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RESULTS

- Flannelmouth sucker (*Catostomus latipinnis*) were collected in the Lee's Ferry reach by electrofishing in conjunction with rainbow trout (*Oncorhynchus mykiss*) monitoring from 1992 - 1997.

YEAR	Catch per Hour
1992	2.2
1993	0.7
1994	1.3
1995	3.2
1996	0.8
1997	1.1

- 212 flannelmouth were collected, including 52 previously tagged by others.
 - Recapture information was identified for 17 fish:
 - 6/17 were tagged in or near the Little Colorado River
 - 9/17 were tagged in the Paria River or it's confluence
 - 1/17 was tagged near Kanab Creek
 - 1/17 was tagged in the Lee's Ferry reach in 1992 and recaptured in 1995
- Most fish were collected within 4.8 km of Glen Canyon Dam.
- Size of fish ranged from 404 – 646 mm total length.

CONCLUSIONS

- Adult flannelmouth sucker are tolerant of cold tailwater habitats.
- Flannelmouth sucker comprise a mobile aggregation of presumed sexually mature fish.
- Relatively stable catch per unit effort among years suggests relatively stable densities of flannelmouth sucker in the Lee's Ferry reach.
- No evidence of an aging population.
- Capture of fish tagged initially as subadults suggests that recruitment to reproductive maturity occurred.

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ECOLOGY OF FLANNELMOUTH SUCKER IN THE LEE'S FERRY TAILWATER, COLORADO RIVER, ARIZONA

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ABSTRACT.—We investigated ecology of flannelmouth sucker (*Catostomus latipinnis*) from 1992 to 1997 in the 26-km Lee's Ferry reach of the Colorado River immediately below Glen Canyon Dam, Arizona. We captured by electrofishing a total of 212 fish and recaptured 52 previously tagged by others. Flannelmouth sucker were captured throughout the tailwater but tended to aggregate within about 5 km of the dam, possibly reflecting blockage of historic migration routes. Catch per hour of electrofishing did not differ among years but was greater from November to February than other periods, suggesting seasonal movements of flannelmouth sucker into the tailwater. Mean lengths and weights of fish did not differ among years or seasons. Length frequency analyses also indicate there were no significant yearly trends in proportion of catch within size classes of fish. Mean condition differed only among seasons and was greatest in February, lowest in August, coinciding respectively with pre- and post-spawning periods of flannelmouth sucker in a tributary just downstream from Lee's Ferry. Recaptured fish migrated from initial tagging locations 1.4–231 km downstream from Lee's Ferry. Fifty-nine percent of recaptured fish with known initial tagging locations increased in length, and fish tagged initially as subadults or adults, respectively, grew an average of 45.9 mm and 5.5 mm per year.

Key words: flannelmouth sucker, movement, distribution, life history, native fish, regulated river, Colorado River.

Native fishes in the Colorado River below Glen Canyon Dam (GCD), Arizona, declined in abundance following emplacement of the hydroelectric facility in 1963 (Minckley 1991). Flannelmouth sucker (*Catostomus latipinnis*) is one of the long-lived native species (Scopetone 1988) endemic to the Colorado River drainage and persists in Glen and Grand canyons and much of the upper Colorado River basin (Minckley 1991). Flannelmouth sucker aggregate in tributaries and associated inflow areas of Glen and Grand canyons (Robinson et al. 1996, Douglas and Marsh 1998, Weiss et al. 1998) and historically were abundant within the Glen Canyon tailwater and downstream (Holden and Stalnaker 1975). Weiss et al. (1998) suggested that an increase in mean lengths of flannelmouth sucker spawning in the Paria River between 1981 and 1993 indicated an aging population with relatively low recruitment to sexual maturity. Although categorized as a species of concern by the U.S. Fish and Wildlife Service (1994), little is known about ecology of flannelmouth sucker (McAda and Wydoski 1985, Douglas and Marsh 1998, Weiss et al. 1998). The species spawns in spring (Douglas and Marsh 1998, Weiss et al. 1998) and migrates long distances (Chart and Bergersen

1992), but temporal distribution and movements are poorly understood. In this study we examined distribution, movements, structural indices, and trends of flannelmouth sucker in the Glen Canyon tailwater (Lee's Ferry reach) during long-term monitoring.

STUDY SITE

Glen Canyon Dam impounds the Colorado River near the Arizona-Utah border and forms Lake Powell, a 653-km² meromictic reservoir. Lee's Ferry reach is confined within Glen Canyon between the dam (river kilometer [RK] –26) and Lee's Ferry (RK 0). Hypolimnetic releases from the reservoir are clear and cold (Stanford and Ward 1991, Shannon et al. 1996, Stevens et al. 1997). More stable operating regimes for GCD were initiated in 1991, following decades of widely variable releases from the dam (Marzolf 1991, Patten 1991). Releases from GCD during the present study generally ranged between about 142 m³s⁻¹ and 708 m³s⁻¹, with daily variations not exceeding ca 227 m³s⁻¹. Other fishes in the Lee's Ferry reach are nonnative rainbow trout (*Oncorhynchus mykiss*) and common carp (*Cyprinus carpio*).

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TABLE 1. Catch per hour (CPUE) of electrofishing (EF) and numbers of recaptures (*N*) for flannelmouth sucker in the 26-km Lee's Ferry reach, Colorado River, 1992–1997.

Year	No. trips	Total EF (hr)	Total catch	CPUE	Recapture (<i>N</i>)
1992	4	33.3	72	2.2	2
1993	2	16.7	11	0.7	0
1994	3	25.0	33	1.3	4
1995	2	16.7	53	3.2	9
1996	4	33.3	26	0.8	5
1997	3	15.0	17	1.1	5

MATERIALS AND METHODS

We electrofished 9–15 fixed transects (ca 2000 sec/transect) randomly placed throughout Lee's Ferry reach between dusk and dawn during 19 trips between February 1992 and December 1997. We electrofished 2–4 times per year (Table 1) and collected samples in all months except January, June, and October (Table 2). We captured flannelmouth sucker using single-pass electrofishing (EF) from an aluminum boat equipped with a Coffelt CPS Mark XX electrofishing unit (Coffelt Manufacturing, Flagstaff, AZ). We employed a complex pulsed system of direct current, applying 215 volts and maintaining a 15-ampere output to a 30-cm-diameter stainless steel anode system (Sharber et al. 1994). We examined fish for previous marks, measured to the nearest millimeter (total body length [TL]), weighed to the nearest gram, injected with a passive integrated transponder (PIT) tag (if none present), and released all fish near capture points. Catch-per-unit-effort (CPUE), computed as the number of fish caught per hour of EF with electrical current in the water, was considered an index of population abundance.

We compared log-transformed weight/length relationships between sexes using a 2-sided *t* test. Mean condition factor ($K = W^5/L^3$), TL and weight among months and years, and seasonal groupings of catch/transect/trip were compared using the Kruskal-Wallis test. Spearman's Rank Order correlation coefficients were calculated to quantify relationships between recapture among months and years and CPUE and size structure among years. Statistical significance was determined at $\alpha = 0.05$ for all tests. We estimated growth rates of fish by subtracting lengths at initial capture from those at recapture and dividing by elapsed time (yr) between capture and recapture. We defined distance moved as displacement of

recaptured fish from locations where they were marked initially to last point of recapture. We assumed that adult and subadult flannelmouth sucker, respectively, were ≥ 390 mm and < 390 mm in length (McAda and Wydoski 1985).

RESULTS

We captured a total of 212 flannelmouth sucker (range 404–646 mm TL) during 19 trips between 1992 and 1997. No fish were captured in September 1993. The highest percentage of fish were 451–500 mm TL (Fig. 1). Most fish (54%; 114/212) also were captured within 4.8 km of Glen Canyon Dam, and 12% (25/212) were captured near a gravel bar at RK -6.6, most (11%; 24/212) during April or May. Mean lengths and weights did not differ significantly among years or months (Table 2). Catch-per-unit-effort ($N = 6$; mean = $0.9 \pm 0.2 s_{\bar{x}}$) varied widely among years (Table 1), and no significant year-to-year trend was evident (Spearman Rank Order correlation, $R = -0.14$). However, catch-per-unit-effort differed significantly ($P = 0.011$) among seasons and was greater from November to February ($N = 6$; mean = $1.4 \pm 0.2 s_{\bar{x}}$) than March to May ($N = 8$; mean = $0.6 \pm 0.2 s_{\bar{x}}$) or July to September ($N = 4$; mean = $0.6 \pm 0.3 s_{\bar{x}}$). Proportion of catch for individual length classes also did not differ among years (Spearman Rank Order correlations for fish 400–450 mm, 451–500 mm, 501–550 mm, 551–600 mm, and > 600 mm TL, respectively, were $R = -0.12$, $R = -0.09$, $R = 0.60$, $R = -0.66$, and $R = -0.07$).

Sex ratio (male:female) was 3.3, based on 52 fish for which gender was determined (manual expression of gametes). Range in length for reproductively mature males and females, respectively, was 421–518 mm and 464–646 mm. Both length and weight data were collected for 30 of these fish, and we found no difference ($P = 0.4412$) in log-transformed

TABLE 2. Mean ($\pm s_{\bar{x}}$) monthly total lengths (mm), weights (g), and condition factors (K) for flannelmouth sucker captured by electrofishing in the 26-km Lee's Ferry reach, Colorado River, 1992-1997. N = number of observations.

Month	Length			Weight			K		
	N	Mean	$s_{\bar{x}}$	N	Mean	$s_{\bar{x}}$	N	Mean	$s_{\bar{x}}$
Feb	19	495	7	19	1345	66	19	1.10	0.03
Mar	19	494	13	19	1253	83	19	1.03	0.04
Apr	11	508	10	11	1371	77	11	1.04	0.03
May	37	496	8	15	1512	140	15	1.08	0.02
Jul	4	496	11	4	1274	102	4	1.04	0.05
Aug	26	518	22	26	1227	58	25	0.97	0.02
Sept	2	468	4	2	1144	146	2	1.12	0.12
Nov	30	501	7	31	1363	54	30	1.09	0.02
Dec	61	503	5	61	1389	45	61	1.07	0.01
All years	209	502	4	188	1348	25	186	1.06	0.01

weight-length relationships between sexes. Weight-length relationships indicated that growth was approximately isometric ($\log W = -4.350 + 2.7665 \log TL$). Mean K, which also did not differ significantly among years, differed ($P < 0.05$) among months and was greatest in February (except for September, when only 2 fish were caught) and lowest in August (Table 2).

There were no multiple recaptures, and cumulative recapture of fish previously tagged was 12% (25/212). Proportion of recaptured fish did not vary significantly among years (Table 1; Spearman Rank Order correlation, $R = 0.60$) or months (Spearman Rank Order correlation, $R = 0.36$). Total length of recaptured fish was 420-582 mm. Seventeen fish were recaptured for which original tagging information is known (Table 3). Thirty-five percent (6/17) were tagged initially in or near the Little Colorado River (RK 98), and 53% (9/17) were tagged in the Paria River or its confluence with the mainstem Colorado River (RK 1.4). One recaptured fish was tagged initially near Kanab Creek (RK 231) and another in the Lee's Ferry reach at RK -22.9 in 1992; the latter was recaptured at the same location in 1995 (Table 3). Mean distance of capture from initial marking location for the 17 fish was $52 \pm 17 s_{\bar{x}}$ km (range 1.4-231 km). All fish tagged as subadults ($N = 3$) moved 98 km from tagging location to recapture site, and those tagged as adults moved between 1.4 km and 231 km ($N = 14$; mean $49 \pm 20 s_{\bar{x}}$; Table 3). Nearly 2/3 (64.7%; $N = 11$) of recaptured fish were caught in November-December (Table 3).

Fifty-nine percent (10/17) of recaptured fish for which location of initial tagging was known

grew in length, and 81% (13/16) increased in weight after initial tagging (Table 3). Thirty-five percent (6/17) of recaptured fish reflected negative growth, and 6% (1/17) showed no growth. Mean growth rate of fish that grew and were marked initially as adults was $5.5 \pm 1.9 s_{\bar{x}}$ mm/yr ($N = 14$; range 1.9-12.8 mm/yr), and mean growth rate for fish marked as subadults (189-365 mm TL) was $45.9 \pm 16.8 s_{\bar{x}}$ mm/yr ($N = 3$; range 25.7-79.3 mm/yr).

DISCUSSION

Our results support the conclusion (Chart and Bergersen 1992) that adult flannelmouth sucker are tolerant of cold tailrace habitats. We suggest that flannelmouth sucker in the Lee's Ferry reach comprised a mobile aggregation of fish of presumed sexual maturity (McAda and Wydoski 1985, Weiss et al. 1998). In our study CPUE differed among seasons and locations but not among years, suggesting generally stable densities of flannelmouth sucker in Lee's Ferry reach between 1992 and 1997. Douglas and Marsh (1998) also concluded that the flannelmouth sucker population in the Little Colorado River and its confluence with the Colorado River was stable during 1991-1995.

Our results agree with previous observations of long-distance movements by flannelmouth sucker (Chart and Bergersen 1992). Forty-one percent of our recaptures for which original tagging information was known were originally marked between 98 km and 231 km downriver from Lee's Ferry. Long-distance seasonal migrations may be integral to life history of flannelmouth sucker (Chart and Bergersen 1992) and

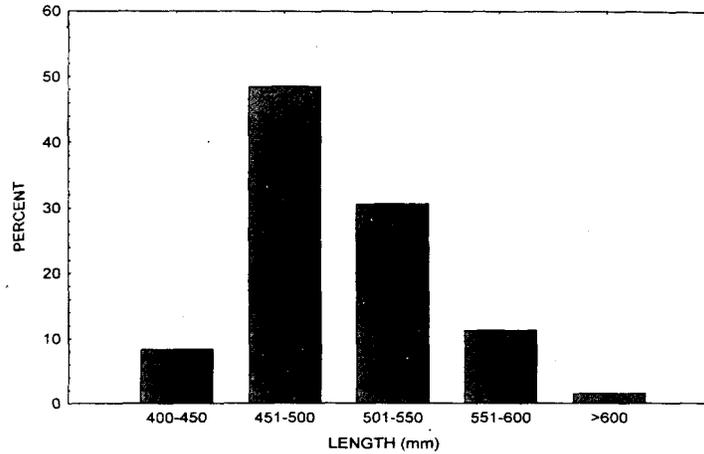


Fig. 1. Length-frequency distribution (percent of total catch by length classes; $N = 212$) of flannelmouth sucker captured by electrofishing in the 26-km Lee's Ferry reach, Colorado River, 1992-1997.

other large-bodied native fishes (Tyus and Karp 1990, Minckley 1991, Modde and Irving 1998). However, a portion of the population likely is sedentary, since 53% of recaptured fish for which original tagging information was known were marked initially in the Paria River or its confluence with the Colorado River (RK 1.4). The flannelmouth sucker population in the White River also was generally mobile, but some fish were sedentary (Chart and Bergersen 1992).

Flannelmouth sucker in our study were captured throughout Lee's Ferry reach from 1992 to 1997, but CPUE indicates they tended to aggregate near the dam and, prior to or during the spring spawning season (Weiss et al. 1998), near a mid-channel gravel bar in Lee's Ferry reach (RK -7). Flannelmouth sucker also aggregate just below Taylor Draw Dam on the White River (Chart and Bergersen 1992), and aggregation below dams may reflect blockage of historic migration routes used by native fishes (Holden 1991, Minckley 1991, Chart and Bergersen 1992). Movements (based on CPUE) of flannelmouth sucker into the Glen Canyon tailwater increased during late fall and winter and declined in spring and summer. Timing of seasonal increase in CPUE in Lee's Ferry reach corresponds with pre-spawning migration to the Paria River and its confluence with the Colorado River (Weiss et al. 1998) and is coincident with a seasonal decline in numbers in

the Little Colorado River and its confluence area (Douglas and Marsh 1998).

We captured 83% of ripe females and 93% of ripe males during February-May, prior to or during Paria River spawning (Weiss et al. 1998). We found a sex ratio (male:female) of 3:1 in Lee's Ferry reach, while Weiss et al. (1998) reported sex ratios of about 2:1 for spawning flannelmouth sucker in the Paria River and Bright Angel Creek and about 1:1 at Paria River confluence with the Colorado River. Forty-two percent of fish we captured were <490 mm, at which length McAda and Wydoski (1985) reported all flannelmouth sucker were reproductively mature. Flannelmouth sucker caught in Paria River spawning areas ranged from 385 mm to 580 mm (Weiss et al. 1998), and we found that reproductively mature fish ranged from 421 mm to 646 mm. Mean length of fish we captured equaled that of flannelmouth sucker caught in the mouth of the Paria River and was greater than mean length of fish captured on upstream spawning areas in the tributary (Weiss et al. 1998).

Average length of spawning flannelmouth sucker in the Paria River increased between 1981 and 1983, possibly indicating low recruitment to reproductive maturity and an aging population (Weiss et al. 1998). However, we found no evidence supporting the hypothesis of an aging population; mean lengths and weights and size structure of fish did not differ

TABLE 3. Date, location of initial tagging (RK = river km), total length (TL = mm), weight (W = g), and computed growth rates (CG = mm/yr) for flannelmouth sucker recaptured by electrofishing in the Lee's Ferry reach, Colorado River, 1992–1997. YAL = years between initial tagging and recapture.

Date	Initial Tagging			Date	Recapture				
	TL	W	RK		TL	W	RK	YAL	CG
2-12-86 ^a	516	1349	1.4	8-26-92	532	1263	-8.6	6.5	2.5
10-14-92 ^c	443	888	98	3-25-96	455	960	-3.0	3.4	3.5
10-16-92 ^c	365	462	98	12-7-94	420	856	-6.5	2.1	25.7
11-11-92 ^a	461	1093	-22.9	12-4-95	468	1136	-23.7	3.1	2.3
3-6-93 ^c	189	54	98	8-27-96	464	1024	-20.8	3.5	79.3
3-29-93 ^b	558	2000	1.4	12-6-95	565	2062	0	3.7	1.9
4-8-93 ^b	527	1400	1.4	5-14-95	524	—	-6.5	1.1	-2.7
4-22-93 ^a	404	677	231	12-6-97	499	1325	-17.5	7.4	12.8
4-8-93 ^b	543	870	1.4	12-7-94	525	1579	-8.6	1.7	-10.5
5-10-93 ^b	4854	1170	1.4	12-6-94	480	1145	-20.8	1.6	-3.1
5-10-93 ^b	508	1120	1.4	12-6-95	500	1236	0	1.6	-5.0
5-16-93 ^a	464	976	98	12-6-97	499	1686	-17.5	2.7	12.8
7-8-93 ^b	467	1150	1.4	12-4-95	467	1232	-23.7	1.4	0
8-18-93 ^b	588	2000	1.4	12-4-95	582	2077	-23.7	2.3	-2.6
3-18-94 ^c	422	700	98	5-13-95	425	761	-20.8	1.2	2.6
7-7-94 ^c	361	376	98	9-1-97	464	998	-5.0	3.2	32.7
3-20-96 ^b	529	1803	1.4	11-19-96	525	1850	-20.8	1.7	-2.4

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among years. Electrofishing may overestimate abundance of larger fish and not accurately represent the size distribution of a population (Reynolds 1996), but the high proportion of small adults (≤ 500 mm) in our study and recapture of fish marked initially as subadults in Grand Canyon suggest that recruitment to sexual maturity is occurring. We captured no subadults, based on a minimum length at maturity of about 390 mm (McAda and Wydoski 1985, Weiss et al. 1998). Movement of flannelmouth sucker into the cold, clear-water Lee's Ferry reach may not occur until about reproductive maturity (Weiss et al. 1998).

Our growth data are questionable due to small samples size and inaccurate measurements. However, patterns of growth for fish tagged originally as adults and subadults were comparable to those reported by McAda and Wydoski (1985). Slow growth rates of adults in Lee's Ferry reach might be explained by senescence or influences of cold water temperatures and inadequate food resources, as suggested for other species (Vanicek and Kramer 1969, Weatherly 1972, Kaeding and Osmundson 1988). However, size structure of fish we recaptured does not indicate senescence, since it remained comparable over time and indicated a high proportion of small adults. Inadequate

food resources also seem unlikely. Flannelmouth sucker feed on benthic macroinvertebrates (Minckley 1991), and secondary producers are abundant in Lee's Ferry reach (Blinn et al. 1995, Shannon et al. 1996, Stevens et al. 1997). Moreover, condition of fish was comparable among years. The 1992–1997 period was characterized by higher minimum and more stable releases than previously from GCD (Marzolf 1991, United States Department of Interior 1995), possibly benefiting flannelmouth sucker (Blinn et al. 1995, Stevens et al. 1997). However, our results fail to support this hypothesis, since mean densities, lengths, weights, and condition of flannelmouth sucker did not differ over the 6-yr study. Electrofishing also might contribute to slower growth of shocked individuals (Dalbey et al. 1996, Thompson et al. 1997), but only 1 fish we recaptured likely was captured initially by electrofishing, and its computed growth rate was near the adult mean.

Between 1984 and 1997 nearly 1000 flannelmouth sucker were marked and released in Lee's Ferry reach, and 9000 or more likely were marked and released at downriver locations. During 6 yr of electrofishing, we recaptured 25 fish, none of which was a multiple recapture, and only 1 was tagged originally in

the Lee's Ferry tailwater. Our cumulative recapture of 12% was comparable to that reported by Chart and Bergersen (1992) for the White River. Douglas and Marsh (1998), using seines and hoop-and-trammel nets in or near spawning areas in Little Colorado River, reported higher recapture rates. Catch rates and size structure of the mobile flannelmouth sucker aggregation in Lee's Ferry reach showed no differences annually between 1992 and 1997, and capture of fish tagged initially as subadults suggests that recruitment to reproductive maturity occurred. We hypothesize that population trend was stable between 1992 and 1997 and that more stable flow regimes during this period had no influences on densities or size structure of the aggregation. Further studies of flannelmouth sucker in Lee's Ferry reach, as well as tributaries (Weiss et al. 1998), will enhance assessment of population trends and allow resource managers to evaluate long-term influences of dam operations on this native species.

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