Use of Otoliths for Determining the Age of Several Fishes from the Bering Sea.

By

Kenneth H. Mosher,
U. S. Fish and Wildlife Service.

SINCE there are few areas in the world today where the fishery stocks are not being exploited to some extent, the opportunity to study virgin populations is rare. Such an opportunity arose in June and July 1949 when the vessel "Deep Sea" was chartered by the U. S. Fish and Wildlife Service to investigate the fishery potentialities of the Bering Sea where previously there had been no regular trawl fishery[1]). Since information on the age-groups present in these virgin populations was of primary importance, it was first necessary to develop methods of determining the ages of the several species of bottom fish. The procedures described herein may be applicable in studies elsewhere of similar species.

The catch was predominantly of six species:—

Pacific cod (*Gadus macrocephalus* Tilesius)
Alaska pollack (*Theragra chalcogramma* Pallas)
or whiting
Pacific halibut (*Hippoglossus stenolepis* Schmidt)
Lemon sole (*Pleuronectes quadrituberculatus* Pallas)
Rock sole (*Lepidopsetta bilineata* Ayres)
Starry flounder (*Platichthys stellatus* Pallas)

Otoliths were collected from all of these species as well as from a single specimen of yellowfin sole (*Limanda aspera* Pallas). For comparison a few scale samples were taken from the cod.

Techniques of Preparing the Otoliths for Age Study.

Otoliths taken in the field from fresh fish, or in the case of the lemon sole, from fish frozen aboard, were preserved dry in coin envelopes bearing identifying numbers. Upon gross examination in the laboratory

[1]) For details of this exploratory cruise, see Ellson, Powell, and Hildebrand, 1950.

the otoliths could be divided into two groups according to size and shape. Those of the Pacific cod and Alaska pollack were longer than wide, somewhat pointed at the ends, serrated along each edge, and crescent-shaped. The largest otoliths from this group measured 25 mm. by 11 mm. by 4 mm. and were taken from a cod 83 cm. in length. The other group consisted of flatfishes whose otoliths were somewhat disk-shaped with various irregularities. The largest earstones, 16 mm. by 2 mm. in size, were found in a halibut 124 cm. in length (se Figure 1).

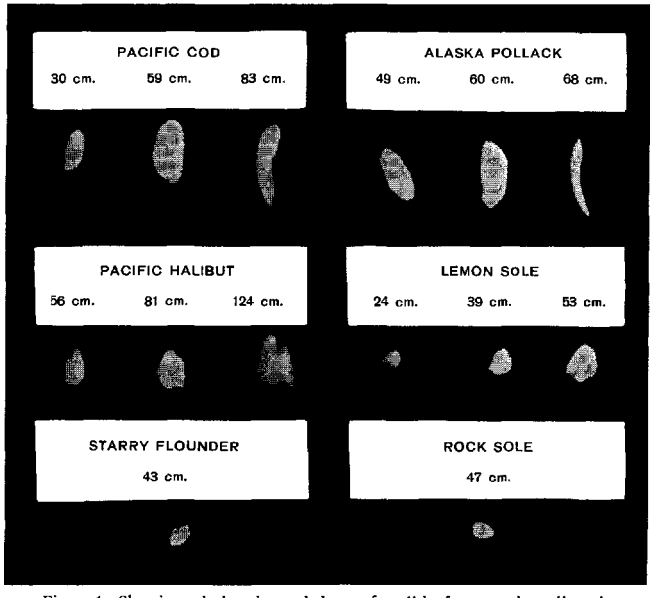

Figure 1. Showing relative size and shape of otoliths from species collected. Largest cod and pollack otolith shown in side view.

Previous workers have obtained variable results in the use of otoliths for age determination in the bottom fishes. Numerous references found in the literature indicate the value of otoliths in the study of the Norwegian cod. Thompson (1914) determined the age of Pacific halibut from otoliths, and workers of the International Fisheries Commission have used otoliths in their halibut studies for many years. On the other hand, Harold G. Orcutt (1950) chose scales instead of otoliths in his research on the starry flounder in California waters and

F. C. Cleaver (1949) working with the starry flounder in Washington waters found the otoliths unsatisfactory for age determinations.

In the study of the Bering Sea collection a number of methods were tried in order to find the one which brought out most clearly the annular marks in each type of otolith. In every case interpretation of the otoliths was improved considerably by grinding the stones on a lapidary wheel using No. 600 abrasive. Because of the variation between species, the most successful procedures are considered separately.

Cod (*Gadus macrocephalus*) and pollack (*Theragra chalcogramma*). These otoliths remained opaque after soaking for weeks in Canada Balsam or glycerine, or even after boiling in these media. No mounting procedure, surface grinding or polishing gave any indication of internal markings whatever. A method in use by the Norwegian investigators in the study of their cod fishery and described orally by Mr. G. Rollefsen proved satisfactory with slight modification.

In this procedure the otolith was broken with the fingers transversely near the middle. To obtain the best definition of the marking, the broken surface was ground, washed, and dipped in glycerine. The piece of earstone was held upright on a microscope slide with wax or modelling clay, and the ground surface examined with a binocular microscope of suitable power. A beam of light from a microscope lamp was directed at right angles to the body of the otolith and when a finger or other object was held in exactly the right position to shade the ground face, the light travelled up through the internal layers to appear on the surface as a series of light and dark bands.

Lemon sole (*Pleuronectes quadrituberculatus*). Even after treatment in various media, no external evidence of annuli could be found on otoliths of this species except in the smallest specimens. However, after they had been ground nearly to the middle from opposite sides leaving a thin section of the earstone for study, the markings became evident. When the otoliths were examined over a black mat in reflected light, the annuli could be seen clearly.

Halibut (*Hippoglossus stenolepis*) and rock sole (*Lepidopsetta bilineata*). Although in some cases these earstones could be read if immersed in glycerine, the markings became much clearer when the concave surface was lightly ground.

Starry flounder (*Platichthys stellatus*) and yellowfin sole (*Limanda aspera*). The earstones of these species show only faint markings when dry or in glycerine, but by removing the opaque surface layer the annuli could be read without difficulty.

Age Determination Procedures.

Two readings of each pair of otoliths were made a day or more apart without reference to the fish length or the previous reading. If the two readings were not the same, a third reading was made at least a day later, and a decision reached as to the most probable age of the fish from which the earstones came. Excepting 33 of the cod specimens which

were selected to represent the smaller sizes, all the fish in the collections were 5 years old or older. Since a reader has less chance of obtaining the same count twice in succession from older fish, the age compositions of virgin stocks containing older fish should give a lower percentage of agreement than those stocks which are regularly fished.

Although the percentage agreement of the first two readings bears some relation to the accuracy of the age determinations, and indicates the clarity of the markings, it is not possible to estimate the degree of accuracy from the limited collections available. Comparisons of ages for such species as are available indicate that the fish from the Bering Sea are slower growing and attain a greater age than similar fish from localities farther south. This is as expected.

Consistency of Results.

For the cod the first two readings were the same in 64·2 per cent. of the cases. All but seven of the age counts differed by only one year.

For the pollack the two readings agreed in 26 per cent. of the cases. The greater difficulty in interpreting these otoliths was attributed to (1) the slower growth-rate of these fish producing annuli closely crowded near the margin of the otolith, and (2) the greater confusion between true and false annuli found in this species. More collections from the Bering Sea with greater numbers of smaller fish are needed to substantiate the usefulness of these techniques in the age determination of the pollack.

For the lemon sole, 64·2 per cent. of the two readings were the same, indicating a fair degree of consistency in interpretation of the earstones. An interesting feature of the otoliths of this species was the central zone, containing the first 3 to 7 annuli, and resembling the freshwater portion of a sockeye salmon otolith. Beyond this zone, the annuli are less distinct and much farther apart as in the ocean growth portion of the sockeye earstone.

This growth pattern suggests that the young of the lemon sole grow very slowly for a few years. Possibly the nursery grounds are in brackish or inside waters, or in localities where they are crowded by the same or other species. After a varying period of time, they grow more rapidly perhaps by migration to areas of more abundant food or better growth conditions, or by the onset or result of sexual development.

For the other species, too few specimens were available to provide accurate information on the percentage agreement between the first two readings, although they indicated that the markings can be read with substantial consistency.

Mortality and Growth-Rates.

Because of the small size of most of the samples, no attempt has been made to determine the natural mortality rates of the different stocks of

Table 1. Age and Size Analysis of Pacific Cod from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 1	2	3	4	5	6	7	8	9	10	11	12	Sample Total
14·1—16·0	1	—	—	—	—	—	—	—	—	—	—	—	1
16·1—18·0	2	—	—	—	—	—	—	—	—	—	—	—	2
18·1—20·0	4	—	—	—	—	—	—	—	—	—	—	—	4
20·1—22·0	—	1	—	—	—	—	—	—	—	—	—	—	1
22·1—24·0	—	—	—	—	—	—	—	—	—	—	—	—	—
24·1—26·0	—	—	—	—	—	—	—	—	—	—	—	—	—
26·1—28·0	—	3	—	1	—	—	—	—	—	—	—	—	4
28·1—30·0	—	—	2	—	—	—	—	—	—	—	—	—	2
30·1—32·0	—	1	3	—	—	—	—	—	—	—	—	—	4
32·1—34·0	—	—	1	—	—	—	—	—	—	—	—	—	1
34·1—36·0	—	—	—	—	—	—	—	—	—	—	—	—	—
36·1—38·0	—	—	2	3	—	—	—	—	—	—	—	—	5
38·1—40·0	—	—	1	1	—	—	—	—	—	—	—	—	2
40·1—42·0	—	—	—	1	—	—	—	—	—	—	—	—	1
42·1—44·0	—	—	—	—	1	—	—	—	—	—	—	—	1
44·1—46·0	—	—	—	4	—	—	—	—	—	—	—	—	4
46·1—48·0	—	—	—	1	—	—	—	—	—	—	—	—	1
48·1—50·0	—	—	—	—	—	—	—	—	—	—	—	—	—
50·1—52·0	—	—	—	—	1	—	—	—	—	—	—	—	1
52·1—54·0	—	—	—	—	2	—	—	—	—	—	—	—	2
54·1—56·0	—	—	—	—	6	1	—	—	—	—	—	—	7
56·1—58·0	—	—	—	1	1	1	—	—	—	—	—	—	3
58·1—60·0	—	—	—	—	2	—	1	—	—	—	—	—	3
60·1—62·0	—	—	—	—	1	1	3	—	—	—	—	—	5
62·1—64·0	—	—	—	—	—	3	—	—	—	—	—	—	3
64·1—66·0	—	—	—	—	1	2	3	2	—	—	—	—	8
66·1—68·0	—	—	—	—	—	3	—	—	—	—	—	—	3
68·1—70·0	—	—	—	—	2	5	3	1	—	—	—	—	11
70·1—72·0	—	—	—	—	—	3	2	—	1	—	—	—	6
72·1—74·0	—	—	—	—	1	1	3	3	2	1	—	—	11
74·1—76·0	—	—	—	—	—	2	3	3	—	—	1	—	9
76·1—78·0	—	—	—	—	—	1	—	3	—	2	—	—	6
78·1—80·0	—	—	—	—	—	—	2	1	—	—	—	—	3
80·1—82·0	—	—	—	—	—	—	—	—	3	—	—	—	3
82·1—84·0	—	—	—	—	—	—	—	—	—	—	—	1	1
84·1—86·0	—	—	—	—	—	—	—	—	—	—	1	—	1
86·1—88·0	—	—	—	—	—	—	—	—	—	2	—	—	2
88·1—90·0	—	—	—	—	—	—	—	—	—	1	—	—	1
90·1—92·0	—	—	—	—	—	—	—	—	—	1	—	—	1
Sample Total	7	5	9	12	18	23	20	13	6	7	2	1	123

fish. However, for future comparison, the main features of the results are summarized below:—

Species	Range of ages	Age of maximum numbers
Pacific cod	1—12*)	6
Alaska pollack	6—15	11
Pacific halibut	5—14	7
Starry flounder	5—13	—
Rock sole	9—15	11, 12

*) Samples selectively supplemented by fish under 5 years of age.

Table 2. Age and Size Analysis of Pollack from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 6	7	8	9	10	11	12	13	14	15	16	Sample Total
46·1—48·0	—	—	2	—	—	—	—	—	—	—	—	2
48·1—50·0	—	1	1	1	—	—	—	—	—	—	—	3
50·1—52·0	1	1	—	—	—	—	—	—	—	—	—	2
52·1—54·0	—	—	—	1	—	—	—	1	—	—	—	2
54·1—56·0	—	—	—	—	—	—	1	—	—	—	—	1
56·1—58·0	—	—	1	—	2	—	—	—	—	—	—	3
58·1—60·0	—	—	—	—	—	2	—	—	—	—	—	2
60·1—62·0	—	—	—	—	—	1	1	—	1	—	—	3
62·1—64·0	—	—	—	1	—	1	—	—	—	—	—	2
64·1—66·0	—	—	—	1	—	1	1	—	—	—	—	3
66·1—68·0	—	—	—	—	—	—	—	1	—	1	—	2
68·1—70·0	—	—	—	—	—	1	—	—	—	—	—	1
70·1—72·0	—	—	—	—	—	—	—	—	—	—	—	—
72·1—74·0	—	—	—	—	—	—	—	1	—	—	—	1
Sample Total	1	2	4	4	2	6	3	3	1	1	0	27

Similarly, there were too few fish present to establish valid growth-rates. For reference in future work the detailed results of the age determinations for these fish are given in Tables 1—6. In addition,

Table 3. Age and Size Analysis of Lemon Sole from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Sample Total
23·1—24·0	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
24·1—25·0	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	3
25·1—26·0	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
26·1—27·0	—	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	3
27·1—28·0	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	3
28·1—29·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29·1—30·0	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
30·1—31·0	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	2
31·1—32·0	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
32·1—33·0	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	2
33·1—34·0	—	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	3
34·1—35·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35·1—36·0	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	2
36·1—37·0	—	—	—	—	—	3	—	—	—	1	—	—	—	—	—	—	4
37·1—38·0	—	—	—	—	—	1	—	1	1	—	—	—	—	—	—	—	3
38·1—39·0	—	—	—	—	2	—	2	2	—	—	—	—	—	—	—	—	6
39·1—40·0	—	—	—	—	1	—	—	1	2	1	—	—	—	—	—	—	5
40·1—41·0	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
41·1—42·0	—	—	1	—	—	—	1	—	—	1	—	—	—	—	—	—	3
42·1—43·0	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	2
43·1—44·0	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
44·1—45·0	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
45·1—46·0	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
46·1—50·0*)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50·1—51·0	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	2
51·1—52·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
52·1—53·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
53·1—54·0	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	2
Sample Total	1	3	8	3	5	9	5	6	4	4	2	0	0	2	0	1	53

*) No records.

Table 4. Age and Size Analysis of Pacific Halibut from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 5	6	7	8	9	10	11	12	13	14	Sample Total
34·1— 36·0	1	—	—	—	—	—	—	—	—	—	1
36·1— 42·0*)	—	—	—	—	—	—	—	—	—	—	—
42·1— 44·0	1	2	—	—	—	—	—	—	—	—	3
44·1— 46·0	—	—	—	—	—	—	—	—	—	—	—
46·1— 48·0	1	—	—	—	—	—	—	—	—	—	1
48·1— 50·0	—	—	—	—	—	—	—	—	—	—	—
50·1— 52·0	—	—	1	—	—	—	—	—	—	—	1
52·1— 54·0	—	2	1	—	—	—	—	—	—	—	3
54·1— 56·0	—	—	1	—	—	—	—	—	—	—	1
56·1— 58·0	—	—	1	—	—	—	—	—	—	—	1
58·1— 60·0	—	—	—	2	—	1	—	—	—	—	3
60·1— 62·0	—	—	1	—	—	—	—	—	—	—	1
62·1— 64·0	—	—	—	—	—	—	—	—	—	—	—
64·1— 66·0	—	—	—	1	—	1	—	—	—	—	2
66·1— 74·0*)	—	—	—	—	—	—	—	—	—	—	—
74·1— 76·0	—	—	—	—	1	—	—	—	—	—	1
76·1— 78·0	—	—	—	—	—	—	1	1	—	—	2
78·1— 80·0	—	—	—	—	—	—	—	—	—	—	—
80·1— 82·0	—	—	—	—	1	1	1	—	—	—	3
82·1— 84·0	—	—	—	—	—	1	—	—	—	—	1
84·1— 86·0	—	—	—	—	—	—	1	—	—	—	1
86·1— 88·0	—	—	—	—	—	—	—	—	—	—	—
88·1— 90·0	—	—	—	—	—	—	—	1	—	—	1
90·1—124·0*)	—	—	—	—	—	—	—	—	—	—	—
124·1—126·0	—	—	—	—	—	—	—	—	—	1	1
Sample Total	3	4	5	3	2	4	3	2	0	1	27

*) No records.

Table 5. Age and Size Analysis of Starry Flounder from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 5	6	7	8	9	10	11	12	13	14	Sample Total
28·1—29·0	1	—	—	—	—	—	—	—	—	—	1
29·1—34·0*)	—	—	—	—	—	—	—	—	—	—	—
34·1—35·0	—	—	1	—	—	—	—	—	—	—	1
35·1—36·0	—	—	—	—	1	—	—	—	—	—	1
36·1—37·0	—	—	—	—	—	—	—	—	—	—	—
37·1—38·0	—	—	—	—	1	—	—	—	—	—	1
38·1—39·0	—	—	—	—	—	—	—	—	—	—	—
39·1—40·0	—	—	—	1	—	—	—	—	—	—	1
40·1—41·0	—	—	—	—	—	—	—	—	—	—	—
41·1—42·0	—	—	—	—	—	—	1	1	—	—	2
42·1—43·0	—	—	—	—	—	—	—	—	—	—	—
43·1—44·0	—	—	—	1	—	—	1	1	1	—	4
44·1—49·0*)	—	—	—	—	—	—	—	—	—	—	—
49·1—50·0	—	—	—	—	—	1	—	—	—	—	1
Sample Total	1	0	1	2	2	1	2	2	1	0	12

*) No records.

Table 6. Age and Size Analysis of Rock Sole from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 9	10	11	12	13	14	15	Sample Total
34·1—36·0	1	—	—	—	—	—	—	1
36·1—38·0	—	—	—	—	—	—	—	—
38·1—40·0	1	—	—	—	—	—	—	1
40·1—42·0	—	1	1	—	—	—	—	2
42·1—44·0	—	—	3	1	—	—	—	4
44·1—46·0	—	—	1	—	—	—	—	1
46·1—48·0	—	—	—	3	—	—	—	3
48·1—50·0	—	—	—	1	—	—	—	1
50·1—52·0	—	—	—	—	—	—	—	—
52·1—54·0	—	—	—	—	—	—	1	1
Sample Total	2	1	5	5	0	0	1	14

otoliths from one large specimen of yellowfin sole (*Limanda aspera*), a female 43·7 cm. in length, were examined; they indicated this fish to be 15 years old (in its 16th year).

Summary and Conclusions.

Age determinations from six species of fish collected in the Bering Sea in June and July 1949 were determined from the otoliths. The various procedures which were required to reveal the annuli for each species represented are described and the results presented in tabular form.

The results of this study indicate that all species examined can be aged satisfactorily if the otoliths are prepared properly. The limited collections made on this cruise point to the need for expanded study on all species to be found in this area.

Literature.

Cleaver, F. C. "The Washington otter trawl fishery with references to the petrale sole (*Eopsetta jordani*)". Washington State Dept. Fish., Biol. Rept. No. 49A, p. 8, Seattle, 1949.

Ellson, J. G., D. E. Powell, & H. H. Hildebrand. "Exploratory fishing expedition to the northern Bering Sea in June and July, 1949". U. S. Fish and Wildl. Serv., Fish. Leaflet No. 369, Washington, D. C., 1950.

International Fisheries Commission (U. S. and Canada). "Regulation and investigation of the Pacific halibut fishery in 1949". Rep. Int. Fish. Comm. No. 15, 24 pp., Seattle, 1951.

Orcutt, H. S. "The life history of the starry flounder (*Platichthys stellatus* Pallas)". Div. Fish Game Calif., Fish. Bull. No. 78, 64 pp., Sacramento, 1950.

Thompson, W. F. "A preliminary report on the life-history of the halibut". Rep. Brit. Columbia Comm. Fish., 1914, pp. 76—99, Victoria, B. C., 1915.