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SAMPLING THE COMMERCIAL CATCH AND USE OF CALCULATED LENGTHS IN STOCK COMPOSITION STUDIES OF PACIFIC HALIBUT

BY

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FOREWORD

The halibut fishery of the Northern Pacific Ocean and Bering Sea has been under scientific investigation and regulation by the International Pacific Halibut Commission since 1924. The most important source of basic information for the study and management of the resource has been the commercial fishery itself, which has provided fishing and catch statistics and data upon the composition of the fishable stock.

This report, the thirty-seventh published by the Commission, presents the history and development of the Commission's program of sampling the commercial catches of halibut and an evaluation of the use of calculated lengths in stock composition studies.

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ACKNOWLEDGMENTS

The Commission acknowledges the cooperation of many persons and companies without which the program reviewed in this paper could not have been accomplished.

Innumerable vessel owners and captains of the United States and Canadian fleets have assisted by keeping accurate records of their catches and by allowing Commission personnel to measure halibut during the unloading process. Also fishermen and plant employees have assisted in many ways to facilitate the work of the samplers.

Certain companies at whose docks sampling was conducted must be named for their special assistance. These are: Booth Fisheries Corporation, San Juan Fishing and Packing Company, Whiz-Eardley Fisheries Company and Washington Fish and Oyster Company, Seattle, Washington; British Columbia Packers (Edmunds & Walker) and Canadian Fishing Company, Vancouver, British Columbia; Atlin Fisheries, British Columbia Packers and the Prince Rupert Fishermen's Cooperative Association, Prince Rupert, British Columbia; Knut Thompson and Son, and Kayler-Dahl, Petersburg, Alaska.

At one time or another most past and present members of the scientific staff of the Commission have assisted in various aspects of this sampling program which was initiated in 1933 by F. Heward Bell, the present Director of Investigations, who was immediately responsible for this program for about 10 years after its inception. The authors are indebted to him for his critical suggestions during the various phases of the study and his review of the manuscript. Douglas G. Chapman, Department of Mathematics, University of Washington, advised on some of the statistical tests employed. Kenneth W. Exelby, presently in charge of market sampling, has also assisted in much of the sampling in recent years.

INTRODUCTION

The number, size and age of the halibut in the catches from different sections of the coast must be known to determine the age structure, recruitment, and rates of growth and of mortality of the stocks, information necessary for the scientific management of the United States and Canadian halibut fishery. Representative samples of fish lengths and associated subsamples of otoliths for age assessment have been collected from the commercial catches at the ports of landing as well as at sea, and from fish rejected during tagging operations. Sampling of the commercial landings, or market sampling, was begun in 1933 and has been a substantial portion of the Commission's field activities each year since.

Two major problems have become apparent in the market sampling program — securing samples of adequate size which collectively represent the total catch by the grounds of origin, and meeting the physical requirements involved in obtaining adequate numbers of measurements of a species as large as halibut. Studies have shown that emphasis of the sampling program should be directed toward obtaining a larger number of samples from a given area which can be combined for analysis rather than a few very large individual samples. The physical problem in securing a large number of samples is evident in the fact that an average of about six to eight fish, some weighing up to 200 pounds each, must be measured per 1000 pounds of landed weight, which requires the handling of three to 20 or more tons of halibut of each load sampled. Also, sampling must be conducted during unloading which is normally completed within a few hours and cannot be delayed. Thus it has been necessary to develop a method which would provide adequate samples and minimize sampling effort but at the same time reduce the sampling crew or allow additional sampling with the same size of staff.

The present method of sampling, in which both the length and age of fish are determined from the otoliths, utilizes the relationship between body-length and otolith-radius demonstrated by Southward (1962b). This method is the most recent development of a long and continuous effort to facilitate the collection of data and improve the quality of the results of the program. By use of such calculated lengths rather than direct length measurements the number of samples was increased 50 percent in 1964 with one-third less staff effort as only one person is required to secure a sample.

This report examines whether estimates of the stock parameters would differ depending on whether lengths of the fish were measured directly or were calculated from otolith measurements. Other studies to be reported on have tested the adequacy of the sampling in representing the fishable stock on the grounds within the limits of gear selectivity.

HISTORICAL DEVELOPMENT OF MARKET SAMPLING TECHNIQUES

At the outset in 1933, sampling was conducted by a field crew of two men since only lengths were being collected and the average size of the fish in the landings was generally small. The following year the collection of otoliths was added for assessment of age, and for a period of eight years commencing in 1935 the depth of body cavity was measured in an early effort to identify the sex. These developments required that a third and fourth man respectively be added to the sampling crew.

Sampling was carried out initially only in Seattle, Washington, where the trips originating from most fishing grounds were landed. During World War II, reduced staff and concentration on other urgent field activities resulted in a decline in the amount of data collected as well as a decrease in the overall representation of the different grounds in the samples.

Sampling for several years immediately following World War II was restricted to catches landed in Seattle. In 1949 it became possible to expand the coverage to other fishing grounds by sampling in Prince Rupert, British Columbia; and beginning in 1958, through modification of technique which permitted a reduction in the size of the sampling crew, in Petersburg, Alaska. The current disposition of personnel in Seattle, Vancouver, Prince Rupert, Petersburg and occasionally in other ports, provides a coverage of the landings more representative of the catches from each section of the coast than was formerly possible.

The numbers of fish measured annually are shown in Table 1, according to the major sections of the coast where the catches were made.

SAMPLING METHODS AND PROCEDURES

A description of the unloading procedures is necessary to understand some of the problems involved in sampling halibut landings. Halibut with entrails removed but heads left on are iced in the holds of the catching vessel. At the landing ports the catch is loaded into cargo-net slings or large tubs and dumped onto a "heading" table upon which two or more crew members behead the fish. The headed fish are drawn from the table by the company grader and placed into boxes or hand trucks according to the trade-weight categories as well as by quality grades. To sample the load it is

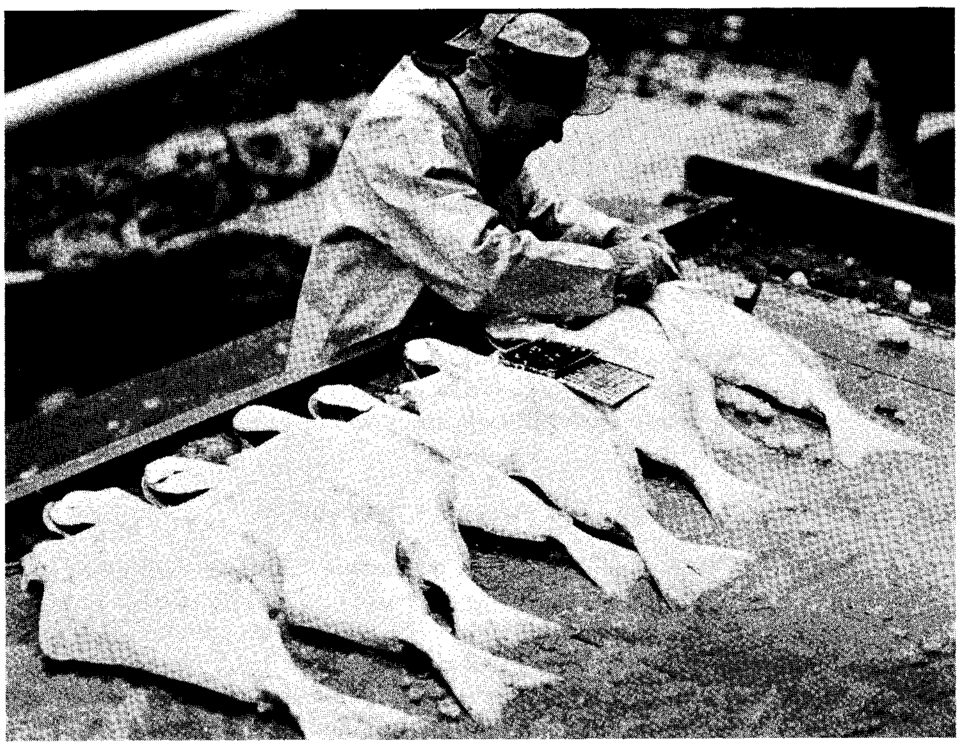

Figure 1. Removing otoliths from halibut during market sampling of landed catch. Note the sectioned box in which the bones are kept in sequence.

Table 1. Numbers of fish measured according to major sections of the coast for the period 1933 to 1964.

	SOUTH OF CAPE SPENCER						WEST OF CAPE SPENCER						
	Wash.-Van. Is.	C. Scott-Goose Is.	W. Coast Q. C. Is.*	Hecate Strait	Dixon Entr.	S. E. Alaska	C. Spencer-C. Cleare	Cook Inlet-Shelikof	Portlock-Albatross	Trinity-Chirikof	Shumagin-Davidson	Bering Sea	Total
1933	1574	12666	—	7421	—	—	939	1470	4240	—	—	—	28310
1934	1544	17857	—	10375	—	3145	10998	2905	6472	—	—	—	53296
1935	3749	24098	—	9473	—	2712	11007	942	14584	6426	—	—	72991
1936	707	23330	1587	6777	—	848	10917	6900	16464	10220	1083	—	78833
1937	—	38228	960	10397	—	—	2664	1985	21806	20872	—	—	96912
1938	1446	25765	567	10164	—	—	5214	—	12480	3556	1069	—	60261
1939	712	36982	275	2171	—	—	5003	—	12227	10335	561	—	68266
1940	1464	33951	—	7853	—	—	10798	5922	14524	6974	—	—	81486
1941	4374	31152	—	5660	—	1411	2244	5394	15531	7545	1246	—	74557
1942	2741	19877	—	851	—	412	3411	—	3262	1652	—	—	32206
1943	689	19952	—	—	—	—	459	924	1428	798	824	—	25074
1944	1232	16418	—	1274	—	—	—	—	1355	764	—	—	21046
1945	—	10913	—	1159	—	—	—	—	—	—	—	—	12072
1946	—	18842	—	—	—	—	—	—	—	—	—	—	18842
1947	—	12926	—	853	—	—	—	—	—	—	—	—	13779
1948	—	11705	—	—	—	—	—	—	—	—	—	—	11705
1949	—	13145	455	7393	566	930	731	4223	9423	5350	2537	—	44753
1950	—	10905	—	8228	1476	—	6126	—	14626	806	887	—	43054
1951	—	10730	617	9201	617	7811	5357	3268	8223	1289	—	—	46496
1952	615	7325	1630	12504	174	6861	6298	—	7951	1825	782	1373	47339
1953	—	9816	1043	8652	—	3647	5464	—	6311	378	3307	1503	40121
1954	—	16331	356	8782	2847	2331	8125	2369	19789	1788	2069	570	65357
1955	1225	13390	1124	10678	1256	2266	10187	805	17773	3981	1717	—	64402
1956	1350	13149	1286	20169	1269	1846	4794	3340	11173	8641	755	—	68472
1957	2223	9603	1466	9739	1392	5061	10453	7470	14641	7823	1454	829	72154
1958	336	10247	938	12363	4417	11272	9582	1731	11699	3175	5159	4592	75511
1959	1339	9496	238	10449	1361	19933	13032	1000	3884	3324	3206	3815	71077
1960	1787	11749	—	16484	—	27221	3361	3348	7988	11653	10295	5361	99247
1961	885	12331	334	19024	403	23872	10551	2629	15477	11220	1984	4052	102762
1962	902	14938	926	9688	1127	18076	9213	2457	11559	14034	985	8400	92319
1963	941	15936	635	6696	1191	10701	8556	2954	18574	9871	4514	10636	91115
1964	1029	10546	3634	5782	382	13234	16585	2888	22165	8757	4633	5095	153164

*West Coast Queen Charlotte Islands.

necessary for the fish to be intercepted before the beheading in a restricted work area in which the heading knives and swinging cargo slings are constant sources of danger. The large average size of halibut from most grounds and the consequential physical effort involved during sampling adds to the difficulty. Also, unloading is effected at a relatively rapid pace which, as noted earlier, cannot be delayed by the sampling.

Three- and Four-Man Sampling System

The original technique of market measuring was perhaps the most direct but required at least three and sometimes four persons. A shallow concave wooden cradle with a 200-centimeter length capacity was placed on one side of the elevated heading table and the measurer stood alongside at the dock level. Fish were supplied to the measurer before beheading by a man on the table who drew a random sample from the pile dumped by the cargo sling. After the fish were measured to the nearest centimeter, they were returned to the headers. Each length was reported to the third person for recording. Otoliths for age determination were taken from a portion of the measured fish sample by a fourth man and placed in a compartmented metal box (Figure 1). The fish were measured in the sequence in which otoliths were removed. The randomness of the total sample depended upon the non-selective manner in which the table-man drew the fish to be measured. An effort was made to represent with age material each length category within the random sample of measured fish.

Figure 2. Three-man sampling crew showing measurer at measuring cradle, table man assisting in opening otolith capsules, and recorder.

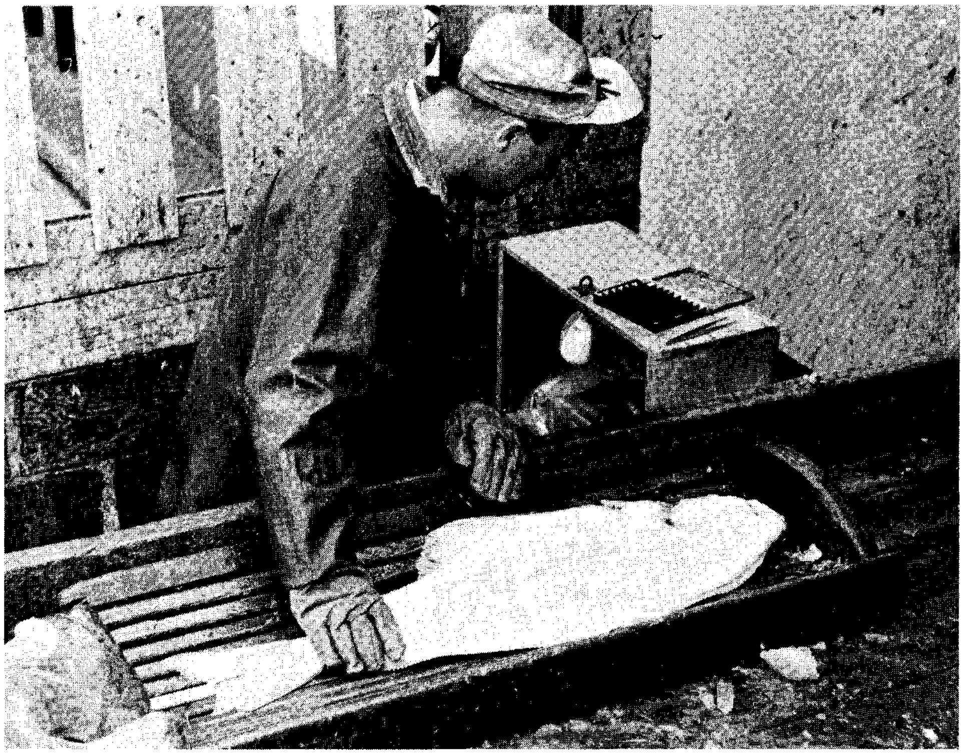

Figure 3. Recording fish length with tape recorder.

This procedure was subsequently modified to a three-man operation with the measurer taking two or three otoliths from each slingload, selected as far as possible according to the range of sizes represented in the total random sample. This stratification was aided by the recorder who kept a continuous tally of measured-only and measured-and-otolithed fish to assure that the frequency in each five-centimeter class of the former was adequately represented by age material from the latter. A three-man crew measuring a landing of relatively small halibut in Prince Rupert is shown in Figure 2.

Tape Recorder Recording

The use of a battery-powered tape recorder made possible the reduction of the sampling crew to two men (Figure 3), the measurer identifying the length as to whether it was associated with an otolithed fish or not. The system was promising but it was abandoned in favor of utilizing otolith measurements to determine fish length.

Photo Recording

Several departures from directly measuring the fish were explored. A remotely-controlled camera was mounted on a tower to photographically record a sample from each slingload. This reduced the sampling crew to two men. Initially a centimeter scale was photographed with each slingload and measurements were made from the projected image of the negative but it was difficult to secure reliable measurements. Subsequently, to facilitate measurement a 4′ x 8′ x ½″ sheet of plywood, scaled with one centimeter lines, each fifth one of which was emphasized with color and identified,

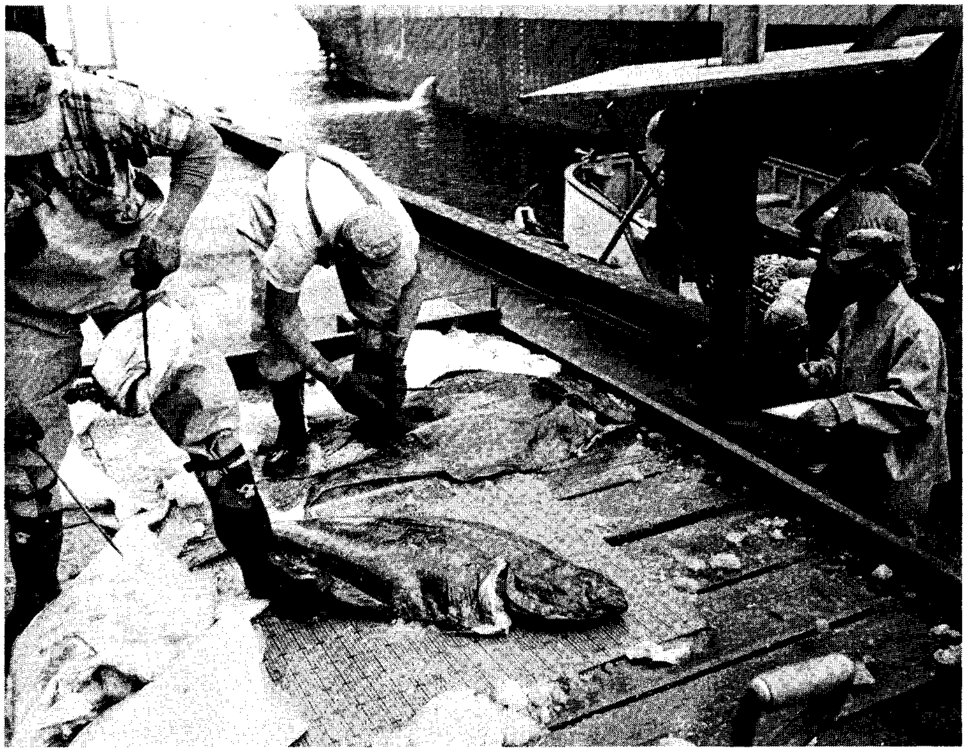

Figure 4. Measuring halibut using the two-man board system. Note fisherman heading the fish after they are measured.

was placed on the heading table. However, it then became obvious that the lengths could be read directly from the grid on the board and the intermediate use of the camera was rejected.

Two-Man Board System

Recording directly from the scaled sheet of plywood became known as the "two-man board" system. The scaled board was placed upon the heading table so that the sideboard of the heading table served as a headboard for measuring (Figure 4). Fish were placed on the scaled board, head to the sideboard and tail on the scale by the table-man who then measured the fish and called the lengths to a recorder. The representative otolith sample was taken by the recorder in the sequence in which the fish were measured.

The foregoing two-man board system was used extensively for several years prior to 1963 but was limited to those locations with a relatively large heading table. This restricted the number of receiving docks at which such sampling could be conducted. However, it was employed exclusively in Petersburg, Alaska, where it was possible to extend the heading table to accommodate the board.

Sampling Using Body Dimensions Other Than Length

During the period in which the foregoing methods were being used, dimensions other than body length, including those of the head and the preopercle were tested as bases for stratification of the age sample (Hardman, MS.).

It had long been suggested that one dimension of an organism was no more descriptive of its size than another (Petrov, 1930). McIntyre (1952) established a regression ($Y=3.38X+7.79$) for the fork-length head-length relationship (measurement from the tip of the snout to the most posterior part of the operculum) of 213 West Icelandic line-caught halibut ranging from 50 to 200 centimeters in length. He considered it to be applicable to such large halibut but suggested that trawl-caught halibut be used to verify the relationship for fish less than 64 centimeters in length. Also while measurements of North Sea halibut "suggested" a similar line, it was felt that whenever a new area was to be sampled the regression should be checked. In the small sample used, McIntyre found no significant differences between sexes.

The fork-length head-length relationship for Pacific halibut and the practicability of applying it to the Commission's sampling program was examined. When the landings of Pacific halibut are beheaded by the fishermen, the heads are frequently retained until the "cheeks" are removed. In the interim the heads can be easily measured by one or two men, preferably a measurer and a recorder, apart from the unloading area. However, since the heading technique does not leave a uniform proportion of the head, the use of head lengths was precluded.

The preopercular length (tip of snout to the posterior edge of the preopercular bone as measured in a straight line over the eye), which is unaffected by the heading process, was next considered. However the use of preopercular lengths was not pursued because in the meantime the fork-length otolith-radius relationship had been established for Pacific halibut as a consequence of growth studies involving the use of otoliths.

SAMPLING USING OTOLITHS ONLY

To utilize the fork-length otolith-radius relationship to calculate the size of the fish, and thus eliminate the difficult and burdensome collection of samples of fork-length measurements, was a logical development, especially since it was already necessary to collect a large number of otoliths for age determination.

By this method one man, unencumbered by equipment except a knife, forceps and a small plastic container, could obtain an adequate random collection of otoliths during the unloading of a vessel at any fish-buying plant, regardless of the size of the unloading table. Thus potentially, the number of field personnel could be reduced or dispersed to collect samples from several landings per day within one port, the same number of persons could individually sample at several ports or their time could be diverted to other activities.

A discussion of the techniques employed and an evaluation of the method follows.

Securing the Sample

When the fish are dumped on the table and before they are beheaded, the sampler draws 6 to 10 fish at random and opens the left auditory capsule of each. The otolith from the left side is considered more legible than the one from the right and has been used to establish the fork-length otolith-radius relationship and to determine the age. After all capsules have been opened the otoliths are removed and placed in a plastic container, usually strapped to the wrist. One person, working throughout the unloading of a vessel, can secure from 250 to 500 or more otoliths depending upon the average size of the fish, the size of the fare and the rapidity with which the vessel is unloaded.

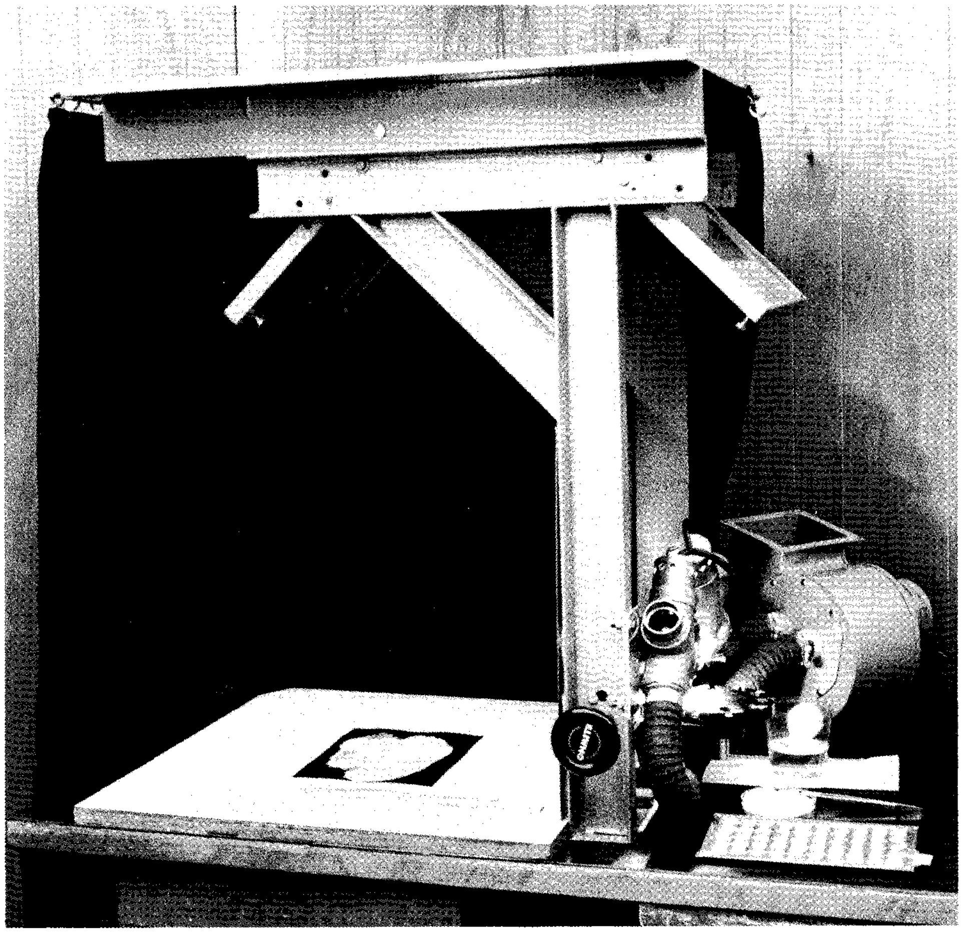

Figure 5. Projector for measuring otolith radii. (Otoliths are placed in rotating dish at right and turned into position under lens behind lamp and cooler assembly. Image is projected through the mirrors and focused upon vinyl table-top screen where the measurements are made.)

Processing

After the sample is secured, the otoliths are cleaned to remove slime and the saccular membrane and placed in a 2-ounce plastic bottle containing a clearing solution of 50 percent glycerine in water to which a few crystals of thymol have been added as a preservative. It has been found that legibility of the otoliths is enhanced if they are not permitted to dry after being removed from the fish. The bottle is labeled according to sample number, boat name and date.

Measuring

In the laboratory the radius of each otolith is measured from a projected image enlarged to 20 diameters (Figure 5). The baloptican-like projection device used has been developed by the authors to project the image of the otolith directly, thus eliminating the slow process of photographing the otoliths as in growth studies (Southward 1962a), and thereby facilitating measurements of greater numbers of otoliths per day. As the measurements are recorded, the otoliths are placed in sequence in sectioned

Table 2. Data output of computer program giving original order of calculated fish lengths and, for each 5-centimeter length class, an ordered distribution of sequential number of each length.

I – 9999 Sunfjord trip I Goose Island   Minimum = I., Maximum = 999. (O.R. Values)   Table of body lengths in original data order.*

73	77	76	81	76	84	72	84	85	74	88	97	82	77	89	88	82	86	82	81	99	90	90	84	97	104	102	113	116	65
103	63	73	76	69	78	76	73	88	73	85	81	77	68	64	65	80	89	77	69	88	77	67	90	84	109	78	88	88	77
102	116	92	99	78	140	109	50	77	82	72	76	68	72	68	70	88	74	88	117	80	100	65	119	85	81	77	78	85	55
72	84	110	80	95	104	131	88	92	89	90	73	80	60	95	84	84	72	119	140	119	107	149	125	149	109	102	76	110	93
60	68	84	78	99	112	96	76	110	117	103	109	102	100	102	119	57	119	99	81	113	110	97	109	137	89	134	116	113	123
112	78	88	63	77	74	90	72	65	58	74	68	148	117	76	97	113	102	72	77	97	76	102	89	76	104	90	88	99	103
113	99	85	99	134	131	113	113	117	104	59	99	104	103	109	89	88	93	109	102	102	107	95	99	132	123	117	113	113	163
131	128	113	113	158	135	117	52	110	123																				

Table of body length location in 5 cm. intervals. (Location in original input vector).

Body length interval (mid-pt.)	Location
52	68 218
57	90 137 160 191
62	32 45 104 121 154
67	30 35 44 46 50 53 73 75 83 122 159 162
72	1 7 10 33 38 40 71 74 76 78 91 102 108 156 158 161 169
77	2 3 5 14 34 36 37 43 49 52 57 60 65 69 72 87 88 118 124 128 152 155 165 170 172 175
82	4 6 8 13 17 19 20 24 42 47 55 70 81 86 92 94 103 106 107 123 140
87	9 11 15 16 18 39 41 48 51 58 59 77 79 85 89 98 100 146 153 174 178 183 196 197
92	22 23 54 63 99 101 120 157 177 198
97	12 21 25 64 95 105 125 127 139 143 166 171 179 182 184 192 203 204
102	26 27 31 61 82 96 117 131 133 134 135 168 173 176 180 190 193 194 200 201
107	56 67 112 116 132 144 195 199 202
112	28 93 119 126 129 141 142 149 151 167 181 187 188 208 209 213 214 219
117	29 62 80 84 109 111 130 136 138 148 164 189 207 217
122	150 206 220
127	114 212
132	97 147 185 186 205 211
137	145 216
142	66 110
147	113 115 163
157	215
162	210

*count from left to right in groups of five.

Table 3. Table for projection of age sample to total sample and calculation of number, weight, percentage of each and average weight at each age using hypothetical data.

Size Class	Av. Wt.	AGE 6 No. Otoliths	AGE 6 No. Meas.	AGE 6 Total Wt.	AGE 7 No. Otoliths	AGE 7 No. Meas.	AGE 7 Total Wt.	AGE 8 No. Otoliths	AGE 8 No. Meas.	AGE 8 Total Wt.	Total Otoliths	Total Measured	Projection Factor	Percent Total Measured	Total Wt.	Percent Total Wt.
60-64	5.1	2	4	20.4	1	2	10.2				3	6	2.0	8.9	30.6	5.6
65-69	6.6	2	6	39.6	2	6	39.6	1	3	19.8	5	15	3.0	22.4	99.0	18.2
70-74	8.3	2	8	66.4	4	16	132.8	2	8	66.4	8	32	4.0	47.8	265.6	48.9
75-79	10.3	1	3	30.9	2	6	61.8	1	3	30.9	4	12	3.0	17.9	123.6	22.7
80-84	12.6							2	2	25.2	2	2	1.0	3.0	25.2	4.6
Total Otoliths		7			9			6			22					
Total Measured			21			30			16			67				
Percent Measured			31.3			44.8			23.9					100.0		
Total Weight				157.3			244.4			142.3					544.0	
Percent of Total Weight				29.0			44.9			26.1						100.0
Average Weight				7.5			8.2			8.9					8.1	

stainless steel trays and stored in tiers in dustproof boxes. On a continuous basis about 750 otoliths can be processed daily by a technician and one assistant. The otolith radii measurements are converted into fork-length measurements using a computer program which also prints a listing of the lengths in the order measured and, for each 5-centimeter length class, an ordered distribution of the sequence number of each otolith (Table 2). For example, the number 30 in body length interval 67 cm. (mid-point of 5-cm. class) identifies it as the 30th otolith (length 65 cms.) in the table of body lengths. From this listing, which takes the form of a frequency distribution, a stratified sample of approximately 100 otoliths, found to be a statistically adequate number, is drawn to be used as the age sample as shown by the vertical line and the remaining otoliths are then discarded.

In addition to the above data but not shown in Table 2, the number and calculated weight of fish for each centimeter and each 5-centimeter-length class and the percentage distribution of each within the 5-centimeter summary is also listed in the output of the computer program.

Otolith Readings

The otoliths selected for the age sample are read using low-power binocular microscopes equipped with 10x occulars and variable objectives (0.66x, 1.3x, and 3x). Two independent readings are made of each sample and the agreements accepted as the age for each fish. Otoliths for which there is disagreement between readings are examined again; if this third reading agrees with either the first or second reading this is accepted as the age. Unless agreement is reached in a fourth examination, the otolith is rejected as illegible and discarded. Since the overall composition of the sample is the primary objective and large volume processing (approximately 40,000 per year) leads to more accurate representation, time is not wasted on determination of the age of occasional overly-difficult otoliths.

Projection of Age Sample to Total Sample

The procedure for projecting the stratified aged sample to the randomly measured total sample, also programmed for computer calculation, is demonstrated with hypothetical data in Table 3.

When age readings are completed, the number at each age is distributed on a "flow sheet" according to length (number of otoliths), and the sums of the number of otoliths in each 5-centimeter size class and at each age are obtained (total otoliths). The ratio between the number of otoliths at each size class and the total number of measurements at that size, of which the otolithed fish are a part, is then obtained (projection factor). The number of otoliths recorded at each age in each size class is then multiplied by the respective projection factors to distribute the total sample measured according to age (number measured). The numbers thus distributed in each size class at each age are then summed to provide the total number at each age (total measured).

In like manner the average weight at each size class, obtained from a standard calculated length-weight relationship, is multiplied by the number measured at each age to yield the total weight at each age at each size class. These products at each size within each age are totalled to provide the weight of the whole sample at each age. Division of this total weight at each age by the aforementioned projected number measured at each age yields the average weight at each age in the sample.

Table 4. Number and percentage frequency at each age based on measured and calculated lengths for samples from four major grounds.

	GOOSE ISLANDS				SOUTHEASTERN ALASKA				PORTLOCK BANK				SHUMAGIN ISLANDS			
	Measured		Calculated		Measured		Calculated		Measured		Calculated		Measured		Calculated	
Age	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
3	10	4.3	7	3.0	—	—	—	—	—	—	—	—	—	—	—	—
4	11	4.7	9	3.8	4	1.0	5	1.3	5	1.3	9	2.4	—	—	—	—
5	18	7.7	23	9.8	5	1.3	10	2.6	31	8.2	22	5.8	—	—	—	—
6	19	8.1	18	7.7	26	6.8	23	6.0	45	12.0	46	12.2	—	—	—	—
7	26	11.1	22	9.4	70	18.3	87	22.8	31	8.2	29	7.7	—	—	—	—
8	18	7.7	21	8.9	90	23.6	79	20.7	47	12.5	50	13.3	18	5.5	17	5.2
9	21	8.7	22	9.4	64	16.7	65	17.0	63	16.8	64	17.0	22	6.7	18	5.5
10	18	7.7	21	8.9	40	10.5	33	8.6	25	6.7	24	6.4	38	11.6	30	9.2
11	15	6.4	23	9.8	25	6.5	30	7.8	25	6.7	27	7.2	13	4.0	10	3.1
12	14	6.0	15	6.4	8	2.1	6	1.6	23	6.1	24	6.4	46	14.1	49	15.0
13	16	6.8	12	5.1	14	3.7	11	2.9	22	5.8	25	6.7	30	9.2	39	11.9
14	13	5.5	12	5.1	17	4.4	14	3.7	20	5.3	23	6.1	37	11.3	37	11.3
15	10	4.3	8	3.4	6	1.6	6	1.6	20	5.3	18	4.8	28	8.6	33	10.1
16	8	3.4	8	3.4	6	1.6	6	1.6	7	1.9	6	1.6	31	9.5	29	8.9
17	6	2.6	6	2.6	3	0.8	2	0.5	—	—	—	—	14	4.3	22	6.7
18	3	1.3	3	1.3	1	0.3	1	0.3	5	1.3	3	0.8	31	9.5	29	8.9
19	8	3.4	4	1.7	1	0.3	2	0.5	6	1.6	5	1.3	9	2.7	11	3.4
20	—	—	—	—	2	0.5	2	0.5	—	—	—	—	2	0.6	1	0.3
21	1	0.4	1	0.4	—	—	—	—	—	—	—	—	1	0.3	1	0.3
22	—	—	—	—	—	—	—	—	—	—	—	—	7	2.1	1	0.3
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	1	0.3	1	0.3	—	—	—	—

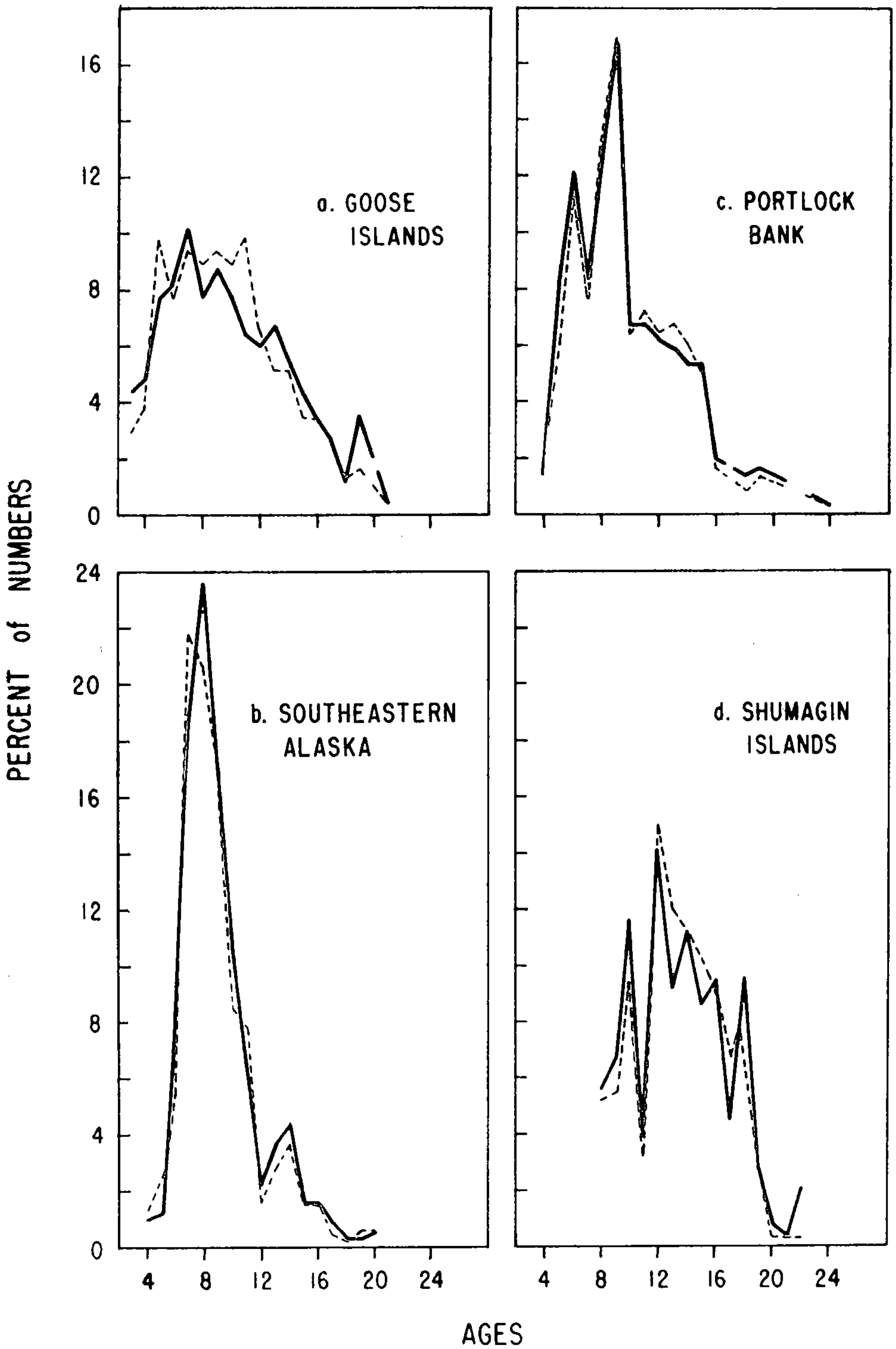

Figure 6. Percentage frequency at each age for samples from four major grounds for which lengths were directly measured (———) and calculated from otolith radii (- - - - -).

VERIFICATION OF SAMPLING PROCEDURE

The use of body lengths (tip of snout to fork of tail) calculated from otolith size in the Commission's market sampling procedure has been verified by comparing in several ways calculated lengths with lengths measured directly. In the first instance an individual sample is drawn from a group of fish and the length of each fish is determined both by measuring the fish and by calculation from the otolith measurement. A stratified selection of the otoliths is read and age composition and weight at each age for the whole sample are computed in the manner just described, using the measured body length. Also using the same fish, but with body lengths calculated from the respective otoliths, the composition and average weights are recomputed and the differences between the results compared.

Secondly, two replicated but independent samples are drawn from the same catch of fish, in each of which the lengths are both measured and calculated as above. Again differences between the age compositions and average weights at each age are examined as well as survival and growth rates. In determining the latter two, the sample is treated *in toto* rather than point by point.

Finally, paired samples, in one of which the lengths of the fish were measured directly while in the other they were calculated, were drawn from different catches taken on the same ground during the same period and examined as to whether the conclusions regarding stock composition, survival and growth would differ, depending on the method used to determine fish length.

Samples in the first category above were collected during tagging operations on the Goose Islands grounds in Queen Charlotte Sound, off Southeastern Alaska, on the Portlock Bank in the Gulf of Alaska, and from grounds off the Shumagin Islands that lie south of the Alaska Peninsula.

It should be noted that age compositions, average weights, survival and growth rates derived from samples of categories 1 and 2 do not necessarily reflect conditions within stocks of Pacific halibut. The samples were from catches of fish unsuitable for tagging and since the present study is one of methods only no attempt was made to assure their representativeness of the total catch.

The percentage age compositions for each ground calculated in the manner demonstrated in Table 3 are in close agreement (Table 4 and Figure 6). The numbers at each age in these samples were found to be not significantly different when tested by Chi-square (Table 5).

Table 5. Values of Chi-Square for Comparison of Age Frequencies for Various Grounds.

Grounds	Chi-Square	Degrees of Freedom
Goose Islands	5.879	19
Southeastern Alaska	6.4766	11
Portlock Bank	4.1416	14
Shumagin Islands	6.4032	11

The average weights at each age based on the two methods of determining fish lengths are given in Table 6 (Figure 7). Except for the sample from the Shumagin Islands grounds there is no consistent pattern of deviation associated with any given span of ages, either according to method used or source of the sample (Table 7).

Table 6. Average weight at each age based on measured and calculated lengths and the 95 percent confidence intervals of the differences for samples from four major grounds.

	GOOSE ISLANDS					SOUTHEASTERN ALASKA					PORTLOCK BANK					SHUMAGIN ISLANDS				
	Average Weight			95 Percent Conf. Limits		Average Weight			95 Percent Conf. Limits		Average Weight			95 Percent Conf. Limits		Average Weight			95 Percent Conf. Limits	
Age	Meas.	Calc.	Diff.	Lower	Upper	Meas.	Calc.	Diff.	Lower	Upper	Meas.	Calc.	Diff.	Lower	Upper	Meas.	Calc.	Diff.	Lower	Upper
3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	8.6	9.1	-0.5	-1.4	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	11.5	13.7	-2.2	-3.3	-0.9	—	—	—	—	—	3.7	4.0	-0.3	-0.7	0.1	—	—	—	—	—
6	7.7	7.6	0.1	-0.6	0.8	4.5	7.0	-2.5	-3.0	-2.0	8.0	8.4	-0.4	-12.6	0.5	—	—	—	—	—
7	10.0	10.0	0.0	-1.2	1.2	6.0	7.8	-1.8	-2.1	-1.5	11.8	12.3	-0.5	-2.3	1.3	—	—	—	—	—
8	8.9	9.4	-0.5	-1.1	0.1	11.7	14.3	-2.6	-3.6	-2.6	17.3	16.1	1.2	-0.9	3.2	19.0	19.4	-0.4	-4.0	3.2
9	15.7	14.8	0.9	-1.2	3.0	13.3	17.5	-4.2	-5.4	-3.0	27.4	25.4	2.0	-0.1	4.1	24.5	22.6	1.9	-2.2	6.0
10	21.2	21.2	0.0	-4.9	4.9	18.5	20.6	-2.1	-3.9	-0.3	36.5	36.5	0.0	-4.4	4.4	42.1	42.1	0.0	-3.9	3.9
11	41.9	34.2	7.7	1.1	14.3	24.7	21.7	3.0	-1.2	7.2	53.2	48.5	4.7	0.5	8.9	32.0	20.8	11.2	6.9	15.5
12	36.4	35.9	0.5	-9.4	10.4	37.6	49.0	-11.4	-22.9	0.1	56.5	50.8	5.7	0.9	10.5	55.9	45.2	10.7	6.8	14.6
13	42.7	66.8	-24.1	-35.1	-13.1	45.2	46.9	-1.7	-7.1	3.7	70.6	61.3	9.3	5.6	14.0	53.8	49.9	3.9	-0.8	8.6
14	51.3	60.1	-8.8	-16.9	-0.6	48.5	59.8	-11.3	-18.4	-4.2	57.2	61.5	-4.3	-14.0	5.4	72.9	68.5	4.4	-1.3	10.1
15	70.3	98.0	-27.7	-49.9	-5.5	70.8	63.0	7.8	-8.4	24.0	81.2	78.9	2.3	-8.0	12.6	81.0	76.8	4.2	-2.6	11.0
16	68.6	65.0	3.6	-18.7	25.9	57.6	74.2	-16.6	-32.7	-0.4	117.7	119.9	-2.2	-11.6	7.2	100.2	90.7	9.5	1.1	17.9
17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	110.6	94.0	16.6	8.8	24.4
18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	86.3	69.5	16.8	7.9	25.7
19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	94.2	89.0	5.2	-20.7	31.1
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

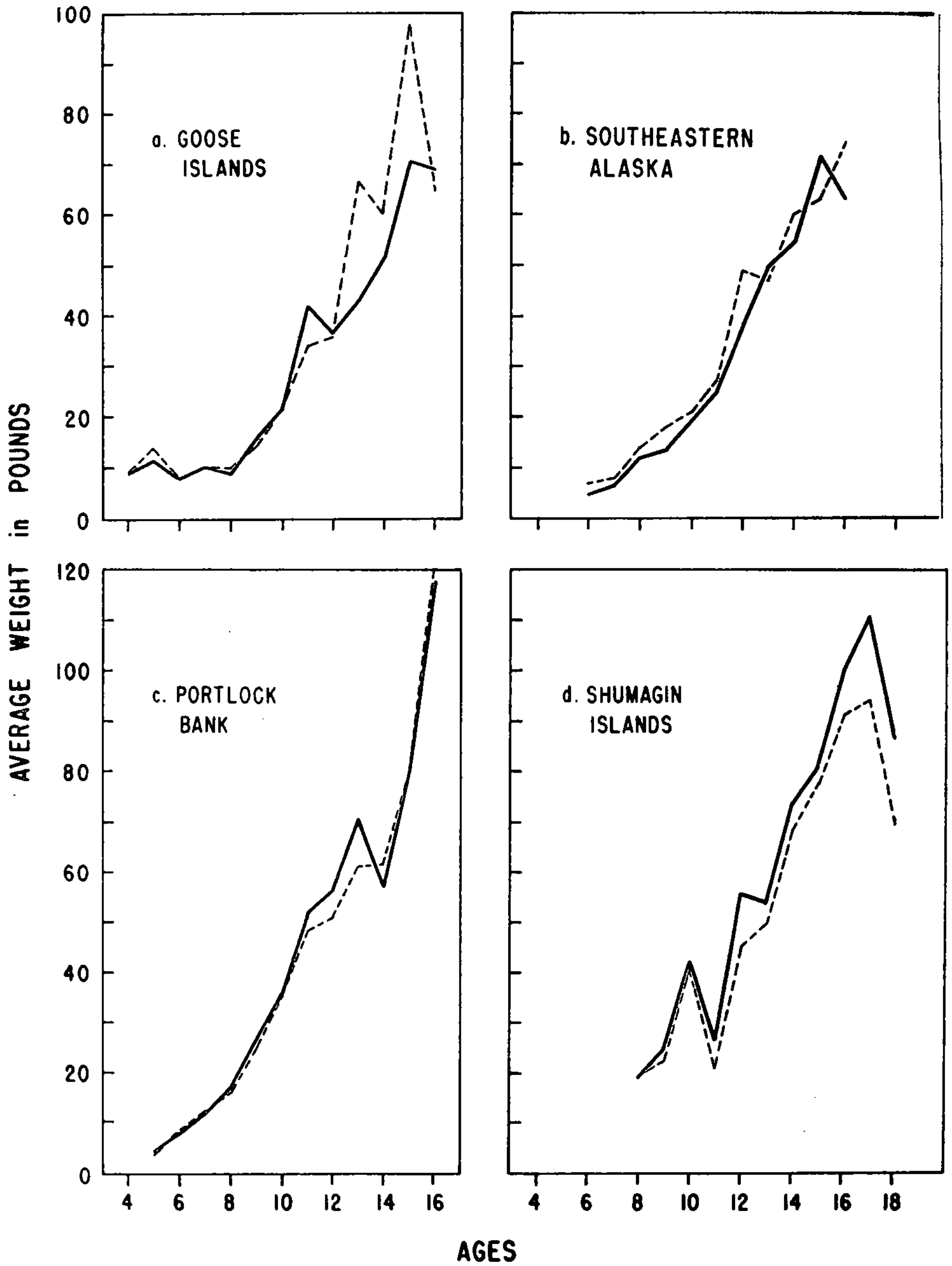

Figure 7. Average weight at each age for samples from four major grounds for which lengths were directly measured (———) and calculated from otolith radii (- - - - -).

Table 7. Deviations* of the average weights based on calculated lengths from those based on measured lengths at each age.

Age	Goose Is. Islands	S. E. Alaska	Portlock Bank	Shumagin Islands	Number of Deviations	Number of +'s	Proportion of +'s
3	+				1	1	1.00
4	+	=	+		2	2	1.00
5	+	+	+		3	3	1.00
6	−	+	+		3	2	0.66
7	=	+	+		2	2	1.00
8	+	+	−	+	4	3	0.75
9	−	+	−	+	4	2	0.50
10	=	+	=	=	1	1	1.00
11	−	−	−	−	4	0	0.0
12	−	+	−	−	4	1	0.25
13	+	+	−	−	4	2	0.50
14	+	+	+	−	4	3	0.75
15	+	−	−	−	4	1	0.25
16	−	+	+	−	4	2	0.50
17	−	+		−	3	1	0.33
18	+	−	+	−	4	2	0.50
19	+	−	−	−	4	1	0.25
20		−		+	2	1	0.50
21	+			−	2	1	0.50
22				+	1	1	1.00

*A plus indicates that the average weight based on the calculated lengths is greater than that based on measured lengths and a minus, the inverse.

The 95-percent confidence intervals for differences between the average weights are also given in Table 6. Confidence intervals at ages having less than three observations have not been computed. If the confidence interval contains zero, no significant difference is indicated. Despite the apparent differences in average weight by age in the four samples there is no consistent pattern of rejection by age even within the sample from the Shumagin Islands. However, as will be seen later, these differences in average weight at each age between methods do not affect determination of growth rates, the primary use of such data.

The use of replicated samples treated as whole units was necessary to compare the within-method variance to the between-method variance. Consequently, as described previously, separate samples were drawn from the same catches and within each sample, measured length and calculated length were determined for each fish. Thus, though different fish were used, the samples were treated identically.

The age composition and average weights by age for two samples each from Goose Islands grounds and Portlock Bank are shown in Figures 8 and 9 and in Table 8. For each area the distribution of number at each age was tested under the assumption that each value was equally likely. For the Goose Islands samples this hypothesis was not rejected (Chi-square=27.31 with 35 degrees of freedom) and therefore the differences in number at each age for these samples is considered to be due to chance alone.

An F ratio of 0.210 resulting from an analysis of the average weight data for the Goose Islands samples shows that the within-method variance is much greater than the between-method variance, and that any of the observed differences in average weight between methods are non-significant statistically.

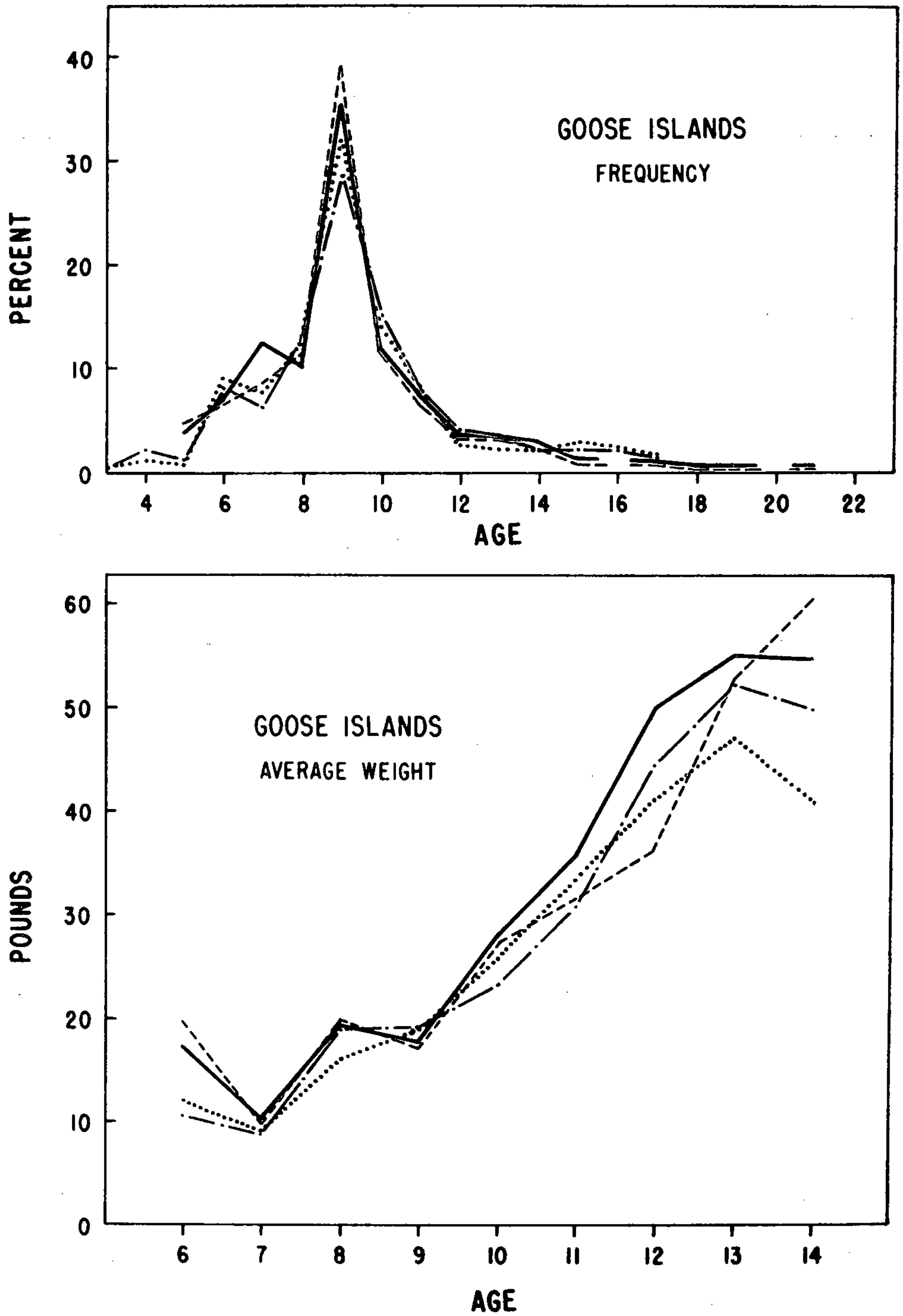

Figure 8. Percentage frequency and average weight at each age for replicate samples from Goose Islands ground for which lengths were both directly measured (Sample A———, Sample B- - - - -) and calculated from otolith radii (Sample A—·—·—, Sample B · · · · ·).

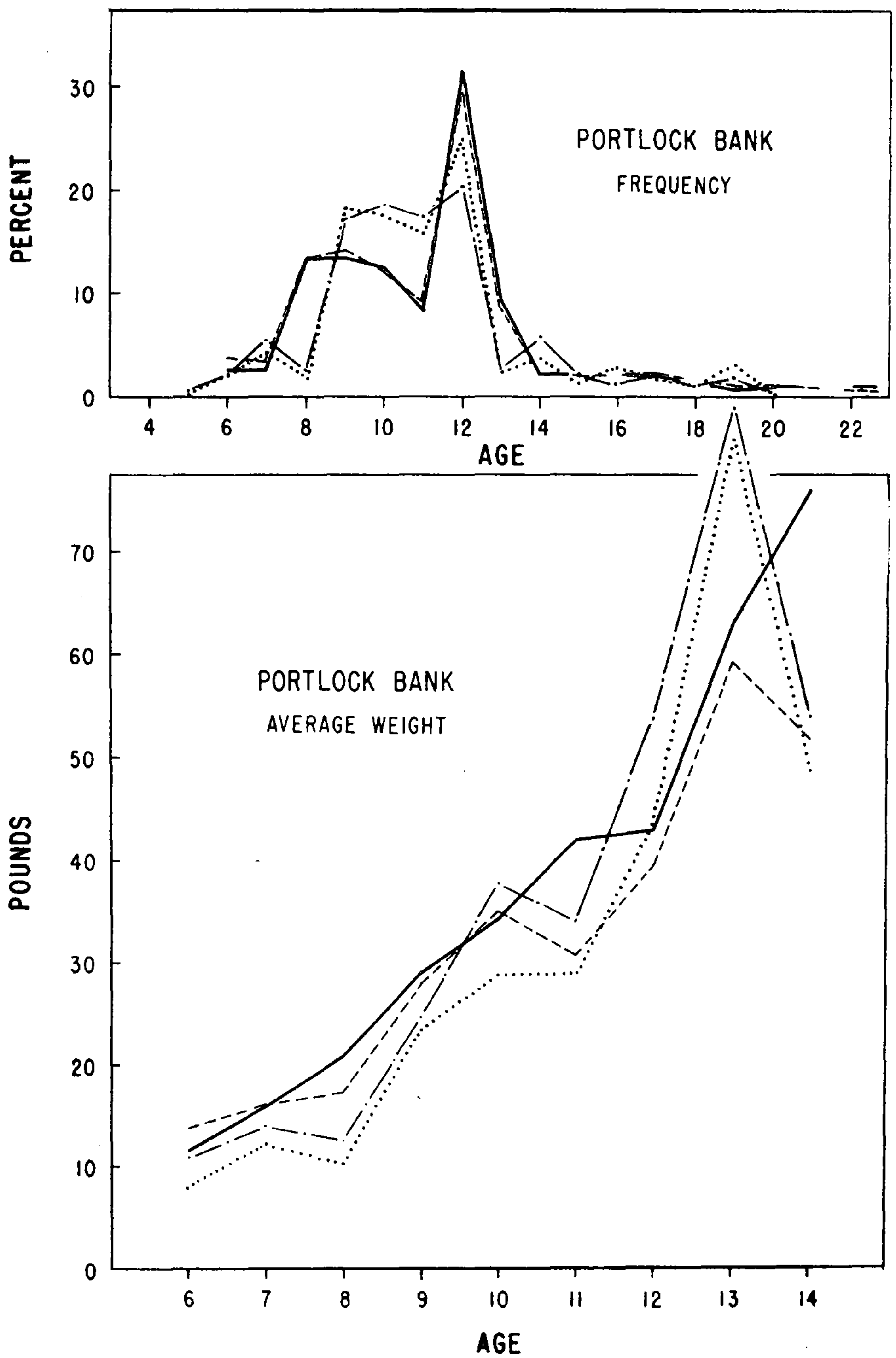

Figure 9. Percentage frequency and average weight at each age for replicate samples from Portlock Bank for which lengths were both directly measured (Sample C———, Sample D- - - - -) and calculated from otolith radii (Sample C—·—·—, Sample D · · · · ·).

Table 8. Number and average weight at each age for replicated samples from Goose Islands Grounds and Portlock Bank using measured and calculated lengths.

	GOOSE ISLANDS								PORTLOCK BANK							
	Sample A				Sample B				Sample C				Sample D			
	Number		Average Wt.		Number		Average Wt.		Number		Average Wt.		Number		Average Wt.	
Age	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
3	—	—	—	—	1	1	2.9	5.1	—	—	—	—	—	—	—	—
4	—	—	—	—	5	3	4.6	5.4	—	—	—	—	—	—	—	—
5	8	10	8.8	13.1	3	2	3.9	3.9	—	—	—	—	1	1	5.1	5.5
6	15	14	17.3	19.6	18	20	10.5	12.0	7	10	11.6	13.7	6	5	11.0	8.0
7	27	18	10.2	9.6	14	17	8.7	9.1	7	9	15.7	15.9	14	11	14.1	12.2
8	22	26	18.3	19.7	29	27	17.7	16.3	37	37	20.7	17.4	6	5	12.6	10.4
9	77	86	17.6	17.1	63	73	18.7	18.4	37	38	29.1	28.1	48	51	24.7	23.7
10	26	25	27.7	27.1	39	30	23.1	23.2	34	36	34.4	35.0	51	48	37.8	28.7
11	16	15	35.6	31.5	18	17	30.7	33.3	23	24	42.1	30.7	48	43	34.1	29.0
12	8	7	49.8	36.2	9	6	44.0	41.0	89	81	42.9	39.7	56	68	53.6	43.6
13	7	7	54.9	52.8	7	5	52.0	46.7	26	24	63.0	59.4	8	7	83.8	80.7
14	6	5	54.4	60.2	3	5	49.5	40.6	6	6	75.8	51.8	15	10	54.4	48.7
15	3	2	56.1	35.2	5	6	67.1	47.4	—	—	—	—	5	3	73.6	78.4
16	—	—	—	—	5	6	74.5	64.2	—	—	—	—	3	7	91.2	56.9
17	2	2	104.0	72.2	3	4	49.2	33.1	5	6	88.3	75.7	5	5	115.9	89.5
18	1	1	84.6	115.8	—	—	—	—	—	—	—	—	2	2	140.6	101.7
19	1	1	94.2	104.5	—	—	—	—	1	2	154.3	59.7	5	7	87.9	67.3
20	—	—	—	—	—	—	—	—	2	2	141.0	127.8	1	1	236.9	236.9
21	1	1	115.8	59.7	—	—	—	—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	2	1	140.6	140.6	—	—	—	—

The assumption that each of the frequencies by age were equally likely was rejected for the replicated samples from Portlock grounds (Chi-square=113.18 with 27 degrees of freedom). However, it is obvious from the close agreement between frequency based on measured and calculated lengths for each sample (Figure 9) that the rejection was due to the unlikely chance of drawing similar replicate samples from a widespread population containing a large range in length composition and not due to difference between methods.

The F ratio of 0.417 resulting from the analysis of the within- and between-method variances for the average-weight data from Portlock shows, as was the case in the data from Goose Islands grounds, that the within-method variance is greater than the between-method variance, indicating again that there is no significant difference between the average weights determined by the different methods.

The use of the calculated lengths in the market sampling program is validated further by comparison of survival and growth rates calculated for the replicated samples. Survival rates were derived using the Robson-Chapman (1961) method of catch curve analysis, and growth rates (g) after the method described by Ricker (1958). The survival rates with the confidence intervals for the difference between survival rates and the average growth rates with results of the "t" test of differences between means are given in Table 9.

Table 9. Survival and growth rates* for replicated samples from Goose Islands grounds and Portlock Bank.

	Survival Rate	95% Confidence Interval**	Average Growth Rate	"t"	Degrees of Freedom	Probability of larger "t" value
GOOSE ISLANDS						
Sample A						
Measured Length	0.55	-0.04 to 0.14	0.20	0.79	18	P > 0.20
Calculated Length	0.50		0.15			
Sample B						
Measured Length	0.58	-0.07 to 0.11	0.27		18	P > 0.20
Calculated Length	0.56		0.26	0.68		
PORTLOCK BANK						
Sample C						
Measured Length	0.40	-0.13 to 0.05	0.21	1.54	16	P > 0.50
Caleulated Length	0.44		0.18			
Sample D						
Measured Length	0.61	-0.04 to 0.04	0.20	0.12	26	P > 0.25
Calculated Length	0.61		0.20			

*Survival and growth rates given in this table do not necessarily reflect stock conditions since they were derived from samples in which no attempt was made to obtain a distribution representative of the total catch.

**Confidence interval for difference between survival rates.

In view of typical variability in fishery data, the difference between the survival rates for each method for either the Goose Islands or Portlock grounds is small. In every case the confidence interval of the difference between survival rates for each sample includes zero, indicating that the differences between the estimated survival rates determined from measured or calculated lengths are not significant.

Average growth rates ($\bar{g}$) for each method within sample A and sample B of the Goose Islands data were also examined. According to the "t" test of difference in means*, the assumption that the average growth rate based on measured lengths is not different from the average growth rate based on calculated lengths is accepted, despite apparent large differences in sample A. On the same basis, there is also no statistical difference between the average growth rates of each sample from Portlock Bank.

Experimental Sampling of Commercial Catches

The feasibility of applying a sampling program as outlined above was tested in the field during the 1963 halibut fishing season. To determine whether or not different general conclusions would be reached if the sampling data were obtained from a market sampling program based on measured lengths or one based on calculated lengths, field crews collected independent paired samples, measuring the fish in one instance and collecting otoliths in the other, from commercial catches taken on Goose Island grounds, Portlock Bank and the Shumagin Islands grounds. Although taken from the same time period, these samples differed from those discussed earlier in that they were of different catches. Thus the following comparisons are between different samples, one using measured lengths and one using calculated lengths, rather than between different methods within a single sample. Percentage age compositions and average weights by age for these data are given in Table 10 (Figure 10).

The agreement is close between the two age compositions of the Goose Islands samples and the agreement between the other samples is as good as usually encountered between different samples from the same grounds and time periods even where measured directly (Table 11).

Comparison of survival rates (Table 12), which involves the sample as a whole and does not consider the data point by point, indicates that the same conclusions regarding survival would be reached whether the data under examination for each ground were derived from measured lengths or from calculated lengths. The confidence interval of the difference between rates of survival estimated from the two methods of determining fish length contain zero in every case, indicating again that these differences are not significant.

Average weights at each age (Figure 10) for the same grounds show that there is agreement in the overall trends. Growth rates were computed and the differences between average growth rates ($\bar{g}$) were compared (Table 13). These differences are non-significant, indicating that the differences between the values of growth rate are not dependent on the method used to derive the length.

The similarity of average weights between the two sources of data for the various samples has been examined by comparing the variability within each method with that between methods using a one-way analysis of variance (Table 14). In every instance the null hypothesis was accepted suggesting, as was the case before, that the within-method variation is greater than the between-method variation.

It must be remembered that since these are not replicated samples of the same catch of fish but are independent samples from the same area and time, more deviation

*The variance of g_i is given by:

$$\text{var}(g_i) = \left(\log(1+\frac{1}{i})\right)^2 \left(\text{var}(b)\right),$$

Where b is the slope of the regression:

log (weight) = a + b log (age), used to compute the logarithms of weight needed in the calculations of g (IPHC Rept. 28, p. 14).

The variance of $\bar{g}$ is:

$$\text{var}(\bar{g}) = \text{average}\left(\log(1+\frac{1}{i})\right)^2 \left(\text{var}(b)\right),$$

Table 10. Percentage frequency and average weight at each age for paired samples taken during the same period from Goose Island Grounds, Portlock Bank and Shumagin Islands Grounds using measured and calculated lengths.

	GOOSE ISLANDS				PORTLOCK BANK				SHUMAGIN ISLANDS			
	Percent Frequency		Average Weight		Percent Frequency		Average Weight		Percent Frequency		Average Weight	
Age	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.	Calc.
4	—	1.8	—	7.9	—	—	—	—	—	—	—	—
5	6.5	5.7	9.2	8.6	—	—	—	—	—	—	—	—
6	11.2	9.8	9.4	9.6	—	—	—	—	—	—	—	—
7	18.3	16.7	11.0	12.3	2.0	—	19.3	—	2.1	3.7	20.2	14.1
8	21.0	22.5	14.4	16.3	10.1	5.8	22.1	18.4	3.9	6.6	26.6	19.0
9	17.5	18.7	15.8	18.6	10.6	10.5	27.5	26.5	13.2	10.5	26.4	23.6
10	12.5	12.3	16.9	20.7	14.6	12.6	37.6	28.8	17.2	12.4	34.3	30.7
11	9.4	9.1	21.9	23.5	20.7	22.9	35.8	32.2	28.5	29.4	42.2	37.9
12	1.8	2.4	35.0	29.3	13.9	17.1	54.8	39.0	9.6	11.6	66.7	45.6
13	1.3	0.3	49.1	34.4	8.2	11.6	57.1	53.4	6.0	8.7	69.3	54.1
14	0.1	0.3	48.1	52.3	5.4	8.4	66.4	54.8	4.9	3.1	72.2	57.6
15	—	—	—	—	5.7	4.5	82.8	69.0	5.0	2.8	85.6	68.4
16	0.2	—	79.7	—	3.7	1.6	79.4	52.2	3.2	3.9	107.6	79.7
17	—	—	—	—	3.5	4.5	79.0	74.8	3.0	2.8	82.4	74.4
18	—	0.5	—	38.5	1.5	1.4	85.5	84.8	1.0	3.1	78.8	98.6
19	—	0.2	—	60.2	—	—	—	—	1.6	1.6	140.6	62.2
20	—	—	—	—	—	—	—	—	0.8	—	169.2	—

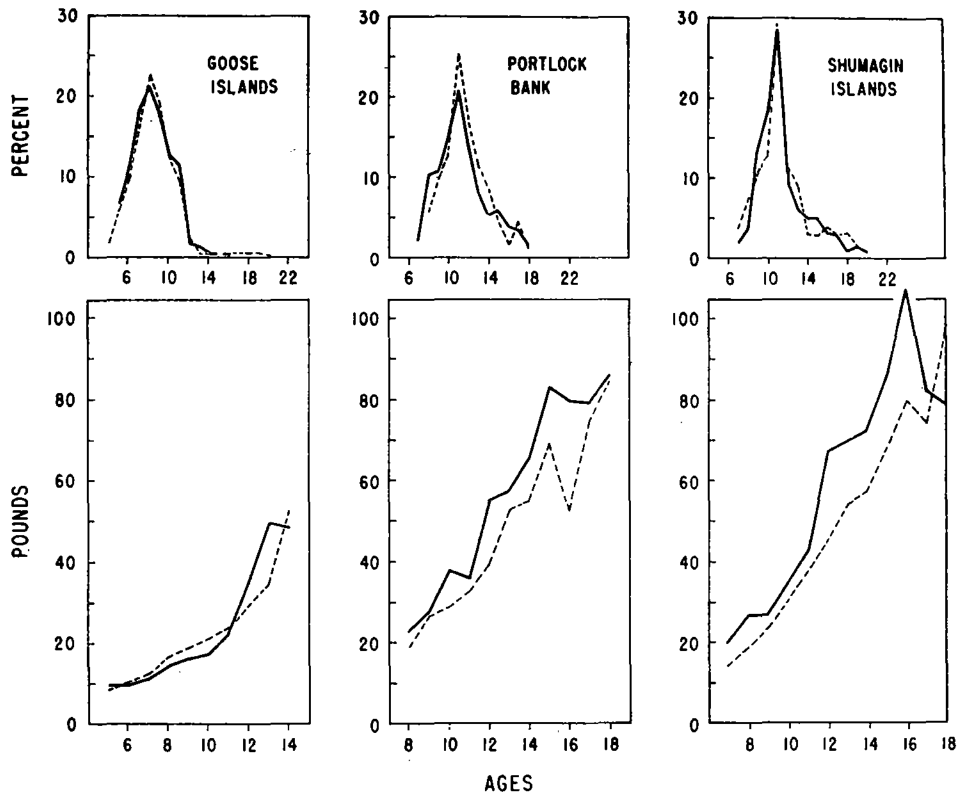

Figure 10. **Percentage frequencies and average weights at each age for paired samples, in one of which the lengths were measured directly (———) and in the other calculated from the otolith radii (- - - - -), from three major grounds.**

is to be expected than from those samples of identical fish illustrated earlier. Nevertheless, in each of the above instances the same general conclusions regarding percentage age composition and average weight would have been reached regardless of the manner in which the length of the fish was determined. This field testing further demonstrates that the use of calculated lengths is not only an effective method but provides results equally valid to those derived from the use of measured lengths.

Limitations of Calculated Lengths

Each calculated body length is an estimate from a regression equation, and has an associated variance, and thus may deviate from the actual measured length to the extent of this variability. One result of this is that lengths of some fish which are actually legal size, but which may have smaller than average otoliths, are calculated to be less than legal size and thus a higher proportion of fish less than legal size would appear in some samples than actually exists.

Also, at the extremes of the age distribution, where the number of fish at each age is small, the variability in the average calculated length is large. This can be overcome only by increasing the sample size, but in most instances this is impossible since all of the fish at the two extremes of the size range within any given catch are usually already included. However this difficulty can be overcome by increasing the number of samples and this is made possible by the use of the present sampling method.

Table 11. Percentage frequency and average weight at each age for three samples each from Portlock Bank and from Shumagin Islands grounds in 1961 in which all the fish were measured directly.

	PORTLOCK BANK						SHUMAGIN ISLANDS					
Age	Percent Frequency	Average Weight	Percent Frequency	Average Weight	Percent Frequency	Average Weight	Percent Frequency	Average Weight	Percent Frequency	Average Weight	Percent Frequency	Average Weight
4	—	—	—	—	0.2	4.5	—	—	—	—	—	—
5	—	—	—	—	5.9	13.1	—	—	—	—	—	—
6	1.2	21.6	1.3	26.0	4.7	10.1	0.5	10.3	—	—	1.3	19.2
7	6.8	21.3	5.4	28.3	8.0	21.9	5.0	19.0	1.4	40.6	3.5	23.1
8	17.1	29.3	11.7	26.9	8.1	26.3	14.1	26.0	3.3	29.8	9.8	27.3
9	12.6	36.7	15.7	28.0	5.6	30.3	19.4	32.9	6.2	38.0	11.4	32.4
10	21.6	37.2	21.0	36.3	18.6	40.4	16.6	44.0	13.9	42.8	24.3	37.2
11	14.2	55.2	6.7	52.6	8.5	49.0	16.6	62.4	19.0	56.9	13.9	50.3
12	8.8	67.1	13.6	55.6	5.9	64.0	10.8	73.4	20.1	59.0	14.2	71.9
13	10.2	80.5	3.1	63.7	6.6	69.0	5.0	72.4	10.2	70.2	10.4	86.8
14	3.1	73.3	5.4	72.0	6.7	80.2	3.3	98.9	7.3	82.7	4.7	93.1
15	1.2	84.6	5.6	73.9	4.0	84.8	4.3	93.5	6.2	81.9	1.6	84.9
16	1.2	82.1	1.3	109.2	7.5	72.8	1.5	138.8	5.5	95.5	0.6	127.8
17	0.0	—	3.6	97.8	2.9	79.5	2.0	135.2	3.6	88.0	2.5	121.0
18	0.9	100.4	1.5	144.0	3.8	84.6	0.3	200.8	2.2	84.0	0.6	115.8
19	1.2	120.6	1.0	141.1	0.7	124.0	0.5	115.8	1.1	168.9	0.6	127.8
20	—	—	1.7	133.1	1.1	83.1	—	—	—	—	0.6	59.7
21	—	—	1.3	104.3	0.2	127.8	—	—	—	—	—	—
22	—	—	—	—	1.0	75.8	—	—	—	—	—	—

Table 12. Survival rates and 95% confidence intervals of the difference between rates for samples based on measured lengths and calculated lengths for various grounds.

Grounds	Survival Rate	95% Confidence Interval
GOOSE ISLANDS		
Measured	0.61	-0.02 to 0.05
Calculated	0.59	
PORTLOCK BANK		
Measured	0.71	-0.03 to 0.07
Calculated	0.69	
SHUMAGIN ISLANDS		
Measured	0.67	-0.04 to 0.04
Calculated	0.67	

Table 13. Average growth rates ($\bar{g}$) based on average weights derived from measured and calculated lengths for paired samples and "t" tests of the average growth rates for various grounds.

Grounds	$\bar{g}$	t	Degrees of Freedom	Probability of or larger t-value
GOOSE ISLANDS				
Measured	0.12	0.54	18	$P > 0.25$
Calculated	0.14			
PORTLOCK BANK				
Measured	0.13	-0.98	24	$P > 0.15$
Calculated	0.16			
SHUMAGIN ISLANDS				
Measured	0.14	-1.07	22	$P > 0.10$
Calculated	0.16			

Table 14. Values of the F ratio resulting from testing for significance of between-method variation in average weight by age for various grounds.

Grounds	F	Degrees of Freedom	Probability of larger F value
GOOSE ISLANDS	0.522	(1, 116)	$P > 0.1$
PORTLOCK BANK	1.484	(1, 42)	$P > 0.1$
SHUMAGIN ISLANDS	1.424	(1, 45)	$P > 0.1$

SUMMARY

Sampling of commercial landings of halibut, begun in 1933 as part of the Commission's investigation of stock composition, is reviewed.

The attendant problems of obtaining representative samples with reasonable effort for a species as large as halibut and under the unloading procedures peculiar to the halibut industry are explained.

At the outset four men were required to obtain each sample of lengths, including measurements of the body cavity for possible use in sex determination. The latter proved to be inconclusive, and it became possible to reduce the sampling crew to three men. Latterly, by using a large scaled board instead of a cradle on which to measure the fish, a two-man crew was effective in some ports.

With the view to further efficiency, photo and tape recording were tested as well as the taking of head dimensions instead of body lengths. While each method had certain merits, all were rejected in favor of using calculated lengths based on the relationship between body length and the otolith radius. Since this required only the collection of otoliths, one person could obtain the necessary data from a landing.

The validity of such calculated lengths has been rigorously tested in several ways using three types of samples:

(1) Those for which there were both directly-measured lengths and lengths calculated from the otolith dimension of the same fish.

(2) Replicate samples from the same catch in which the lengths were both measured and calculated in each sample.

(3) Paired samples from different catches from the same grounds and season in which the lengths were measured for one sample and calculated for the other.

The resultant age compositions from the two methods were compared on a point-by-point basis using Chi-square where applicable. The within-method and between-method variance of the average weights also were examined, and in every case the within-method variance was greater than the between-method variance.

In addition, survival and average growth rates using directly measured and calculated length data were found to be not significantly different and any conclusions regarding survival and growth would be the same regardless of the method by which body length was determined.

Accordingly, the use of calculated body length in age composition studies of halibut, requiring only one man to sample a catch, is shown to be a valid method which will permit broader coverage of the commercial landings.

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