter with a smooth chorion, no oil globules, a narrow perivitelline space, and an embryo that remains unpigmented until later developmental stages. Sablefish eggs are unlike those of most other cottoids, which are demersal, about 1-2 mm in diameter, and have a single oil globule.

Eggs obtained from the deep plankton tows along the continental slope off Washington, Oregon, and northern California (diameter range 1.80-2.09 mm), and eggs stripped, fertilized, and reared under the supervision of D. F. Alderdice[2] at the Pacific Biological Station (diameter range 2.07-2.11 mm) compare favorably with the description by Mason et al. (1983b) and are similar to some collected off southeastern Alaska (Table 2). Identification of eggs from the plankton is thus possible based on the combination of the size of the eggs (1.8-2.2 mm), smooth chorion, narrow perivitelline space, lack of oil globules, myomere count (61-66), and lack of pigment on late-stage embryos which have a long gut (>50 percent body length). The embryos and newly hatched larvae fit into a series leading to larger larvae with diagnostic meristic characters.

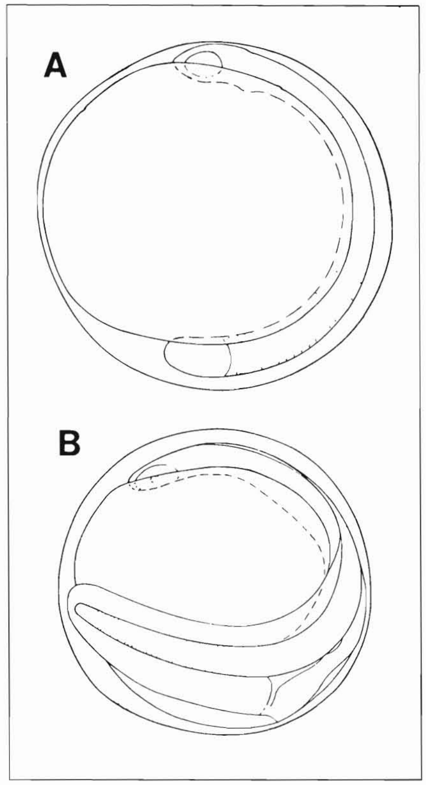

Figure 1.—Eggs of sablefish: A) Late middle-stage egg (283 hours) reared at Pacific Biolological Station, Nanaimo, B.C.; B) late-stage egg collected off the Washington coast, March 1984.

Larvae

Newly hatched larvae (5.0-6.0 mm NL) are unpigmented (Fig. 2A). Pigment first appears in larvae larger than 6.0 mm NL when the eyes are pigmented. Melanophores, which appear along the entire dorsal surface of the gut when larvae are about 6.5 mm SL, are larger and more concentrated posteriorly (Fig. 2B). Pigment also appears along the ventral body midline with several melanophores immediately posterior to the anus and a short series along the posteriormost 10 or so myomeres. Along the dorsal midline, melanophores extend from about midway along the postanal body to near the last myomere. Pigment continues to increase along the dorsal midline in larvae larger than 6.5 mm SL, extending from the head and nape to the last myomere, but the short series of ventral midline melanophores does not appear to increase anteriorly

[2]Alderdice, D. F., J. O. T. Jensen, and F. P. J. Velsen. Preliminary trials on incubation of sablefish eggs (*Anoplopoma fimbria*). Pac. Biol. Stn., Nanaimo, B.C. Unpubl. manuscr., Jan. 1986.

Table 2.—Collections of sablefish eggs, larvae, and epipelagic juveniles.

Area of sampling	Dates of sampling	Size range ($\bar{x}$) (mm)	Number	Gear[1]	References
Eggs					
Cape St. James, Queen Charlotte Island	Winter 1937, 1941	(2.097)	80	Plankton	Thompson, 1941
Off British Columbia	9 January-20 April 1980	1.8-2.2	43[2]	Bongo	Mason et al., 1983b
S.E. Alaska	19-25 January 1984, 2 February 1985	1.8-1.9	>68	Bongo	NWAFC files[3]
WA-OR-CA	12-28 March 1984	1.8-2.09 (2.00)	5	Bongo	NWAFC files[4]
Larvae and juveniles					
Monterey Bay		75	1	(at surface)	Gilbert, 1915
Off Oregon	23-25 May 1939	21-35 SL	4	Dipnet	Brock, 1940
Aleutians (Attu-Umnak)	8 July-13 August 1955-56	11.3-30.2 TL 25.4 BL	16	Neuston	Kobayashi, 1957
Aleutian Islands, Bering Sea, Gulf of Alaska	12 June-13 August 1955-69	5.6-43.5	164	Neuston	Hokkaido University, 1957a,b, 1958, 1959a,b, 1960a,b, 1961, 1964, 1968, 1969, 1970
So. Calif./Baja Calif.	June, July 1964-68	66-149 SL	650	Purse seine	Mitchell and Hunter, 1970
Bering Sea	June-August 1970-79	Not given	382	Neuston	Haryu et al., 1985
Most lat. 46°00'N, long. 121°00'W; some OR and CA	May 1972	9.0-32.5 SL	468	Neuston	Ahlstrom and Stevens, 1976
Off Oregon	March 1972-75, April 1972, 1973	Not given	16[5]	Bongo	Richardson et al., 1980
Bering Sea lat. 52°-60°N, long. 166°-179°W	1 June-23 July 1979	11.0-25.2 (15.5) SL	306	Neuston	Text foonote 10
WA-OR-CA	4 April-13 May 1980	6.3-37.0 (14.2) SL	621	Neuston	Text footnote 6
Off British Columbia	11 March-20 April 1980	6-9 (most 7-8) TL	55	Bongo	Mason et al., 1983b
Gulf of Alaska	19-22 April 1981	8.1-11.6 (9.9) SL	2	Neuston	Bates and Clark[6]
Gulf of Alaska off Kodiak Island	19 June-9 July 1978	11.0-26.2 (19.1) SL	19	Neuston	Kendall and Dunn, 1985
WA-OR-CA	9 May-2 June 1981	10.5-38.0 (23.43) SL	24	Neuston	Text footnote 4
Line "P", 70 and 175 km offshore	Late March 1982	9-10 TL	4	Neuston	Mason et al., 1983b
Gulf of Alaska	22-30 May 1982	8.8-10.0 SL	2	Bongo	NWAFC files[4]
WA-OR-CA	3-30 May 1982	10.7-41.2 SL	77	Neuston	NWAFC files[4]
WA-OR-CA	24 April-8 May 1983	7.2-38.0 (16.04) SL	259	Neuston	Text footnote 8
		10.4-12.1 (11.43) SL	4	Bongo	
Gulf of Alaska	22-28 May 1983	9.0-20.3 (14.63) SL	227	Neuston	NWAFC files[4]
WA-OR-CA	12-28 March 1984	7.1-28.5 (11.16) SL	202	Neuston	NWAFC files[4]
		5.6-8.3 (6.93) SL	14	Bongo	
Off Vancouver Island	16 April-10 May 1984	8 TL-38 FL (16.6)	722	Neuston	Shaw et al., 1985
S.E. Alaska	23-26 May 1985	10.4-21.1 SL	46	Neuston	NWAFC files[3]
	7, 14 July 1985	21.1-30.9 SL	3	Neuston	NWAFC files[3]

[1]Bongo: A paired plankton net usually 50-70 cm in diameter towed obliquely from a specified depth (e.g., 400 or 200 m) to the surface. Neuston: A plankton net of various dimensions towed at the surface.
[2]Occurrences in 303 samples.
[3]Wing, B. L. Auke Bay Lab. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, P.O. Box 210155, Auke Bay, AK 99821. Unpubl. data.
[4]Kendall, A. W., Jr., and J. B. Clark. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. Unpubl. data.
[5]Occurrences in 306 samples.
[6]Bates, R. D., and J. B. Clark. 1983. Ichthyoplankton off Kodiak Island and the Alaskan Peninsula during spring 1981. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 83-09, 105 p.

(Fig. 2C). Specimens larger than 7.0 mm NL collected in neuston net tows have pigment along both the dorsal and ventral midlines, and possess some lateral pigment about midbody (Fig. 2D).

Sablefish change gradually in morphology between notochord flexion (10-16 mm SL) and about 35 mm SL when they can be considered epipelagic juveniles. The larvae are elongate and heavily pigmented (Fig. 3). They develop remarkably large pectoral fins that are especially heavily pigmented near the distal margin of their blades. The eye is large and, in contrast to larvae of most other scorpaeniforms, there are no head spines. The head becomes relatively longer and the body deeper (more robust) as the larvae grow (Table 3). The size of the eye, and the preanal length grow in proportion to length of smaller larvae, but increase in proportion slightly in larger larvae. A morphological feature that appears to be diagnostic for sablefish larvae is the unique shape of the anus which curves ventrad in specimens larger than 6.0 mm SL. There is no marked morphological transformation from the larval to juvenile stage, probably because both stages are epipelagic and have evolved a form adapted to this habitat.

Since the literature (e.g., Kobayashi, 1957), indicates that sablefish larvae are often measured using total length, we performed a simple linear regression using 30 sablefish larvae (6.2-26.4 mm SL) to compare total length and standard length. The following equation resulted:

$$TL = (-1.668) + 1.279\ (SL)$$
$$r = 0.999.$$

Sablefish larvae may be confused with other heavily pigmented larvae such as those of sauries, *Cololabis saira*, in the southern part of their range, and with those of greenlings (Hexagrammidae), cryptacanthodids, *Lyconectes/Delolepis*, and prowfish, *Zaprora silenus*,

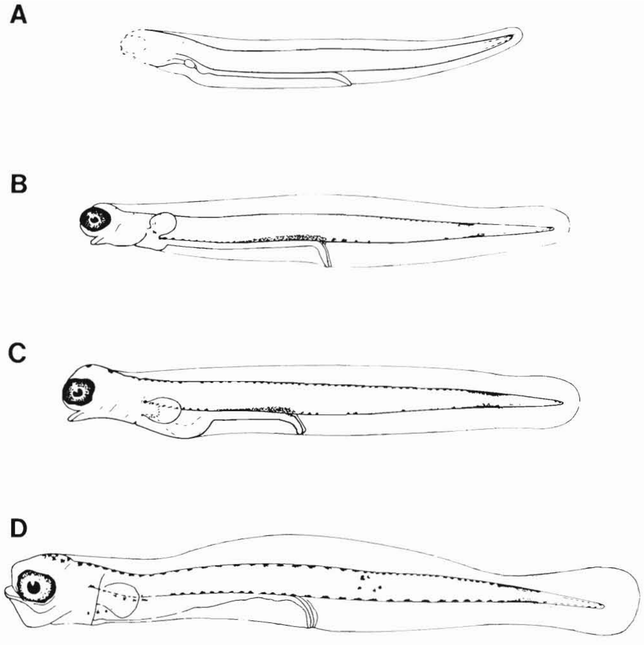

Figure 2.—Early larvae of sablefish: A) 5.6 mm SL; B) 6.5 mm SL; C) 6.9 mm SL; D) 8.8 mm SL. A-C were collected off the Washington coast in March 1984 and D was collected in a neuston tow in the Bering Sea in 1977.

Table 3.—Measurements and body proportions (mm) of sablefish larvae. Mean and standard deviation given for each body proportion are expressed as percentages of notochord length (NL) or standard length (SL)[1].

Notochord/ standard length	Head length	Eye dia.	Snout to anus length	Body depth at pectoral fin base	Body depth at anus
Preflexion larvae					
5.6	0.9		3.3	0.4	0.4
6.5	0.9	0.5	3.4	0.4	0.4
6.6	1.1	0.5	3.6	0.6	0.5
6.6	0.9	0.5	3.4	0.7	0.5
6.8	1.1	0.5	3.5	0.7	0.5
6.9	1.1	0.5	3.6	0.7	0.4
7.6	1.2	0.5	3.9	0.8	0.4
7.6	1.2	0.5	4.1	0.8	0.5
Summary of Preflexion					
Sample size	8	7	8	8	8
Mean (% NL)	15.5	7.2	53.3	9.3	6.7
S.D.	1.1	0.4	2.6	1.7	0.9
Flexion larvae					
10.3	1.9	0.8	5.5	1.0	0.9
10.8	2.3	0.8	6.0	1.4	1.2
13.3	2.3	0.8	6.6	1.4	1.3
13.5	2.7	1.0	7.5	1.7	1.5
13.6	2.7	1.0	7.2	1.5	1.5
14.5	3.0	1.0	8.1	1.7	1.6
15.3	3.2	1.2	8.1	2.0	1.7
15.4	3.2	1.1	8.0	1.9	1.7
15.6	3.3	1.1	8.1	1.9	1.8
16.1	3.4	1.1	8.2	1.9	1.8
Summary of Flexion					
Sample size	10	10	10	10	10
Mean (% NL)	20.2	7.2	53.1	11.8	10.8
S.D.	1.3	0.5	2.1	1.1	0.9
Postflexion larvae					
16.1	3.8	1.3	8.7	2.5	2.2
16.5	4.2	1.3	9.3	2.6	2.4
18.5	4.8	1.6	10.5	2.8	2.7
18.6	5.0	1.6	11.0	3.2	2.7
19.4	4.9	1.4	12.0	2.9	2.6
19.6	5.2	1.6	11.1	2.9	2.7
21.4	5.3	1.8	12.1	3.2	3.0
25.3	6.6	1.9	13.8	3.8	3.6
26.4	6.9	1.9	14.5	4.3	3.6
26.6	6.9	2.1	15.5	4.2	3.8
Summary of Postflexion					
Sample size	10	10	10	10	10
Mean (% SL)	25.7	8.0	56.9	15.5	14.1
S.D.	1.0	0.5	2.4	0.8	0.4

[1]Measurements were made following definitions in Matarese et al. (1981), except NL which was measured from the snout tip to notochord tip prior to development of caudal fin.

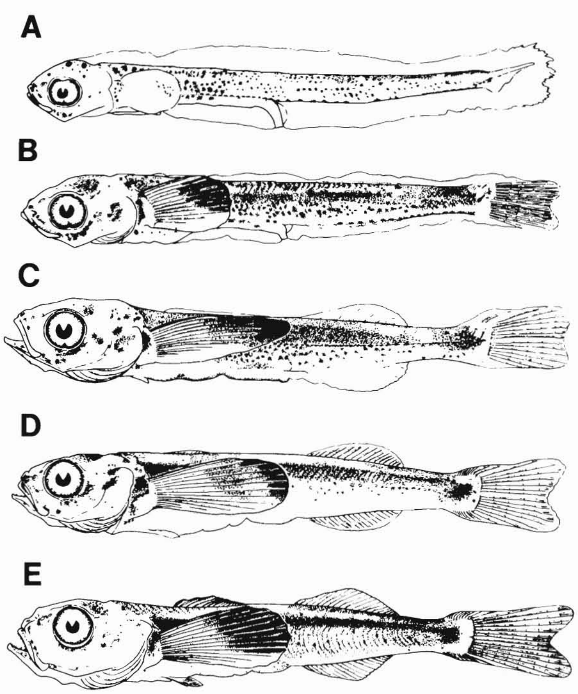

Figure 3.—Later larvae of sablefish from Ahlstrom and Stevens (1976): A) 11.7 mm SL; B) 13.8 mm SL; C) 18.6 mm SL; D) 23.0 mm SL; E) 33.0 mm SL.

throughout their range. However, the enlarged, pigmented pectoral fins are diagnostic of sablefish larvae.

Spawning Season

Mason et al. (1983b) reviewed and augmented information on time of spawning derived from gonadal maturity observations of adults. In various parts of the North Pacific Ocean spawning seems to occur from late fall through early spring. Spawning seems to take place earlier in the year in the southern part of the range (December off California) and becomes progressively later toward the north (May off the Aleutian Islands). The gonadal cycle of females from off British Columbia indicated a rather short spawning season from January to March with a distinct peak in mid-February.

Boehlert and Yoklavich (1985) estimated the birth dates of specimens used for their larval growth study and found, assuming a 13-day incubation period and an equal time before first feeding when otolith increments may begin to be laid down, that peak spawning off Washington and Oregon would have occurred in early March. These data may be biased toward spawning later in the season, because the neuston nets used allow larger specimens to escape, and the sampling was done when specimens from spawning earlier in the year would no longer have been vulnerable to capture.

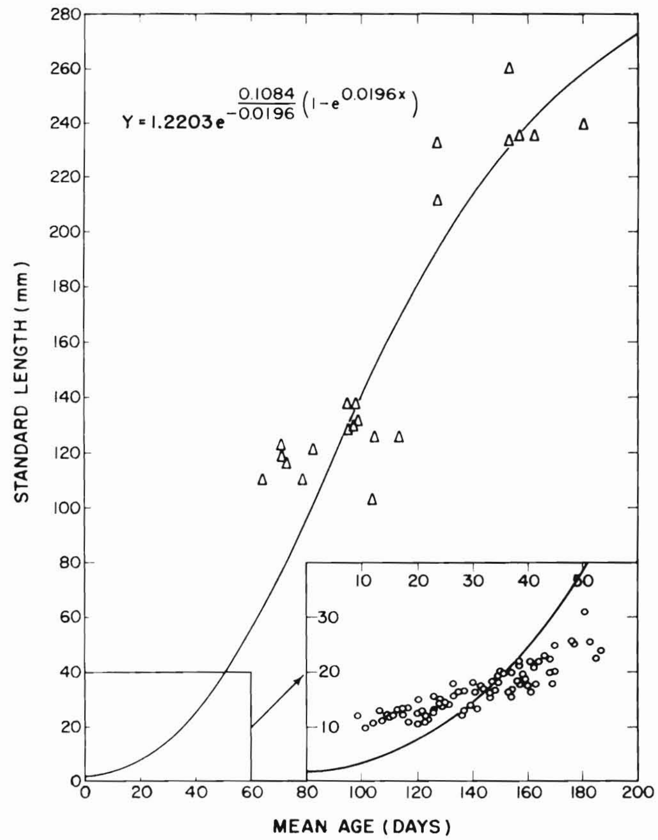

Figure 4.—Growth rate of young sablefish from Boehlert and Yoklavich (1985).

Developmental Rates

Egg Incubation Period

Based on maximum seasonal catches of eggs in February and those of larvae in April, Mason et al. (1983b:2129) suggested an incubation period "exceeding several weeks." Based on an empirical relationship between egg size and incubation time, Boehlert and Yoklavich (1985) suggested that sablefish, with a 2 mm egg, would have an incubation time of 13 days. The effect of development at considerable depths (300-400 m) and at prevailing incubation temperatures of less than 6°C (Mason et al., 1983b) on this relationship is unknown. Recent rearing experiments on sablefish eggs held at 4.0°C yielded an estimate of time from fertilization to 50 percent hatch as 400.9 hours (16.7 days)[2].

Larval Growth

Since sablefish spawn during a fairly restricted season (mainly January-February) off British Columbia it has been possible to estimate growth rate by observing the length frequency of young-of-the-year juveniles. This method led to the statement that "young of the year are inshore in July at 5 cm and grow to 28 cm by November" (McFarlane and Beamish, 1983b). Nine juveniles (23-27 cm) captured in February had 270-350 daily growth increments on their otoliths indicating that they were close to a year old (Beamish et al., 1983). Mason et al. (1983a) stated concerning these same juveniles that "the pattern of daily growth suggested that the first month of growth occurs at spawning depths, then there is a period of approximately 4 months during which growth is irregular as the larval sablefish moves inshore in the surface waters." They did not tell what daily growth patterns led to these conclusions.

Boehlert and Yoklavich (1985) studied growth during the first 6 months of life in more detail using daily growth increments on otoliths of 105 field-caught specimens, validated by data from three laboratory-held specimens. They found growth of fish 9.8 to 41.2 mm SL could be described by the straight line:

$$(\text{SL}) = 0.375\ (\text{age, d}) + 5.27$$
$$n = 71,\ r^2 = 0.838.$$

Growth of fish 102.8 to 259.6 mm SL could be described by the straight line:

$$\text{SL} = 1.469\ (\text{age, d}) - 0.926$$
$$n = 21,\ r^2 = 0.822.$$

Combining all data, for fish 9.8 to 259.6 mm SL, the best fit among the various models tried was to the Laird-Gompertz model:

$$L_t = L_0(A_0/\alpha)(1-\exp(-\alpha t))$$

where L_t = standard length at age t (d),

L_0 = initial length (y-intercept),

and A_0 and α are fitted parameters.

For the sablefish examined, L_0 = 1.2203, A_0 = 0.1084, and α = 0.0196 produced the best fit. This is a sigmoid curve showing slow growth up to 50 days and 25 mm SL, followed by an accelerating growth rate through the young-of-the-year juvenile stage (Fig.

4). The juveniles are growing at about 2 mm per day during the fastest period of growth. This growth curve indicates that the 111-148 mm SL fish Heyamoto (1962) estimated to be 6 months were actually much younger (about 3 months old). Boehlert and Yoklavich (1985) caution against applying this growth model outside the size range of specimens examined (9.8 to 259.6 mm SL), because it predicts a smaller size at age zero days and a lower asymptotic maximum length than is reasonable. It is unknown at what age the first daily increment is laid down in sablefish otoliths, but in most other fish studied it occurs around the time of hatching or first feeding.

The juveniles that Beamish et al. (1983) aged from daily otolith increments were 208 to 245 mm SL, and had 270-350 observable increments. Based on the Boehlert and Yoklavich (1985) curve these fish would have been less than 170 days old. This would imply that since the fish were collected in February, they would have been spawned in mid-summer. Hughes (1981) reported finding ripe, spawning, and recently spent sablefish in the water column above Gulf of Alaska seamounts in June. However, most other data indicate that sablefish spawn in late winter, so apparently the juveniles of Beamish et al. (1983) had grown much slower than those examined by Boehlert and Yoklavich (1985). A reasonable explanation for this discrepancy is that juvenile growth may be quite slow between summer when Boehlert and Yoklavich (1985) sampled their largest fish and February when Beamish et al. (1983) collected their fish, which were indeed approaching 1 year old.

Shenker and Olla (1986) held field-caught larvae and juveniles in the laboratory to examine the effects of various diets and feeding levels on their growth. They found that fish fed ad libitum grew up to 2.3 mm per day at lengths where the curve of Boehlert and Yoklavich (1985) predicts the fastest growth. This tends to substantiate the growth rate determined by the otolith aging technique, and indicates that epipelagic juvenile sablefish used in the growth study were finding sufficient prey in the field to sustain a growth rate near the maximum observed in the laboratory. The smaller fish in the field grew slower than those on high rations in the laboratory, indicating that food limitation in the field may have impeded growth of the smaller fish.

Larval Feeding

Feeding of sablefish larvae and epipelagic juveniles has been investigated by examining gut contents of wild-caught fish, as well as by examining effects of different foods and rations under experimental conditions in the laboratory. Grover and Olla (1986) found that the size of food eaten by larvae varied with larval size. Based on analysis of 267 larvae collected at 10 locations off Washington and Oregon in 1980, three size classes of larvae were evident: ≤12.5, 12.6-20.5, and 20.6-28.5 mm SL. As the larvae grew, they ate a wider range of sizes of prey.

Copepod nauplii were the most important food item in smaller larvae, and while larger larvae also ate nauplii, they consumed more small (<1 mm) copepods. Larger copepods (>2 mm) were more important in the diets of 20.6-28.5 mm SL larvae. Grover and Olla (1986) also found morphological evidence of starvation (empty shrunken guts, emaciated appearance) in small (<12.5 mm SL) larvae at one station. They deduced that a shortage of copepod nauplii at this station had caused the larvae to become emaciated.

Grover and Olla (In press) compared the diets of the same three size classes of larvae caught in 1980 with those caught in 1983, an El Niño year (Fig. 5). Sablefish larvae occur off Oregon at a transitional time of year (spring) between the winter plankton assemblage which originates to the south, and the summer assemblage which originates to the north. During the El Niño year, the winter assemblage dominated through spring and into July (Miller et al., 1985). Zooplankton density was reduced, possibly as low as 30 percent of a non-El Niño year. Although there was no evidence of starvation in 1983, sablefish larvae had more small copepods in their diet than in 1980. This could have impacted growth because of the lower caloric value, and an increase in energy spent in capturing and handling the smaller copepods.

Laboratory studies with epipelagic sablefish have shown them to be hardy and fast growing (Shenker and Olla, 1986). Two live prey species (brine shrimp and a mysid shrimp) were fed to juveniles in individual tanks at rations of 10, 20, and 30 percent body weight per day and also ad libitum. The mysids were more nutritious. Growth rates for fish fed on mysids varied from 0.90 mm/day at 10 percent ration to 2.24 mm/day when fed ad libitum. Growth rate in length decreased linearly with increase in length, although weight increased as a power function of increasing length. The smaller fish (40 mm SL) increased by 13-15 percent body weight per day, while 110 mm SL fish increased by 5-7 percent body weight per day. Sablefish are among the fastest growing epipelagic juvenile fish studied to date (Shenker and Olla, 1986).

Distribution of Eggs and Larvae

Vertical Distribution

No systematic study has been conducted to investigate the vertical distribution of sablefish eggs and larvae at sea. However, the following inferences can be drawn from the collection depths of the eggs and larvae during surveys and from limited laboratory work: Sablefish eggs have been found to be pelagic, but occur deeper than 200 m. Toward the end of the yolk-sac stage, the larvae move to the surface of the sea where they remain as part of the neuston from about 10-80 mm SL.

Data on vertical distribution of sablefish eggs obtained from our deep-water plankton collections in 1984 agree with previous studies (Thompson, 1941; Mason et al., 1983b). Eggs and newly hatched larvae, previously unknown in samples from the upper 200 m of the water column, were collected when the sampling depth was increased to 400 m. The presence of eggs at depths greater than 200 m coincides with the available data on the bathymetric distribution of mature sablefish (Sasaki, 1985). Presumably eggs are spawned and hatch at depths greater than 200 m as indicated by our collection of eggs and small (~7.0 mm SL) larvae exclusively in deep-water plankton tows. No sablefish eggs and only 5 larvae (<8.3 mm SL) were collected in the 125 bongo tows to 200 m that were taken on the same cruise. Larvae in neuston collections during this cruise were larger with a mean length of 11.16 mm SL.

Mason et al. (1983b) interpreted the absence of late-stage eggs and prevalence of newly hatched larvae (5-6 mm) in his samples as evidence for an egg descent into waters exceeding 400-500 m prior to hatching and maintenance of that deep position at least until hatching. Recent laboratory studies on sablefish egg density[2] lend some support to this hypothesis. The density of early- and middle-stage eggs was found to be about 1.0264. Based on this egg density, egg diameter, and the density of the ambient water (if spawning occurs around 500 m (d = 1.0269)), the eggs would rise in the water column to about 300 m during incubation. However, just prior to hatching, egg density was observed to increase, causing them to sink somewhat.

Small sablefish larvae (<10 mm SL) are rare in field collections. The few that have been taken have been almost exclusively in oblique plankton tows which have sampled to maximum depths of 400, 200, or 120 m (Table 3). There is no direct field evidence to support the contention that these larvae are deeper in the water column than 400 m (Mason et al., 1983b), although reared yolk-sac larvae have been found to be negatively buoyant[3]. From the presence of eggs deeper than 200 m and the presence of larvae larger than 10 mm SL in surface waters (see below), it is reasonable to suppose that as the yolk sac is absorbed the larvae swim to the surface. Newly hatched larvae of most fish are delicate and poorly represented in plankton catches, because they are extruded through the net meshes.

Larvae and early juveniles (10-80 mm SL) of sablefish appear to be obligate neustonic animals, i.e., they are found only at the surface of the sea. Larvae

[3]G. A. McFarlane, Pac. Biol. Stn., Nanaimo, B.C. V9R5K6. Personal commun., June 1986.

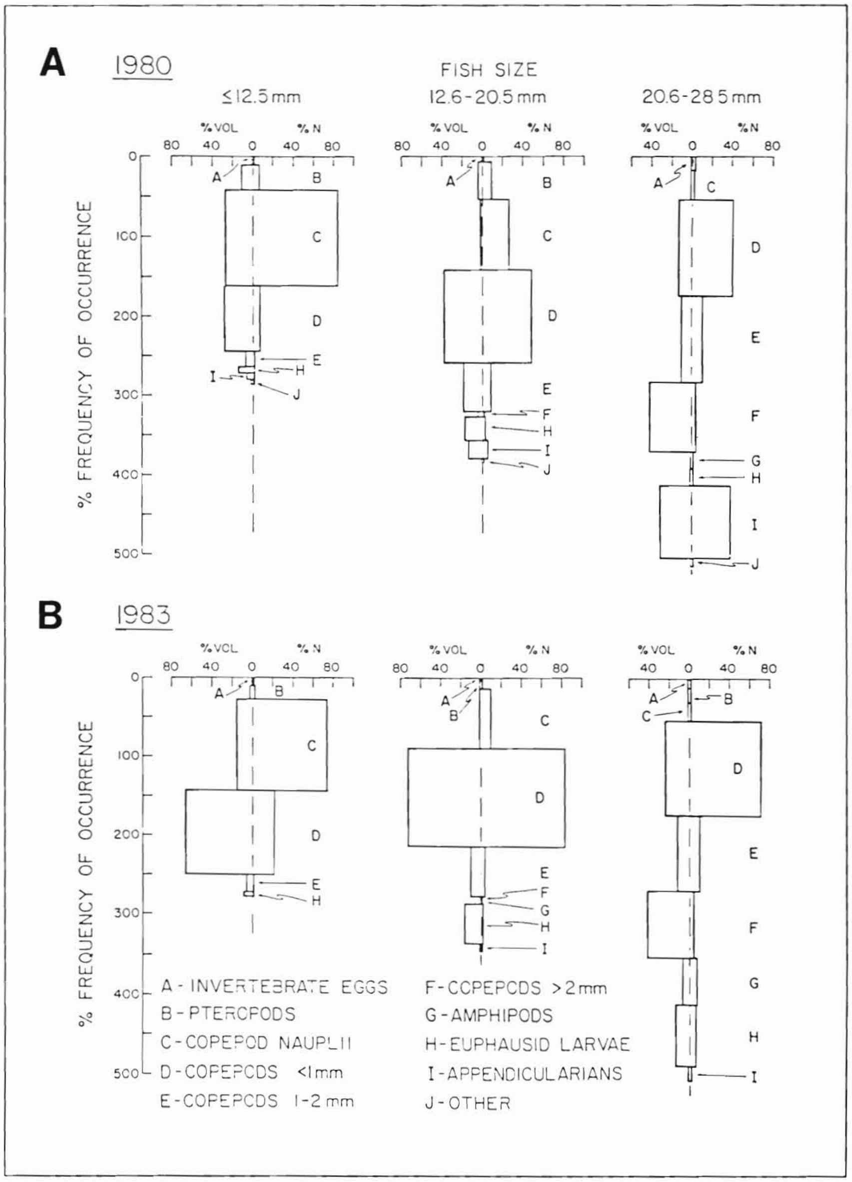

Figure 5.—Prey of larval sablefish, 1980 and 1983, from Grover and Olla (In press).

10-30 mm SL are frequently caught in neuston nets in spring, but are rarely seen in oblique tows, which are taken concurrently (Table 3). Juveniles up to 80 mm SL were taken in abundance in a larger neuston trawl, indicating that the upper size limit of fish in smaller neuston nets is caused by net avoidance of larger juveniles, not their departure from the surface layer (Shenker, 1984).

Although juveniles larger than 50 mm SL have mainly been reported in nearshore waters (McFarlane and Beamish, 1983b), some up to 250 mm SL have been collected in offshore surface waters by small-mesh purse seine[4]. In the laboratory, sablefish 20-80 mm SL swim

[4]W. Pearcy, Oregon State Univ., Corvallis, OR 97331. Personal commun.

continuously above the bottom but do not orient to the very surface of the water[5].

Seasonal/Geographic Distribution

Sablefish eggs have been reported in January and February off southeast Alaska (Table 3), in January through March off northern British Columbia (Thompson, 1941), in January through April, with a peak in February, all along the coast of British Columbia (Mason et al., 1983b), and in March off Washington and Oregon (NWAFC sampling; cruise report not yet completed) (Fig. 6). Their absence in samples taken at appropriate times of the year in other areas may be due in part to their apparent occurrence at depths greater than 200 m, the maximum depth of sampling in several other programs (e.g., CalCOFI and Bering Sea work by OCSEAP and the Soviets). The seasonal occurrence of eggs and larvae in field samples must be evaluated, taking into account the sporadic nature of many of the sampling programs.

Larvae of sablefish have been taken almost exclusively in neuston nets, which have only recently been used in large-scale surveys to sample ichthyoplankton (Table 3). Most larvae taken in neuston nets are 7-40 mm SL; based on growth rates of sablefish of this size (Boehlert and Yoklavich, 1985), this length interval would last about 12 weeks.

Larvae and epipelagic juveniles have been collected north from Baja California in the northeast Pacific Ocean and in the Bering Sea; they have not been reported off Japan (Sasaki, 1985). The following summarizes these collections.

Juveniles up to 149 mm SL were the fourth most abundant fish taken in purse seine sets that surrounded drifting masses of kelp off southern California and Baja California (Mitchell and Hunter, 1970). There, fish were collected in June and July and were seen by divers to remain some distance (0.75 to 8 m) from the kelp mass. In a May cruise off the Pacific coast of the United States, Ahlstrom and Stevens (1976) reported

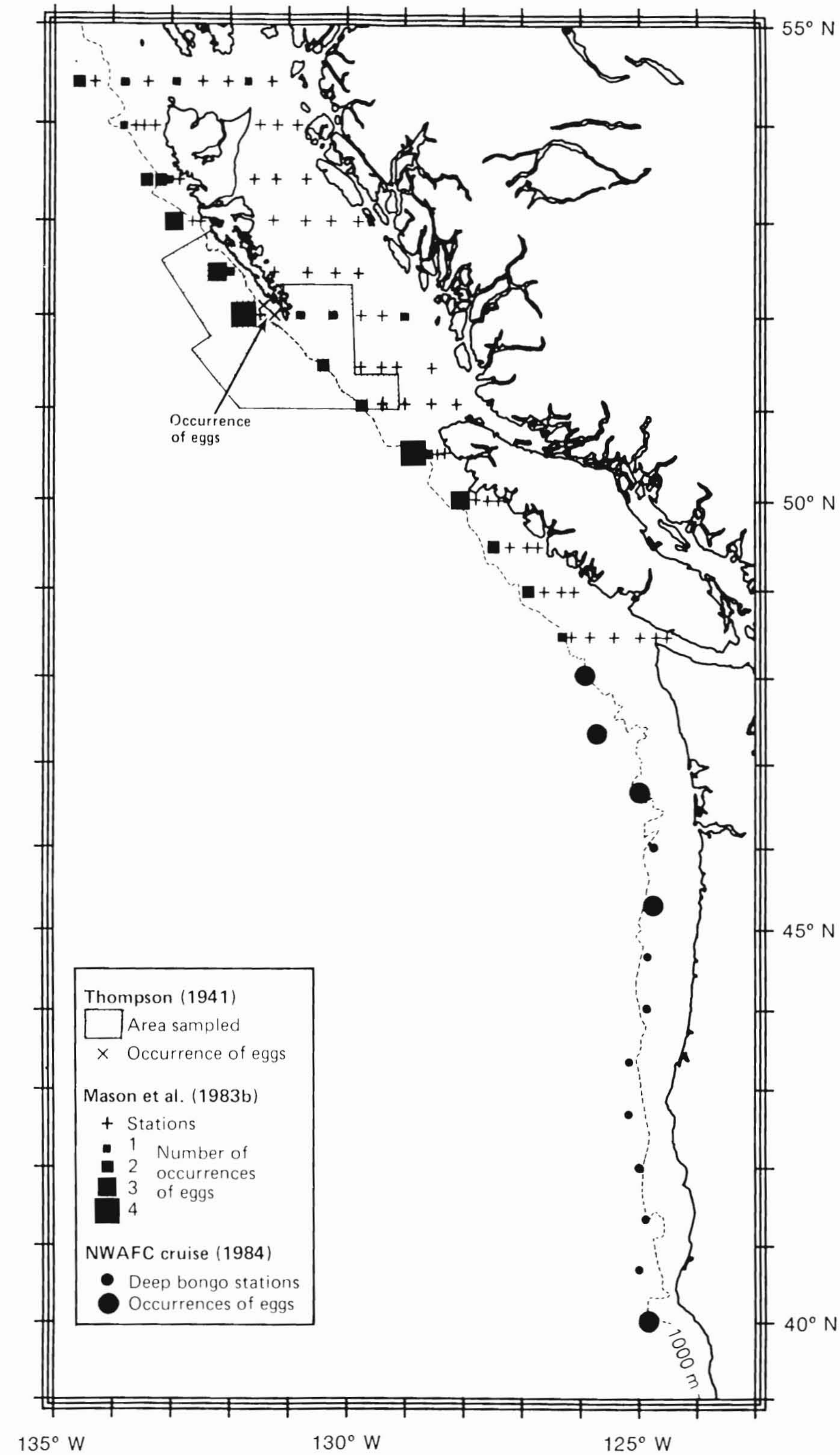

Figure 6.—Occurrences of sablefish eggs based on Thompson (1941), Mason et al. (1983b), and NWAFC sampling.

[5]B. L. Olla, Oregon State Univ., Newport, OR 97365. Personal commun.

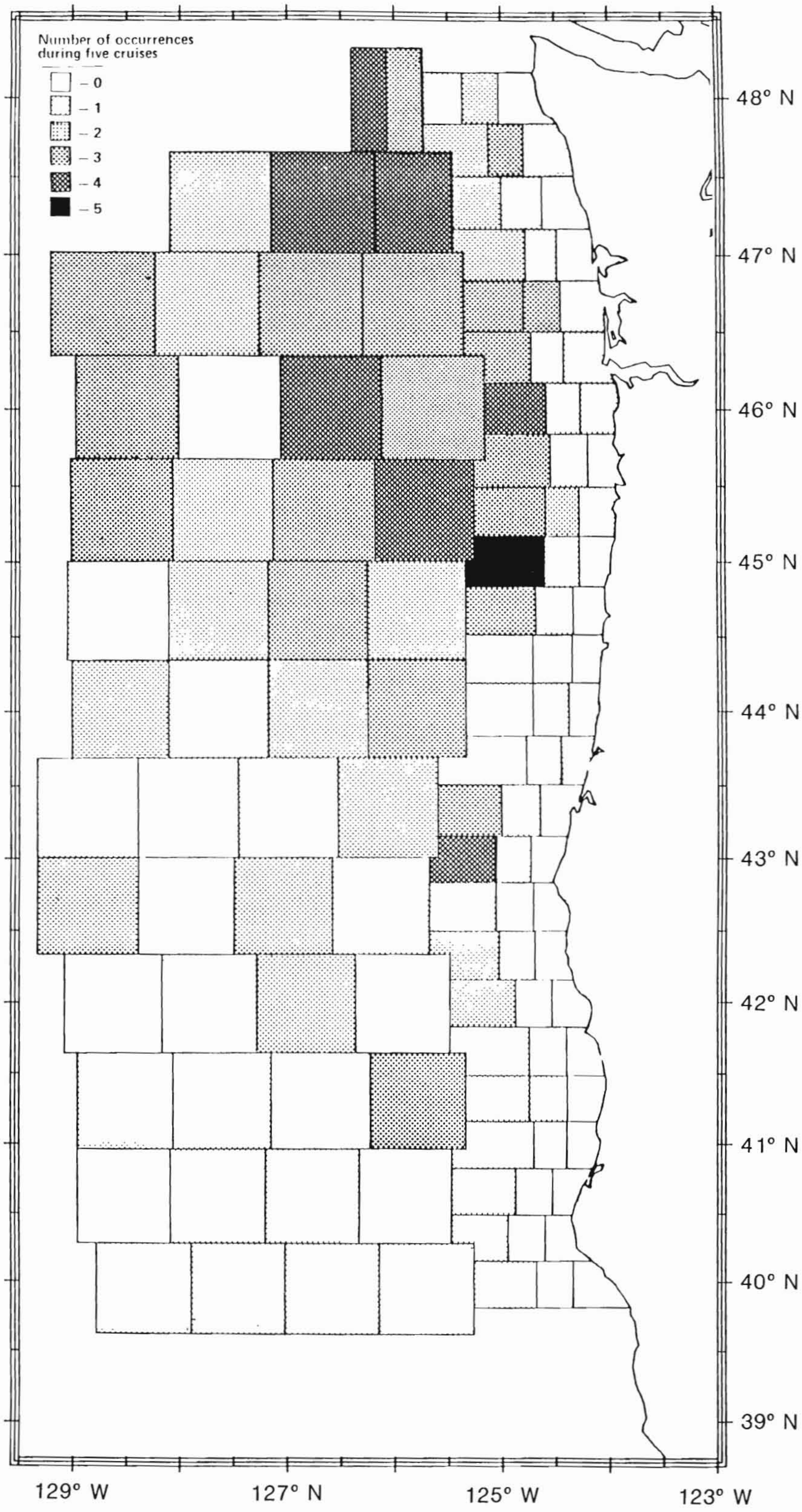

Figure 7.—Occurrences of sablefish larvae off the U.S. west coast.

larvae (9.0-32.5 mm SL) in 7 of 105 neuston collections, including one catch of 443 specimens off northern Oregon (the tow filtered about 250-300 m^3 of water).

Among 306 oblique plankton tows to a depth of 150 m off Oregon in March and April of several years, sablefish larvae occurred in low numbers and in all but one of six cruises (Richardson et al., 1980). Altogether they occurred in only 16 tows. In April 1973 they were abundant enough to be included in an assemblage analysis when they grouped with transitional species that occurred near the 200 m depth contour (28-46 km from shore). No sizes of the larvae were given, but from their capture in oblique plankton tows in March and April, they were probably recently hatched larvae (<15 mm SL).

Larval and juvenile sablefish (6.3-41.2 mm SL) off Washington, Oregon, and northern California were collected widely during cruises to the area each year from 1980 to 1984 between March and June[6,7,8,9]. All the juveniles and most larvae, except a few less than 13 mm from oblique bongo tows, were taken in neuston tows. They were found from the shorewardmost stations (5.6 km from shore), to those farthest offshore (370 km from shore). They also occurred throughout the latitudinal range of the sampling area (lat. 48°-40°N), although most were found in the northern half of the area (Fig. 7).

Off British Columbia, a few small larvae (6-10 mm SL) have been caught in

[6]Kendall, A. W., Jr., and J. B. Clark. 1982. Ichthyoplankton off Washington, Oregon, and northern California April-May 1980. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 82-11, 44 p.

[7]Clark, J. B. 1984. Ichthyoplankton off Washington, Oregon, and northern California April-May 1980. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 84-11, 46 p.

[8]Clark, J. B., and A. W. Kendall, Jr. 1985. Ichthyoplankton off Washington, Oregon, and northern California April-May 1983. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 85-10, 48 p.

[9]Kendall, A. W., Jr. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. Unpubl. data.

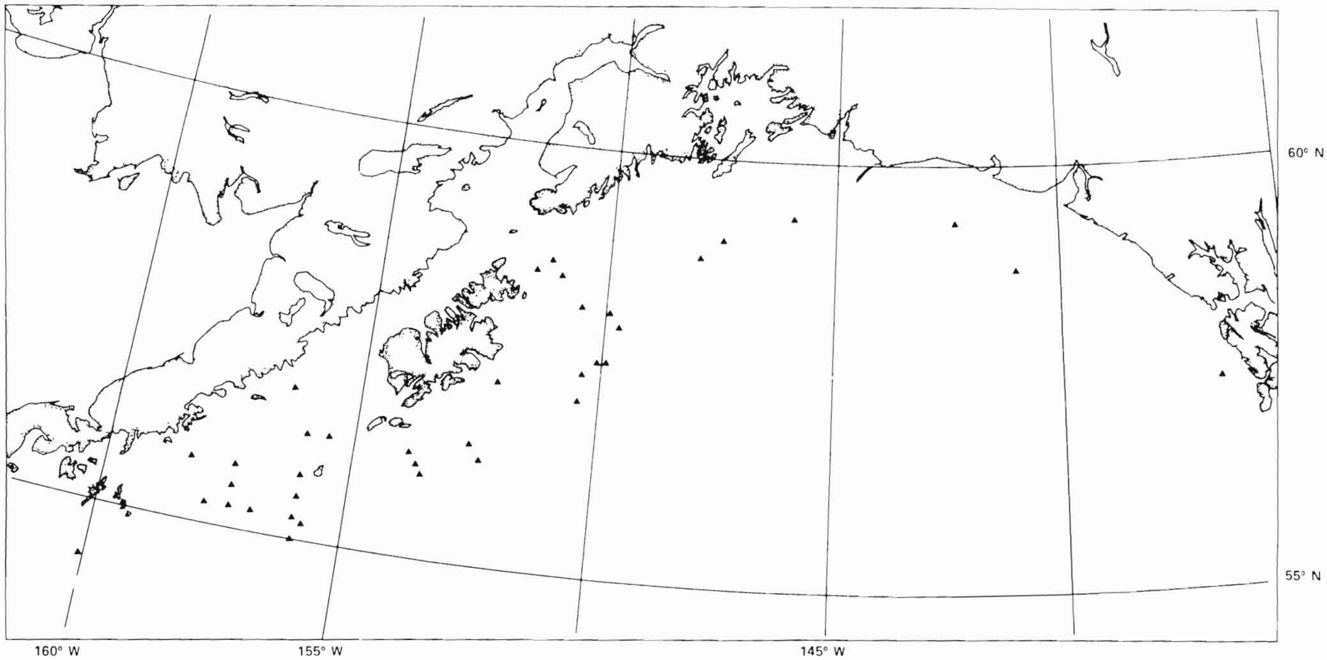

Figure 8.—Occurrences of sablefish larvae in the Gulf of Alaska, based on NWAFC sampling.

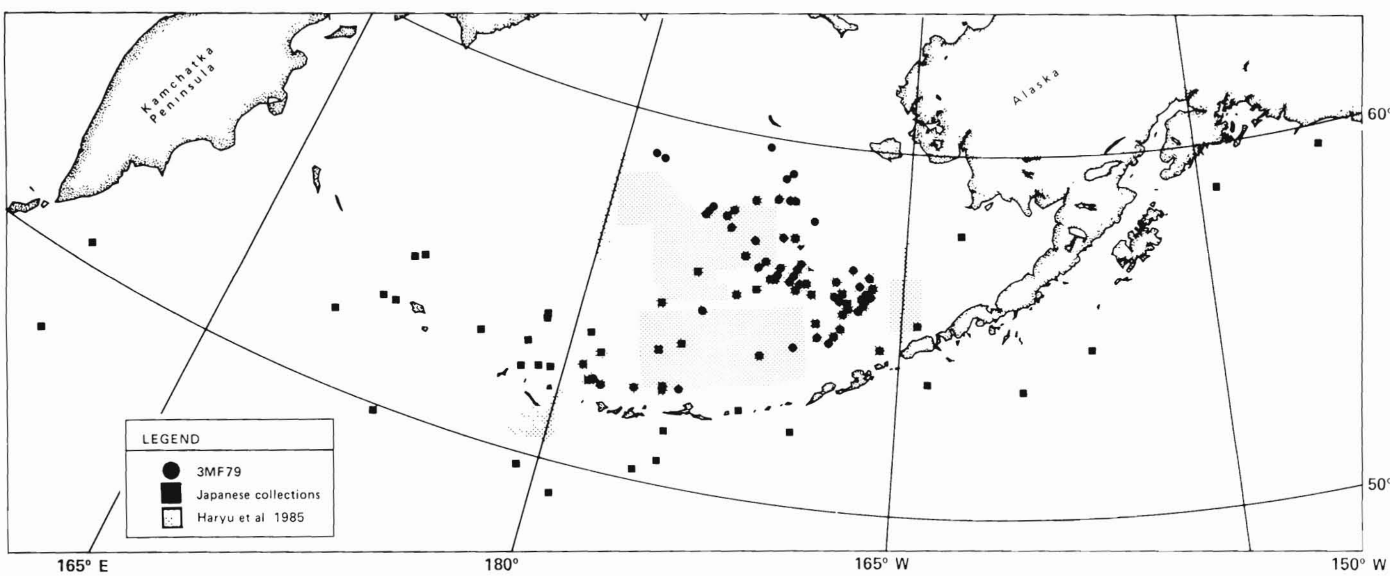

Figure 9.—Occurrences of sablefish larvae based on cruises by Hokkaido University (var. years) and the NWAFC cruise in Bering Sea, 1979 (text footnote 10).

oblique plankton tows in March and April (Mason et al., 1983b) and larger larvae (8-38 mm) were taken mainly at stations between the 200- and 2000-m depth contours in neuston tows in April and May (Shaw et al., 1985). In the Gulf of Alaska, larvae have been collected primarily in the neuston from late May through early July; however, sampling has been inadequate to infer much about their distribution (Table 3, Fig. 8).

Near the Aleutian Islands and in the Bering Sea, small numbers of larvae and juveniles have been collected in surface nets over the years since 1955 by Japanese training ships from Hokkaido University (Fig. 9). Catches have occurred from 12 June to 13 August and larvae have ranged in length from 5.6 to 43.5 mm SL (Hokkaido Univ., 1957a,b, 1958, 1959a,b, 1960a,b, 1961, 1964, 1968, 1969, 1970). Between 1955 and 1969, the last year for which larval fish data were reported, larvae occurred in 47 hauls, although only 3 hauls had more than 10 larvae (each haul sampled about 790 m^2 of sea surface). The catches were mainly within about 240 km of shore all along the Aleutian Island chain. Haryu et al. (1985) summarized the occurrences of nearly 400 sablefish larvae in surface samples from the Bering Sea during the summers of 1970-78. They were more abundant at night than during daytime and occurred widely over the continental shelf as well as the basin of the eastern Bering Sea. Walline[10] reported on the occurrence of more than 300 sablefish larvae (11.0-25.5 mm SL) from neuston collections mainly along the edge of the continental shelf in the eastern Bering Sea from 1 June through 23 July 1979 (Fig. 9).

Determination of Year-class Size

Although measurements of year-class strength of sablefish are not very precise at present, it appears that at least a fourfold variation in year-class size occurs (McFarlane and Beamish[11]). As with other fish, most of this variation is probably due to interannual differences in survival of the eggs and larvae. Causes of such variation are generally attributed to presence of appropriate food for the larvae, predation on the eggs and larvae by a variety of planktonic and nektonic organisms, or rate and direction of drift from the spawning area to nursery areas. As is the case for most fish, the exact cause of variation in year-class strength of sablefish is unknown, but their biology suggests several promising avenues of research.

No direct measurements of mortality of eggs or larvae of sablefish in the sea have been made. However, some idea of the mortality rate during the first few months of life can be deduced from several life history parameters. The fecundity of sablefish is expressed by the relationship $F = 1.11987 \ FL^{2.8244}$ (Mason et al., 1983b). Females of mean length, about 60 cm (an age of about 5 years), thus produce about 120,000 eggs. With a mortality rate of 0.1 (McFarlane and Beamish 1983a) acting on post-settling fish for 4.5 years, a pair of spawners would represent 3.1 fish at settlement (July). The daily mortality rate required to reduce 120,000 eggs to 3.1 settlement juveniles in 6 months (February-July) would be 0.058.

Not enough is presently known of the distribution of eggs and yolk sac larvae of sablefish to estimate their mortality rate from field samples. Also, the neuston nets generally used to sample the larvae are avoided by larger larvae, especially during daytime, making it difficult to use these samples for mortality estimates.

Mortality of planktonic fish eggs and larvae is generally thought to be due to poor feeding, predation, and adverse drift, acting singly or in concert. The high food consumption rates and associated rapid growth may make food shortage a potentially significant source of mortality in sablefish larvae. Grover and Olla (1986) found emaciated small larvae in a field sample and concluded that a paucity of copepod nauplii was responsible for the condition which would have probably resulted in the death of the larvae. McFarlane and Beamish[11] speculated that strong year classes of sablefish off British Columbia are produced in years with above normal sea surface temperatures and increased onshore Ekman transport during the egg and larval period. Such conditions may favor high production of nauplii of *Neocalanus plumchrus* and *Neocalanus cristatus*, two of the most abundant copepods in the subarctic Pacific Ocean, which are probable food sources of young larval sablefish. Grover and Olla (In press) found that off Washington and Oregon in an El Niño year (1983) sablefish larvae had fed on more small southern copepods (*Paracalanus parvus*) than in a year without El Niño conditions. Water temperatures were higher and zooplankton volumes lower in the El Niño year. Thus, the factors contributing to sablefish larval food production may not be the same off British Columbia and Washington-Oregon.

No direct evidence on rates of predation on eggs or larvae of sablefish exists, although McFarlane and Beamish (1983b) reported the occurrence of juveniles in the guts of several species of fish and they are frequently found in salmon stomachs off southeastern Alaska in summer (Wing, 1985). Shenker and Olla (1986) observed a 14 mm SL sablefish in an aquarium being eaten by a 35 mm SL sablefish, and apparent avoidance behavior of a 27 mm SL specimen in the presence of a 35 mm SL fish. This would indicate that larval sablefish recognize the potential of predation by slightly larger fish. However, since sablefish larvae seem to occur singly and are relatively rare at sea, it is not probable that predators regularly key on them. The protective coloration (counter shaded: Dark on the dorsal surface, silvery on the ventral surface) is characteristic of other neustonic animals (e.g., hexagrammid larvae, Kendall and Vinter, 1984) and probably enhances the ability of larval sablefish to avoid predators.

Sablefish seem to spawn near the edge of the continental shelf in waters deeper than 300 m (McFarlane and Beamish, 1983a). Larvae occur up to at least 370 km from shore in the relatively fast moving surface waters. Young-of-the-year juveniles are found inshore in July (McFarlane and Beamish, 1983b). Thus, there is a possibility for onshore-offshore as well as alongshore transport of larvae, and an active inshore migration is indicated. The velocities of these physical transport mechanisms surely vary from year to year, and will influence the distribution and possible survival of young sablefish as they move to inshore nursery areas.

Early Life History Work in Relation to Management

In trying to manage the sablefish fish-

[10]Walline, P. D. 1981. Distribution of ichthyoplankton in the eastern Bering Sea during June and July 1979. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115. NWAFC Processed Rep. 81-3, 13 p.

[11]McFarlane, G. A., and R. J. Beamish. 1985. Production of strong year-classes of sablefish (*Anoplopoma fimbria*) off the west coast of Canada. Pac. Biol. Stn., Nanaimo, B.C. Draft manuscr. presented at 1985 Int. North Pac. Fish. Comm. symp.

ery using information from the adults alone, several difficulties arise (Sasaki, 1985), which early life history studies may help resolve. Assessment of population size is generally based on catch per unit of effort in standardized fishing gear (longlines, traps, or trawls), which can only give a measure of relative abundance and trends in abundance. Broad-scale surveys of pelagic eggs, when combined with data on population fecundity, avoid many of the problems associated with surveying adult abundance directly and can be used to estimate spawning biomass. Since sablefish spawn during a restricted time each year, this method of population assessment may be viable.

Year-class strength of sablefish is difficult to determine by sampling the fishery because of problems in determining the ages of older adults (Beamish et al., 1983). Year-class strength in fishes is thought to be determined mainly during the pelagic egg and larval stages. Thus with sablefish, epipelagic juvenile abundance may indicate year-class strength. These fish might be sampled efficiently when they are a few months old to give an indication of recruitment strength to the fishery several years later. Further work on the factors influencing survival of larval sablefish could enhance our understanding of the recruitment process and allow forecasts of year-class strength, which would permit a sounder long-term basis for management of the resource.

Acknowledgments

We thank Beverly Vinter, NWAFC, who identified, measured, and illustrated the eggs and larvae examined in this study, and D. F. Alderdice, Pacific Biological Station, who kindly loaned us sablefish eggs from his rearing experiments as well as his unpublished manuscript outlining the incubation procedures of sablefish eggs. We thank several who were then at Oregon State University who allowed us to use material in manuscripts in various stages of preparation: Jill Grover, George Boehlert, Jon Shenker, and Bori Olla. Gordon McFarlane, Pacific Biological Station, clarified several points concerning sablefish studies conducted in Nanaimo, B.C., and reviewed the manuscript. George Kudo, NWAFC, translated portions of a Japanese publication that dealt with sablefish. Jim Balsiger, NWAFC, reviewed the manuscript focusing on sections dealing with the fishery and its management. Bruce Wing, NWAFC Auke Bay Laboratory, reviewed the manuscript and provided unpublished information on eggs and larvae of sablefish from off southeastern Alaska. Gary Stauffer, NWAFC, supported our efforts throughout this study.

Literature Cited

Ahlstrom, E. H., and E. Stevens. 1976. Report of neuston (surface) collections made on an extended CalCOFI cruise during May 1972. Calif. Coop. Oceanic Fish. Invest. Rep. 18:167-180.

Beamish, R. J., G. A. McFarlane, and D. E. Chilton. 1983. Use of oxytetracycline and other methods to validate a method of age determination for sablefish. *In* Proceedings of the international sablefish symposium, p. 95-116. Lowell Wakefield Fish. Symp. Ser., Univ. Alaska, Fairbanks, Alaska Sea Grant Rep. 83-8.

Bell, F. H., and J. T. Gharrett. 1945. The Pacific coast black-cod, *Anoplopoma fimbria*. Copeia 1945:94-103.

Boehlert, G. W., and M. M. Yoklavich. 1985. Larval and juvenile growth of sablefish, *Anoplopoma fimbria*, as determined from otolith increments. Fish. Bull., U.S. 83:475-481.

Brock, V. E. 1940. Note on the young sablefish, *Anoplopoma fimbria* (Pallas) 1811. Copeia 1940: 268-270.

Gilbert, C. H. 1915. Fishes collected by the United States steamer "Albatross" in southern California in 1904. Proc. U.S. Natl. Mus. 48:305-380.

Grover, J. J., and B. L. Olla. 1986. Morphological evidence for starvation and prey size selection of sea caught larval sablefish, *Anoplopoma fimbria*. Fish. Bull., U.S. 84:484-489.

________, and ________. In press. Effects of an El Niño event on the food habits of larval sablefish, *Anoplopoma fimbria*, off Oregon and Washington. Fish. Bull., U.S. 85(1).

Haryu, T., T. Nishiyama, T. Tsujita, H. Ogi, and S. Mishima. 1985. Kinds and distribution of fish larvae in the surface layer of the Bering Sea in summer. Mem. Kushiro City Mus. 10:7-18. [In Jpn., Engl. abstr.]

Heyamoto, H. 1962. Age of young sablefish, *Anoplopoma fimbria* (Pallas) 1811. J. Fish. Res. Board Can. 19:1175-1177.

Hokkaido University. 1957a. 1955 cruise of the *Oshoro maru* to the Bering Sea and northern North Pacific (Norpac Project). Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 1:67-132.

________. 1957b. 1956 cruise of the *Oshoro maru* to the Bering Sea. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 1:133-243.

________. 1958. 1957 cruise of the *Oshoro maru* to Aleutian waters. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 2:1-124.

________. 1959a. The *Oshoro maru* cruise 42 to the Bering Sea in May-July 1958 (IGY Programme). Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 3:83-153.

________. 1959b. The *Hokusei maru* cruise 4 to the North Pacific and the Okhotsk Sea in May-August 1958. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 3:155-296.

________. 1960a. The *Oshoro maru* cruise 44 to the Bering Sea in June-July 1959. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 4:1-112.

________. 1960b. The *Hokusei maru* cruise 6 (1-3) to the North Pacific and Okhotsk Sea in June-August 1959. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 4:113-221.

________. 1961. The *Oshoro maru* cruise 46 to the Bering Sea and North Pacific in June-August 1960. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 5:51-243.

________. 1964. The *Oshoro maru* cruise 4 to the Bering Sea and northwestern North Pacific in May-July 1963. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 8: 200-295.

________. 1968. The *Oshoro maru* cruise 24 to northern North Pacific and Bering Sea in June-August 1967. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 12: 292-418.

________. 1969. The *Oshoro maru* cruise 28 to the northern North Pacific, Bering Sea and the Gulf of Alaska. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 13:2-134.

________. 1970. The *Oshoro maru* cruise 32 to the northern North Pacific, Bering Sea and Bristol Bay in June-August 1969. Hokkaido Univ., Hakodate, Data Rec. Oceanogr. Obs. Explor. Fish. 14:2-120.

Hughes, S. E. 1981. Initial U.S. exploration of nine Gulf of Alaska seamounts and their associated fish and shellfish resources. Mar. Fish. Rev. 43(1):26-33.

Kendall, A. W., Jr., and J. R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv. Tech. Rep. NMFS 20, 89 p.

________, and B. M. Vinter. 1984. Development of hexagrammids (Pisces: Scorpaeniformes) in the northeastern Pacific Ocean. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv. Tech. Rep. NMFS 2, 44 p.

Kobayashi, K. 1957. Larvae and young of the sablefish, *Anoplopoma fimbria* (Pallas), from the sea near the Aleutian Islands. Bull. Jpn. Soc. Sci. Fish. 23:376-382.

Kodolov, L. S. 1968. Reproduction of the sablefish (*Anoplopoma fimbria* Pall.). Probl. Ichthyol. (Engl. transl. Vopr. Ikhtiol.) 8:531-535.

________. 1976. Osobennosti biologii i raspredeleniya ugol'noi ryby (*Anoplopoma fimbria* Pall.). (Details of biology and distribution of blackcod (*Anoplopoma fimbria* Pall.)). Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 100:19-42. [In Russ.]

Mason, J. C., R. J. Beamish, and G. A. McFarlane. 1983a. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) in waters off the Pacific coast of Canada. *In* Proceedings of the international sablefish symposium, p. 137-140. Lowell Wakefield Fish. Symp. Ser., Univ. Alaska, Fairbanks, Alaska Sea Grant Rep. 83-8.

________, ________, and ________. 1983b. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) off the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 40:2126-2134.

Matarese, A. C., S. L. Richardson, and J. R. Dunn. 1981. Larval development of Pacific tomcod, *Microgadus proximus*, in the northeast Pacific Ocean with comparative notes on larvae of walleye pollock, *Theragra chalcogramma*, and Pacific cod, *Gadus macrocephalus* (Gadidae). Fish. Bull., U.S. 78:169-171.

McFarlane, G. A., and R. J. Beamish. 1983a. Biology of adult sablefish (*Anoplopoma fimbria*) in waters off western Canada. *In* Proceedings of the international sablefish symposium, p. 59-80. Lowell Wakefield Fish. Symp. Ser., Univ. Alaska, Fairbanks, Alaska Sea Grant Rep. 83-8.

______, and ______. 1983b. Preliminary observations on the juvenile biology of sablefish (*Anoplopoma fimbria*) in waters off the west coast of Canada. *In* Proceedings of the international sablefish symposium, p. 119-135. Lowell Wakefield Fish. Symp. Ser., Univ. Alaska, Fairbanks, Alaska Sea Grant Rep. 83-8.

Miller, C. B., H. P. Batchelder, R. D. Brodeur, and W. G. Pearcy. 1985. Response of the zooplankton and ichthyoplankton off Oregon to the El Niño event of 1983. *In* W. S. Wooster and D. L. Fluharty (editors), El Niño north, Niño effects in the eastern subarctic Pacific Ocean, p. 185-187. Univ. Wash., Seattle, Wash. Sea Grant Publ. WSG-WO 85-3.

Mitchell, C. T., and J. R. Hunter. 1970. Fishes associated with drifting kelp, *Macrocystis pyrifera*, off the coast of southern California and northern Baja California. Calif. Fish Game 56: 288-297.

Phillips, J. B. 1958. The fishery for sablefish, *Anoplopoma fimbria*. Calif. Fish Game 44:79-84.

Richardson, S. L., J. L. Laroche, and M. D. Richardson. 1980. Larval fish assemblages and associations in the north-east Pacific Ocean along the Oregon coast, winter-spring 1972-1975. Estuarine Coastal Mar. Sci. 11:671-689.

Sasaki, T. 1985. Studies on the sablefish resources of the North Pacific Ocean. Bull. Far Seas Fish. Res. Lab. (Shimizu) 22, 107 p.

Shaw, W., G. A. McFarlane, D. Davenport, and W. T. Andrews. 1985. Distribution and abundance of larval sablefish (*Anoplopoma fimbria*) in the surface waters off the west coast of Vancouver Island, April 16 to May 10, 1984. Can. MS Rep. Fish. Aquat. Sci. 1835, 41 p.

Shenker, J. M. 1984. Biology of neustonic larval and juvenile fishes and crabs off Oregon, 1984. Ph.D. Thesis, Oregon State Univ., Corvallis, 156 p.

______, and B. L. Olla. 1986. Laboratory feeding and growth of juvenile sablefish, *Anoplopoma fimbria*. Can. J. Fish. Aquat. Sci. 43:930-937.

Shubnikov, D. A. 1963. Nekotorye dannye po biologii ugol'noi ryby Beringova morya (Data on the biology of sablefish of the Bering Sea). Tr. Vses. Nauchno-Issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 48 (Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 50):271-295. [In Russ., transl. by Isr. Program Sci. Transl., 1968, p. 287-296 *in* P. A. Moiseev (editor), Soviet fisheries investigations in the northeast Pacific, Part 1.] Avail. from U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, VA, as TT 67-51203.

Thompson, W. F., Jr. 1941. A note on the spawning of the blackcod (*Anoplopoma fimbria*). Copeia 1941:270.

Wing, B. L. 1985. Salmon stomach contents from the Alaska troll logbook program 1977-84. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-91, 43 p.