Otoliths, Growth Patterns, and A New Direction for Walleye Pollock?

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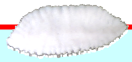
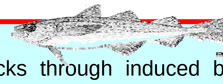
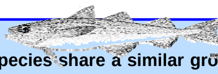




Abstract

Otoliths are routinely used to assess fish stocks through induced biotags, elemental fingerprinting, and most commonly as age structures. **Character of age data can be mediated through technological or interpretive means**: preparation methodology evolved in the 1970's from then-conventional though seriously inaccurate examination of otolith surfaces, to the now widely-accepted "break and burn" technique; and interpretation of complex growth patterns may evolve through reader expertise/talent or through increment validation studies. For some species the **complex growth patterns can potentially mislead pattern interpretation effort**, resulting in data that do not accurately reflect the true age range. Validation of biochronicity is often after-the-fact and expensive. In absence of requisite increment validation studies, **we present potential tools and reiterate several concepts which may aid and ground-truth early development of otolith growth pattern interpretation criteria**. **We also present an alternate age (older) and species profile for walleye pollock (*Theragra chalcogramma*)** resulting from reinterpretation of their complex growth pattern.

Concepts



Most animal species share a similar growth strategy: early rapid growth to achieve competitive or niche-balanced size; transitional growth, commencing with the onset of sexual maturity when energy is partitioned to accommodate both sexual reproduction and somatic growth; and, increasingly slower growth emphasizing sexual reproduction over somatic growth. Species are relatively classified "fast growing" to "slow growing". Individuals exhibit variation from stereotypical species' somatic growth. **Age structure growth (accretion) and patterns reflect somatic growth and variation therein.**

Growth Pattern Dimensionality (Difficulty)

Growth patterns can be dimensionally classified (Figure 1) to describe pattern character and difficulty in interpretation. Application of incorrect interpretation criteria can result in error compounded by the degree of dimensional misclassification. With complex growth patterns it **is possible to be generally accurate in assessing the age range of the species or individual animal or even completely inaccurate** (Figure 2).

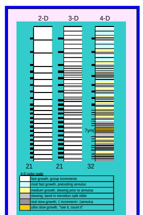


Fig 1 Simple example of pattern dimension.

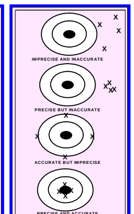


Fig 2 Accuracy vs Precision.

Growth Variation

Growth of a species or population is generally described through its "average growth". **Variation from stereotypic growth is normal**, and likely mediated by both fluctuations in the environment and genetic predisposition. **Growth variation can result in growth patterns that complicate interpretation**. Increased complication to interpretation is often revealed in repeatability (precision) tests as higher error (imprecision) although higher error is not indicative of gross inaccuracy (Figure 3). Other growth variation, for example, divergent growth, may suggest alternate species' strategies which may be critically important to successful management of that species or stock.

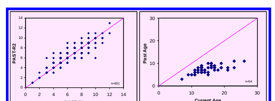
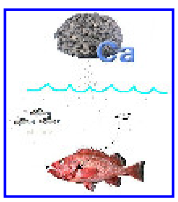


Fig 3 Relatively good (a) versus poor (b) precision; the latter is matched samples with past vs present-day age estimates.



Calcium Metabolism

Calcium carbonate is the primary component of otoliths. **Calcium is ubiquitous in the marine environment, crucial in physiological processes, and evolutionarily conserved**. Therefore, **a coarse comparison of somatic size to otolith size may suggest and/or corroborate an appropriate age range for a species**, and relative to species growth type (Fig4).

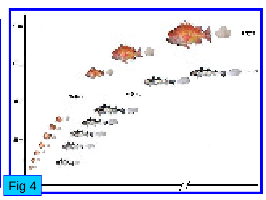
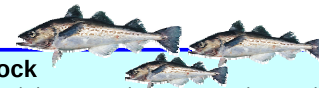


Fig 4

Walleye Pollock



Walleye pollock (*Theragra chalcogramma*) are the basis for the world's largest fishery and are a major prey species for Stellar Sea Lion[2]. Walleye pollock age structures have been aged to develop population profiles and contribute to management strategies for decades. Their history of aging has been troubled[3,4,5]. Since year 2000 there has been renewed concern over dramatically different interpretation of pollock growth patterns amongst age reading locations (Figure 7). Current age data (Figure 8) and other otolith observations describe a very different life history for walleye pollock (see species profile below). Misinterpretation of otolith growth patterns may have arisen from a visually vague representation of growth events perhaps compounded by then-conventional assumptions of species growth.

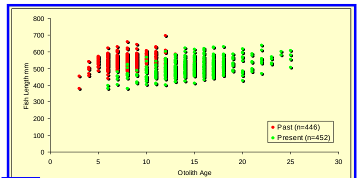


Fig 7 Example of past vs present walleye pollock age data (unmatched samples, all PWS).

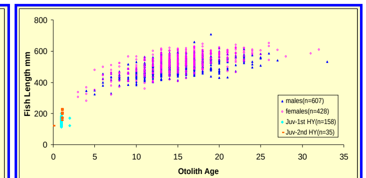


Fig 8 Example of Alaska walleye pollock age-at-length (pooled statewide management areas, 1996-2002, n=1228).

New Walleye Pollock Species Profile

- ❖ Known: juveniles found in shallower, nearshore; adults inhabit cold, deep water; population cycles in year class strength; population integrity
- ❖Demonstrate rapid growth for the first two years, transition to slower growth over ~3-7years
- ❖ Current ADFG pattern interpretation suggests overall trend is to likely "slightly underestimate" believed actual age
- ❖ Maximum age now exceeds 30 years; refinement to interpretation could result in species max age approaching 40 years (patterns don't support >>40years)
- ❖ Otoliths display many growth patterns, not just generally "fast"
- ❖ Low incidence of growth/pattern-type suggests can be high age at very small somatic size, i.e. divergent growth trajectory; otolith morphometrics support observation of this "small, ultra-slow growing, longer-lived" form
- ❖ Opportunistic and dynamic growth changes: patterns suggest multi-year growth cycles
- ❖ Regional growth patterns suggest population integrity; stock patterns range from easy to difficult
- ❖ Patterns and otolith measurements suggest persistent year-class differences in growth accomplishment

Acknowledgements

Lyn Dunbar and Ken Koolmo produced the majority of otolith measurement data used in comparisons. Additional data (age/measurement) or assistance provided by: Jeremy Botz, Joan Brodie, Willy Dunne, Curtis McNeil, Christine Schmale, Kathy Smikrud, Monique Wilkinson, and Karen Koolmo. Britt Constantine provided valuable final edit suggestions. Mandy Lindeberg (NMFS) assisted in printing the poster. This poster is dedicated to the memory of Lyn Dunbar: a more responsible and personable person there never was.

References

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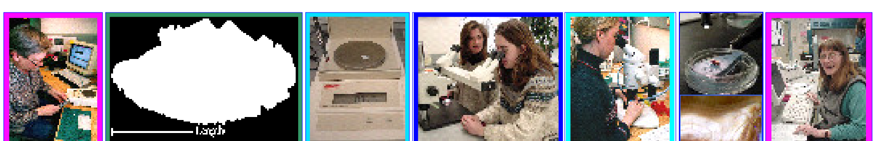
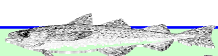
Rockfish Images:http://www.afsc.noaa.gov/groundfish/RockfishGuide/index.htm ; Pollock images: Cohen,D.M.,T.Inada,T. Iwamoto and N. Scialabba,1990 ; and Grant,D., M. Gjernes and N.Venables, 1996.

Poster Date: February 2004



Measuring…. dimensions measured…. weighing (0.001)…. calibration…. production…. Happy camper because she doesn't have to age 'em….

Tools



Initiating pattern-interpretation criteria for a species is generally not difficult given congeners of similar growth type or niche. Caution is needed when extending interpretation of growth patterns across genera having no previous age validation. In absence of such knowledge, pattern interpetation is often based upon strength of visual information; with lack of such, unintentional personal biases can easily be written in to fill the gaps.

Otolith Measurements / Otolith Index

Graphical interpretation of otolith measurements provides an objective means to determine if/when changes and to what degree variation occurs within growth structures. **Otolith size coarsely follows somatic size[1]**; inflections observed through graphing these data correspond to growth transitions. Appropriate consideration must be made in interpreting the growth pattern information which correspond to these inflections/transitions. **The otolith index[1] (OI) is an objective comparison of unit length to unit weight** (Figure 5), and diminishes disproportionate effect of weight attributed to faster growth during early years. It may highlight outliers in age data as genuine growth variants, not field or aging error.

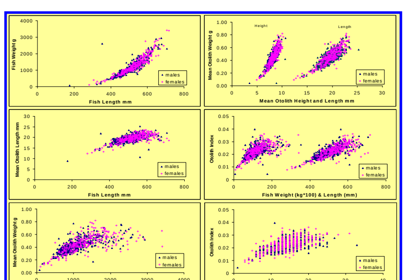


Fig 5 Comparison of objective somatic and otolith measurements to Otolith Index and age, for walleye pollock (n = 442 males, 305 females).

Otolith Calcium Investment Index

The **"Otolith Calcium Investment Index" (OCI Index) may provide early indication of a species age range**. Its recommended use would be to project a likely range of age for a species to guide early pattern interpretation if growth pattern information were vague or complex (Figure 6, Table 1). More work is needed to refine this index to adjust for pronounced differences in juvenile growth rate.

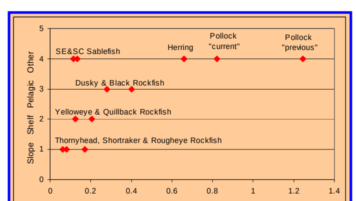
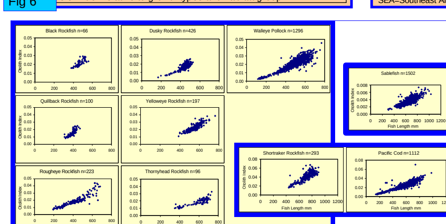


Fig 6 OCI Index relative to growth types and habitat group.

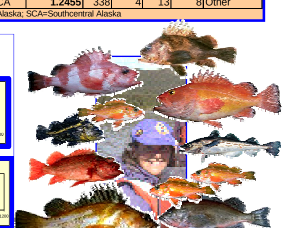
Table 1 OCI indices and sample age range breakdown.

NAME	AREA *	OCI Index	n=	MIN AGE	MAX AGE	MEAN AGE	COMPLEX
Rougheye	SCA	**0.1705**	61	14	105	39	Slope
Shortraker	SCA	**0.0812**	180	20	160	86	Slope
Yelloweye	SEA	**0.1250**	190	14	110	41	Shelf
Quillback	SEA	**0.2051**	97	11	85	37	Shelf
Thornyhead	SCA	**0.0627**	56	21	98	58	Slope
Black	SEA	**0.4012**	66	10	36	17	Pelagic
Dusky	SEA	**0.2793**	283	6	47	20	Pelagic
Sablefish	SEA	**0.1159**	664	2	44	12	Other
Sablefish	SCA	**0.1338**	179	2	11	7	Other
Herring	SEA	**0.6596**	11	2	8	4	Other
Pollock c	SCA	**0.8208**	751	1	33	15	Other
Pollock p	SCA	**1.2455**	338	4	13	8	Other

*SEA=Southeast Alaska; SCA=Southcentral Alaska



Additional species Otolith Index vs fish length …



Lyn and buddies…