Assessment of Fin Erosion by Comparison of Relative Fin Length in Hatchery and Wild Trout in Utah

Thomas Bosakowski and Eric J. Wagner

Utah Division of Wildlife Resources, Fisheries Experiment Station, 1465 West 200 North, Logan, UT 84321, USA

Bosakowski, T., and E.J. Wagner. 1994. Assessment of fin erosion by comparison of relative fin length in hatchery and wild trout in Utah. Can. J. Fish. Aquat. Sci. 51: 636–641.

We measured all fins of 600 hatchery trout sampled from all 10 state fish hatcheries in Utah, and of wild fish sampled as controls comprising 58 rainbow trout (*Oncorhynchus mykiss*), 33 cutthroat trout (*O. clarki*), and 54 brown trout (*Salmo trutta*). A strong linear correlation was found between fin length and total body length (100–300 mm) for all fins of wild rainbow trout. "Relative fin length" (fin length/total body length × 100) proved to be a useful comparative measure, as this statistic was not biased by fish length in the wild fish sampled (all slopes <0.01%). Interspecific comparison of wild rainbow, cutthroat, and brown trout showed slight but statistically significant differences in some fin lengths. In intraspecific comparisons, hatchery fish had significantly shorter (10–50%) rayed fins than wild fish. The dorsal fin was most severely eroded in rainbow and brown trout, followed by the pectoral, anal, ventral, and caudal fins. In cutthroat trout the pattern was the same except that pectoral fins had more extensive erosion than dorsal fins. No species was clearly more susceptible to fin erosion in hatcheries, but the Fish Lake – DeSmet strain of rainbow trout had significantly shorter fins than other rainbow trout strains.

Nous avons mesuré toutes les nageoires de 600 truites d'élevage prélevées dans les 10 écloseries d'État de l'Utah, et de poissons sauvages prélevés comme témoins : 58 truites arc-en-ciel (*Oncorhynchus mykiss*), 33 truites fardées (*O. clarki*) et 54 truites brunes (*Salmo trutta*). Nous avons trouvé une forte corrélation linéaire entre la longueur des nageoires et la longueur totale du corps (100–300 mm) pour toutes les nageoires des truites arc-en-ciel sauvages. La «longueur relative des nageoires» (longueur de la nageoire/longueur totale du corps × 100) s'est révélée une mesure comparative utile, car cette donnée n'est pas biaisée par la longueur des poissons chez les spécimens sauvages échantillonnés (toutes les pentes <0,01 %). La comparaison interspécifique des spécimens sauvages de truite arc-en-ciel, de truite fardée et de truite brune a révélé des différences légères mais statistiquement significatives dans la longueur de certaines nageoires. Dans les comparaisons intraspécifiques, les poissons d'élevage présentaient des nageoires rayonnées nettement plus courtes (10–50 %) que les poissons sauvages. C'est la nageoire dorsale qui était la plus érodée chez la truite arc-en-ciel et la truite brune, suivie par les nageoires pectorales, anales, ventrales et caudales. Chez la truite fardée, le schéma était le même, mais les nageoires pectorales étaient plus érodées que les nageoires dorsales. Aucune espèce ne semblait nettement plus vulnérable que les autres à l'érosion des nageoires dans les écloseries, mais la souche Fish Lake – DeSmet de truite arc-en-ciel présentait des nageoires nettement plus courtes que les autres souches de la même espèce.

Received March 19, 1993
Accepted October 7, 1993
(JB850)

Reçu le 19 mars 1993
Accepté le 7 octobre 1993

Fin erosion is a common problem in hatchery-raised salmonids both in Utah and worldwide. This condition is so pervasive that it is often used as an indicator in the field to identify recently stocked fish. Studies have shown that fins clipped from one half of two thirds their length will regenerate in approximately 6 mo with only minor deformities (Eipper and Forney 1965), but fins reduced to the point of attachment with the bone will usually not regenerate (Stuart 1958; Eipper and Forney 1965; Jones 1979). Heimer et al. (1985) found no difference in survival of rainbow trout (*Oncorhynchus mykiss*) missing pectoral fins due to erosion when compared with control fish with intact pectoral fins. Gjerde and Refstie (1988) have also reported no significant differences in survival between fin-clipped and unclipped fish.

However, other studies have described detrimental effects on survival (Saunders and Allen 1967; Weber and Wahle 1969; Nicola and Cordone 1973; Mears and Hatch 1976). Because active fin erosion in hatchery fish is often accompanied by microbial infection and hemorrhage (Schneider and Nicholson 1980; Goede and Barton 1990), the ability to survive in the wild could be compromised, even if the effects of partial fin loss on swimming ability may be marginal. The lack of aesthetic appeal of fish with fin erosion is also a management and marketing problem with regard to satisfaction levels of discriminating anglers and consumers.

The purpose of this investigation was to (1) quantify the extent of fin erosion in the Utah State hatchery system, (2) compare the degree of erosion in hatchery-reared fish with that in wild populations, (3) determine the extent of affliction for individual fins, (4) evaluate the relationship between fin length and body length, and (5) compare fin erosion among hatcheries, strains, and species.

Materials and Methods

At total of 600 hatchery trout were sampled from 17 March 1992 to 1 May 1992 at all 10 state hatcheries in Utah. During this period, fish loads were near their maximum just prior to spring stocking. At each of the 10 hatcheries, two to four samples of 20 fish were taken from raceways or ponds. This sampling included 22 groups of rainbow trout, two groups of albino rainbow trout, four groups of cutthroat trout (*O. clarki*), and one group each of brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*). Overall, the survey included a mixture of fish 200–300 mm long (catchables) and 100–200 mm long (subcatchables), all fish being no older than 22 mo. All fish were fed the same brand of food, but there may have been subtle differences in food storage conditions, feeding methods, and ration levels that could not be accounted for.

Fish were temporarily immobilized with tricaine methanesulfonate (MS-222), weighed to the nearest 0.1 g, and measured for total length to the nearest millimetre. All rayed fins were subsequently measured to the nearest millimetre by taking the maximum length reading, parallel to the fin rays (Fig. 1). Adipose fins were measured for maximum length from the anterior point of attachment to end of the posterior lobe. One of the authors (T.B.) made all of the fin measurements to avoid any possible observer bias. To determine the pattern and extent of fin wear, fin length measurements of hatchery trout were divided by total body length × 100 (Kindschi 1987) to obtain relative fin lengths for comparison with wild populations.

Using electrofishing equipment, 58 wild rainbow trout (113–285 mm) were sampled in August 1992 from Summit Creek, Cache County, Utah. A total of 33 wild cutthroat trout (139–297 mm) and 54 wild brown trout (116–297 mm) were sampled in January 1993 from the East Fork of the Little Bear River, Cache County, Utah. Identical procedures were used to measure these fish.

Ordinary least-squares linear regression of fin length or relative fin length against total length was performed with the SAS statistical software program (SAS Institute, Inc. 1988). For comparison of fin erosion between hatchery and wild fish, all hatchery rainbow trout (N = 440) data were pooled. Comparisons of relative fin length among the hatchery and the wild populations were made for each fin with the SAS procedure "NPAR1WAY WILCOXON", a nonparametric rank test (SAS Institute, Inc. 1988). This test was also used to evaluate differences among strains of rainbow trout, controlling for hatchery. The GLM procedure (general linear models; SAS Institute, Inc. 1988) was used in a two-way analysis to analyze rank transformed data for differences among hatcheries, species, and their interaction. For comparison of fin erosion among species within a hatchery, one-way analysis of variance (ANOVA) of rank transformed data was used. A significance level of $p < 0.05$ was used for each comparison.

Results

Linear regression plots were constructed by comparing fin lengths with total body length of wild rainbow trout (Fig. 2). Results showed a clear linear relationship for all fins within the size range of fish sampled (100–300 mm). High correlation coefficients ($r > 0.88$) indicated a strong correlation for all fins. All slopes were significantly greater than zero ($p < 0.0001$).

Relative fin lengths were generated and regressed against total body length (Table 1). These relationships were generally stable as fish length increased for wild rainbow trout, with the exception of the slightly negative slope (0.006%) for caudal fin values. Results for wild brown and cutthroat trout revealed slightly less stable relationships for relative fin length as body length increased, but slopes were minimal (all slopes < 0.01%).

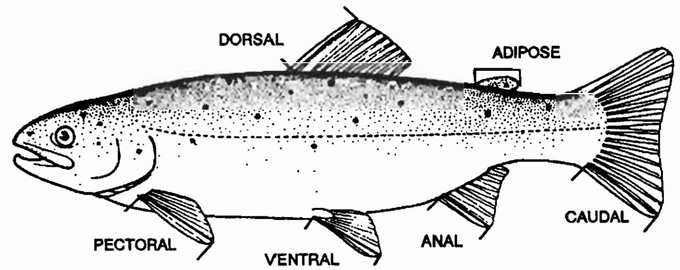

FIG. 1. Location of measurements taken for maximum fin length.

Intraspecific comparison of relative fin length for hatchery and wild fish showed that all rayed fins were significantly shorter in the hatchery rainbow, cutthroat, and brown trout (Fig. 3). In contrast with rayed fins, relative fin length for adipose fins was either the same (brown and cutthroat) or longer (rainbow) for hatchery fish. For rainbow and brown trout, fin erosion was most severe for dorsal fins, followed by the pectoral, anal, caudal, and ventral fins. The pattern for cutthroat trout was similar except that pectoral fins had greater erosion than dorsal fins.

Interspecific comparison of the wild populations (Fig. 4) showed that relative fin lengths for rainbow and brown trout tended to be the same for all rayed fins whereas for cutthroat, relative fin lengths were typically shorter for all rayed fins, except the caudal fin. The adipose relative fin length was unique for each species.

Among hatchery fish, species differences in relative fin length were examined within hatcheries to eliminate the effect of hatchery differences (Table 2). At the Egan Hatchery, there was an overall difference among the four trout species for each of the fins (ANOVA, $p < 0.0001$). Similarly, at the Kamas Hatchery, there was an overall difference for each of the fins of rainbow, albino rainbow, and cutthroat trout (ANOVA, $p < 0.0001$). At the Midway and Kamas hatcheries, relative dorsal and anal fin lengths of albino rainbow trout were significantly longer than the corresponding fins of pigmented rainbow trout, but the other fins were variable, with no consistent differences across both hatcheries.

In three of four hatcheries, relative dorsal fin lengths of rainbow trout were significantly shorter than those of cutthroat trout. On the other hand, cutthroat trout had greater erosion of the pectoral fins than rainbow trout at three of four hatcheries. In the Egan Hatchery, there was no significant difference in pectoral fin erosion as a result of the poorer condition of the rainbow trout fins, as opposed to the better condition of fins of the cutthroat trout. Differences in erosion of the ventral fins of cutthroat and rainbow trout were variable, with neither species clearly better or worse than the other.

Individual fin lengths were also compared by strain, but the number of statistically valid comparisons was limited to only four comparisons (Table 3). Rainbow trout of the Fish Lake – DeSmet (FD) strain generally had significantly shorter rayed fins than the albino (AB), Sand Creek (SC), and Shepherd of the Hills (SH) strains. Exceptions were the rel-

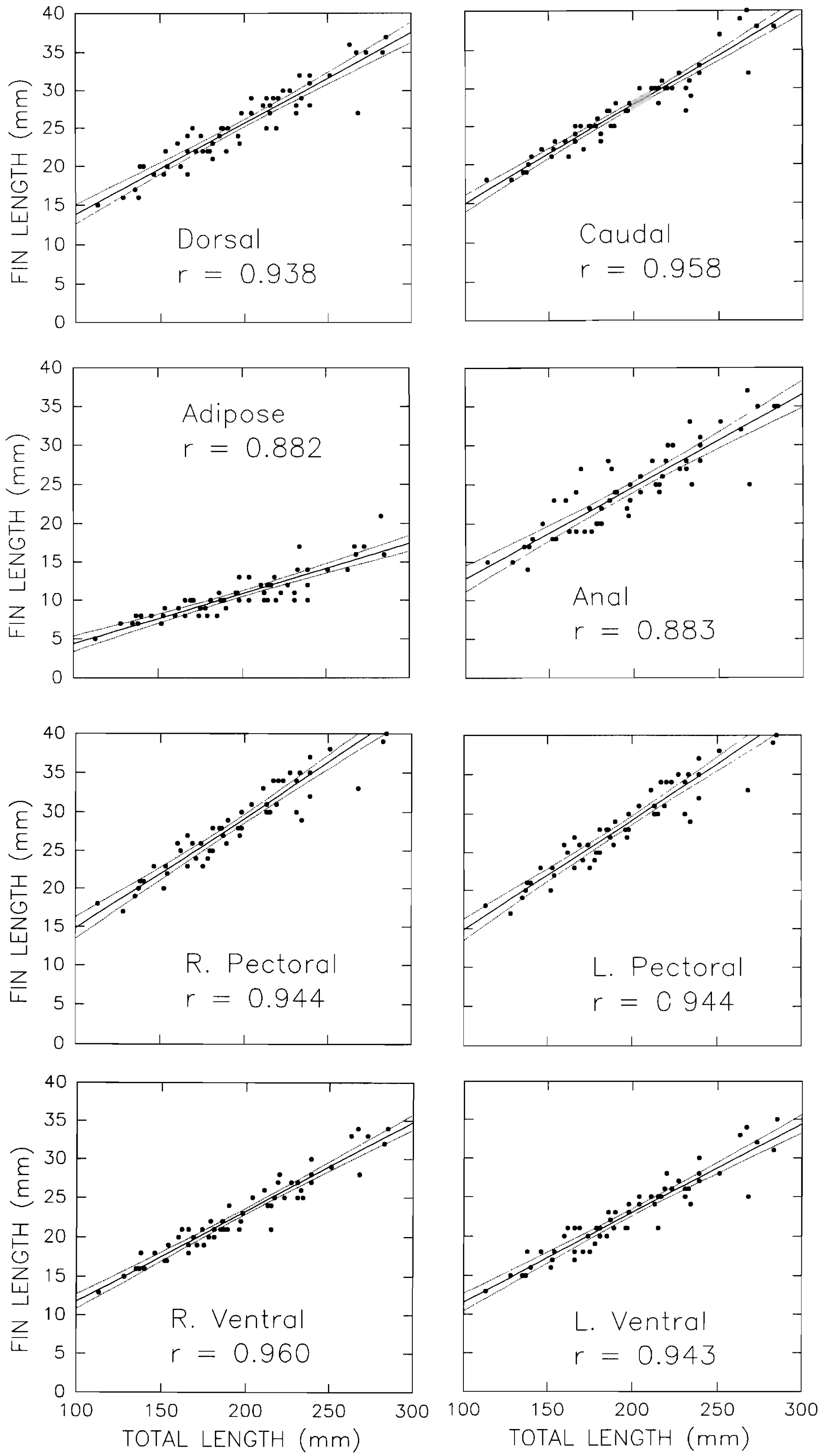

FIG. 2. Linear regression plots of fin length against total body length for wild rainbow trout (N = 58) from Summit Creek, Utah. Solid line = regression line; dotted lines = 95% confidence interval of the mean.

TABLE 1. Results of regression of relative fin length (%) with total body length for rainbow, cutthroat, and brown trout from wild populations. r = correlation coefficient, p = ANOVA probability that slope equals zero, m = slope (percent change per millimetre), b = y-intercept (relative fin length), DR = dorsal, CD = caudal, AD = adipose, AN = anal, RP = right pectoral, LP = left pectoral, RV = right ventral, LV = left ventral.

Species		DR	CD	AD	AN	RP	LP	RV	LV
Rainbow	r =	0.216	0.336	0.287	0.082	0.062	0.010	0.082	0.028
(N = 58)	p =	0.1027	0.0099	0.0287	0.5412	0.6457	0.9353	0.5378	0.8291
	m =	−0.0048	−0.0065	0.0047	−0.0025	−0.0015	−0.0003	−0.0014	−0.0006
	b =	13.86	15.27	4.46	12.87	14.90	14.59	11.93	11.61
Cutthroat	r =	0.449	0.586	0.455	0.114	0.049	0.026	0.462	0.222
(N = 33)	p =	0.0088	0.0003	0.0001	0.5284	0.7887	0.8870	0.0068	0.2148
	m =	−0.010	−0.0086	0.0058	0.0018	−0.0007	−0.0003	−0.0041	−0.0020
	b =	14.10	16.19	4.97	11.66	13.82	13.69	12.12	11.45
Brown	r =	0.380	0.491	0.432	0.347	0.491	0.523	0.190	0.070
(N = 54)	p =	0.0046	0.0002	0.0010	0.0102	0.0002	0.0001	0.1900	0.6142
	m =	−0.0042	−0.0055	−0.0063	0.0050	−0.0092	−0.0094	−0.0018	−0.0006
	b =	14.25	15.39	8.35	11.26	17.21	17.27	12.13	11.84

TABLE 2. Species differences in relative fin lengths (%) of trout from five Utah hatcheries. CT = cutthroat trout, RT = rainbow trout, BK = brook trout, BN = brown trout, AB = albino rainbow trout, TL = total body length (mm); other abbreviations listed in Table 1. A common superscript letter among species within a hatchery indicates no significant difference (p > 0.050). ***No comparison because these cutthroat trout were adipose fin clipped.

Hatchery	Species	N	TL	DR	CD	AD	AN	RP	LP	RV	LV
Egan	CT	20	172.2[a]	8.3[a]	10.9[a]	6.3[a]	9.8[a]	6.9[a]	7.2[a]	8.6[a]	8.6[a]
	RT	20	190.9[b]	6.3[b]	9.0[b]	6.5[a]	7.1[b]	6.8[a]	6.9[a]	7.7[b]	7.6[b]
	BK	20	207.1[c]	8.0[abc]	11.2[a]	6.2[a]	9.8[a]	11.3[b]	10.5[b]	7.3[b]	6.8[b]
	BN	20	186.5[b]	7.0[c]	11.1[a]	7.1[b]	9.9[a]	9.9[b]	9.8[b]	9.9[c]	9.5[c]
Kamas	CT	20	143.4[a]	7.3[a]	11.2[a]	6.2[a]	9.6[a]	6.8[a]	6.5[a]	7.2[a]	6.9[a]
	RT	40	157.2[a]	8.6[b]	12.4[b]	6.8[b]	10.2[a]	11.3[b]	11.5[b]	9.9[b]	9.9[b]
	AB	20	217.2[b]	9.7[c]	12.5[b]	6.2[a]	10.8[b]	9.4[c]	9.5[c]	9.3[c]	9.1[c]
Ft. Green	CT	20	177.3[a]	8.1[a]	12.1[a]	***	10.3[a]	10.5[a]	10.5[a]	8.2[a]	8.6[a]
	RT	40	243.0[b]	6.2[b]	11.5[b]	***	9.7[b]	11.2[a]	11.3[b]	9.9[b]	9.9[b]
Mantua	CT	20	308.9[a]	8.4[a]	10.1[a]	***	9.3[a]	6.2[a]	6.4[a]	8.4[a]	8.3[a]
	RT	20	203.6[b]	6.5[b]	10.3[a]	***	7.8[b]	8.4[b]	8.4[b]	8.6[a]	8.2[a]
Midway	AB	20	227.0[a]	10.5[a]	12.9[a]	6.6[a]	11.1[a]	11.0[a]	10.9[a]	10.4[a]	10.4[a]
	RT	60	209.0[b]	7.9[b]	12.8[a]	5.9[b]	10.4[b]	11.8[a]	11.9[a]	10.2[a]	10.1[a]

TABLE 3. Comparison of relative fin length (%) between different strains of rainbow trout within hatcheries. AB = albino, FD = Fish Lake – DeSmet, SH = Shepherd of the Hills, SC = Sand Creek; other abbreviations listed in Table 1. *Significant difference between strains within the hatchery (p < 0.050).

Hatchery	Strain	N	TL	DR	CD	AD	AN	RP	LP	RV	LV
Midway	AB	20	227.0	10.4	12.9	6.6	11.0	11.0	10.9	10.4	10.4
	FD	20	209.0*	7.9*	12.7	5.9	10.4*	11.7	11.9*	10.1*	10.1*
White Rocks	SH	20	232.6	8.2	12.0	6.5	10.3	11.2	11.4	10.5	10.5
	FD	20	182.3*	5.9*	11.2*	6.1	9.2*	9.9*	10.0*	9.2*	9.0*
Mammoth Creek	FD	20	228.8	5.0	10.6	6.3	8.6	3.9	4.1	9.4	9.3
	SC	20	121.9*	3.5*	11.7*	7.7*	9.6*	10.4*	10.6*	9.5	9.4
Loa	FD	20	227.2	2.6	9.4	6.9	5.7	4.7	4.6	9.3	9.2
	SC	40	146.8*	3.8*	11.3*	7.8*	8.4*	11.6*	11.2*	9.5	9.7*

ative dorsal fin and left pectoral fin lengths of the SC and AB trout strains, respectively, which were significantly greater in the FD strain.

Discussion

The proportion of fin length over total body length, termed "relative fin length" in this paper, was proposed by Kindschi (1987) as a method for quantifying fin erosion. However, questions arose concerning the stability of this ratio over a range of fish sizes. A comparison of relative fin length among fish of different sizes would be biased if the relationship was not linear. In this study, we determined that there was a clear linear relationship between fin length and total body length in wild rainbow, brown, and cutthroat trout ranging from 100 to 300 mm in length. The stability of rel-

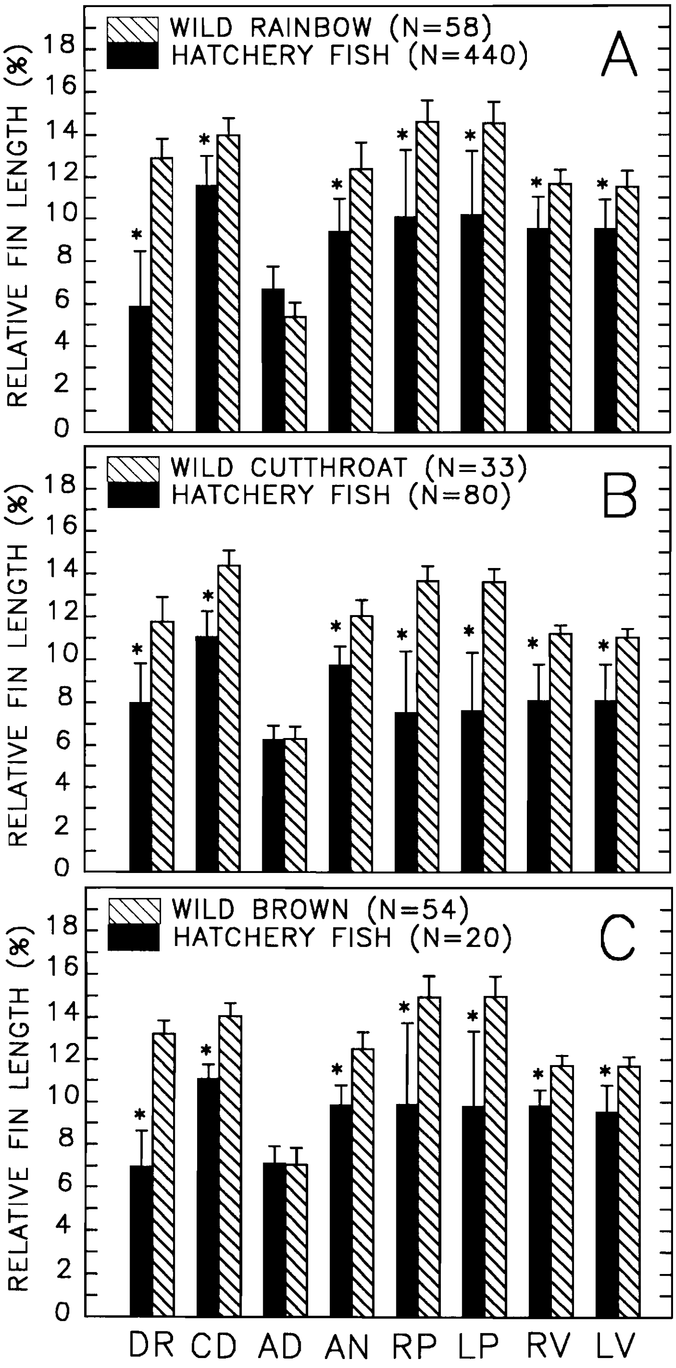

FIG. 3. Comparison of relative fin length between wild and hatchery (A) rainbow, (B) cutthroat, and (C) brown trout. Bar heights represent the mean, with error bars indicating the standard deviation. An asterisk indicates significant difference ($p > 0.05$) between hatchery and wild trout. Fin abbreviations are given in Table 1.

ative fin length, as size increases, was demonstrated for nearly all fins of the wild rainbow trout examined. Exceptions for cutthroat and brown trout fins were minor; all slopes were <0.01%. At least within the typical size range of hatchery trout (100–300 mm), this level of accuracy should be sufficient for quantifying fin erosion. In this investigation, average erosion was 10–50% for rayed fins.

Relative fin length for adipose fins was either the same (brown and cutthroat) or longer (rainbow) for hatchery fish.

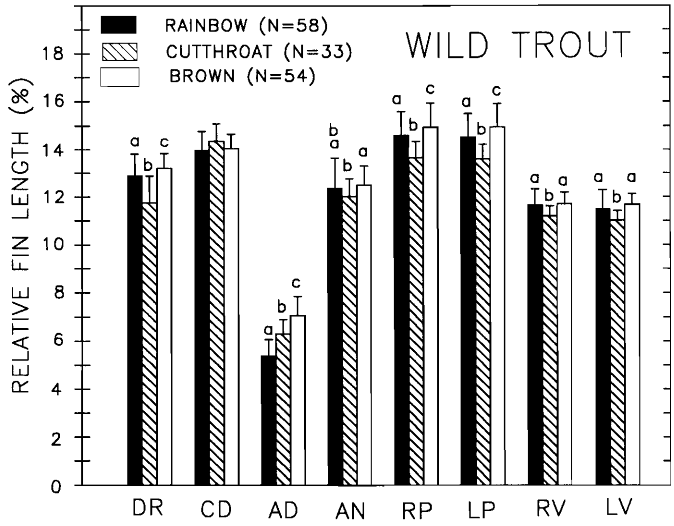

FIG. 4. Comparison of relative fin length among wild populations of rainbow, cutthroat, and brown trout. Bar heights represent the mean, with error bars indicating the standard deviation. A different letter indicates significant difference ($p > 0.05$). Fin abbreviations are given in Table 1.

This result demonstrates that the adipose fin is not subject to erosion and may even increase in size in hatchery fish. Simpson et al. (1992) found that adipose fin length and five body morphometrics could be used in a multiple regression model to successfully predict fat levels of hatchery Atlantic salmon (*Salmo salar*).

In using relative fin length, we document for the first time that all rayed fins of hatchery trout were significantly shortened by the fin erosion process. Intraspecific comparison between wild and hatchery fish showed that the dorsal fin of rainbow and brown trout was the most severely eroded, followed by the pectoral, anal, ventral, and caudal fins. Kindschi et al. (1991a) examined only the dorsal fins of wild and hatchery juvenile steelhead trout and found significant erosion in hatchery fish between 28 and 200 mm in length. Abbott and Dill (1985) observed that fin nipping in juvenile steelhead trout was primarily directed at the dorsal fin. Kindschi et al. (1991a) noted that steelhead trout held in isolation had excellent fins, indicating that fin erosion was a result of aggressive interaction, stress, or some water quality factor correlated with low density. Nutrition was clearly not involved in this particular case although it can influence fin erosion (Halver 1954; Ketola 1983; Lemm et al. 1988; Kindschi et al. 1991b).

In the wild populations, species differences in relative fin length were slight, but statistically significant in most cases. Fins of rainbow and brown trout were most similar, but most fins of cutthroat were usually slightly shorter. Our results for hatchery fish showed that all trout species (including brook trout) were susceptible to fin erosion, although no species showed greater susceptibility. Fin erosion has not been previously quantified in either brook, brown, or cutthroat trout. However, there were significant interspecific differences for fin susceptibility to erosion. For example, rainbow trout generally had greater erosion of the dorsal fin than cutthroat trout, but the reverse was true for pectoral fins. This result may be related to differences in aggressive behavior that have been noted for these two species (Nilsson and Northcote 1981).

There were significant differences in fin erosion among different strains of rainbow trout. The FD strain generally had the most severe fin erosion. Statements regarding strain differences are tempered by the possibility that there are genetically based differences in fin lengths that could affect the interpretation of strain comparisons. For example, research on intraspecific morphological variation has documented local adaptation in fin size for both chum (*O. keta*) and pink salmon (*O. gorbuscha*) (see review by Taylor 1991). Whether significant intraspecific variation occurs in the fin size of trout has not yet been established.

Under current hatchery practices (generally following those outlined in Piper et al. 1989 and Brannon 1991), the problem of fin erosion in trout from Utah hatcheries still appears to be widespread. Furthermore, the problem is not confined to dorsal fins, but significantly affects all rayed fins. Such findings demonstrate the need for continued research into reducing hatchery-induced fin erosion. The present study demonstrates that relative fin length can be used to accurately quantify the degree of fin erosion in hatchery and wild trout. This method represents a viable parametric alternative to the use of subjective categorical "fin scores, fin grades, or fin index" (Soderberg and Meade 1987; Lemm et al. 1988; Mork et al. 1989; Goede and Barton 1990). Statistical "power" is always decreased with categorical statistical tests (Zar 1974), so relative fin length may represent a more powerful tool for assessing fin erosion damage in hatchery trout.

Acknowledgments

We thank John Wullschleger for leading the electrofishing crews and all of the Utah fish hatchery staff for their assistance. We also thank Bruce Schmidt, Joe Valentine, Russ Lee, Christopher Wilson, and Ron Goede for their review of the manuscript. Research was supported by the Federal Aid in Sport Fish Restoration Program, project No. F-35-R, and the Utah Division of Wildlife Resources.

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