

ISSN: 0579-3920

INTERNATIONAL PACIFIC HALIBUT COMMISSION

**ESTABLISHED BY A CONVENTION BETWEEN
CANADA AND THE UNITED STATES OF AMERICA**

Technical Report No. 46

**Aging manual for Pacific halibut:
procedures and methods used at the
International Pacific Halibut
Commission**

by

Joan E. Forsberg

**SEATTLE, WASHINGTON
2001**

The International Pacific Halibut Commission has three publications: Annual Reports (U.S. 0074-7238), Scientific Reports, and Technical Reports (U.S. ISSN 0579-3920). Until 1969, only one series was published (U.S. ISSN 0074-7426). The numbering of the original series has been continued with the Scientific Reports.

Commissioners

James Balsiger	Richard Beamish
Ralph Hoard	Kathleen Pearson
Andrew Scalzi	John Secord

Director

Bruce M. Leaman

Scientific Advisors

Loh-Lee Low
Max Stocker

INTERNATIONAL PACIFIC HALIBUT COMMISSION
P.O. BOX 95009
SEATTLE, WASHINGTON 98145-2009, U.S.A.
www.iphc.washington.edu

Aging manual for Pacific halibut: procedures and methods used at the International Pacific Halibut Commission

Joan E. Forsberg

Contents

Abstract.....	4
General background on otoliths and age determination	4
Halibut otolith collection and storage	7
Market Sample otoliths	9
Survey (“General Series”) otoliths	10
History of Pacific halibut age determination	11
Clearing	12
Aging Procedures	12
Surface	14
Break and Burn	14
Age ranges.....	18
Areas of difficulty	19
Accuracy, precision and quality control	41
Validation	41
Measuring precision	42
Historical protocol for precision testing	42
Current protocol and standards	44
Training	46
Exchanges	47
Current and Future Research	48
Marginal increment analysis (MIA).....	48
Right/left break and burn age comparison, right vs. left rate of crystallization and left otolith rates of crystallization by area	48
Consistency of application of criteria via computer images and software	48
Break and burn percentage agreement	48
Changes in assigned ages over time due to changes in application of criteria and equipment	48
Acknowledgements	49
References	49
Appendix I	51
Appendix II	53
Appendix III.....	54

Aging manual for Pacific halibut: procedures and methods used at the International Pacific Halibut Commission

Joan E. Forsberg

Abstract

Since its inception, the International Pacific Halibut Commission (IPHC) has collected Pacific halibut otoliths for use in age determination. This manual provides an overview of generalized age determination procedures for fish otoliths as well as detailing otolith preparation, storage, and aging techniques used at the IPHC.

General background on otoliths and age determination

In fisheries management or research, accurate age determinations for the fish species in question are critical for estimating growth and mortality rates as well as population age structure (Pentilla and Dery 1988, Chilton and Beamish 1982). Otoliths were first used for age determination by a researcher named Reibisch in 1899. Otoliths, also called “ear-bones” or “ear-stones”, are calcareous structures found in the head of most fish. All teleost fishes have three pairs of otoliths: the *asteriscae*, *lapillae* and *sagittae*. The sagittae are much larger in size than the other otoliths and are the pair most often used in age determination. Each sagittal otolith is enclosed in a fluid-filled sac called the *sacculus* within the otic capsule of the head. The otic capsules are situated on either side of the posterior portion of the brain. Otoliths are not true bone; they are acellular and avascular, unlike skeletal bone. Rather, otoliths are composed of calcium carbonate in the crystalline form of *aragonite*, in a protein matrix. Otoliths act as sound receptors and also play a role in balance and orientation. Otolith size and shape, particularly of the sagittae, varies greatly among species. Size and shape of the sagittae are related to their function, namely sound detection in the fish (Popper and Lu 2000).

As the fish grows, so does the otolith. The otolith begins as a very small spherical body in the ear of the larval fish and with the growth of the fish, increases in size by the deposition of concentric *lamellae* or layers of material around the outside. Deposition is much greater in two planes than in the third, producing a flattened structure in the adult (Fig. 1).

In addition, seasonal changes in the fish’s growth rate are reflected in the otolith. Material is deposited on the otolith from the *endolymph*, the fluid that surrounds the otolith. The deposits are formed in bands of alternating optical density, which appear either opaque or translucent under reflected light. The alternating zones on the otolith are due to differences in the amount of protein (called *otolin*) in the zones and shape of the aragonite crystals; aragonite crystals form longer and narrower at higher temperatures, shorter and

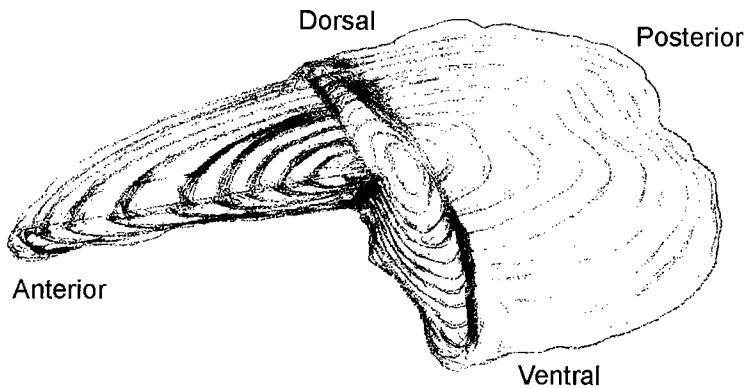


Figure 1. Cutaway three-dimensional illustration of a halibut otolith showing deposition of concentric lamellae.

wider at lower temperatures (Hagen 1997). A year's growth consists of both an opaque and translucent zone. The opaque zone is formed during the period of faster growth, which typically occurs in the summer and is made up of longer aragonite crystals. The translucent zone is formed during slower growth, which typically occurs in the winter, and is composed of shorter crystals of aragonite and contains comparatively more protein. The opaque and translucent zones are also often referred to as the summer and winter zones respectively. Winter-spawning fish such as halibut are assigned an arbitrary January 1 "birth date" by international convention. Therefore, the translucent or winter zones of halibut otoliths are counted to determine the age of the fish in years. The winter growth zones are also referred to as *annuli* (singular: *annulus*) or *hyaline zones*.

Within the opaque (summer) and translucent (winter) zones on the otolith are *daily rings*. Daily rings are, as the name implies, laid down daily and are composed of two alternating zones with different optical properties, as in annual zones. The differing appearances of the two zones in daily increments are due to the orientation of organic fibers in relation to the aragonite crystals and the relative widths of the zones. The alternating deposition of zones of different appearance and composition is related to both external (temperature, food, light, salinity, etc.) and internal (e.g., calcium metabolism and interaction of various hormone feedback systems) factors (Simkiss, 1974). Daily rings are only visible under high magnification and are not used in the production aging of Pacific halibut. In most species, daily rings are legible only through the first year. After the first year, daily growth rings are too compressed to differentiate. Weekly, bi-weekly and monthly patterns (as well as daily and annual) can also be seen in some species.

The otolith reflects growth rate changes over the years as well as seasons within a year. As the fish grows older, the relative width of the otolith zones decreases. In the first few years, otolith growth is rapid, resulting in broad opaque zones. As the fish ages, the opaque zones become narrower until they are almost the same width as the translucent zones.

Otolith terminology can be confusing; different agencies or researchers can use different terms for the same structures. The terms "opaque" and "translucent" are a particular problem, since the optical properties of these zones depend on whether illumination is reflected or transmitted. The opaque zone appears white under reflected light, but dark with transmitted light, since light doesn't pass through it. The translucent

zone appears dark under reflected light but since light passes through it, it appears bright with transmitted light. Since reflected light is used in Pacific halibut aging techniques, in this manual *translucent* refers to the zone of slow growth and *opaque* to the zone of faster growth. See glossary in Appendix I for complete list of terms.

Other hard structures in fish have similar alternating patterns caused by seasonal changes in growth rates and may be used for age determination along with or instead of otoliths. These other structures include vertebrae, scales, fin rays, opercular bones, and cleithra. Certain structures show growth patterns more clearly in a given species. One advantage to using otoliths is their stability. Scales can be lost and replaced; a regenerated scale has fewer annual rings than the total age of the fish. Moreover, calcium can be resorbed from scales and other calcareous deposits in the body under certain physiological conditions, resulting in the loss of some previously deposited growth rings. On the other hand, calcium is not resorbed from otoliths, so otoliths provide a “permanent” record of growth.

Some additional sources of information on general aging procedures are listed in Appendix II.

The International Pacific Halibut Commission (IPHC) has used sagittal otoliths for aging halibut since 1914 (Fig. 2). Otoliths can provide other information as well as age; at one time, otolith radius, length, and weight (Table 1) were used to estimate the size of individual halibut (Clark et al. 2000). Other properties such as shape have been used to distinguish between stocks of fish in other species. At IPHC, otolith shape and a combination

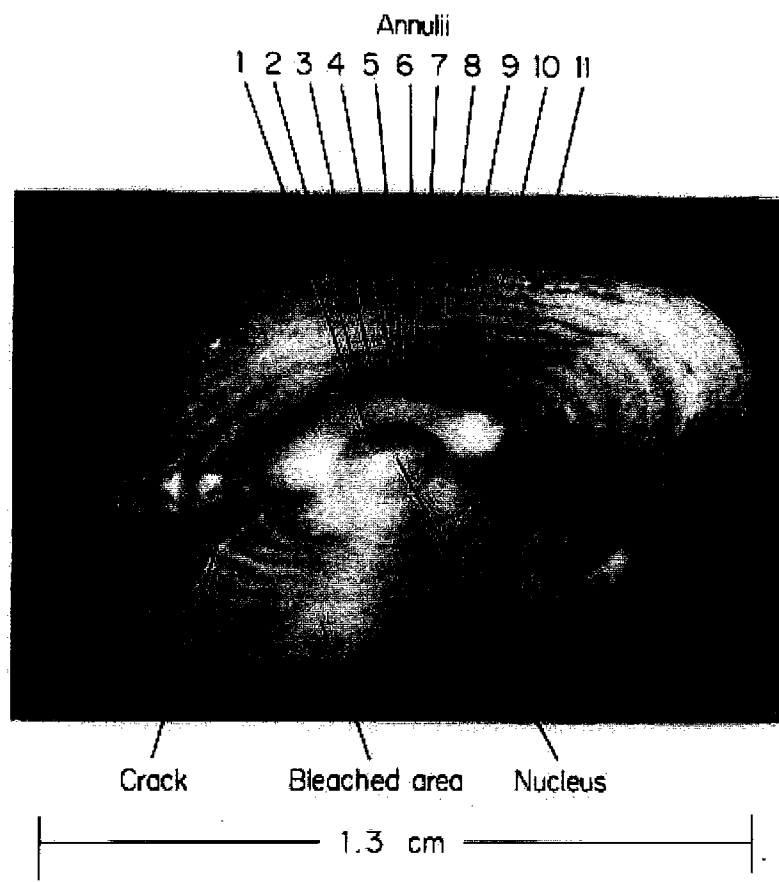


Figure 2. A left (blind) side halibut otolith with annuli marked.

Table 1. Otolith data collected and entered into database since 1963.

Year	Otolith data entered
1963-1967	Age, otolith radius
1968-1977	Age, otolith length
1978-1992	Age, otolith weight, otolith length
1993-1994	Age
1995	Age, otolith weight
1996-1998	Age, otolith weight, otolith length
1999-	Age, edge code

of otolith weight, length, and age were used in an attempt to discriminate sex in commercially caught halibut, for which sex data is unavailable (Forsberg and Neal 1993). Currently, only age data from otoliths is utilized; age data is incorporated into the annual stock assessment.

This manual describes the current otolith collection, storage, and age determination methods, criteria for making age determinations, and

quality control measures at IPHC as well as outlining past procedures for the same. The accompanying otolith photographs should be useful both in training new readers and as a reference for experienced readers.

Halibut otolith collection and storage

The IPHC collects halibut otoliths from the following sources: commercial catch (market samples), setline and trawl surveys (general series), and recaptured tagged halibut. Currently, we routinely collect only the left, or blind side, sagittal otolith from commercial and survey samples. Only the left otolith is used for age determination. Both sagittae are collected from tagged halibut that were part of an oxytetracycline (OTC) age validation study, but only the left is aged. It was determined in early investigations into aging of Pacific halibut that the left otolith is easier to read and ages could be made with higher confidence than when the right, or eyed side, otolith is used. Figures 3 and 4 show the two methods used to extract halibut otoliths.

The Alaska Department of Fish and Game (ADF&G) has collected otoliths from sport-caught halibut from 1990 to present and also aged these samples until 1998. During the same period, yearly exchanges of a subset of Alaskan sport-caught halibut otoliths were made between ADF&G and IPHC. Sport halibut otoliths continue to be collected but are not currently being aged by either ADF&G or IPHC.

Otoliths collected in the field are either stored dry (tagged fish otoliths) or in 50% glycerin solution (commercial sample and survey). The glycerin solution used at IPHC consists of equal parts water and glycerin plus a small amount of *thymol*, a preservative, which is added to deter fungal and bacterial growth (the "recipe" for 50% glycerin solution can be found in Appendix III). Tag recovery otoliths are stored in individual envelopes until they are sent to the Seattle office, where they are set out on trays and covered in glycerin solution to clear. Accompanying data for each recovered tagged-fish is recorded on the envelope. Market sample and setline survey otoliths are collected in special boxes that have cells that keep the individual otoliths separate and are filled with glycerin solution. The accompanying specimen data are recorded on forms. Up until 1996, setline survey otoliths were stored dry in envelopes in the field and not put in glycerin solution to clear for, sometimes, many months. ADF&G sport-caught halibut otoliths are stored dry in envelopes. Prior to aging, the otoliths were immersed in glycerin solution and allowed to clear for several weeks.

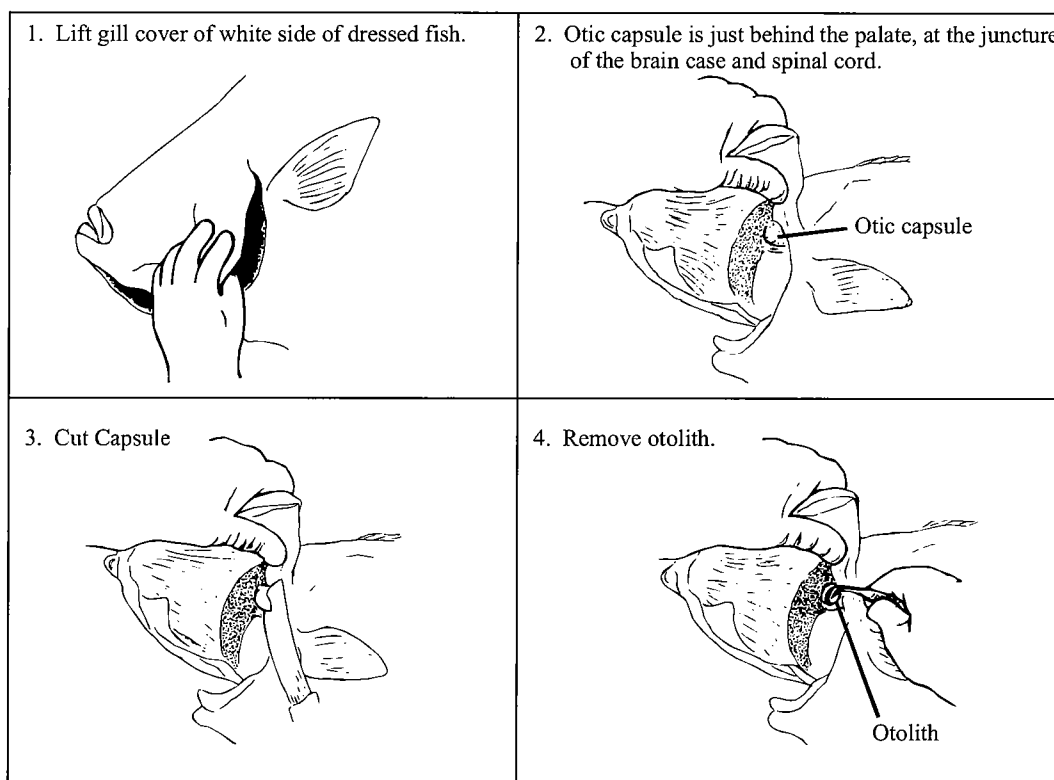


Figure 3. Extraction of left side otolith from dressed halibut.

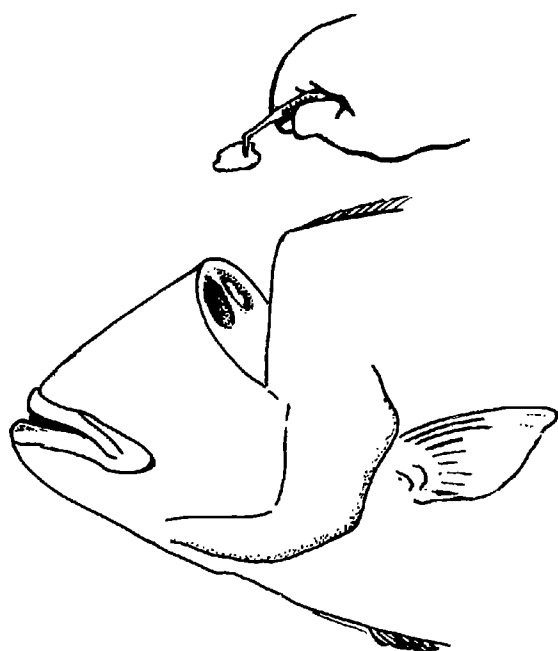


Figure 4. Extraction of left otolith from undressed halibut showing position of head cut.

All otoliths are put in vials (either glass or plastic) and covered in 50% glycerin solution with thymol for permanent storage. Market sample, setline survey, and tag otoliths are stored in vials measuring 19 mm by 65 mm with about 25 otoliths to a vial. Vials are stored in custom-made cardboard boxes with dividers to keep the vials separated and in order. Otoliths within the vials are stacked in order by otolith number, one on top of the other, with numbered paper disks just slightly smaller than vial diameter placed between to identify the individual otoliths. The stacking method works very well for whole otoliths from legal-sized halibut, but very small or broken otoliths can slip between the paper disks and the side of the vial and become mixed up. The very small otoliths from past IPHC juvenile trawl surveys were stored in small, individual vials. Trawl survey

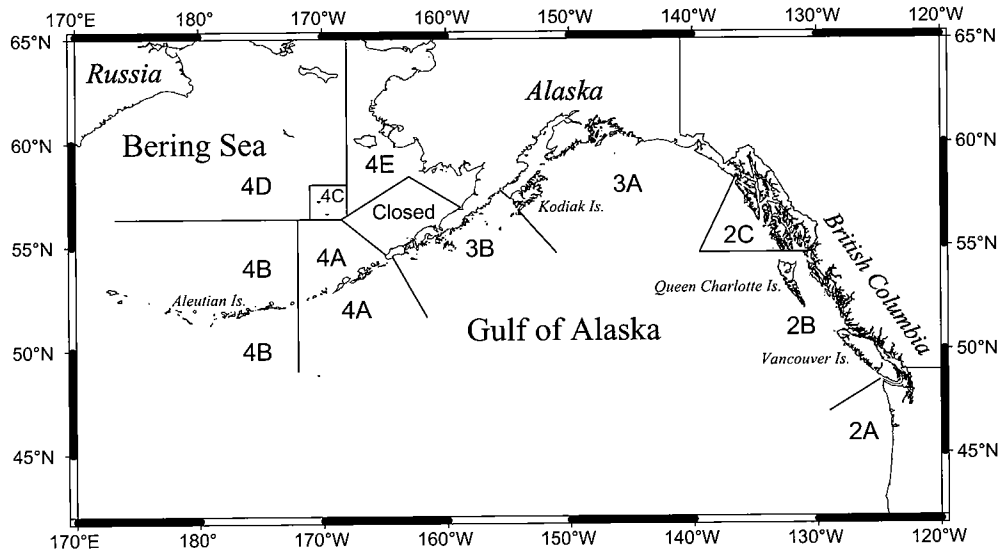
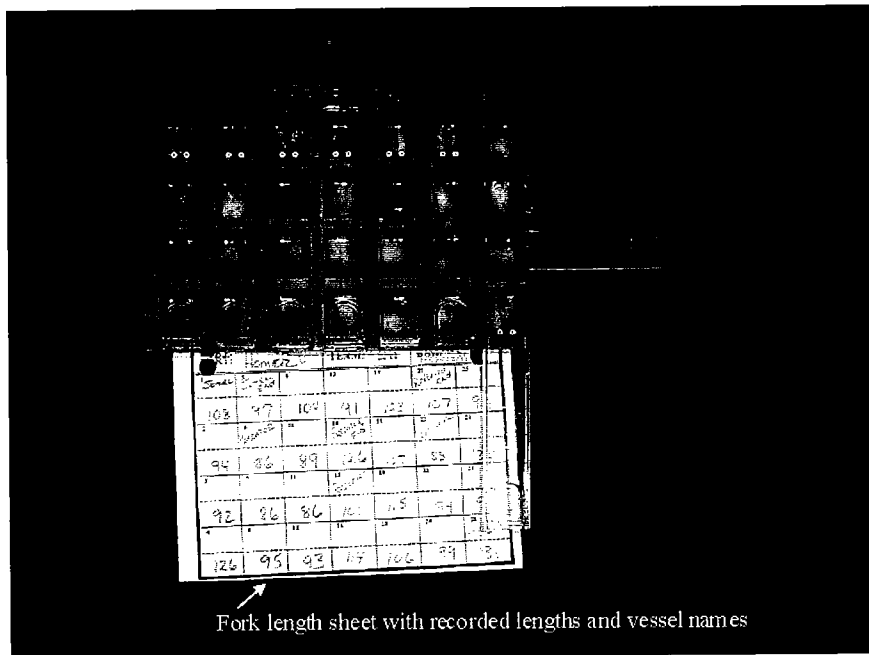


Figure 5. IPHC regulatory areas.

otoliths collected on National Marine Fisheries Service (NMFS) research cruises are stored in individual vials (with 50% glycerin solution) in Styrofoam boxes.

Market Sample otoliths

Currently, commercial samples are taken annually at a pre-set rate calculated to provide a target number of otoliths for each IPHC regulatory area. Regulatory areas are shown in Figure 5. Current annual otolith target numbers are 1000 for Area 2A; 2000 for each of Areas 2B, 2C, 3A, 3B, 4A and 4B; and 2000 for Areas 4C and 4D combined (Wade et al. 2001). Otoliths are not collected from Area 4E. Samples are taken throughout the entire nine-month fishing season. Vessels are sampled randomly and proportionally by weight.



Fork length sheet with recorded lengths and vessel names

Figure 6. Medication organizer used to collect market sample otoliths.

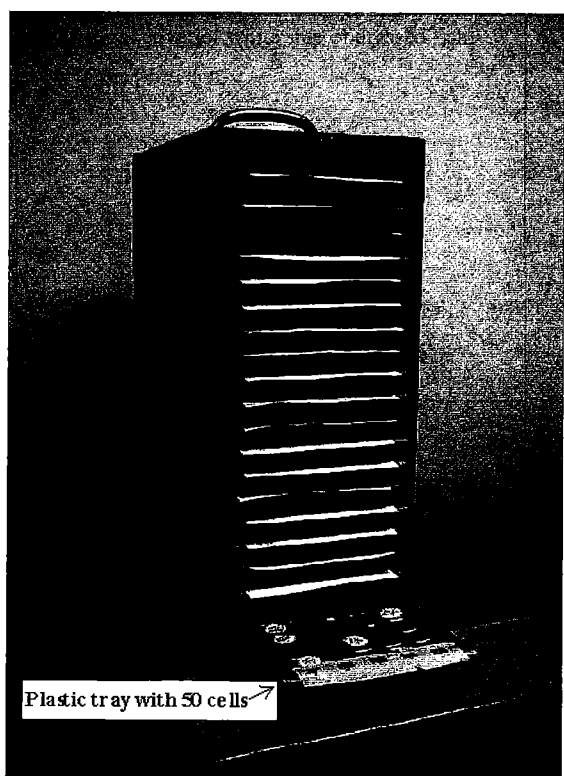


Figure 7. Boxes and plastic trays used to hold market sample and recovered tag otoliths for aging.

Survey (“General Series”) otoliths

Setline survey otoliths are stored in custom-made plastic containers (referred to by staff as “*Barto Boxes*” after the box’s designer). The *Barto Box* consists of a black plastic bottom made up of 100 cells with a clear Plexiglas lid that tightens with screws (Fig. 8). Setline survey otoliths are kept in the *Barto Boxes* until final storage.

Survey halibut are also sampled at a predetermined rate set to achieve the collection of 2000 otoliths per regulatory area each year. When oversampling occurs for a given area, if possible only a subset of otoliths is aged in order to bring the number aged down to the target number of 2000. For example, if 2500 otoliths were collected, every 5th otolith would not be aged. Sometimes all otoliths from an area must be aged, even if over the target number. In order to subsample to a target number, the total

Details on commercial catch sampling procedures can be found in Gilroy et al. (1995) and Quinn et al. (1983). Otoliths are stored in medication organizers in the field (Fig. 6) and covered immediately with glycerin/water/thymol solution. Due to a limited number of medication organizers, market sample otoliths are transferred on arrival in the Seattle office to uncovered trays held in wooden boxes (Fig. 7). The open trays are more convenient for aging as otoliths are more accessible, however trays must be handled carefully to avoid spilling or mixing of otoliths. Otoliths on the uncovered trays are especially prone to getting mixed up if the tray is jostled or tipped before the otoliths have been covered with glycerin solution. All market sample otoliths are aged, even when collections exceed the target numbers for the different areas.



Figure 8. *Barto Box* for collection and short-term storage of longline survey otoliths.

number of otoliths collected in an area must be known. In 1999, survey otoliths from certain regulatory areas began to be included in the stock assessment. Ages must be available for stock assessment by mid to late October. In order to meet this deadline, aging must begin in August. If survey collections in an area are not complete by August, reading must begin, so subsampling is foregone and all otoliths for that area are read. Details on recent age-reading schedule changes can be found in Forsberg et al. (2001).

History of Pacific halibut age determination

The first ages for Pacific halibut were determined by reading scales. McMurrich (1913) looked at the scales of three halibut. Of 13 sampled, only three had scales suitable for aging. Former IPHC director W.F. Thompson was the next person to determine ages of Pacific halibut, using sagittal otoliths. (**Note:** since only sagittal otoliths are used for aging halibut, from here on, “*otolith*” will be synonymous with “*sagittal otolith*” in this report, unless specified otherwise.)

In an unpublished thesis written during the 1940s, another former IPHC director, Henry Dunlop, compared ages from halibut scales and otoliths. Otolith-derived ages averaged higher than ages obtained from examining scales. He stated that scale markings were sometimes fairly distinct on young fish, but only toward the center of scales of older fish. Scale markings are generally less distinct than those of otoliths and halibut scales are also very small and difficult to work with, therefore Dunlop recommended using otoliths exclusively for age determinations. Dunlop describes a halibut otolith in the following passage:

“It displays a series of irregularly concentric broad opaque, and narrow transparent zones which alternate from the center to the margin. The zones extend around the circumference of the otolith, conforming to the shape and size of the otolith at the time each was laid down. They are deposited successively from the center to the margin as the otolith increases in size during the life of the fish. Opaque and transparent zones correspond respectively to seasons of rapid and retarded growth, roughly to summer and winter.”

Dunlop noted that some otoliths are quite irregular and difficult to interpret. He pointed out that opaque zones might at times be hidden from the surface view. The practice in the 1930s was to count only the distinct zones and not the “obscure” zones. He stated that “*due to this practice and the possibility that some opaque zones may not show, age determinations must be regarded as minimum values*”.

Since ages are determined by counting annuli, knowledge of the time of year the annulus is completed is vital to assigning individuals to the correct age-class.

Dunlop described a *marginal increment analysis* (MIA) that was performed to determine the time of year of annulus formation. By measuring the width of the opaque zone outside the last complete annulus on a series of otoliths collected throughout the year, he found that the translucent zone or annulus was completed between February and May for the study samples. He also found that there was a great deal of variation in the time of year translucent growth began: new opaque zones begin in some before the transparent margins become distinct in others and at no time are the margins of all otoliths transparent.

Dunlop cautioned that although the MIA results showed that the annulus is completed in the winter and spring, it doesn't prove that one is laid down *every* year.

Clearing

In 1915 and 1916, W. F. Thompson experimented with different preparations in an attempt to make otoliths more “readable”. He found that freshly collected otoliths were easier to read than those that had dried out after removal from the fish. Otoliths *in situ* contain water; this water evaporates after the otolith is removed from the fish and the otolith takes on a whiter, more opaque appearance and contrast between zones is reduced. Thompson compared the results of soaking otoliths in pure glycerin, 50% glycerin, water, and ethanol. Ethanol and 50% glycerin produced the best result in terms of restoring contrast between opaque and translucent zones. He also found that otoliths that dried out completely before being soaked cleared less well than otoliths placed in clearing medium immediately after collection.

Thompson also tried sectioning and polishing techniques and compared transmitted and reflected light on different preparations (Figures 9 and 10). However, the standard preparation and method used for production aging of halibut has been surface reading of whole otoliths that have been cleared in 50% glycerin solution and are illuminated by reflected light.

Aging Procedures

Currently, two age determination methods are used by IPHC readers: 1) surface and 2) break and burn. Pacific halibut otoliths are all surface-aged at IPHC. We look at the distal surface of the otolith for surface reads; the proximal surface has a deep groove (the

sulcus acousticus) and annuli are obscured (Fig. 11). However, annuli *can* be seen from the proximal surface in the otoliths of young halibut (five years and under) since the otoliths are still relatively thin and the sulcus groove is less prominent. In fact, young otoliths are often viewed from the proximal side as a check of the age observed on the distal surface. In cases



Figure 9. Transverse (dorso-ventral) cross-section of halibut otolith under reflected light.

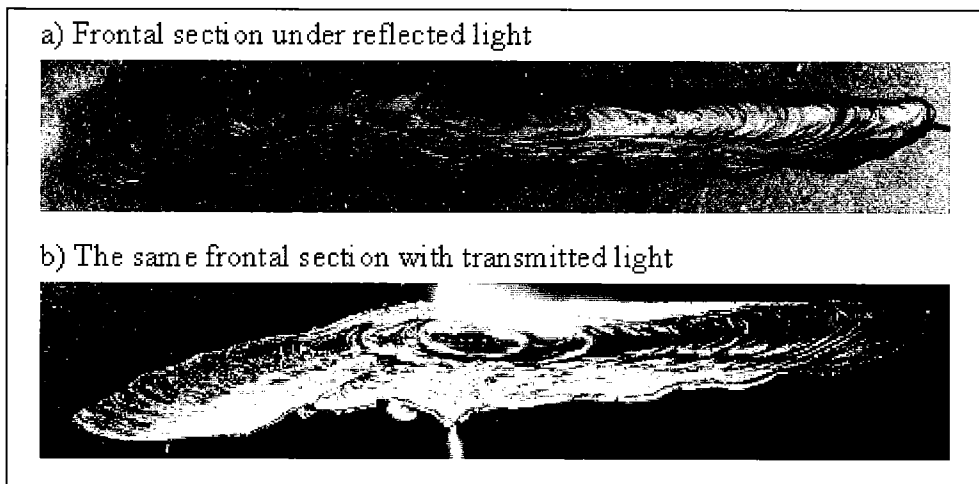


Figure 10. Frontal (antero-posterior) section of halibut otolith.

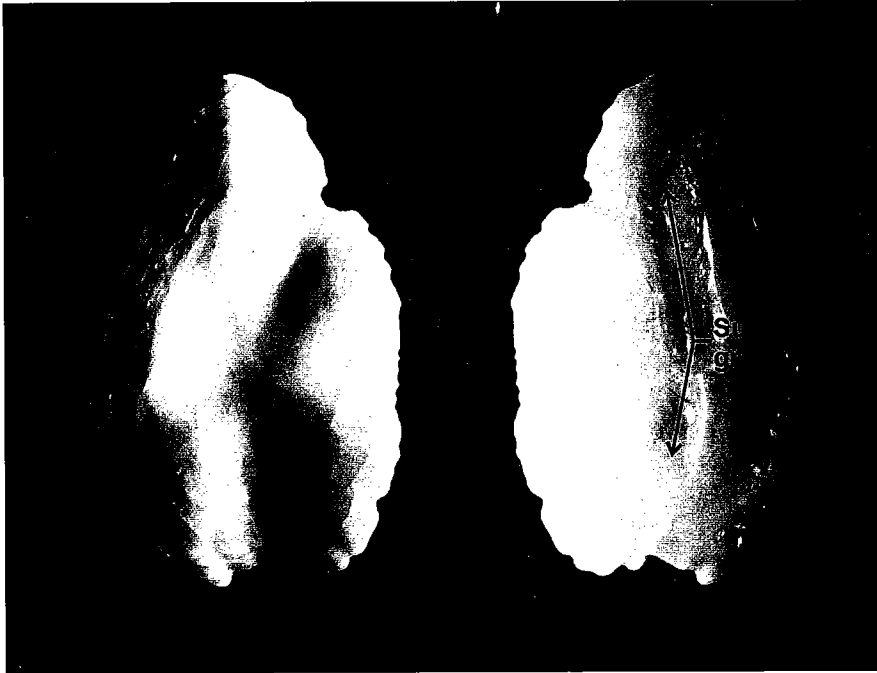


Figure 11. (L-R) Distal and proximal surfaces of a left sagittal halibut otolith.

where we are not confident of the surface age, (e.g., thick or steep edge, opaque or cloudy surface, odd growth pattern, etc.) a break and burn age determination is made. For both methods, the narrow winter zones (annuli) between the nucleus and the edge are counted to determine the age in years.

A dissecting microscope is used for both methods. Otoliths are observed at 5X to 50X power with reflected light from a fiber-optic light source (Fig. 12).

Data provided to the reader at the time of aging includes date and regulatory area of capture. In the past, fork length was included as well, but since there is a rough relationship

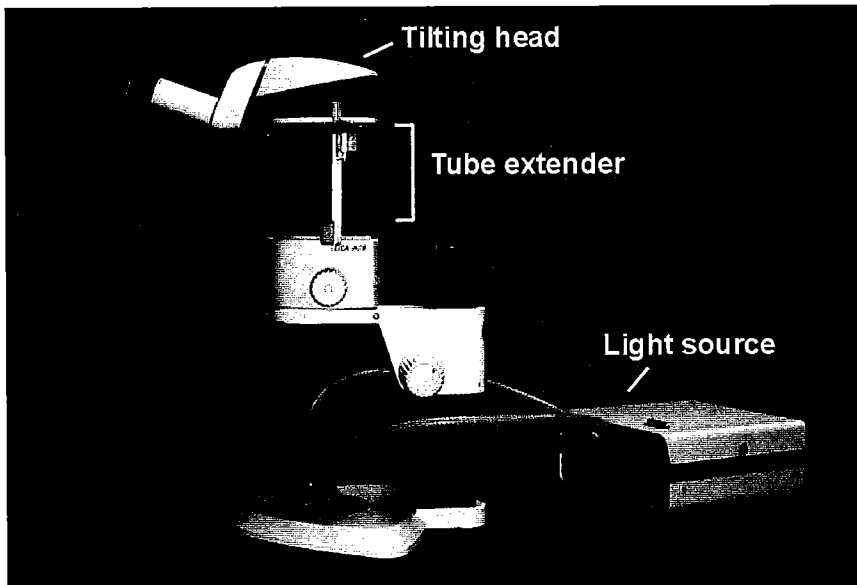


Figure 12. Stereo dissecting microscope and fiberoptic light source used for aging halibut otoliths. Tilting head and tube extender are ergonomic features.

of 10 cm length per year, it was decided that fork lengths should be withheld from agers to avoid potential bias from knowledge of this relationship. We record age(s), edge growth code (which indicates whether opaque edge growth was present, counted as last year's, or new), as well as remarks (such as crystallized, thick, questionable age, etc.). Only the ages and, as of 1999, the edge codes are entered. Only one age is used for assessment, however, an otolith may be read multiple times by different readers and several ages may be entered.

Surface

Surface ages are made under reflected light with the otolith immersed in water on a piece of black cloth in a container (to minimize glare from the light source and maximize contrast, respectively). Otoliths are rinsed to remove glycerin before reading, since the mixing of the two liquids with different refractive properties makes focusing on the otolith difficult. Adding a drop of liquid dish detergent to the water in the viewing container helps keep any glycerin not rinsed from the otolith from mixing with the water (Steve Wischniowski, IPHC, PO Box 95009, Seattle, WA 98145-2009, personal communication). The translucent zones are counted and since date of capture is provided at the time of aging, the edge is "interpreted" i.e., a decision is made whether to add an additional year to the annulus count or not. Figure 13 shows the preferred axes for making an annulus count on an otolith surface. Magnification for surface readings ranges from 5-10X.

The practice in the 1930s was to count only the "distinct" zones, and since some faint or overlapping annuli might have been missed, assigned ages were minimum values. Since information such as date of capture was not provided when ages were determined, all opaque zones were counted, including the edge, and the degree of development of the edge indicated. The width of the outermost opaque zone was recorded as a fraction, indicating its approximate width in relation to that of the next adjacent complete zone. Fish were later assigned to the appropriate age group according to dates of capture (Dunlop, unpublished thesis).

Break and Burn

Since deposition on the various surfaces of the otolith changes as the fish grows older, some annuli may not be visible from the distal surface. Viewing the otolith in cross-section allows viewing of such "hidden" annuli that may only be visible on the proximal surface. "Burning" increases the contrast between the opaque and translucent zones; the opaque zones turn light brown while the translucent (or hyaline) zones, due to their higher concentration of protein, turn dark brown when

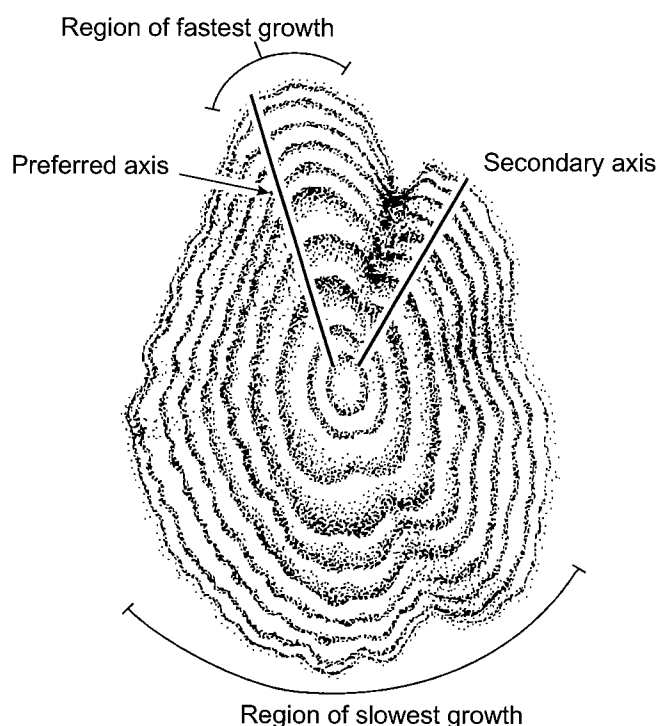


Figure 13. Preferred reading axes for halibut otolith surfaces.

heated. The following are the criteria a reader uses to decide whether an otolith should be broken and burned.

Break and burn criteria:

1. High surface age
2. Thick otolith, steep edges
3. Opaque/surface pattern obscured
4. Difficult surface pattern
5. Discrepancy in readings between different sites on the otolith
6. Choice surface-reading site broken off

Our break and burn technique is similar to that described in Chilton and Beamish (1982). The reader usually outlines the first annulus in lead pencil after making the surface reading and while the otolith is still under the microscope. The otolith is rinsed in water and dried with a paper towel then the otolith surface is scored through the nucleus (using the pencil mark as a guide) with a razor blade and then snapped in two by hand along the dorso-ventral axis. The dorso-ventral axis is also called the “transverse” plane and sections resulting from a cut or break along this axis are referred to as transverse sections. A section not commonly used for halibut otoliths is the frontal section, in which the otolith is cut along the antero-posterior axis. Figure 14 illustrates the axes and “geographical” regions of a halibut otolith. If the break is not through the nucleus or is very uneven, the reader

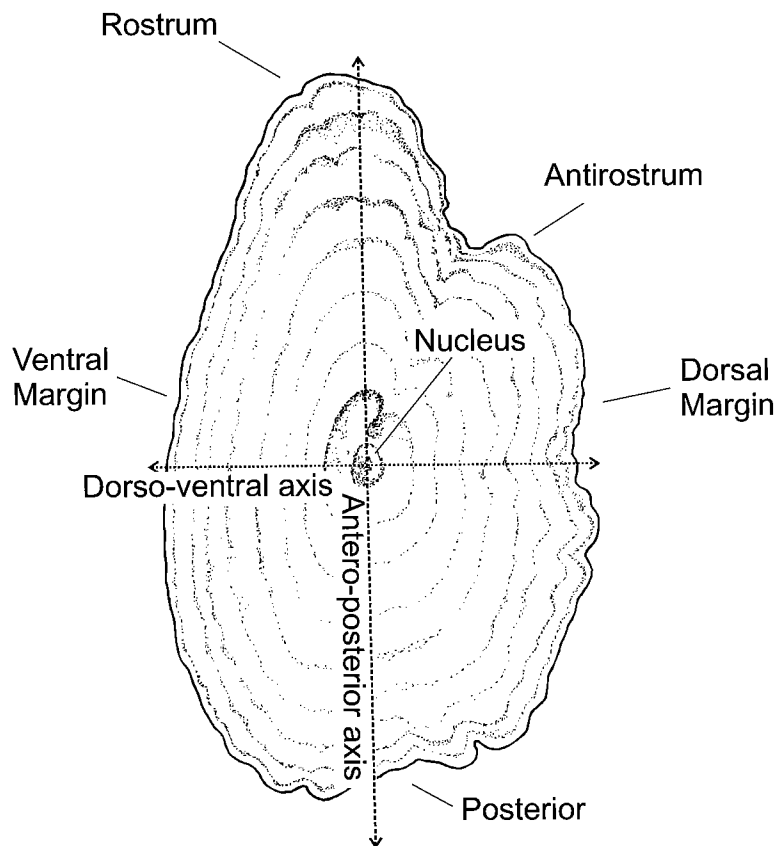


Figure 14. Distal surface of left sagittal Pacific halibut otolith (terminology from Härkonen 1986).

must use fine-grit sandpaper to sand the section down to the nucleus using the pencil mark as a guide. If the section is sanded, it must be cleaned in water and dried with a paper towel before burning to avoid sandpaper grit burning onto the surface. Some readers find that a straighter break can be achieved by laying the scored otolith over a straightened paper clip (as illustrated in Figure 15) with the scoring parallel to the paper clip. The

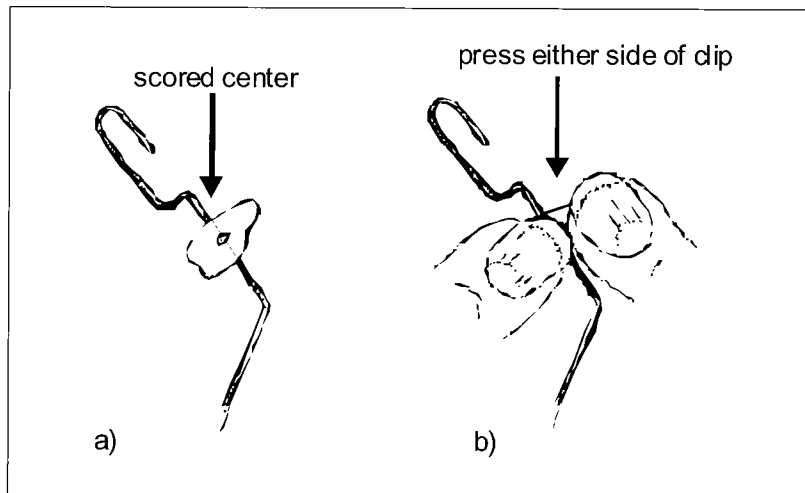


Figure 15. Breaking an otolith in half using the “paperclip method”.

posterior end is held down with the left index finger while the right index finger pushes down on the anterior end. The clip seems to spread the pressure across the dorso-ventral axis so that the anterior section is more likely to break off in one piece. The IPHC also has a low speed Isomet saw (Fig.16), which is occasionally used

for cutting especially thick otoliths in half. To “burn” the otolith section, the broken surface is held over the flame of a small alcohol burner (Fig. 17). Some readers hold the section with the broken surface facing the flame, as in Figure 17. Others prefer to hold the section with the broken surface facing the reader, sulcus side down, since this way the reader can monitor the progression of the burn. Still another burning method is to hold the section with the broken surface up and the posterior end in the flame.

Note: keep as far away from the burner as possible while burning; otoliths can explode while heating. Some agencies have readers wear goggles or place the burner behind a plastic shield. Surface moisture can cause pieces to break off while burning, so sections should be dried before burning.

After burning one of the halves (keeping one unburned to repeat a surface reading), the sections are held in position by mounting in Plasticene™ or other type of modeling clay, then coated with mineral oil before viewing (Fig. 18). (Figures 18-74 are located on pages 21-36 of this report). Burnt sections are viewed at higher magnification than are surfaces (about 30-50X). Figure 19 shows the preferred sites for reading on a burnt section. The pencil marking the first annulus on the surface is still visible after burning and by tipping the section, the

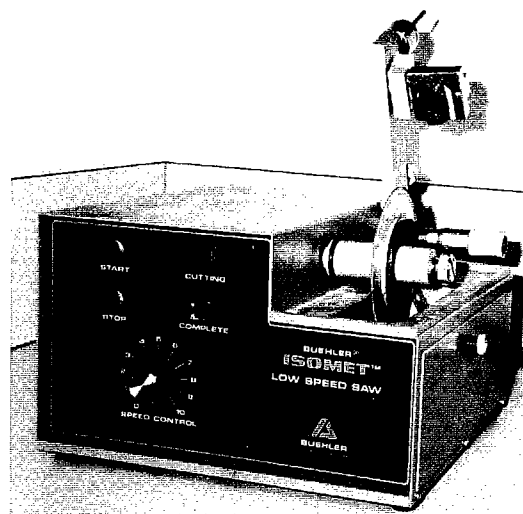


Figure 16. Low speed Isomet saw used for cutting otoliths.

reader can see the pencil mark and match it to the first annulus in cross section. Usually, we burn only the posterior half, leaving the anterior portion of the otolith to repeat the surface reading if necessary. The anterior half may also be burned if the posterior half is damaged during breaking, burns poorly, or explodes during burning. We used vegetable oil for coating the burnt sections until 1999, when we switched to mineral oil on the advice of colleagues in another age lab. Glycerin and vegetable oil react to make a jelly-like sludge on the otolith, so burnt sections retrieved for a second reading had to have the “jelly” scraped off before viewing.

Most of the readers at IPHC prefer to complete a series of surface readings, noting the otoliths that need to be broken and burned on the age forms, then do the necessary burns afterwards. This method is more efficient than interspersing surface reading with burns as they come up. After surface-aging a “batch” (usually one *Barto Box* of survey otoliths or group of sequential market samples from one port), the otoliths noted for burning are removed and set out in order on another tray, ready for rinsing and burning. Since most brands of soft modeling clay eventually dissolve in mineral oil, the clay becomes rather gooey and can ooze up onto the reading surface, necessitating removal and cleaning of the section. Burnt sections must also be cooled before mounting in soft modeling clay or the clay will melt and the section will tip over, getting melted clay on the reading surface.

As a result of such problems with soft modeling clay, some IPHC readers recently began using hardened mounts for holding burnt sections. Such mounts are made of Sculpey™ or Fimo™ brand bakeable modeling clay, which is scored with otolith-sized grooves in rows of five or ten, then baked in a regular oven according to package directions until hard (Fig. 20). Baked clay mounts do not dissolve in oil and sections can be mounted while still hot, however the fixed groove size limits the amount one can physically manipulate sections to optimize pattern visibility. Colored Silly Putty™ is used by some age labs and doesn't seem to dissolve in oil, but otoliths must still be cooled before mounting or the putty will melt and stick to the sections. For readers who do break and burns in batches, using soft clay requires an intermediate cooling step, i.e., sections must be set down on a metal or other heat-resistant surface to cool before mounting. Sections to be cooled must be laid out in a line or in an indented metal tray to keep the otoliths in order. Using a hardened mount eliminates this cooling step and the chance of sections getting out of order before or during transfer to the mounting medium.

There are alternatives to burning otoliths over a flame to achieve the heightened contrast burning produces. Other agers have used muffle furnaces and toaster ovens. In 1999, an IPHC reader compared the break and burn technique with the “break and bake” method (Barto 1999). Break and bake involves breaking the otolith through the nucleus in the same manner as is done for break and burn, but the sections are baked in a toaster oven

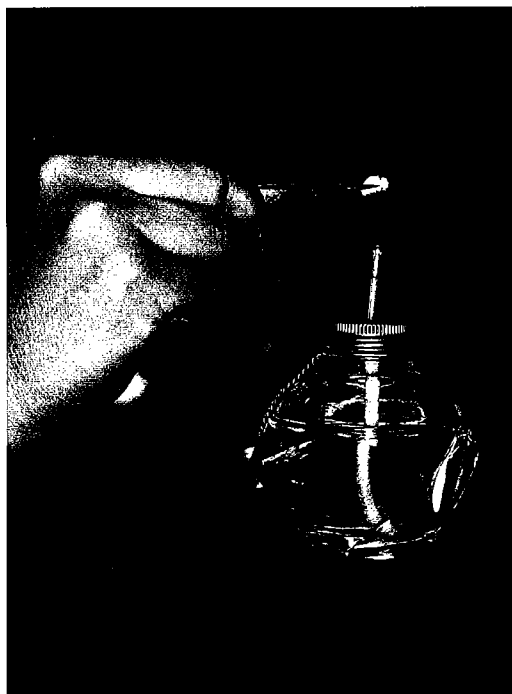


Figure 17. Burning a halibut otolith section over an alcohol flame.

at 500 degrees F for 10-15 minutes. In the study, the two halves of the otolith were given either the bake or burn treatment. Treatment was alternated between anterior and posterior halves. There was no significant difference in ages produced by the two methods, however the variance was somewhat lower for ages of otoliths that underwent the bake treatment. Readers now use either method, depending on sample size of otoliths to be sectioned and burned. Break and burn is more time efficient for small numbers of otoliths, whereas baking is more efficient when there are a large number of otoliths to be burned, since many can be baked at once. For baking, we use metal trays that are divided into 50 indented cells, which keep the otoliths from getting mixed up (Fig. 21).

There is a problem of burnt otolith sections “fading” over time in some species (Chilton and Beamish 1982). Fading of the hyaline zones can occur over a period of hours or years, but is not evident in Pacific halibut burnt otoliths. An otolith section that had been burned in 1993 was re-examined in 2000 and compared with a photograph of the section taken in 1993. No fading had occurred. One problem we have experienced with burnt sections at IPHC is with sections getting mixed up in the storage vials. At the current rate of break and burn determinations, this problem is not critical as long as care is taken in positioning the otolith sections on the paper discs while filling the storage vials, and even greater care taken during extraction of stored otoliths from the vials. However, if break and burn rates increase, alternate storage procedures will be necessary.

The break and burn method was first used with Pacific halibut otoliths in 1980. Readers from the Pacific Biological Station (PBS) in British Columbia aged a sample of halibut otoliths by break and burn and their ages were compared with IPHC surface ages for the same otoliths. The break and burn ages averaged higher than surface ages. Another exchange was made in 1987 and IPHC readers were trained in the break and burn technique by PBS staff. Break and burn ages were not routinely used at IPHC until 1992. At that time, some or all otoliths were aged twice, three times if the first two ages were different. If any paired readings differed by two or more years, a break and burn determination was made. In 1994, readers began breaking and burning otoliths that met the criteria described above, namely those that were thick, had steep edges, had a difficult pattern, were incompletely cleared, or had a high surface age. Numbers of break and burn determinations have increased over time, as readers became more familiar with and confident in the technique, and due to increasing numbers of otoliths meeting the break and burn criteria (Forsberg et al. 2001).

The 1987 comparison between IPHC surface ages and PBS burn ages indicated separation in the age methods at and above a surface age of 17, with the break and burn method producing a higher age for a given otolith. At that time, ages of 17 and over were grouped for stock assessment purposes so surface aging continued to be the standard aging method used at IPHC. A more recent comparison of surface and break and burn ages for a set of otoliths has indicated that the ages obtained begin to differ after a surface age of 14 (Calvin Blood, PO Box 95009, Seattle, WA 98145-2009, unpublished data). Current break and burn criteria may be amended in the future so that all otoliths above a certain surface age will be broken and burned.

Age ranges

The majority of halibut in both the setline survey and market samples are between 10 and 14 years old (>65% for market samples). Due to the size selectivity of longline gear and the 82-cm minimum commercial size limit, less than 1% of halibut in the market samples are 5 years old and younger.

Fewer than 10% of halibut in both commercial and survey samples are over the age of 20. The maximum age observed to date for Pacific halibut is 55 years. Two fish have been

