AGE-LENGTH-WEIGHT AND DISTRIBUTION OF ALASKA PLAICE, ROCK SOLE, AND YELLOWFIN SOLE COLLECTED FROM THE SOUTHEASTERN BERING SEA IN 1961

Japanese fishing companies explored the trawl fish resources of the eastern Bering Sea in 1929 and 1931. They began commercial fish meal production in 1933 and continued until 1937; a frozen fish operation was initiated in 1940 but was interrupted by World War II (Bourgois 1951).[1] In 1954, Japan resumed trawling in the eastern Bering Sea, again producing fish meal and frozen fish. The Soviet Union began sending bottom trawl fleets to the eastern Bering Sea in 1959, and combined annual catches of flatfishes (excluding Pacific halibut, *Hippoglossus stenolepsis*) by Japan-USSR rose to a peak in 1961 when it exceeded 600,000 metric tons (Fadeev 1965). In the years following 1961, eastern Bering Sea flatfish catches by Japan decreased and in the period 1963-1970 have averaged less than 20% of the 456,890 metric tons caught in 1961 (International North Pacific Fisheries Commission 1973). Comparable Soviet data are not available.

Prior to intensive exploitation of eastern Bering Sea resources, there were two groups of surveys in which samples of flatfish were taken to assess the age-length structure of the population. One such series was conducted by the U.S. Fish and Wildlife Service in 1947-49 (King 1949; Ellson et al. 1950; Wigutoff and Carlson 1950). The other surveys were made 10 yr later by the Soviet Union (summarized by Moiseev 1965). Age-length determinations from flatfish samples collected in 1949 were reported by Mosher (1954); the Soviet collections of 1957-60 were studied by Fadeev (1963), Mineva (1964), and Shubnikov and Lisovenko (1964).

In July-August 1961, personnel of the Bureau of Commercial Fisheries (now National Marine Fisheries Service) conducted a trawl survey of the southeastern Bering Sea. This survey, although conducted principally to estimate the abundance of Alaska king crab, *Paralithodes* spp., provided an opportunity to sample several flatfish species. The purpose of the present report is to present biological information on the distribution, age, length, and weight by sex for three commercially important species of Bering Sea flatfish: yellowfin sole, *Limanda aspera* (Pallas); rock sole, *Lepidopsetta bilineata* (Ayres); and Alaska plaice, *Pleuronectes quadrituberculatus* Pallas.

[1]Bourgois reported that Alaska pollock was the principal species taken by these Japanese fisheries. However, Alverson et al. (1964) pointed out that the areas of the eastern Bering Sea fished by Japanese trawlers from 1933 to 1941 were the same locations as post-World War II flounder fisheries, so there is reason to doubt the complete accuracy of Bourgois' information as to species.

Methods and Materials

Sample Collection

Otter trawl hauls of 1-h duration were made at 51 predesignated stations 20 nautical miles (37 km) apart (Figure 1). The trawling speed of the vessel was about 2.5 knots (4.6 km/h). The trawl was a 400-mesh, Eastern type, as described by Greenwood (1958). A 1.5-inch (3.8 cm) mesh liner was laced into the cod end to retain small specimens which might otherwise pass through the 3-inch (7.6 cm) meshes in that part of the trawl. At the completion of each haul, the catch was examined, and the weight of each major component was estimated. At five of the stations where one or more of the target species was abundant, samples of yellowfin sole, rock sole, and Alaska plaice was selected for length-weight-age determination. Specimens were measured to the nearest centimeter to obtain a representation of individuals throughout the available length range. Each fish to be retained was then frozen individually in a plastic bag which was sealed to prevent shrinkage and weight loss through dehydration.

At the laboratory, 3 mo after collection, the specimens were thawed, the total length (snout to longest rays of the tail fin) was measured, the weight recorded to the nearest gram, and sex determined from an examination of the gonads.

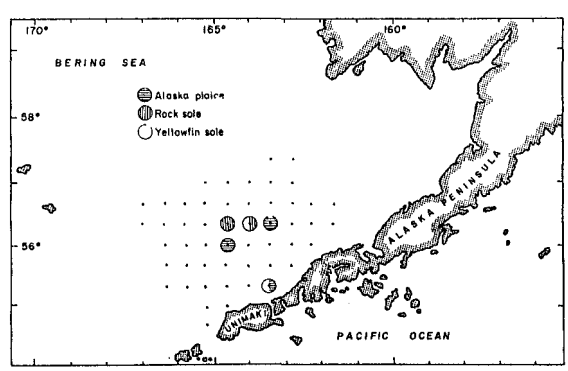

FIGURE 1.–Sampling station pattern and location of sample collections for 7 July-4 August 1961 survey.

Both otoliths were removed and placed in 95% ethyl alcohol.[2]

Age Determination Procedure

Studies by Hatanaka (1968) of yellowfin sole from the southeastern Bering Sea indicate that the translucent zone of an otolith is formed once a year during the winter months. In our readings on otoliths from all species, each translucent zone was considered an annular mark. The outermost edge of each otolith was also translucent except in the younger fish where there was evidence of some beginnings of opaque summer growth. Thus, the ages recorded are the number of translucent rings starting with the smallest observable and including the outermost. For example, a fish captured in July 1961 with 10 rings on its otolith was considered to have been spawned and hatched in 1951. Fadeev (1965), through gonad examination, stated that Bering Sea yellowfin sole spawn in June-August, Alaska plaice in April-June, and rock sole in February-May. Shubnikov and Lisovenko (1964), who reported that rock sole in Bristol Bay spawn in March-June, are in general agreement with Fadeev.

For reading, the otoliths were immersed in water in a petri dish with a black mat background and examined at 10× under reflected light with a dissecting microscope. Both otoliths were considered in age determination, but when a discrepancy occurred between the two otoliths, a decision was based on the eyed-side (right) otolith. In situations where the annular rings were not clear, the otoliths were ground on fine, water soaked, carborundum paper. In most samples grinding improved interpretation of annular rings, but the grinding of rock sole otoliths often exposed additional opaque and translucent zones to further confuse the readers.

Consistency of Age Determinations

Without reference to fish size, otoliths were interpreted by each author. A third, independent interpretation was made by an experienced otolith reader at the Northwest Fisheries Center. The observed ages, as agreed upon between the two authors, were compared with ages determined by the experienced reader. Initial agreement between authors and reader was 76% for yellowfin sole, 72% for Alaska plaice, and 85% for rock sole. Disagreements were not confined to a particular age class; only 3% differed by more than 1 yr, and these differences were equally negative and positive. The similarity of results by authors and reader suggests that the method used produced consistent age-growth data. Otolith interpretations not in agreement between the authors and the reader were reread and a joint decision was made on the most probable age of the fish.

Results and Discussion

Distribution

Yellowfin sole is the most abundant flatfish taken in the eastern Bering Sea. Alaska plaice (33% by weight of yellowfin sole caught) was usually encountered together with yellowfin sole and share a similar distribution within the sampling area (Figure 2). Fadeev (1970) and Maeda et al. (1967) note that yellowfin sole concentrate in the colder waters of Bristol Bay during the spring and summer months. In July of 1961, a tongue of cold water extended into the sampling area and the greatest concentrations of yellowfin sole and Alaska plaice were taken at bottom temperatures of 3°C or less.

The distribution of rock sole within the sampling area (28% by weight of yellowfin sole catch) was spotty with the denser concentrations occurring toward the eastern edge of the area inhabited by yellowfin sole and Alaska plaice. The 1961 observations are compatible with the contention of Shubnikov and Lisovenko (1964) that rock sole disperse during the summer into shallower water than they occupy in winter and spring.

Age-Length Observations

The age-length-weight composition for the three southeastern Bering Sea flatfish species sampled in 1961 are given in Tables 1-3.[3] It is difficult to compare the 1961 data with any earlier reports except in a generalized manner since in only one instance (Pruter and Alverson 1962) is there a determination of age by sex. The data presented in Tables 1-3, and also in studies of eas-

[2]All otoliths from the 1961 collection are in permanent storage at the Northwest Fisheries Center, Seattle, Wash.

[3]Individual age determinations and related lengths and weights, by sex, are available upon request from the Northwest Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, Wash.

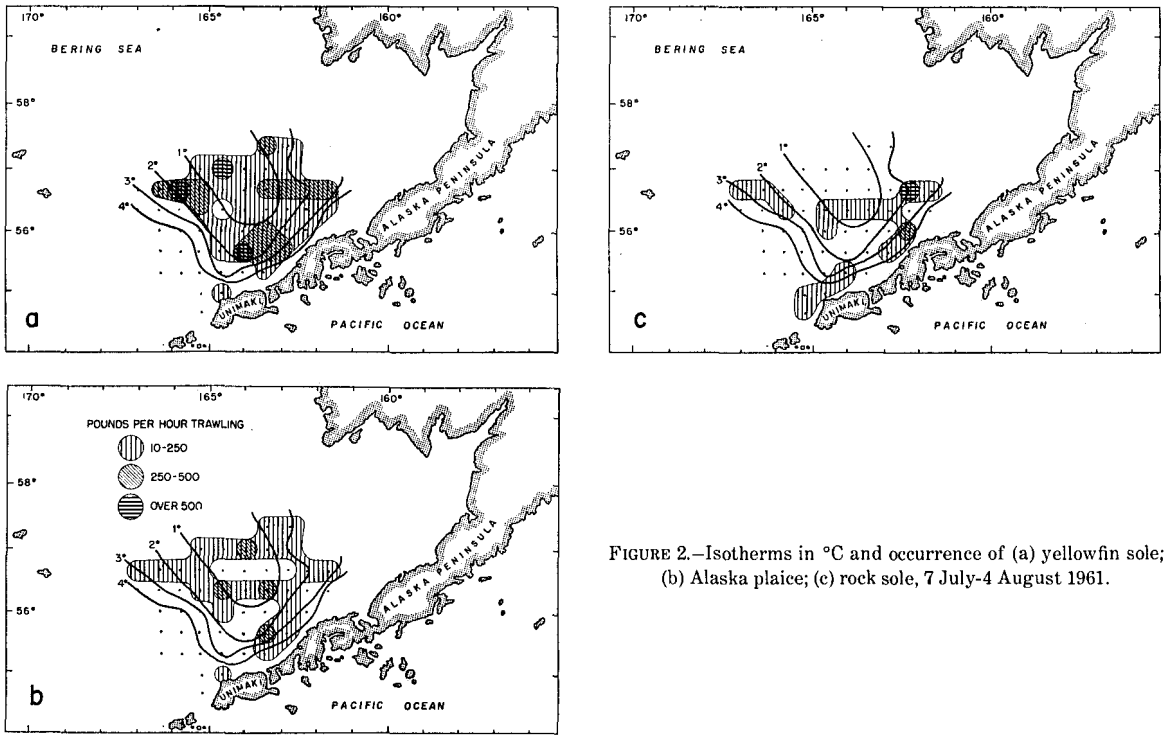

FIGURE 2.–Isotherms in °C and occurrence of (a) yellowfin sole; (b) Alaska plaice; (c) rock sole, 7 July-4 August 1961.

TABLE 1.–Observed age and length distribution of male (M) and female (F) yellowfin sole taken in the southeastern Bering Sea in 1961.

Length (cm)	4		5		6		7		8		9		10		11		12		13		Total		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Total
17.5	1	1																			1	1	2
18.5				1			1														1	1	2
19.5			2	1	1		1			1	1										5	2	7
20.5					2		1	1	3	2	1										7	3	10
21.5				2	1		2	4	6	4	4										13	10	23
22.5			1	2	2	1	4	2	7	4	3										17	9	26
23.5							4	1	3	2											7	3	10
24.5					1		1		5	3			1	1							8	4	12
25.5						1	1		6	2	2	2				1					9	6	15
26.5									1	4	2		1								4	4	8
27.5								1	1	2	2	1	2	2			1				6	6	12
28.5								1	1		2	2	1	1	1						5	4	9
29.5										1		1		1		1		1				5	5
30.5												1					1				1	1	2
31.5																		2	1		1	2	3
32.5														2								2	2
33.5																1		1				2	2
34.5																				1		1	1
Total	1	1	3	6	7	2	15	10	33	25	17	7	5	7	1	3	2	4	1	1	85	66	151
Average length[1] (M)	18.0		20.6		21.8		22.5		23.6		24.3		27.2		28.5		28.9		32.0				
(F)	17.3		21.2		23.9		23.3		24.2		28.0		29.1		30.0		31.6		34.8				
Average weight (g) (M)	57		94		130		128		145		150		226		280		269		409				
(F)	54		108		145		147		163		262		310		350		364		538				

[1]Calculated from ungrouped data.

tern Bering Sea yellowfin and rock sole by Hatanaka (1968), Maeda (1969), and Levings (1967), indicate that growth is different for each sex.

The ages of 12 yellowfin sole (10 female, 2 male) taken 50 miles south of Nunivak Island in the eastern Bering Sea in August 1959 (Pruter and Alverson 1962) fall within the range of our observations with some suggestion that the younger fish in their samples are slightly smaller. Maeda (1969) and Hatanaka (1968) derived age-length curves

TABLE 2.–Observed age and length distribution of male (M) and female (F) Alaska plaice taken in the southeastern Bering Sea in 1961.

Length (cm)	4		6		7		8		9		10		11		12		14		16		Total		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Total
21.5		1																				1	1
22.5	1																				1		1
23.5																							
24.5																							
25.5	1																				1		1
26.5																							
27.5			1																		1		1
28.5			1																		1		1
29.5			1																		1		1
30.5			4	1					1												5	1	6
31.5									1				1	1							2	1	3
32.5			1	1	4	1			2		1	1	1								9	3	12
33.5			2	1		2	2			1			1								5	4	9
34.5			1		1	1	2	1	1		1		1	1							7	3	10
35.5						1	1	1	1			1	3			1					5	4	9
36.5								1	2		1	2									3	3	6
37.5				1				1					1	1		1					1	4	5
38.5										1		1	1		1						2	2	4
39.5										1		1						1		1		4	4
40.5												1		1								2	2
41.5										1						1						2	2
42.5										1				1								2	2
43.5										1												1	1
44.5																1						1	1
Total	2	1	11	4	5	5	5	4	8	6	3	7	9	5	1	4		1		1	44	38	[1]82
Average length[2] (M)	23.7		31.0		33.1		34.4		34.0		34.5		35.0		39.0								
Average length[2] (F)	21.5		33.7		33.9		36.4		40.0		37.2		37.3		40.1		40.0		39.5				
Average weight (g) (M)	168		384		438		484		503		531		538		690								
Average weight (g) (F)	108		545		530		651		925		687		738		860		715		862				

[1]One additional male, age 18 yr, length 47.6 cm, 1,380 g.
[2]Calculated from ungrouped data.

TABLE 3.–Observed age and length distribution of male (M) and female (F) rock sole taken in the southeastern Bering Sea in 1961.

Length (cm)	4		6		7		8		9		10		11		Total		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Total
18.5		1													1		1
19.5																	
20.5																	
21.5																	
22.5																	
23.5							1								1		1
24.5							1				1				2		2
25.5			2				2		2	1		1			6	2	8
26.5					3			2	6		5				14	2	16
27.5					1		1	2			2	1			4	3	7
28.5							1	2	2	2	1	4		1	4	9	13
29.5							1			2		3			1	5	6
30.5										2		3		1		6	6
31.5										1						1	1
32.5										1				2		3	3
33.5												1		1		2	2
34.5												1				1	1
Total		1		2		4		7	6	10	9	9	14		5	33	34	67
Average length[1] (M)		18.1		25.7		27.1		26.6		26.8		26.8						
Average length[1] (F)								27.6		29.8		29.9		31.6				
Average weight (g) (M)		55		198		217		216		212		219						
Average weight (g) (F)								223		330		320		404				

[1]Calculated from ungrouped data.

from large samples of eastern Bering Sea yellowfin sole collected in 1963 and 1965-66, respectively. There is no appreciable difference between the two above age-length curves and our 1961 data (Figure 3).

With rock sole, the only comparative age-length data by sex is presented by Levings (1967) for samples collected in the northeastern Bering Sea in 1963. Levings' age-length observations on male rock sole are similar to our collections, but a considerable difference exists in female lengths-at-age. The females taken in 1963 are older and at a

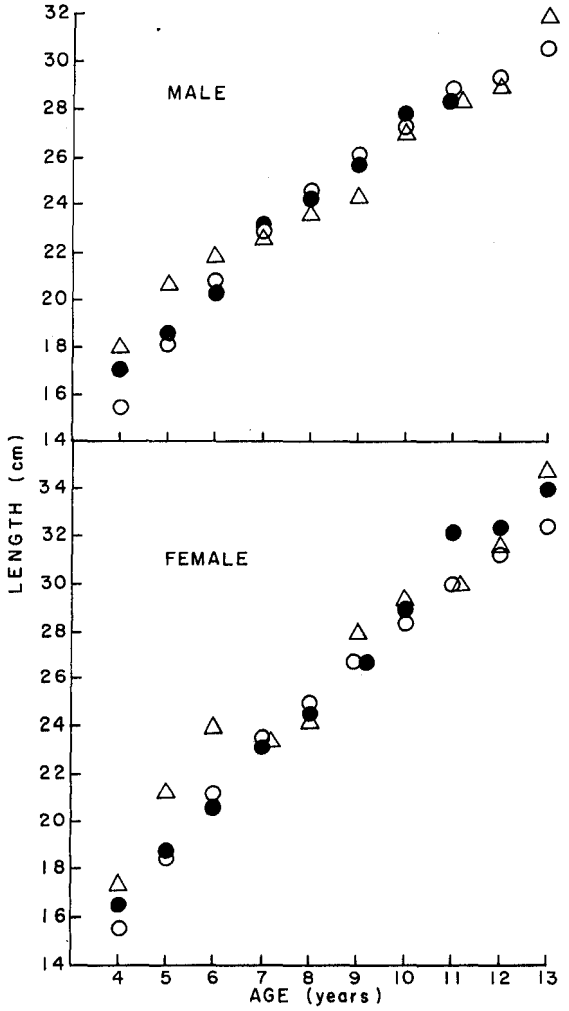

FIGURE 3.–Age-length comparison for yellowfin sole taken in the eastern Bering Sea in 1961 (open triangles); 1963 (closed circles, Maeda 1969); and 1965-66 (open circles, Hatanaka 1968).

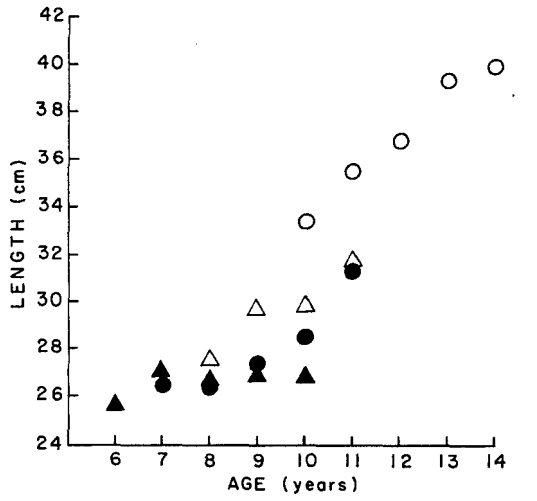

FIGURE 4.–Age-length comparison for rock sole taken in the eastern Bering Sea in 1961 (open triangles, female; closed triangles, male), and in 1963 (open circles, female; closed circles, male; from Levings 1967).

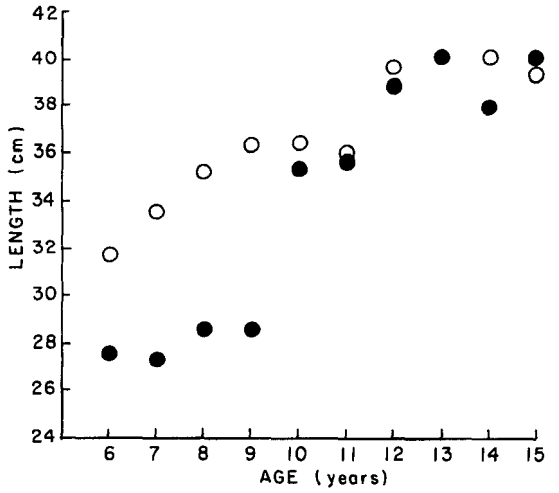

FIGURE 5.–Age-length composition (average length of combined sexes) for Alaska plaice taken in the eastern Bering Sea in 1949 (closed circles, from Mosher 1954) and 1961 (open circles).

comparable age average 10% greater in length (Figure 4).

No age-length information has been reported for Alaska plaice except that by Mosher (1954). The otolith observations by Mosher in 1949, though not separated by sex, indicate a markedly slower growth rate for younger fishes than that observed in our 1961 samples (Figure 5). Mosher (1954) comments that in his sample of Alaska plaice the first three to seven annular rings on each otolith were compressed and that beyond this zone, the annuli were farther apart. We noticed this same growth pattern in some of the otoliths from our collection, but it was not consistent.

In reflecting on the significance of similarities or differences between our results and those obtained by other authors, we feel that a number of points should be considered. First, we recognize that our samples were collected from the southern part of the distribution of these species in the eastern Bering Sea, and some of the specimens with which we make comparisons were taken in another part of the range and may represent another population. It was determined by Fadeev (1970) that the yellowfin sole of the southeastern

Bering Sea do constitute a single population, but no such determinations have been made for rock sole and Alaska plaice. Second, there is no evidence of validity for the ages we obtained from otoliths; that is to say that we do not know how well the otolith ages represent the true age of the fish. Additionally, we must assume that otoliths were interpreted and recorded in essentially the same manner by all investigators.

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