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IDENTIFICATION AND CONTRIBUTION OF WILD AND HATCHERY STEELHEAD STOCKS IN LAKE MICHIGAN TRIBUTARIES[1]

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and

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[1]A contribution from Dingell-Johnson Project F-35-R, Michigan

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ABSTRACT

We developed and validated an assignment rule based on quantified scale characteristics for the identification of wild and hatchery stocks of Great Lakes steelhead (*Salmo gairdneri*). This rule was used to assess the relative contributions of these stocks to adult steelhead populations in the northwestern Lower Peninsula of Michigan during the period 1983–84 for seven rivers and during the additional periods 1968–70 and 1979–82 for one river. Adults returning during these periods were representative of pre-1983 hatchery production in Michigan, when yearling parr was the typical life stage stocked. Scale samples were collected from steelhead of known wild and hatchery origins. A number of scale characteristics, chosen to provide information on first-year growth patterns, were quantified. One characteristic, Ratio 23 (the relationship between winter and spring growth rates), met our criteria of being distinct between wild and hatchery adults, yet consistent among life stages, years, and geographic locations within each respective wild and hatchery group. Ratio 23 was used to develop an assignment rule and classification error rates. This rule was applied to samples of unknown-origin adult steelhead collected in seven rivers in the northwestern Lower Peninsula of Michigan during 1983–84 to estimate the percentage of wild fish in each river and its variance. The percentage of wild fish in the adult population was estimated to be 100% for an unstocked trout river, 93% for four stocked trout rivers, and 60% for two stocked marginal trout rivers. In summary, an assignment rule developed using the scale character Ratio 23 provided a simple and accurate method of identifying wild and hatchery origins for Lake Michigan steelhead. Application of this rule to samples of unknown-origin adults indicated that past stockings of yearling steelhead parr in trout rivers have contributed little to adult populations in these rivers.

INTRODUCTION

The steelhead (*Salmo gairdneri*), or anadromous rainbow trout, has provided a productive and popular sport fishery in the Great Lakes since its introduction from the Pacific Coast in the late 1800's (MacCrimmon and Gots 1972). Present Great Lakes steelhead populations are maintained both by natural reproduction (Biette et al. 1981; Seelbach 1986) and by supplemental plantings of hatchery-raised fish (Seelbach 1987). In many rivers, however, the relative contributions of these two sources to steelhead fisheries are largely unknown. This information is vital for the optimal management of a given river system (i.e., enhancement or protection of wild populations versus supplementation with hatchery fish), and for the development of lake-wide management policies.

Understanding of the relative contributions of wild and hatchery stocks has been limited by the difficulties inherent in identifying the origins of adult steelhead. Adult origins can be clearly identified when juvenile fish are uniquely marked prior to their entry into the lake (the last point at which groups can be kept distinct), however, the marking of large numbers of wild and hatchery fish is costly and impractical. Ideally, origins could be determined using some easily examined natural characteristic such as scale circuli patterns. Circuli patterns have been widely used for the identification of stock origins of numerous salmonid species. Patterns of circuli and annuli spacing on scales reflect fish growth patterns and are useful in identifying the origins of fish which have experienced distinct growth regimes. Chapman (1958) noted differences between the scale patterns of wild and hatchery steelhead in Oregon but did not quantify these differences. He observed differences in the patterns of circuli spacing during the freshwater phase of life, when wild and hatchery fish (which are typically stocked as yearlings) live in radically different environments. Scales from hatchery fish showed uniform circuli spacing during the entire freshwater phase of growth, reflecting the moderate winter temperatures and continuous feeding experienced by hatchery fish. Scales from wild fish showed narrowed circuli spacing just prior to the first annulus followed by wider spacing; this was a reflection of slow winter growth followed by rapid spring growth.

We noticed similar differences in patterns of circuli spacing between some hatchery and wild steelhead from the Great Lakes region (Figure 1). This observation and that of Chapman (1958), however, are limited in application without the development of an objective assignment rule and the validation of this rule for the specific stocks in question. Accordingly, the first objective of this study was to develop and validate an assignment rule based on quantified scale characteristics for the identification of wild and hatchery stocks of Great Lakes steelhead.

The second objective of this study was to use our developed assignment rule to assess the relative contributions of wild and hatchery stocks to the sizable and popular steelhead fisheries of seven rivers in Michigan's northwestern Lower Peninsula during 1983–84 and in one of these rivers during 1968–70 and 1979–82. Prior to 1983, several of these rivers had received annual stockings of yearling steelhead parr, however, the contribution of these to subsequent adult populations had not been measured. Parr are juvenile steelhead which have not yet smolted. Smolting is a size-related physiological transformation which occurs in preparation for ocean life and in conjunction with an active downstream migration.

METHODS

General methodology

We used the general methodology for assessing the composition of stock mixtures described by Worlund and Fredin (1962), Cook and Lord (1978), and Pella and Robertson (1979). Random samples were collected from individuals of known wild and hatchery origins. These were divided into equal groups called the learning and test samples, respectively. The learning sample was used to develop an assignment rule based on differences in the frequency of occurrence of a particular scale character (or characters) between wild and hatchery groups. The test sample was used to estimate the classification error rates of this rule. Each group was used alternately as the learning and test sample and the results were averaged to give a mean assignment rule and mean classification error rates. Random samples were also collected from individuals of unknown origins in several rivers of interest. The above rule was used to assign individuals from the unknown samples to either wild or hatchery origin. The assigned proportions and the classification error rates calculated from the test samples were used to estimate the stock composition of the unknown samples and the precision of these estimates.

Analysis of scales of known-origin fish

Scale samples were collected from 1,207 steelhead from five known wild and four known hatchery populations during the period 1977–87 (Tables 1 and 2, Figure 2). Wild groups were representative of populations located in the northwestern Lower Peninsula of Michigan and hatchery groups were representative of a variety of groups which have been stocked into the Great Lakes. These included groups grown at both southern and northern Great Lakes latitudes; northern growth conditions typically produce a high proportion of yearling parr, as opposed to yearling smolts, while southern conditions typically produce a higher proportion of yearling smolts. In addition, the sampled hatchery groups included two different steelhead strains, the Michigan and the Skamania. The Michigan is the strain most commonly planted in Michigan and is a first-generation product of wild parents collected by the Michigan Department of Natural Resources (MDNR) from the Little Manistee River (Figure 2). The Skamania strain is a genetically selected hatchery strain from Washington which has recently been introduced into the Great Lakes. Wild age-1+ parr were sampled in various rivers in

September by electrofishing. Wild smolts were sampled using smolt traps in the Little Manistee River. Wild adults were sampled upon their return to an MDNR weir on the Little Manistee River and were identified by a fluorescent pigment mark given to them as smolts, just prior to their entry into Lake Michigan. Juvenile hatchery fish were sampled at the hatchery prior to stocking, with the exception of one group which was sampled using smolt traps in the Little Manistee River. Adult hatchery fish were sampled upon their return to the MDNR weir described above and were identified by a distinct fin clip given prior to stocking.

Scales were collected from 44–112 fish per group, samples which were adequate to estimate group means for the scale characters described in Table 3 with an error bound of 5% (Scheaffer et al. 1979). Scales were collected from an area just beneath the posterior edge of the dorsal fin, above the lateral line. Scales were magnified using a microprojector and measurements and circuli counts were made along a radial line 20° from the longest axis (Figure 3). Measurements and counts were taken from one scale per fish, as preliminary studies indicated that within-fish variation was low with coefficients of variation less than 18%. The characters used were chosen to provide information on first-year growth patterns with an emphasis on the patterns just before and just after the formation of the first annulus, and were similar to those used in other studies of salmonid scale growth patterns (Table 3) (personal communication, 1982, N. M. MacHugh and L. Van Dyke, Oregon Department of Fish and Wildlife, Corvallis).

Scale characters were evaluated for utility using the following criteria and statistical tests. All statistical tests were run using the SPSS^{X} computer package (Anon. 1986) at a significance level of 0.05.

Criterion 1.—Scale characters were distinct between wild- and hatchery-origin adults. This was a primary criterion as the test will be applied principally to adults. Wild adults from the Little Manistee River were compared with hatchery adults which had been experimentally stocked as yearling smolts in that river (both groups were of the 1983 smolt cohort) using the t-test.

Criterion 2.—Scale characters were consistent among life stages. It was most desirable to find scale characters for adult steelhead which were consistent (within each wild and hatchery group) among years and among geographic locations, however, known-origin adults were not available from a variety of years or locations. Samples from juvenile fish were available from several years and locations, thus it was necessary to find characters which were consistent among life stages so that the effects of year and location could be analyzed and the results applied to adult populations. Three comparisons were made among wild parr, smolt, and adult life stages from the Little Manistee River, with each comparison including parr and smolt groups from the same cohort and adults from the 1983 smolt cohort. Two comparisons were made between hatchery smolt and adult life stages; one comparison involved Wolf Lake Hatchery fish of the 1983 cohort and the other involved Twin Branch Hatchery fish of two separate cohorts. Group means were compared using either the t-test or a one-way Analysis of Variance (ANOVA) and Scheffe's test for multiple comparisons between means.

Criterion 3.—Scale characters were consistent among years. Two comparisons were made for wild fish; one among parr collected during four different years in the Little Manistee River and one among smolts collected during 4 years in this river. Two comparisons were made between cohorts of hatchery yearlings; one between parr from the Platte River Hatchery and one between smolts from the Wolf Lake Hatchery. Group means were compared as above.

Criterion 4.—Scale characters were consistent among geographic locations. One comparison was made among wild parr from five different rivers and one comparison was made among hatchery yearlings from four separate hatcheries (many of these groups were from different years as well). Group means were compared as above.

Only one character, Ratio 23 (Table 3), met all of the above criteria (see Results) and was thus used to develop an assignment rule. The mean and variance of this character were calculated for each group (wild and hatchery) from the learning sample and a point midway between the overlapping 95% confidence intervals of the groups (± 2 standard deviations) was chosen as the assignment rule. Using this rule with the test sample, the following frequencies of assignment (after Worlund and Fredin 1962) were calculated in order to determine classification error rates:

P_{aa} = relative frequency of wild fish classified as wild

P_{ab} = relative frequency of wild fish classified as hatchery

P_{bb} = relative frequency of hatchery fish classified as hatchery

P_{ba} = relative frequency of hatchery fish classified as wild

Analyses of scales of unknown-origin fish

Scales were collected from adult fish of unknown origin at the Little Manistee River weir by MDNR during 1968–70 and 1979–84 (Tables 2 and 4, Figure 2). This river was never stocked during this period and thus was assumed to represent a baseline wild population. Any fish assigned to hatchery origin would represent either baseline straying or test inaccuracy.

Scales were also collected from adult fish of unknown origin in six additional rivers located in northwestern lower Michigan during 1983–84 by volunteer anglers (Tables 2 and 4, Figure 2). These rivers were all stocked annually at varying rates (Table 4). Of the seven rivers sampled, the northern five lie in a region where stream flow is greatly augmented by groundwater inputs, and either are, or have tributaries which are, noted trout streams. The two southernmost rivers lie in a transitional zone between the trout streams of northern Michigan and the warmwater streams of southern Michigan. Groundwater contributes much less to stream flow in these rivers and they are generally considered marginal trout waters.

Ratio 23 was calculated for these scales and the above rule used to assign individuals to either wild or hatchery groups for each river during 1983–84 and for the Little Manistee River during the additional periods 1968–70 and 1979–82. Using the estimated proportion of wild fish (R_a), sample size (N), and the assignment frequencies (P_{aa}, P_{ab}, P_{bb}, P_{ba}) in the formulas below (from Worlund and Fredin 1962), the relative abundance of wild fish in the unknown-origin samples (F_a) and its variance [$V(F_a)$] were calculated.

$$F_a = (R_a - P_{ba}) / (P_{aa} - P_{ba})$$

$$V(F_a) = [1 / (P_{aa} - P_{ba})]^2 \, V(R_a)$$

where

$$V(R_a) = (1 / N) [F_a F_b (P_{aa} - P_{ba})^2] + \{F_a [(P_{aa} P_{ab}) - (P_{ba} - P_{bb})]\} + (P_{ba} P_{bb})$$

and

$$F_b = 1 - F_a$$

Confidence intervals (95%) for F_a were calculated as:

$$F_a \pm 1.96 [V(F_a)]^{.5}$$

Analyses of variation among scale readers

Steelhead of unknown origins could have potentially experienced a variety of growth patterns. This, coupled with the uniform circuli spacing shown by hatchery fish, can make the location of the first annulus fairly difficult. Errors in annulus location could result in large classification errors. To examine this source of variation, a test sample of 50 known wild and 50 known hatchery fish was examined by the senior author and three other persons who were experienced in scale reading but not with steelhead scales. Each group of 50 fish was made up of five equal subgroups from the groups listed in Table 1. The error rates resulting from these examinations were compared to the expected error rates determined from the test samples described above. Errors in assignment were examined by subgroup origin to see whether any subgroup was particularly difficult to read.

RESULTS

Examination of scale characteristics

Only one characteristic, Ratio 23, satisfactorily met our criteria for use in an assignment rule (Table 5). Significant differences were found between wild and hatchery adults for all characteristics except Distance 1, Circuli 2, and Ratio 21. There were no significant differences for wild fish between years, life stages, or locations for Ratio 23, with the exception of one among-year comparison and one among-location comparison. All other characteristics displayed some significant differences for at least one of the criteria for wild fish. For hatchery fish, none of the characteristics were statistically similar for all of the criteria, however, Ratio 23 had the greatest number of nonsignificantly different results.

Development and testing of an assignment rule

The learning samples showed a mean Ratio 23 of 0.615 and a variance of 0.014 ($N = 622$) for wild fish (Figure 4). Hatchery fish had a mean Ratio 23 of 0.830 with a variance of 0.019 ($N = 585$). The point midway between the overlapping confidence intervals averaged 0.705 and the following decision rule was formulated: If Ratio 23 $\leq = 0.70$, then wild origin is assigned, and if Ratio 23 > 0.70, then hatchery origin is assigned. The following mean assignment frequencies were found for the test samples: $P_{aa} = 0.826$, $P_{ab} = 0.174$, $P_{bb} = 0.850$, $P_{ba} = 0.150$.

Relative contributions of wild fish to unknown-origin samples

The proportion of wild fish in the adult steelhead population of the Little Manistee River was estimated to be 100% (actually 103% ± 6%) during the periods 1968–70, 1979–82, and 1983–84 (Table 6), indicating little, if any, contribution from stray hatchery fish. The proportion of wild fish in adult populations in the four stocked northern trout rivers (Betsie, Manistee, Pere Marquette, and Pentwater) ranged from 86% to 100% (Table 6), however, sample sizes in several of these were too small to provide estimates with acceptable confidence intervals (±10%). An estimate of the percentage wild fish pooled across all four trout rivers was 93% (±7%) and was not significantly different (using 95% confidence intervals) from the Little Manistee River estimate for the same period. This indicated little, if any, contribution from either stray hatchery fish or from hatchery parr stocked in these rivers. Sample sizes in the two southern marginal trout rivers were also quite small, so data from these rivers were pooled providing an estimate of 60% (±20%) wild fish in the adult populations. This estimate was significantly lower (using 95% confidence limits) than the Little Manistee estimate, indicating some contribution of hatchery fish to runs in these rivers.

Variation among scale readers

The error rate of the assignment rule varied with the reader's experience in reading steelhead scales. The senior author tested the above rule and had an error rate of 10%, somewhat lower than the expected rate of 16% (the mean of P_{ab} and P_{ba}). The three additional readers had error rates ranging between 18 and 29%, somewhat higher than the expected rate. For all readers, misidentified fish were spread evenly among the 10 subgroups, although one reader had a concentration in the wild subgroups.

DISCUSSION

Development of the assignment rule

No information has been published on quantitative differences in scale characters between wild and hatchery steelhead from either the Great Lakes or the Pacific Coast regions.

The assumption was made during this study that the known-origin samples were representative of the particular wild and hatchery groups present in the unknown-origin samples. The validity of this was difficult to assess, as the origins of steelhead entering a given river were unknown and potentially quite varied. We tried to validate this assumption by including a wide range of groups in our known-origin samples. In doing this, however, we may have created an artificially high level of variability in the learning and test samples, thereby biasing the classification error rates. This scenario was supported by unrealistically high ($\geq$100%) estimates of the proportion of wild fish in several of the unknown samples, an indication that the misclassification rate (P_{ba}) was too high.

An assignment rule developed using the scale characteristic Ratio 23 provided a simple and accurate method of identifying wild and hatchery origins for Lake Michigan steelhead of a variety of origins. Winter temperatures in this region are cold enough to greatly reduce growth during winter, resulting in a relatively low Ratio 23. This method should be applicable in other regions with similar temperature regimes and possibly to other species which spend a full year in a hatchery. The accuracy of this method will be maximized by the use of experienced steelhead scale readers.

Application

Our estimates of high proportions of wild fish in the rivers of northwestern lower Michigan were supportive of the findings of several other investigations. Studies from both the Pacific Coast and Michigan have shown that steelhead parr stocked in trout streams remain in the stream following stocking, suffer high mortalities due to competition with existing populations of wild trout, and would be expected to contribute little to returning adult populations (Chrisp and Bjornn 1978; Seelbach 1987). Stauffer (from Biette et al. 1981) and Seelbach (1986) followed the returns of marked wild smolts and reported that 66–84% and at least 71%, respectively, of the adult runs in two Lake Michigan tributaries were made up of wild fish produced in those rivers. Finally, Seelbach (1986) showed that the rivers of northwestern lower Michigan produced large numbers of wild fish.

The results of this study supported Seelbach's (1987) conclusion that historical plantings of yearling steelhead parr in rivers which support abundant wild steelhead populations have probably contributed little to adult populations in these rivers. In several cases, parr were stocked at river mouths, and this study suggests that these stockings also did not contribute much to returning adult populations. The higher proportions found in marginal trout rivers could have resulted from fewer wild adults being present, higher survival of hatchery parr in these rivers due to less competition from wild parr, more hatchery strays entering these rivers for some unknown reason, or some combination of these.

In 1983 the MDNR began stocking yearling steelhead smolts. These quickly leave the river following stocking (Seelbach 1987) and thus avoid the high in-river mortality experienced by stocked parr. The contribution of yearling smolts to returning adult populations has yet to be examined.

ACKNOWLEDGMENTS

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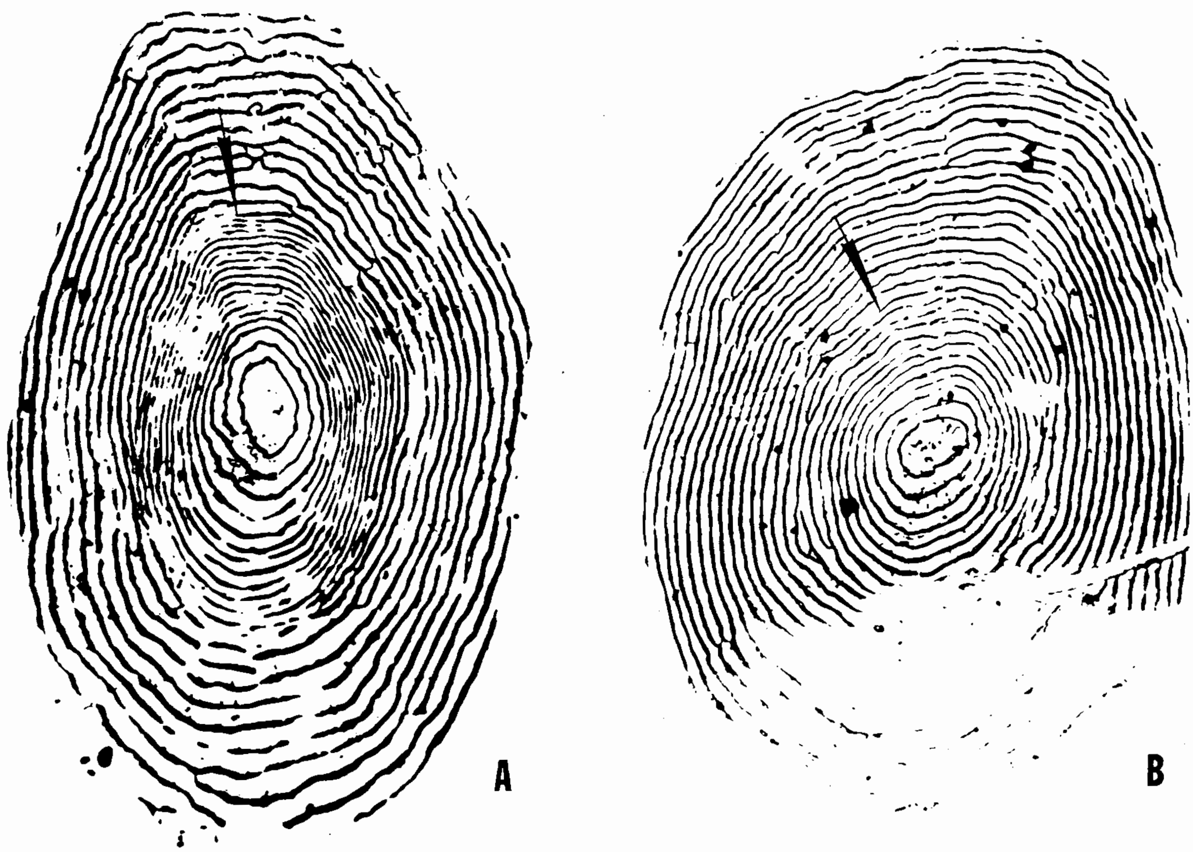

Figure 1. Photographs of known-origin wild (A) and hatchery (B) scales from age-1 fish showing the rapid increase in growth following the first annulus seen in wild fish. The first annulus is shown with an arrow.

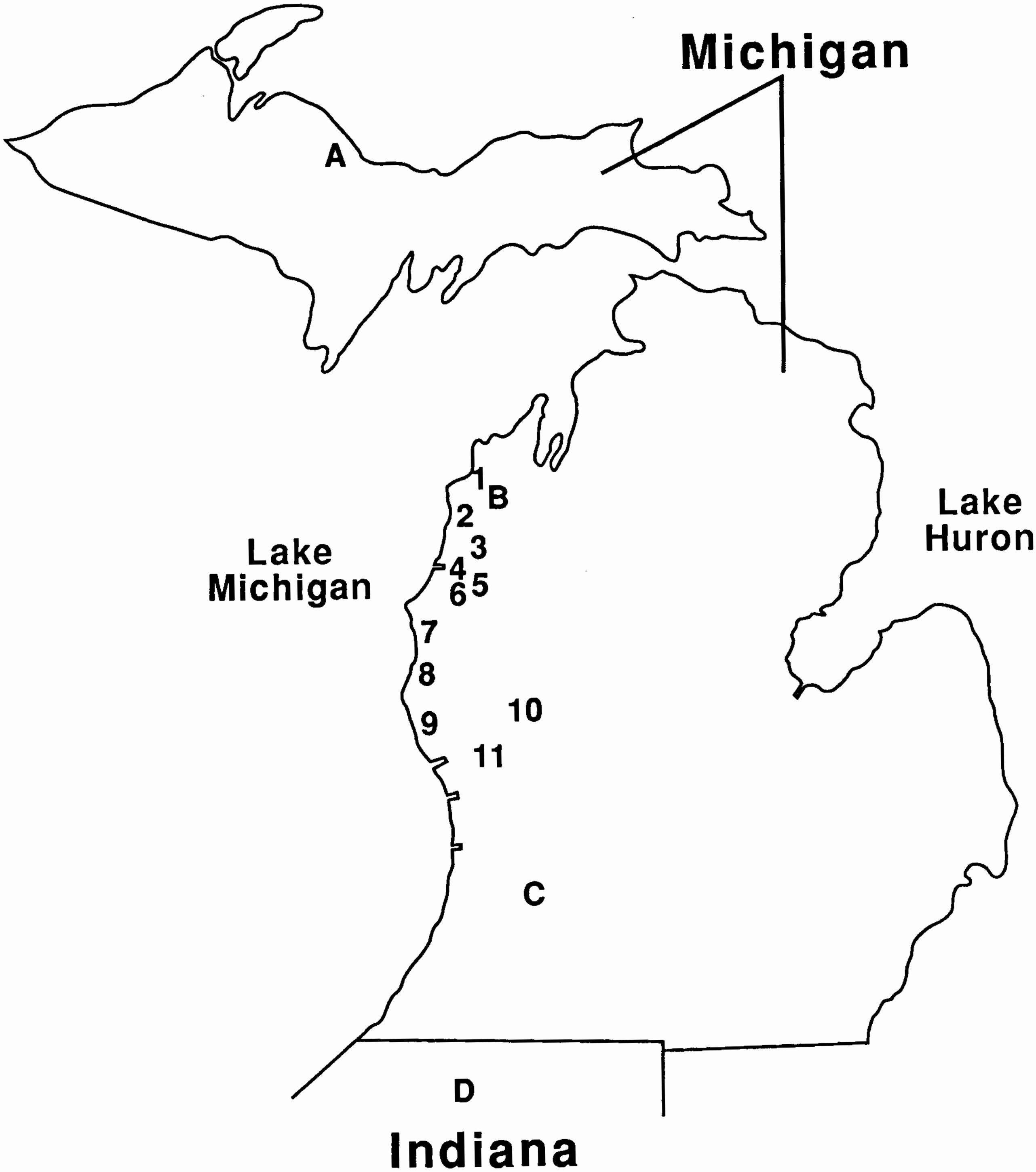

Figure 2. Locations of hatcheries and rivers in Michigan and Indiana from which scales were obtained for this study. Hatcheries shown are: A-Marquette; B-Platte River; C-Wolf Lake; and D-Twin Branch. Rivers shown are: 1 - Platte River; 2-Betsie River; 3-Bear Creek; 4-Manistee River; 5-Pine Creek; 6-Little Manistee River; 7-Pere Marquette River; 8-Pentwater River; 9-White River; 10-Bigelow Creek; 11-Muskegon River.

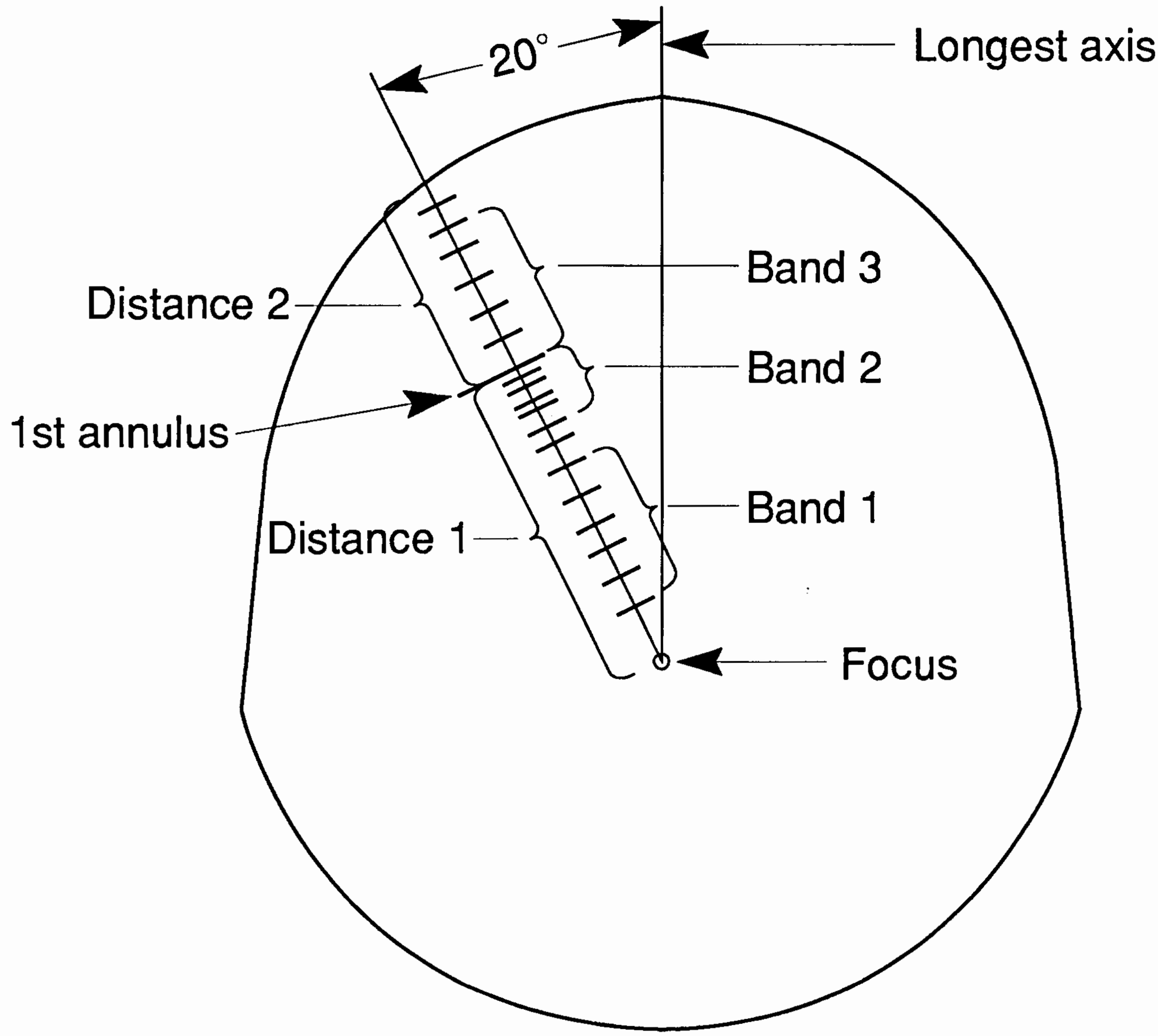

Figure 3. Scale measurements and descriptions used in this study.

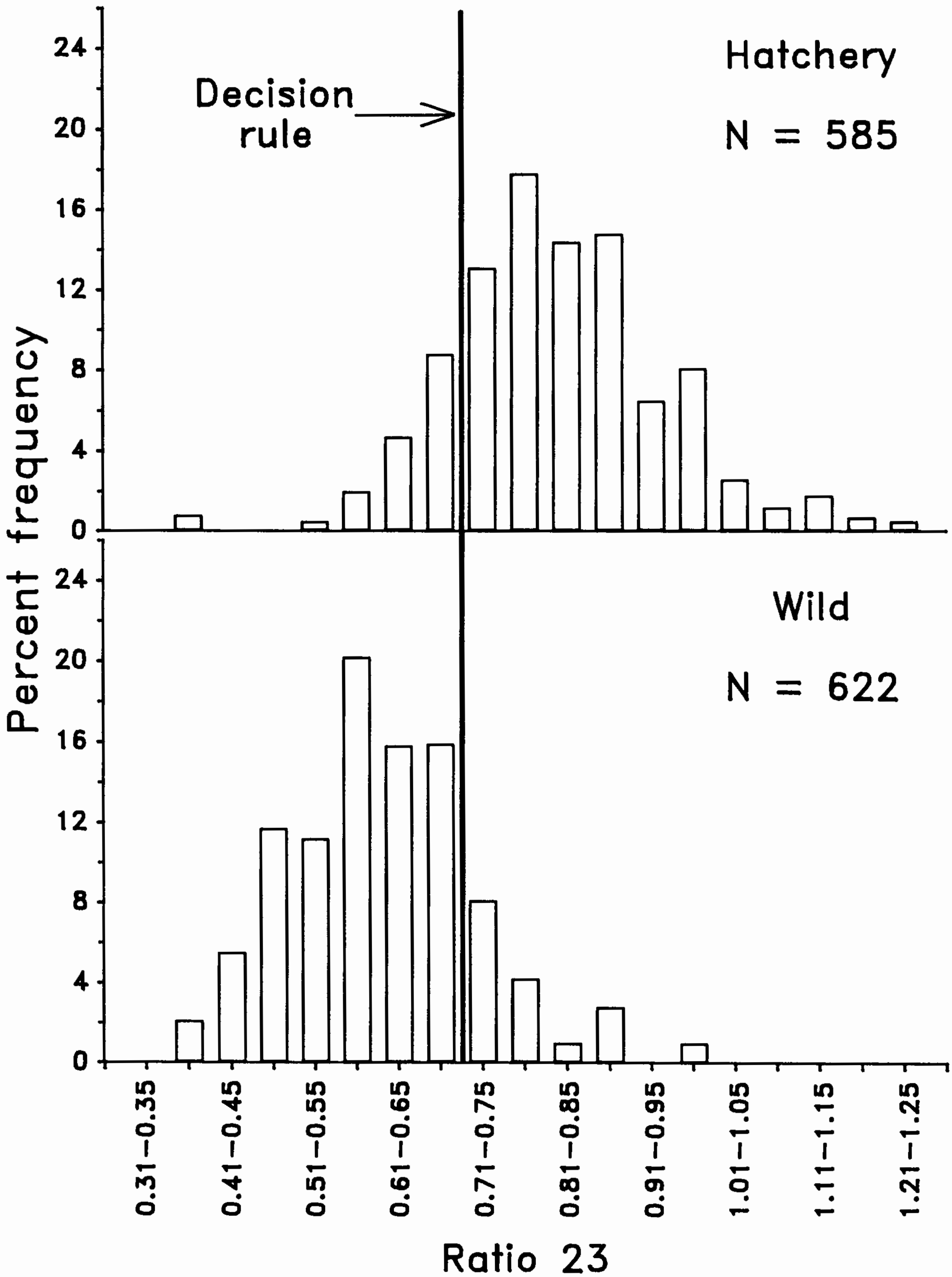

Figure 4. Frequency distribution of Ratio 23 for wild and hatchery steelhead trout (all data pooled) showing the location of the assignment rule developed in this study.

Table 1. Groups from which scales of known-origin steelhead were obtained.

Origin	State	Strain	Life stage	Year sampled	Number
Hatchery					
Platte River	MI	Michigan	Parr	1981	98
Platte River	MI	Michigan	Parr	1982	92
Wolf Lake	MI	Michigan	Smolt	1983	112
Wolf Lake	MI	Michigan	Smolt	1987	50
Marquette	MI	Michigan	Parr	1986	50
Wolf Lake	MI	Michigan	Adult	1984–86	44
Wolf Lake	MI	Skamania	Smolt	1984	49
Twin Branch	IN	Skamania	Smolt	1986	40
Twin Branch	IN	Skamania	Adult	1984	50
Total					585
Wild					
Little Manistee River	—	—	Parr	1980–83	200
Little Manistee River	—	—	Smolt	1981–84	200
Little Manistee River	—	—	Adult	1984–86	50
Bear Creek	—	—	Parr	1983	30
Pine Creek	—	—	Parr	1977–78	50
Bigelow Creek	—	—	Parr	1977–78	50
Platte River	—	—	Parr	1986	42
Total					622

Table 2. Groups used for rule development and applications.

Group	Study section: Rule development	Study section: Rule application
Hatchery		
Marquette (MI)	X	—
Platte River (MI)	X	—
Wolf Lake (MI)	X	—
Twin Branch (IN)	X	—
River		
Platte River	X	—
Betsie River	—	X
Bear Creek	X	—
Manistee River	—	X
Pine Creek	X	—
Little Manistee River	X	X
Pere Marquette River	—	X
Pentwater River	—	X
White River	—	X
Bigelow Creek	X	—
Muskegon River	—	X

Table 3. Scale characteristics used to describe the steelhead groups.

Characteristic	Definition
Band 1 (B1)	Width of the first 5 intercirculi spaces (those between Circuli 1 and 6)
Band 2 (B2)	Width of the five intercirculi spaces just inside of the first annulus
Band 3 (B3)	Width of the five intercirculi spaces just outside of the first annulus
Distance 1 (D1)	Distance from the scale focus to the first annulus
Distance 2 (D2)	Distance from the first annulus to the next check—either the second annulus or the smolt check (for hatchery presmolts the scale edge was assumed to be the smolt check)
Circuli 1 (C1)	Number of circuli included within Distance 1
Circuli 2 (C2)	Number of circuli included within Distance 2
Ratio 21 (Rat21)	Ratio between Band 2 and Band 1
Ratio 23 (Rat23)	Ratio between Band 2 and Band 3
D2D1 (D2D1)	Ratio between Distance 2 and Distance 1

Table 4. Rivers from which scales were obtained from adult steelhead of unknown origins.

River[1]	Year sampled	Number	Mean annual stocking rate (1975–82)[2]
Betsie	1983–84	58	12,000
Manistee	1983–84	201	23,000
Little Manistee	1968–70	238	0
	1979–84	775	0
Pere Marquette	1983–84	14	5,000
Pentwater	1983–84	30	5,000
White	1983–84	31	10,000
Muskegon	1983–84	23	26,000

[1] Listed by geographical location from north to south.

[2] From Michigan Fish Stocking Record, 1975–1982, Michigan Department of Natural Resources, Lansing.

Table 5. Summary of statistical test results on all scale characteristics. The symbols (+) and (–) denote the t-test and ANOVA, respectively. Test results are denoted as: ns—not significant at $P <= 0.05$; *—significant at $P < 0.05$; and **—significant at $P < 0.01$.

Comparison	Scale characteristic									
	B1	B2	B3	D1	D2	C1	C2	Rat21	Rat23	D2D1
Hatchery vs. wild										
Adults (+)	**	**	**	ns	**	**	ns	ns	**	**
Among life stages										
Wild (–)										
Parr-smolt-adult	**	**	**	**	**	**	**	**	ns	**
Parr-smolt-adult	**	**	**	**	**	**	**	**	ns	**
Parr-smolt-adult	**	**	*	ns	**	**	**	**	ns	**
Hatchery (+)										
Smolt-adult	**	ns	ns	ns	**	ns	*	**	*	**
Smolt-adult	ns	*	**	ns	ns	ns	**	**	ns	ns
Among years										
Wild (–)										
Smolts	ns	ns	ns	**	**	**	ns	ns	ns	*
Parr	**	*	**	**		**		ns	*	
Hatchery (+)										
Platte River	**	**	ns	ns	**	*	**	ns	**	**
Wolf Lake	**	**	**	**	**	*	**	**	*	**
Among locations										
Wild (–)	**	**	**	**		**		**	ns	
Hatchery (+)	**	**	**	**	**	**	**	**	*	**

Table 6. Proportion of wild fish in adult steelhead populations (with 95% confidence limits) in some Michigan rivers.

	Year		
River[1]	1983–84	1979–82	1968–70
Betsie	0.93 (±0.16)	— —	— —
Manistee	0.90 (±0.09)	— —	— —
Little Manistee	1.03 (±0.06)	1.02 (±0.05)	1.12 (±0.06)
Pere Marquette	1.05 (±0.27)	— —	— —
Pentwater	0.86 (±0.23)	— —	— —
White	0.64 (±0.26)	— —	— —
Muskegon	0.55 (±0.30)	— —	— —

[1] Listed by geographical location from north to south.

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