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Changes in Commercial Catch Sampling and Age Determination Procedures for Pacific Halibut, 1982 to 1993

by

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and William G. Clark

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ABSTRACT

The International Pacific Halibut Commission has sampled the commercial catch since the 1930s. Documentation for the years 1982 to 1993 of port coverage, logbook data collected, sampling methods, otolith sample size, the processing of otoliths in the lab, and otolith-related studies are presented in this report.

Sampling ports were added as the pattern of landings shifted. Logbook data forms changed to reflect the use of more than one gear type per vessel and the use of non-halibut gear. Also initiated was the collection of information on gear lost or abandoned during the ever shortening openings. Length/age sampling within a port was changed from representing a port proportionally, to representing a vessel's hailed weight proportionally. This change was made in response to the shorter, higher volume unloading periods and was accomplished by changing from systematic sampling of slings (cargo nets) of fish to unbiased random sampling of fish. The total otolith sample size was reduced and sample sizes were set for each management area. Double blind aging was discontinued. Otolith studies relating to glycerin absorption, age validation using oxytetracycline, automated aging, and the use of otoliths to determine sex were undertaken.

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INTRODUCTION

The International Pacific Halibut Commission (IPHC) manages the Pacific halibut (*Hippoglossus stenolepis*) fishery for Canada and the United States. Otoliths collected from the commercial catch provide the age composition data needed for the annual stock assessment. Also, from 1982 to 1990, the otolith weight provided estimates of fish length and weight. The IPHC has sampled the halibut catch since the 1930s. Details of sampling methods for the years prior to 1982 can be found in Hardman and Southward (1965), Southward (1976), and Quinn et al. (1983). Clark et al. (1995, in press) documents sampling procedures as well as the market sample data file contents and structure for the years 1935 through 1994.

Also essential for the annual stock assessment is catch per unit effort (CPUE) data. The IPHC has collected CPUE data through fishing logbooks since 1932. Although it is a legal requirement of the captain to keep a logbook, the Commission collects the information on a voluntary basis in the belief that compulsory reporting could result in false records. In addition to CPUE, the logbook data is also used to assign fishing locations to the otolith samples and the landing records. The standard logbook data collected from 1932 to 1993 consisted of vessel name, fishing dates, fishing locality, amount and type of gear used, and total weight of halibut taken daily in each locality. Answers to a variety of specific questions were also obtained through the logbook interviews. For example, foreign vessels fishing in Alaska were of particular interest in the late 1960s and 1970s, and data on their sightings was collected during logbook interviews. The types of data collected from the fisher's logbooks prior to 1982 have not been published but are summarized in this report in Appendix Tables 1, 2, and 3.

IPHC Regulatory Areas 2A, 2B, 2C, 3A, and 3B were unchanged between 1982 and 1993. However, in the Bering Sea, the portion of Area 4 closed to commercial halibut fishing was reduced in 1983, and further reduced in 1990 (Figure 1). These reductions of the closed area occurred after it was determined that a commercial fishery would not adversely affect the nursery grounds in that area. Other Area 4 divisions (4A, 4B, 4C, 4D, 4D-N, and 4E) were created and modified to distribute the fleet throughout Area 4. These divisions are insignificant to the sampling data collected and are therefore not considered in this report.

This report describes port sampling activities and modifications to port sampling procedures from 1982 to 1993. The items discussed include port coverage, logbook data collection, sampling methods, otolith sample sizes, and the processing of the otoliths. Some otolith research studies are also discussed. Although tagged halibut data were collected during commercial catch sampling, tag returns will not be discussed in this report.

Modifications to the sampling program were made in response to various changes in the halibut fishery. These changes include: a larger fleet size, higher gear efficiency,

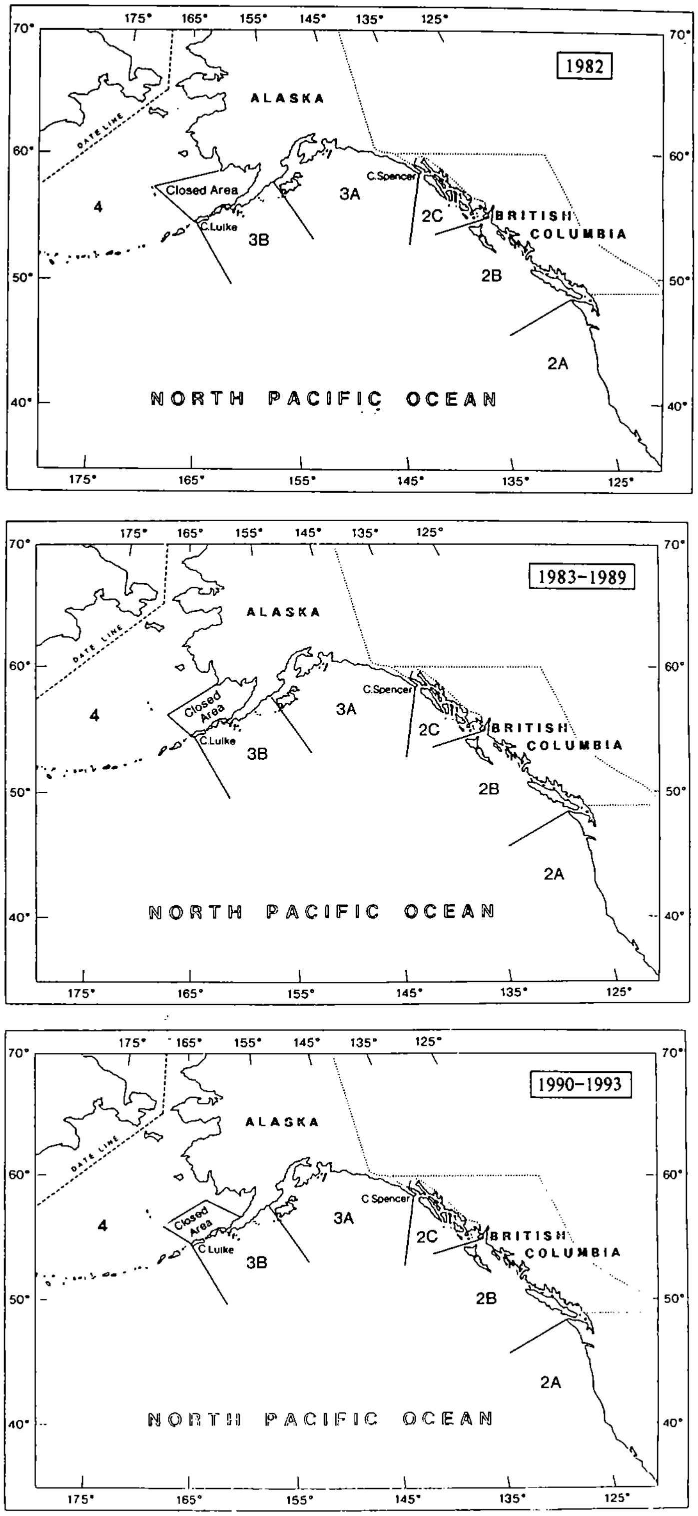

Figure 1. **IPHC Regulatory Areas for 1982 to 1993.**

shorter seasons, and new management measures such as fishing period limits. Season lengths decreased between 1982 and 1993 from 49 days to 10 hours in Area 2A, and from 11 days to 2 days in Area 3A. The length of the Area 2B fishing season was shortened from 61 days to 10 days (with any one vessel restricted to 6 fishing days) between 1982 and 1990. In 1991, the Canadian Department of Fisheries and Oceans (DFO) implemented an Individual Vessel Quota (IVQ) fishery with a seven-month fishing season. As fishing season lengths changed over the years, the length of time that samplers spent in the ports affected both sampling efficiency and sampling methods.

SAMPLING IN THE PORTS

Sampling the commercial fishery includes removing the left (blind side) sagittal otoliths from a selected sample of fish, obtaining fishing information by copying logbooks and/or interviewing the captains of vessels, recovering tagged halibut, and commencing in 1991, measuring the fork length of sampled halibut. From 1963 to 1990, the following otolith measurements: radius (1963-1967); length (1968-1977); weight (1978-1990) were used to estimate fish weight. Evaluation of the relationship between otolith weight and halibut weight revealed significant differences between actual fish weights and otolith-generated estimates of fish weight between regions and over time (Clark 1992). Therefore, in 1991, the IPHC resumed measuring the actual fork lengths of sampled halibut for use in estimating fish weight.

During the fishing seasons, logbook data are collected by an interview process which enables the Commission staff to observe changes in the fishery. Changes such as the introduction of crucifiers (automated hook strippers), different hook spacings, and new hook types were noted as port samplers collected data in the field. Management decisions were made after analysis of the logbook data; for example, crucifiers were banned in 1987 and CPUE standardization was revised based on changes in hook spacing (Skud 1972) and hook type (Quinn et al. 1985). With good coverage in the ports, it is easier to notice such changes and react in a timely manner.

Special projects were occasionally undertaken during port sampling to help answer specific questions. For example, in the early 1980s, halibut heads were counted and weighed to validate head to body weight ratios; from 1982 to 1984, additional information was collected on the number of fish to estimate the total number of fish in a trip. In some years, extra data was also collected for other research projects. For example, in 1988, larger otolith samples were taken from trips that fished the "Sitka Spot" (in Area 2B) during commercial openings both before and after a depletion-fishing and tagging study in that location. The extra otoliths were used for a comparison of age distributions.

Port Coverage and Selection

Field samplers are placed in ports to sample the halibut catch being landed at the processing plants. The sampling effort allocated to the various ports is based on the percentage of the total catch that the port processes, the management area the fish are caught in, and the ability to obtain unbiased samples. Deciding how to spread this sampling effort was accomplished by predicting at the beginning of the year the proportion of pounds to be landed into the sampled ports and from these predictions port selections were made. Ports were added or dropped if it was determined areas were over/under-sampled in the previous year. Also the previous year's sampling methods were evaluated to determine if unbiased samples could be obtained in each of the ports. Table 1 illustrates the changes that occurred in port coverage from 1982 to 1993. In 1982, the nine

Table 1. **The ports where samplers collected otoliths and percent of total catch into the sampled ports by year, 1982-1993.**

LOCATION		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
OR:	Newport		x	x	x	x	x	x	x	x	x	x	x
WA:	Westport							x	x		x		
	La Push										x	x	x
	Neah Bay					x		x	x	x	x	x	x
	Seattle	x	x	x	x	x	x	x	x	x		x	x
	Anacortes									x			
	Bellingham		x	x	x	x	x	x	x	x	x		
	Blaine				x	x	x	x	x	x			
B.C.:	Vancouver	x	x				x	x	x	x	x	x	x
	Port Hardy									x		x	x
	Prince Rupert	x	x	x	x	x	x	x	x	x	x	x	x
AK:	Ketchikan										x	x	x
	Metlakatla										x	x	
	Petersburg	x	x	x	x	x	x	x	x	x	x	x	x
	Wrangell	x										x	x
	Sitka	x	x	x	x	x	x	x	x	x	x	x	x
	Excursion Inlet	x	x	x		x	x	x	x	x	x	x	x
	Pelican							x					
	Seward	x	x	x	x	x	x	x	x	x	x	x	x
	Cordova												x
	Homer					x	x	x	x	x	x	x	x
	Kodiak	x	x	x	x	x	x	x	x	x	x	x	x
	King Cove									x	x	x	x
	Dutch Harbor/Unalaska				x	x	x	x	x	x	x	x	x
	Atka							x					
	St Paul		x										
% of total catch into sampled ports		62	59	54	53	58	64	66	66	60	63	67	63

sampled ports received 62% of the total catch, whereas in 1993, 18 ports had to be sampled for a similar percentage of the total catch.

Over the years, improvements in transportation, additional cold storage plants, and economic forces have combined resulting in an increase in the distance between unloading sites and the market. Seattle was the leading port of landing during the 1930s, processing 40% of the total catch, while during the 1970s, Prince Rupert was the leader, processing to 20% of the total catch (Quinn et al. 1983). The leading port continued to move farther from the market place, with Kodiak becoming the leading port in the 1980s, processing between 18% and 28% of the yearly halibut catch. As the ports changed in importance as unloading sites, so did their relative importance to the sampling program.

New sampling ports were added when it appeared that all or part of a regulatory area was under-sampled. For example, King Cove was added in 1990 to increase the sampling coverage of Area 3B, while Ketchikan was added in 1991 to obtain samples from the southern portion of Area 2C. In other cases, ports were dropped, as Vancouver was for three years, because of the difficulty in obtaining otolith samples. Sampling goals sometimes varied as well; for instance, in all years but 1988, samplers were sent to Pelican to collect logbook data only. Otoliths and fishing logs from the Area 2A commercial Tribal halibut fisheries were collected at Neah Bay between 1987 and 1993, and at La Push, between 1991 and 1993. Otoliths and logbook data were collected in 1991 and 1992 by the Metlakatla Indian community during special fishing seasons within the Annette Island Reserve waters.

The ports processing Area 2A and Area 4 fish frequently changed in relative importance. In Area 2A, as many ports as realistically possible were sampled, although in some cases, the ports with samplers received only a small proportion of the total catch. Westport was staffed by port samplers from 1988 through 1991, although no landings occurred there in 1990. This illustrates one of the problems with Area 2A catch sampling; namely, it was difficult to predict which ports would receive the most fish, so occasionally samplers were sent to unproductive ports. Seattle and Bellingham varied in importance for this area between years, although otoliths were routinely collected for other regulatory areas in these two ports. Part of the difficulty sampling Area 2A lay in the fact that there were small catch limits, therefore a large portion of the catch had to be sampled intensively to obtain the number of otoliths needed for stock assessment.

Samplers lived in the ports for the summer fishing seasons from 1982 through 1984. The short fishing periods from 1985 to 1993 did not warrant the ports being staffed for the full season, therefore samplers were in ports to sample for the unloading period only. The samplers arrived the opening day of fishing and left after all vessels were unloaded, which took approximately one week. The lowest percentage of the total catch landed in the sampled ports occurred during the years when the transition was made from having samplers living in the ports in 1984 to short-term staffing of ports in 1985 (Table 1). The exception to short-term staffing in later years was Area 2B port coverage; 2B ports were staffed for the duration of the IVQ fisheries for 1991 through 1993.

There was a drawback to the short-term staffing of the ports. Occasionally, samplers left town prior to the arrival of all the vessels. This occurred in the ports in southeast Alaska where samplers left town prior to the arrival of all of the Area 3A vessels, which due to the longer travelling time from the grounds, often arrived in the southeast ports a day or 2 after all of the southeast vessels had offloaded. This "missed" poundage for each season was included in the calculation of percent of pounds into sampled ports (Table 1) because this poundage would have been sampled, had the samplers remained in the port. Bellingham and Seattle were exceptions, as pounds sampled were used in the calculation instead of pounds landed. The reason for this was that only specific trips were sampled in these two ports to meet otolith sampling rate targets in under-sampled regulatory areas.

The other change in port sampling between 1982 and 1993 was the increase in the number of samplers required to cover some of the ports. In the early 1980s, one or two persons were stationed in each port. With the fast pace of the short unloading periods in the mid-1980s to 1993, from one to ten people were needed to adequately cover a port.

Logbook Data Collection

The halibut fishery regulations from 1982 to 1993 required all operators of any vessel five net tons or greater to keep a fishing log and to make it available to IPHC employees or fisheries officers. Although logbooks are a legal requirement, the Commission obtains the logbook information on a voluntary basis assuming compulsory reporting could result in false records. Fishing logs contain information on date, locality, amount of gear used, and total weight of halibut taken daily in each locality. Although it was not a requirement, fishing log information was also collected from vessels smaller than five net tons. During the summer fishing seasons, samplers obtained fishing log data from as many captains as possible; generally between 80 to 100% of the captains in the port. Special emphasis was placed on collecting log data from trips that were sampled for otoliths, otherwise there was no selection or targeting of specific vessels for log data. At the beginning of the following year, all captains who had delivered more than 5,000 pounds, and had not given logbook information, were sent log forms with a request to complete and return them by mail. For areas with smaller catch limits (e.g., Area 2A), captains delivering less than 5,000 pounds were also sent log forms to complete.

From 1982 to 1993, the following information was collected: location fished, depth, type of gear fished, number of skates hauled, pounds of halibut caught, (or number of halibut caught), date of landing, buyer, and port of landing. The fishing location preferred was latitude/longitude or loran, but name locations were acceptable until 1993. In 1993, charts that partition fishing areas into 10 by 10 minute squares were used to pinpoint fishing areas as an alternative to place names.

In addition to the list above, from 1982 to 1986, information was also collected on average soak time, number of sublegal halibut caught, and the amount and type of bait used. These data were not collected after 1986, as only short soak times were possible during 1-day seasons, the number of sublegals caught was too subjective to give an accurate count, (e.g., "a lot" to one skipper could mean a "few" to another skipper), and the type of bait used had not changed in many years.

As the number of vessels increased in the fishery, some seasons were shortened to as few as one or two days. Some of the data collected changed as the fishery went from longer seasons to the "derby" style fishery. For the long fishing seasons, occurring from 1982 to 1986, the gear information was not collected during every interview. In 1982, gear information was only requested for the first trip of the year, as it was assumed that gear was constant throughout the year. From 1983 to 1986, gear information was collected at every interview or the information was edited onto the log from previous trips.

With the 1-day seasons spread between the spring and fall in the late 1980s, some fishers were using different gear types from one opening to the next. Therefore, in 1987, gear information was collected each time a log was taken. The short seasons resulted in fishers attempting to maximize the number of skates fished and, in some cases, setting more gear than they could haul. In 1987, the fishers were questioned on the amount of gear that was "lost" or "not retrieved". From this information an estimate of wastage was calculated and, starting in 1989, was included as one of the removals from the halibut biomass in the stock assessment. Also, with the large amounts of gear being set by a vessel during a fishing period, black cod and mixed types of gear were being fished. In 1989, the log form was changed to facilitate recording more than one gear type per vessel and the calculation of CPUE was modified to compensate for mixed gear. Also, data on hook size were collected and entered into the database. Information on hook sizes was not used in CPUE calculations, although the data are available for future studies.

Another change in gear during this period was the transition from J to circle hooks, which took place between 1982 and 1984. Since 1984, most vessels have used the circle hooks, although all captains are still asked what hook type is used. The quick transition between hook types is a reflection of the doubling in fishing power that accompanied it (Quinn et al. 1985).

The increase in the number of vessels landing halibut, along with increasing catch limits in the mid-1980s resulted in an increase in the data processing needs. There was insufficient time for editing and entering data in order to use it for stock assessment work. To overcome this, in 1989 the actual landing weight was added to the log form so CPUE could be calculated without requiring the computer to match the fish ticket to the log to get the landed weight.

Canadian logbook data collection changed dramatically in 1991 with the advent of the IVQ fishery. A joint logbook program was initiated with DFO which required the captains of all halibut vessels to mail in tear-out pages of the logbook to both IPHC and DFO. The logbooks were provided to the fishers when they received their halibut license from DFO. In ports with IPHC samplers, the sampler still interviewed the captains when possible to make sure the logbooks were filled out correctly and completely. The same data as previously listed were collected, with the addition of round-weight of other species (various rockfish, sablefish, cod, and salmon), the average soak time, and the amount of bait used for the trip. DFO requested the bait information so they could monitor the amount of bait used and adjust the number of bait permits issued accordingly. The other species catch data are to be used by DFO in their stock assessment of rockfish. IPHC did not use the other species catch in CPUE calculations or stock assessment of halibut, but it is present in the database for future use.

The logbook data collected from 1984 to 1993, accounted for 50% to 78% of the total coastwide catch in pounds (Table 2). All logbook data were used to assign fishing location to otolith samples and landing records but some information was incomplete and, therefore, unusable for CPUE calculations. CPUE data were collected from 31% to 87% of the catch depending on the year and the regulatory area (Table 3). CPUE data used for the stock assessment were only 14% to 57% of the catch. This difference between amount collected and used is due in part to the quantity of snap-on gear that was not incorporated into the stock assessment. The stock assessment used CPUE data from only fixed-hook gear in all the Alaskan regulatory areas, while in Area 2B, fixed hook gear only was used north of Vancouver Island but both snap-on and fixed hook gear were used in the southern areas and in Area 2A. CPUE from snap-on gear was not used in the northern parts of the coast as a correlation between snap-on and fixed hook gear was not available. The goal in the future is to incorporate all snap-on gear records directly into the CPUE calculations in the stock assessments.

Over the years, special projects were undertaken to collect data to answer specific questions posed by IPHC or other fishery agencies (Table 4). These data were entered into the IPHC computer database or summarized and/or forwarded to other agencies.

Table 2. **The logbook data (representing actual weight of landings) collected as a percent of the total coastwide catch by year.**

Year	Logbook data as a percent of total catch
1984	64
1985	50
1986	75
1987	74
1988	66
1989	74
1990	71
1991	70
1992	77
1993	78

Table 3. **The percent of catch (pounds) by regulatory area for which CPUE data were collected and CPUE data were used in stock assessment calculations, range for 1984 to 1992.**

Regulatory Area	CPUE data collected, as a percent of catch	CPUE data used, as a percent of catch
2A	31 - 55	31 - 55
2B	51 - 87	16 - 26
2C	39 - 53	14 - 28
3A	63 - 76	28 - 49
3B	46 - 69	31 - 55
4	47 - 78	40 - 57

Table 4. Additional data collected during logbook interviews between 1982 and 1993.

Data Collected	Years	Description of questions & Location of questioning	In computer	Conclusion
Light Sticks	1986	How many used per skate. Captain's opinion of effectiveness. All areas.	No	Light sticks were not used enough to effect CPUE data.
Crucifiers	1986	Was a crucifier used. All areas.	No	A vessel charter was initiated to further study crucifiers.
Prospecting	1987	Location, depth, number of skates hauled and pounds of halibut. All areas.	Yes	Amount varied greatly, reliability suspect therefore data not analyzed.
Halibut Bycatch in Black Cod Fishery	1988	Location fished for black cod. How much halibut was caught (to the nearest 2,000 pounds). Five ports.	No	Halibut bycatch in sablefish fishery, not as low as foreign bycatch rate, not as high as domestic observer program bycatch rates[a].
Bycatch of Rockfish	1988	Amount discarded of Yelloweye and other rockfish. SE Alaska.	No	Data given to ADF&G.
Bycatch of Rockfish	1991-1993	Amount of rockfish caught and amount sold. SE Alaska.	No	Data given to ADF&G.

[a] Williams, G.H. and R.J. Trumble. Unpub. Results of an IPHC field program to estimate halibut bycatch in the U.S. longline sablefish fishery. Int. Pac. Halibut Comm. Stock Assessment Document II: 1989:57-61.

Otolith Collection

Number of Otoliths Collected, Weighed, and Aged

The sampling of the commercial catch from 1982 to 1993 was accomplished by setting target numbers for otolith collection by geographical areas, either IPHC regulatory areas (Figure 1) or International North Pacific Fisheries Commission (INPFC) regions (Figure 2). Area 4 was considered a single area when regulatory areas were used for otolith targets.

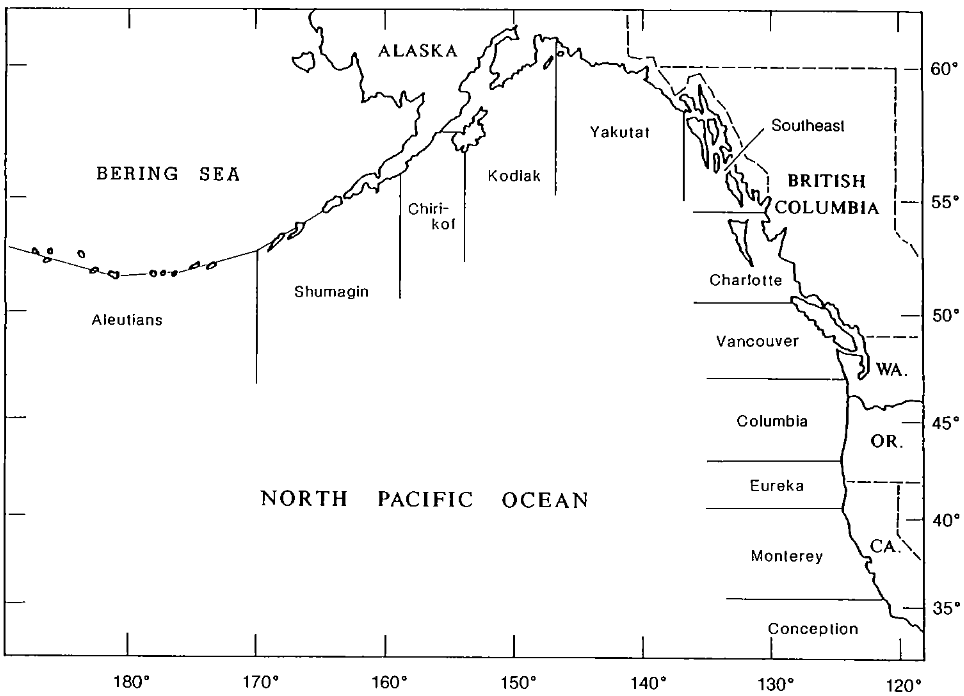

Figure 2. International North Pacific Fisheries Commission Regions.

From 1982 to 1986, catch sampling followed the procedures outlined by Quinn et al. (1983). Whole "slings" (the large cargo nets used to unload halibut at most plants, which hold about 1,000 pounds) of halibut were sampled and large numbers of otoliths were collected and individually weighed. Fish lengths were estimated from the otolith weights, and a proportional subsample of otoliths from each length interval was aged to estimate an age composition for each time-area stratum. A time-area stratum was one month in one INPFC area.

Quinn et al. (1983) calculated the coefficient of variation of the individual age composition estimates that resulted from age subsamples of varying sizes. They considered a number of criteria for choosing a subsample size and in the end, recommended a minimum of 250 and a target of 600-700 aged otoliths per stratum. The target sample size assured that at least one estimated age proportion would have a coefficient of variation of 10% or less, and that all ages making up 5% or more of the catch would be estimated with a coefficient of variation of 20% or less.

Beginning in 1987, otolith targets were set by IPHC regulatory area rather than

INPFC area, and stratification by time was dropped. The objective was to estimate the age composition of the landings for a whole regulatory area for the entire year. Smith (Unpub.)[1] calculated the variance of a population biomass estimate obtained from cohort analysis when the age composition was estimated by subsampling the otolith size distribution, as was the case at IPHC. He also considered the effect of random aging error on the variance of the estimates, and whether it was worthwhile to perform two or more independent readings of each otolith and decide on a single resolved age, like IPHC was doing. His findings were:

(i) Even optimal subsampling provided only a slight increase in precision over simple random sampling. In other words, for the same total expenditure one could achieve almost the same precision by simply collecting a random sample of otoliths and aging all of them, as by collecting a (somewhat larger) random sample, weighing them, and then aging an optimally chosen subsample. The reason was that otolith weight was a poor predictor of age. As a result of this finding, subsampling was discontinued.

(ii) There was little gain in precision beyond a sample size of a few thousand otoliths. While picking a point on the graph of precision versus sample size was somewhat arbitrary, Smith stated there was little point in spending more than $5,000 on port sampling when the full cost of collecting, weighing, and aging an otolith was a little over a dollar. On the basis of this recommendation, and other considerations, targets of 5,000 otoliths per regulatory area were adopted in 1987, 4,000 in 1988, and 3,000 in 1989. (However, Smith's results would have supported a much smaller recommended target about as well.)

(iii) At the recommended sample size, double readings of otoliths increased the precision of the population estimate by about 10%. On the basis of this finding, double readings were continued. (Smith estimated the age misclassification matrix and incorporated it into the formula for the variance of the population estimate to represent single readings of otoliths. He treated double readings, once reconciled, as being true ages. He then worked out optimal allocations of sampling effort for each variance formula, and found that double readings allowed about a 10% reduction in the standard deviation of the population estimate, This certainly overstates the gain, because double readings do not always yield the true age, or even the same age.)

In 1990, a Monte Carlo study was carried out by Clark and Vienneau (Unpub.)[2] to see whether otolith sample size could be further reduced and double reading discontinued without significantly reducing the precision of the age composition estimate.

By this time a sample was drawn by taking a fixed proportion by weight of as many landings as possible (e.g. 1% or 2% or 4%). The effect of different sample sizes was determined by resampling the 1988 age data from each regulatory area at a range of sampling rates, chosen to achieve a corresponding range of sample sizes from 500 to

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[1] Smith, P.J. Unpub. Optimal Two Phase Sampling For Estimating The Exploitable Biomass Of Halibut Accounting For Nonsampling Errors. Int. Pac. Halibut Comm. Stock Assessment Document II: Research Results, 1987: 1-10.

[2] Clark, W.G. and B. Vienneau. Unpub. Evaluation of Otolith Sample Size and Double Reading. Int. Pac. Halibut Comm. Report of Commission Activities 1991: 227-231.

4,000 otoliths per regulatory area. The 1988 data were appropriate for this purpose because in 1988 the sample was drawn by taking a whole sling (or two) from each sampled trip, resulting in typically twenty or more otoliths from each sampled landing. This data set was treated as the true age distribution of an infinite population of otoliths, clustered by landing.

Given a target sample size (e.g., 4,000 otoliths) and the corresponding sampling rate (e.g., 1.6%), each trial consisted of choosing landings randomly with replacement from the data until the total weight of those landings reached the amount that was actually sampled in the ports (25-35% of the total in each regulatory area). Within each sampled landing, otoliths were drawn randomly with replacement until the weight of the sample reached the target proportion of the weight of the landing. The age composition of the otoliths drawn from all landings in the simulated sample was then taken as one observation from the distribution of the age composition estimates at that target sample size.

For each target sample size and each regulatory area 10,000 trials were carried out to determine the variance of the estimated proportion of the catch at each age. The entire simulation was run twice, once using the "resolved" ages based on two or more readings, and once using one of the independent readings chosen at random. The aim was to see whether double reading provided any increase in precision.

The results were very similar for all regulatory areas when the resolved ages were used. Taking Area 2B as an example (Figure 3), a sample of 500 otoliths produced estimated proportions at age with coefficients of variation (standard deviation of the estimate divided by the true value) of about 10% for ages 8 to 12, which are the most abundant ages by far. Increasing the sample size to 2,000 reduced those coefficients of variation to about 7%. A further doubling of the sample size to 4,000 hardly reduced the coefficients except at the older ages, and the improvement was not great there. On the basis of these results it was decided to lower the sample size to 2,000 otoliths in all areas. For practical reasons (cost and number of personnel needed) the target for Area 2A was set at 1,000 otoliths.

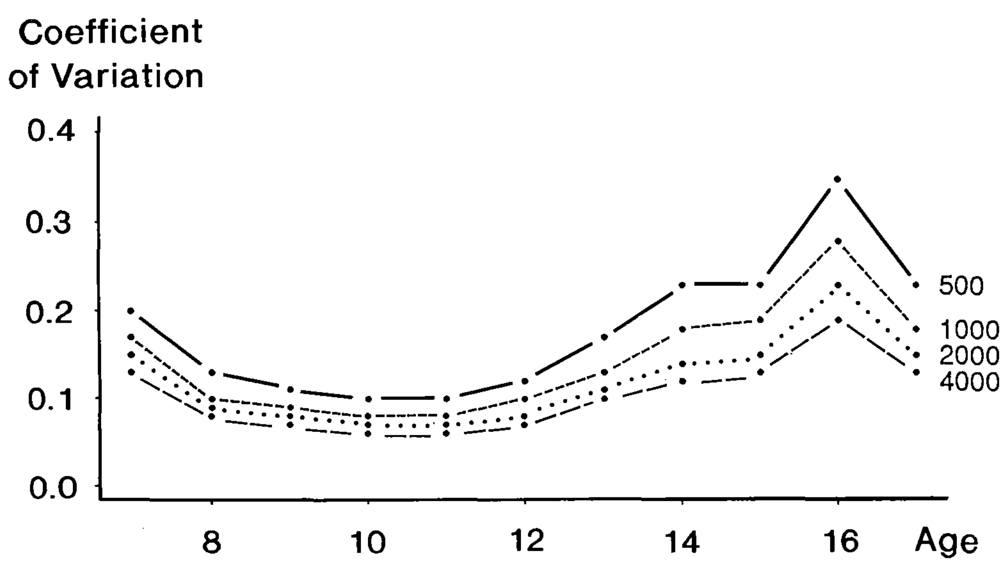

Figure 3. **Coefficient of variation of estimated proportion at age, by market sample size, based on data from Area 2B.**

Using one of the independent age readings instead of the resolved age had no effect on the precision of the estimates (Figure 4). In fact, the results indicated that the independent readings produced slightly more precise estimates than the resolved ages, but this was a quirk of the sample data. The important conclusion was that there was no practical difference in precision between age composition estimates based on single readings and those based on resolved readings. As a result of this finding, double readings were discontinued.

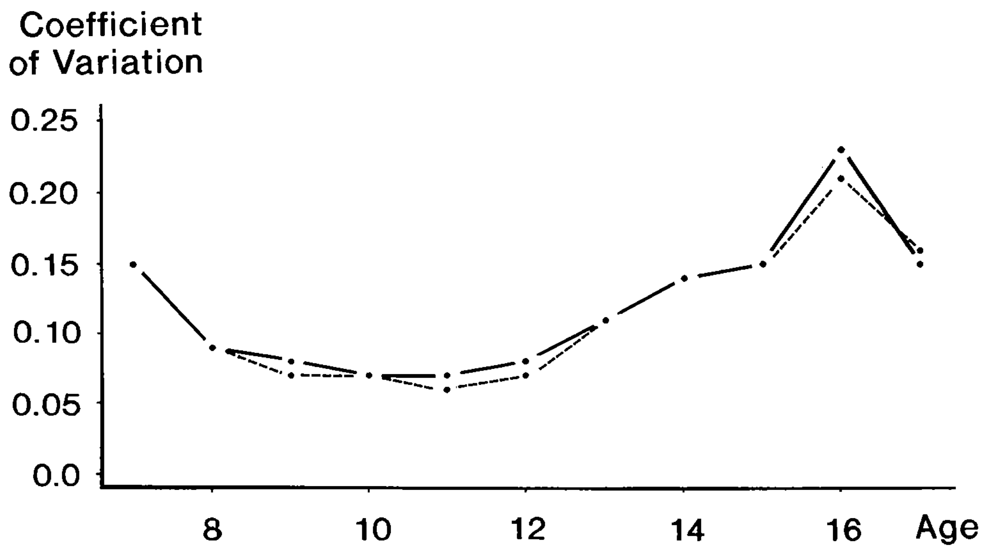

Figure 4. **Coefficient of variation of estimated proportion of age, for resolved readings (solid line) and single readings (broken line), based on data from Area 2B. Market sample size = 2,000 otoliths.**

The number of otoliths collected, weighed, and aged varied over the years as the target sample sizes to be collected and aged changed. From 1988 to 1993, subsampling took place either in the field or at the lab prior to weighing so the actual number collected for these years is unknown. The number of otoliths aged for each regulatory area from 1982 to 1993 are shown in Table 5, as well as the number of otoliths collected each year from 1982 to 1987, and the target otolith sample size for 1988 to 1993.

<u>Sampling Methods</u>

The goal from 1982 to 1985 was to obtain a proportional sample for each port where samples were collected. This sampling method was designed in 1980 to obtain a representative set of samples for a month-region stratum (Quinn et al. 1983). In each port, the target was to sample 1/3 of vessels with a trip size $\geq$ 5000 lbs and 1/9 of vessels with a trip size < 5000 lbs over the fishing season (except for Regulatory Area 4, where an attempt was made to sample as many vessels as possible). To accomplish this, initially a higher rate (> 1/3) of vessels was sampled. This compensated for the vessels that were missed as a large number of vessels landed concurrently after the closure of the fishing

Table 5. The number of otoliths collected or the otolith target and the number aged by regulatory area for 1982-1993.

Year	2A	2B	2C	3A	3B	4	Total	2A	2B	2C	3A	3B	4	Total
	NUMBER COLLECTED							NUMBER AGED						
1982	149	7,917	1,968	7,675	3,604	2,730	24,043	149	3,798	1,133	2,248	978	1,160	9,466
1983	284	5,297	2,291	7,075	3,480	4,920	23,347	284	2,139	1,202	1,201	1,725	2,591	9,142
1984	881	11,163	1,958	5,951	1,560	3,990	25,856	881	2,357	1,119	1,710	1,384	2,723	10,174
1985	894	10,115	3,499	7,484	3,575	4,845	30,590	894	2,867	2,399	2,310	1,922	2,538	12,930
1986	2,843	5,696	3,504	10,311	2,765	5,641	30,805	1,554	1,657	2,347	2,392	1,631	2,769	12,350
1987	216	5,399	4,556	5,501	2,934	1,718	20,324	216	4,266	3,415	4,151	2,299	1,547	15,894
	OTOLITH TARGET							NUMBER AGED						
1988	4,000		4,000	4,000	4,000		16,000	657	3,645	4,053	4,151	2,377	2,072	16,955
1989	3,000		3,000	3,000	3,000		12,000	819	3,095	2,903	4,132	1,655	1,586	14,190
1990	2,000	2,000	2,000	2,000	2,000	2,000	12,000	1,385	3,581	1,669	2,441	2,849	2,872	14,797
1991	1,000	2,000	2,000	2,000	2,000	2,000	11,000	976	2,390	2,033	2,691	2,998	2,236	13,324
1992	1,000	2,000	2,000	2,000	2,000	2,000	11,000	845	3,731	2,517	2,594	2,131	2,743	14,561
1993	1,000	2,000	2,000	2,000	2,000	2,000	11,000	1,030	3,167	1,797	2,728	2,543	2,491	13,756

period. During these years, full slings were sampled. The sling sampling rates were set by trip size categories: 1/2 of the slings for vessels landing 1,000 to 4,999 pounds and 1/6 of the slings for vessels landing over 5,000 pounds. Vessels landing less than 1,000 pounds were not sampled.

As the fishing seasons shortened, it was not possible to sample 1/3 of the vessels with the manpower available. Therefore, in 1986 as many vessels as possible were sampled. As a result of using sling sampling rates similar to those used from 1982 to 1985 and in combination with sampling fewer vessels, large numbers of otoliths were taken from very few vessels and only a small percentage of the total catch was sampled (Table 6). The procedure of systematic sling sampling throughout the landing process produced uniform sampling rates for all trip sizes from all areas, but the goal of representative sampling of strata was not achieved (Quinn et al. 1983, Clark et al. 1995).

Table 6. The percent of the total catch (pounds) sampled* for age composition by regulatory area, 1982-1993.

Year	Area 2A	Area 2B	Area 2C	Area 3A	Area 3B	Area 4	Total
1982	3	22	10	17	17	30	18
1983	6	18	9	13	17	31	16
1984	13	19	7	9	7	32	12
1985	6	15	7	9	8	17	10
1986	20	9	6	9	9	18	9
1987	13	25	18	24	19	21	22
1988	35	16	11	12	15	21	14
1989	26	23	12	18	17	26	19
1990	22	44	25	25	37	25	29
1991	38	48	22	24	29	21	28
1992	35	68	24	27	24	25	31
1993	37	63	25	29	26	29	34

$$* \left(\frac{Total\ Weight\ of\ Sampled\ Trips}{Total\ Weight\ of\ Total\ Landings} \right) x100\ (by\ area)$$

In 1987, the objective was to sample the vessels in proportion to the distribution of landed weight, and to sample a greater number of vessels and take fewer otoliths per vessel. Each port was given an otolith quota for each opening. The otolith quotas were set

by distributing the yearly target in proportion to the predicted landings for the opening and port. The otolith quotas were calculated as follows:
(1) Opening otolith requirement:

$$Oto_{Op} = \frac{C_{T,Op}}{C_T} \; x \; Oto_{year}$$

Where:

Opening otolith requirement = Oto_{Op}
Estimated total catch for opening = $C_{T,Op}$
Total catch (catch limit for year) = C_T
Yearly otolith quota = Oto_{year}

(2) Port otolith quota:

$$Oto_{port} = C_{port} \; x \; \frac{Oto_{Op}}{C_{T,Op}}$$

Where:

Port otolith quota = Oto_{port}
Estimated poundage landed in port = C_{port}
Opening otolith requirement = Oto_{Op}
Estimated total catch for opening = $C_{T,Op}$

To accomplish sampling more vessels and taking fewer otoliths per vessel, systematic sling sampling of each vessel was discontinued. Instead, a sample was generally one sling of fish taken at a given location and/or at a given time (spot sampling). This was an attempted to sample the vessels in proportion to the landing patterns. Also, attempts were made to sample at more unloading locations or fish plants than in the previous year.

Samplers collected otoliths at different unloading sites in a port on a set schedule (time based) and, larger trips, which took longer to unload, were sometimes still unloading when the samplers returned and were thus sampled more than once. In 1987, multiple samples were taken from some trips, but the whole vessel catch weight was recorded for each sample in the computer data files; therefore caution must be used in calculating total pounds sampled for this year. In all subsequent years, all otoliths from a trip were treated as a single sample, even though the otoliths from each sampling stop were placed in separate vials in the field.

The problem with this new method of otolith quotas for a given port and regulatory area was that occasionally, samplers collected more otoliths than desired. When this occurred, the number of otoliths was reduced accordingly by subsampling back in the lab. The subsampling method used was as follows: for each regulatory area within each port, the target number of otoliths was divided by the number collected, and the resulting fraction was kept from each sample (e.g., if 900 otoliths were collected and the target number was 600, two of every three otoliths from each sample would be kept). All otoliths in a sample were removed from the vial and laid out in a line for subsampling, so that every otolith had an equal probability of being selected. Initially in 1988, the subsampling method was changed in an attempt to reduce the amount of time spent by lab staff on subsampling. Subsampling was accomplished by randomly selecting then discarding whole vials of otoliths. However, sometimes all otoliths from a trip would be discarded. Since one of the objectives of this sampling method was to sample a greater number of vessels, after the first fishing period of 1988, the 1987 line subsampling methods were resumed.

Spot sampling increased the number of vessels sampled, but undersampling or oversampling occurred if the port's predicted and actual landings did not match. Also, sampling stopped as soon as the otolith target was met, even if this occurred before all vessels in a port had delivered, possibly biasing the sample. Because of these shortcomings in the sampling program, the sampling method was changed in August of 1989. Also, the practice of sampling the entire sling of fish was discontinued. From mid-1989 to 1993, the sampling objectives were to collect otoliths from a sample of fish proportional in weight to the vessel's hailed weight, as well as to continue to maximize the number of vessels sampled, and to sample throughout the unloading period. The new goal was to sample between 25-35% of the total catch for each regulatory area (Table 6). Sampling rates were calculated for each regulatory area and for each port. For example, if 2,000 otoliths were needed in Area 2C, then 70,000 pounds of fish had to be sampled (2,000 x mean weight of 35 pounds). The overall sampling rate if one sampled the total catch would be .7% (70,000/10,000,000 pound catch limit). Not all the fish is landed in the sampled ports, therefore the sampling rates have to be calculated for sampled ports only. If 70% of the catch is landed in the sampled ports then the sampling rate for those ports would be 1% (.007/.7). Even with several samplers in a port, not all fish are available to sample. Thus, if only 45% of the catch is available, the sampling rate would be 2% (1/.45 rounded to the nearest .5%). In this example port, if a vessel landed 10,000 pounds, 200 pounds would be sampled. Since this method of sampling was less structured, the lead person in the port was responsible for the otolith collection whether he or she did it themselves or supervised others. Port by port, the sampling could be organized such that fish could be pulled off a line, (e.g., every 5th fish) until the goal weight of the sample was reached, or other methods of choosing unbiased, random samples of fish could be determined by the port leader. All otoliths collected were both weighed and aged, with the exception of the August Area 4 samples, in which case individual samples were subsampled to obtain the target number of otoliths for the estimated poundage of the trip.

Through the period from 1982 to 1991, some samples were taken from vessels using troll gear. Although these samples were aged, the ages were not used for age composition. In Area 2B, the IVQ system allowed fishers to retain incidental halibut caught while trolling for salmon. These trips were sampled at a higher rate (25%), while troll trips targeting halibut were sampled at the same rate as longline trips (2%). The extra samples taken from troll landings in Area 2B will be used to compare the age compositions of troll and longline caught halibut.

Otolith samples from Tribal commercial fisheries in Areas 2A and 2C were included in the age composition from 1991 to 1993, but earlier data were not used due to incomplete data and possible sampling bias.

Aging Criteria, Reader Comparison, and Otolith Measurements

Age determinations from 1982 through 1993 were made by surface reading of the otoliths following the criteria described in Quinn et al. (1983). All otoliths from the commercial catch samples were aged once by each of two readers ("double blind aging"), a third time if the first two ages disagreed, from 1983 through 1985 and from 1987 through 1989. In 1982 a few samples were aged twice, but double blind aging was not the routine procedure, as a new reader was being trained, and in 1986 there was only a single reader. {Note: there were 3 ages recorded for each otolith; the double blind ages (reader one and reader two) and a resolved age. The resolved age was the third independent age reading in cases where the first two ages disagreed.} If the double blind ages agreed, this age was entered in the "resolved age" column. Due to the time involved in processing and aging otoliths, the data used for the age composition in the current year contained only the first set of age readings. The age composition was updated in the following year using the resolved ages. From 1982 to 1987, estimates of fish length and weights (calculated from the corresponding otolith weights) were printed and available for the age readers. This was discontinued in 1988, as it was felt that fish lengths could influence the age interpretation, since there is a rough relationship of about 10 cm growth per year of age. Double blind readings were discontinued in 1990, although 20% of the otoliths were still read twice by a senior age reader for quality control purposes from 1990 through 1993. In addition, break and burn readings were performed by the senior age reader on otoliths from the 20% quality control sample when there was more than two years difference between the original and quality control ages, or when an otolith was too thick to provide a reliable surface age.

A comparison of age compositions will not necessarily detect between-reader variations or biases; (e.g., if one reader consistently ages higher or lower than another reader). Since the identity of the readers were not recorded in the database, between-reader comparisons of age determinations were not easy to obtain. In the future, a "reader ID" field will be added to the appropriate database tables to make such comparisons more straightforward.

The IPHC age department currently has three readers; two readers who have been aging since 1987 and perform the production readings, and a more experienced reader, the "tester", with 10+ years experience, who performs resolved or quality control readings. The current tester did production readings from 1983 through 1986, production and resolved readings from 1987 through 1989, and quality control readings from 1990 through 1993. We examined the double blind ages for the years 1987 through 1989 (these ages were determined by the 3 readers presently with IPHC) using the method of Kimura and Lyons (1991), which analyzes overall percentagreement, coefficient of variation (CV), and percentage plus and minus bias. Also, average percent error (APE) was calculated as in Beamish and Fournier (1981). The results are presented in Tables 7a-f.

I. Percentage Agreement = (number that agree/n)x100
where n = number otoliths aged

II. Coefficient of Variation (CV) = (SD/*mean*)x100
where *mean*=(tester age + reader age)/2

$$\text{SD (standard deviation)} = \sqrt{[(\text{tester age}-mean)^2 + (\text{reader age}-mean)^2]}$$

III. Between-reader bias = reader age - tester age

IV. Percentage Bias = [(reader age - tester age)/*mean*]x100

V. Average Percentage error is calculated as follows:

step 1): *Let* $X_j = \frac{1}{R}\sum_{i=1}^{R} X_{ij}$

where: R is the number of times the fish are aged;
and X_{ij} is the ith age determination of the jth fish,
and X_j is the average age calculated for the jth fish,

Then,

step 2) $\frac{1}{R}\sum_{i=1}^{R} \frac{|X_{ij} - X_j|}{X_j} x100$

is the average percentage error in aging the jth fish.

We also looked at one year of ages (Table 7g) where the double blind ages were produced by two readers (the current tester, and the former tester, now retired), as well as a set of duplicate readings (Table 7h) by the current tester (one of the double blind readings and the resolved reading).

The results show a "learning" curve in 1987 (Tables 7a-b), the year readers 1 and 2 were first trained; both readers 1 and 2 had about a 20% plus bias and about a 10% plus bias (e.g., both readers were over-aging). The percent agreements of readers 1 and 2 with the tester increased over the years 1987-1989 and the CV and APE's decreased, indicating an increase in precision (Tables 7c-f). In 1988, reader 1 had a slightly higher percent minus bias, while reader 2 had a slightly greater percent plus bias for 1987 through 1989. Total percent agreement (+/- 0 year) was between 50 and 70 percent for ages 6 through 15 for readers 1 and 2 for the first year, then between 60 and 90 for the next two years. Total agreement was lower for ages 16 and up for all three years (however, sample size for older fish is also considerably lower). Agreement within one year (+/- 1) was between 80 and 100 percent for all three years for ages 6 through 15. Total percent agreement of between 55 and 80% or agreement within one year for 80-95% of the readings is usual for halibut (Blood, Unpub.)[3]. Smith (Unpub.)[4] examined more than 80,000 initial and resolved readings made by the current tester and found that the initial readings agreed with the resolved reading 70% of the time, 25% of the readings differed by one year and 5% by more than one year. As indicated in Table 7g, the percent agreements, percent biases, CV's, and APE's of the current tester's ages versus the former tester's ages for 1985 are similar to those of readers 1 and 2 versus the current tester's. The results of the comparison of the current tester's first and resolved readings from 1987 follow the same trend (Table 7h).

The lack of strong biases and/or extreme fluctuations in biases from year to year, as well as consistently low CV's, support the decision to discontinue double blind aging of market sample otoliths.

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[3]Blood, C.L. Unpub. Guidelines for Surface Ageing of Pacific halibut. IPHC: 1993.

[4]Smith, P.J. Unpub. Optimal Two Phase Sampling For Estimating The Exploitable Biomass Of Halibut Accounting For Nonsamping Errors. Int. Pac. Halibut Comm. Stock Assessment Document II: Research Results, 1987:1-10.

Table 7. **Percentage agreement and aging biases between age readers.**

Table 7a. Tester vs Reader 1 (1987)

Tester Age	# Aged	Percentage Agreement +/- 1	+/- 0	CV	APE	Reader Deviation From Tester % -	% +	Bias From Tester Bias (Yr)	Bias(Yr)/ Ave.Age
4	1	0.0	0.0	38.6	27.3	0.0	100.0	3.00	54.5
5	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
6	20	90.0	50.0	7.2	5.1	0.0	50.0	0.70	10.2
7	233	87.6	48.9	6.2	4.4	2.1	48.9	0.64	8.1
8	596	92.3	66.1	3.6	2.6	3.7	30.2	0.37	4.1
9	885	90.8	64.9	3.4	2.4	6.0	29.2	0.33	3.2
10	1525	94.7	69.9	2.5	1.8	9.5	20.6	0.15	1.2
11	931	93.0	66.0	2.7	1.9	14.8	19.2	0.08	0.5
12	749	94.0	68.2	2.3	1.6	16.3	15.5	0.02	0.0
13	586	90.6	65.4	2.5	1.8	18.9	15.7	-0.06	-0.7
14	489	90.0	64.0	2.5	1.8	22.3	13.7	-0.14	-1.2
15	214	88.3	63.1	2.7	1.9	25.7	11.2	-0.23	-1.8
16	155	77.4	52.9	3.5	2.4	35.5	11.6	-0.41	-2.8
17	96	84.4	60.4	3.0	2.1	26.0	13.5	-0.32	-2.3
18	58	74.1	55.2	4.0	2.8	32.8	12.1	-0.55	-3.6
19	38	76.3	36.8	3.7	2.6	42.1	21.1	-0.34	-2.1
20	29	75.9	51.7	3.5	2.5	37.9	10.3	-0.66	-3.6
21	15	53.3	46.7	4.4	3.1	40.0	13.3	-0.73	-3.9
22	11	72.7	45.5	3.9	2.7	45.5	9.1	-0.45	-2.4
23	8	62.5	37.5	4.5	3.2	62.5	0.0	-1.38	-6.4
24	7	57.1	28.6	4.9	3.5	57.1	14.3	-1.00	-4.6
25	8	37.5	37.5	14.1	10.0	62.5	0.0	-3.75	-20.0
26	2	50.0	50.0	2.8	2.0	50.0	0.0	-1.00	-4.0
27	1	0.0	0.0	5.4	3.8	100.0	0.0	-2.00	-7.7
28	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
29	1	100.0	0.0	2.4	1.7	0.0	100.0	1.00	3.4
30	2	50.0	50.0	2.4	1.7	50.0	0.0	-1.00	-3.4
33	1	0.0	0.0	19.5	13.8	100.0	0.0	-8.00	-27.6

Percent Agreement (+/- 1) = 91.2 [n=4339]
Percent Agreement (+/- 0) = 65.1
Percent Minus Bias = 13.7 [n= 915]
Percent Plus Bias = 21.1 [n=1409]

Total CV = 3.0
Total APE = 2.1

Table 7b. Tester vs Reader 2 (1987)

Tester Age	# Aged	Percentage Agreement +/- 1	Percentage Agreement +/- 0	CV	APE	Reader Deviation From Tester % -	Reader Deviation From Tester % +	Bias From Tester Bias (Yr)	Bias From Tester Bias(Yr)/ Ave.Age
4	1	0.0	0.0	38.6	27.3	0.0	100.0	3.00	54.5
5	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
6	24	100.0	62.5	4.1	2.9	0.0	37.5	0.38	5.8
7	273	99.3	77.7	2.2	1.6	3.7	18.7	0.15	1.9
8	701	97.6	74.0	2.4	1.7	3.1	22.8	0.23	2.6
9	985	96.5	72.1	2.4	1.7	6.4	21.5	0.18	1.8
10	1729	96.8	72.6	2.2	1.5	7.6	19.8	0.13	1.1
11	1045	95.6	72.0	2.1	1.5	10.8	17.2	0.08	0.6
12	834	92.6	66.8	2.5	1.8	15.6	17.6	0.01	-0.1
13	634	91.8	62.5	2.6	1.8	15.6	21.9	0.10	0.6
14	541	93.2	64.5	2.3	1.6	18.9	16.6	-0.04	-0.5
15	233	91.4	63.5	2.3	1.6	19.7	16.7	-0.02	-0.3
16	181	84.0	56.9	3.4	2.4	26.0	17.1	-0.22	-1.7
17	105	84.8	52.4	2.8	2.0	28.6	19.0	-0.15	-1.1
18	72	73.6	47.2	3.9	2.8	36.1	16.7	-0.28	-1.9
19	42	83.3	61.9	2.7	1.9	16.7	21.4	0.05	0.0
20	31	80.6	48.7	2.7	1.9	22.6	29.0	0.06	0.1
21	17	94.1	47.1	2.2	1.6	23.5	29.4	-0.06	-0.4
22	11	72.7	45.5	4.4	3.1	45.5	9.1	-1.09	-5.4
23	10	70.0	40.0	4.6	3.3	30.0	30.0	-0.80	-4.0
24	8	87.5	62.5	2.3	1.7	25.0	12.5	-0.50	-2.3
25	6	83.3	50.0	1.9	1.4	50.0	0.0	-0.67	-2.7
26	2	0.0	0.0	10.1	7.2	50.0	50.0	-1.50	-6.9
27	1	100.0	0.0	2.7	1.9	100.0	0.0	-1.00	-3.8
28	1	0.0	0.0	10.9	7.7	100.0	0.0	-4.00	-15.4
29	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
30	2	100.0	50.0	1.2	0.8	50.0	0.0	-0.50	-1.7
33	1	0.0	0.0	22.3	15.8	100.0	0.0	-9.00	-31.6

Percent Agreement (+/- 1) = 94.4 [n=5174]
Percent Agreement (+/- 0) = 69.1
Percent Minus Bias = 11.4 [n= 855]
Percent Plus Bias = 19.5 [n=1463]

Total CV = 2.4
Total APE = 1.7

Table 7c. Tester vs Reader 1 (1988)

		Percentage Agreement				Reader Deviation From Tester		Bias From Tester	
Tester Age	# Aged	+/- 1	+/- 0	CV	APE	% -	% +	Bias (Yr)	Bias(Yr)/ Ave.Age
4	2	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
5	7	100.0	85.7	1.8	1.3	0.0	14.3	0.14	2.6
6	44	97.7	75.0	3.0	2.1	4.5	20.5	0.18	2.6
7	324	98.5	77.8	2.3	1.6	1.2	21.0	0.22	2.8
8	1174	98.3	78.8	2.0	1.4	4.3	17.0	0.15	1.6
9	1768	97.6	80.0	1.7	1.2	9.2	10.8	0.03	0.2
10	1676	97.4	72.8	2.1	1.5	15.4	11.8	-0.03	-0.5
11	2234	97.4	75.2	1.8	1.3	15.7	9.1	-0.07	-0.8
12	1200	95.3	67.4	2.3	1.6	23.4	9.2	-0.16	-1.5
13	770	91.7	64.0	2.6	1.8	25.8	10.1	-0.22	-1.9
14	600	89.7	62.5	2.6	1.9	30.0	7.5	-0.32	-2.5
15	440	88.6	60.9	2.6	1.9	30.5	8.6	-0.31	-2.3
16	191	84.3	62.8	2.8	2.0	28.3	8.9	-0.39	-2.7
17	134	85.8	53.0	3.0	2.1	38.8	8.2	-0.50	-3.2
18	90	83.3	53.3	2.8	2.0	34.4	12.2	-0.44	-2.7
19	62	83.9	67.7	2.3	1.6	27.4	4.8	-0.42	-2.4
20	44	65.9	43.2	4.2	3.0	50.0	6.8	-0.98	-5.3
21	26	88.5	61.5	2.0	1.4	34.6	3.8	-0.50	-2.5
22	17	82.4	70.6	2.4	1.7	17.6	11.8	-0.35	-1.9
23	9	88.9	77.8	1.4	1.0	11.1	11.1	-0.22	-1.1
24	10	80.0	60.0	1.8	1.3	30.0	10.0	-0.40	-1.8
25	4	75.0	50.0	4.6	3.3	25.0	25.0	-1.00	-4.6
26	8	50.0	37.5	5.1	3.6	37.5	25.0	-0.13	-1.0
27	2	100.0	50.0	1.3	0.9	50.0	0.0	-0.50	-1.9
28	3	66.7	66.7	3.6	2.6	33.3	0.0	-1.33	-5.1
29	4	75.0	25.0	3.8	2.7	50.0	25.0	-1.00	-3.7
30	2	50.0	50.0	3.7	2.6	50.0	0.0	-1.50	-5.3
31	1	100.0	0.0	2.3	1.6	100.0	0.0	-1.00	-3.3
34	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0

Percent Agreement (+/- 1) = 95.3 [n=7830]
Percent Agreement (+/- 0) = 72.2
Percent Minus Bias = 16.8 [n=1822]
Percent Plus Bias = 11.0 [n=1195]

Total CV = 2.1
Total APE = 1.5

Table 7d. Tester vs Reader 2 (1988)

		Percentage Agreement				Reader Deviation From Tester		Bias From Tester	
Tester Age	# Aged	+/- 1	+/- 0	CV	APE	% -	% +	Bias (Yr)	Bias(Yr)/ Ave.Age
4	3	100.0	66.7	6.7	4.8	33.3	0.0	-0.33	-9.5
5	1	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
6	42	97.6	88.1	1.6	1.1	2.4	9.5	0.10	1.3
7	316	99.7	86.7	1.3	0.9	.3	13.0	0.13	1.7
8	1192	98.5	88.5	1.1	0.8	1.4	10.1	0.10	1.2
9	1769	98.9	86.8	1.1	0.8	2.8	10.4	0.09	0.9
10	1657	98.7	80.5	1.4	1.0	4.5	15.0	0.12	1.0
11	2350	98.6	82.7	1.2	0.8	5.3	12.0	0.08	0.6
12	1273	97.7	78.4	1.4	1.0	8.9	12.7	0.05	0.3
13	896	96.4	74.8	1.6	1.1	9.7	15.5	0.08	0.5
14	720	96.9	74.6	1.4	1.0	9.7	15.7	0.08	0.4
15	533	95.5	73.7	1.5	1.1	12.9	13.3	0.01	0.0
16	277	93.1	69.7	1.7	1.2	13.4	17.0	0.04	0.1
17	172	89.5	69.2	1.9	1.3	20.3	10.5	-0.16	-1.1
18	151	94.0	68.2	1.7	1.2	23.8	7.9	-0.25	-1.5
19	85	90.6	70.6	1.7	1.2	17.6	11.8	-0.11	-0.7
20	65	78.5	44.6	3.0	2.2	38.5	16.9	-0.46	-2.5
21	51	70.6	39.2	3.4	2.4	39.2	21.6	-0.39	-2.1
22	24	70.8	45.8	3.7	2.6	45.8	8.3	-0.83	-4.1
23	17	82.4	58.8	2.3	1.6	11.8	29.4	0.18	0.6
24	17	82.4	52.9	1.9	1.3	17.6	29.4	0.18	0.6
25	13	92.3	69.2	1.1	0.8	23.1	7.7	-0.23	-1.0
26	9	100.0	66.7	0.9	0.6	22.2	11.1	-0.11	-0.5
27	8	50.0	37.5	5.6	3.9	50.0	12.5	-1.25	-5.2
28	4	100.0	75.0	0.6	0.4	0.0	25.0	0.25	0.9
29	2	50.0	0.0	5.8	4.1	50.0	50.0	1.50	4.7
30	5	60.0	40.0	6.9	4.8	60.0	0.0	-2.60	-9.7
31	4	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
34	2	50.0	50.0	3.3	2.3	50.0	0.0	-1.50	-4.6

Percent Agreement (+/- 1) = 97.4 [n=9363]
Percent Agreement (+/- 0) = 80.3
Percent Minus Bias = 6.9 [n= 806]
Percent Plus Bias = 12.8 [n=1489]

Total CV = 1.4
Total APE = 1.0

Table 7e. Tester vs Reader 1 (1989)

		Percentage Agreement				Reader Deviation From Tester		Bias From Tester	
Tester Age	# Aged	+/- 1	+/- 0	CV	APE	% -	% +	Bias (Yr)	Bias(Yr)/ Ave.Age
3	1	0.0	0.0	35.4	25.0	0.0	100.0	2.00	50.0
4	1	0.0	0.0	28.3	20.0	0.0	100.0	2.00	40.0
5	17	94.1	58.8	5.9	4.2	0.0	41.2	0.47	8.4
6	86	95.3	79.1	2.9	2.0	2.3	18.6	0.22	3.2
7	246	96.7	79.7	2.3	1.6	4.5	15.9	0.15	1.8
8	879	97.6	83.8	1.6	1.1	3.0	13.2	0.13	1.5
9	2050	97.9	83.4	1.5	1.0	4.7	11.9	0.10	0.9
10	2280	96.2	81.1	1.6	1.1	6.8	12.1	0.08	0.7
11	1852	96.2	77.6	1.7	1.2	10.4	11.9	0.03	0.2
12	2250	96.6	79.0	1.5	1.0	11.6	9.4	-0.02	-0.3
13	1124	92.8	74.2	1.9	1.3	15.1	10.7	-0.05	-0.6
14	753	91.8	69.7	2.1	1.5	18.1	12.2	-0.09	-0.8
15	598	91.8	66.1	2.2	1.5	22.4	11.5	-0.16	-1.2
16	419	88.8	70.2	2.0	1.4	21.0	8.8	-0.23	-1.6
17	208	82.2	54.8	2.9	2.1	32.7	12.5	-0.34	-2.2
18	155	85.8	61.9	2.4	1.7	24.5	13.5	-0.18	-1.2
19	82	92.7	72.0	2.0	1.4	19.5	8.5	-0.28	-1.8
20	69	81.2	62.3	2.5	1.8	30.4	7.2	-0.51	-2.8
21	32	59.4	43.8	4.4	3.1	37.5	18.8	-0.50	-2.8
22	24	70.8	50.0	2.9	2.1	33.3	16.7	-0.46	-2.3
23	18	66.7	44.4	3.0	2.1	33.3	22.2	-0.28	-1.4
24	8	62.5	50.0	2.7	1.9	50.0	0.0	-0.88	-3.8
25	3	33.3	0.0	10.3	7.3	100.0	0.0	-3.33	-14.6
26	3	66.7	66.7	1.7	1.2	0.0	33.3	0.67	2.5
27	2	0.0	0.0	9.9	7.0	100.0	0.0	-3.50	-14.1
28	2	100.0	50.0	1.3	0.9	50.0	0.0	-0.50	-1.8
29	3	100.0	0.0	2.5	1.8	100.0	0.0	-1.00	-3.5
31	3	100.0	33.3	1.5	1.1	0.0	66.7	0.67	2.1
33	1	0.0	0.0	4.4	3.1	100.0	0.0	-2.00	-6.3

Percent Agreement (+/- 1) = 95.0 [n=10187]
Percent Agreement (+/- 0) = 77.4
Percent Minus Bias = 11.0 [n= 1454]
Percent Plus Bias = 11.6 [n= 1528]

Total CV = 1.8
Total APE = 1.2

Table 7f. Tester vs Reader 2 (1989)

		Percentage Agreement				Reader Deviation From Tester		Bias From Tester	
Tester Age	# Aged	+/- 1	+/- 0	CV	APE	% -	% +	Bias (Yr)	Bias(Yr)/ Ave.Age
3	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
4	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
5	17	100.0	88.2	1.5	1.1	0.0	11.8	0.12	2.1
6	80	100.0	91.3	1.0	0.7	3.8	5.0	0.01	0.1
7	229	99.1	88.2	1.2	0.9	3.1	8.7	0.07	0.8
8	772	97.9	87.0	1.3	0.9	1.7	11.3	0.12	1.4
9	1833	97.7	88.1	1.1	0.8	1.8	10.1	0.11	1.1
10	2175	97.4	85.7	1.2	0.8	2.7	11.6	0.11	1.0
11	1788	96.6	79.9	1.5	1.0	3.5	16.7	0.17	1.4
12	2131	97.4	85.9	1.0	0.7	4.2	9.9	0.08	0.6
13	1054	96.7	77.6	1.4	1.0	9.7	12.7	0.04	0.2
14	698	93.6	71.6	1.9	1.3	10.5	17.9	0.09	0.4
15	571	93.0	74.8	1.5	1.1	10.2	15.1	0.08	0.4
16	399	95.2	71.9	1.5	1.1	13.5	14.5	0.02	0.0
17	194	93.8	71.1	1.6	1.1	10.3	18.6	0.11	0.5
18	141	87.9	70.9	1.8	1.3	13.5	15.6	0.04	0.1
19	80	95.0	72.5	1.3	0.9	15.0	12.5	-0.09	-0.5
20	57	86.0	59.6	2.4	1.7	17.5	22.8	-0.12	-0.8
21	28	89.3	71.4	1.4	1.0	25.0	3.6	-0.32	-1.6
22	26	76.9	65.4	2.0	1.4	26.9	7.7	-0.38	-1.9
23	13	69.2	38.5	3.2	2.3	46.2	15.4	-0.69	-3.2
24	7	57.1	42.9	4.7	3.3	42.9	14.3	-0.43	-2.2
25	4	50.0	50.0	12.2	8.6	50.0	0.0	-3.50	-17.3
26	6	83.3	83.3	1.4	1.0	16.7	0.0	-0.50	-2.0
27	5	60.0	40.0	2.7	1.9	60.0	0.0	-1.00	-3.8
28	1	100.0	0.0	2.6	1.8	100.0	0.0	-1.00	-3.6
30	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
31	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
32	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
33	1	100.0	0.0	2.2	1.5	100.0	0.0	-1.00	-3.1

Percent Agreement (+/- 1) = 96.5 [n=10119]
Percent Agreement (+/- 0) = 82.2
Percent Minus Bias = 5.2 [n= 646]
Percent Plus Bias = 12. [n= 1550]

Total CV = 1.3
Total APE = 0.9

Table 7g. Former Tester vs Current Tester (1985)

Tester Age	# Aged	Percentage Agreement +/- 1	Percentage Agreement +/- 0	CV	APE	Reader Deviation From Tester % -	Reader Deviation From Tester % +	Bias From Tester Bias (Yr)	Bias From Tester Bias(Yr)/ Ave.Age
4	2	100.0	0.0	15.7	11.1	0.0	100.0	1.00	22.2
5	8	87.5	62.5	6.2	4.4	0.0	37.5	0.50	8.7
6	60	93.3	56.7	5.5	3.9	0.0	43.3	0.52	7.7
7	240	96.7	72.1	3.0	2.1	2.9	25.0	0.26	3.3
8	865	97.2	75.0	2.4	1.7	6.0	19.0	0.16	1.7
9	1119	96.5	68.1	2.8	2.0	13.1	18.8	0.08	0.6
10	1219	91.9	61.2	3.4	2.4	19.3	19.5	0.03	0.0
11	1146	91.7	54.0	3.6	2.5	23.3	22.7	-0.01	-0.4
12	1043	89.5	54.7	3.5	2.5	28.5	16.9	-0.16	-1.6
13	600	87.8	49.3	3.7	2.6	34.8	15.8	-0.25	-2.2
14	407	79.9	44.5	4.3	3.1	35.1	20.4	-0.29	-2.5
15	286	81.5	49.7	3.8	2.7	33.6	16.8	-0.28	-2.2
16	213	77.0	45.5	4.2	3.0	34.3	20.2	-0.31	-2.3
17	130	70.0	26.2	4.8	3.4	43.8	30.0	-0.32	-2.2
18	95	74.7	37.9	4.1	2.9	38.9	23.2	-0.37	-2.4
19	46	63.0	26.1	5.1	3.6	39.1	34.8	-0.33	-2.2
20	40	50.0	22.5	5.9	4.2	52.5	25.0	-0.65	-3.8
21	24	50.0	20.8	5.3	3.8	58.3	20.8	-0.71	-3.8
22	27	70.4	51.9	3.7	2.6	37.0	11.1	-0.52	-2.7
23	10	50.0	10.0	5.4	3.8	50.0	40.0	-0.50	-2.6
24	4	0.0	0.0	8.5	6.0	75.0	25.0	-1.75	-8.1
25	4	100.0	50.0	1.4	1.0	50.0	0.0	-0.50	-2.0
26	1	0.0	0.0	5.7	4.0	100.0	0.0	-2.00	-8.0
27	1	0.0	0.0	11.3	8.0	100.0	0.0	-4.00	-16.0
30	1	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0

Percent Agreement (+/- 1) = 89.9 [n=4388]
Percent Agreement (+/- 0) = 57.8
Percent Minus Bias = 22.3 [n=1695]
Percent Plus Bias = 19.9 [n=1508]

Total CV = 3.4
Total APE = 2.4

Table 7h. Current Tester Self-Test (1987)

Tester Age	# Aged	Percentage Agreement +/- 1	Percentage Agreement +/- 0	CV	APE	Reader Deviation From Tester % -	Reader Deviation From Tester % +	Bias From Tester Bias (Yr)	Bias From Tester Bias(Yr)/ Ave.Age
4	2	100.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0
5	3	100.0	66.7	4.3	3.0	0.0	33.3	0.33	6.1
6	42	92.9	81.0	3.1	2.2	2.4	16.7	0.26	3.6
7	292	96.2	83.6	2.0	1.4	1.0	15.4	0.20	2.5
8	550	95.3	83.1	1.9	1.3	3.5	13.5	0.17	1.8
9	632	95.4	79.0	2.0	1.4	4.3	16.8	0.17	1.6
10	871	95.6	82.3	1.6	1.1	5.3	12.4	0.10	0.8
11	503	96.0	76.3	1.8	1.3	10.1	13.5	0.06	0.4
12	362	91.4	69.3	2.4	1.7	13.8	16.9	0.06	0.3
13	218	91.7	69.3	2.2	1.6	12.8	17.9	0.10	0.5
14	166	91.6	74.1	1.9	1.3	10.2	15.7	0.14	0.9
15	101	86.1	63.4	2.6	1.9	20.8	15.8	-0.06	-0.6
16	52	88.5	71.2	2.6	1.8	17.3	11.5	-0.21	-1.7
17	50	82.0	72.0	2.6	1.8	12.0	16.0	0.16	0.6
18	27	85.2	51.9	2.6	1.8	18.5	29.6	0.22	1.1
19	26	88.5	76.9	2.1	1.5	19.2	3.8	-0.31	-1.9
20	21	90.5	61.9	1.9	1.4	9.5	28.6	0.38	1.8
21	14	85.7	57.1	2.1	1.5	14.3	28.6	0.21	0.9
22	10	80.0	50.0	2.5	1.8	20.0	30.0	0.40	1.7
23	6	66.7	16.7	4.1	2.9	50.0	33.3	0.00	-0.2
24	5	80.0	60.0	2.8	1.9	0.0	40.0	1.00	3.9
25	6	66.7	50.0	3.5	2.5	50.0	0.0	-1.17	-5.0
27	4	50.0	25.0	10.0	7.0	50.0	25.0	-2.25	-10.5

Percent Agreement (+/- 1) = 94.0 [n=3069]
Percent Agreement (+/- 0) = 77.4
Percent Minus Bias = 7.6 [n= 302]
Percent Plus Bias = 14.9 [n= 592]

Total CV = 2.0
Total APE = 1.4

In an attempt to resolve at least one possible cause of age discrepancies between readers, in 1990 IPHC readers began noting the amount of edge growth and whether or not this edge growth was included in the count of annuli. Many of the commercial otolith samples are collected in May and June, and often the translucent or winter zone (the zones counted as annuli to determine age) has not yet been deposited, or is still in the process of forming on the otolith edge. There is a problem of deciding whether edge growth on a particular otolith is new (from the current spring or summer) or from the previous summer. As a general rule, IPHC readers have included the edge in the annulus count if the edge growth is greater than half the width of the previous opaque (summer) zone in fish older than 10 years, or almost the same width as the previous opaque zone in fish younger than 10 years. The edge is not counted in younger fish unless it is about the same width as the previous year's growth because young fish start their growth season earlier in the year when compared with older fish, and may already have close to half the previous year's width of new growth by late May or early June.

From 1982 through 1989, otolith lengths were measured on Starret dial calipers, recorded, and entered into the computer database along with the ages. In 1989, the dial calipers were replaced by a Mitutoyo digital micrometer and, in 1991, the micrometer was connected to the computer so that otolith lengths were recorded directly into the computer. The 1212 MP Sartorius balance used to weigh otoliths from 1982 through 1992 was also connected directly to the computer. However, since fork lengths replaced otolith weights for estimating fish weight, otolith weighing was discontinued after the 1992 season, as was the measuring of otolith lengths, which were used for a sexing project.

Processing and Storage

There were no major changes in the processing and storage of otoliths collected from the commercial landings from 1982 through 1993. Otoliths were placed in a 50% glycerin solution for clearing and permanent storage upon arrival in Seattle. From 1982 through 1990, otoliths from a given sample were placed in a vial with 50% glycerin in the field, then set out in trays in separate cells after weighing in the lab. In 1991, vials were replaced with "Medi-Set" pill boxes (each box with a lid and 28 separate cells) for collecting the otoliths in the field, in order to match each otolith with its corresponding fork length. Since the pill boxes cannot be sealed, samplers used one or two drops of 100% glycerin per cell (100% glycerin is very viscous, and does not leak from the pill boxes) to avoid the mess caused by leakage of 50% glycerin. Samples that were delivered to Seattle shortly after collection, at which time the 100% glycerin was replaced with 50% glycerin, had no problem with clearing. However, since Canadian samples were only sent to Seattle when there were several full boxes to mail, the otoliths were stored in 100% glycerin for up to two months, and these otoliths did not clear completely, even after soaking in 50% glycerin for several weeks. Therefore, Canadian samplers were instructed to cover the otoliths with 50% glycerin after the 1991 season.

After aging, otoliths are put away for permanent storage. Otoliths are stored in groups of about 25, one on top of the other, separated by individually labeled paper disks, in 1 cm diameter vials,. The vials are then stored in cardboard boxes in lots of 144. Glass vials sealed with corks were used from 1982 through mid-1988. In order to avoid possible breakage of the vials, plastic pop-top vials were used from late-1988 through 1993.

Port Evaluation

Quinn et al. (1983) recommended a yearly review of the sampling activities. When samplers lived in the ports, from 1981 through 1984, in-season monitoring was accomplished by mailed-daily information listings of the vessels landed and their catch information. Termination reports were completed at the end of the season by summer employees to recommend improvements to the program and to assist future samplers. The termination reports were reviewed by IPHC staff and assisted in the planning for the following year's program.

In 1986, reports on the sampling activities were completed by the port leads after each opening. The port summary form used in 1986 evolved into the form that was used from 1990 to 1993 (Figure 5). These reports provided data to evaluate the sampling program throughout the field season. They assisted in determining additional ports to sample, available pounds to be sampled in each port, and the number of people necessary to do an adequate job. Reports were also completed on the method used to collect the otoliths; this provided information to ensure that unbiased, random samples were continually taken.

PORT SUMMARY

Port:__________ Fishing Period:__________ Port Leader:__________

Number of Landings and WOW by Plant (and Packer)

Area Fished

Plant or Packer	#	WOW	#	WOW	Total #	Total WOW
Total						

Daily Breakdown of Landings, Logs, and Tags

Date						Total
Field Information						
Direct Landings						
# Boats < 1000						
# Boats > 1000						
Packers						
# Packers						
# of Logs (from current opening)						
lbs. < 1000						
lbs. > 1000						
Total Logs from previous opening						
# of Tags						
Personnel						
IPHC/Contract						
Locals						
Total #: people						

NOTE: REMEMBER TO ASK FOR DATES WHEN GETTING DEALER SUMMARIES!!
(over)

Daily Sampling Summary by Area

Date						Total
Area ____						
# of Samples						
# of Otoliths						
Hail of Samples						
Area ____						
# of Samples						
# of Otoliths						
Hail of Samples						

Tag Summary

Intially:
Total Hats:________Colour________
________Colour________

Remaining:
Total Hats:________Colour________
Total Hats:________Colour________

Tags redeemed:_______
Total hats given out: _______
Total "$5.00" rewards: _______
No. duplicate rewards: _______
Excuses why they don't balance??? ____________________

Administrative

Temporary Evaluation(s) submitted? Yes/No
Comments and\or recommendations for the next port schedule or port leader (attach page if necessary):

Complete form to the best of your ability (note if estimating)

Side (a) Side (b)

Figure 5. Port summary form completed from 1990 to 1993 by port leaders to assist in port evaluation.

Commencing in 1991, the Canadian samplers faxed weekly reports to the head office in Seattle on the port activities. At the end of each IVQ sampling season, the samplers summarized the sampling methods and made recommendations on how to improve the system.

RELATED STUDIES

Since 1982 the IPHC staff have conducted several research projects involving otoliths and aging. Most of these studies have been or will be published as separate works, but are described briefly in the following section:

Glycerin Absorption

Between 1962 and 1991, the IPHC used predictive relationships between otolith measurements and fish weight to estimate fish weight for sampled halibut from commercial landings. Because of the importance of otolith weight in the estimation of fish weight, a study was initiated to determine the effect of different handling procedures upon otolith weight. A solution of 50% glycerin and 50% water containing a small amount of thymol (5.5 g per gallon of 50% glycerin), an anti-bacterial and anti-fungal agent, is the clearing and storage medium for halibut otoliths. Otolith samples from the commercial fishery from 1982 to 1991 were immersed in 50% glycerin within the day of collection. Although the solution was drained off prior to the otoliths being transported back to Seattle, otoliths had already absorbed some glycerin, and cleared more completely when replaced in glycerin solution at the lab than otoliths kept dry after collection (such as tag recovery and research survey otoliths). The otolith weight-fish length relationship was developed using the weight of otoliths stored in a 50% glycerin solution from one month to many years.

Hay (Unpub.)[5] initiated the first study of the effect of wet and dry storage on otolith weight. Halibut otoliths were received from the field in two forms, air dried or stored in a glycerin solution. After weighing, all otoliths were placed in trays and covered with glycerin solution to clear for aging. Dry otoliths placed in glycerin increased significantly in weight over a 35 day period and appeared to be some time away from the saturation point. The weight loss for wet otoliths subject to air drying however, was not significant at any point over the 35 day period.

Bijsterveld (Unpub.)[6] performed three experiments to study the effects of different soak times in glycerin solution on otolith weight, the effects of different personnel and different balances on otolith weight, and methods of accelerating glycerin absorption. Samples were divided into six weight interval classes (100-699) of 100 mg each.

In the first experiment, 15 otoliths from each of the six weight interval classes were subjected to four different treatments with regard to storage solution and length of time soaked in glycerin:

1. Otoliths soaked in glycerin solution for one week in sealed vial, then glycerin drained off and otoliths resealed in vial with no solution for one more week, and finally soaked in glycerin for:

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[5]Hay, E. Unpub. IPHC: 1978.

[6]Bijsterveld, L. Unpub. Some Sources of Variability Due to Glycerin Absorption by Otoliths From Pacific Halibut (Hippoglossus stenolepis Schmidt). IPHC: 1980.

a) one day before weighing.

b) The same otoliths were returned to glycerin for another five days then weighed again.

2. Otoliths soaked in glycerin solution in sealed vial for two weeks then weighed.
3. Otoliths soaked in water overnight in sealed vial then weighed.
4. Otoliths soaked in glycerin solution for one week in sealed vial, then glycerin drained off and otoliths resealed in vial with no solution for one more week, then otoliths washed in soap and water before weighing.

All otoliths were dried off with paper towels before weighing. Bijsterveld found that all treatments except storage in water resulted in significant (a=0.05) weight gain. Weight gain was roughly equal between treatments 1a, 2 and 4. Otoliths subjected to treatment 1b (reweighed after an extra five days in glycerin) gained 40% more weight than otoliths subjected to treatments 1a, 2 and 4. The increase in otolith weight observed in treatment 1b was similar to that observed by Hay (1978), and Bijsterveld recommended further studies to find the "saturation" point of glycerin in otoliths.

In Bijsterveld's second experiment, dry otoliths were weighed by two people, one with three years experience and the other with no previous experience. Each person weighed the same sample twice on a 1212 MP Sartorius balance and a 350 DT Digimetric balance. Otolith weights were transformed to fish length (cm). Weight interval, the effect of the balances, weighing experience, and repeated trials were tested for significant differences by means of a four-way analysis of variance. Experience was treated as a random effect while balances and trials were treated as fixed effects (Winer 1962). No significant differences were found.

Four methods were used to determine if glycerin absorption could be accelerated and make the otoliths available for use in a shorter time. The treatment methods included room temperature, microwave, drying oven, and wetting solution (otoliths coated with dishwashing detergent then covered with 50% glycerin solution). Within each method, the original and transformed data were tested for significant differences using two-way analyses of variance (Winer 1962), with the weight interval and treatment as the two factors. All methods resulted in significant weight gain and there were also significant differences between methods. There were no significant differences between the original dry weights. Results indicated that otoliths stored in glycerin at room temperature for long periods of time absorb the greatest amount of glycerin. After six weeks in glycerin, it appeared the otoliths were still gaining weight.

Blood (Unpub.)[7] conducted two ten-week experiments on glycerin absorption and found that by week four, otolith weight gain stabilized at a level not significantly higher than that of week 1. In contrast, Price (Unpub.)[8] followed with a five week study and after testing with analysis of variance by weight, week, and weight class, no trends in weight change could be detected. The conclusion was that otoliths collected in the field could be weighed immediately upon receiving. However, the clearing of the otoliths prior to reading averaged about three weeks.

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[7]Blood, C.L. Unpub. IPHC: 1982.

[8]Price, R. Unpub. IPHC: 1984.

Age Validation

An age validation study was begun in 1982. Oxytetracycline hydrochloride (OTC) was injected interperitoneally into tagged halibut which were then released. OTC fluoresces under ultraviolet light revealing the "time-mark" of injection. Comparing the "time-mark" with the number of rings laid down during the time at large confirms or rejects the concept that one ring is equal to one year of growth. Analysis by Blood (Unpub.)[9] confirmed the annular relationship between age rings and time. Readers, however, tended to overestimate the time-at-large for tag recovered halibut. The apparent reason for this bias was due to the difficulty in determining the position of the OTC mark relative to the annulus for halibut injected during May, a time when the annulus is being formed and new growth is beginning. This, coupled with the fact that the band of fluorescence is diffused and appears wider than the annulus in some cases, made it difficult to discern on which side of the annulus the OTC mark was located in these halibut.

Automated Aging

The feasibility of automated aging of halibut otoliths was examined by Neal (1987). Age estimates were generated by a microcomputer-based digital imaging system and compared with ages determined by humans.

For each otolith, several parallel transects were sampled from the digitized image. A transect consisted of the luminance values or "gray levels" in a straight line from the nucleus to the edge of the otolith image. The "minima" or low luminance levels on the transect correspond not only to the dark hyaline zones or annuli of the otolith, but to cracks and false annuli or checks. "Smoothing" algorithms were performed on the transects to eliminate such checks. The transect minima were then counted and the average count for an otolith became its estimated age.

A "direct" ring counting method using transect minima counts yielded a classification agreement rate* of 71%, whereas an "indirect" method using transect counts along with size measurements (otolith weight, surface area, diameter, and perimeter length) yielded a classification agreement rate* of about 75%. (* plus or minus one year of resolved human age). Problems with both methods of automated aging were inclusion of false annuli and/or loss of true annuli in smoothing.

Neal and Forsberg (Unpub.)[10] attempted to improve on the results obtained by Neal (1987) by combining ring counts derived from a form of differential smoothing of the transect (to compensate for the fact that annuli are relatively widely spaced in the center of the otolith and more closely spaced towards the edge of the otolith) with other parameters in a feature vector. This feature vector contained the following information from 600 otoliths made up of four age groups (9-, 10-, 11-, and 12-year-olds):

1. Otolith weight
2. Number of minima (bands of low luminance levels) along transect

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[9] Blood, C.L. Unpub. Age Validation of Pacific halibut. IPHC. 1993

[10] Neal, P.R. and J.E. Forsberg. Unpub. A comparison of classifier systems for automated aging of halibut otoliths. Int. Pac. Halibut Comm. Report of Research and Assessment Activities 1991: 283-286.

3. Sum of the pixel counts from each minima found (corresponds to the sum of the width of the annuli)
4. Ratio of the number of minima to transect length
5. Ratio of the sum of the pixel counts from each minima to transect length
6. Transect length

These data were z-transformed and used as input to two different classification algorithms; classical linear discriminant function analysis or *LDFA*, using the DISCRIMINANT function in SPSSX version 3.1 (SPSS, 1988) and a back propagated *artificial neural net* (ANN), using the equations from Lippmann (1987). The LDFA correctly classified 47.5% * of the cases from the training data set and 43.5% * of the cases from the test data set. Otolith weight was the most important predictor variable for classification, followed by the sum of the pixel counts from each minima, the ratio of the number of minima to transect length, and finally, transect length.

The ANN produced successful classification rates of 59% * on the training data set but only 38% * on the test data set (* complete agreement with resolved human age). It was not possible to ascertain the impact each predictor variable had on the output from the ANN.

Results from both the LDFA and the ANN were better than chance alone. If the classification process was purely random, the classification rate should have been approximately 25%. The correct classification rates from the LDFA and ANN on the test data indicate that more accurate valley counts or some other information is necessary before high classification rates can be obtained. Future work will expand upon the single transect method to focus on the otolith as a whole. In particular, the incorporation of two-dimensional relationships in the predictor vector will be examined to see if they can lead to better classification success.

Estimating Sex Using Otolith Shape

This study (Forsberg and Neal 1993) was a continuation of work begun in 1990 in developing a method of sexing halibut from their otoliths. A "visual" method of sexing was employed in 1990 which relied on morphological features of otoliths that displayed some degree of sexual dimorphism (e.g., size, inter-annular spacing, thickness, and shape) to classify an otolith by sex. However, this method yielded relatively poor results in terms of successful classification by sex (69% to 77% correctly sexed), particularly in younger fish. It was thought that sex-related differences in these morphological features might still be present in younger otoliths, but are too subtle to detect with the naked eye.

Otolith shape is one feature that appears to differ between the sexes. Otoliths from males tend to be more elongate while those from females tend to have broad bases and narrower tips. Shape can also be quantified relatively easily and it was felt that subtle sex-related differences in shape could be detected mathematically. In an attempt to quantify and analyze the differences in shape, Fourier shape descriptors were obtained from digitized otolith images. The descriptors, with and without otolith weight, were used to classify otoliths by sex. The data was divided into training and test sets of various sizes for classification analysis. Successful classification rates ranged between 82.64% to 87.50% for the training sets and between 71.43% and 73.61% for the test sets when otolith weight was included in the analysis. When the descriptors alone were used, successful classification rates were 79.86% to 91.67% for the training sets and 63.89% to 65.31% for the test sets. Training set success rates were higher for males, a finding indicating somewhat higher variation in otolith shape among females. Given the results achieved in this study, otolith shape alone does not appear to be a reliable indicator of sex in Pacific halibut. However, if otolith shape information is used in conjunction with information on interannular spacing, sex discrimination may be improved to a level that could be of use in stock assessment.

SUMMARY AND FUTURE RESEARCH

In the 1980s, the halibut fishery changed considerable. The number of vessels landing halibut increased. Fishing periods were long (12 days) in the early years and short (1 day) in the later years. The commencement of an IVQ fishery in Canadian waters in 1991 changed the length of the halibut season from less than one week to seven months. In some instances, there was a lag time before the sampling procedures caught up with the fishery changes, but by 1993, the otolith and logbook data collection methods were appropriate. Otoliths were collected proportional to the hail weight of the vessel, and 25 - 35% of each regulatory areas catch were sampled. The logbook data collected were appropriate for short opening including collecting information on lost gear and allowing for more than one gear type.

In the future, snap-on gear will be incorporated into the stock assessment. As mentioned previously, in some regulatory areas a high proportion of the vessels fish with snap-on gear. For example, in the 1990 Area 2C fishery, the logbook data from snap-on gear represented 2.6 million pounds of the catch, compared to the 2.2 million pounds represented by fixed-hook gear. The incusion of snap-on gear will increase the percentage of the logbook data used to calculate CPUE.

When the planned Individual Fishery Quota (IFQ) is implemented in Alaska, the sampling methods used will change dramatically. Once again, people will be stationed in the ports throughout the season. It will be important to evaluate the sampling methods on a continual basis as the fishing patterns of vessels change and to continue to have the samplers recommend improvements to the program. If similar sampling methods are continued (e.g., partial sling samples), it will be extremely important to make sure the methods do not become biased or non-random over time. This could be accomplished by having the samplers summarize their sampling methods, say monthly, and by also having a supervisor visit the ports at random. Also, if non-target fishing (e.g., targeting species other than halibut, but still retaining halibut) becomes prevalent, those trips should be identified in order to make adjustments for CPUE calculations and possibly different otolith sampling rates.

Future otolith research will include the development of a method to compare readers' interpretations of annuli and monitoring reader "drift" (the possible tendency for a reader to change the way they determine ages over time). Even when two readers agree on an age in a double-blind reading, it cannot be assumed that they have "read" the same annuli, especially on older or cloudy otoliths (e.g., one reader may have counted the edge while another counted what the first reader considered to be a check). A Discussion Tube or dual-reader microscope is useful in resolving certain discrepancies and training new readers, but one reader may be influenced by the other's interpretation, and may accept or ignore a ring or rings that he/she normally would not. For this reason, the discussion tube is not the best tool to use in checking for reader bias and drift.

There is no permanent record of any particular age interpretation using either the discussion tube or double blind readings. A reader cannot replicate 100% of his or her own ages, let alone another reader's. In these cases of disagreement, whether with oneself or another reader, the reader(s) must be interpreting the growth patterns differently, and it may not be clear why, or where the discrepancy(s) occur(s). In 1990, IPHC age readers began noting their interpretations of the edge growth (e.g., whether or not the edge was included in the total annulus count or not), but even this procedure only has the potential to resolve discrepancies that occur at the edge.

To further study age discrepancies and to identify and monitor reader drift (if it occurs) IPHC age readers may utilize OPTIMAS ©(1987) image analysis software in the future. Images from a set of otoliths can be recorded and the readers can mark what they are calling annuli on the images. Marks can be removed and recalled to the screen as desired and could be compared between readers so that interpretations could be standardized. Images and corresponding marks for the different readers could be stored on video tape and used on an annual basis for monitoring reader drift or calibration for precision tests.

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APPENDIX

APPENDIX

Table 1. Vessel, landing, and general information collected as part of the logbook data collection, 1932 to 1981.

Data Collected	Years
Vessel name	1932 - 1981
Vessel number (state number)	1975 - 1981
Captain's name	1932 - 1981
Captain's address	1958 - 1981
Trip number for the year	1932 - 1979
Number of men	1932 - 1981
Bait: type, in comments	1958 - 1960
Bait: used, fresh or frozen herring, salmon, octopus, frozen cod, gurdy	1961 - 1981
Sighting of foreign vessels: date, nationality, number and type	1967 - 1973
Sighting of foreign vessels: interference (if any), lost gear due to it	1967 - 1979
Date copied	1943 - 1981
Copied by (sampler's initials)	1975 - 1981
Log source (written, verbal, other)	1975 - 1981
Plant, port, and date of sale	1975 - 1981
Future plans (regulatory areas, salmon, and other)	1975 - 1981

APPENDIX

Table 2. Catch and location information collected by fishing day as part of the logbook data collection, 1932 to 1981.

Data Collected	Years
Fishing dates	1932 - 1981
Number of day (e.g. 1, 2, 3, 4)	1961 - 1974
Fishing location from captain (place name, latitude/longitude, loran)	1932 - 1981
Depth (individual column in 1980-1981, other years with location)	1975 - 1981
Compass: NW, SE	1932 - 1957
Statistical Area (Dist.): edited in office	1932 - 1981
Skates hauled (gear run)	1932 - 1981
Skates hauled: actual and effective	1958 - 1959
Time set and hauled (little information)	1975 - 1980
Average soak time	1978 - 1981
Hail: total weight (pounds)	1932 - 1981
Hail: numbers of fish (found occasionally)	1940
Hail: catch by medium, large, chix (pounds)	1943 - 1944
Hail of other species: sablefish, rockfish, ling cod	1934, 1940, 1944
Reason code: edited in office for how to use information	1961 - 1981

APPENDIX

Table 3. The gear information collected during logbook data collection, 1932 to 1981.

Data Collected	Years
Groundline	1932 - 1942
Groundline: weight and kind (m)	1943 - 1979
Gangion	1932 - 1942
Gangion: weight and kind (hemp, cotton)	1943 - 1979
Hooks (large, medium)	1932 - 1942
Size of hooks	1943 - 1981
Rig (spacing of hooks)	1932 - 1981
Number of lines in a skate	1932 - 1979
Length of skate (feet)	1980 - 1981
Number of skates on vessel	1935 - 1979
Type of gear (conventional, snap)	1973 - 1974
Type of gear (conventional, troll, snap, other)	1975 - 1979
type of gear (conventional, troll, snap, tub, other)	1980 - 1981