Razorback Sucker (*Xyrauchen texanus*) Status, Reproduction, and Recruitment in Senator Wash Reservoir, CA.

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DISCLAIMERS

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Abstract:

Information regarding razorback sucker (*Xyrauchen texanus*) at Senator Wash Reservoir, CA, is limited although researchers have documented the presence of adult and larval razorback suckers since reservoir completion. Razorback suckers were initially entrained within Senator Wash Reservoir when dam construction was completed in 1966. An additional 4,857 razorback suckers were stocked into Senator Wash Reservoir from 1987 to 1990. We designed this study to assess the status of adult razorback sucker in Senator Wash Reservoir, identify razorback sucker size and age classes to assess natural recruitment, document the presence or absence of larval fish, determine characteristics of the Senator Wash Reservoir system that facilitate razorback sucker spawning, and determine the overall fish community structure in Senator Wash Reservoir. To meet our objectives, adult and juvenile fish were sampled from October 2002 and July 2004 with the use of night electrofishing, and between July 2003 and July 2004 with the use of overnight trammel net sets. In addition, larval light traps were used to collect larval fish from January to May 2004. All adult razorback suckers were implanted with Passive Integrated Transponder (PIT) tags for a mark-recapture population estimate, and fin clips were collected from razorback suckers for age analysis. We estimated the razorback sucker population size in Senator Wash Reservoir at 280 fish (95% Confidence Interval 212 to 400 fish) and they ranged in age from 12 to 29 years. No larval razorback suckers were collected, however razorback sucker spawning behavior was observed. This suggests that larval fish have a high mortality rate, possibly due to predation, or reservoir regulation (changes in water surface elevation of up to 2 meters in elevation overnight). While pump-back water storage reservoirs may provide good grow-out facilities for razorback suckers, they do not provide necessary requirements for natural recruitment of razorback suckers.

INTRODUCTION

During the last 120 years, massive changes have occurred in the Colorado River system including changes in river morphology, creation of impoundments, and the introduction of non-native fish. These changes have impacted the native fish community of the lower Colorado River. As a result, seven of ten fish species native to the Colorado River are listed on federal or state threatened and endangered species lists (Minckley et al. 1991; USFWS 1999; Mueller et al. 2002).

The razorback sucker (*Xyrauchen texanus)* is an endangered fish native to the Colorado River system. Razorback suckers have suffered severe population declines due to habitat alteration and destruction, changes in water quality, and competition with and predation by nonnative fishes (Carlson and Muth 1989; Mueller et al. 2002). In November of 1991, the United States Fish and Wildlife Service (USFWS) listed the razorback sucker as an endangered species under the Endangered Species Act of 1973 (USFWS 1991) and created a draft razorback sucker recovery plan in 1993 (USFWS 1993; USFWS 1998). In April of 1994, critical habitat status was established throughout the historic range of the razorback sucker (59 FR 13374).

In the lower Colorado River basin, razorback sucker populations are currently limited to Lake Mohave, Lake Mead, Lake Havasu, Senator Wash Reservoir, and the Colorado River below Davis Dam (Minckley 1983; Ulmer et al. 1985; Marsh and Minckley 1989; Minckley et al. 1991; USFWS 1991; Mueller 2006). Razorback sucker populations in reservoirs are made up of old adult fish from pre-impoundment conditions and younger fish stocked from hatcheries (Minckley 1983; McCarthy and Minckley 1987; Tyus 1987; USFWS 1991).

Razorback sucker recovery efforts in the lower Colorado River basin have been in effect for over 20 years. There is some evidence of razorback sucker reproduction in the wild, but recruitment has rarely been documented (Mueller 1995; Mueller et al. 2002; Mueller 2006). Information on recruitment events is critical to future management of the razorback sucker (USFWS 2002). Several studies have focused on the importance of off channel habitat, backwaters, and other refugia to the successful survival of larval razorback suckers and their recruitment into the population (Tyus 1987; Modde et al. 2001; Gurtin et al. 2003).

Knowledge of the survival rate of stocked razorback suckers in Senator Wash Reservoir is important in evaluating the effectiveness of using off-channel reservoirs as razorback sucker grow-out ponds in the future. Adult razorback suckers were first documented in Senator Wash

Reservoir, California (CA), in 1973 during gill netting surveys conducted by an unknown agency, probably California Department of Fish and Game (CDFG). Razorback suckers in Senator Wash Reservoir were first studied by Ulmer et al. in 1980 and the population was estimated at 54 ± 22 adult fish (Marsh and Minckley 1989). Ulmer et al. also conducted telemetry studies, documented spawning, and initiated stocking of razorback suckers into Senator Wash Reservoir. From 1987 to 1990, approximately 4,857 razorback suckers were stocked into Senator Wash Reservoir (Table 1). The majority of fish stocked were offspring of Lake Mohave broodstock obtained from Niland Native Fish Ponds. One stocking, however, consisted of fish grown in Blythe Golf Course Ponds that originated from razorback sucker eggs collected from Senator Wash Reservoir.

Adult and larval razorback suckers were found in Senator Wash Reservoir in 1999 and 2001 (Scott Gurtin, Arizona Game and Fish Department, pers. comm., 2003) indicating that either 1) razorback suckers sampled by Ulmer et al. (1985) were still reproducing, 2) razorback suckers recruited from previous spawning events or stocked fish were reproducing, or 3) larval fish were being entrained from the mainstem Colorado River. Population levels between 1985 and 1999 and survival of razorback suckers stocked in Senator Wash Reservoir are unknown, and there have been no observations of recruitment occurring since CDFG hypothesized that it was occurring in 1985 (Loudermilk 1980; Medel-Ulmer 1983; Loudermilk 1985; Ulmer et al. 1985).

To assess the status of adult razorback sucker in Senator Wash Reservoir, we identified razorback sucker size and age classes to assess recruitment, attempted to document the presence of larval fish, identified characteristics of the Senator Wash Reservoir system that facilitated razorback sucker spawning, and determined the fish community structure in Senator Wash Reservoir.

Study Area

Senator Wash Reservoir is located near Yuma, Arizona (AZ), on the California side of the Colorado River two miles upstream from Imperial Dam (Figure 1). Senator Wash Reservoir was completed in 1966 and currently has a surface area of approximately 470 acres (57.97 hectares; Figure 2). Senator Wash Reservoir is used for pump-back water storage for farm irrigation purposes. During this study, we observed Senator Wash Reservoir fluctuate up to 2 meters (m) overnight due to farm water orders and irrigation releases.

The water on the eastern side of the reservoir varies between seven and fifteen meters deep, mostly due to the dam, outtake, and intake valves being located on this side of the reservoir. The water on the western side of the reservoir is much shallower than the eastern side, varying between one and five m deep. The substrate of the eastern side of the reservoir is visually comprised of medium to large cobble interspersed with gravel. The bottom of the western side of the reservoir is silt, which has flowed into the reservoir from the adjacent wash and filled the area. There is little to no aquatic vegetation present in Senator Wash Reservoir with the exception of mixed emergent aquatic plants (*Typha spp., Scirpus spp., Tamarix spp*.) growing in the silt substrate in the littoral areas on the western side of the reservoir. The water temperature of Senator Wash Reservoir fluctuates diurnally and seasonally. During this study, we recorded water temperatures between 6.6° and 31.1° Celsius.

Senator Wash Reservoir contains endangered razorback sucker as well as an assembly of non-native fishes including flathead catfish (*Pylodictis olivaris*), channel catfish (*Ictalurus punctatus*), striped bass (*Morone saxatilis*), threadfin shad (*Dorosoma petenense*), largemouth bass (*Micropterus salmoides*), carp (*Cyprinus carpio*), and various sunfish species (*Lepomis spp*).

METHODS

Sampling Sites

For sampling purposes, Senator Wash Reservoir was divided into six sections and each section was divided into three subsections based on substrate type (Figure 3). Sampling sites were selected randomly for larval fish trapping, electrofishing, and trammel netting from the 18 subsections. Personnel from the Arizona Game and Fish Department (AGFD) and California Department of Fish and Game (CDFG) participated in all fish sampling surveys.

Collection of Larval Fish

To assess the presence or absence of larval razorback suckers in Senator Wash Reservoir, we conducted monthly larval light trapping from January through May 2004 (Figure 5). Ten larval light traps were constructed based on the design of Kilgore (1994) with slight modifications (Figure 4). Traps had 4-millimeter gaps for larval fish to swim through and the light source consisted of four 3.6 volt Light Emitting Diodes (LEDs). On the top of the trap, we added a watertight container to hold two size D batteries. We wired 4 LED lights together in a row and connected them to batteries. The LED lights were enclosed in 2.5-centimeter diameter plastic tubing that was 30.5 centimeters long. The plastic tube was sealed on both ends with cork and was then dipped in plasti-dip® (Plasti Dip International; Blaine, MN) to create a waterproof container for the LED lights. The wiring connecting the batteries to the LED lights was also enclosed in plasti-dip® for waterproofing. On the bottom of the trap, we attached a screw-on container with five 300 micron mesh-covered circular holes that allowed water to drain from the collection container while gathering larval fish.

We deployed light traps 1.5 to 3.1 m from shore in water 1 to 1.5 m deep. Because the water level often fluctuated up to 2 m overnight, we anchored the traps on shore with rope long enough to ensure that the traps would not become stranded on shore if the water level dropped overnight.

Larvae collected in traps were placed in alcohol for identification in the laboratory using Synder and Muth (1990).

Collection of Adult and Juvenile Fish

Adult and juvenile fish were sampled monthly from July 2003 to July 2004 using multifilament trammel nets. Adult razorback suckers were collected using four trammel nets per night that measured 42.7 m long, with 3.8 centimeter (cm) inner mesh, and 30.5 cm outer mesh and one trammel net that measured 25 m long, with 3.8 cm inner mesh, and 30.5 cm outer mesh. Juvenile razorback suckers were sampled from April 2004 to July 2004 using four trammel nets per night measuring 15.2 m long, with 1.3 cm inner mesh, and 27.9 cm outer mesh. All trammel nets were set at dusk and pulled at dawn in the same order that they were set.

The shoreline fish community structure was determined quarterly from October 2002 to July 2004 using nighttime boat electrofishing surveys. A boat equipped with a Smith-Root 5.0 generator powered pulsator (GPP) electofishing system equipped with two anode electrode arrays attached to the bow of the boat, and a cathode electrode array with stainless steel dropper cables hung from either side was used to conduct our electrofishing surveys. We used a standard setting of 7-10 amps, 40 Hertz, and 60 pulses per second to capture fish. We electroshocked six randomly chosen subsections of the reservoir for a standard average of 600 seconds each. Catch rates are reported as fish caught per hour.

All fish that were captured were held in live wells with aeration. Fish that were collected during trammel netting and electrofishing surveys were identified to species and we recorded total length (TL; to the nearest 1 mm) and weight (to the nearest 0.1 g) of all adult fish collected for CPUE and length frequency estimation. Collected razorback suckers were immediately weighed and measured, scanned for the presence of a Passive Integrated Transponder (PIT) tag, and untagged fish were implanted with a PIT tag for growth and population estimation (see Mark-Recapture section below) and immediately returned to the reservoir. Sex of razorback suckers was recorded during spawning season when sexually dimorphic characteristics were present such as the presence of tubercles on males and extended vent and pink coloration on females (Mueller 2006). Razorback suckers were considered ripe when milt or eggs were extruded. All other fish were returned to the reservoir after the entire net was pulled or the electrofishing survey was completed in each subsection to avoid double captures.

Mark-Recapture

A multiple mark-recapture population estimate (White et al. 1982) was conducted on adult razorback suckers in Senator Wash Reservoir from June 2003 to June 2004. To conduct this population estimate, we assumed that the population met all assumptions of a closed population.

From June 2003 to July 2004 all razorback suckers collected were tagged with uniquely numbered AVID® (AVID Identification Systems Incorporated; Folsom, LA) (June to December 2003) or Biomark® (Biomark Inc.; Boise, ID) (January to July 2004) 125 KHz PIT tags so that individual capture histories could be established and to allow for growth estimation. Both AVID® and Biomark® scanners were used in the field for the entire study to ensure detection of both tag types.

We obtained one full year of mark-recapture data on razorback suckers in Senator Wash Reservoir. We did not recapture any razorback suckers until January of 2004. We did not recapture any razorback suckers marked prior to October of 2003.

Capture-recapture data for razorback suckers was entered as a data matrix into the Colorado State University computer program, CAPTURE (White et al. 1982), to conduct a closed mark-recapture population estimate on the adult razorback suckers in Senator Wash Reservoir. CAPTURE was used to compare the absolute and relative fit of population estimation models to data and the best probability model was selected. Time, behavioral response to capture, and heterogeneity (statistical variability in the population) and their effects on capture probability were factored into the models (White et al. 1982).

We considered each encounter with an individual razorback sucker as a capture-recapture event in the data matrix. We allowed each razorback sucker to have an individual capture probability. We assumed that the population was closed because there was no immigration or emigration within Senator Wash Reservoir, there was no recruitment within the population, and due to the length of our study mortality was not an issue. In addition, we assumed that within the population, each razorback sucker had an equal probability of capture, and that the past capture history of an individual did not affect its future capture probability (no behavioral response to the gear).

Age and Growth

Pectoral fin clips have been used to reliably age razorback suckers (McCarthy et al. 1987, Holden et al. 2000). To determine if natural reproduction and recruitment had been occurring within Senator Wash Reservoir, the left pectoral fin ray was chosen as a reliable structure for aging (McCarthy et al. 1987, Holden et al. 2000). From January to May 2004 we collected 21 fin ray clips from razorback suckers that were representative of pre-determined length groups based on the construction of a length frequency chart. Fin clips were collected from the middle of the left pectoral fin ray number 2 of adult razorback suckers following the BioWest Inc. fin clip protocol used to age Lake Mead razorback suckers (Biowest, personal communication, 2003). Fin ray clips were aged following the BioWest Inc. aging protocol (Biowest, personal communication, 2003). A small sample was cut from the collected fin clip sample. The small sample was mounted on a microscope slide with thermoplastic epoxy resin. The samples were perpendicularly sawed, sanded, and polished until growth rings could be clearly seen under a compound microscope. We took photographs of the fin ray clips through a Leica S8 APO stereo zoom microscope to aid in aging the razorback suckers. Three independent readers aged each fin ray clip. If discrepancies were found between the readings, an age range was assigned to the clip. For example, if one reader found the sample to be 14 and another 16, the sample was assigned an age range of 14-16.

RESULTS AND DISCUSSION

Razorback Sucker Spawning Areas

Razorback sucker spawning behavior was observed at several locations in Senator Wash Reservoir (Figure 6, 7). Spawning areas were also tentatively identified by the capture of ripe razorback suckers. These locations were the same spawning locations identified by Ulmer et al. in the 1970's (Ulmer 1985). These areas had a substrate of mixed medium size cobble and gravel, with slopes of 30-45%. Spawning at Senator Wash Reservoir occurred from late November through early May, with peak spawning activity occurring in December through March, measured by proportion of ripe razorback suckers captured. During the spawning season, water temperature ranged from 6.6 to 25.5° C.

Collection of Larval Fish

The most abundant larval fish species collected was carp (Table 2). Threadfin shad were the second most frequent larval fish species collected in light traps. No razorback suckers were identified within the larval samples that we collected. All other species observed in Senator Wash Reservoir were also captured in razorback sucker spawning areas. This indicated that while spawning is spatially separated, adult nonnative fish are frequenting and utilizing spawning and rearing habitat for larval razorback suckers.

The paucity of larval razorback suckers in Senator Wash Reservoir is likely due to a combination of factors including predation by other fish species and large fluctuations in water levels which may result in razorback sucker egg desiccation prior to hatch (Ulmer et al. 1985, Carlson and Muth 1989, Mueller et al. 2002). Razorback suckers in the reservoir spawn earlier than all other fish species, making larval razorback suckers very vulnerable to predatory species during this period of time (Carlson and Muth 1989, Mueller et al. 2002). Additionally, piscivorous fish, including carp, flathead catfish, largemouth bass, and sunfish occurrence in razorback sucker spawning and rearing areas could contribute to the lack of razorback sucker recruitment at Senator Wash Reservoir. Predation on razorback sucker larvae has been implicated in razorback sucker recruitment failure in other Colorado River reservoirs (Carlson and Muth 1989, Minckley et. al 1991, Mueller 2006).

Reservoir regulation practices may also contribute to reduced survival of razorback sucker eggs and larvae. Razorback sucker were observed spawning in water less than 2 m deep, and Senator Wash Reservoir varies up to 2 m overnight, which may lead to razorback sucker egg desiccation and stranding. Ulmer et al. (1985) observed recent spawning areas subjected to stranding. Larval razorback suckers may also be entrained and transported out of the reservoir, however, this probably occurs at a low frequency because the intake and outtake pumps and valves are located in water deeper than 10 m.

Fish Community Structure

Electrofishing catch per unit effort (CPUE; fish/hour) for razorback sucker was 1.7 (SE= 0.8) in 2002, 1.5 (SE= 1.0) in 2003, and 0 (SE= 0) in 2004 (Table 3). Catch rates by electrofishing were not significantly different among years. Largemouth bass and bluegill sunfish were the most common fish species captured by electrofishing (Table 4).

Trammel netting catch per unit effort (CPUE; fish per hour per 1000 m of trammel net) for razorback sucker collected in large mesh trammel nets was 1.6 (SE= 0.3) in 2003, and 3.0 (SE= 0.5) in 2004 (Table 3). There was significant evidence that CPUE varied between 2003 and 2004 for razorback suckers captured using large mesh trammel nets (ANOVA, F_1 = 5.62, P = 0.02). This variance may be due to the random placement of nets in the reservoir, leading to sampling of areas of high density in one year and low density the next year. Carp were the most abundant and razorback suckers the second most abundant species captured by large mesh trammel nets (Table 4). Trammel net catches of razorback sucker were highest in January and February when fish were spawning.

Trammel netting catch per unit effort (CPUE; fish per hour per 1000 feet of trammel net) for razorback sucker collected in small mesh trammel nets was 0.2 (SE= 0.1) in 2004 (Table 3). No young razorback suckers were captured using smaller mesh trammel nets.

Razorback suckers collected in 2002 had a mean length of 572 mm (SE= 21) and weight of 2117 g (SE= 17); in 2003 they had a mean length of 601 mm (SE= 5) and weight of 2576 g (SE= 58); in 2004 they had a mean length of 604 mm (SE= 3) and weight of 2707 g (SE= 49) (Table 5).

Captured razorback suckers ranged from 445 to 679 mm in total length, and there were two distinct length classes of razorback suckers in Senator Wash Reservoir (Figure 8). The smaller length group ranged from 445 to 610 mm and the larger length group ranged from 620 to 679 mm. Based on the fish that we sexed (61% of the razorback suckers captured), the smaller length group (445 to 610 mm) were males and the larger length group (620 to 679 mm) were females. Razorback suckers with total lengths less than 520 mm might be fish that were recruited into the population. However, fin clip data were not collected from this length group so we could not verify if this was true.

Razorback Sucker Population Estimation

We obtained one full year of mark-recapture data on razorback suckers in Senator Wash Reservoir. We did not recapture any razorback suckers until January 2004. We caught most recaptures when razorback suckers congregated for spawning. We assumed that tag loss was negligible during this study although we did not specifically test for it. A total of 127 adult razorback suckers were captured during our study, 125 were tagged, and there were 48 recaptures accounting for a total of 181 captures.

The razorback sucker population size (*N*) in Senator Wash Reservoir was estimated at 280 fish (95% C.I. 212 to 400 fish; SE, 46.6). The average probability of capture was very low, 2.22%. The coefficient of variation of *N* (100·SE/ mean) was 16.63%, indicating good precision because reliable studies require a coefficient of variation of less than 20% (White et al. 1982).

Survival of Stocked Razorback Suckers

Based on records of 4,587 razorback suckers stocked, and a present population size of 280, approximately 6% of razorback suckers stocked into Senator Wash Reservoir still survive. This is much higher than the 0.1% survival rate found for razorback suckers stocked into the mainstem of the Colorado River (Schooley et. al In Press). The difference may be due to a lack of larger bodied predators due to low productivity within the reservoir (Table 5). It also might reflect different size classes stocked into Senator Wash Reservoir, with higher survival at larger stocking size (Schooley et. al In Press) as well as better survival of old age classes in the reservoir prior to stocking.

The population and survival rate estimates do not take into account the 1996 removal of an unknown number of razorback suckers from Senator Wash Reservoir that were stocked into the Colorado River (Scott Gurtin, Arizona Game and Fish Department, pers. comm., 2003) or the removal of an unknown number of fish for electrophoretic analysis in the 1980s (Buth et al. 1987), or the marginal possibility that fish were pumped out of the reservoir through trash racks with 4-6” openings (in place since 1979; Kretschmann 2006). Therefore, our long-term estimate of 6% survival is a conservative estimate, and survival is probably somewhat higher for razorback suckers stocked from 1987 to 1990.

Age and Growth

Based on ages of fish from fin ray samples, we have no evidence of razorback sucker recruitment in Senator Wash Reservoir. However, we were unable to collect fin ray clip samples from all razorback sucker size classes (Figure 9), and therefore cannot definitively state that recruitment never occurred. There were large discrepancies between individuals reading the fin ray clips, but all readers assigned ages from 12 to 29 years (Table 6). Accurate determination of age was hampered due to slower growth of large fish, and crowding or overlapping of annuli. We aged no fish younger than the latest stocking of razorback suckers in Senator Wash Reservoir. In addition, we found groups of similarly aged fin clips, which correspond to years that razorback suckers were stocked into Senator Wash Reservoir. Within the fin clip samples taken, we saw no evidence of recruitment into the population.

MANAGEMENT IMPLICATIONS

Razorback sucker spawning behavior was observed at Senator Wash Reservoir. However, eggs and larval razorback suckers in Senator Wash Reservoir are not surviving due to a combination of factors including predation by other fish species and large fluctuations in water levels, which may be resulting in razorback sucker egg and larval desiccation. Thus, no young of the year or juvenile razorback suckers were captured during this study. All adult razorback suckers aged were over 12 years old.

Current strategy for stocking razorback sucker into the mainstem Colorado River includes use of grow-out ponds to rear fish to a size large enough to escape predation by large fish such as flathead catfish. (U.S. Bureau of Reclamation 2006). Most predatory fish in Senator Wash Reservoir are relatively small (Table 5) and thus the reservoir could serve as a grow-out location for razorback sucker. Off-channel habitats appear to be effective as razorback sucker grow-out ponds and should be more widely used in the future (Mueller 2006). However, it appears that Senator Wash Reservoir will not sustain a self-recruiting population.

Senator Wash Reservoir offers an opportunity to observe razorback sucker spawning in the wild, and there may also be options for improving razorback sucker recruitment such as removing the water level fluctuations in the reservoir, and providing larval fish protection from predators, including inundated artificial structures or floating artificial vegetation. For example, there is some evidence indicating that inundated vegetation in Lake Mead may contribute to greater survival of larval and juvenile razorback sucker (C. Minckley, U.S. Fish and Wildlife Service, pers. comm., 2006).

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Table 1. Stocking history of razorback suckers in Senator Wash Reservoir, 1987-1990.

Date Stocked	**Number of Fish**	**Fish/lb**	**Mark**	**Source**
02/09/1987	82	2.30		Niland Native Fish Ponds
02/26/1988	70		Left Pelvic Clip	Niland Native Fish Ponds
03/04/1988	1,630	16.30	Left Pelvic Clip	Blythe Golf Course Pond
09/20/1990	36	1.50	Left Pectoral Clip	Niland Native Fish Ponds
01/31/1990	548	1.17		Niland Native Fish Ponds
02/26/1990	690	1.19	Right Pectoral Clip	Niland Native Fish Ponds
02/26/1990	1,073	1.50	Right Pectoral Clip	Niland Native Fish Ponds
02/27/1990	692	1.70	Right Pectoral Clip	Niland Native Fish Ponds
09/20/1990	36	1.50	Left Pectoral Clip	Niland Native Fish Ponds
Total	4,857			

Table 2. Species, number, and percent catch of larval fish using larval light traps, Senator Wash Reservoir, January- May 2004.

Species	**N**	**Percent of Total**
Common Carp	149	55.1
Threadfin Shad	36	13.3
Unknown Centrarchid	31	11.4
Largemouth Bass	24	8.8
Unknown Non-*Catastomid*	21	7.7
Green Sunfish	7	2.6
Bluegill	2	0.7
Striped Bass	1	0.4
Total	271	100.0

Table 3. Catch per unit effort of fish species collected in Senator Wash Reservoir 2002-2004. Standard error is in parentheses. Electrofishing units are fish per hour, and trammel netting units are fish per hour per 1000 m of net. Superscript letters indicate values that are statistically different (ANOVA; $P < 0.05$) among years for a given species.

	2002	**2003**	**2004**
		Electrofishing	
Total Effort:	**2.2 h**	**3.3 h**	**2.1 h**
Goldfish	7.3 (5.1)	3.2 (2.0)	0.0 (0.0)
Common Carp	0.4^{a} (0.4)	4.9^{a} (1.6)	12.4^{b} (3.8)
Threadfin Shad	0.0 (0.0)	9.6 (4.4)	2.8 (2.1)
Channel Catfish	5.8 (1.6)	6.9 (2.1)	2.4 (0.8)
Green Sunfish	0.0 (0.0)	0.6 (0.4)	2.2 (1.5)
Warmouth	0.4 (0.4)	0.0 (0.0)	0.0 (0.0)
Bluegill	20.0 (9.2)	10.0 (5.5)	27.8 (8.9)
Redear Sunfish	13.9 (8.0)	0.3 (0.3)	9.4 (5.4)
Largemouth Bass	52.7^{b} (8.4)	12.8^{a} (3.4)	19.0^{a} (6.4)
Striped Bass	9.2 (7.5)	1.8 (1.2)	3.3 (2.0)
Black Crappie	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Flathead Catfish	2.3 (1.5)	1.2 (0.6)	2.6 (2.0)
Razorback Sucker	1.7 (0.8)	1.5 (1.0)	0.0 (0.0)
	2002	**2003**	**2004**
	Trammel Netting (3.8 cm inner mesh, 30.5 cm outer mesh)		
Total Effort:		**79 net sets**	**80 net sets**
Goldfish		$0.4 (0.2)^{b}$	$0.0 (0.0)^{a}$
Common Carp		11.4^{b} (1.1)	7.1^{a} (0.8)
Threadfin Shad		0.0 (0.0)	0.0 (0.0)

Table 3 (cont.)

Channel Catfish		1.2^{b} (0.2)	0.3^{a} (0.1)
Green Sunfish		0.0 (0.0)	0.4 (0.3)
Warmouth		0.0 (0.0)	0.0 (0.0)
Bluegill		0.7 (0.1)	1.1 (0.2)
Redear Sunfish		0.2 (0.1)	0.2 (0.1)
Largemouth Bass		1.3 (0.2)	1.0 (0.2)
Striped Bass		1.2 (0.3)	0.6 (0.2)
Black Crappie		0.0 (0.0)	0.1 (0.1)
Flathead Catfish		1.2 (0.2)	1.7 (0.5)
Razorback Sucker		1.6^{a} (0.3)	3.0^{b} (0.5)
	2002	**2003**	**2004**
	Trammel Netting (1.3 cm inner mesh, 27.9 cm outer mesh)		
Total Effort:			**26 net sets**
Goldfish			0.0 (0.0)
Common Carp			0.5 (0.2)
Threadfin Shad			18.3 (9.7)
Channel Catfish			0.5 (0.2)
Green Sunfish			1.5 (0.5)
Warmouth			0.1 (0.1)
Bluegill			7.4 (1.6)
Redear Sunfish			0.5 (0.2)
Largemouth Bass			0.5 (0.2)
Striped Bass			0.2 (0.1)
Black Crappie			0.0 (0.0)
Flathead Catfish			0.2 (0.1)
Razorback Sucker			0.2 (0.1)

Table 4. Relative abundance (percent) of fish species collected in Senator Wash Reservoir 2002-2004.

	2002	**2003**	**2004**
Species		**Electrofishing**	
Goldfish	6.9	5.7	0.0
Common Carp	0.4	9.2	15.2
Threadfin Shad	0.0	18.4	3.5
Channel Catfish	5.0	13.2	2.9
Green Sunfish	0.0	1.1	2.9
Warmouth	0.4	0.0	0.0
Bluegill	16.5	19.0	33.9
Redear Sunfish	11.5	0.6	11.7
Largemouth Bass	46.7	24.1	22.8
Striped Bass	8.4	3.4	4.1
Black Crappie	0.4	0.0	0.0
Flathead Catfish	2.3	2.3	2.9
Razorback Sucker	1.5	2.9	0.0
	2002	**2003**	**2004**
	Trammel Netting (3.8 cm inner mesh, 30.5 cm outer mesh)		
Goldfish		1.3	0.0
Common Carp		61.1	46.4
Threadfin Shad		0.0	0.0
Channel Catfish		6.4	2.2
Green Sunfish		0.0	2.9
Warmouth		0.0	0.0
Bluegill		3.9	8.2

Table 4 (cont.)

Redear Sunfish		0.9	1.9
Largemouth Bass		6.4	6.5
Striped Bass		6.5	4.0
Black Crappie		0.0	0.2
Flathead Catfish		6.3	8.4
Razorback Sucker		7.2	19.4
	2002	**2003**	**2004**
	Trammel Netting (1.3 cm inner mesh, 27.9 cm outer mesh)		
Goldfish			0.0
Common Carp			1.3
Threadfin Shad			67.0
Channel Catfish			1.3
Green Sunfish			4.3
Warmouth			0.2
Bluegill			20.7
Redear Sunfish			1.3
Largemouth Bass			1.5
Striped Bass			0.9
Black Crappie			0.2
Flathead Catfish			0.4
Razorback Sucker			0.4

Table 5. Mean total length (mm) and weight (g), and number of each species measured from electrofishing and trammel netting samples in Senator Wash Reservoir 2002-2004. Standard error is in parentheses.

		2002		2003		2004	
Species		**N**	**Mean (SE)**	**N**	**Mean (SE)**	**N**	**Mean (SE)**
Goldfish	Length	18	323 (2)	12	351 (10)	-	----
	Weight	-	444 (9)	12	612 (38)	-	----
Common Carp	Length	-	----	-	----	26	476 (19)
	Weight	-	----	-	----	21	1541 (314)
Threadfin Shad	Length	-	----	6	116 (8)	155	116 (2)
	Weight	-	----	6	15 (2)	99	19 (2)
Channel Catfish	Length	13	437 (21)	70	375 (15)	24	362 (29)
	Weight	13	768 (97)	59	652 (39)	20	729 (104)
Green Sunfish	Length	-	----	2	99 (11)	43	82 (2)
	Weight	-	----	2	20 (10)	13	12 (2)
Warmouth	Length	1	125 (-)	-	----	1	88 (-)
	Weight	-	----	-	----	-	----
Bluegill	Length	43	128 (2)	62	139 (7)	203	107 (3)
	Weight	32	37 (3)	44	111 (11)	100	63 (7)
Redear Sunfish	Length	30	167 (4)	8	232 (15)	38	112 (9)
	Weight	27	83 (8)	8	226 (38)	13	136 (34)
Largemouth Bass	Length	122	256 (8)	89	306 (7)	87	296 (9)
	Weight	111	335 (33)	85	409 (30)	87	402 (26)
Striped Bass	Length	22	284 (9)	54	392 (14)	33	329 (14)
	Weight	22	253 (35)	51	565 (35)	32	376 (29)
Black Crappie	Length	-	87 (-)	-	----	1	309 (-)
	Weight	-	----	-	----	1	240 (-)

Table 5 (cont.)

		2002		2003		2004	
Species		**N**	**Mean (SE)**	**N**	**Mean (SE)**	**N**	**Mean (SE)**
Flathead Catfish	Length	6	499 (22)	51	535 (14)	60	525 (16)
	Weight	6	1348 (206)	51	1673 (111)	57	1518 (119)
Razorback Sucker	Length	4	572 (21)	60	601 (5)	126	604 (3)
	Weight	3	2117 (17)	58	2576 (58)	125	2707 (49)

Table 6. Razorback sucker age estimates for fin clip samples, 2004.

Total Length (mm)	Weight (g)	Sex	Low Age Estimate	High Age Estimate	Range
599	2810	M	14	16	2
627	3260	F	14	21	7
653	3470	F	14	29	15
654	3500	F	14	27	13
641	4430	F	14	25	11
579	2360	M	14	22	8
620	3480	F	14	20	6
645	3340	F	14	16	2
630	3340	F	17	19	2
619	3000	F	16	18	2
567	2470	M	14	15	1
630	1610		12	24	12
636	2760	F	14	16	2
622	3350	F	14	16	2
645	3470	F	17	18	1
564	1990	M	17	18	1
539	1990		17	16	1
656	3390	F	21	14	7
663	3120	F	14	17	3
555	2090		14	17	3
624	2650	F	13	17	4
		Minimum:	12	14	1
		Maximum:	21	29	15

Figure 1. Senator Wash Reservoir location within the lower Colorado River system below Martinez Lake.

Figure 2. Topography of Senator Wash Reservoir, CA (1955).

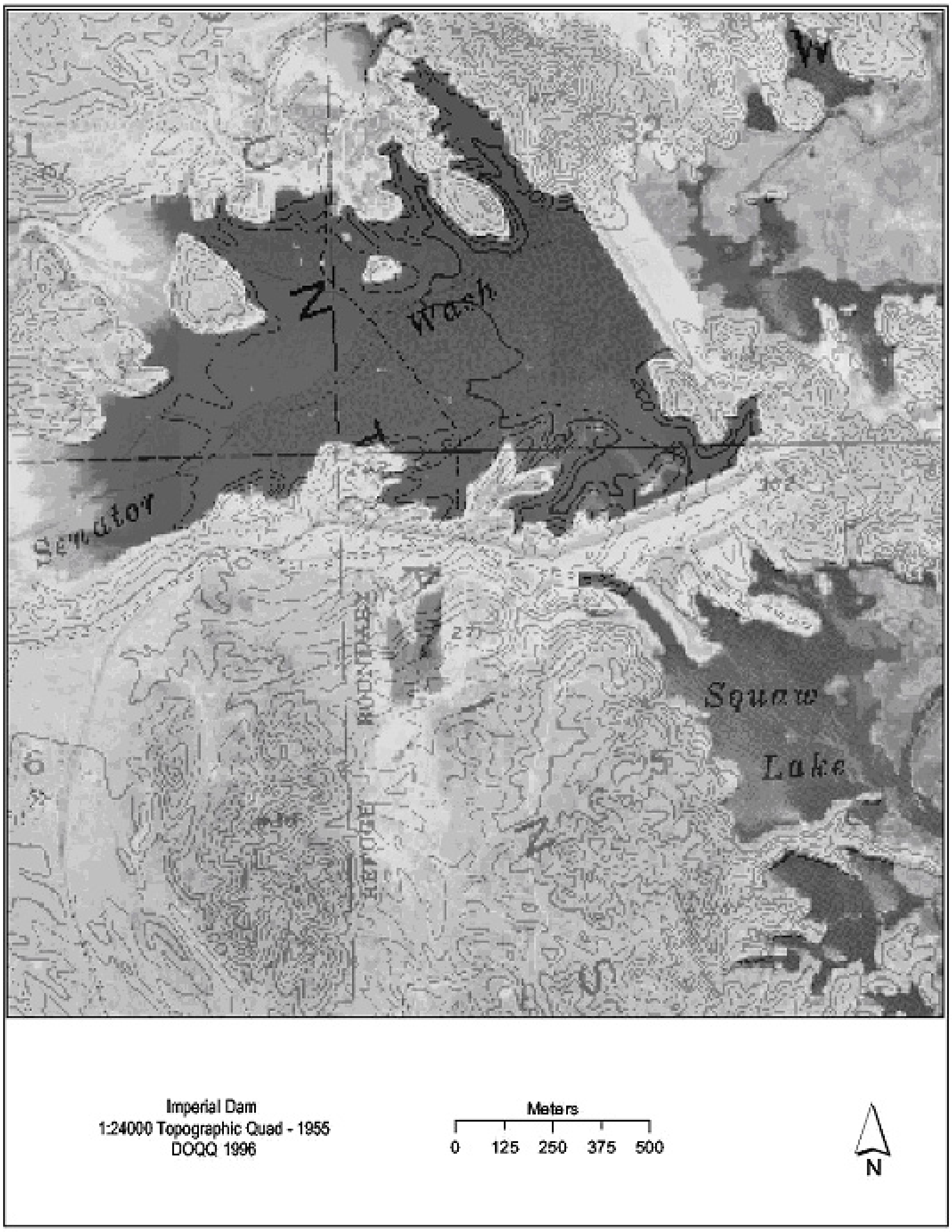

Figure 3. Razorback sucker sampling sites at Senator Wash Reservoir, CA. Labels indicate section and subsection numbers.

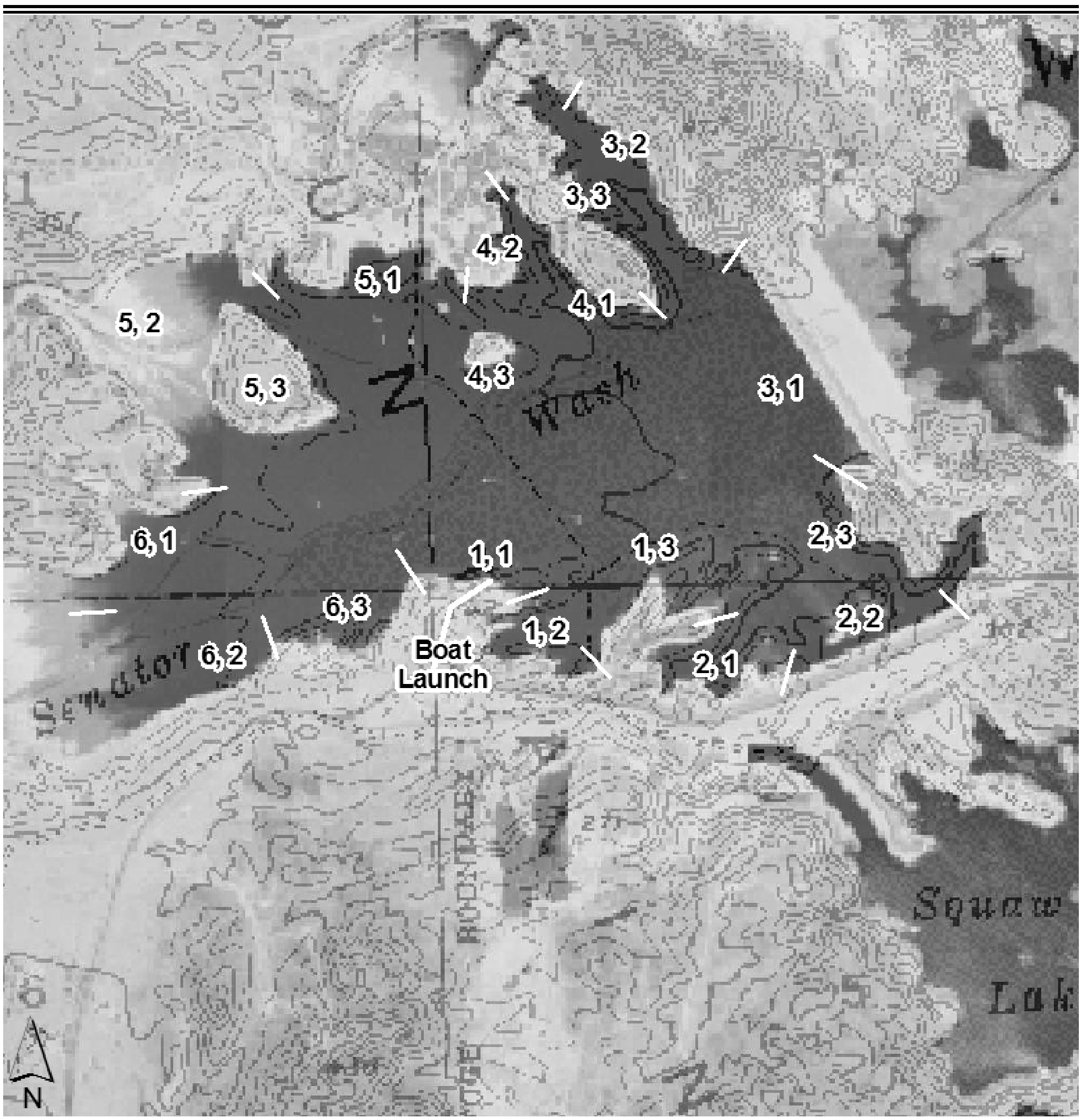

Figure 4. Design of larval light traps used to collect larval fish at Senator Wash Reservoir, CA.

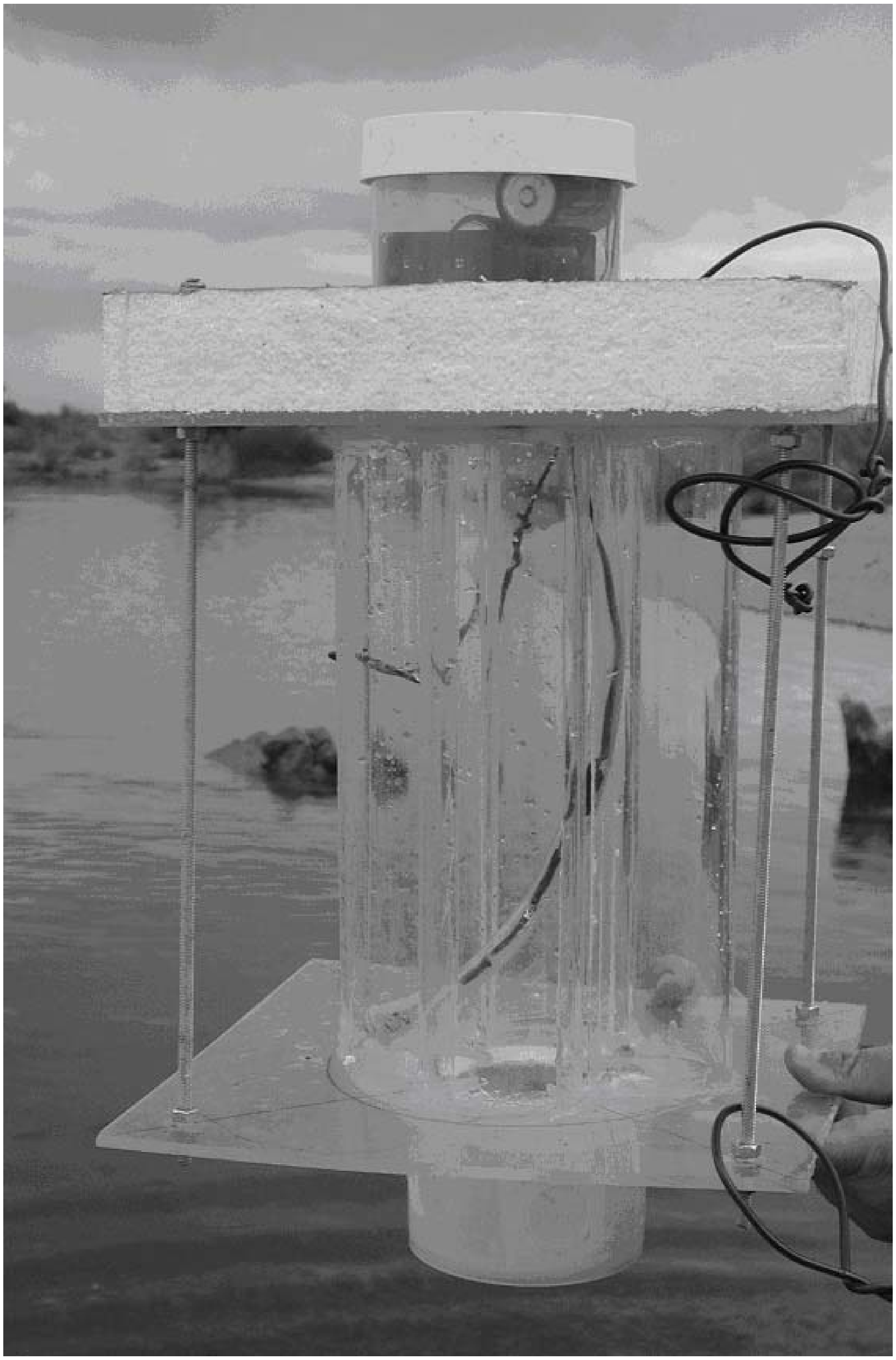

Figure 5. Deployment of larval light traps along shoreline of Senator Wash Reservoir, CA.

Figure 6. Map of observed razorback sucker primary spawning areas and secondary spawning areas based on spawning behavior observations at Senator Wash Reservoir, CA (2002-2004).

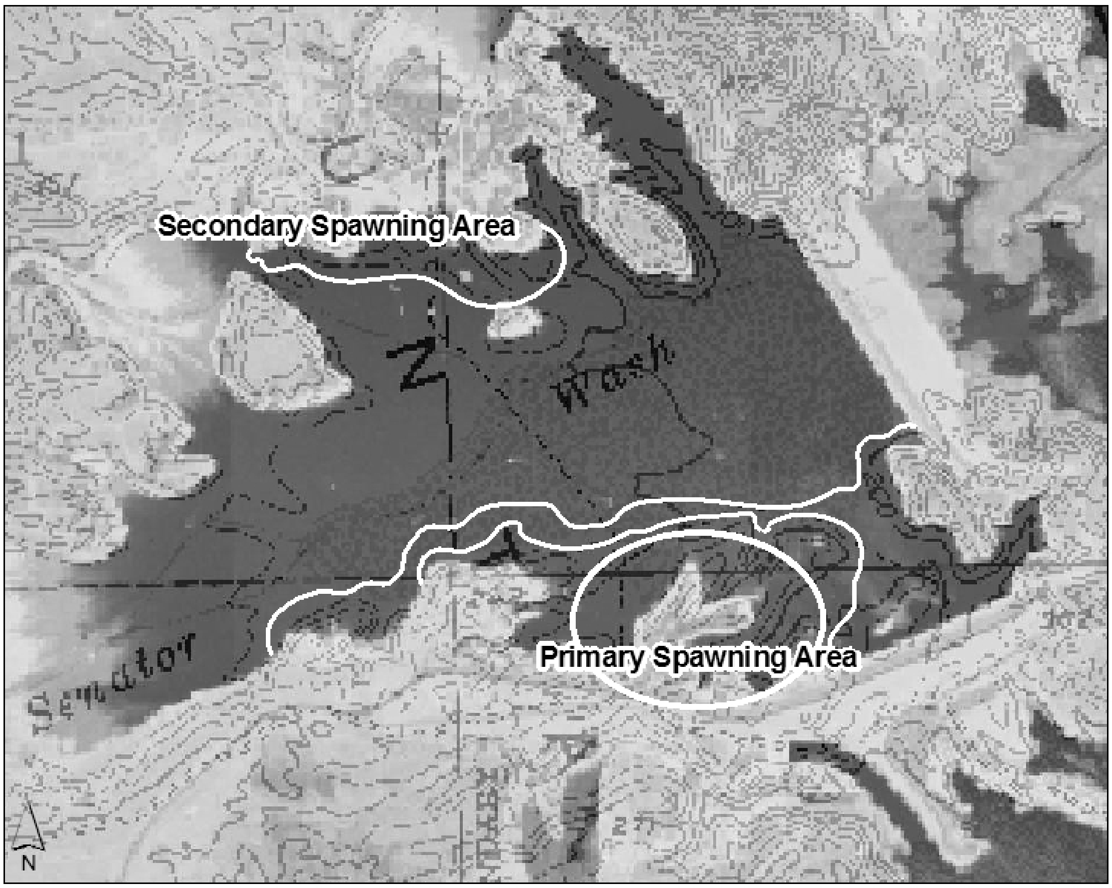

Figure 7. Senator Wash Reservoir, CA showing gravel and cobble bars in sections 1 and 2 where razorback sucker were observed spawning, 2004 (Areas out of water as a result of dyke repair drawdown).

Figure 8. Size structure of razorback suckers in Senator Wash Reservoir, CA collected by electrofishing and trammel netting, by 10-mm length interval, 2002-2004.

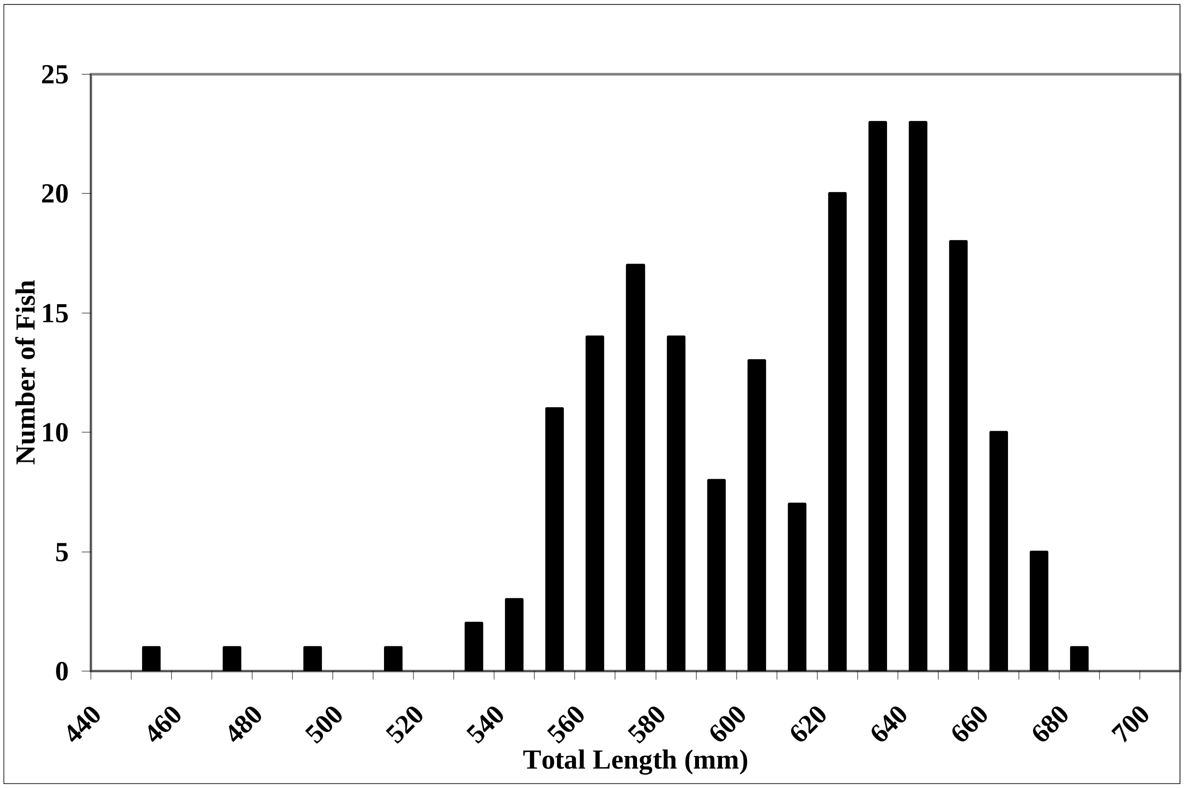

Figure 9. Length frequency of razorback sucker fin clip samples, 2004.