Recapture and growth rates of three Colorado River endangered fish species: a comparison between electrofishing and non-electrofishing gear

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Key Words: Carlin tag, Colorado pikeminnow, electrofishing injury, endangered species, fish, Floy tag, growth rate, humpback chub, PIT tag, razorback sucker, recapture rate, Upper Colorado River Basin.

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EXECUTIVE SUMMARY

Colorado pikeminnow, *Ptychocheilus lucius*, humpback chub, *Gila cypha*, and razorback sucker, *Xyrauchen texanus,* are endangered fishes that reside in the Upper Colorado River Basin and are often captured by electrofishing for research or management purposes. Because of increased evidence of electrofishing injuries in fish and concerns about potential negative effects on populations there have been recommendations to curtail its use on endangered fishes. The objective of this study was to determine if the effects of electrofishing on these three species were similar to the effects of other sampling gears. Two hypotheses tested whether 1) recapture rates or 2) growth rates were similar for electrofishing and non-electrofishing gear types.

A database of endangered fish captures and recaptures between 1975 and 2000 was compiled and used for all analyses. Recapture rate was calculated for fish that were recaptured at least once. For all three species, recapture rates of fish initially captured by electrofishing were similar to recapture rates of fish initially captured by non-electrofishing gears. Differences in recapture rate, based on gear type, ranged from 1.2% to 2.7% and except for Colorado pikeminnow the rates were not statistically different. Although recapture rates for Colorado pikeminnow were statistically different (P=0.04), the difference in rates was small (2.4%) and determined not biologically meaningful. Mean monthly growth rate was calculated for fish for the first and second growing season between initial capture and first recapture. Growth rates for each of the three species were similar for fish initially captured by electrofishing or non-electrofishing gears and not statistically different. These results indicate that

effects of electrofishing on these species were similar to those of non-electrofishing gears and that electrofishing was no more harmful than other gears.

INTRODUCTION

Electrofishing has been used extensively to sample fishes in the Upper Colorado River Basin and its use has increased to monitor population status and trends of endangered fishes in the basin (Osmundson and Burnham 1998; McAda 2002). Although a practical and effective technique, electrofishing has received increased scrutiny because of documented lethal or sub-lethal effects to individual fish (Sharber and Carothers 1988; Dalbey et al. 1996). Snyder (1992, 1995) reviewed studies that exposed injuries to individual fish and along with Nielsen (1998) recommended that its use be curtailed or severely limited with endangered species. Electrofishing is usually selected over other sampling gears in the Colorado River Basin because it is more effective in fast, turbid waters. Schill and Beland (1995) argued that electrofishing is no more harmful than other sampling gears and the most important implication is whether electrofishing has population-level effects. Effective sampling is essential for obtaining adequate data for research or to determine population status and all gear types have the potential to cause injury, harm, or death to an individual animal. However, it is critical that a sampling gear not cause population-level effects, especially with rare species.

This study examined capture-recapture data for three endangered fish species from the Upper Colorado River Basin with the objective of determining if the effects of electrofishing were similar to the effects of non-electrofishing sampling gears. All sampling gears were assumed to have some negative effects on the captured animal. The critical issue was whether electrofishing had greater negative effects on the animal than other non-electrofishing sampling gears. Effects were measured at both individual and population levels. Population-level effects were measured with recapture rate that represented a relative index of fish survival for each sampling gear type based on the assumption that recapture rate would be lower if a particular sampling gear caused higher post-sampling mortality. The hypothesis was that recapture rates of each species were similar for the two gear types (electrofishing or non-electrofishing). Individual-level effects were measured by examining growth rate, an important indicator of fish health. It was assumed that nonlethal, negative effects of a sampling gear would reduce fish growth. I compared growth of fish captured by electrofishing to growth of fish captured by non-electrofishing gears to test the hypothesis that growth rates were similar for the two gear types.

METHODS

Endangered fish capture data were obtained from the data repository at the U.S. Fish and Wildlife Service (USFWS),Grand Junction, Colorado field station, agency reports, and individual researchers to create a working database of capture events in the Upper Colorado River Basin. The database contained unique records for each capture event of a tagged fish. Each uniquely-tagged fish had at least one record for the initial capture and tagging event and if a fish was recaptured there was a record for each subsequent recapture. Fields were examined for obvious errors and corrected when possible using original data sources, otherwise erroneous or irreconcilable data were removed from analyses. Fish that died at capture or were moved to a hatchery were excluded from analyses.

Three tag types were used to mark endangered fishes in the Upper Colorado River Basin and all types were included in the analyses. Between 1975 and 1978, endangered fish were tagged with Floy spaghetti tags and from 1978 to 1989, fish were tagged with Carlin dangler tags attached by monofilament through the dorsal musculature under the dorsal fin. Due to concerns with tag loss and infection. Carlin tags were discontinued in 1989 and few fish were tagged between 1989 and 1990 (Bates et al. 1993; Burdick and Hamman 1993). After 1990, fish were tagged with PIT (Passive Integrated Transponder) tags injected into the body cavity with a hypodermic needle.

All analyses were based on a comparison of fish initially captured by either electrofishing or non-electrofishing gear types. Electrofishing gear consisted primarily of boat-mounted, Coffelt VVP-15 or Smith-Root CPS electrofishers that produced pulsed-DC currents. Non-electrofishing gears were pooled and included trammel, gill, hoop, trap, and fyke nets and angling. Captures from seines, block and shock, undocumented, or unknown gear types were not included in the analysis. The capture technique known as “block and shock” used both net and electrofishing gears concurrently and was excluded because it was not possible to distinguish which gear actually captured the fish. Seine captures were excluded because seines targeted smaller fish that were not equally susceptible to electrofishing.

Rate of recapture was defined as the proportion of fish initially captured by either electrofishing or non-electrofishing gears that were recaptured at least once. Based on the assumption that potential acute mortality attributable to the sampling gear would occur within 30 days post capture, only fish recaptured after 30 days were included in the analysis. A chi-square test was used to detect statistical differences in recapture rates. Biological significance was based on the magnitude of differences in rates of recapture.

Growth was measured for the interval between initial capture and first recapture and growth rate was calculated for each fish by the equation:

(length at recapture – length at initial capture) / (recapture interval / 30).

Length was measured as total length (mm). Recapture interval was a count of days from initial capture to recapture but only included days between 1 April and 30 September when most growth typically occurs (Hawkins 1992). Each growth season consisted of this 6-months period. Any part of the interval that a fish spent outside of the growth season (1 October to 31 March) was not counted in the recapture interval to reduce the influence of non-growth periods on growth rate. Growth rate was standardized as a monthly (30 days) interval and was examined separately for the first and second growing seasons after initial capture. The first season included recaptures 1–5 months (31–182 days) after initial capture and the second season included recaptures 6–12 months (182–364 days) after initial capture. A minimum of 31 days was used because measurable differences in growth may not be detectable in a shorter interval and to minimize compounding effects of minor measurement errors (Manire and Gruber 1991).

Analysis of covariance (ANCOVA) was used to detect statistical differences between the two gear types in growth rate for each species and growing season. Growth rate increment was the dependent variable and *log_{10} total length* was the covariate. *Log_{10} total length* was used because residual plots revealed a better fit of the data than with non-transformed total length. The ANCOVA terms for interaction of *(log_{10} total length X gear)* and *gear* were tested for homogeneity of regression-line slopes and intercepts, respectively. A non-significant interaction term in the first ANCOVA indicated that the regression lines of growth rate as a function of *log_{10} total length* for each gear type (regression slopes) were parallel. If slopes were parallel, then least-squares means of growth rate (population marginal means; Searle et al. 1980) were calculated for each group of fish captured by the two gear types after accounting for the covariate (*log_{10} total length*) as recommended by Trippel and Hubert (1990) and differences in intercepts were tested by the second ANCOVA. A significant difference between intercepts in the second ANCOVA indicated that growth rate differed depending on gear at initial capture. If the first ANCOVA detected non-parallel slopes, then mean growth rates were calculated without adjusting for initial fish length and a *t*-test was used to detect statistical differences in means. The ANCOVA and *t*-test were conducted with SAS statistical software (SAS Institute 1988). Biological significance of each group was based on differences between the means and confidence intervals around those means.

RESULTS

The database contained 14,714 records for the period 1975 to 2000. These included captures of Colorado pikeminnow (*Ptychocheilus lucius*, N=8,254), humpback chub (*Gila cypha*, N=3,723), and razorback sucker (*Xyrauchen texanus*, N=2,737) and represented 11,463 individual fish and 3,251 recaptures (Table 1). Recapture records represented fish that were recaptured one to 11 times during the period of record. Razorback sucker records included 12 putative razorback sucker X flannelmouth sucker (*Catostomus latipinnis*) hybrids and humpback chub records included 676 putative humpback chub X roundtail chub (*G. robusta*) hybrids. A smaller subset of these records was used for each analysis because records were excluded based on previously defined filters or due to incomplete data (e.g. records with fish length not recorded).

For all species, recapture rates of fish initially captured by electrofishing displayed minimal differences compared to recapture rates of fish captured by non-electrofishing gears (Table 2). Humpback chub and Colorado pikeminnow caught by electrofishing were recaptured at a rate slightly less than recapture rates of the same species caught by non-electrofishing gears. Recapture rate of razorback sucker showed an opposite trend and was slightly higher for fish initially captured by electrofishing. The differences in recapture rates for the two gear types were minimal for all three species and ranged 1.2% to 2.7%, although for Colorado pikeminnow the difference (2.4%) was statistically different at the 95% significance level (P=0.04). Of the three species, humpback chub had the lowest recapture rates.

Mean growth rates were similar for each of the three species and treatments regardless of initial sampling gear type (Table 3). Mean growth rates of Colorado pikeminnow and humpback chub after capture by electrofishing were sightly higher (differences ranged 0.02–1.28 mm/month) than growth rate after capture by non-electrofishing gears. The ANCOVA analysis did not detect significant differences in growth rates of Colorado pikeminnow in the first or second growing seasons after initial capture (Tables 3, 4, and 5; Figure 1). For humpback chub recaptured during the first growing season, ANCOVA analysis revealed that regression-line slopes were significantly different (P=0.05), thus precluding the second ANCOVA test for detecting different growth rates (Tables 5 and 6; Figure 2); however, simple-mean growth rates were similar between gear types (Table 3) and not statistically different. For humpback chub recaptured within the second growth season, ANCOVA analyses detected no difference in growth rates between gear types (Tables 5 and 6; Figure 2).

Mean growth rates of razorback sucker were also similar for each treatment regardless of sampling gear type at initial capture. Differences in growth rate ranged from 0.03–2.1 mm/month for razorback sucker and although growth rate was slightly less for electrofishing caught fish, the difference was small and not statistically significant. Razorback sucker recaptured within the first growth season after initial capture were not analyzed by ANCOVA because most fish comprised two distinct size groups with little overlap in length (Figure 3). To adjust for size differences, mean growth rate was calculated separately for small fish ($\leq$ 400-mm total length) and large fish (>400-mm total length) and mean growth rates of razorback sucker in each length group were similar and not significantly different (Table 3). Growth rates of razorback sucker captured in the second growing season overall were low and similar between gear types (Tables 3, 5 and 7; Figure 3).

DISCUSSION

If a sampling gear caused higher mortality compared to another gear, then the expectation would be lower recapture rates of fish captured by the former gear due to the increased mortality. For all three species, recapture rates of fish initially captured by electrofishing were similar to rates of fish captured by non-electrofishing gears and did not suggest substantially higher mortality due to gear type. Although the recapture rate of Colorado pikeminnow initially captured with electrofishing was lower and statistically different (P=0.04) than the recapture rate of Colorado pikeminnow captured by non-electrofishing gears, the difference was small (2.4%) and statistical significance was likely due to the extremely large sample size providing high statistical power to detect small differences. The biological significance of this small difference is likely minimal. In contrast, razorback sucker initially caught by electrofishing were recaptured at a higher rate than those caught by non-electrofishing gears; however, the difference was also relatively small (2.7%) and not statistically different.

Generally, these results agree with those of Schneider (1992) who found that after 1–2 years, survival of largemouth bass (*Micropterus salmoides*) and walleye (*Stizostedion vitreum*) was similar among gear types (electrofishing, trapping, and angling). These results also agree with results of Dalbey et al. (1996) who found that neither electrofishing gear type nor injury severity affected long-term (335 day) survival of rainbow trout (*Oncorhynchus mykiss*).

If electrofishing had nonlethal negative effects on individual fish that were greater than non-electrofishing gears, the expectation would be lower growth rates for fish initially captured by electrofishing. This study showed that growth of Colorado pikeminnow, humpback chub, and razorback sucker captured by electrofishing was similar to growth of the same species caught by non-electrofishing gears during both the first and second growing seasons after initial capture. Also, none of the treatments were statistically different. These results agree with those of Schneider (1992) who found no growth differences in largemouth bass and walleye 1–2 years after capture with 230-V AC currents compared to fish captured by trap nets or angling. In other studies, growth rates were lower for fish severely injured by electrofishing compared to those with no or minor injuries (Dalbey et al.1996; Gatz, et al. 1986), but in this study it was unknown whether any fish had severe injuries caused by sampling gear.

Overall, there was no compelling data to suggest differences in recapture or growth rates due to the sampling gear, suggesting that electrofishing and non-electrofishing gear types have similar effects on these species. The use of each gear should continue when appropriate and used carefully for the collection of endangered fishes in the Upper Colorado River Basin.

CONCLUSIONS

- Recapture rates of humpback chub and Colorado pikeminnow initially captured by electrofishing were similar to rates of fish initially captured by non-electrofishing gears.

- Growth rates of Colorado pikeminnow, humpback chub, and razorback sucker were similar for fish initially captured by electrofishing or non-electrofishing gears.

RECOMMENDATIONS

- Continue to use electrofishing when required and appropriate for endangered fish sampling.
- Ensure electrofishing equipment is configured and operating properly.
- Establish standard protocols and provide frequent training of field crews in netting, electrofishing, and fish handling techniques that reduce stress and injury to fish.
- Follow tagging and data reporting protocols to ensure accurate and reliable data.

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Table 1—Number of capture records for endangered fishes in the Upper Colorado River Basin, 1975–2000.

Species	Years represented	Number of records	Number of individual fish	Number of recapture records [a]
Colorado pikeminnow	1978–2000	8,254	6,175	2,079
humpback chub [b]	1979–1999	3,723	3,118	605
razorback sucker [c]	1975–2000	2,737	2,170	567

[a] Includes fish recaptured multiple times.
[b] Includes putative humpback chub X roundtail chub hybrids.
[c] Includes putative razorback sucker X flannelmouth sucker hybrids.

Table 2— Rate of recapture of Upper Colorado River Basin endangered fishes after initial capture by electrofishing or non-electrofishing gears. X^2 denotes the chi-square statistic for recapture rates of the two sampling gears and P denotes the significance of the test that the recapture rates are similar between sampling gears.

Sampling gear at initial capture	Number of fish tagged	Number of fish recaptured	Recapture rate (%)	X^2	P
		Colorado pikeminnow			
electrofishing	3,448	617	17.9	4.086	0.04
non-electrofishing	1,526	310	20.3		
		humpback chub			
electrofishing	1,972	115	5.8	1.051	0.31
non-electrofishing	526	37	7.0		
		razorback sucker			
electrofishing	489	113	23.1	0.379	0.54
non-electrofishing	108	22	20.4		

Table 3—Mean growth rate of three Colorado River endangered fishes during first and second growing seasons after initial capture by electrofishing or non-electrofishing gears. Means were either least-squares means adjusted for initial fish length or simple means not adjusted for fish length (denoted by asterisk). *SE* denotes standard error about the mean and *P* denotes the significance of the test that means are similar between sampling gears. During the first growing season after initial capture, razorback sucker lengths by gear were mostly non-overlapping, so means were calculated for fish in two size groups: small (≤400 mm total length) and large (>400 mm total length).

Interval after initial capture	Sampling gear at initial capture	No. of fish	growth/month (mm)	*SE*	*P*
	Colorado pikeminnow				
1st growth season	Electrofishing	175	3.34	0.31	0.21
	Non-electrofishing	122	2.74	0.37	
2nd growth season	Electrofishing	169	3.84	0.20	0.97
	Non-electrofishing	91	3.82	0.27	
	Humpback chub				
1st growth season	Electrofishing	12	2.01 *	0.82	0.17
	Non-electrofishing	46	0.73 *	0.36	
2nd growth season	Electrofishing	6	1.23	0.14	0.39
	Non-electrofishing	32	0.92	0.32	
	Razorback sucker				
1st growth season (small-fish)	Electrofishing	3	14.89 *	0.94	0.63
	Non-electrofishing	47	16.99 *	3.63	
1st growth season (large-fish)	Electrofishing	26	0.43 *	0.33	0.11
	Non-electrofishing	6	1.68 *	0.62	
2nd growth season	Electrofishing	35	0.28	0.11	0.93
	Non-electrofishing	8	0.31	0.23	

Table 4—Analysis of covariance for growth rate (mm/month) as a function of $\log_{10}$ total length (mm) of Colorado pikeminnow during first and second growing seasons after initial capture. Probability values for the intercept tests are differences in means between groups (gear) designated by the indicator variable (first or second growing season) after adjustments were made for the covariate ($\log_{10}$ total length). The interaction term tests whether slopes were equal between groups (gear).

Effect	df	Sum of squares	*F*	*P*	R^2
1st growing season after initial capture					
Slope test					
$\log_{10}$ Length	1	1,290.82	78.39	<0.0001	0.25
Gear	1	0.005	0.00	0.99	
$\log_{10}$ Length X Gear	1	0.003	0.00	0.99	
Intercept test					
$\log_{10}$ Length	1	1,496.79	91.21	<0.0001	0.25
Gear	1	25.59	1.56	0.21	
2nd growing season after initial capture					
Slope test					
$\log_{10}$ Length	1	1,486.11	232.99	<0.0001	0.53
Gear	1	18.19	2.85	0.09	
$\log_{10}$ Length X Gear	1	18.18	2.85	0.09	
Intercept test					
$\log_{10}$ Length	1	1,836.62	285.88	<0.0001	0.53
Gear	1	0.01	0.00	0.97	

Table 5—Least-squares statistics for regression of growth rate (G, mm/month) as a function of $\log_{10}$ total length (TL, mm) of three Colorado River endangered fishes during first and second growing seasons after initial capture. Regressions are $G = a + b \cdot \log_{10} TL$. Razorback sucker data from the first growing season were not appropriate for ANCOVA analysis because total-length ranges by gear were mostly non-overlapping.

Treatment					
Recapture interval	Sampling gear at initial capture	df	Intercept (SE) a	Slope (SE) b	r^2
Colorado pikeminnow					
1st growing season	electrofishing	174	86.42 (11.13)	-30.45 (4.09)	0.24
	non-electrofishing	121	86.08 (14.20)	-30.55 (5.19)	0.22
2nd growing season	electrofishing	168	85.77 (5.76)	-30.27 (2.13)	0.55
	non-electrofishing	90	69.41 (7.17)	-24.44 (2.64)	0.49
humpback chub					
1st growing season	electrofishing	11	62.22 (15.60)	-24.18 (6.26)	0.60
	non-electrofishing	45	15.12 (12.98)	-5.86 (5.28)	0.03
2nd growing season	electrofishing	5	15.60 (6.67)	-6.03 (2.75)	0.55
	non-electrofishing	31	21.72 (5.89)	-8.42 (2.42)	0.29
razorback sucker					
2nd growing season	electrofishing	34	39.84 (12.23)	-14.56 (4.51)	0.24
	non-electrofishing	7	47.84 (24.17)	-17.50 (8.87)	0.39

Table 6—Analysis of covariance for growth rate (mm/month) as a function of $\log_{10}$ total length (mm) of humpback chub during first and second growing seasons after initial capture. Probability values for the intercept tests are differences in means between groups (gear) designated by the indicator variable (first or second growing season) after adjustments were made for the covariate ($\log_{10}$ total length). The interaction term tests whether slopes were equal between groups (gear).

Effect	df	Sum of squares	*F*	*P*	R^2
1st growing season after initial capture					
Slope test					
$\log_{10}$ Length	1	57.92	10.36	0.002	0.20
Gear	1	23.13	4.14	0.05	
$\log_{10}$ Length X Gear	1	21.53	3.85	0.05	
2nd growing season after initial capture					
Slope test					
$\log_{10}$ Length	1	5.30	8.20	0.007	0.31
Gear	1	0.16	0.25	0.62	
$\log_{10}$ Length X Gear	1	0.15	0.22	0.64	
Intercept test					
$\log_{10}$ Length	1	9.50	15.03	0.0004	0.31
Gear	1	0.47	0.75	0.39	

Table 7—Analysis of covariance for growth rate (mm/month) as a function of $\log_{10}$ total length (mm) of razorback sucker during first and second growing seasons after initial capture. Probability values for the intercept tests are differences in means between groups (gear) designated by the indicator variable (second growing season) after adjustments were made for the covariate ($\log_{10}$ total length). The interaction term tests whether slopes were equal between groups (gear).

Effect	df	Sum of squares	*F*	*P*	R^2
2nd growing season after initial capture					
Slope test					
$\log_{10}$ Length	1	6.35	14.91	0.0004	0.29
Gear	1	0.05	0.13	0.73	
$\log_{10}$ Length X Gear	1	0.05	0.12	0.73	
Intercept test					
$\log_{10}$ Length	1	6.67	16.01	0.0003	0.29
Gear	1	0.003	0.01	0.93	

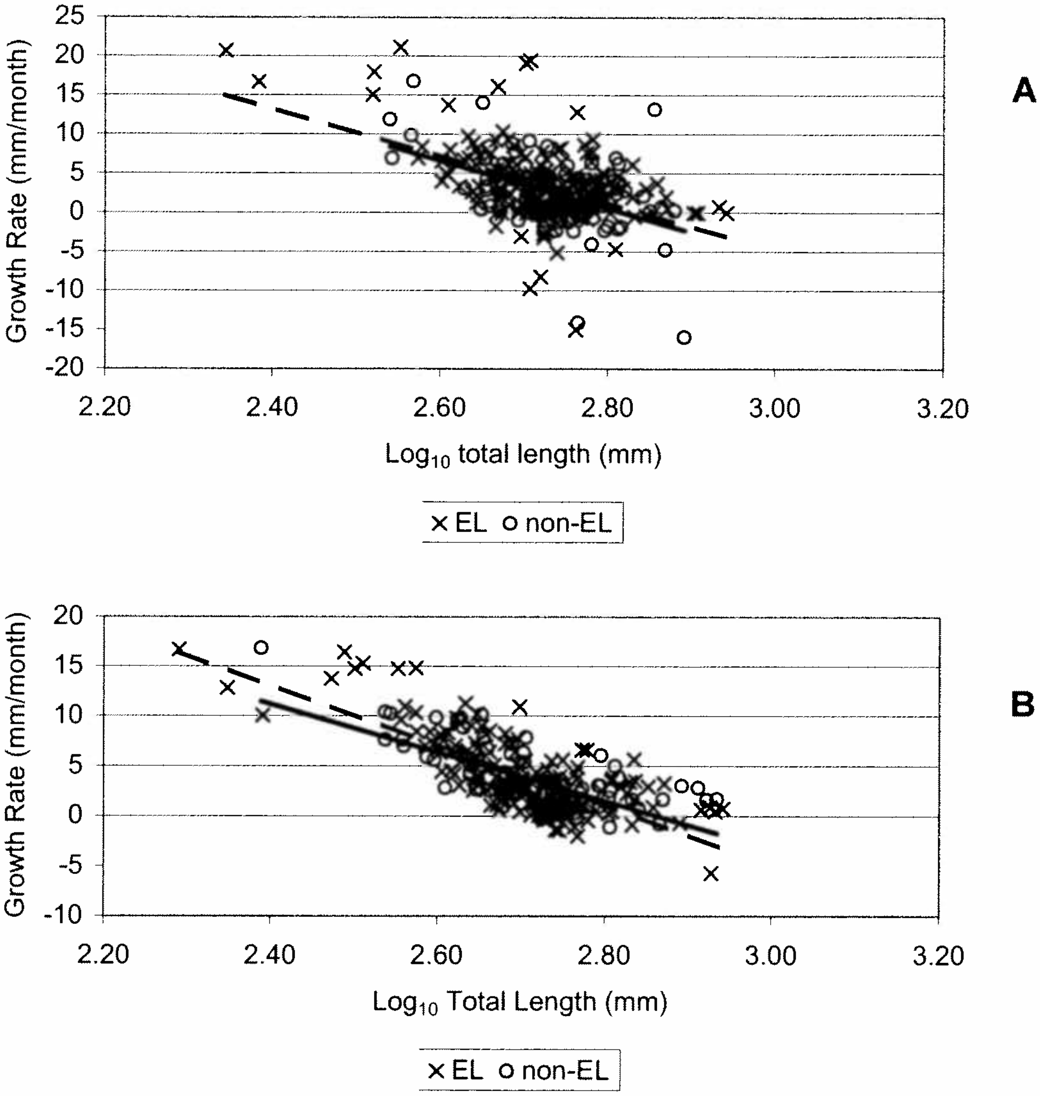
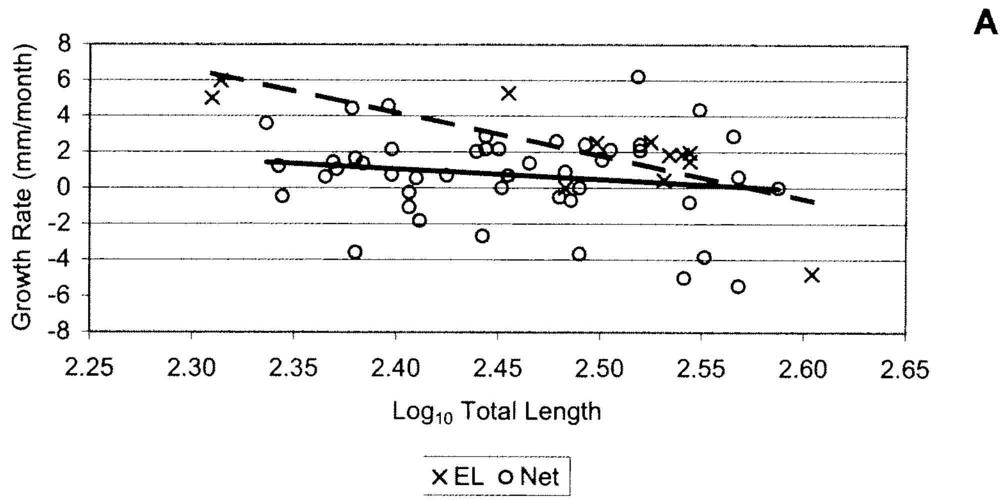


Figure 1—Regresssion of growth rate (mm/month) as a function of $\log_{10}$ total length (mm) for Colorado pikeminnow recaptured during first (A) or second (B) growing seasons after initial capture by electrofishing (dashed line) or non-electrofishing (solid line) gears. See Table 5 for regression equations.



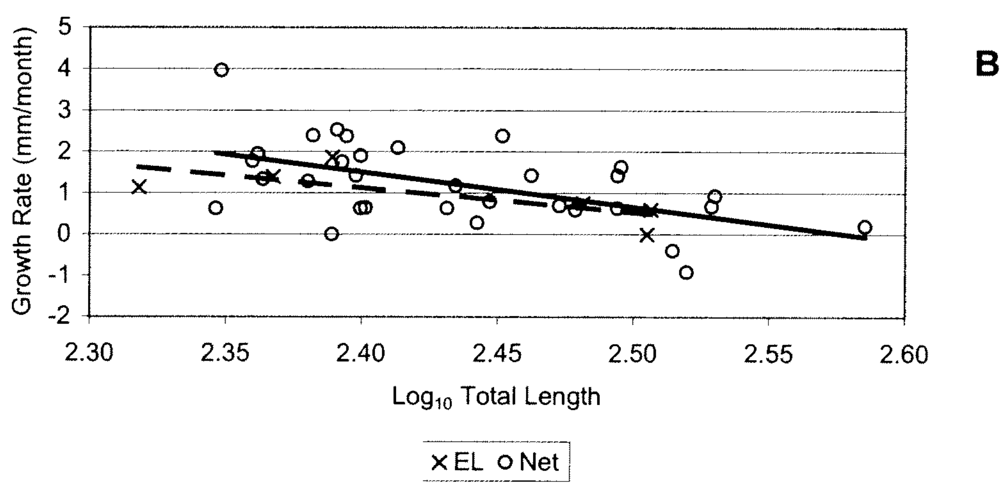


Figure 2—Regresssion of growth rate (mm/month) as a function of $\log_{10}$ total length (mm) for humpback chub recaptured during first (A) or second (B) growing seasons after initial capture by electrofishing (dashed line) or non-electrofishing (solid line) gears. See Table 5 for regression equations.

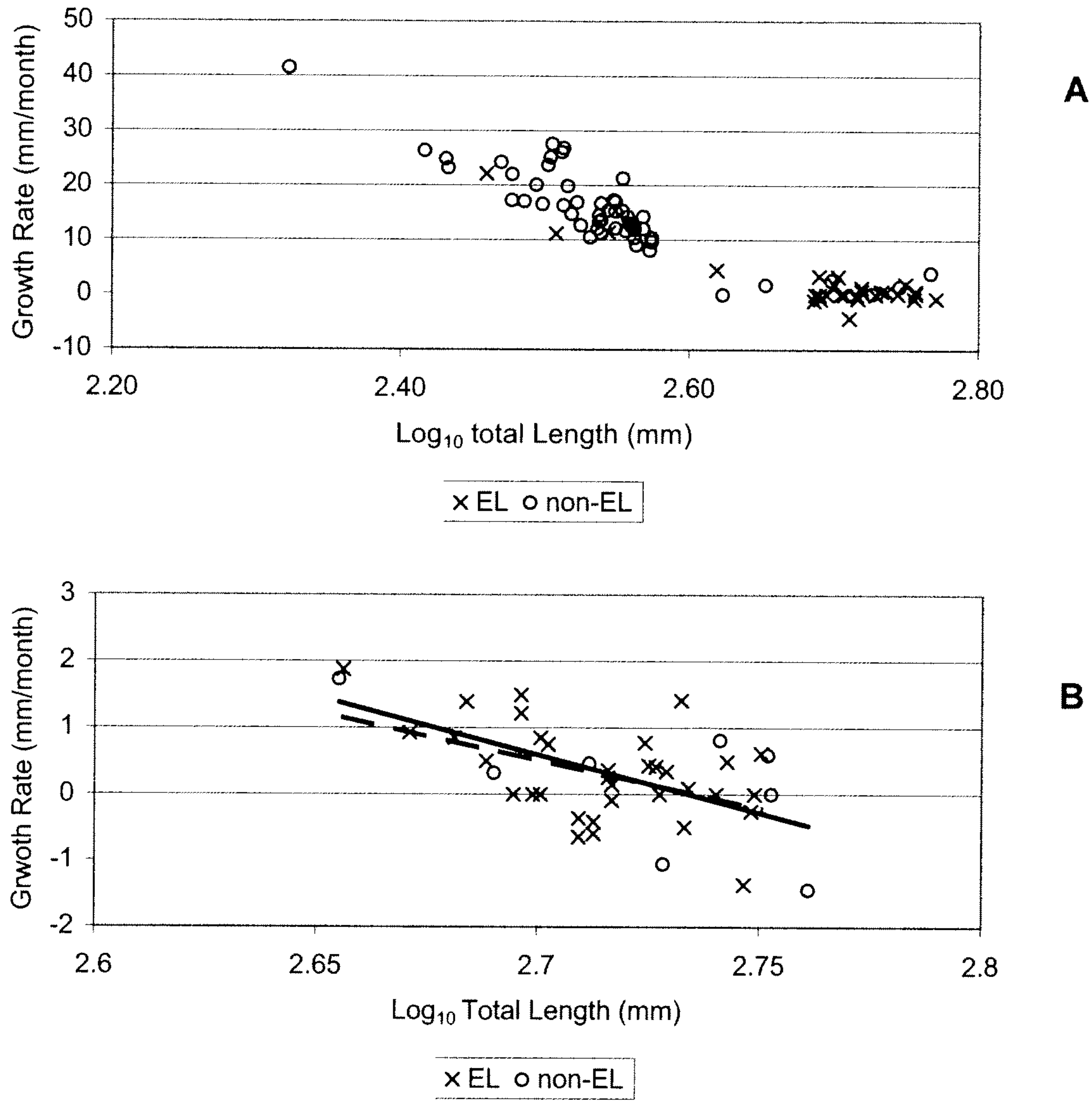


Figure 3—Regresssion of growth rate (mm/month) as a function of $\log_{10}$ total length (mm) for razorback sucker recaptured during first (A) or second (B) growing seasons after initial capture by electrofishing (dashed line) or non-electrofishing (solid line) gears. See Table 5 for regression equations.