Report of the Ageing Methodologies Working Group

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Abstract

Results of and inter-Region survey to determine ageing methodologies are summarized by species and Region. Information on Regional contacts, ageing structure used, preparation techniques, conventions and precision are included. Additional information on training and standard terminology for describing interpretations are also summarized. An extensive bibliography is appended.

Résumé

Le présent document résume les résultats, par espèce et par région, d'une étude interrégionale destinée à déterminer les méthodes de calcul de l'âge. Il énumère les personnes-ressources des diverses régions, et fournit des renseignements sur la méthode de calcul de l'âge, les techniques de préparation et les conventions utilisées, ainsi que sur leur précision. On y trouve aussi de brefs renseignements sur la formation et sur la terminologie standard auxquelles on a recours dans les interprétations. Une bibliographie exhaustive y est jointe.

Introduction

A working group of the Sampling, Surveys and Statistics Subcommittee was given a mandate to collate documentation on age determination techniques for each Region. Representatives from each Region (D. Power, Newfoundland; G. Chaput, Gulf; J. Hunt, Chair, Scotia-Fundy; I. McQuinn, Quebec) were appointed to co-ordinate Regional input. Information on the various aspects of age determination methods was completed by Regional age reading experts with a questionnaire.

This report summarizes responses to the questionnaires and provides some additional comments on comparisons between Regions.

Results

The questionnaire used to record comments is shown in Table 1 and completed forms for major species were returned by all Regions.

Information provided for each species was extracted from the completed forms and summarized in Table 2. Additional detail and comments by age readers is provided for many species in the questionnaires which will be kept on file by the author.

While not consistent between Regions, the following definitions are suggested for use in describing age determination methods:

Age - the number of completed hyaline zones (and may include the nucleus) plus any partial zones included after the birth date;

Agegroup - all fish of the same age in the same calendar year are considered part of the same agegroup. Fish caught in their first year and prior to the birth- date are considered 0-group. Agegroup denotes the number of completed years and thus fish may be noted as 3+ but the '+' is not usually included in descriptions;

Year-class - the year sampled minus the age in years, where the age used has been adjusted from the reading to conform with all relevant conventions. A fish caught in 1982 and placed in agegroup 5 would be assigned to the 1977 year-class (1982-5 = 1977). All fish spawned in the same year are considered

part of the same year-class and will be assigned to this year-class in all subsequent years if ageing is correct;

Hyaline zone - that part of the otolith which appears translucent or dark colored under reflected light;

Opaque zone - that part of the otolith which appears white or light colored under reflected light;

Nucleus - center or focus of the otolith representing early growth and can represent first year over winter growth;

Annulus - hyaline zone assessed to represent one complete winter season;

Edge - periphery of the otolith and classified in relation to extent of new forming opaque or hyaline material;

Reading - number of hyaline zones considered annuli by the age reader including any hyaline edge . The edge is excluded from the age in fall and early winter but included after the birthdate in late winter and spring;

A number of additional codes have been adopted for describing in more detail the exact interpretation of an otolith for use in workshops and exchange of samples between age readers. These are outlined below:

(a) Hyaline edge

VNH - very narrow hyaline, winter growth just visible at edge
NH - narrow but well defined hyaline at edge, winter growth just starting
H - hyaline, winter growth well established
WH - wide hyaline, winter growth completed

(b) Opaque edge

VNO - very narrow opaque, summer growth just visible at edge
NO - narrow opaque, summer growth just starting
O - opaque, summer growth well established
WO - wide opaque, summer growth almost complete or complete

(c) Hyaline zones

N - nucleus
SPL - split zone assessed to be only one annulus
Cn - check or secondary zone - check between the n and n+1 annulus
SC - spawning check
<u>xx</u> - strong or clear zone (underscore)
$\overline{xx}$ - weak or diffuse zone (overscore)

(d) Recording of age

6(5)- probable and preferred age is 6, but may be 5 years
6? - indicated age inconsistent with other data (eg length)
(e) Other

PZ - pelagic zone indicating pelagic/demersal migration

species-specific characteristic.

A typical code for an age 5 fish might be N,2,C2,3,SPL4,5,ND indicating the nucleus was strong and counted as an annulus, the second annulus was normal intensity, a check was observed between the second and third annulus, the third annulus was strong, the fourth was split, the fifth was normal and the edge was considered narrow opaque.

A bibliographic search of primary literature published between 1981 and 1991 resulted in over 1000 titles containing the key words 'otolith or scales and age' and gives some indication of the extent of research in these fields. In addition, there are numerous articles in secondary or technical publications. A selected subset of the primary publications is given in Appendix I. Readers should take note of at least four of the listed titles:

Bagenal, TB. Ageing of Fish

Chilton, DE and RJ Beamish. Age determination methods.....

Pettila, J. and LM Dery. NMFS Age determination methods....

Summerfelt, RC and EG Hall (ed). Age and growth in Fish

The author also can provide a copy of age determination methods in the Scotia-Fundy Region, an unpublished Technical Report.

Conclusions

Age determination methods are similar between Regions but for some species differences were noted. Examples include sectioned vs broken, transmitted vs reflected light, burned (stained) vs untreated, birthdate, hyaline vs opaque zones enumerated and inclusion of the nucleus.

In general accuracy of age determinations is not well documented and known age fish are not available. Various techniques such as modal analysis, tag recapture and yearclass progression are used to validate estimates of age.

Precision is maintained by replicate readings, multiple readers, use of reference collections, interlab exchanges and occasional workshops.

Training programs for new readers appear to follow a structured and similar approach between Regions. Literature review, discussion with experienced readers, ageing of historical or reference samples followed by independent ageing until species and Region specific precision is achieved are the typical pattern.

Acknowledgments

The author thanks all those who took time to complete questionnaires and, in particular, members of the Working Group who cooridinated input for each Region.

TABLE 1. **INTER-LABORATORY SURVEY OF AGE DETERMINATION METHODOLOGIES**

Laboratory _____

Branch/Division/Section _____

Completed by _____ Telephone _____

Species aged by this group (mark species aged only occasionally with an '*')

1_____	6_____	11_____
2_____	7_____	12_____
3_____	8_____	13_____
4_____	9_____	14_____
5_____	10_____	15_____

Associated Personnel (indicate species aged with number from species list; indicate contract personnel with a 'C')

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

COLLECTION AND PREPARATION OF AGEING SAMPLES

Note: Combine groups of species/stocks with common techniques. Use a separate sheet for each species/stock group.

Species	Number aged per year		Number aged per year	
_____	____	_____	____	
_____	____	_____	____	
_____	____	_____	____	

	FINFISH				OTHER
Type of structure used for ageing	Otoliths	Scales	Finrays	Other (specify)	(specify)
	___	___	___	_____	_____

	Random	Length Stratified	Other
Age Sample collection	___	___	_____

	Maximum number by				Sample	Post-collection
Optimization protocol for samples aged	Spatial	Temporal	Gear	Length	Priorization	Sub-sample
	___	___	___	___	___	___

Statistical Test (specify) _____

	Post-collection			Post-ageing		
Storage media for sample	Dry	Wet (specify sol'n)	Other	Dry	Wet	Shelf life
	___	_____	_____	___	___	_____ yrs

Sample Preparation for ageing (multiple entries if required)

CROSS-SECTION ___ Broken ___ Sectioned ___ WHOLE STRUCTURE ___ Polished ___ Burned ___ Stained ___ Mounted ___

Liquid Immersion ___ Photograph ___ Image Analysis ___

Other _____

Viewing Technique

Light Source: Reflected ___ Transmitted ___ Colored ___ Polarized ___

Microscope Magnification ___

Video System ___ Photographs ___

Other _____

INTERPRETATION OF STRUCTURES

Defined Conventions: Birthdate _____ Nucleus Included ___ Preferred Reading Axis _____ Other _____

Special Characteristics: CHECKS Spawning ___ Migration ___ Other _____

OTHER _____

Zones Enumerated: Winter/hyaline ___ Summer/opaque ___

Maximum Recorded Age: Enumerate all zones ___ Use plusgroup after ___ yrs

VERIFICATION AND VALIDATION OF INTERPRETATIONS

Accuracy: Known Age Fish ___ Tagging ___ Chemical Markers ___ Modal Analysis ___ Other _____

REFERENCE AVAILABLE

Precision: Replicate Readings Frequency ___% ___ Two Readers by Consensus ___ Interlab Exchanges ___ Multiple Structures ___ Data Editing ___

Reference Collection ____ Image Analysis ____

Minimum acceptable level of agreement for replicate readings ___%

TRAINING PROGRAM

Please provide a brief outline of training procedures used to develop expertise including items such as: protocol, standards used to determine level of ability interaction with other age readers and laboratories, etc.
Separate sheet _____ or_____

DOCUMENTATION

List of published or in-house reports

Table 2. Summary of ageing techniques by Region and species.

Species	Region			
	Newfoundland	Gulf	Scotia-Fundy	Quebec
INVERTEBRATES				
Snowcrab				
Contact	-	M. Comeau	-	-
Structure	-	Carapace	-	-
Storage	-	dry (10 yrs)	-	-
Preparation	-	radio-assay	-	-
Convention	-	age since last moult	-	-
Validation	-	known age sample	-	-
Reference	-	CJFAS 46:720-724	-	-
Clams/Quahog				
Contact	-	-	D. Roddick	-
Structure	-	-	Shell	
Sample	-	-	stratified	-
Storage	-	-	dry	-
Preparation	-	-	sectioned	-
Viewing	-	-	microscope/video	-
Conventions	-	-	preferred axis	-
Maximum age	-	-	no plusgroup	-
Validation	-	-	radio-assay	-
Scallop				
Contact	-	-	R. Chandler	-
Structure	-	-	whole shell	
Sample	-	-	random	-
Storage	-	-	dry	-
Viewing	-	-	by eye	-
Birthdate	-	-	January	-
Maximum age	-	-	10 yrs no +group	
Checks	-	-	exclude #1 spring check	-
ANADROMOUS				
Salmon				
Contact	G. Furey	G. Chaput	B. Jessop	-
Structure	scales	scales	scales	-
Sample	random	random	random	-
Priorization	spatial/temporal	systematic	temporal	-
Storage	dry	dry	dry	-
Preparation	acetate	acetate & mount	mounted	-
Viewing	transmitted	projected	reflected	-
Birthdate	January	May	-	-
Checks	spawning/migr	spawning	spawning	-

Species	Region: Newfoundland	Gulf	Scotia-Fundy	Quebec
Annulus	winter	winter	winter	-
Maximum age	all zones	all zones	all zones	-
Accuracy	modal analysis	known age/tags	known age/tags modal analysis	-
Precision	25% replicate	consensus	replicate and consensus (10%)	-
Minimum agreement	80%	-	-	-
Training	structured ages verified	ad hoc reference used	ad hoc reference used	-
Reference	-	ICES CM 89/M:7	Tec Rep MAR/T74-1	-
Arctic Char				
Contact	G. Furey	-	-	-
Structure	otoliths	-	-	-
Sample	length based	-	-	-
Priorization	length & temporal	-	-	-
Storage	dry	-	-	-
Preparation	polished, liquid immersion	-	-	-
Viewing	transmitted	-	-	-
Birthdate	January	-	-	-
Checks	spawning and migration	-	-	-
Maximum age	all zones	-	-	-
Accuracy	modal analysis	-	-	-
Precision	25% replicate and consensus	-	-	-
Agreement	85%	-	-	-
Training	structured	-	-	-
Gaspereau, Shad Bass, Smelt				
Contact	-	G. Chaput	-	-
Structure	-	scales (smelt otoliths)	-	-
Sample	-	random & length	-	-
Priorization	-	length	-	-
Storage	-	dry (glycerin for otoliths)	-	-
Preparation	-	scales mounted otoliths in glycerin	-	-
Viewing	-	scales transmitted otolith reflected	-	
Birthdate	-	spring	-	
Checks	-	spawning	-	
Annulus	-	winter hyaline	-	-

Species		Region: Newfoundland	Gulf	Scotia-Fundy	Quebec
	Maximum age	-	all zones	-	-
	Precision	-	10% replicates	-	-
	Training	-	literature	-	-
MARINE MAMMALS					
Seals					
	Contact	W. Penny	-	-	-
	Structure	teeth	-	-	-
	Sample	random	-	-	-
	Priorization	spatial/temporal	-	-	-
	Storage	alcohol/glycerin	-	-	-
	Preparation	sectioned	-	-	-
	Viewing	transmitted and polarized	-	-	-
	Annulus	dentine	-	-	-
	Checks	moulting	-	-	-
	Accuracy	known age/tags	-	-	-
	Precision	replicates, consensus and exchanges	-	-	-
	Training	structured	-	-	-
	Reference	various			
PELAGIC					
Capelin					
	Contact	J. Carscadden	-	-	J-D Lambert
	Structure	otoliths	-	-	otoliths
	Sample	stratified	-	-	stratified
	Priorization	length	-	-	length
	Storage	dry mounted	-	-	dry mounted
	Viewing	reflected	-	-	reflected
	Annulus	hyaline	-	-	opaque
	Maximum age	all zones	-	-	six
	Accuracy	-	-	-	known age
	Precision	data edit	-	-	80% replicates
	Training	-	-	-	structured
	Reference	-	-	-	CAFSAC Res Docs
Mackerel					
	Contact	-	-	-	M. Castonguay
	Structure	-	-	-	otoliths
	Sample	-	-	-	random
	Priorization	-	-	-	spatial/temporal
	Storage	-	-	-	dry mounted

	Region			
Species	Newfoundland	Gulf	Scotia-Fundy	Quebec
Viewing	-	-	-	reflected
Convention	-	-	-	nucleus and rostrum
Checks	-	-	-	regional differences
Annulus	-	-	-	opaque
Maximum age	-	-	-	16
Accuracy	-	-	-	modal analysis
Precision	-	-	-	exchanges 75% agreement
Training	-	-	-	workshops
Herring				
Contact	J. Wheeler	C.MacDougall	J. Sochasky	I. McQuinn
Structure	otoliths	otoliths	otoliths	otoliths
Sample	random	length strat	length strat	random
Priorization	sample	spatial, gear temporal	spatial, gear temporal	sample
Storage	dry	dry	dry	dry
Preparation	mounted	mounted	mounted	mounted
Viewing	reflected	reflected	reflected	reflected
Birthdate	January	January	January	January
Annulus	opaque	hyaline	hyaline	hyaline
Conventions	rostrum nucleus	spawning group	spawning group pararostrum	rostrum
Maximum age	10 plusgroup	10 plusgroup	11 plusgroup	11 plusgroup
Accuracy	-	modal analysis	modal analysis	modal analysis
Precision	-	replicate	replicate and consensus 90% agreement	20% replicate 20% consensus 90% agreement
Training	one reader	one reader	structured	structured
Reference	.....various.....			
Swordfish				
Contact	-	-	J. Porter	-
Structure	-	-	otoliths, fin rays	-
.....new initiative under development.....				
GROUNDFISH				
Redfish				
Contact	W. Legge	-	K.Zwanenburg	D. Gascon
Structure	otolith	-	otolith	otolith
Sample	stratified	-	random experimental	random
Priorization	length	-	-	length
Storage	dry	-	dry	dry

Species	Region			
	Newfoundland	Gulf	Scotia-Fundy	Quebec
Preparation	broken	-	broken polish burned	broken burned
Viewing	reflected alcohol	-	reflected	reflected
Birthdate	January	-	-	-
Annulus	hyaline	-	opaque	hyaline
Maximum age	30 plusgroup	-	all zones	30 plusgroup
Accuracy	modal analysis	-	radio assay	-
Precision	consensus	-	consensus	consensus
Training	structured	-	-	structured
Reference	NAFO SCR 80/VI/79	-	CJFAS 47:1	-
Flatfish				
Contact	W. Brodie	R. Tallman	J. Hunt	-
Structure	otoliths	otoliths	otoliths	-
Sample	stratified	stratified	stratified	-
Priorization	length	spatial temporal statistical	sample	-
Storage	dry	glycerin	glycerin/dry	-
Preparation	polished	liquid	liquid	-
Viewing	reflected colored	reflected	reflected	-
Birthdate	January	January	February	-
Annulus	hyaline/opaque nucleus	hyaline	hyaline	-
Maximum age	all zones	all zones	all zones	-
Accuracy	CJFAS 24:1077-1099	-	-	-
Precision	data edit	replicate 70% agreement	-	
Training	structured	structured	not aged routinely	-
Silver hake				
Contact	-	-	J. Hunt	-
Structure	-	-	otolith	-
Sample	-	-	stratified	-
Priorization	-	-	subsample	-
Storage	-	-	dry/glycerin	-
Preparation	-	-	liquid	-
Viewing	-	-	reflected	-
Birthdate	-	-	February	-
Checks	-	-	pelagic	-
Maximum age	-	-	all zones	-
Accuracy	-	-	modal analysis	-
Precision	-	-	replicate, exchanges workshops	
Agreement	-	-	80+%	
Training	-	-	structured	-
Reference	-	-	various NAFO	-

	Region			
Species	Newfoundland	Gulf	Scotia-Fundy	Quebec
White Hake				
Contact	-	D. Clay	-	-
Structure	-	otolith	-	-
Sample	-	stratified	-	-
Priorization	-	spatial gear	-	-
Storage	-	dry	-	-
Preparation	-	mounted sectioned	-	-
Viewing	-	reflected	-	-
Birthdate	-	January	-	-
Annulus	-	rostrum hyaline	-	-
Maximum	-	13 plusgroup	-	-
Accuracy	-	modal analysis	-	-
Precision	-	replicate	-	-
Agreement	-	70%	-	-
Cod Haddock Pollock				
Contact	C. Bishop	G. Chouinard	J. Hunt	A. Frechet
Structure	otolith/scales	otoliths	otoliths	otoliths
Sample	stratified	stratified	stratified	stratified
Priorization	temporal gear	temporal gear	spatial temporal subsample	temporal gear spatial length
Storage	dry	dry	dry	dry
Preparation	broken mounted	sectioned	sectioned mounted	sectioned
Viewing	transmitted	reflected	reflected	transmitted
Birthdate	January	February	February	January
Annulus	hyaline	hyaline	hyaline	hyaline
Maximum age	all zones	all zones	all zones	all zones
Accuracy	modal analysis	tagging	tagging	-
Precision	exchanges edits	replicates	replicates edits exchanges	replicates consensus
Agreement	80%	70%	80%	80%
Training	structured	structured	structured	structured
References	.....various.....			

Appendix I; Selected bibliography

Bagenal TB (ed). 1974. Ageing of Fish. The Gresham Press. England. ISBN 0 9502121 1 3.

Bagliniere JL. 1985. Age determination of Atlantic salmon (Salmo salar) by scale reading in south distribution area: Use and difficulties of this method. CONSEIL SUPERIEUR DE LA PECHE; BOVES (FRANCE); 1985; 105 pp; BULL. FR. PECHE PISCIC.; no. 298

Beamish RJ; McFarlane GA; Chilton DE. 1983. Use of oxytetracycline and other methods to validate a method of age determination for sablefish. PROCEEDINGS OF THE INTERNATIONAL SABLEFISH SYMPOSIUM, MARCH 29-31, 1983, ANCHORAGE, ALASKA.; 1983; pp. 95-118; ALASKA SEA GRANT REP. ALASKA SEA GRANT PROGRAM ALASKA UNIV.; no. 83-8

Bedford BC. 1983. A method for preparing sections of large numbers of otoliths embedded in black polyester resin. J. CONS. CIEM.; vol. 41, no. 1, pp. 4-12;

Bennett JT; Boehlert GW; Turekian KK. 1982. Confirmation of longevity in Sebastes diploproa (Pisces: Scorpaenidae) from 210 Pb/226 Ra measurements on otoliths. MAR. BIOL.; vol. 71, no. 2, pp. 209-215;

Boehlert GW. 1985. Using objective criteria and multiple regression models for age determination in fishes. FISH. BULL.; vol. 83, no. 2, pp. 103-117;

Boehlert GW; Yoklavich MM. 1984. Variability in age estimates in Sebastes as a function of methodology, different readers and different laboratories. CALIF. FISH GAME.; vol. 70, no. 4, pp. 210-224;

Bouain A; Siau Y; 1988. A new technique for staining fish otoliths for age determination. J. FISH BIOL.; vol. 32, no. 6, pp. 977-978;

Brothers EB. 1981. What Can Otolith Microstructure Tell Us About Daily and Subdaily Events in the Early Life History of Fish?. THE EARLY LIFE HISTORY OF FISH: RECENT STUDIES.; 1981; pp. 393-394

Brothers EB. 1984. Otolith studies. ONTOGENY AND SYSTEMATICS OF FISHES, BASED ON AN INTERNATIONAL SYMPOSIUM DEDICATED TO THE MEMORY OF ELBERT HALVOR AHLSTROM. THE SYMPOSIUM WAS HELD AUGUST 15-18, 1983, LA JOLLA, CALIFORNIA.; 1984; pp. 50-57; SPEC. PUBL. AM. SOC. ICHTHYOL. HERPETOL.; no. 1

Brothers EB. 1987. Methodological approaches to the examination of otoliths in aging studies. AGE AND GROWTH IN FISH.; 1987; pp. 319-330

Campana SE. 1990. How reliable are growth back-calculations based on otoliths?. CAN. J. FISH. AQUAT. SCI.; vol. 47, no. 11, pp. 2219-2227;

Campana SE; Neilson JD. 1985. Microstructure of fish otoliths. CAN. J. FISH. AQUAT. SCI.; vol. 42, no. 5, pp. 1014-1032;

Campana SE; Zwanenburg KCT; Smith JN. 1990. Super(210)Pb/super(226)Ra determination of longevity in redfish. CAN. J. FISH. AQUAT. SCI.; vol. 47, no. 1, pp. 163-165; 1990

Castonguay M; Simard P; Gagnon P. 1991. Usefulness of Fourier analysis of otolith shape for Atlantic mackerel (Scomber scombrus) stock discrimination.CAN. J. FISH. AQUAT. SCI.; vol. 48, no. 2, pp. 296-302;

Chilton DE; Beamish RJ. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. 107 pp; CAN. SPEC. PUBL. FISH. AQUAT. SCI.; no. 60

Clay D; Hurlbut T. 1986. Catch-at-age and estimates of growth of Canadian bluefin tuna. COLLECT. VOL. SCI. PAP. ICCAT/RECL. DOC. SCI. CICTA/COLECC. DOC. CIENT. CICAA.; vol. 24, pp. 143-148;

Cleary L; Hunt JJ; Moores J; Tremblay D 1982. Herring ageing workshop, St. John's Newfoundland. CAFSAC Res. Doc. 82/41.

D'Amours D; Landry JG; Lambert TC. 1990. Growth of juvenile (0-group) Atlantic mackerel (Scomber scombrus) in the Gulf of St. Lawrence. CAN. J. FISH. AQUAT. SCI.; vol. 47, no. 11, pp. 2212-2218;

Dale T. Embryogenesis and growth of otoliths in the cod (Gadus morhua L.). THE PROPAGATION OF COD GADUS MORHUA L. AN INTERNATIONAL SYMPOSIUM, ARENDAL, 14-17 June 1983. pp 231-250. Floedevigen Rapp. no 1.

Dawson WA. 1986. Analysis of the mackerel (Scomber scombrus L.) otolith exchange programme. ICES; COPENHAGEN (DENMARK); 1986; 19 pp; ICES COUNCIL MEETING 1986 (COLLECTED PAPERS).

Dawson WA. 1986. Mackerel (Scomber scombrus L.) otolith L sub(1) analysis as a method of stock separation. ICES; COPENHAGEN (DENMARK); 1986; 13 pp; ICES COUNCIL MEETING 1986 (COLLECTED PAPERS).

Dawson WA. 1987. Further analysis of mackerel, (Scomber scombrus L.) otolith L sub(1) measurements. ICES; COPENHAGEN (DENMARK); 1987; 13 pp; ICES COUNCIL MEETING 1987 (COLLECTED PAPERS).

Dery LM. 1983 Use of laminated plastic to impress fish scales. PROG. FISH-CULT.; vol. 45, no. 2, pp. 88-89;

Farber MI; Lee DW. 1981. Ageing Western Atlantic Bluefin Tuna, Thunnus thynnus , Using Tagging Data, Caudal Vertebrae and Otoliths. COLLECT. VOL. SCI. PAP. ICCAT/REAL. DOC. SCI. CICTA/COLECC. DOC. CIENT. CICAA.; vol. 15, no. 2, pp. 288-301;

Foucher RP; Bakkala RG; Fournier D. 1984. Comparison of age frequency derived by length-frequency analysis and scale reading for Pacific cod in the North Pacific Ocean. SYMPOSIUM ON DETERMINING EFFECTIVE EFFORT AND CALCULATING YIELD IN GROUNDFISH FISHERIES, AND ON PACIFIC COD BIOLOGY AND POPULATION DYNAMICS.;1984; pp. 232-242; BULL. INPFC.; no. 42

Gauldie RW; Nelson DGA. 1990. Otolith growth in fishes.COMP. BIOCHEM. PHYSIOL., A.; vol. 97A, no. 2, pp. 119-135;

Geffen AJ. 1986. The growth of herring larvae, Clupea harvengus L., in the Clyde: An assessment of the suitability of otolith ageing methods. J. FISH BIOL.; vol. 28, no. 3, pp. 279-288;

Geffen AJ; Summerfelt RC. 1987. Methods of validating daily increment deposition in otoliths of larval fish. AGE AND GROWTH IN FISH.; 1987; pp. 223-240

Gjoesaeter H. 1985. Report on the Otolith Workshop. PROCEEDINGS OF THE SOVIET-NORWEGIAN SYMPOSIUM ON THE BARENTS SEA CAPELIN (Mallotus villosus).; pp. 233-236

Graham JJ; Joule BJ; Crosby CL; Townsend DW. Characteristics of the Atlantic herring (Clupea harengus L.) spawning population along the Maine coast, inferred from larval studies. J. NORTHWEST ATL. FISH. SCI.; vol. 5, no. 2, pp. 131-142;

Hoenig JM; Heisey DM. 1987 Use of a log-linear model with the EM algorithm to correct estimates of stock composition and to convert length to age. TRANS. AM. FISH. SOC.; vol. 116, no. 2, pp. 232-243;

Hopkins CCE; Nyholmen O; Solheim L. 1986. Qualitative and quantitative models relating otolith zone deposition to growth and condition in sexually mature male and female capelin (Mallotus villosus). POLAR BIOL.; vol. 6, no. 1, pp. 25-36;

Hopkins PJ. 1986. Mackerel stock discrimination using otolith morphometrics. ICES; COPENHAGEN (DENMARK); 1986; 17 pp; ICES COUNCIL MEETING 1986 (COLLECTED PAPERS).

Hunt JJ. 1980. Guidelines for age determination of silver hake. JNAFO vol 1, pp 65-79.

Hunt JJ. 1982. Age determination of white hake in the Gulf of St. Lawrence. CAFSAC Res. Doc. 82/25

Hunt JJ. 1987. Herring sampling program in the Scotia-Fundy Region, 1975-85. 24 pp; CAN. MANUSCR. REP. FISH. AQUAT. SCI.; no. 1923

Hunt JJ. ____ Age determination methods of the Marine Fish Division, Scotia Fundy Region. Unpublished. (available from the author) St. Andrews

Hurlbut T; Clay D; Currie L. 1985. Age of bluefin tuna (Thunnus thynnus , L.) in Canadian waters. COLLECT. VOL. SCI. PAP. ICCAT/RECL. DOC. SCI. CICTA/COLECC. DOC. CIENT. CICAA.; vol. 22, pp. 248-252;

Jones C. 1986. Determining age of larval fish with the otolith increment technique. FISH. BULL.; vol. 84, no. 1, pp. 91-104;

Keniry MJ; Albrect RJ. 1985. Distinguishing annual checks from accessory checks on scales of Lake Superior lake herring (Coregonus artedii L.). PROGRAMS AND ABSTRACTS OF THE 28th CONFERENCE ON GREAT LAKES RESEARCH. UNIVERSITY OF WISCONSIN-MILWAUKEE, JUNE 3-5, 1985.; p. 47

Krantz DE; Jones DS; Williams DF. 1984. Comparison of growth increment and stable isotope age determination methods for the Atlantic deep-sea scallop, Placopecten magellanicus (Gmelin). J. SHELLFISH RES.; vol. 4, no. 1, p. 92;

Maeda R; Hankin D. 1983. Age and growth of sablefish landed in Eureka, California: A comparison of conventional surface age assignments with sectioned otolith assignments. PROCEEDINGS OF THE INTERNATIONAL SABLEFISH SYMPOSIUM, MARCH 29-31, 1983, ANCHORAGE, ALASKA.; 1983; pp. 81-94; ALASKA SEA GRANT REP. ALASKA SEA GRANT PROGRAM ALASKA UNIV.; no. 83-8

Mayo RK; Gifford VM; Jearld A Jr. Age Validation of Redfish, Sebastes marinus (L.), From the Gulf of Maine-Georges Bank Region. J. NORTHW. ATL. FISH. SCI.; vol. 2, pp. 13-19;

McKone WD; Legge W; 1980. Evidence for using otoliths to age redfish. NAFO SCR Doc. 80/VI/79.

Messieh SN; MacDougall C; Claytor R. 1989. Separation of Atlantic herring (Clupea harengus) stocks in the southern Gulf of St. Lawrence using digitized otolith morphometrics and discriminant function analysis. 26 pp; CAN. TECH. REP. FISH. AQUAT. SCI.; no. 1647

Messieh SN; Moore DS; Rubec P; Summerfelt RC. 1987. Estimation of age and growth of larval Atlantic herring as inferred from examination of daily growth increments of otoliths. AGE AND GROWTH IN FISH.; pp. 433-442

Munekiyo M; Sinoda M; Sugimura O. 1982. A possibility of fish age estimation by means of a replica of the vertebral centrum. BULL. JAP.

SOC. SCI. FISH.; vol. 48, no. 10, pp. 1371-1374;

Nedreaas K. 1990. Age determination of Northeast Atlantic Sebastes species. J. CONS. CIEM.; vol. 47, no. 2, pp. 208-230;

Neilson JD; Geen GH. 1981. Method for Preparing Otoliths for Microstructure Examination. PROG. FISH-CULT.; vol. 43, no. 2, pp. 90-91;

Newman RM; Weisberg S. 1987. Among- and within-fish variation of scale growth increments in brown trout. AGE AND GROWTH IN FISH.; pp. 159-166

Pawson MG. 1990. Using otolith weight to age fish. J. FISH BIOL.; vol. 36, no. 4, pp. 521-531;

Penttila J; Dery LM. 1988. Age determination methods for Northwest Atlantic species. NOAA Tech. Rep. NMFS. 72.

Pickard RP; Peppar JL. 1983. Ages of adult Atlantic salmon samples from the Dalhousie Trap, Restigouche River system, 1972-80. 1983; 18 pp; CAN. DATA REP. FISH. AQUAT. SCI.; no. 393

Prince ED; Pulos LM. 1983. Proceedings of the International Workshop on Age Determination of Oceanic Pelagic Fishes: Tunas, Billfishes, and Sharks Held at Miami, Florida on February 15-18, 1982. 208 pp; NOAA TECH. REP.

Rice JA. 1987. Reliability of age and growth-rate estimates derived from otolith analysis. AGE AND GROWTH IN FISH.; 1987; pp. 167-176

Ryan PM; Cole LJ; Wakeham D. 1981. Age and Growth of Salmonids in the Experimental Ponds Area, Central Newfoundland. 1981; 285 pp; CAN. DATA REP. FISH. AQUAT. SCI.; no. 304

Schlueter LR. 1989. Simple removal of sagitta otoliths from walleyes. N. AM. J. FISH. MANAGE.; vol. 9, no. 1, p. 123;

**Sikstrom CB. Otolith, pectoral fin ray, and scale age determinations for Arctic grayling.

Small GJ; Hirschhorn G 1987. Computer-assisted age and growth pattern recognition of fish scales using a digitizing tablet. AGE AND GROWTH IN FISH.; 1987; pp. 397-410 Summerfelt RC; Hall GE (eds.)

Strong MB; Neilson JN; Hunt JJ. 1986. Aberrant crystallization of pollock otoliths. Can. J. Fish. Aquat. Sci. 43:1457-1463.

Strong MB; Hunt JJ; Robicheau RK. 1985. A new method for preparing Gadoid otoliths. CAFSAC Res. Doc. 85/70.

Summerfelt RC; Hall GE (ed.). Age and Growth in Fish. Iowa State Press, AMES, IA (USA); 544 p; ISBN 081380733-6

Suthers IM; Frank KT. 1989. Dispersal, growth, and condition of juvenile pelagic cod (Gadus morhua L.) in southwestern Nova Scotia. THE EARLY LIFE HISTORY OF FISH. THE THIRD ICES SYMPOSIUM, BERGEN, 3-5 OCTOBER 1988.; 1989; pp. 466-467; RAPP. P.-V. REUN. CIEM.; vol. 191

Suthers IM; Frank KT; Campana SE. 1989. Spatial comparison of recent growth in postlarval Atlantic cod (Gadus morhua) off southwestern Nova Scotia: Inferior growth in a presumed nursery area. CAN. J. FISH. AQUAT. SCI.; vol. 46, no. suppl. 1, pp. 113-124;

Vero M; Paulovits G; Biro P. An improved grinding technique for examining fish otoliths for age and growth studies with special consideration of the eel, Anguilla anguilla L. AQUACULT. FISH. MANAGE.; vol. 17, no. 3, pp. 207-212;

Weisberg S. 1986. A linear model approach to backcalculation of fish length. J. AM. STAT. ASSOC.; vol. 81, no. 396, pp. 922-929;

Weisberg S; Frie RV. 1987. Linear models for the growth of fish. AGE AND GROWTH IN FISH.; 1987; pp. 127-143

Wells R. 1981. Age Determination of Cod From Otoliths Collected in Divisions 2J, 3K and 3L. NAFO SCI. COUNC. STUD.; vol. 1, pp. 77-101;

Winters GH. 1981. Growth Patterns in Sand Lance, Ammodytes dubius , From the Grand Bank. CAN. J. FISH. AQUAT. SCI.; vol. 38, no. 7, pp. 841-846;