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Determination of age and growth of white hake (Urophycis tenuis Mitchill) from the southern Gulf of St. Lawrence, Canada

(including techniques for commercial sampling).

by:

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Rapport technique canadien des sciences halieutiques et aquatiques

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ON DETERMINING AGE BY OTOLITHS

"It must be clearly set down that determination of these otoliths [is] a personal matter. The number of bands counted depends on the magnification used, the illumination, relative apparent lightness and darkness of the bands and their relative width. Had I seen the scale tracings or known the length of the fish for each otolith as I read it, I have little doubt that agreement would have been recorded in every case. At the same time, had I started out without any prejudice at all I could not have assigned any age owing to the presence of rings in the core."

Graham 1928

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ABSTRACT

Clay,D. and H.Clay 1991. Determination of age and growth of white hake (Urophycis tenuis Mitchill) from the southern Gulf of St. Lawrence, Canada (including techniques for commercial sampling). Can. Tech. Rep. Fish. Aquat. Sci. 1828: 29 +vi p.

White hake (Urophycis tenuis) is a locally important commercial fish in the Gulf of St. Lawrence. The mean landings during the past 30 years have been about 6500 tonnes, the third most important demersal species. Despite this, little biological work was conducted on this species before the early 1980's. Age determination is a key element in the analytical assessment process and this report attempts to define the age determination techniques, interpretation criteria, and growth estimated for white hake in the southern Gulf.

White hake are often landed in a semi-processed state, head-off and gutted. A variety of conversion factors were investigated to account for this difficulty. The most satisfactory conversion was found to be total fish length to first dorsal fin length. An alternate conversion using otolith weight was also developed to estimate total length, and allow age determination, from a sample of heads only.

A comparison of growth estimated from otoliths and vertebrae indicates both these hard parts exhibit the same pattern of ring formation. Marginal increment analysis indicates the slow growth zone ring is laid down in spring and early summer. Modal analysis of research survey length frequency data indicate year classes of fish at the same general size as determined from counting the rings on the otoliths. Growth of white hake is sexually dimorphic and is near linear for the ages most commonly found in the commercial fishery. From von Bertalanffy growth estimates, L_{∞} for males is about 86 cm and for females is about 136 cm. These values appear reasonable compared to the largest fish caught in our annual resource surveys.

RESUME

Clay,D. and H.Clay 1991. Determination of age and growth of white hake (Urophycis tenuis Mitchill) from the southern Gulf of St. Lawrence, Canada (including techniques for commercial sampling). Can. Tech. Rep. Fish. Aquat. Sci. 1828: 29 +vi p.

La merluche (Urophycis tenuis) est un poisson commercial démersal important dans la région et elle est une espèce commune dans le golfe du Saint-Laurent. Même si elle se classe au troisième rang pour ce qui est des débarquements de poissons démersaux, peu de travail a été fait sur les caractéristiques biologiques de cette espèce avant le début des années 1980. La détermination de l'âge est l'élément clé du processus d'évaluation analytique, et ce rapporte tente de définir les techniques de détermination de l'âge, les critères d'interprétation et la croissance évaluée de la merluche dans le sud du golfe.

Les débarquements de merluche arrivent dans un état semi-transformé, c'est-à-dire que la te est enlevée ainsi que les viscères. Divers facteurs de conversion ont été étudiés pour tenir compte de l'état du poisson. Le facteur de conversion le plus satisfaisant s'est avéré être la longueur globale du poisson par rapport à la longueur jusqu'à la première nageoire dorsale. Un autre facteur de conversion a été mis au point en utilisant le poids des otolithes pour évaluer la longueur globale et permettre la détermination de l'âge uniquement à partir d'un échantillon de têtes.

Un comparaison de la croissance évaluée à partir des otolithes et des vertèbres indique que ces parties rigides illustrent le même modèle de formation de cercles. L'analyse modale des données recueillies à partir des relevés de recherche révèle des classes d'âge de poisson se situant dans l'ensemble à la même taille qui est déterminée par le dénombrement des cercles sur les otolithes. La croissance de la merluche se caractérise par le dimorphisme sexuel et elle est presque linéaire pour les âges que l'on retrouve le plus communément dans la pêche commerciale. D'après les évaluations de la croissance effectuées par von Bertalanffy, la longueur maximale (L_{∞}) des poissons mâles se situe à environ 86 cm et celle des poissons femelles est d'environ 136 cm. Ces valeurs semblent raisonnables si l'on en juge d'après les plus gros poissons pêché dans nos recensements annuels des ressources.

ACKNOWLEDGEMENTS

Initial training of contract and Department of Fisheries and Oceans (DFO) 'agers' and background information was provided by Joe Hunt, DFO, St. Andrews, New Brunswick (NB). The assistance of Joe and the staff of the 'Ageing Unit' is gratefully acknowledged. At the beginning of this investigation preliminary discussions on age determination and interpretation criteria were conducted with Linda Currie and Tom Hurlbut of DFO, Moncton.

The weighing of all the otoliths except those of the RV Lady Hammond was carried out through the summers of 1985 and 1986 by Elizabeth Clay. The lengths and weights of the otoliths from the RV Lady Hammond was completed by Debbie Haight, who also carried out some of the statistical analysis. The photomicrographs of the otoliths (Figure 10) were kindly done by the DFO Photo Section at Bedford Institute of Oceanography.

The authors wish to thank Joe Hunt, DFO, St. Andrews, Ghislain Chouinard, Tom Hurlbut and Mark Hanson, DFO, Moncton for helpful reviews of an earlier manuscript.

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The mention of trade names or commercial products does not imply endorsements by either the authors or the DFO, Canada.

I. INTRODUCTION

The Gulf of St. Lawrence is one of the most productive inland seas in the world (Dunbar, 1979). Its finfish and invertebrate fisheries contribute significantly to the economy of eastern Canada. White hake has been important to the inshore groundfish fishery for over 50 years.

A life history study, including a preliminary investigation of growth from otoliths (Nepszy, 1968), was begun on white hake in 1965 due to its 'growing importance as a commercial species' (Kohler, 1966). Little further biological research was conducted on white hake, (Urophycis tenuis Mitchill), of the southern Gulf of St. Lawrence until the early 1980's. Interest increased at this time because the catch increased from an average of 5000 to 6000 tonnes per annum to over 14000 tonnes in 1981. No data were available to determine an optimal catch, thus for 1982 a precautionary TAC (Total Allowable Catch) was set at 12000 tonnes on advise from the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC). Work was then directed towards gathering the data necessary to determine the long term optimal catch.

In Atlantic Canada, estimates of fish stock population numbers and predictions of future fish stock size are used to set the annual TAC using VPA models (Virtual Population Analysis). Biological parameters such as year class strength, age of recruitment, age of sexual maturity and mortality are used in assessing a fish stock. Since accurate age determination is a vital aspect of all these calculations, it is important that there should be close agreement both within and between age readers. Low variability in age determination is a key element in producing valid unbiased population numbers-at-age estimates.

The first analytical stock assessment (VPA) of white hake from the southern Gulf of St Lawrence, was completed in 1985 (Clay et al., MS 1985, MS 1985). The only previous studies of age determination from this stock was an initial study of 1596 white hake by Hunt (MS 1982) and preliminary work by Clay et al. (MS 1984). By 1990, over 21,000 white hake had been aged on a routine basis at the Gulf Fisheries Centre (GFC), Department of Fisheries and Oceans (DFO), Moncton, New Brunswick. This included historical otolith collections from the 1970's and 1980's that had been archived at the St Andrews Biological Station, DFO.

In the past, hake were predominantly salted and dried for export. Since the early 1980's, increased concern over quality and the new regulations prohibiting the dumping of offal in the nearshore areas, led to more hake landings being made after gutting and beheading at sea. The recent shift to sea processing has resulted in difficulties in obtaining the traditional commercial port samples routinely collected by Departmental staff. Hake without heads cause two problems for age determination, that of the unknown total length and that of unavailability of otoliths.

This study, in addition to providing estimates of growth, and methods of sampling for 'hard parts', outlines the techniques, methods and interpretation criteria proposed to serve as a basis for ensuring consistency of future age determination of white hake.

II. STUDY AREA AND METHODS

There are two main sources of fish hard parts available to white hake researchers. The first is the annual resource survey of demersal fish which has been conducted every September since 1971 in the southern Gulf of St. Lawrence (NAFO division 4T, Figure 1) (Hurlbut and Clay (eds), 1990). As a routine component of these surveys, hard parts are collected for age determination of white hake and other species. The second source of hard parts is the 'traditional' sample collected by 'port samplers' who randomly select and measure fish from the commercial catch. DFO samplers take a stratified sub-sample of otoliths, in the Gulf of St. Lawrence it is usually 1 per cm grouping (Clay, 1989).

a. AGE AND GROWTH

For the purpose of this study, the only hard parts considered for age determination were vertebrae and otoliths . Although marks were expected and subsequently observed, the periodicity was unknown. To validate that these marks were annual, several techniques were investigated, among them: comparisons between the marks on different body parts, relationships between body parts and fish size, marginal increment analysis, back calculation of the fish size at ring formation, and analysis of length frequency data.

Comparative study

A sample of 245 fish was obtained from which both otoliths and vertebrae were taken. These fish were collected from the 1983 research vessel (RV) survey (RV E.E. Prince P296) in order to compare the age estimated from these different hard parts.

Figure 1. Stratification design for the annual resource survey of the southern Gulf of St. Lawrence (NAFO division 4T). All strata coded above 414 have been surveyed every year since 1971, those coded below 405 have been surveyed only since 1984.

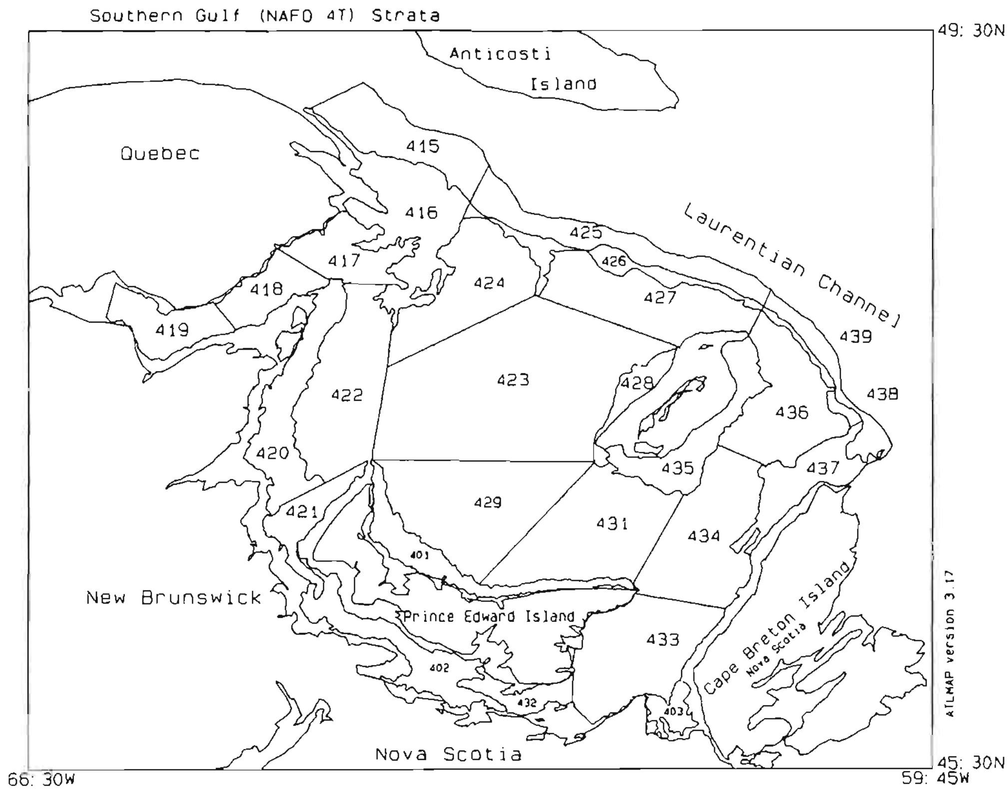


Figure 2. Right and left sagittal otoliths exposed in the cranial cavity of a white hake (Urophycis tenuis).

Preparation of material for age determination

Preparation of vertebrae

The first three unattached trunk or abdominal vertebrae from immediately behind the skull were selected for age reading. After removal they were partially cleaned by removing excess tissue and blood, then placed in labelled bags and frozen. Vertebrae were relatively easy to collect and did not require sectioning or staining, however, the presence of oil, ligaments and notochordal tissue necessitated some cleaning. Boiling in water for ten minutes removed attached tissue, they were then scrubbed clean with a toothbrush and air dried. Three vertebrae from each fish were glued to the bottom of a labelled disposable plastic petri dish and stored ready for age determination.

Preparation of otoliths

Otoliths were removed from white hake by holding the eye sockets with the thumb and forefinger of one hand and cutting the top of the skull behind the eyes, down and back to the upper edge of the gill cover. The dorsal and inner proximal surface of the two large sagittae were revealed and these otoliths were easily removed with forceps (Figure 2). Both sagittal otoliths were stored in a numbered envelope, the number corresponding to separate biological data recorded for the fish.

Unlike some groundfish otoliths, such as American plaice (Hippoglossoides platessoides), which can be read directly without further treatment, white hake sagittae are thick, opaque, and the annuli are not clearly visible through the external surface. Simply breaking the sagittae as is sometimes done with cod (Gadus morhua) and redfish (Sebastes mentella) does not present a satisfactory surface for examining annuli. The best results have been obtained by taking thin transverse sections through the nucleus of the otolith. The thinness of the section and proximity to the nucleus are important for obtaining accurate results.

The general technique followed that outlined by Hunt (1980, MS 1982). The otolith was cleaned of any adhering debris and centred on a small, numbered cardboard which has a cross-hair marked at its centre (Figure 3).The nucleus of the sagitta was located over the centre of the cross hair and a little melted paraffin wax containing some powdered charcoal was dropped on the sagitta to attach it to the card. Thin sections, of approximately 0.5 mm thickness, were cut through the sagitta using a low speed 'Buehler Isomet' saw as described by Silveri (1986) similar to the ideas set out by Rauck (1976). These sections were then mounted in numerical sequence in wells on black plastic trays (Figure 4). A layer of clear 'Crystal Sheen' or 'Enviro Tek' acrylic resin was poured over the sagittal section to attach it and to enhance the contrast. After the resin dried (hardened) in 6 to 8 hours, the sagittal section was ready for examination.

An initial attempt was made to bulk section the hake otoliths in resin blocks, as described by Bedford (1983). This technique has been used in the Gulf Fisheries Center for cod otoliths and by staff of the St. Andrews Biological Station for several gadoid species (Strong et al. MS 1985). This was not satisfactory for the hake as the surface of the otolith was scratched to the degree that some checks and possibly annuli were obscured.

Other methods of enhancement including using higher magnification, burning, staining with methyl violet, acid etching and polishing have been used with little improvement (Hunt MS 1982). A high resolution black and white video camera mounted on a microscope and connected to a monitor proved useful for demonstration purposes but too slow for the large numbers of otoliths routinely read in our assessment unit. There was also a loss of resolution and especially contrast with the video camera, which was particularly noticeable with older fish.

Otolith size to fish size

A further study of the relationship between otolith size and fish size was conducted on otoliths collected from fish from research vessel surveys in 1985 (RV Navicula N012) and 1986 (RV Lady Hammond H159) and commercial sampling in 1984. The 1971 collection of archived white hake otoliths from the research survey on the RV E.E. Prince (P091) was also examined to investigate any differences over time.

Whole otolith mass was recorded to the nearest mg on an electronic digital balance and length was measured with vernier calipers to the nearest 0.01 mm. For each fish from which otoliths were collected, the total length rounded to the nearest cm, mass to the nearest 10 g and sex were recorded.

Regression analysis was used to derive a formula for transforming otolith size to total length of fish. Analysis of covariance (Snedecor and Cochran, 1978) was used to determine if differences existed between data sets.

Figure 3. The process of preparing and 'mounting' a white hake otolith for sectioning. (Left to right) A cross hair is drawn on a cardboard tag that fits in a chuck for an 'Isomet' slow speed diamond saw. The cross hair indicates where the blade will cut and the otolith is aligned with the nucleus over the cross. Melted paraffin (with powdered carbon) is applied to hold the otolith in place. Two cuts are made through the otolith to produce a section $\leq$0.5 mm thick (shown between the third and fourth tags).

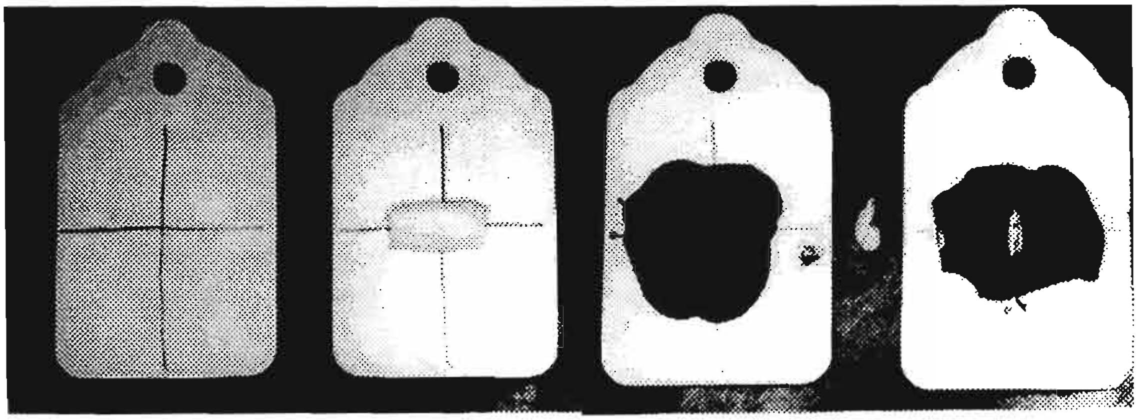


Figure 4. Sectioned white hake otoliths mounted in 145 mm x 95 mm plastic trays holding 50 otoliths under a clear protective resin.

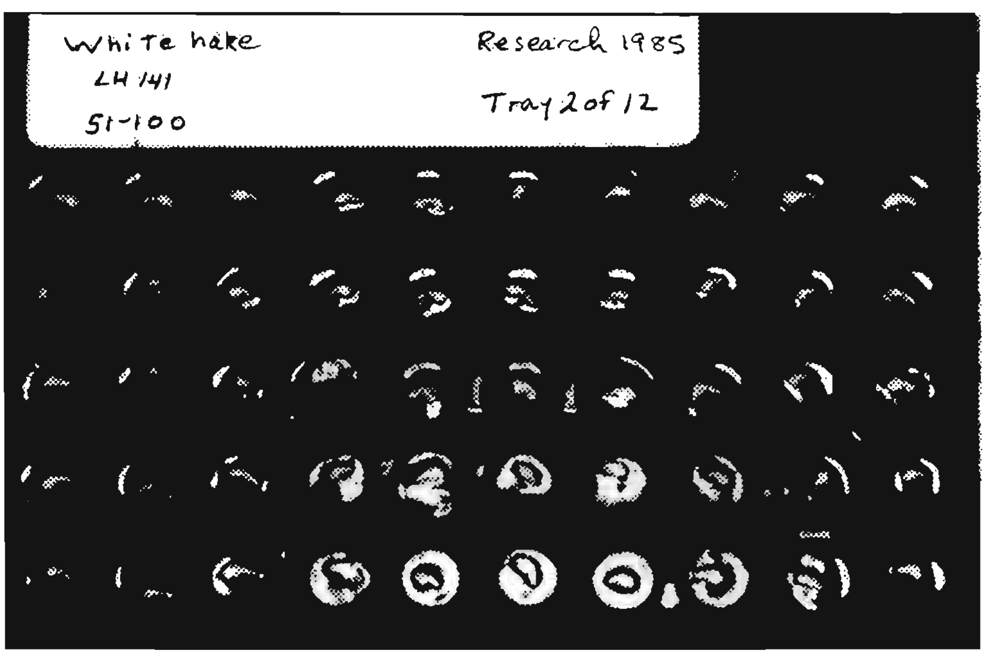
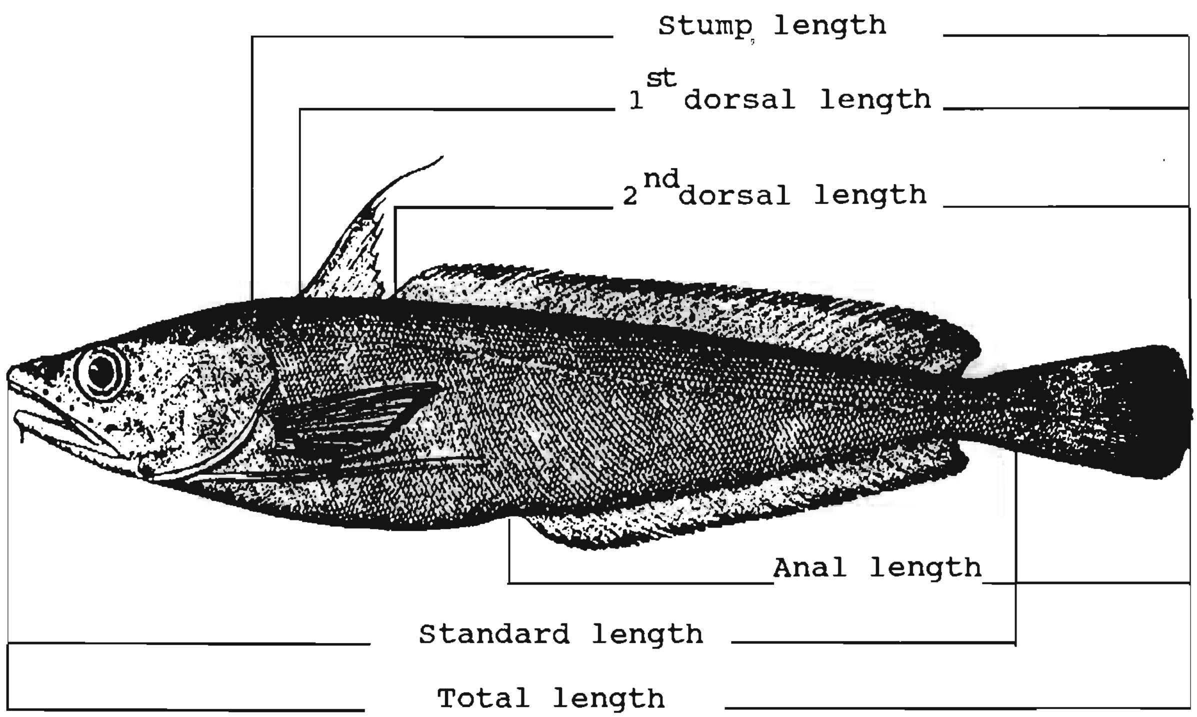


Figure 5. Length measurements of white hake considered for the conversion of various processed lengths to total length (Figure after Bigelow and Schroeder, 1953).



b. SAMPLING SEMI-PROCESSED WHITE HAKE

Sampling for length

Fish used in the investigation of total length to beheaded length conversions were measured to the nearest cm for total length and the secondary measure (Figure 5). These lengths were: the 'first dorsal' and 'second dorsal' lengths (the length from the anterior edge of the respective dorsal fin to the tip of the tail) the 'anal length' (the length from the mid-point of the anus or vent to the tip of the tail) and the 'stump length' or as the P.E.I. fishermen refer to it, the 'meat length' (the overall length of the 'stump' after beheading by commercial hake fishermen). The first three measures were carried out by DFO staff while the fourth was measured by PEI Department of Fisheries and Labour staff after the fish were processed by commercial fishermen.

Sampling for age

The alternative forms of length measurement described have been used by DFO port samplers in the Gulf of St. Lawrence since 1984. This solution to the length sampling difficulty does not resolve the problem of obtaining hard parts (otoliths) for age determination. In order to supplement the limited number of otoliths available from routine sampling of whole fish, random samples of hake heads were obtained from fishermen. All otoliths from this sample were collected and the average individual mass for each pair of otoliths was used to determine the equivalent total length of the fish. The ages can then be determined from either the entire collection or from a stratified sub-sample.

III. AGE DETERMINATION

a. SEASONAL MARKS

Hard Parts

Fish can be aged using many different hard parts including scales, vertebrae, otoliths, finrays, operculi, etc. These various 'bony' structures have been used to determine age of fish for decades. In the past, the most commonly accepted method of ageing fish has been from scales; Hoffbauer (1899) first determined the age of carp from its scales. Age determination from scales has been developed and refined by many workers but in some cases it has been found to seriously underestimate the age of older fish (Dubois and Lageux, 1968) and there is evidence that scales are unreliable for estimating the age of certain species (Beamish and McFarlane, 1983). Osteolysis, or resorption of calcium from scales, has been reported when fish stop feeding. Crighton (1935) described this effect in salmon but it may also occur in many other fish. Simkiss (1974) found there is no evidence for resorption of calcium in otoliths but Panella (1971) suggests resorption occurs in all bony structures during periods of stress.

Reibisch (1899) was one of the first workers to document a relationship between the time of formation of otolith rings and gonad development of North Sea plaice (Pleuronectes platessa). Cunningham (1905) disagreed with Reibisch as to when the opaque zone was formed. Using otoliths, scales and vertebrae of cod, plaice and whiting, Cunningham concluded the opaque zone is formed in summer and the clear translucent zone in winter.

Other workers such as Heincke (1908) found vertebrae best for determining the age of fish, especially in the older age groups. Panella (1971) has found otoliths useful for determining daily growth rings in fish. Since ages determined from scales may not always be accurate and as the zonations on otoliths and vertebrae are frequently more distinct and continue to grow with the fish, the latter two methods were tested for white hake age determination.

Ring Formation

Calcium metabolism in fish is complex and not well understood, however it is generally accepted that the deposition of calcium on hard parts of fish is affected by feeding activity, reproduction and environmental variables (Van Oosten 1944). Studies have shown that fish from temperate regions lay down two different zones on the edge of bones and scales each year (Cunningham 1905). These two zones, one light opaque and one dark translucent, when viewed with reflected light, represent distinct periods of rapid and slow growth, respectively.

Fish otoliths are composed of alternating opaque and hyaline (translucent) bands. The opaque band is richer in nitrogen and the hyaline band is richer in calcium (Casselman, 1974). Immermann (1908) investigated the microscopic structure of North Sea plaice otoliths and found the distinction of light and dark bands was due to the optical effect of light being reflected back from the radial rows of inorganic calcium carbonate needles and from light passing through the organic ground substance. Panella (1971) found in a period of rapid growth, light coloured inorganic calcium carbonate, in the form of aragonite crystals, is added to calcium structures throughout the fish. During this period of rapid growth there is a higher ratio of inorganic (90%) to organic material (10%) deposited on the edge of bony structures. Slow growth is characterized by a dark translucent zone (under reflected light), composed of thin layers of predominantly organic material with very little inorganic calcium.

b. WHITE HAKE VERTEBRAE AND OTOLITHS

Vertebra morphology

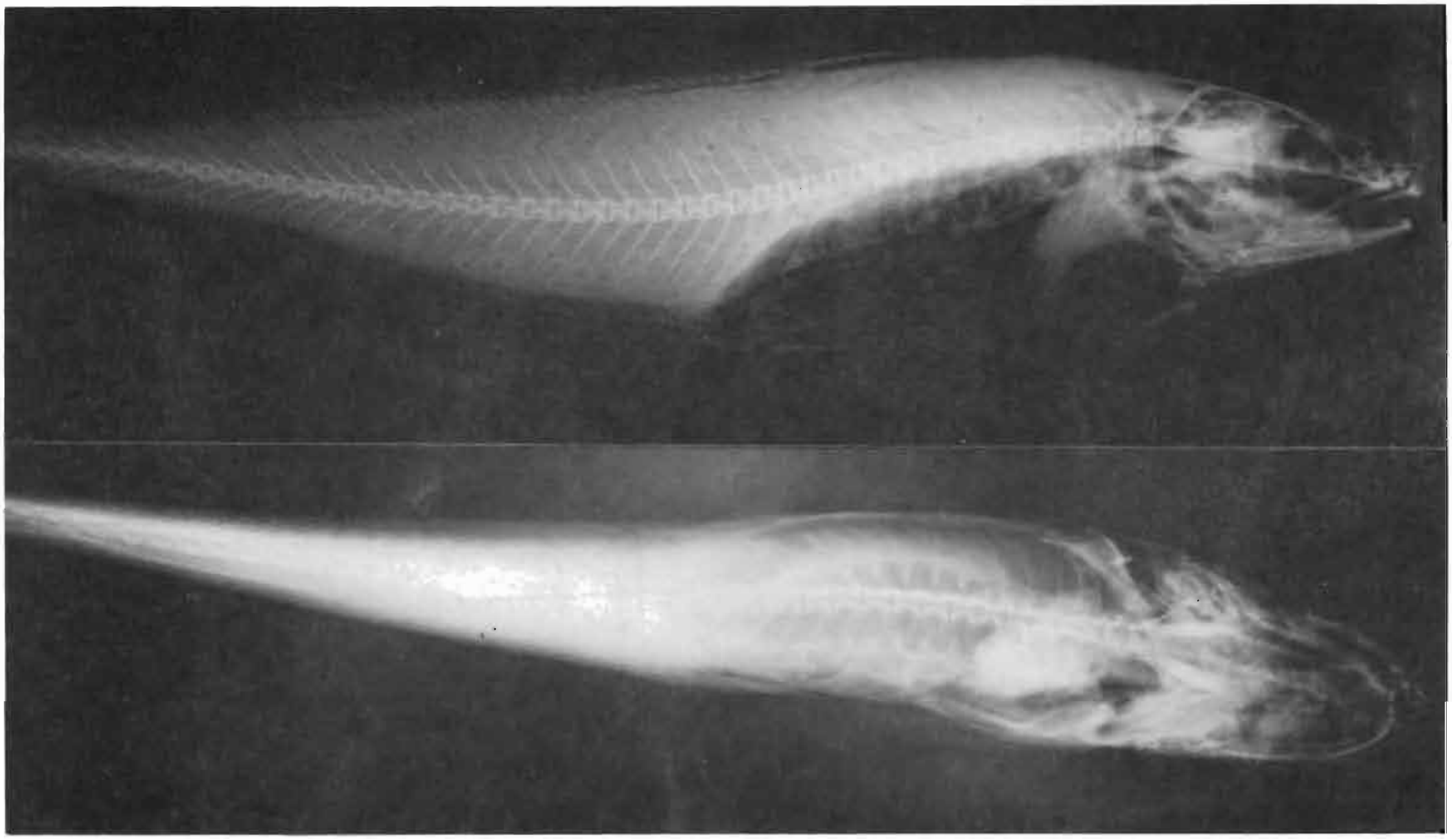
White hake in the southern Gulf of St Lawrence have 48 or 49 vertebrae (Musick 1969), varying in size according to position along the spinal column. The largest vertebrae, which were selected for ageing purposes, lie immediately behind the skull (Figure 6). The smallest vertebrae are in the caudal region. There are two types of vertebrae in fish, the caudal or tail vertebrae (Figure 7) and the abdominal or trunk vertebrae. Both types of vertebrae have neural arches and neural spines but only the latter have haemal arches and haemal spines (Kent, 1965). Both types can be used to age the fish but for ease of viewing and sampling, the first three abdominal vertebrae were selected.

Each vertebra has a solid centrum which is concave on both anterior and posterior faces. The centrum is surmounted by a neural arch which encloses the neural canal through which passes the spinal cord. A small hole in the centre of the centrum marks the position of a strongly constricted notochord. Between centra, the notochord sheath forms strong intervertebral ligaments which strengthen the spinal column. On the surface of each centrum are ridges and alternating translucent and opaque rings. These bands are concentric around the apex of the centrum and vertebra growth occurs at the outer edge of the centrum. As in other hard parts of fish, these bands correspond to changes in calcium metabolism and reflect changes in the rate of growth.

Otolith morphology

Otoliths are calcium carbonate structures found on each side of the head in cavities at the base of the semicircular canals (Figure 6 and Figure 2). There are three pairs of otoliths in fish, the sagitta, the lapillus, and the astericus. These small inorganic bodies together with the semicircular canals form part of the auditory (vibratory sentation) and balance system of fish (Lagler

Figure 6. X-ray of juvenile white hake showing skeletal structure and location of otoliths and vertebrae. The top photo is the lateral view and the bottom photo is the dorsal view (X-ray photos courtesy T. Hurlbut).

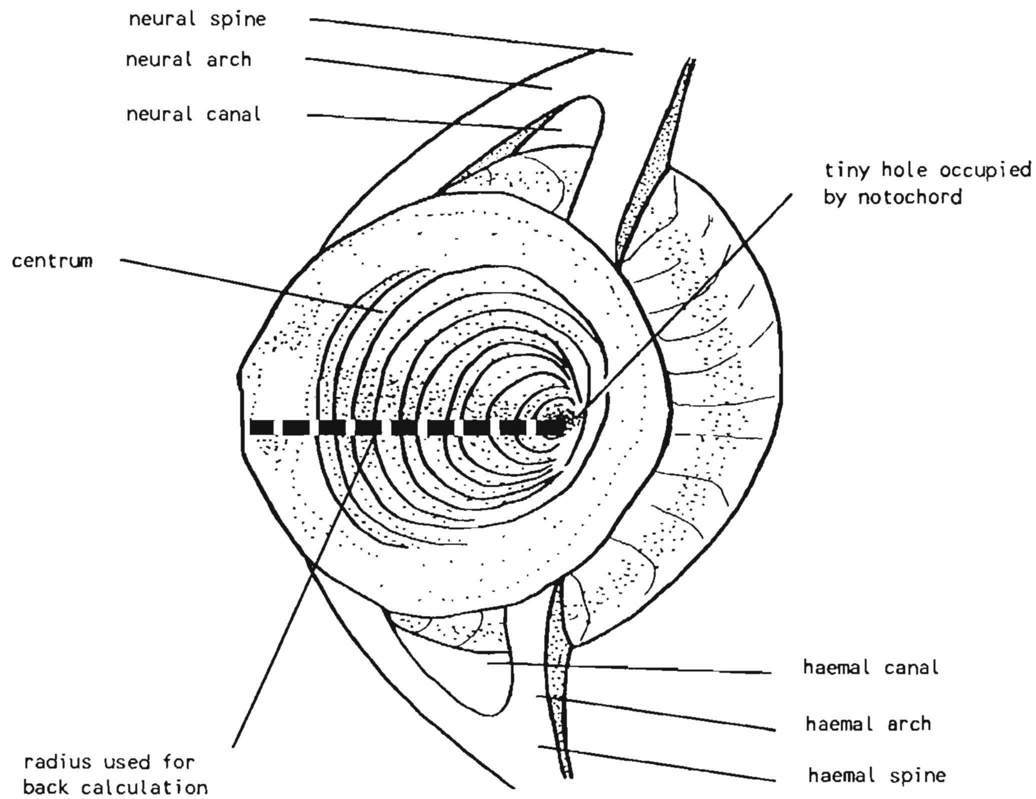


et al., 1977). Of the three pairs of otoliths the largest, the sagittae, have been used extensively to age fish since the late 1890's.

The sagittal pair of otoliths from white hake consists of long, thin, slightly curved structures ranging in length from a few millimeters to 2 or 3 centimeters (Figure 8a). The left and right sagittae are almost identical mirror images of each other. When viewed in the head cavity, the sagittae lie with the longer axis oriented in an anterior-posterior direction with the rostrum pointing anteriorly. The uppermost dorsal edge is rounded and the outer distal surface is smooth and convexly curved. The inner proximal (to the brain) surface is concave and has a crenulated surface divided by a long groove called the sulcus acusticus, which is part of the auditory system and contains nerve fibres.

Growth gradients represented in the sagittae of fish are not isometric and the highest growth rate occurs along the length of the otolith in an anterior-posterior direction (Figure 8b). Intermediate growth occurs on the proximal surface and the lowest area of otolith growth is the distal surface and in the area of the sulcus (Gauldie and Nelson 1990). As the fish grows older, more calcium is deposited on the internal or proximal surface than the external or distal surface. According to Chilton and Beamish (1982) it is possible that no material is deposited on the external surface of some fish in some years. The sagittae are thickest in the centre and when examined in transverse section, this thickened area reveals an internal structure of light and dark zones concentric around a nucleus.

Figure 7. Schematic drawing of the caudal vertebrae of white hake.



c. TECHNIQUES OF AGE DETERMINATION

Interpretation criteria: Vertebrae

Direct observation of growth rings from the face of the centrum of a vertebra were made using a Wild Leitz M3 binocular microscope with low power 6.4X objective lens, 10X21 eyepieces and reflected light using the medium setting on the transformer. Measurements of the centrum along the ventral radius (Figure 7) can be made with an ocular micrometer. The rings are also present in relief as ridges on the centrum and can be enhanced if rubbed with a soft carbon pencil. The radius from the centre of the centrum to each annular ring can be recorded for back calculation purposes.

Interpretation criteria: Sagitta otoliths

Sectioned white hake otoliths are examined using a Wild Leitz M3 binocular microscope with 16X objective lens and 10X21 eyepieces and reflected light at a medium setting on the transformer scale. It is important not to increase the magnification used to view white hake otoliths without thorough consideration of the effects. There are numerous thin translucent zones or checks which are not annuli. These checks are visible in juvenile white hake only 5-7 cm in length. Changing magnification or increasing the lighting can result in higher age counts. The best readings are obtained using reflected light and a dark background. Under reflected light, zones of slow growth and low mineralization appear as dark translucent or hyaline rings and zones of rapid growth and denser calcification reflect the light and appear as opaque white rings. Using an optical pointer greatly assists counting rings.

In cross-section, the zone of fastest growth is from the nucleus to the edge along the ventral axis (Figure 9) it is here that the rings are furthest apart and easiest to read. This is usually the clearest zone for viewing and counting annuli. A second count of the rings is taken along the shorter axis from the nucleus to the dorsal edge. Generally the growth zone in the distal area and near the sulcus groove is so slow that rings are too close together or disappear entirely and do not give a reliable

Figure 8a. Sagittal otoliths of white hake, dorsal and ventral view.

Figure 8b. Schematic drawing of the sagittal otolith of white hake under 16x magnification.

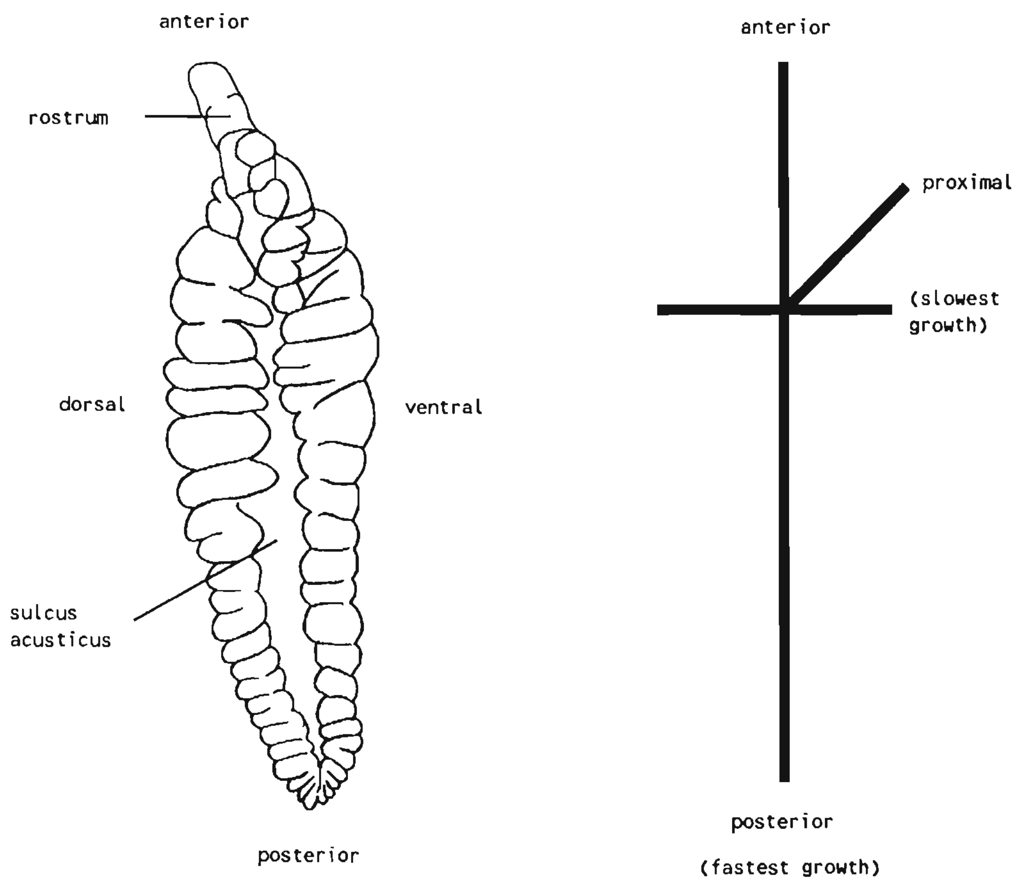
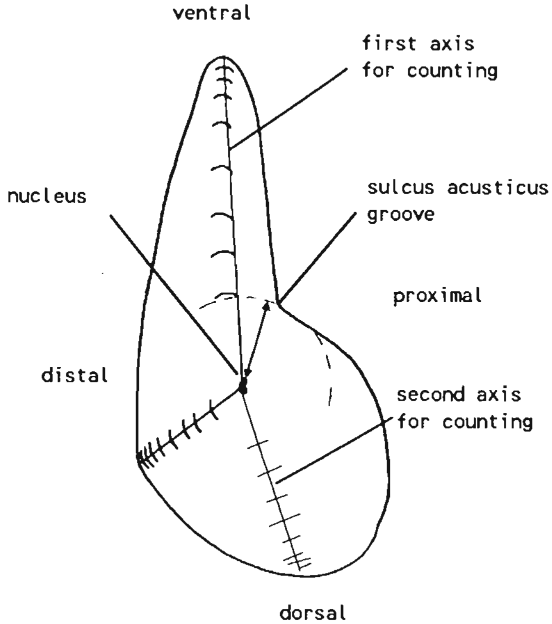


Figure 9. Cross section of a sagittal otolith of a white hake.



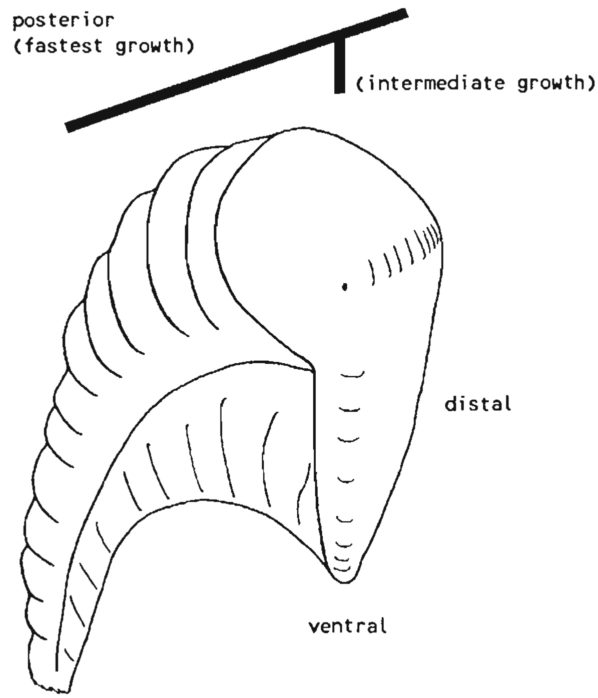
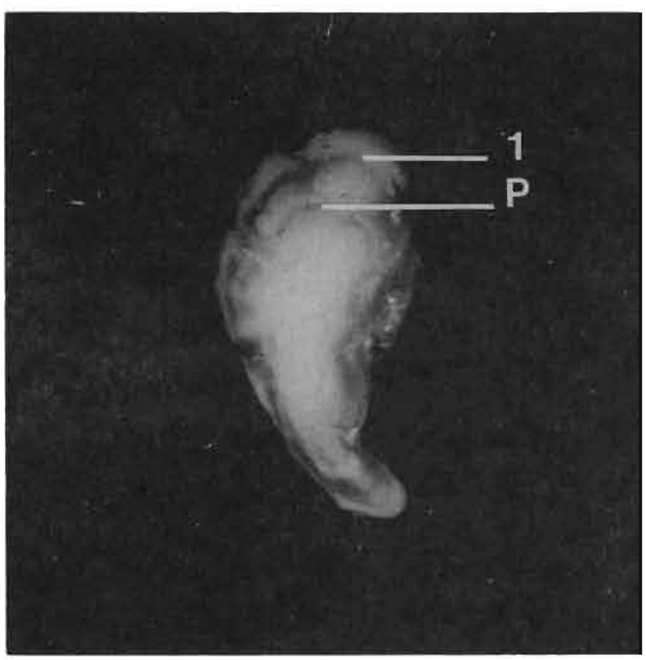


Figure 10a. Photographs of white hake otolith cross sections viewed under 16x magnification. One year old male 27 cm in length with a wide opaque edge and a 'pelagic' ring probably laid down during the first winter, at about 6 months of age.



reading. The dorsal and ventral axis readings are compared and any discrepancy between the two is reconciled before the number of annuli is recorded.

Counting rings (age) commences at the first clear annulus which appears as a distinct wide dark band under reflected light. This first annulus occurs after an unusually wide opaque zone at a distance of approximately 1 mm from the nucleus. Although this distance is not and should not be used as a criteria for determining the first ring, it is a rough guide as to where the ring might be expected. Another general guide for determining the location of the first ring is to identify the apex of the sulcus acusticus groove and draw a radius from the nucleus. No annual rings are generally found along the proximal axis between the nucleus and this radius distance. Samples of three different age white hake are shown in Figures 10.

General Interpretation criteria

Often, the first annulus is the most difficult ring to determine on both a vertebra and an otolith. This is true for four reasons:

1. A pseudo or 'pelagic' ring is often found between the nucleus and what we are assigning as the first ring. This pelagic ring is formed during the first winter of life when the hake has reached a length of 12 to 16 cm at about 6 months of age. For assessment purposes we assign January 1 as the birth date, thus the first annulus is actually laid down at about 18 months of age.

2. The unusually wide opaque zone around the nucleus, gives the appearance of irregular spacing. White hake have a protracted spawning period in the summer in the Gulf of St Lawrence (Nepszy 1968) and rapid larval and post larval growth probably produce this wide opaque zone. Based on the assumption of dark translucent rings laid down during the period of slow growth, this first hyaline ring will occur at some irregular period with subsequent rings more regular at one year intervals.

3. Checks are numerous and common on white hake vertebrae and sagittae. They can be observed around the nucleus and on either side of the 'winter' annulus. Often it is difficult to determine whether a ring is a check or an annulus, the only guide is that checks are usually faint, irregularly spaced or incomplete. Often four or five dark rings, which may be mistaken for annuli, form at regular intervals during the first few months of development (sometimes referred to as a 'pelagic' ring (Hunt 1980)). These are discounted if they occur between the nucleus and a distance equal to the distance to the apex of the sulcus groove.

4. The distance from the nucleus to the first annular ring may be variable between different otolith sections because the transverse cut through the sagitta may not always hit the nucleus. Back calculation is the best way to solve this problem.

The second and third annuli are widely spaced and there are often numerous checks making the interpretation of the exact position of these rings difficult. The spacing between the rings shows a slight decrease between each subsequent ring as the fish gets older. Despite the dense packing of rings due to the slower growth in the dorsal radius, this region is useful for verifying any obscured, cloudy or otherwise difficult zones on the ventral tip (Figures 10).

Determining the edge type is subjective. A translucent or hyaline zone is apparent on the outer edge of otoliths sampled during summer. It may be a narrow hyaline or a fully formed wide hyaline zone, depending on environmental factors affecting the fish. The transition from narrow to wide edge type is subjective, but in general the width is determined by comparison with previous annuli. If the ring is less than half the width of previous translucent zones, it is considered narrow and if the zone appears almost fully formed, it is designated a wide edge type. As autumn progresses, a narrow opaque band begins to form on the edge. This zone is often difficult to observe in the early stage of formation due to reflection of light at the edge of the otolith. If the growth zone is wider than half of the previous opaque zone, it is then designated a wide opaque zone. Typically, a wide opaque zone occurs in late autumn and early winter when growth is assumed at its peak. In spring, growth of white hake slows down and a translucent zone appears at the edge. This band persists until late summer early autumn when warmer waters, the end of the spawning 'commitment', and changing feeding patterns begin the formation of an opaque ring again.

d. UNRESOLVED DIFFICULTIES IN INTERPRETATION

Otolith interpretation is subjective. Many different kinds of false rings can be observed - split, double, check rings, etc. These must be discounted in some way.

1. Otoliths from hake 12 cm and less show numerous weak false rings and the lack of outer annular rings makes it difficult to determine the formation of the first

reading. The dorsal and ventral axis readings are compared and any discrepancy between the two is reconciled before the number of annuli is recorded.

Counting rings (age) commences at the first clear annulus which appears as a distinct wide dark band under reflected light. This first annulus occurs after an unusually wide opaque zone at a distance of approximately 1 mm from the nucleus. Although this distance is not and should not be used as a criteria for determining the first ring, it is a rough guide as to where the ring might be expected. Another general guide for determining the location of the first ring is to identify the apex of the sulcus acusticus groove and draw a radius from the nucleus. No annual rings are generally found along the proximal axis between the nucleus and this radius distance. Samples of three different age white hake are shown in Figures 10.

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1. Otoliths from hake 12 cm and less show numerous weak false rings and the lack of outer annular rings makes it difficult to determine the formation of the first

annual ring. Often the early rings present in small hake are not visible in larger hake.

2. Hyaline ring formation on the edge is hard to observe. Deposition of new material occurs first on the anterior and posterior ends and can be identified more readily there.

3. Although all members of a year class, by convention, are assigned a single birth date (ie. January 1), it is often difficult to assign the true chronological age. This is because the true age of any one year class can vary by up to 5 months due to the extended spawning season. This is dependent upon the length of time since spawning, and the time spent in the larval stage.

4. Hake from some areas appear to have a higher proportion of unreadable or hard to read otoliths.

IV. RESULTS AND DISCUSSION

a. AGE VALIDATION AND VERIFICATION

Vertebra/Otolith comparisons

A comparison was conducted on the age determined from 245 fish from both otoliths and vertebrae. The age determined from vertebrae was similar to that estimated from otoliths of the same fish (Figure 11). Seventy eight percent of the fish were interpreted as having the same age from both types of hard parts (age range 2 to 10). Otoliths indicated a higher age in 13% and a lower age in 7% of the observations. Slightly more than 1% of the total readings differed by two years.

Cyclical annulus formation

Because of the number of checks, it is to be expected that any analysis of time of annulus formation would not provide as clear a pattern as observed in species with fewer checks.

Samples collected from seasonal surveys (Clay, 1991) and commercial sampling were used to identify the time of the annual ring formation (marginal increment analysis). Although data are not available for all months and despite the difficult and subjective nature of edge type determination the results do indicate a seasonal pattern, with 'winter' ring formation occurring in spring and summer (Figure 12). This does not agree with the hypothesis that the formation of the annulus is due to reduced growth in the winter period. Hunt (MS 1982) also noted in his study that the edge type observed on otoliths collected in September '[did] not conform to [the] expected types ... representing summer growth'.

If annulus formation is due to a factor other than temperature, the formation of the annulus may not be 'time' dependent. White hake in the southern Gulf overwinter in the relatively warm (5-6^{o}C) deep waters of the Laurentian Channel (>200 m) (Clay, 1991). Later they migrate from these warm waters to the shallower regions of the southern Gulf of St. Lawrence in May and June where water temperatures are less than 2^{o}C. At this time the gonads are developing in preparation for summer spawning, thus the ring formation (reduced growth) could be due to a combination of the lower water temperatures of the shallows in spring and spawning. Spawning in these hake requires substantial energy outputs and thus could result in reduced growth. Further study would be desirable to confirm this marginal increment analysis, such further study should be directed specifically to ring formation incorporating sexual ripeness with season.

Both hake age readers have commented on the fact that a small percentage of the otoliths were different in appearance from the majority, they noted that these fish were not randomly distributed throughout the otolith collection but occurred in clumps (ie. many in a single sample). Hurlbut and Clay (MS 1990) reported that at least two stocks of white hake probably exist in the southern Gulf of St. Lawrence. These stocks inhabit different thermal regimes possibly leading to two patterns of annulus formation. Although Clay and Hurlbut (MS 1990) found no significant difference in growth between the deep and shallow water components of the southern Gulf hake stocks, however, they did not investigate systematic differences in the pattern of annulus formation. More work is required to investigate whether such a difference is visible and can be attributed to stock differences.

Length frequency analysis

The length frequency of white hake (sexes combined) caught in the resource surveys of September 1985 and 1986 were analysed for any pattern(s) that might indicate year classes. Data from both years (Figures 13 and 14) showed a definite series of modes that, for the younger ages, are likely to indicate year classes. Modes occur at 18 to 22 cm, 31 to 33 cm, and 41 to 44 cm. Often a mode of small fish (6 to 10 cm), also few in number, are collected on these surveys. These latter fish are believed to be the 0 group of the year found mostly

Figure 11. Comparison of number of annuli estimated from vertebrae and otoliths of the same white hake collected in 1983 from Gulf of St. Lawrence. The small numbers indicate the actual number of fish while the large numbers are the percent of fish with either equal age estimates (on the line) or age estimates off by one or more years.

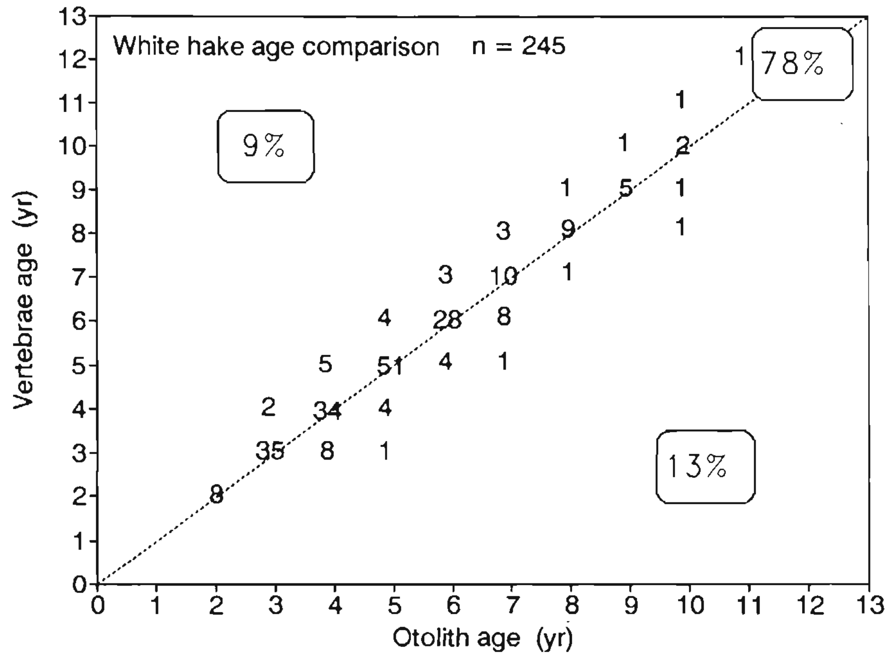


Figure 12. Marginal increment analysis of white hake based on presence of the opaque edge type (fast growth period) on the outer edge of the sectioned otoliths. Line indicates occurence of opaque edge types, bars indicate sample sizes. The highest proportion of fish indicate slow growth ending in September.

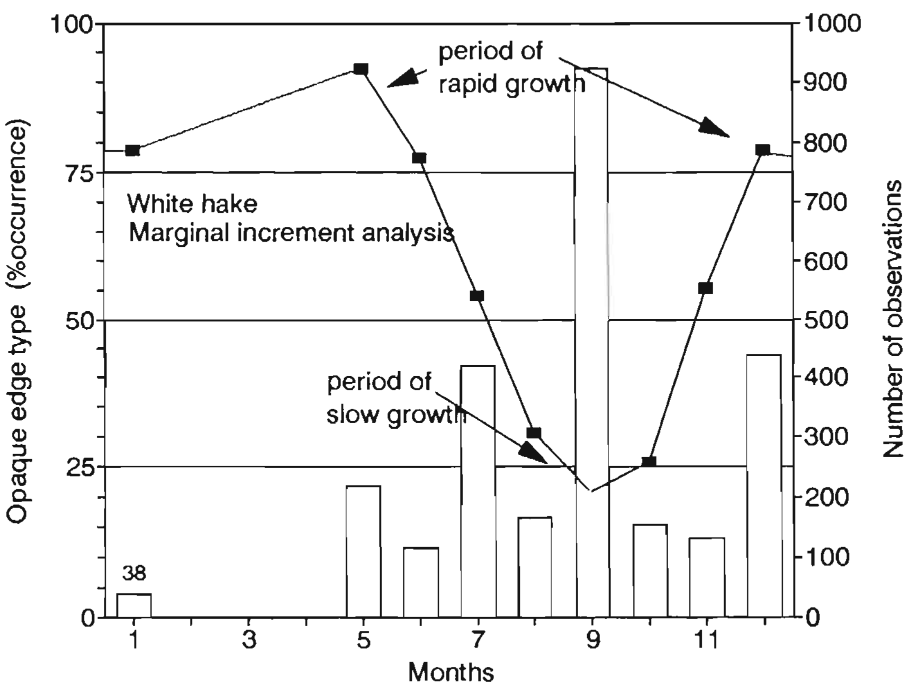
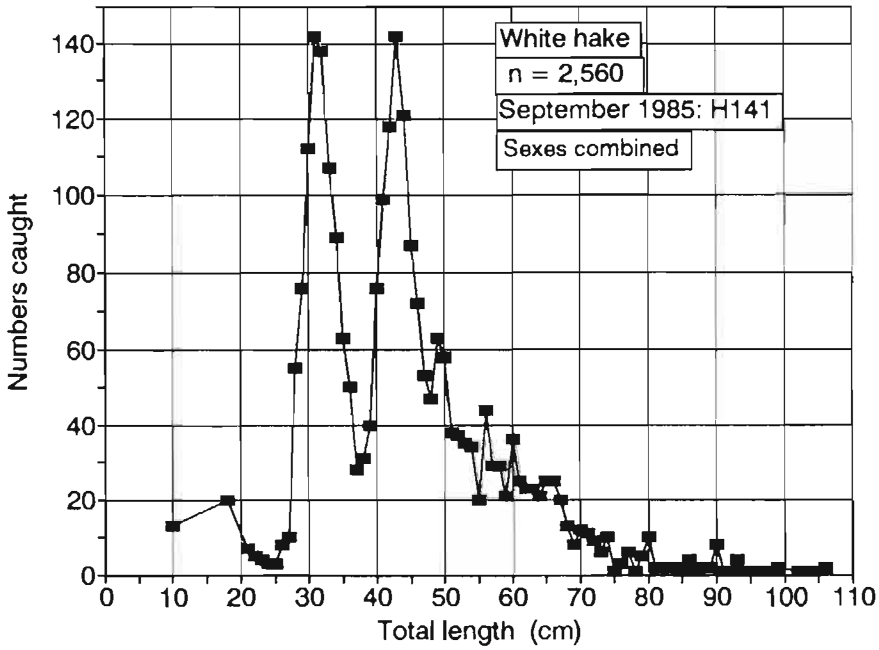


Figure 13. Length frequency (sexes combined) of white hake caught during the annual September survey of the southern Gulf of St. Lawrence in 1985.



inshore of the surveyed area. These modes agree with the annuli observed on the vertebrae and otoliths. The relative size (proportion) of the first three modes changed between 1985 and 1986, however, the data do show clear modes. In the older age groups (>50 cm) the length frequency exhibits a less obvious pattern as the male and female modes are not necessarily coincident among these larger fish.

The 1990 resource survey was the first survey having length frequencies of sexed fish recorded for white hake (Figure 15). In this survey, each sex exhibits modes in approximately the same size range as were observed in the sexes combined surveys of 1985 and 1986. (There may have been some difficulty in determining the sex of immature fish on this survey, thus the authors feel no notice should be taken of the sex ratio of the first two modes.)

When analysed by the commercial modal analyses computer software MIX (adapted from the technique of Macdonald and Pitcher 1979) the mean and percent composition of each mode of the younger age groups matched that estimated by conducting 'age reading' on otoliths from a stratified subsample of the research survey catch (Table 1). The standard deviation did not match as well. It was considered that this technique was not suited to age validation as too much 'input knowledge' was required to 'age' the length frequency. This is particularly true on sexes combined data, thus no further analysis was attempted during this study with modal analysis techniques.

Table 1. Comparison of population structure by modal analysis of length frequencies and age reading of otoliths.

Age group	1986					
	len. freq. analysis			age deter.		
	mean	s.d.	p.c.	mean	s.d.	p.c
1	21.6	2.5	6	25.0	4.1	5
2	31.5	2.2	45	31.5	2.0	30
3	41.9	2.5	22	37.6	4.5	21
4	50.6	2.3	16	45.6	5.1	21

Figure 14. Length frequency (sexes combined) of white hake caught during the annual September survey of the southern Gulf of St. Lawrence in 1986.

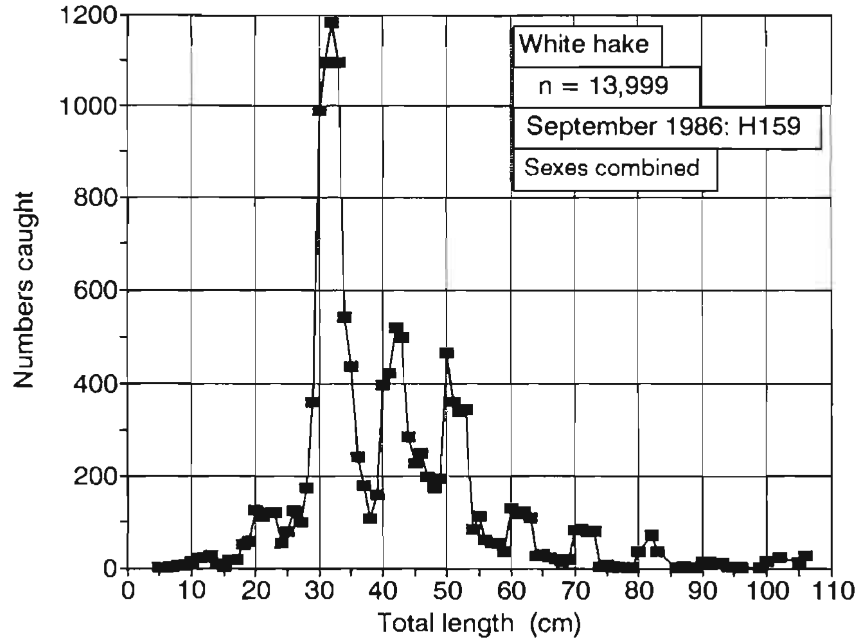
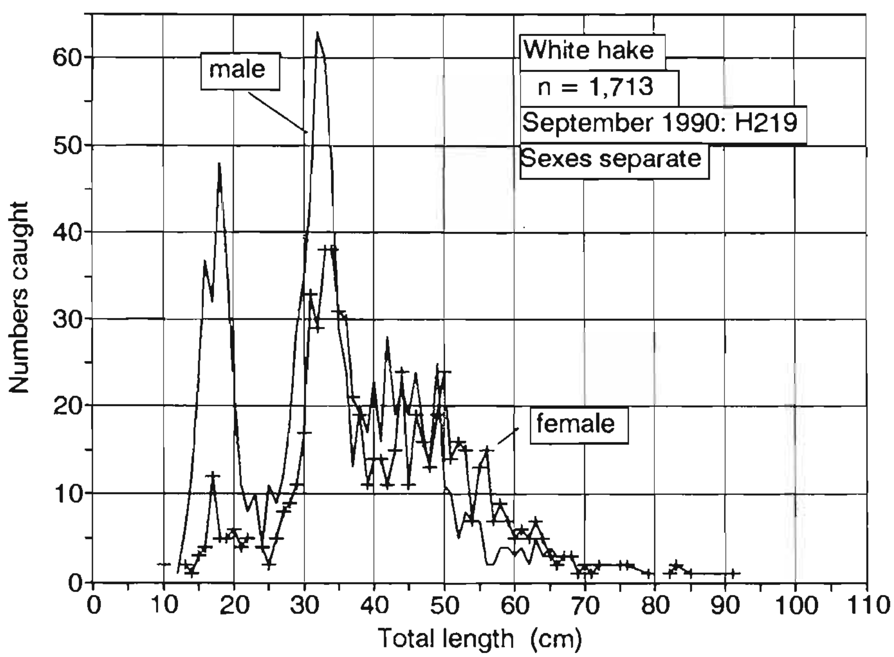


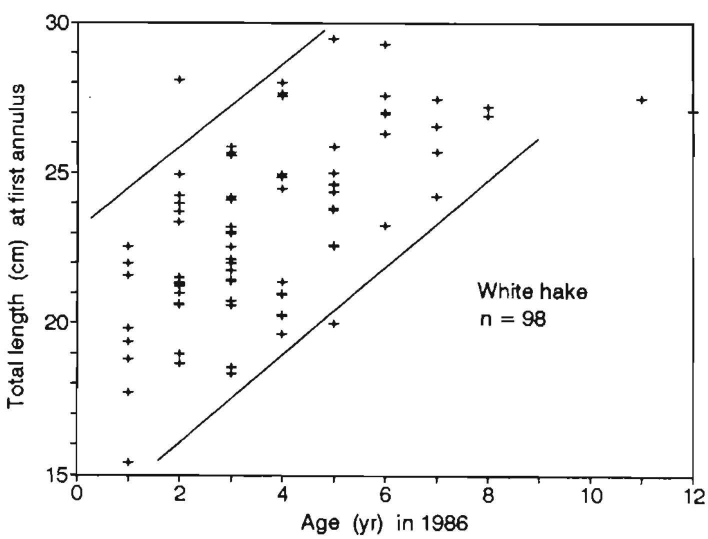
Figure 15. Length frequency (sexes separate) of white hake caught during the annual September survey of the southern Gulf of St. Lawrence in 1990.



Back calculation

Length at the time of formation of each previous annuli was estimated by back calculation for a sample of 98 otoliths from the September 1986 resource survey. The radius of each ring (annulus) was measured and expressed as a percentage of the total sectioned otolith radius. Casselman (1990) has shown a seasonal and size dependent relationship for otolith and fish growth, however, the authors consider that this phenomenon will not substantially affect the results as all of the otoliths were collected during one month. The direct proportion method of assigning a length for each annulus was used (as discussed in Clay, 1982). The Lee phenomenon (Lee, 1912) was observed when the length at age one (first annulus) of sexed samples of these fish was plotted against their age in 1986 (Figure 16). The length at age one appears to be greater for older fish. A similar pattern was observed with the length at both ages two and three. The length at age estimated from individual fish (Figure 17) indicates a substantial difference in length at age between male and female white hake at age 4 and above. The growth estimated from total annulus counts of the entire 1986 resource survey (Figure 18) indicates a similar pattern, but extended to higher ages due to the larger sample size (n = 2005).

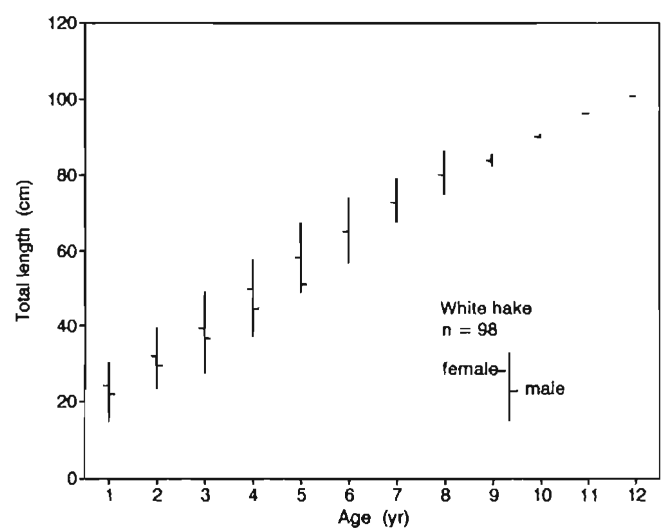
Figure 16. Lee phenomenon (Lee, 1912) exhibited by white hake. This indicates older age fish generally have faster growth in the first one to three years than younger fish.



Plotting the 4 oldest females according to the method of Walford (1946) (Figure 19) indicates growth approximating a straight line with an incline to intersect the 45^{o} line at 171 cm (often considered L_{∞}). The oldest males, for which back calculated age data were available were age 4, in their case, the short period of growth creates the illusion of near linear growth parallel to the 45^{o} line.

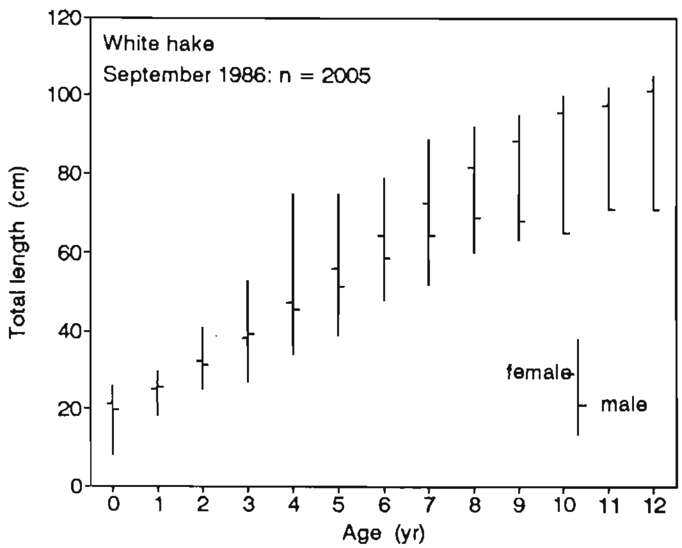
The mean size at age estimated by back calculation (Figure 17) should not necessarily correspond with the mean size at age estimated from reading 'total age' from otoliths collected on the same September survey (Figure 18), especially if the ring is formed in the cold winter months. In this case, however, there is a close correspondence, for the younger ages, in fact the mean length in September is slightly above the length at ring formation. From back calculation the mean length is the length in the middle of the period of reduced growth, ie.

Figure 17. Back calculated length at age of white hake caught during the 1986 annual resource survey of the southern Gulf of St. Lawrence. The fish represent a random sub-sample of those fish collected for routine age determination. The vertical bar indicates the range of lengths at age, ticks to the right of the bar indicate the mean length at age of males, ticks to the left represent females.



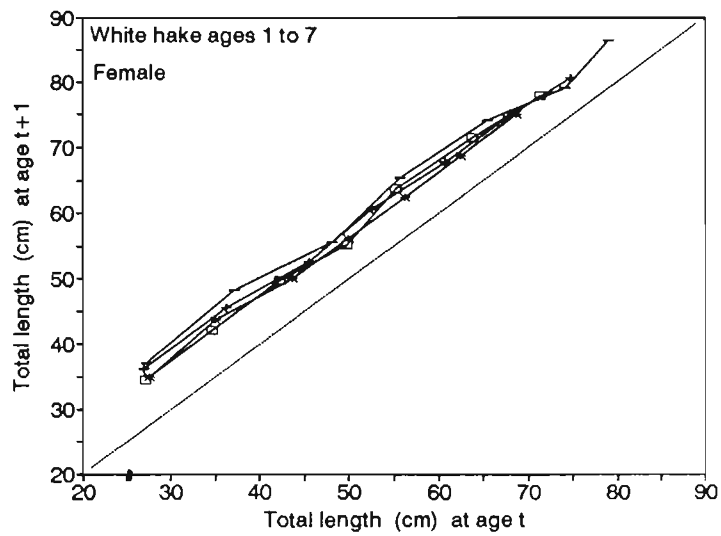
the length at the third annulus is the length on the fishes third 'birthday'. The length of a fish 'aged' 3 from routine 'total age' determination is the length of a fish past its third 'birthday' and some period into its fast growth phase. This implies the time of ring formation must have been relatively close and prior to September.

Figure 18. Length at age of white hake caught during the 1986 annual resource survey of the southern Gulf of St. Lawrence. These fish are a random stratified sample of all fish caught. The vertical bar indicates the range of lengths at age, the right ticks indicate the mean length at age of males, the left ticks represent females.



where TL is the total length in cm and M is the body mass in g. An analysis of covariance of data collected between 1985 and 1989 (five annual surveys) (Table 2) indicates a significant difference ($p<0.01$) between years for females but not for males. That is probably due to differences in sexual ripeness of females in different years. There is no sexual dimorphism in body form when considering the body length-mass relationship, however, Hurlbut and Clay (MS 1990) observed 1 of 9 meristic characters and 10 of 19 morphometric characters to exhibit significant differences for to sex.

Figure 19. Walford plot of 4 oldest female white hake whose age was back calculated. The combined data indicate an intersection with the 45^{0} at 171 cm.



b. GROWTH OF WHITE HAKE

Length mass relationship

The body length - mass relationship of white hake (Figure 20) from the 1986 September survey on the RV Lady Hammond (H159) for males is:

$$M = 0.003998 \times TL^{3.1718}, \; n=1227, \; r^2=0.97$$

and for females is:

$$M = 0.004320 \times TL^{3.1472}, \; n=1006, \; r^2=0.98$$

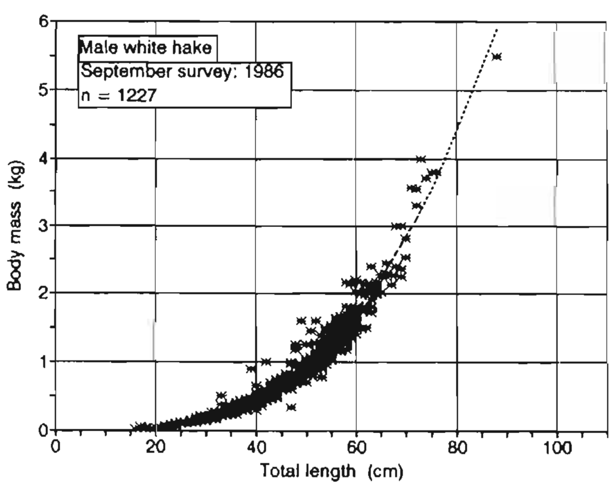
Von Bertalanffy growth equation

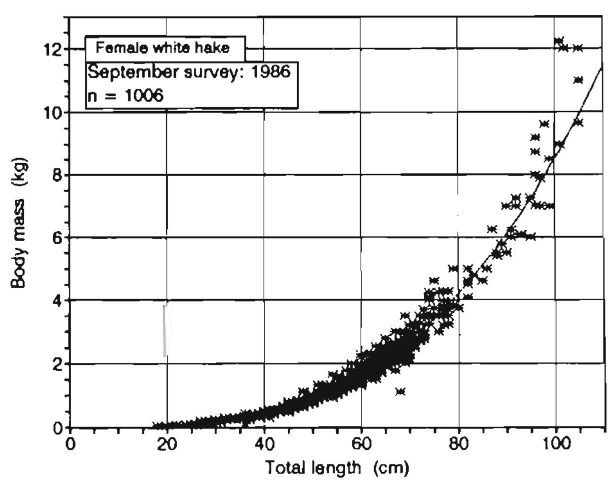
Mean length at age estimated from sectioned otoliths for the ten resource surveys from 1980 to 1989 indicate relatively stable (consistent) growth and/or age determination (Figure 21). Assessing growth year by year on individual year classes (Figure 22) also indicates relatively stable growth.

Table 2. Body length (cm)- mass (g) relationship for three annual September surveys on the RV Lady Hammond for white hake.

Year	Cruise	Sex	'a'	'b'	n	r^2
1985	H141	Male	0.002357	3.282	289	0.973
1986	H159	Male	0.003319	3.222	1286	0.970
1987	H179	Male	0.003041	3.222	418	0.964
1988	H192	Male	0.002169	3.316	264	0.980
1989	H204	Male	0.004520	3.126	437	0.981
1985	H141	Female	0.002332	3.299	312	0.986
1986	H159	Female	0.003792	3.181	1006	0.978
1987	H179	Female	0.002318	3.289	406	0.978
1988	H192	Female	0.002108	3.319	230	0.986
1989	H204	Female	0.003643	3.181	282	0.988
1985	H141	Combined	0.002501	3.283	602	0.982
1986	H159	Combined	0.004441	3.143	2295	0.989
1987	H179	Combined	0.002607	3.261	824	0.975
1988	H192	Combined	0.003235	3.210	499	0.981
1989	H204	Combined	0.004574	3.122	723	0.984

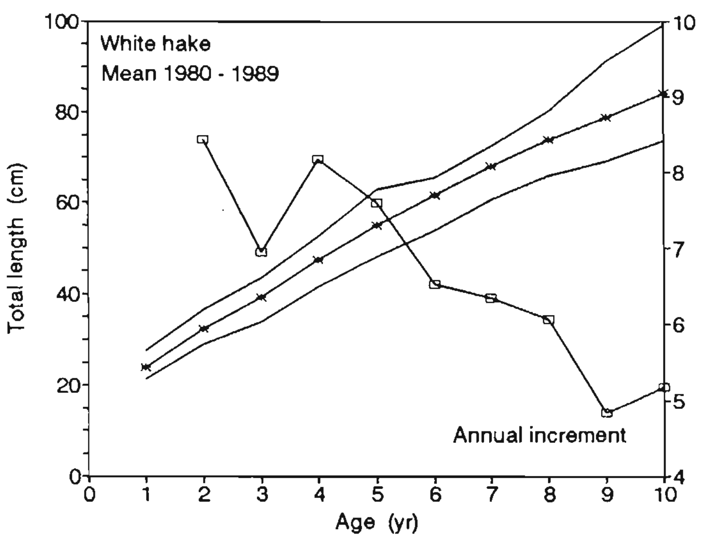
Figure 20. Length mass relationship of white hake collected from the southern Gulf of St. Lawrence annual September resource survey.





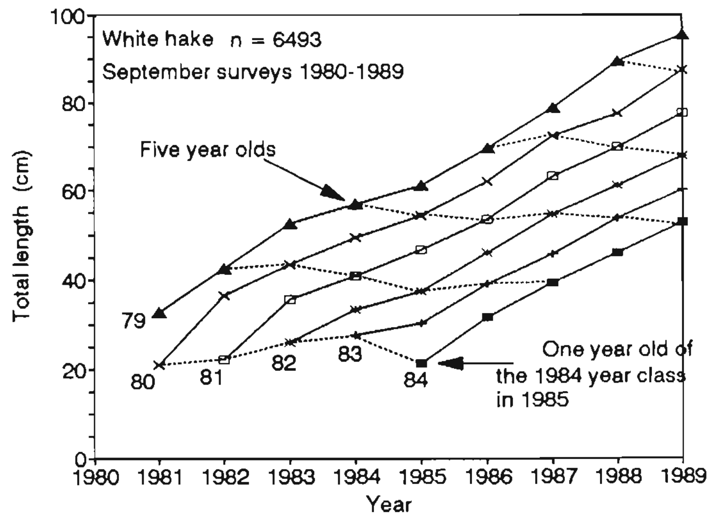
In any one year, a range of lengths at age is observed. To identify if growth compensation is present, plots were made of growth of female individuals from age 1 to age 2 (Figure 23), age 1 to 3 and age 1 to age 5. Large fish (or possibly fast growing fish) at age 1 are still large fish at age 2 and 3. The relationship begins to break down by age 5. Similar growth patterns were observed for male hake. Growth compensation does not appear to be a major factor in the growth of white hake. The wide range of growth observed in any one age of a year class (referred to as growth plasticity by Weatherley (1990)) is possibly due to the wide range of habitats but also, no doubt to the protracted spawning period of this species in the southern Gulf.

Figure 21. Mean length at age (asterisk) of white hake from 10 individual September resource surveys (1980 to 1989). The mean annual growth increment is shown by the open boxes. The lines without symbols represent the range of mean lengths at age.



Growth can be expressed in many ways, although controversial, the von Bertalanffy growth equation remains one of the most common forms. The growth of white hake is sexually dimorphic, females become larger-at-age after about three years. Using individual survey years, great differences are observed in the L_∞, these differences move beyond reasonable values as the number of age groups decreases. The estimates of length at age for the age groups for which data are available are generally reasonable, however, the predictive value beyond the data range is poor.

Figure 22. Mean length at age of individual year classes of white hake from estimated each year. Each symbol represents 'a' year class (solid line) whose length at age was estimated in 'a' year. Odd numbered age groups are indicated by dashed lines.



When using data from individual fish, the relatively small sample size of large (old) male fish from the resource surveys ($\geq$ age 8) results in L_∞ values in the range of 700 cm. Females with greater numbers of older fish ($\geq$ age 12 to 14) yield L_∞ values in the range of 180 to 200 cm, similar to that estimated from the Walford plot. Using commercial data with more large fish sampled and the ages combined to give mean length at age, we calculated an L_∞ for males (ages 3 to 10) of 84 cm and for an L_∞ for females (ages 2 to 16) of 137 cm (Table 3). These latter estimates (Figure 24) best agree with the largest fish of each sex observed in the southern Gulf research surveys.

c. SAMPLING OF SEMI-PROCESSED WHITE HAKE

Length sampling

Four conversions for 'head off' lengths to total lengths have been derived. The first two measures were based on the first and second dorsal lengths. The linear regressions are:-

$$TL = -0.24 + 1.34\ DL_1,\ n = 225,\ r^2 = 0.99$$

$$TL = -2.06 + 1.55\ DL_2,\ n = 225,\ r^2 = 0.99$$

Table 3. Parameter estimates for the von Bertalanffy growth equation calculated from commercial and research data. The commercial estimates are based on the mean length at age (ie. one estimate per age) while the research estimates are based on individual fish.

Sex	Source	L_∞	k	t_0	r^2	n	ages	range
male	research	120.79	0.0842	-1.6379	0.83	1071	12	0 - 12
female	research	454.36	0.0200	-1.5518	0.87	849	13	0 - 13
male	commercial	84.02	0.2180	0.1263	0.85	8	8	3 - 10
female	commercial	136.63	0.1062	-0.2755	0.95	15	15	2 - 16

where TL is the total length in cm and DL_1 is the first dorsal length in cm and DL_2 is the second dorsal length in cm. The same measures based on standard length (SL) are:

$SL = -1.12 + 1.21\ DL_1$, $n = 85$, $r^2 = 0.98$

$SL = -2.51 + 1.39\ DL_2$, $n = 85$, $r^2 = 0.98$

The third measure was the anal length (AL) in cm, the linear regression is:-

$TL = -6.92 + 1.91\ AL$, $n = 216$, $r^2 = 0.89$

A fourth measure was derived from the 'stump length', the linear regression is:

$TL = -0.9311 + 1.2468\ StL$, $n = 220$, $r^2 = 0.95$

where StL is the stump length in cm.

The anal length conversion has the poorest relationship, probably due to theeffect on vent size of various ripeness stages, especially among the larger females.

Although the stump length conversion has a high coefficient of correlation, the potential variability caused by differences in processing (cutting) practices by various groups of fishermen in different years has led us to select the first dorsal length for conversion purposes.

Creaser and Lyons (1986) conducted a similar study on white hake in the Gulf of Maine and derived an equation producing results less than 1.5 percent different. They went on to develop a measuring board calibrated for headless white hake that allows the total length to be read directly from the board.

Age sampling

The form of the equation used to convert otolith mass to total length is:-

$TL = a \times OM^b$

and the formula to convert otolith length to total length is:-

$TL = a \times OL^b$

where TL is total length in cm, OM is otolith mass in mg, OL is otolith length in mm and 'a' and 'b' are the parameters given in Table 4. The coefficients of determination (over 0.97 for all resource survey data) indicate a strong relationship between fish and otolith length. This equation is near linear, especially for samples dominated by smaller fish.

Analysis of covariance was conducted on the data sets from the RV Lady Hammond and RV Navicula to compare cruise/area and sex differences in the data. Table 5 summarizes the results.

All of the above relationships except the comparison of otolith lengths from the RV Lady Hammond are statistically different (see Figures 23, 24, 25, and 26). This indicates there is some form of sexual dimorphism

Figure 23. Length of individual female white hake at age 1 compared to the same individual at age 2.

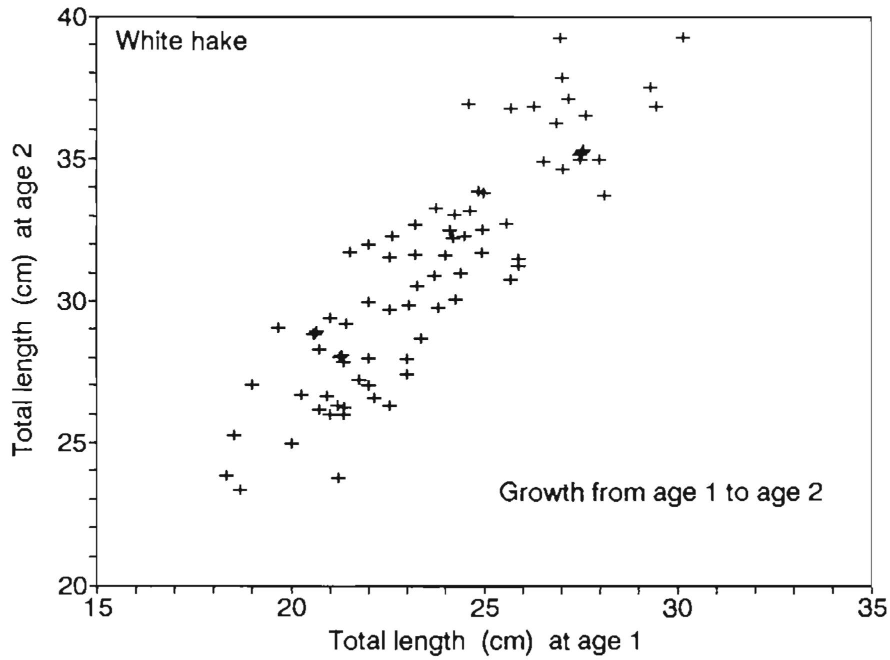


Figure 24. Growth of white hake represented by the von Bertalanffy growth curve for males and females collected from the commercial fisheries during 1986 to 1989. Values beyond the range of our data are indicated by the open symbols without lines.

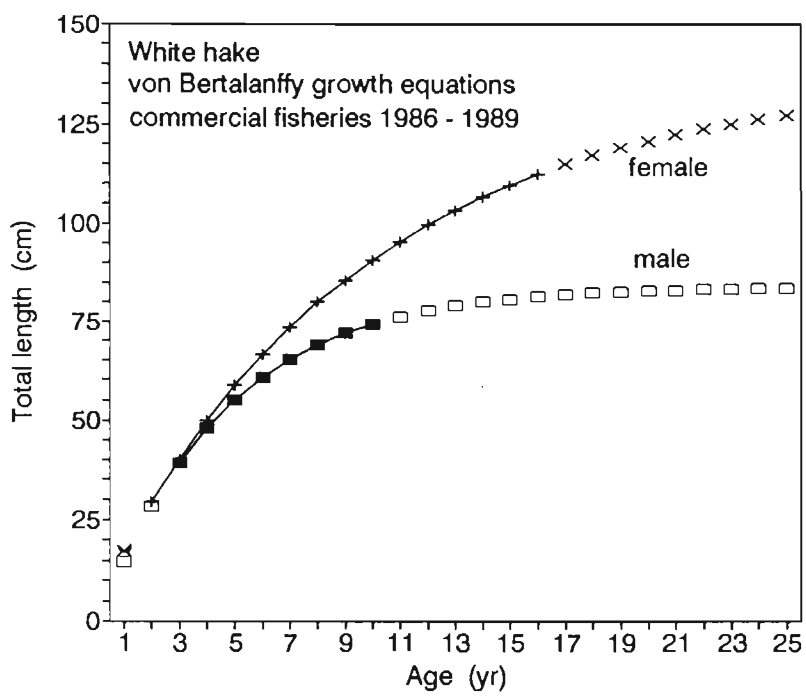


Table 4. The parameters for the regressions of otolith mass and otolith length versus fish total length.

Source*		**H159**	**H159**	**N014**	**N014**
Date		**Sept/86**	**Sept/86**	**Jun-Sept/86**	**Jun-Sept/86**
Sex		**M**	**F**	**M**	**F**
OTOLITH LENGTH					
	a	1.52504	1.41152		
	b	1.14562	1.17528		
	r	0.989	0.984		
	n	232	184		
OTOLITH MASS					
	a	4.10108	3.85320	3.13279	3.04376
	b	0.45531	0.47180	0.50812	0.51776
	r	0.989	0.983	0.992	0.994
	n	247	201	298	220

Source*		**A005**	**P091**	**P091**	**Comm.Samples**	
Date		**Jul/86**	**Sept/71**	**Sept/71**	**Jun/84**	**Jun/84**
Sex		**M**	**M**	**F**	**M**	**F**
OTOLITH MASS						
	a	3.28991	3.52142	3.00570	6.38077	1.74314
	b	0.49994	0.48893	0.52049	0.38637	0.61201
	r	0.972	0.971	0.974	0.843	0.862
	n	246	20	17	63	18

*

Note H159 - research vessel Lady Hammond: cruise H159 survey of entire southern Gulf in 1986
N014 - research vessel Navicula: cruise 87-14 survey of St. Georges Bay (Nova Scotia)
P091 - research vessel E.E.Prince: cruise P091 survey of entire southern Gulf in 1971
A005 - charter vessel survey in 1985, Baie Verte, NB
Comm.Samples - commercial samples from Cape Tormentine, NB

Table 5. Results from analysis of covariance conducted on otolith size to fish total length regressions for white hake. All the relationships of otolith mass showed a significant difference between sex and area. The otolith length relationship showed no significant difference between males and females.

Comparison between	Bartlett's X^2	F		df
SEX - H159 *	7.01			1
(otolith length)		slope	4.60	1,412
		elev	2.10	1,413
SEX - H159	7.86			1
(otolith mass)		slope	8.23	1,444
		elev	14.49	1,445
SEX - N014	14.74			1
(otolith mass)		slope	1.99	1,514
		elev	25.27	1,515
AREA - H159/N014	9.90			1
(male-otolith mass)		slope	74.81	1,541
		elev	3.28	1,542
AREA - H159/N014	12.66			1
(female-otolith mass)		slope	23.82	1,417
		elev	0.35	1,418

* no significant difference at 5% level (P>0.05)

in the otoliths of white hake. To further examine this, samples of each sex were randomly split into two approximately equal groups and an analysis of covariance conducted within sexes. Both males and females for the RV Lady Hammond and RV Navicula samples were found to have no significant difference within sexes. This implies there is sexual dimorphism in otolith size at fish length within the southern Gulf white hake population. Echeverria (1987) found sexual dimorphism in 17 of 30 Sebastes sp. investigated for otolith length to fish length.

Differences also result between areas sampled. This suggests possible distinct stocks within the southern Gulf. Clay (1991) showed that hake in the southern Gulf have definite seasonal movements within the southern Gulf from area to area. The differences observed between areas (surveys) may really be differences between seasons. Further analysis will be required to identify the determining factor.

Although significant differences were found between the sexes, the actual differences were slight, being in the order of less than 1 cm for fish in the most common commercial size range for Gulf white hake (40 to 50 cm). The difference ranged from 1 to 2.5 % with the greatest difference occurring in fish over 70 cm in total length (fish in that size range comprise less than 10% of the landings). Thus, for a sex combined relationship the difference for any individual fish should be less than 0.5 cm. This is considered an acceptable error - especially in view of our commercial sampling protocol of rounding all measurements to the nearest cm.

Otolith mass is an easier measurement to collect than otolith length. It is less subject to errors due to chipping of the tip of these otoliths which are fragile and easily broken. Chips can often affect the length by 5% or more while affecting the mass by less than 0.5%. Otolith mass read from a digital top loading balance is less

Figure 23. Otolith mass and total fish length for sexes combined data from the 1971 cruise of the RV E.E.Prince and commercial sampling data from Cape Tormentine, NB in 1984.

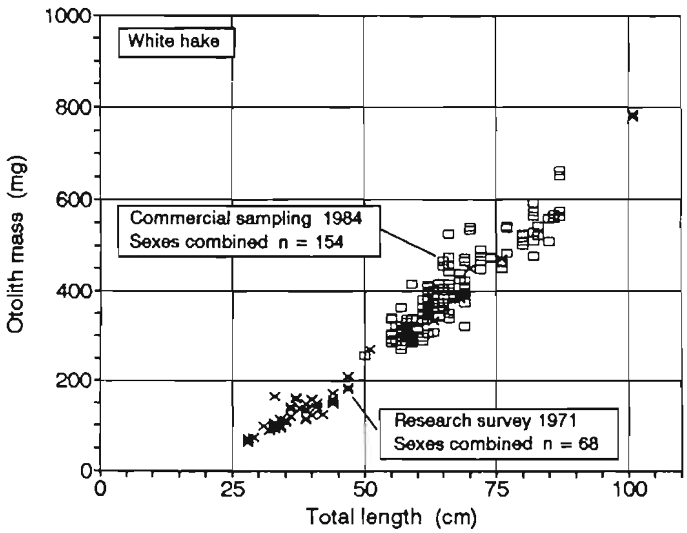


Figure 24. Otolith mass and total fish length for sexes combined white hake collected from the 1986 cruise on the RV Navicula in St. Georges Bay, NS.

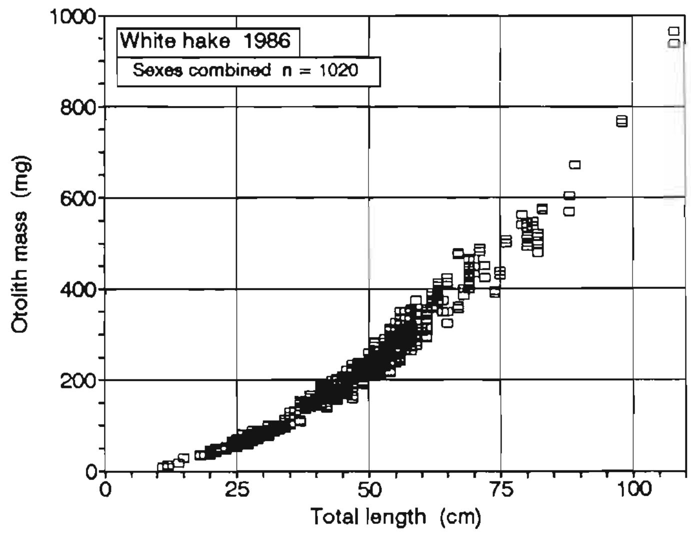


Figure 25. Otolith length and mass and total fish length for female white hake collected from the 1986 cruise on the RV Lady Hammond throughout the southern Gulf of St. Lawrence.

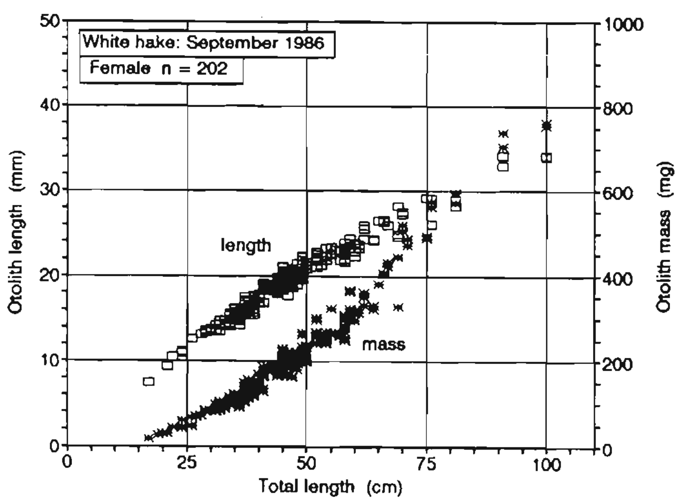
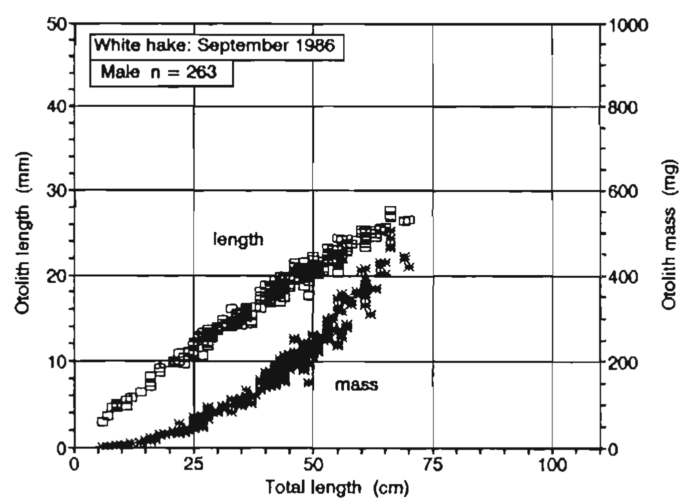


Figure 26. Otolith length and mass and total fish length for male white hake collected from the 1986 cruise on the RV Lady Hammond throughout the southern Gulf of St. Lawrence.



susceptible to operator misreading than is length read from vernier calipers. For these reasons, the following sexes-combined otolith mass (OM) to fish length (TL) relationship is proposed for conversion of otolith measurements to total length for the southern Gulf of St. Lawrence white hake:-

$$TL = 3.48756 \times OM^{0.48884}, n = 966, r^2 = 0.977$$

Clay and Clay (MS 1980) investigated the fish length to otolith length and otolith mass relationships for Atlantic redfish (Sebastes mentella) from the Nova Scotia shelf. Although they were unable to estimate age from otolith size as hoped, it was suggested that sampling otoliths without accompanying lengths could provide necessary data for both length frequencies and age determination. This situation is similar to that found with white hake.

The purpose of this part of the study was to permit otolith sampling of beheaded fish in commercial fisheries. In addition these otolith size relationships can also be used to determine the length of white hake from otoliths found in the gut of predators and to confirm fish length records when age determinations are outside the range of acceptable values.

The commercial white hake fishery is conducted mainly by small inshore vessels, often landing a mixed catch with less than 300 kg of hake per trip. When this is the case, if all the heads can be obtained it is more convenient to 'sample' the heads than to sample the 'trunks' and later convert to total length (except in the case when only length information is required). Although there are many advantages to sampling just heads it is difficult to know if a sample of heads brought to port by a fisherman is truly random or may have a bias introduced as the fisherman tried to 'assist' the sampler. Thus we use head only samples for either entire catches or catches when it can be confirmed that the sample is truly random.

V. CONCLUSIONS

White hake are one of the more difficult species for age determination. The authors have read annuli from several different species of tropical and semi-tropical freshwater fish and several species of fish from the northwest Atlantic and we have found this species to be the most difficult. This observation is not new; Petrov (MS 1973) observed the 'complicated composition of zones ... makes it difficult to determine the age ...', Markle et al. (1982) noted such difficulties and speculated they may be due to the movement of these hake between different thermal regimes. Dery (1988) noted that 'white hake otoliths normally exhibit weak[er] growth patterns ...'.

Otoliths from southern Gulf of St. Lawrence white hake have many fine closely spaced annuli which provide the opportunity for various interpretations. The authors consider the age and growth estimated by the above techniques to approximate that found in the populations of hake in the southern Gulf. Hunt (MS 1982) estimated similar growth to that found in this investigation.

More independent work, such as tag and recapture studies and marking otoliths with oxy-tetracyline, is encouraged to verify this conclusion. However, until that is done, it is important for stock assessment purposes to maintain consistent interpretation techniques for age determination of this species. Kimura (1973) reported how a suspected long term gradual change in growth of Pacific sardine (Sardinops caerula) was actually due to a shift in ageing criteria amonst the age readers. To maintain the interpretation criteria developed here we have created a reference collection of 350 research survey otoliths and 185 commercial sample otoliths. This collection along with detailed data sheets are kept at the Marine and Anadromous Fish Division of DFO in the Gulf Fisheries Center (GFC), Moncton. These otoliths have been 'read' several times by two age readers and later discussed to ensure agreement.

The current protocol to maintain quality control of age determination on this species at the GFC is:

- no reference to the size or sex of the fish, nor to the place or date of capture

- read 4 'new' trays (Figure 4) of otoliths (approximately 200 fish), then read a randomly selected reference tray, and finally a randomly selected one of the four 'new' trays again.

For the ages of the four trays to be accepted the percent agreement must be over 75% with past interpretation criteria (reference collection) and over 80% with the recently interpreted tray.

Growth described using these criteria can be summarized as follows. After the age of about 3, white hake are sexually dimorphic in regards growth, with females growing faster, to a larger size, and to an older age. White hake spawn in different areas of the Gulf of St. Lawrence between June and September, spawning

St. Lawrence between June and September, spawning peaks in mid summer. The juveniles (6 to 10 cm during the September resource survey) remain in the shallows of the southern Gulf of St. Lawrence during at least the early part of winter (December/January) rather than migrating to the Laurentian Channel with the adults. This 'cold' period coincides with the occasionally observed early 'pelagic ring' formed on fish 12 to 16 cm in length. The following summer of life is spent in the shallow inshore areas where they reach about 20 cm by the time of the September resource survey. The 'first' annual ring is not yet complete. In this and subsequent years these fish (20 to 25+ cm) migrate from the shallows of the Gulf in November/December to the deep, stable, warmer water of the Laurentian Channel. Growth continues during this time. In May these fish move out of the Laurentian Channel (5 to 6 ^{O}C) to the shallows (<2^{O}C), at the same time the gonads (of mature fish) begin to ripen. This is the period (May to July) of annulus formation in these hake, the 'first' being formed at about 25 cm. The 'second' annual ring is laid down at about 32 cm in length.

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