Scale Ageing Errors

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The Beginning

"the age of a scaly fish may be told by the size and hardness of its scales"

Aristotle, Historia Animalium, ca. 340 B.C.

"altho all the scales, are not just of the same shape, I have yet observed, in many of them, as I judged, the same number of circular lines. From whence I conclude that every year the scale encreased one circular line… "

Leeuwenhoek 1685

Scale Pattern Analysis

- Age data and life history types
- Detailed growth rates
- Stock composition (e.g., Kamchatka vs. Alaskan origin)
- Hatchery vs. Wild determinations

Importance of Good Age Data

- Growth rates and curves
- Maturation rates
- Mortality rates
- Recruitment and Production patterns
- Forecasts based on sibling regression

Age Data from Salmon Scales

Advantages:

Non-lethal sampling possible, like GSI , but unlike CWT recovery

Disadvantages:

Subject to scale ageing errors

Need to validate and perform QC

Sources of Ageing Error

- Bad samples
- Subjectivity
  - Precision, Repeatability
- Misclassification
  - Accuracy

Bad Samples

ADFG’s Age-Sex-Length data protocol includes these descriptors for ageing problems:

1. Otolith
2. Inverted
3. Regenerated
4. Illegible
5. Missing
6. Reabsorbed
7. Wrong species
8. Not preferred

Subjective Error

- Reader variability
- Experience
  - Depth: practice, practice, …
  - Breadth: experience with different stocks and life history types
  - Local knowledge (e.g. life history type)

Misclassification

- Wrong Age
  - Resorption -> underestimate annuli
  - Checks in growth -> overestimate annuli
- Wrong Life History Type : stream vs ocean
  - Estuarine checks misclassified as freshwater annuli
- Wrong Growth patterns, etc.

Age Validation Methods

Campana, S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J. Fish Biol. 59:197-242

- BEST method -> Release known age, marked fish
  - CWT
  - PIT tags
  - Otolith marking
  - Chemical marks, e.g. calcein

“Gorilla” Assumption

Marked/tagged fish are representative of population of interest

Validation: Metrics

Subjectivity/Precision

- % Agreement between 2 readings (NB: very sensitive to # of age classes)
- CV or RPE if different # of classes

Misclassification/Accuracy

- % Correct
- Matrix of ACTUAL vs. ASSIGNED w/ probabilities of each combination

Misclassification Matrix

Newman, K.B., A.C. Hicks, and D.G. Hankin. July 7, 2004. A marking, tagging, and recovery program for Central Valley hatchery chinook salmon.

Table 8: Aging error matrix used in the simulations (G. Kautsky, Hoopa Tribal Fisheries Department & Allen Grover, CDFG, pers. comm.). Rows are the true age and columns are the age that is assigned to the fish.

			Assigned Age			
			2	3	4	5
T		2	98	2	0	0
r	A	3	0	98	2	0
u	g	4	0	10	90	0
e	e	5	0	0	40	60

Validation: Availability

Most agencies do measure precision; at least some scales are read by multiple people

Not enough validation and most validation results are not published

Accuracy studies based on tagged fish are usually hatchery stocks

Validation: In-River Samples

- Klamath-Trinity Fall Chinook, 1998
- Hoopa Valley Tribe, Yurok Tribe, USFWS
- 10,057 scales used, 2 independent readings
- 1,987 bad samples

Klamath CWTed fish	
Age	% Correct
2	100% (n=4)
3	96% (n=277)
4	74% (n=125)
5	83% (n=6)

Trinity CWTed fish
95% Accuracy
5s as 4s, 60% of time
4s as 3s, 19% of time

2006 Validation matrices

Klamath R. Technical Advisory Team, 2007

Age 2: 86%, 99%

Age 3: 91%, 96%

Age 4: 93%, 97%

Age 5: **59%, 50%**

Table 4a. 2006 Klamath River scale validation matrices.

Number

		Known Age 2	3	4	5	
Read Age	2	105	1	3	0	
	3	17	95	19	0	
	4	0	8	349	7	
	5	0	0	5	10	Total
	Total	122	104	376	17	619

Percentage

		Known Age 2	3	4	5
Read Age	2	0.861	0.010	0.008	0.000
	3	0.139	0.913	0.051	0.000
	4	0.000	0.077	0.928	0.412
	5	0.000	0.000	0.013	0.588
	Total	1.00	1.00	1.00	1.00

Table 4b. 2006 Trinity River scale validation matrices.

Number

		Known Age 2	3	4	5	
Read Age	2	180	2	0	0	
	3	1	109	9	0	
	4	0	3	336	2	
	5	0	0	3	2	Total
	Total	181	114	348	4	647

Percentage

		Known Age 2	3	4	5
Read Age	2	0.994	0.018	0.000	0.000
	3	0.006	0.956	0.026	0.000
	4	0.000	0.026	0.966	0.500
	5	0.000	0.000	0.009	0.500
	Total	1.00	1.00	1.00	0.00

Validation: In-River

Data from Tim Heyne

San Joaquin River Basin, 1990-2000, 1148 fish

	2	3	4
n	296	755	97
Under	0	20	29
Over	28	50	5

Actual	1	2	3	4	More
2	3%	88%	9%		
3	2%	3%	89%	7%	
4		4%	30%	61%	5%

Validation: In-River

From R. McNichol:

Godfrey et al. (1971)

- Comparison of four experienced scale readers (four agencies; one Cdn, three U.S.)
- 200 chinook of known age (via fin-clip, hatchery) from terminal Columbia R. returns (ocean and stream type stocks) aged via scales
- Accuracy ranged from 64-83%; average ~75%
- Lower degree of accuracy among stream-type samples

Validation: In-River

Data from Kevleen Melcher (ODFW), through R. McNichol

Columbia R. Zone 1-5 Fishery

Year	*n*	% Right	% Over	% Under
2001	531	90	3.0	7.2
2002	167	93	0.6	6.0
2003	155	90	2.6	7.7

Columbia R. Buoy 10 Fishery

Year	*n*	% Right	% Over	% Under
2001	106	92	6.6	1.9
2002	178	80	10.1	10.1
2003	41	88	2.4	9.8

Validation: In-River

Data from Paul Hoffarth, WDFW

20 fish under-aged, 6 over-aged

Columbia R. Hanford Reach Sport

Year	*n*	% Right
2004	19	84
2005	30	93
2006	13	77

Columbia R. Upriver Bright Carcass Sampling

Year	*n*	% Right
2004	110	90
2005	61	89
2006	48	90

Validation: Near River

Data from Gary Morishima

From R. McNichol:

Quinault Terminal Net Fishery

- WA Coast and Grays Harbor
- 95% Accuracy for 1977-2001

Validation: Ocean Fisheries

From R. McNichol:

Yole (1989)

- 280 scale samples from mixed-stock commercial fisheries of known age (CWTd), mixture of coastwide stocks, stream and ocean type.
- Avg. accuracy of experienced (2): 95-99%
- Avg. accuracy of inexperienced (3): 88-91%

Validation: Ocean Fisheries

From R. McNichol:

Bilton (unpublished manuscript)

- 7 readers from Canada, U.S. and Japan: some experienced, some not very
- 86 scale samples from mixed-stock commercial fisheries of known age (CWTd)
- Accuracy in total age: 16.3-95.3%
- Average: 69%

Validation: Ocean Troll

Canadian Triple Blind Study (2004)

R. McNichol et al. (in prep.)

91-94% Accuracy for 495 hatchery fish in mixed-stock ocean troll

83.3% agreement (all 3 readers)

Validation: FW age, “Mixed Stock” Fishery

Doug Eggers, ADFG

- 200 scales of *naturally spawning* fish
- 8 PNW stocks (.0) and 2 AK (.1) stocks
- 20 scales each for 200 scales
- Blind test, read by 2 ADFG scale readers unfamiliar with ocean-type scales, twice
- 30-62% Accuracy/Agreement; 36-67% Over-aged
- Estuarine check interpreted as FW annulus in absence of experience or knowledge of source
- Especially bad for WA (17%, 58%) and OR (27%, 47%) Coastal stocks

Implications

Effects of ageing errors can cascade through multiple analyses

E.G., Spawning escapement at age ->

used to calculate recruitment at age->

used to calculate productivity->

used to calculate effective population size

Implications

Ageing errors can have synergistic effects with other errors

- E.G. impacts of misspecified *M* on CA

Mertz and Myers. 1991. CJFAS(54)

The summation over ages in the cohort reconstruction can lead to a serious cumulative error when there is an overestimate in *M* which is comparable with the fishing mortality. In fractional terms, the severity of the error when *M* is underestimated is not as great, but it can nevertheless be appreciable. Based on our analysis (Fig. 2 in particular) we would suggest that $|\Delta M| \leq 0.5F$ is necessary for accurate cohort reconstruction. This implies that stocks that experience low fishing mortalities, in the range of 0.1–0.2, are particularly vulnerable to gross errors of estimation of the cohort size.

Conclusions: Mitigate Errors

- Bad samples ->
  - Sampling protocols
  - Increase sample sizes
  - Quality control
- Subjectivity/Precision ->
  - 1-on-1 training w/ experienced reader
  - At least 10% of scales read by 2 people
  - Double-blind reading, 3rd read ->consensus
- Misclassification/Accuracy ->
  - Validation studies, comparison w/ known age

Conclusions

- Stream-type and Age 5 fish are most likely to have age underestimated
- Estuarine rearing fish are most likely to have age overestimated

Conclusions

Measure and correct for ageing errors before performing cohort analyses or sibling regression forecasts

KRTAT used this:

Kimura, D.K and Chikuni, S. 1987. Mixtures of empirical distributions: an iterative application of the age-length key. Biometrics 43:23-35

Conclusions

Richards, L.R., J.T. Schnute, A.R. Kronlund, and R.J. Beamish. 1992. Statistical Models for the Analysis of Ageing Error. Can. J. Fish. Aquat. Sci. 49: 1801-1815

Framework for estimating true age distribution based on

- Multiple readings of same sample
- Using previously estimate classification matrix

Sample sizes should take ageing error into account

Conclusions

Growth rates and Proportion non-vulnerable at age should be based on ACCURATE age data, or incorporate errors

Jason M. Cope and André E. Punt. 2007. Admitting ageing error when fitting growth curves: an example using the von Bertalanffy growth function with random effects. Can. J. Fish. Aquat. Sci. 64(2): 205-218

Conclusions

- Resorption can pose a significant problem in spawning areas
- Fin rays and otoliths can be used for total age where scale resorption is a problem

Conclusions

– 82-96% accuracy for fin rays

Chilton and Bilton (1986)

– 88% accuracy for fin rays

Kiefer et al. (2001)

– 100% accuracy for otoliths and scales

Flain and Glova (1988)

– 80-94% accuracy for otoliths

Murray (1994)

Conclusions

- Routine Precision and Accuracy monitoring results need to be made more available
- Need a repository (StreamNet?) – not really scientific journal material

Conclusions

- Readers of mixed-stock scales need training & experience with stocks coast-wide (most training is NOT based on known age fish)

- Need “reference” scale collection to facilitate better training

Conclusions

If GSI can determine stock ID of individuals…

- Scale pattern analysis might be used to further identify hatchery vs. wild
- Stock specific age composition (albeit with error) can be estimated in mixed-stock fisheries