Wayne A. Hubert, Wyoming Cooperative Fishery and Wildlife Research Unit
University of Wyoming, Laramie, Wyoming 82071

and

George T. Baxter and **Mark Harrington,** Department of Zoology and Physiology
University of Wyoming, Laramie, Wyoming 82071

Comparison of Age Determinations Based on Scales, Otoliths and Fin Rays for Cutthroat Trout from Yellowstone Lake

Abstract

Ages determined from scales, otoliths, dorsal fin rays, and pectoral fin rays of a sample of Yellowstone Lake cutthroat trout (*Salmo clarki*) were compared. The four structures yielded similar precision between separate readings by a single observer. Discrepancies in age determinations between scales and the other structures were observed. Otoliths tended to yield older ages than scales, whereas fin rays tended to yield ages similar to or lower than those based on scales. The use of scales may lead to an aging bias that results from the failure of some fish to form scales during their first year of life.

Introduction

The use of scales to age fish began in the late 19th-century and is now widely applied for aging cutthroat trout, Salmo *clarki*. Scales have been used to age cutthroat trout from Yellowstone Lake, Yellowstone National Park, since management of the lake was initiated in the late 1940's (Laakso and Cope 1956, Bulkley 1961, Benson and Bulkley 1963), but fishery biologists have not been satisfied with the precision of estimates based on scale readings. This study was initiated in an attempt to find a more satisfactory method for age assessment.

Recent research has indicated that other structures may provide more precise estimators of age among slow-growing, soft-rayed, freshwater fishes. Because the most promising structures appeared to be otoliths and fin ray sections, we selected them for assessment and comparison with scales in this study.

Otoliths have been used to estimate the age of brook trout, *Salvelinus fontinalis* (Reimers 1979); Arctic grayling, *Thymallus arcticus* (Sikstrom 1983); lake whitefish, *Coregonus clupeaformis* (Barnes and Power 1984); round whitefish, *Prosopium cylindraceum* (Jessop 1982); cisco or lake herring, *Coregonus artedii* (Morin 1980); and longnose sucker, *Catostomus catostomus* (Tripp and McCart 1974). In general, few differences between ages determined from scales and from otoliths have been observed among young fish, but estimates based on otoliths were consistently older than those based on scales for older fish.

Fin ray sections have been used to age brown trout, *Salmo trutta* (Burnet 1969); Arctic grayling (Sikstrom 1983); lake whitefish (Mills and Beamish 1980); and white sucker, *Catostomus commersoni* (MacCrimmon 1979). Like otoliths, fin ray sections have tended to yield older age estimates than scales among older fish. Burnet (1969) found that two observers correctly read scales from only 6 of 29 known-age brown trout, whereas Burnet correctly read fin ray sections from all of 22 known-age brown trout.

On the basis of the results of previous studies with otoliths, dorsal fin ray sections, and pectoral fin ray sections, we selected these structures to determine if they would yield better precision than scales in aging Yellowstone Lake cutthroat trout. We assessed the precision of age estimates between independent readings of the same structure by one observer, as well as the precision of age estimates among the four structures based on age determinations derived from readings by three observers.

Methods

Cutthroat trout were obtained during the annual gill-netting assessment of Yellowstone Lake fish stocks by the U.S. Fish and Wildlife Service, on September 18, 1984. Scales, dorsal fins, and right pectoral fins were removed in the field, stored in individually coded envelopes, and returned to the laboratory for preparation and aging. Scales were scraped with a knife from above the lateral line near the dorsal fin. Fins were cut at the base with surgical scissors. Otoliths were removed through the roof of the mouth, after gills and the isthmus had been removed to expose the ventral surface of the cranium. The otoliths were removed with forceps, and placed in individual glass vials containing 70% ethanol.

Scale preparation closely followed the procedure of Hagenbuck (1970). A wet mount of several scales was made on a microscope slide and one scale showing clear annuli was photographed. Dorsal and pectoral fins were embedded in epoxy and sectioned (0.7-0.9 mm thick) with a microstructural cutting saw. Cross sections were mounted on a microscope slide with Permount, one to two drops of xylene, and a cover slip; then examined under a dissecting microscope. Otoliths were placed in anise oil for four to six weeks (Reimers 1979). Cleared otoliths were placed on microscope slides with a drop of toluene to remove the anise oil residue, and were examined under a dissecting microscope, utilizing reflected light (Mosher and Eckles 1954).

Annuli on scales were identified according to the techniques of Lux (1971). We relied on only the presence of discontinuous or broken circuli to identify annular marks. When otoliths were observed, layers making up spring and summer growth appeared as white, opaque bands, and layers laid down during fall and winter appeared as dark, translucent bands (Lux 1971). Similar zonation patterns were observed on fin-ray sections. The first annulus was difficult to identify in many fin-ray sections.

Two independent age determinations (the reader did not know the results of the previous reading) were made on each structure by one technician who had been trained in annulus identification, to determine the precision among readings by one observer.

One reading of each structure was conducted independently by each of two additional technicians. The first reading by the three technicians was used as the estimate of fish age. When two or three of the readings agreed, this value was accepted as the correct age. When no two readings agreed, the median value was accepted as the age.

Results were analyzed by determining the percent agreement among independent readings of a structure by one technician, as well as among age determinations when different structures were used. Chi-square analysis was used to determine significant trends. The "Index of Average Percent Error" (AEI%) of Beamish and Fournier (1981) was computed for all comparisons.

Results

Reader Agreement

Percent agreement of age determination between two independent readings ranged from 51% with otoliths to 72% with pectoral fin rays (Table 1). The AEI% ranged from 15% for scales to 33% for otoliths. Precision between readings was the poorest for otoliths and the best for scales and pectoral fin rays.

A comparison of the number of agreements and disagreements among the four structures, made by using a 2 x 4 Chi-square contingency table, yielded a significant difference in the ratio of agreements to disagreements (Chi-square = 12.557, df = 3, $p < 0.01$). When the same comparison was made without otoliths, no significant difference in the ratio of agreements to disagreements was observed. These results indicated that the agreement between first and second readings was similar among the structures, except for otoliths which produced a higher level of disagreement.

Age determinations based on the two independent readings differed by as much as three years (Table 1). Age determinations differed by one year in 26% of the pectoral fin ray readings, and in 35% of the otolith readings.

Comparisons of Age Determinations

Agreement between age determinations was lowest (51%) for the comparisons between otoliths and fin ray sections and highest (56%) between scales and all three of the other structures (Table 2). A 2 x 6 Chi-square contingency test of the number of agreements and disagreements in age determination among the six comparisons of structures indicated no significant difference among the structures. This test indicated that no two structures yielded a higher level of aging precision than any of the others.

The AEI%, computed for the six comparisons of aging precision among the four structures (Table 2), ranged from 22% for scales and pectoral fin ray sections to 28% for otoliths and pectoral fin ray sections.

TABLE 1. Results of two independent age determinations by a trained technician using four different structures from Yellowstone Lake cutthroat trout.

Structure	Sample size	Percent agreement	Percent disagreement by different numbers of years			AEI%[a]
			One	Two	Three	
Scales	110	72	26	2	0	15
Otoliths	107	51	35	10	3	33
Dorsal fin rays	108	68	29	2	2	19
Pectoral fin rays	108	72	26	1	1	15

[a]See text for explanation.

TABLE 2. Percent agreement between age determinations based on four different structures from Yellowstone Lake cutthroat trout. The index of average percent error (AEI%) is in parentheses.

Structure	Structure Compared		
	Scales	Otoliths	Dorsal Fin Rays
Otoliths	56 (26)		
Dorsal fin rays	56 (24)	51 (27)	
Pectoral fin rays	56 (22)	51 (28)	54 (23)

Bias in age determination among the four structures was indicated (Figure 1). When scales were compared to the other structures, scales tended to yield lower ages than otoliths (figure 1a), to have about the same aging bias as dorsal fin rays (Figure 1b), and to yield higher ages than pectoral fin rays (Figure 1c). Otoliths tended to yield higher age determinations than either dorsal fin rays or pectoral fin rays (Figure 1d, e). When dorsal fin ray age determinations were compared to those of pectoral fin rays, it was observed that dorsal fin rays tended to yield higher age determinations (Figure 1f).

Discussion

The results of this study disagreed with recent literature indicating that the use of scales for aging slow-growing fishes may be a less desirable choice than otoliths or fin ray sections. Differences in the life span of Yellowstone Lake cutthroat trout compared with that of fish in other stocks that were studied may contribute to the disagreement. The Yellowstone Lake cutthroat trout in our sample were from one to six years old. Samples used in other studies included fish with a life span more than twice that of Yellowstone Lake cutthroat trout. Differences in age determinations tended to appear among fish older than six years in the other studies (Beamish and Harvey 1969, Beamish and Chilton 1977, Power 1978, Sikstrom 1983, Barnes and Power 1984).

Discrepancies in age determinations between scales and other structures may be partly due to the frequent failure of Yellowstone Lake cutthroat trout to grow large enough to form scales during their first year of life (Laakso 1955). The only structure to show a trend toward older age determination was the otolith. Fin rays tended to yield age determinations similar to, or less than, those given by scales. This tendency may be due to the difficulty in identifying the first annulus in fin ray cross sections (Beamish 1973).

Otoliths tended to yield older age determinations than sections of either pectoral or dorsal fin rays. This tendency may be further evidence that the first annulus was not being identified on many of the fin ray cross sections.

The results of this study indicated that aging precision was not high with any structure studied, and otolith and fin ray cross sections did not yield better precision in age determinations of Yellowstone Lake cutthroat trout than scales. However, the data indicated that the use of otoliths may reduce some aging bias that occurs when using only scales. Age estimates may be

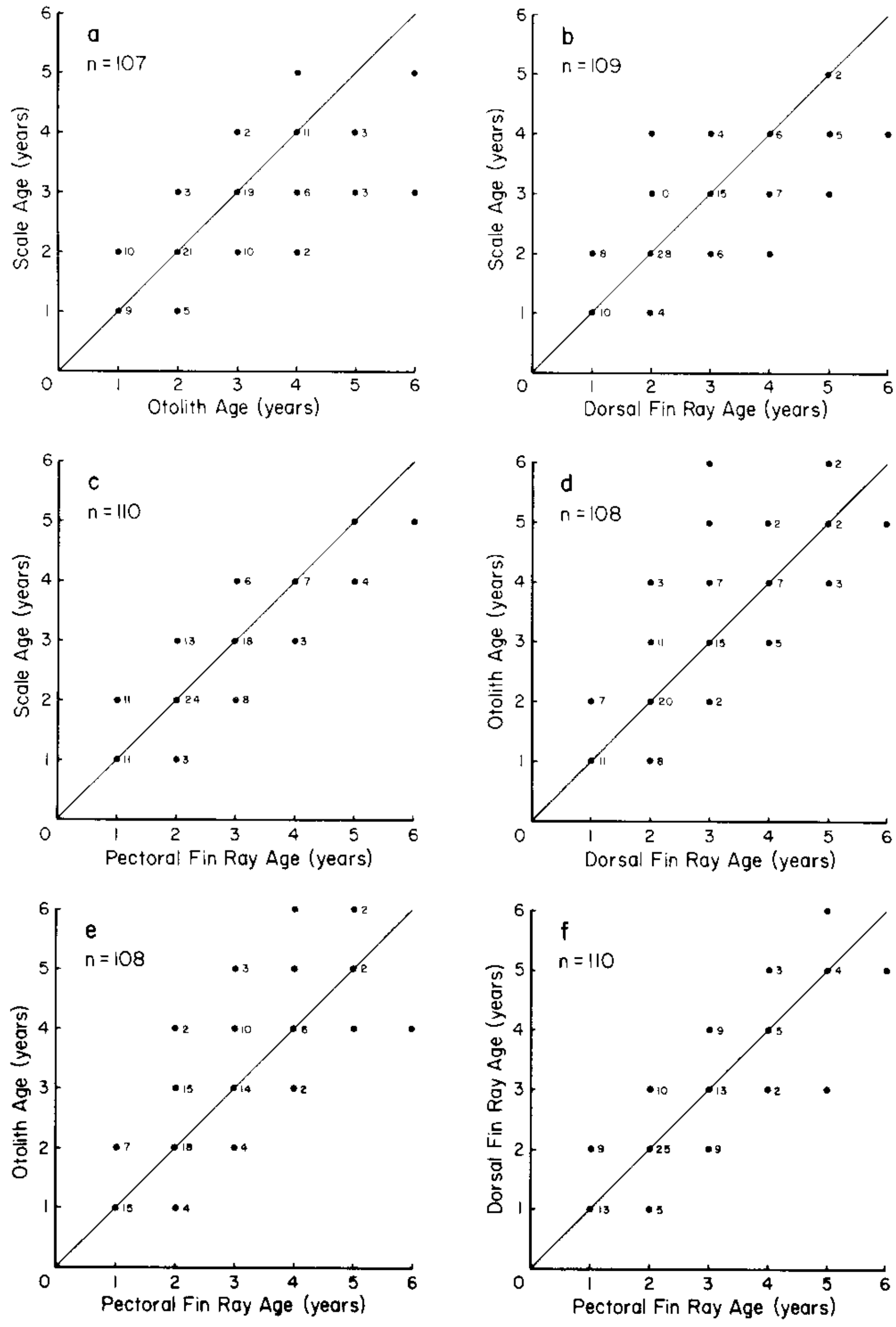

Figure 1. Comparisons of age determinations based on scales, otoliths, dorsal fin rays, and pectoral fin rays for Yellowstone Lake cutthroat trout. Points are individual fish except where indicated by a number. Points on diagonal line indicate comparisons where assigned ages by both structures were identical.

more accurate if scales and otoliths are used in combination. When the techniques described are used, otoliths are easy to remove from fish in the field and to prepare and read in the laboratory. We believe that the use of both scales and otoliths for aging Yellowstone Lake cutthroat trout should be considered.

Beamish and McFarlane (1983) cautioned fishery workers to validate age and growth studies by using mark-recapture experiments or assessment of known-age fish from a population. Such a validation has not been done on Yellowstone Lake cutthroat trout and would be difficult because both the lake and the population are large. They suggested that if validation studies are not possible, fish should be aged by several methods, and the possibility of errors in age estimates be considered. Our study provided a basis for suggesting that the use of one or two additional methods for determining the age of cutthroat trout would improve aging techniques currently used at Yellowstone Lake.

Acknowledgments

We appreciate the assistance of the U.S. Fish and Wildlife Service's Yellowstone Fishery Assistance Project Crew—specifically Ronald Jones, Robert Gresswell, and Leo Lentsch. David Gulley provided field help and Eric Featherston provided laboratory assistance. The study was supported by the University of Wyoming—National Park Service Research Center. The Wildlife Research Unit is supported by the University of Wyoming, the Wyoming Game and Fish Department, the Wildlife Management Institute, and the U.S. Fish and Wildlife Service.

Literature Cited

Barnes, M. A. and G. Power. 1984. A comparison of otolith and scale ages for western Labrador lake whitefish, *Coregonus clupeaformis*. Environ. Biol. Fish. 10:297-299.

Beamish, R. J. 1973. Determination of age and growth of populations of the white sucker (*Catostomus commersoni*) exhibiting a wide range in size at maturity. J. Fish. Res. Board Can. 30:607-616.

Beamish, R. J., and D. Chilton. 1977. Age determination of lingcod (*Ophiodon elongatus*) using dorsal fin rays and scales. J. Fish. Res. Board Can. 34:1305-1313.

Beamish, R. J., and D. A. Fournier. 1981. A method for comparing the precision of a set of age determinations. Can. J. Fish. Aquat. Sci. 38:982-983.

Beamish, R. J., and H. H. Harvey, 1969. Age determination in the white sucker. J. Fish. Res. Board Can. 26:633-638.

Beamish, R. J., and G. A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Tran. Amer. Fish. Soc. 112:735-743.

Benson, M. G. and R. V. Bulkley. 1963. Equilibrium yield and management of cutthroat trout in Yellowstone Lake. U.S. Fish Wildl. Serv. Res. Rep. 66.

Bulkley, R. V. 1961. Fluctuations in age composition and growth rate of cutthroat trout in Yellowstone Lake. U.S. Fish Wildl. Serv. Res. Rep. 54.

Burnet, A. M. R. 1969. An examination of the use of scales and fin rays for age determination of brown trout (*Salmo trutta* L.). New Zealand J. Mar. Freshwat. Res. 3:147-151.

Hagenbuck, W. W. 1970. A study of the age growth of the cutthroat trout from the Snake River, Teton County, Wyoming. University of Wyoming, Laramie. Thesis.

Jessop, B. M. 1972. Aging round whitefish (*Prosopium cylindraceum*) of the Leaf River, Ungava, Quebec, by otoliths. J. Fish. Res. Board Can. 29:452-454.

Laakso, M. 1955. Variability in scales of cutthroat trout in mountain lakes. Proc. Utah Acad. Sci. Arts Let. 32:81-87.

Laakso, M. and O. B. Cope. 1956. Age determination in Yellowstone cutthroat trout by the scale method. J. Wildl. Manage. 20:138-153.

Lux, F. E. 1971. Age determination of fishes (Revised). U.S. Natl. Mar. Fish. Serv. Fish. Leafl. 637.

MacCrimmon, H. R. 1979. Comparative annulus formation on anatomical structures of the white sucker, *Catostomus commersoni* (Lacepede). J. Fish. Manage. 10:123-127.

Mills, K. H. and R. J. Beamish. 1980. Comparison of fin ray and scale age determination for lake whitefish (*Coregonus clupeaformis*) and their implications for estimates of growth and annual survival. Can. J. Fish. Aquat. Sci. 37:534-544.

Morin, R. 1980. Ecology of anadromous coregonine fishes in estuaries of eastern James-Hudson Bay. Laval University, Quebec. Thesis.

Mosher, K. H., and H. H. Eckles. 1954. Age determination of Pacific sardines from otoliths. U.S. Fish Wildl. Serv. Res. Rep. 37.

Power, G. 1978. Fish population structure in arctic lakes. J. Fish. Res. Board Can. 35:53-59.

Reimers, N. 1979. A history of a stunted brook trout population in an alpine lake: a lifespan of 24 years. Calif. Fish Game 65:196-215.

Sikstrom, C. B. 1983. Otolith, pectoral fin ray, and scale age determinations for Arctic grayling. Prog. Fish-Cult. 45:220-223.

Tripp, D. B., and P. J. McCart. 1974. Life histories of grayling (*Thymallus arcticus*) and longnose suckers (*Catostomus catostomus*) in the Donnelly River system, Northwest Territories. *In* Canadian Arctic Gas Study Limited. Biological Report Series. Vol. 20, Chap. 1.

Received 3 January 1986
Accepted for publication 29 May 1986