



Photo by Cy Fernandez, Southern Nevada Water Authority.

Elastomer dye-marked woundfin from the lower Virgin River.

LOWER VIRGIN RIVER ENDANGERED FISH STUDIES, 1998-2000

**Evaluation of mechanical removal of red shiner (*Cyprinella lutrensis*),
survival of stocked woundfin (*Plagopterus argentissimus*), and results of monitoring**

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EXECUTIVE SUMMARY

Nevada Division of Wildlife woundfin stocking experiments in the lower Virgin River from 1993 to 1998 did not result in the establishment of woundfin populations. Heinrich (1999) concluded that hatchery-reared fish may not be able to survive in the river, but that large numbers of red shiner may also have been a factor in the lack of survival of stocked woundfin. To further determine if stocked woundfin could be used to re-establish a woundfin population in the Virgin River, additional stocking studies were conducted in 1999. Stockings occurred on May 7 and October 21, 1999, and red shiner removal efforts preceded both stockings. Red shiner removal consisted of sampling an Experimental Reach (between the Mesquite and Bunkerville Diversions) with seines for 3 consecutive days and removal of red shiner and other nonnative fishes just prior to the woundfin stockings. An additional red shiner removal was conducted in early June 2000 to remove red shiner around the spawning time for woundfin. This report discusses the results of the red shiner removals, subsequent monitoring of stocked woundfin, use of an injectable elastomer dye as a marking technique, and results of monitoring three other sites from April 1998 to June 2000.

Over 7,800 red shiner were removed from the 5-mile Experimental Reach between the two diversion dams on May 4, 5, and 6, 1999. Approximately 1,700 1-year-old woundfin were stocked into the reach on May 7. Woundfin numbers declined during the summer to relatively low numbers by August. Red shiner numbers increased because of spawning and growth of young during the same period. This experiment suggested that even with lower red shiner numbers, 1-year-old woundfin still could not survive in the lower Virgin River. The only positive note was that some reproduction of woundfin did occur during the summer; however, those young also disappeared by the end of the summer.

A second red shiner removal occurred on October 19, 20, and 21, 1999, and over 20,000 red shiner were removed from the Experimental Reach. On the evening of October 21, approximately 9,500 young-of-the-year (YOY) woundfin were stocked. Catch rates of these fish remained fairly consistent throughout the winter of 1999-2000 and the spring of 2000. On June 6, 7, and 8, 2000, another red shiner removal was conducted and over 7,000 red shiner were captured. An injectable elastomer dye was used to mark woundfin on June 6, and recaptures on June 7 allowed for a population estimate which showed that about 625 stocked woundfin survived from the October 1999 stocking. In addition, over 240 YOY woundfin were collected, indicating the stocked fish had spawned successfully. This experiment suggested that stocking larger numbers of younger hatchery-reared woundfin resulted in much improved survival compared with using older fish.

Continued monitoring of three other study reaches (Riverside, Mesquite, and Beaver Dam Wash) from April 1998 to June 2000 showed that: a small wild woundfin population continued to exist at the Riverside Reach, all native fish except woundfin were fairly common in the Beaver Dam Wash Reach, and the Mesquite Reach did not harbor many native fishes. Red shiner numbers remained very high in the Riverside and Mesquite reaches.

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INTRODUCTION

The Virgin River is home to six native fish species, including the endangered woundfin (*Plagopterus argentissimus*) and Virgin River chub (*Gila seminuda*). Water withdrawals, habitat alterations, and the proliferation of nonnative fish species have all led to the decline of native fishes, especially the woundfin, in the Virgin River, most notably in the Nevada reaches where only low numbers of native species survive among large numbers of the nonnative red shiner (*Cyprinella lutrensis*) (Deacon and Hardy 1984, Deacon 1988, Holden and Abate 1999). The Virgin River Fishes Recovery Plan identifies the removal of nonnative species, especially red shiner, and re-establishment of the native fish community, especially woundfin, as one of its top objectives (USFWS 1995). The general protocol used to meet this objective is poisoning river reaches between fish barriers, starting at the upstream limit of red shiner occurrence, and allowing the river to recolonize with native species, either by downstream movement from native fish strongholds or by stocking hatchery-reared fish. Poisoning in the lower Virgin River (Arizona and Nevada) will not occur until all upstream reaches have been restored with native fishes. In the upper Virgin River in Utah, attempts at red shiner eradication have already begun (Comella and Fridell 1998). Although initially successful, the numerous attempts to poison the first 4-mile reach of river in Utah since the early 1990s have ended with the eventual recolonization of red shiner.

In an attempt to initiate recovery activities in the lower Virgin River prior to poisoning and to better understand how hatchery-reared fish can be used to recolonize an area, several studies have been conducted in the Arizona and Nevada portions of the Virgin River since the early 1990s. Holden and Abate (1999) conducted fish population studies in the lower river from 1993 through 1997, and monitoring activities have continued to the present time. These studies clarified what native fish populations still existed in the lower river and where they were found. In 1993, the Nevada Division of Wildlife (NDOW) began stocking woundfin from Dexter National Fish Hatchery into the Nevada reaches of the Virgin River. The purpose of this stocking was to evaluate marking techniques and determine how hatchery-reared fish could be successfully reintroduced to historic habitats (Heinrich 1999). Woundfin were marked, primarily using a coded wire tag, and stocked around the Mesquite and Riverside Bridge areas from October to April during the 1993 to 1998 time period. Unfortunately, the stockings proved to be unsuccessful, with few fish surviving more than 2 or 3 months after being stocked (Heinrich 1999). Heinrich (1999) concluded that either the habitat in the Nevada reaches was unsuitable for woundfin survival or that hatchery-reared woundfin were unable to survive when reintroduced to the riverine environment.

One of the reasons that habitat may be unsuitable in the Nevada reaches is the abundance of red shiner. Red shiner have been implicated in the decline of native fishes in the Virgin River, including the federally endangered woundfin (Cross 1975, Gregory and Deacon 1994, Holden and Abate 1999). Therefore, stocking woundfin in areas with large red shiner populations may not allow the best chance for survival. Additionally, most of the woundfin stocked by Heinrich (1999) were close to 1-year old (age-1). Trammel and Archer (2000) had excellent success stocking young

of year (YOY) Colorado pikeminnow in the San Juan River. Younger fish (4- to 5-months old versus 1 year) of some species may be better able to adapt to the natural riverine conditions (feeding, habitat, predators) compared with adults that were raised in hatchery ponds on artificial feed in a predator-free environment. Understanding survival limitations of hatchery-reared woundfin is a crucial part of any effort to restore woundfin populations to viable levels following poisoning or to restore woundfin to areas where they have become locally extinct. In addition, an understanding of the interactions between woundfin and red shiner that effect woundfin survival is also important for the eventual recovery of woundfin in the Virgin River.

In May 1999, the Lower Virgin River Recovery Implementation Team began an experimental woundfin stocking study directed at systematically evaluating stocking efforts in order to better understand mechanisms limiting their success. BIO/WEST, Inc. (BIO/WEST) took the lead role in these studies, working cooperatively with the Southern Nevada Water Authority (SNWA), NDOW, Arizona Game and Fish Department, U.S. Bureau of Reclamation (USBR), and U.S. Fish and Wildlife Service (USFWS). An Experimental Reach bounded by diversion structures was chosen as the site of the experiments. Although not impassible, the diversions prevented extensive upstream movement of red shiner and woundfin, and provided clear boundaries of the study reach.

From May 1999 through June 2000, the Experimental Reach was subjected to three red shiner removal efforts, two of which were followed by stocking woundfin. The objectives of the study were to determine (1) if red shiner numbers could be significantly reduced through mechanical means, (2) if a reduction in red shiner numbers allowed better survival of stocked woundfin, and (3) if higher numbers of young hatchery-reared woundfin survive better than lower numbers of adult hatchery-reared woundfin. Meeting these objectives may provide necessary information for the future management and success of woundfin recovery efforts throughout the Virgin River. Support for these studies was provided by SNWA funding for lower Virgin River studies and by the USBR in Boulder City, Nevada, through Federal Grants No. 99-FG-30-00050 and 00-FC-30-0019. This report covers the results of the study from May 1999 to June 2000.

The study is continuing into 2001 with additional funding from the SNWA, USBR, and USFWS in Salt Lake City, Utah, and may continue for several years. Similar annual progress reports will be provided each study year. This report provides the results of red shiner removals, subsequent woundfin stockings, and follow-up monitoring from May 1999 to June 2000, as well as results of a June 2000 population estimate of the remaining stocked woundfin. In addition, this report includes an update on BIO/WEST's continued monitoring of three other long-term study reaches on the lower Virgin River.

METHODS

Study Area

The study area for these projects is the section of the Virgin River extending from the mouth of Beaver Dam Wash in Arizona to Lake Mead, Nevada (Figure 1). In 1996, BIO/WEST established

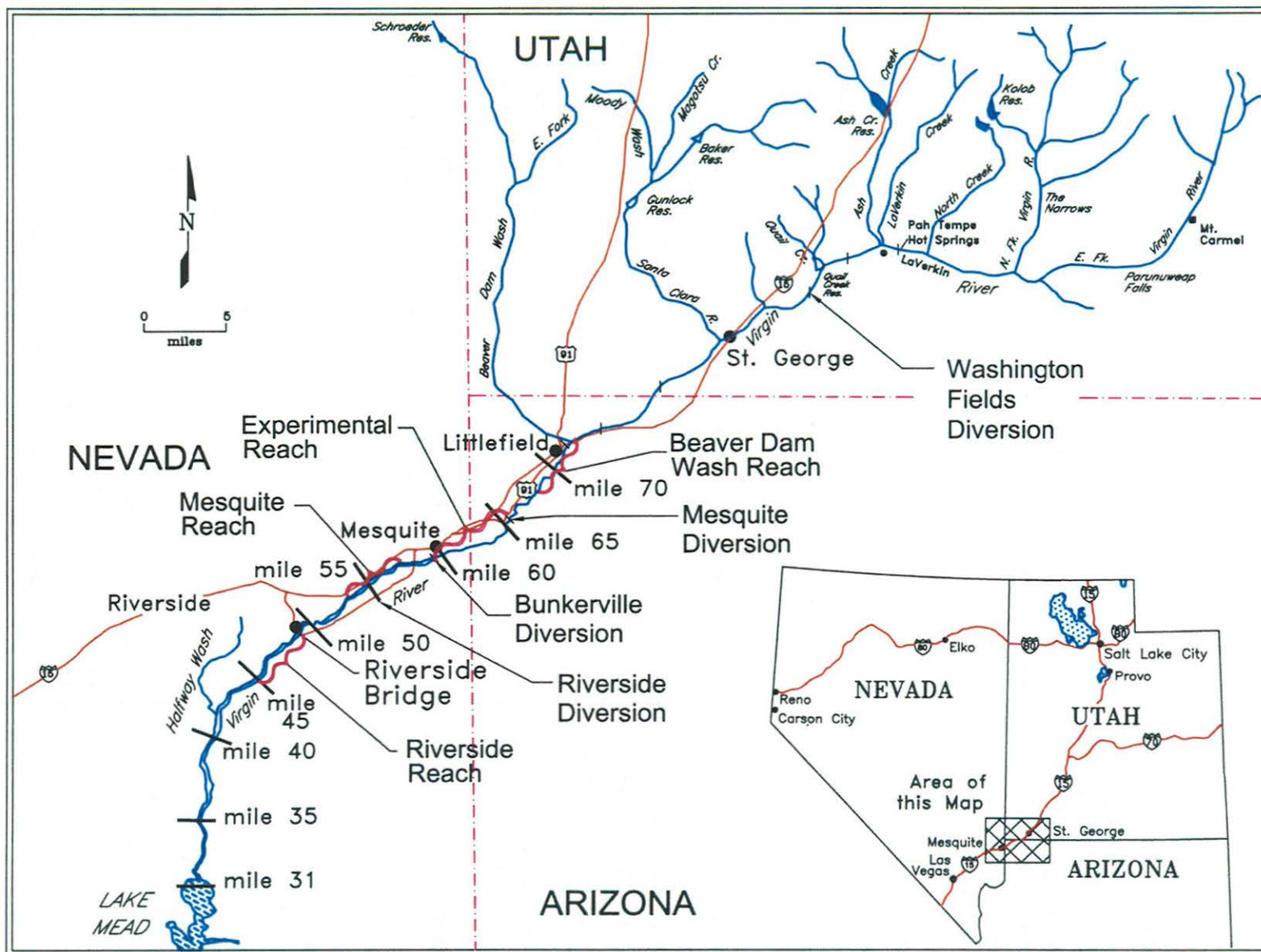


Figure 1. Study area map showing location of sampling reaches.

three standard monitoring reaches in this area of the river: the Beaver Dam Wash Reach starting at the mouth of Beaver Dam Wash and extending 3.5 miles downstream (River Mile [RM] 72.00 - 68.50), the Mesquite Reach starting at the Mesquite Bridge and extending 3.5 miles downstream (RM 58.00 - 54.50), and the Riverside Reach starting at the Riverside Bridge and extending 3.5 miles downstream (RM 49.25 - 45.50). Holden and Abate (1999) provide a more-complete description of these three reaches.

In May 1999, an Experimental Reach was established to carry out woundfin stocking and red shiner removal experiments. The area selected for this study was a 4- to 5-mile reach of the Virgin River in Arizona and Nevada contained between two diversion structures (RM 63.3 to 59.25 according to topographic quad map; however, the river meandered more than shown on the map and so it was slightly longer). The most-upstream structure, the Mesquite Diversion, is located approximately 3.0 to 3.5 miles above the Arizona-Nevada state line (RM 63.3). The Bunkerville Diversion is approximately 1.5 miles below the state line (RM 59.25). Although sites within this reach have been sporadically monitored throughout the years of woundfin research, this reach has not been part of a regular monitoring or research program. This reach was selected because it was expected that a red shiner reduction effort would be more effective over time if the reach was somewhat isolated from red shiner immigration through its relatively impassable diversions at either end.

The reach is physically characterized as similar to the contiguous downstream reach (the Mesquite Reach) regularly sampled during the ongoing monitoring conducted by BIO/WEST. Just below the Mesquite Diversion where the channel is maintained between conglomerate bluffs on either side, the channel has small cobble and sand islands, and a relatively high portion of cobble substrate (RM 63.3 to RM 62.75). After a short section bound by tamarisk and willow banks (RM 62.75 to RM 62.25), the floodplain widens and the substrate is more sandy overall, with small sections of cobble substrate creating slow riffles and areas of channel braiding. The channel remains this way to the Bunkerville Diversion, except for a few short (<0.5 mile) sections bound by tamarisk and willow. For approximately 0.25 mile above the Bunkerville Diversion, the substrate is characterized by exceedingly deep, shifting sand and tamarisk and willow banks. These characteristics are common above diversion structures where pooled water allows sediment to form deep deposits, causing banks to become stabilized by the grade structure.

Fish Sampling

The basic sampling methodology involved one crew (two people seining and one person recording data) walking downstream through a reach, sampling with a 4 by 15 foot seine with 0.125 inch mesh. The number and type of habitats sampled represented a stratified, random sampling design (similar effort within each river mile and among habitat types; habitat types were chosen randomly within river miles). As much habitat as possible was sampled. During low-flow conditions, a higher percentage of available habitat was seinable than during high-flow conditions. Each sample followed the protocol used by BIO/WEST for monitoring the lower Virgin River (Holden and Abate 1999). This protocol involves completing a data sheet for each seine haul. Data recorded includes habitat type, river mile, date, time-of-day, habitat area, habitat length, water temperature

(hourly), crew names, number of each species collected, and total length of all native fishes (until a total of 100 fish per species was collected). Native fishes were returned to the river unharmed, and nonnative fishes were discarded on the river bank.

Stream temperature was measured with a hand-held mercury thermometer approximately every hour during sampling trips. Flow information was obtained from the U.S. Geological Survey for the Virgin River at Littlefield gage. Flows in the river were checked via telephone and the Internet prior to field trips. Field trips generally were not conducted when average daily flows were over 300 cubic feet per second (cfs), since this flow level made seining in the river difficult and inefficient.

Removals and Stockings

Methods used during the red shiner reduction effort were similar to those described for fish sampling. Seining focused on quantity of habitats sampled and habitats that were expected to yield high numbers of red shiner rather than sampling habitats thought to be more suitable for woundfin (e.g., backwaters v. pools below riffles) or a stratified random design. Habitat measurements were not taken, data were recorded in field notebooks, and only endangered fish were measured during the red shiner removal efforts. Native fishes were returned to the river, and nonnative fishes were discarded. Seining crews with personnel from BIO/WEST, USBR, SNWA, NDOW, University of Nevada-Las Vegas, and USFWS all participated in one or more of the red shiner removals. Several crews were typically available, and they were split between the upper and lower portions of the Experimental Reach. During the third day of removal, crews typically were combined to sample the upper portion of the reach where red shiner were more common.

Immediately following the red shiner removals, woundfin from Dexter National Fish Hatchery were stocked at two sites in the Experimental Reach just below the Arizona-Nevada border around RM 60.00. The numbers stocked in May and October were ~1,700 and ~9,500, respectively. Woundfin stocked in May 1999 were all marked with coded wire tags (Northwest Marine Technology), were primarily 1-year-old fish spawned in May 1998 and had a mean length of 66.5 mm ($n = 103$). Most of the fish stocked in October 1999 were YOY spawned in May 1999 and had a mean length of 56 mm ($n = 131$). A few of the October-stocked fish had been used for experiments at Willow Beach National Fish Hatchery and were a combination of 1998 and 1999 year-class fish. The fish were removed from a holding tank in the delivery truck and taken to the river in 5-gallon buckets. They were acclimated to river temperature for several minutes in the buckets and then allowed to swim out of the buckets.

Monitoring Protocol

The first monitoring took place within 1 week after each stocking. The purpose of this trip was to set a baseline prior to extensive mortality of the stocked fish so that future mortality could be discerned from capture efficiency. After the May stocking, the reach was monitored bimonthly until July and once in August. After the October stocking, the reach was monitored bimonthly until January and then monthly until the June removal. Monitoring included 1 full day of seining the

entire reach (from the Mesquite Diversion to the Bunkerville Diversion). After the October monitoring, sampling of the reach was sometimes increased to 2 days to allow for more-intense sampling. Overall, 17 monitoring trips were conducted in the Experimental Reach between May 1999 and May 2000, and seven monitoring trips were conducted in the other reaches from April 1998 through May 2000. BIO/WEST personnel led most monitoring trips, the remainder were led by NDOW. Crew members were comprised of BIO/WEST, SNWA, NDOW, or USBR biologists. Methods described above for fish sampling were employed on all monitoring trips.

Mark and Recapture Estimate

During the June 2000 red shiner removal, BIO/WEST conducted a mark and recapture woundfin population estimate. Woundfin were marked with a visible implant fluorescent elastomer tag (Northwest Marine, Inc.). The tag was inserted under the skin on the back of the fish near the dorsal fin with a small hypodermic syringe and needle. On the first day, crews in the upper reach tagged woundfin at the base of the dorsal fin on the right side with red elastomer. Crews in the lower reach tagged woundfin at the base of the dorsal fin on the right side with green elastomer. Untagged fish caught on the second day were tagged with the same colors, but on the left side at the base of the dorsal fin. A population estimate was made from day one to day two using the Petersen-Jackson Method, $N = Mn/m$ where N = the population, M = the number initially marked and released on day one, n = the total number marked and unmarked individuals caught on day two, and m = the number of marked individuals found on day two.

RESULTS

Flow and Temperature Data

Figure 2 shows flows in the Virgin River at the USGS gage near Littlefield, Arizona (USGS Gage # 094150000), during the study period. Flows during 1998 were relatively high with April, May, and June flows over 300 cfs and peak flows during runoff over 1,000 cfs. Flows during 1999 and 2000 were low with no obvious spring peak, and flows at the Littlefield gage were below 100 cfs by June during both years. Summer flows in 1999 were enhanced by storm events, and the river remained fairly turbid until late summer when it became clear. In 2000, flows dipped below 100 cfs prior to May 15, and the river became clear in late May. Peak flow in 2000 occurred in February, when peak discharge reached 877 cfs.

Figure 3 shows the lowest and highest daily stream temperatures recorded during sampling trips in all reaches. Temperatures ranged from a low of 7° C in January 2000 to a high of 31.5° C in July of 1998. Diel fluctuation varied from 1° C in February 2000 to 13° C in June 1999. In general, highest temperatures were measured on summer afternoons, and the lowest temperatures on winter mornings. Although both 1999 and 2000 were low-flow years, differences did occur. Temperatures over 30° C occurred in May 2000, but they did not occur until June in 1999. Flow also was lower earlier in 2000 than 1999.

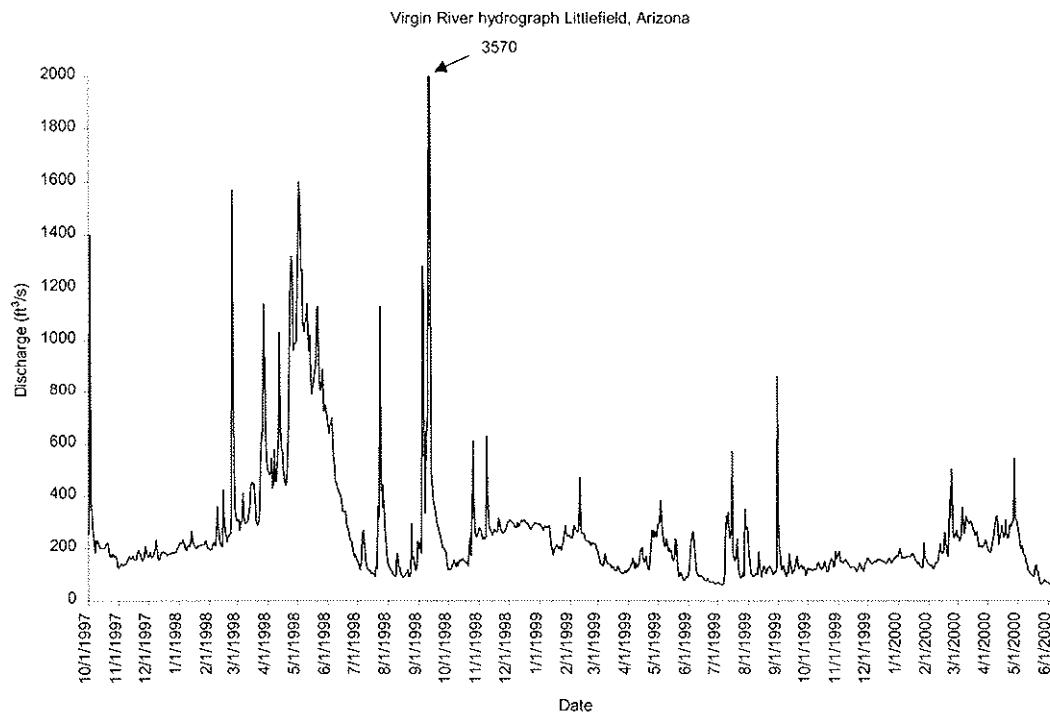


Figure 2. Mean daily discharge at the USGS gage near Littlefield, Arizona, January 1998 to June 2000.

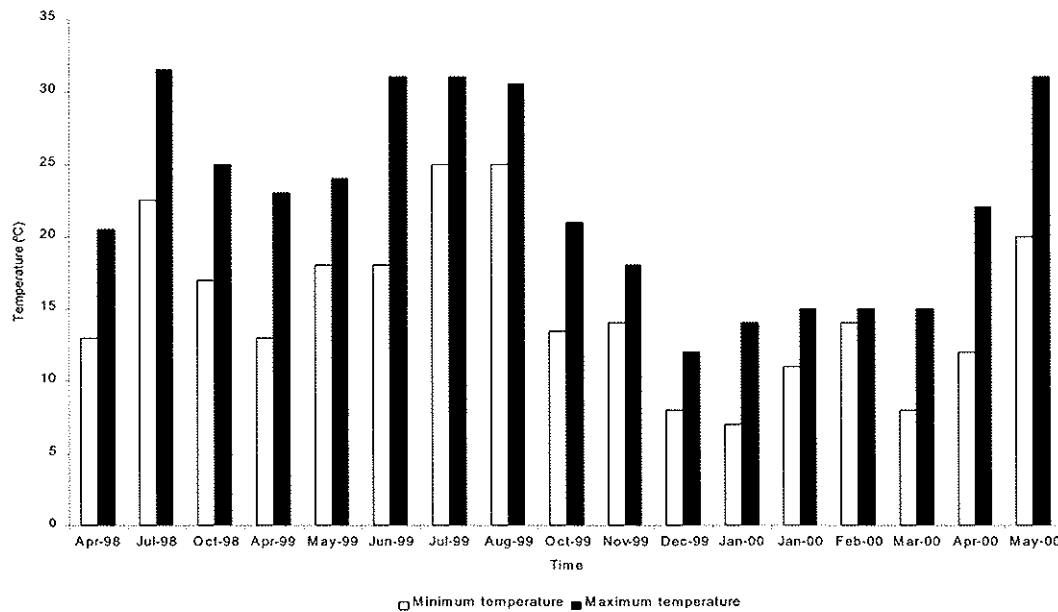


Figure 3. Maximum and minimum surface water temperature as measured during sampling trips on the Virgin River, April 1998 to June 2000.

May 1999 Red Shiner Removal and Woundfin Stocking

The first red shiner removal effort occurred on May 4, 5, and 6, 1999. Table 1 shows the number of seine hauls and fish caught during the removal. The red shiner catch rate declined over the 3 days of the May 1999 removal. A total of just under 8,000 red shiner was removed from the river, and only nine wild woundfin were collected during the 3 days of sampling. Over 23,000 YOY suckers dominated the collections. Six Virgin River chub were collected in the 630 seine hauls. Approximately 1,700 1-year-old woundfin were stocked in the Experimental Reach near the Nevada-Arizona border on May 7, following the 3 days of red shiner removal.

Table 1. Number of seine hauls and all species captured during the May red shiner removal in the Experimental Reach (RM 63.25 - 59.25).

DATE	# HAULS	RS ^a	RS (CR)	WF	WF (CR)	FM	DS	YS	SD	RC	MF	BB	CC	CP	LB
05/04/1999	153	2,936	19.19	2	0.01	18	8	6,302	189	3	0	1	0	0	0
05/05/1999	183	1,683	9.20	4	0.02	97	20	5,615	201	0	0	3	2	0	2
05/06/1999	294	3,186	10.84	3	0.01	100	32	11,645	211	3	0	2	2	0	0
Total	630	7,805	12.39	9	0.01	215	60	23,562	601	6	0	6	4	0	2

^aRS = red shiner, WF = woundfin, FM = flannelmouth sucker, DS = desert sucker, YS = young-of-year suckers, SD = speckled dace, RC = Virgin River chub, MF = mosquitofish, BB = brown bullhead, CC = channel catfish, CP = common carp, LB = largemouth bass, CR = the catch rate in # of fish/seine haul.

High flows in the Virgin River at the time of the May removal most likely decreased effectiveness of seining. On May 4, flows were over 300 cfs by 8:00 a.m. and rose to over 500 cfs that evening (mean daily discharge for May 4 was 417 cfs). The flow of over 500 cfs was the peak discharge for the 1999 spring runoff season. The high flows resulted in difficult seining conditions and poor efficiency. Flows remained around 300 cfs throughout the day on May 5 (mean daily discharge was 323 cfs). On the third day, May 6, mean daily discharge was 263 cfs. Flows dropped from just under 300 cfs in the morning to just above 250 cfs later that day.

The Experimental Reach was monitored six times prior to the October removal. Table 2 shows the number of fish of all species caught during these sampling trips. Woundfin catch rate peaked on the June 24, 1999, sampling trip, about 6 to 7 weeks after the fish were stocked. However, over 55% of the 25 woundfin captured did not have coded wire tags. The catch rate at the end of July was similar to the May and June catch rates. The catch rate is deceiving in the July collection because only eight of the 18 fish caught were adults, and of those eight only three had coded wire tags. By August no woundfin with coded wire tags were found, and only five adult woundfin were captured. It is suspected that the coded wire tags were shed fairly rapidly by the woundfin and that most of the adult woundfin collected during the monitoring were stocked fish. Woundfin did reproduce during summer 1999 in the Experimental Reach as evidenced by collection of YOY (Figure 4). It is likely that some of the stocked fish reproduced, perhaps along with the few wild

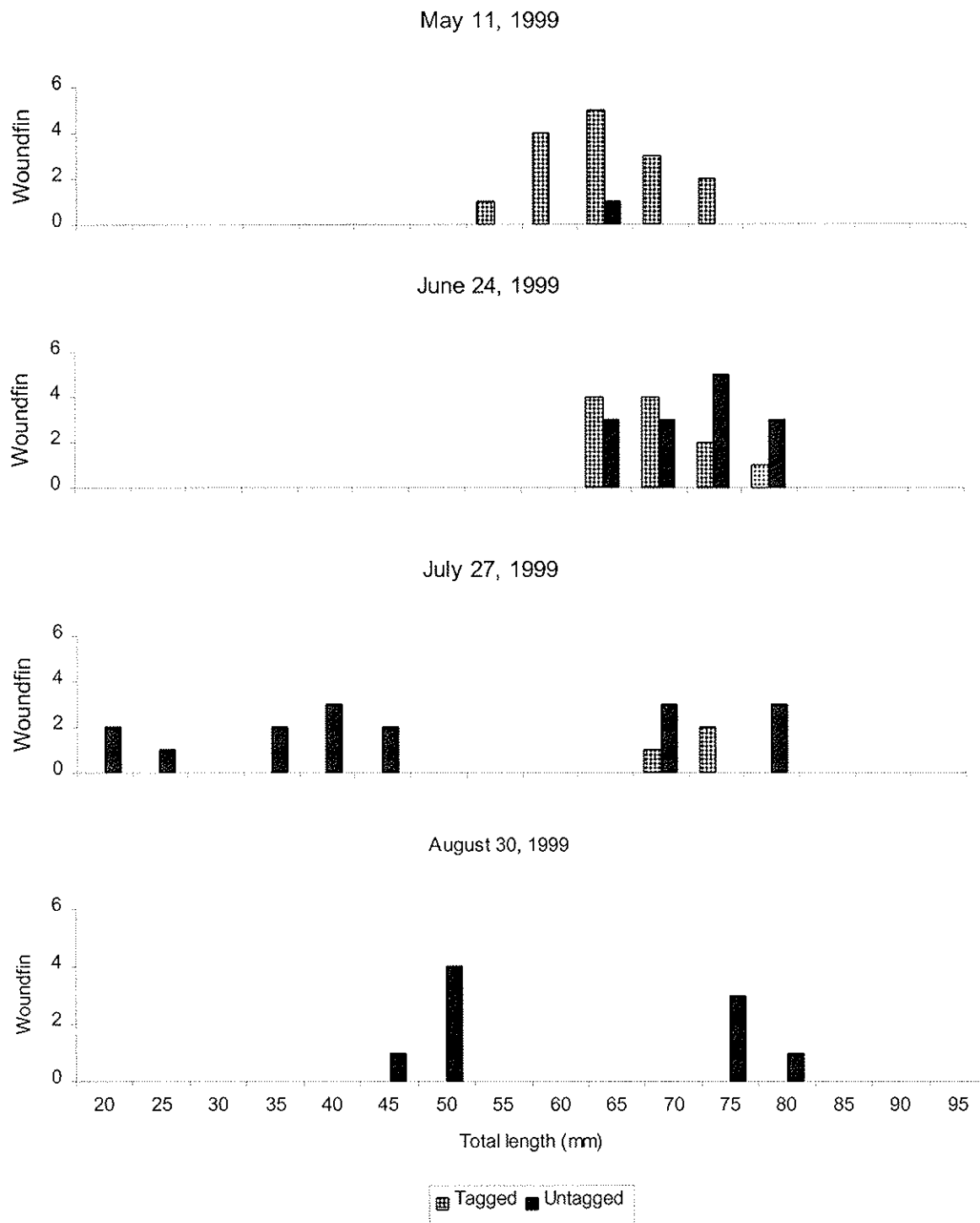


Figure 4. Length frequency diagrams for woundfin caught in the Experimental Reach during the monitoring following the May, 1999 stocking.

Table 2. Number of seine hauls and all species captured on each day of sampling from May 11, 1999 through August 30, 2000.

DAY	SEINE HAULS	WF ^a	WF (CR)	WF (YOY)	RS	RS (CR)	RC	YS	FM	DS	SD	BB	CC	LB	MF	CP
5/11/99	118	17(16)	0.14	0	812	6.88	0	2,665	18	8	207	1	0	0	0	0
6/1-2/99	225	36(2)	0.16	0	2,471	10.98	3	3,879	102	2	11	0	0	0	0	0
6/24/99	98	25(11)	0.26	0	405	4.13	6	0	907	360	44	0	0	0	1	4
7/15/99	109	1	0.009	0	1,031	9.46	7	0	572	39	53	17	0	4	0	0
7/27/99	105	8(3)	0.17	10	1,229	11.7	0	0	541	364	220	1	3	0	6	0
8/30/99	109	5(0)	0.09	5	2,931	26.89	7	0	465	246	93	1	9	0	3	1

^aWF = woundfin, RC = Virgin River roundtail, FM = flannelmouth sucker, DS = desert sucker, SD = speckled dace, RS = red shiner, BB = black bullhead, CC = channel catfish, LB = largemouth bass, MF = mosquitofish, CP = common carp, CR=the catch rate in # of fish/seine haul. Number in parentheses after woundfin is the number of captured woundfin that had tags.

fish. Virgin River chub numbers remained low throughout summer 1999, but native sucker numbers remained high (Table 2).

The red shiner catch rate remained low during the June and July sampling trips but increased dramatically during the August trip. This was because of the influx of YOY red shiner that had been too small to capture during June and July. Stocked woundfin declined prior to the increased catch of red shiner.

The important findings of this experiment were that the stocked woundfin had nearly disappeared as early as 10 weeks after they were introduced into the river system, similar to past experiments (Heinrich 1999), but the stocked fish did appear to reproduce for the short period they were in the river. Red shiner numbers were reduced by mechanical removal, but once the 1999 cohort became large enough to catch in the seines, red shiner numbers increased to pre-eradication numbers or higher.

October 1999 Removal and Stocking

A second removal was conducted on October 19, 20, and 21, 1999. During the October removal flows were much lower than those that occurred during the May removal. Mean daily discharges were 135 cfs, 110 cfs, and 108 cfs, respectively, for the 3 days of the October removal, and seining conditions were ideal. Over 20,000 red shiner were removed (Table 3), evidence of the excellent sampling conditions and increased sampling in the upper part of the reach where red shiner were more abundant. Almost three times the number of red shiner were removed in October than were removed in May, and catch rates were nearly 1.6 times higher in October (Table 3). The red shiner catch rate declined after the first day of the removal, indicating that red shiner were being significantly reduced in the Experimental Reach.

Table 3. Number of seine hauls and all species captured during the October red shiner removal in the experimental reach (RM 63.25 - 59.25).

DATE	# HAULS	RS ^a	RS (CR)	WF	WF (CR)	FM	DS	YS	SD	RC	MF	CC	CP	LB	GS
10/19/1999	251	7,552	30.09	1	0.003	237	70	0	8	11	319	1	0	0	0
10/20/1999	445	7,189	16.16	1	0.002	114	67	0	19	3	162	0	1	0	1
10/21/1999	356	5,399	15.17	3	0.008	227	55	0	43	32	68	1	1	0	0
Total	1,052	20,140	19.14	5	0.005	578	192	0	70	46	549	2	0	0	1

^aRS = red shiner, WF = woundfin, FM = flannelmouth sucker, DS = desert sucker, YS = young-of-year suckers, SD = speckled dace, RC = Virgin River chub, MF = mosquitofish, CC = channel catfish, CP = common carp, LB = largemouth bass, GS = green sunfish, CR = the catch rate in # of fish/seine haul.

During the October removal only 5 woundfin were caught in over 1,000 seine hauls, showing that woundfin numbers were virtually nonexistent in the reach and further confirming that the May stocking had not been successful. The young sucker catch remained high, and fairly high numbers of young Virgin River chub were collected. Most of these Virgin River chub were collected in the plunge pools below the Mesquite Diversion.

On October 21, approximately 9,500 woundfin from Dexter National Fish Hatchery, primarily YOY, were stocked into the Experimental Reach. After the October stocking, the reach was sampled 11 times before the June 2000 red shiner removal. Table 4 shows the number of fish of all species caught during these sampling trips. After the first sampling, woundfin catch rates were relatively high and consistent until February, when they peaked at 1.95 woundfin/seine haul. March also had a high catch rate before it fell to pre-February levels in April. May had the lowest catch rate of all sampling trips. The low initial catch rate can probably be attributed to the woundfin being fairly clumped in their distribution after stocking. Therefore, missing a few key seine hauls could have lowered the catch rate substantially. Flows on the February, March, and April trips were notably higher than the other sampling dates. On February 16 and 17, mean daily discharge was 186 and 260 cfs, on March 8 and 9 mean daily discharge was 254 and 270 cfs, and on April 11 mean daily discharge was 292 cfs. Most of the other sampling trips had flows between 100 to 150 cfs. Fish seemed to be utilizing more-shallow and slower side run habitats during the February and March trips, possibly contributing to a higher catch rate even with fairly high flows in the river. The highest flows, which occurred during the April trip, may have lowered sampling efficiency. The red shiner catch rates remained low during winter and spring monitoring, compared with the October removal period. The highest catch rates were in February and March, when flows may have forced many fish into slower side run habitats that were more accessible for sampling efforts.

Table 4. Number of seine hauls and all species captured on each day of sampling from 10/25/99 through 5/22/00.

DATE	SEINE HAULS	WF ^a	WF (CR)	RS	RS (CR)	RC	YS	FM	DS	SD	RC	MF	CC	CP	LB	BB	GS
10/25/99	125	63	0.5	786	6.29	1	0	173	113	50	1	9	1	0	0	0	0
11/8-9/99	134	169	1.26	949	7.08	2	0	124	179	59	2	0	4	2	0	0	0
12/2-3/99	174	132	0.76	1,461	8.40	8	0	91	87	7	8	0	0	0	0	0	0
12/13-14/99	142	108	0.76	237	1.67	0	0	54	115	13	0	4	0	0	0	0	0
12/29-30/99	250	176	0.70	1,687	6.7	1	0	55	45	7	1	74	0	0	0	0	0
1/11-12/00	158	122	0.77	349	2.21	0	0	15	50	3	0	0	0	0	0	0	0
1/24-25/00	163	112	0.69	900	5.52	0	0	38	74	3	0	8	0	0	1	0	0
2/16/00	102	199	1.95	1,343	13.16	1	0	427	270	86	1	2	10	0	0	1	0
3/8-9/00	116	199	1.72	2,122	18.29	1	0	280	180	48	1	6	25	1	0	1	5
4/11/00	117	98	0.84	1,247	10.7	3	0	108	71	66	3	0	8	0	0	2	5
5/22/00	134	32	0.24	650	4.85	1	1,485	170	44	27	1	0	0	0	13	0	10

^a WF = woundfin, RS = red shiner, FM = flannelmouth sucker, DS = desert sucker, YS = young-of-year suckers, SD = speckled dace, RC = Virgin River roundtail, MF = mosquitofish, CC = channel catfish, CP = common carp, LB = largemouth bass, BB = black bullhead, GS = green sunfish, CR = the catch rate in # of fish/seine haul.

Length frequency graphs (Figures 5a and 5b) show that the stocked woundfin seemed to exhibit little growth over winter. The average size per sampling trip did not increase from the average size at stocking until February, when it increased to 60 mm. By May, the average size of captured woundfin had risen to 68.5 mm. The stocked woundfin also changed distribution in the Experimental Reach during the monitoring (Figure 6). During the fall they spread upstream from the stocking areas and were most common in RM 63 just below the Mesquite Diversion. During the winter, they spread downstream and were common throughout the reach except for RM 59. During spring, they were most common in RM 62 as they concentrated in riffle habitats for spawning.

June 2000 Removal and Population Estimate

The third red shiner removal occurred during June 6, 7, and 8, 2000. Mean daily discharge was the lowest of any of the sampling trips, measuring 75 to 86 cfs at the Littlefield gage. However, irrigation withdrawals had dropped flows in the Experimental Reach even further. Flows were estimated 35 to 45 cfs, and they declined over the 3 days in the Experimental Reach. These low flow conditions promoted incredibly high water clarity, which may have reduced seining effectiveness during this time period by allowing fish to see researchers and move away from the net. Table 5 shows the number of fish of all species caught during these sampling trips. Red shiner numbers were almost three times lower than during the October removal, and catch rates were the lowest of all three removals, indicating that the October red shiner removal successfully lowered the number of red shiner for almost 8 months. However, large numbers of YOY red shiner, too small to capture in the seines, were evident along shorelines and in quiet water areas throughout the Experimental Reach.

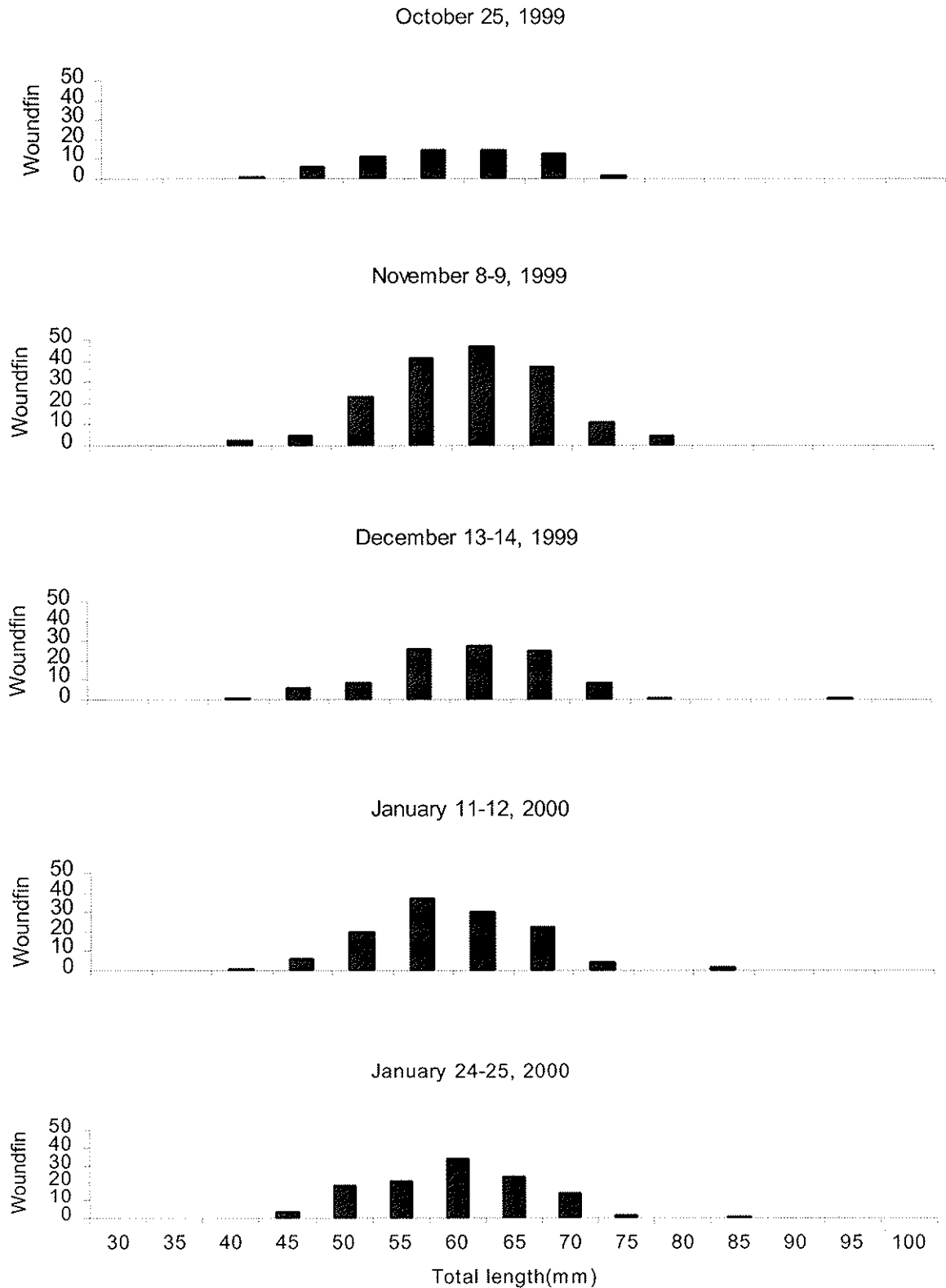


Figure 5a. Length frequency histograms of woundfin caught in the Experimental Reach from October 1999 to January 2000.

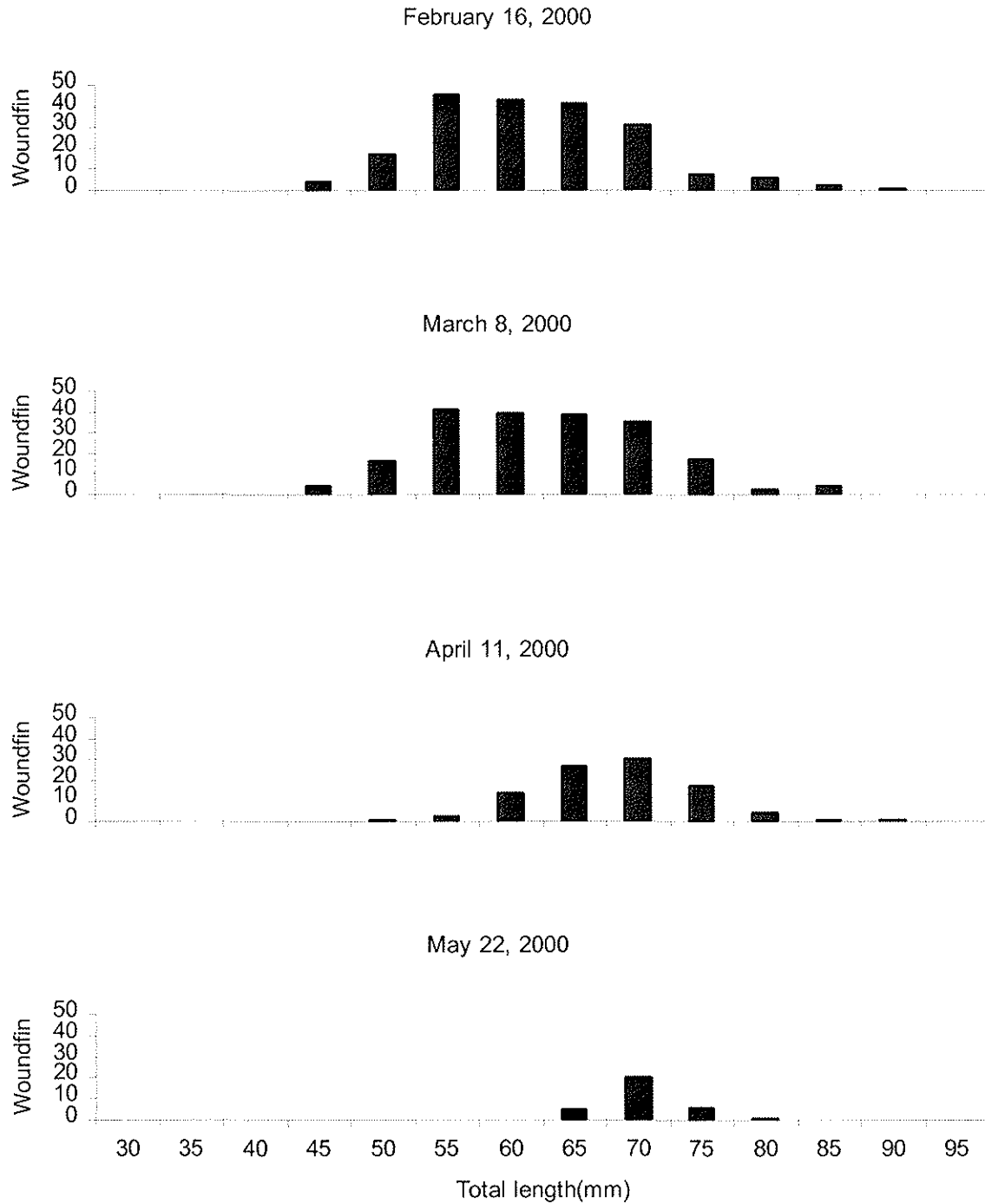


Figure 5b. Length frequency histograms of woundfin caught in the Experimental Reach from February to May 2000.

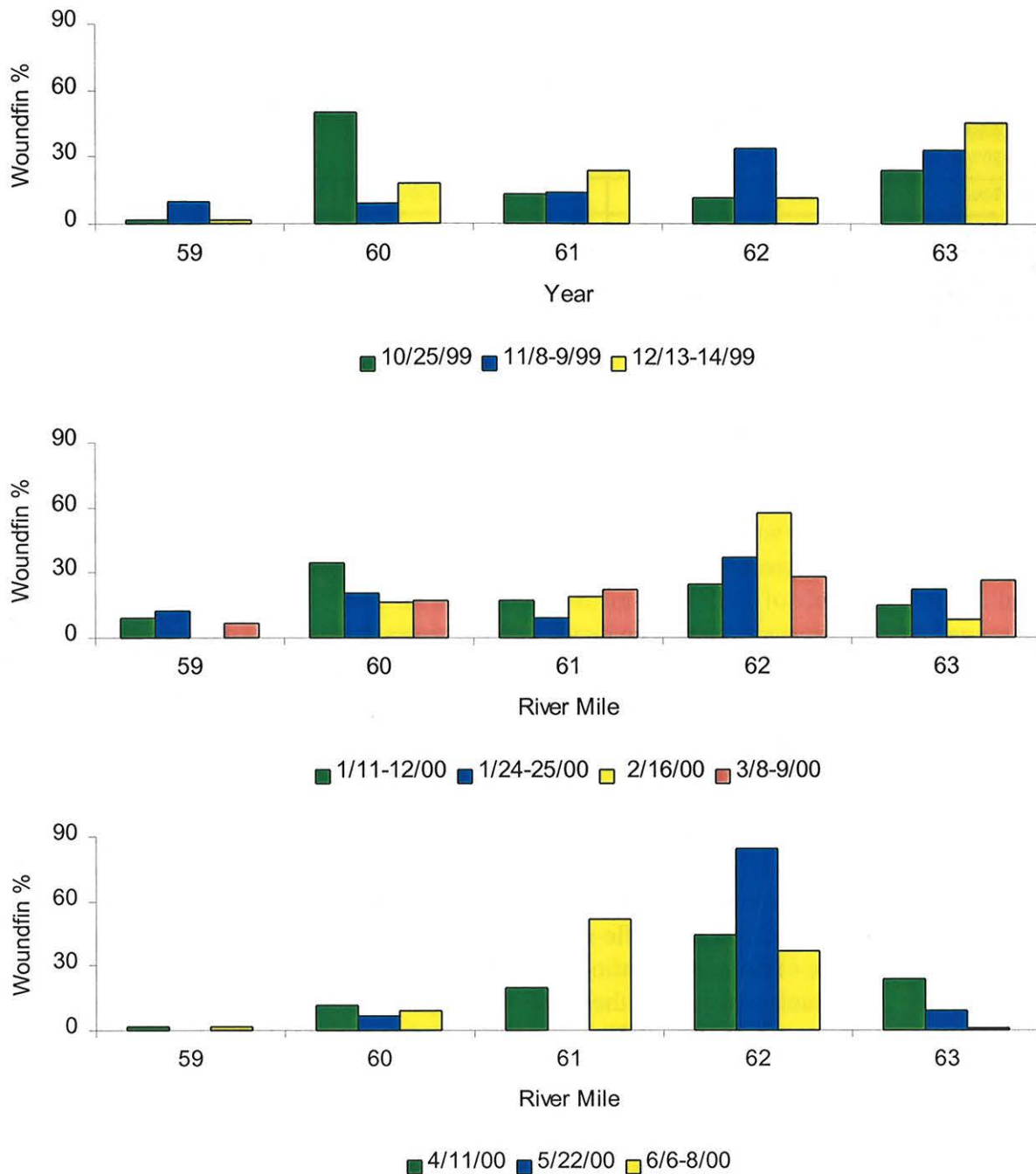


Figure 6. Woundfin captured per river mile throughout the follow-up monitoring to October stocking. River Mile 63 = Mesquite Diversion RM 63.30 to RM 63.00, River Mile 62.00 = RM 63.00 to 62.00, River Mile 61 = RM 62.00 to 61.00, River Mile 60 = RM 61.00 to 60.00, River Mile 59.00 = RM 60.00 to Bunkerville Diversion.

Table 5. Number of seine hauls and all species captured during the June red shiner removal in the Experimental Reach (RM 63.25 - 59.25).

DATE	# HAULS	RS ^a	RS (CR)	WF	WF (CR)	WF (YOY)	FM	DS	YS	SD	RC	MF	CC	CP	LB
06/06/2000	436	3,707	8.50	142	0.33	7	4,786	182	1,251	100	2	149	0	45	50
06/07/2000	479	2,389	4.99	185(42)	.39	163	500	104	5,196	175	3	156	1	4	11
06/08/2000	202	1,074	5.32	73(47)	.36	72	102	24	1,041	66	3	16	0	1	2
Total	1,117	7,170	6.42	400	.36	242	5,388	310	7,488	341	8	321	1	50	63

^aRS = red shiner, WF = woundfin, FM = flannemouth sucker, DS = desert sucker, YS = young-of-year suckers, SD = speckled dace, RC = Virgin River chub, MF = mosquitofish, CC = channel catfish, CP = common carp, LB = largemouth bass, CR = the catch rate in # of fish/seine haul. Number in parentheses after the number of woundfin signifies the number of recaptures.

Additionally, 311 individual adult woundfin were captured during the 3 days of the June 2000 removal. Marking adult woundfin with the elastomer dye allowed for recapture determination on June 7 and 8, hence the total of 400 woundfin for the 3 days in Table 5 both new fish and recaptures. A total of 89 woundfin was recaptured during the last 2 days of sampling. In addition, 242 YOY woundfin were collected. Because of their small size and the potential effects of handling, only a sample of YOY were measured (Figure 7). The YOY woundfin in the 15-25 mm size range had not been previously seen by most of the crews, so numbers reported on the first day of the removal were lower than those actually captured. Discussions that evening, and closer inspection the second day, confirmed that YOY woundfin were being collected, and the numbers reported increased during the next 2 days (Table 5). Adult woundfin were generally found in or near riffle and riffle run habitats during the removal. These habitats are suspected spawning areas.

Figure 8 shows the habitats in which woundfin were collected during the study from May 1999 to June 2000. Run habitat was primarily used, except for the first sampling after the October stocking while the stocked fish were still becoming familiar with their new environment. A significant change in habitat use, to riffles and riffle-runs, occurred during May and June 2000, as spawning commenced. Because of the concentration of woundfin in these habitats, up to 22 woundfin were captured in an individual seine haul in these habitats. This habitat shift may have been the reason for the low woundfin catch in May 2000, since riffles had not been targeted previously and were not targeted during that trip.

The elastomer dye-marking system worked extremely well with the adult woundfin. The tags were easy to administer, had little apparent effect on the fish, and were easy to see when the fish was recaptured. Using the Petersen-Jackson mark and recapture method for June 6 and 7, a population estimate of adult woundfin for the reach was calculated as follows:

$$\begin{aligned}
 N &= Mn/m, \\
 N &= 142(185)/42 = 625 \\
 \text{S.E.} &= [Mn^2 (n-m)/m^3]^{0.5} = [142^2 185^2 (185-42)/42^3]^{0.5} = 96.85 \\
 N &= 625 \pm 97 = 528 - 722
 \end{aligned}$$

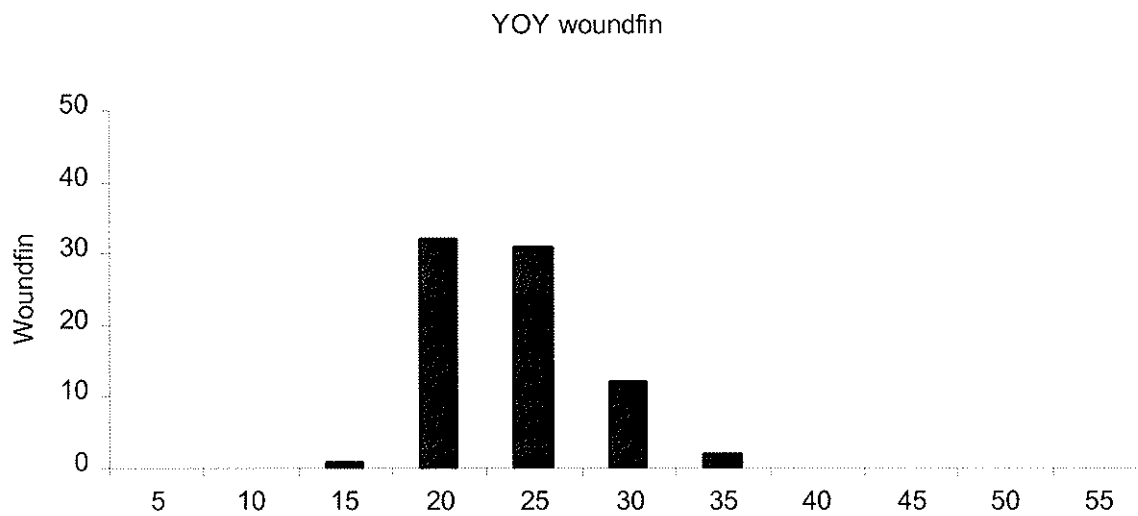
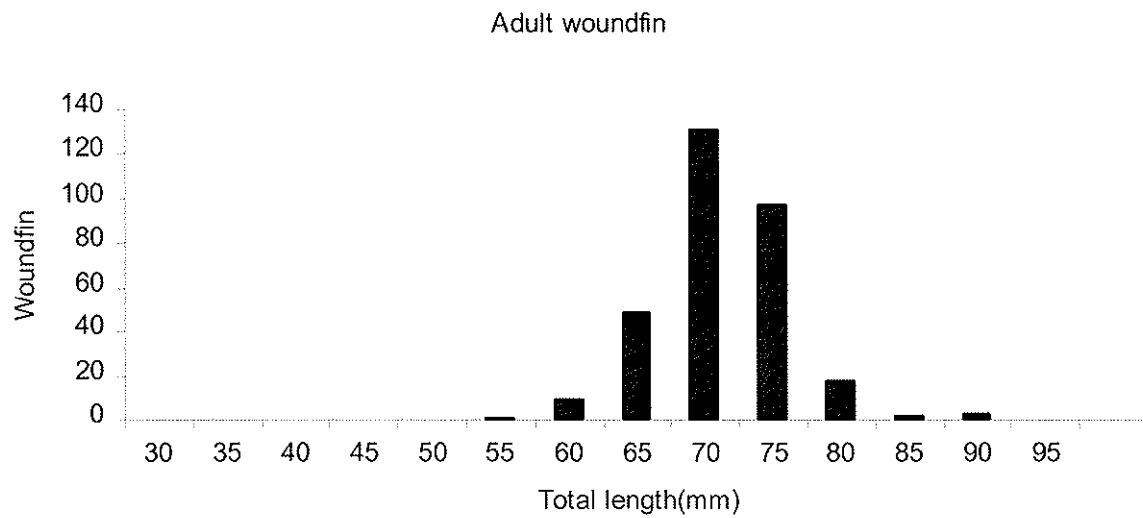


Figure 7. Length frequency histograms of young-of-year (YOY) and adult woundfin caught during the June, 2000 red shiner removal.

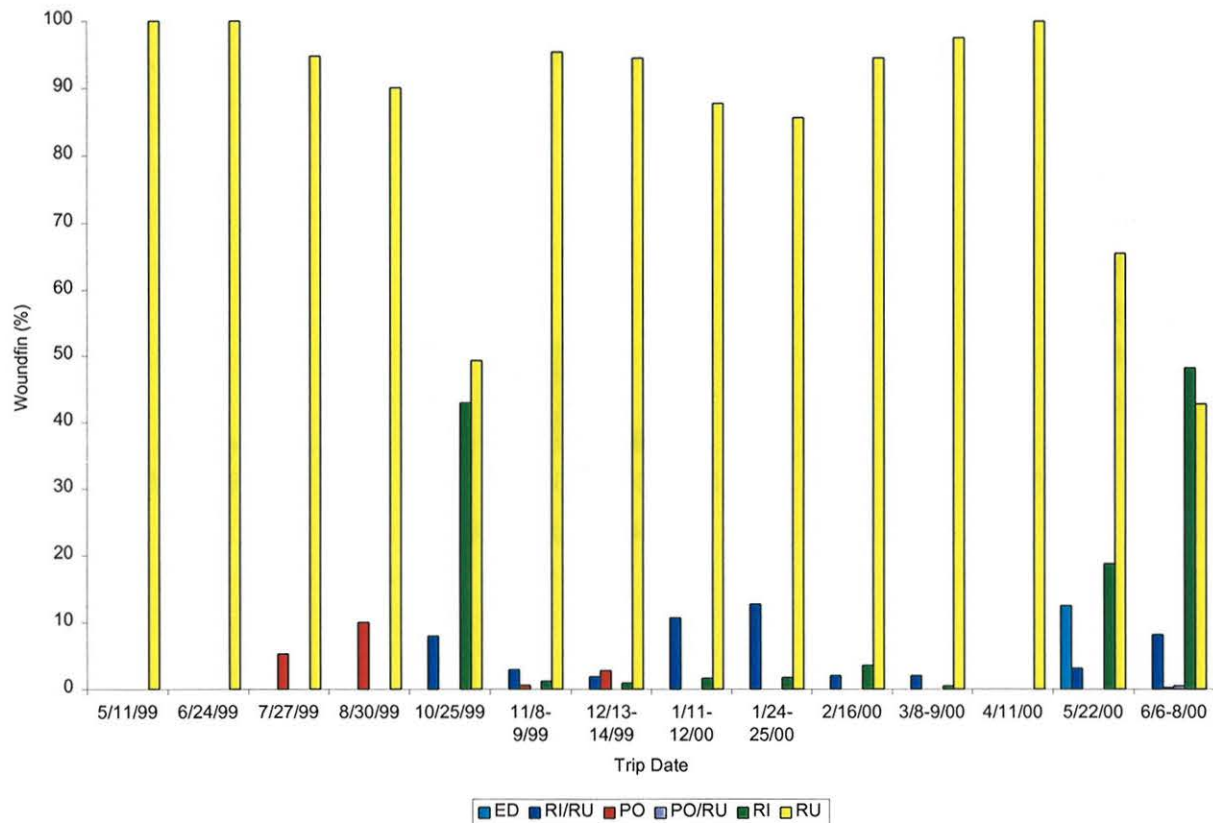


Figure 8. Habitats where woundfin were collected during monitoring trips in the Experimental Reach and the June 2000 red shiner removal.

Therefore, it appears as though 5.5 to 7.5% of the fish stocked in October 1999 survived through 8 months in the river and reproduced. In addition to the adult woundfin, it was estimated (based on capture efficiency) that up to 2,000 YOY woundfin also inhabited the Experimental Reach during the June removal. The number of adults and new young confirms that the October 1999 stocking has been the most successful woundfin reintroduction attempt to date.

Standard Monitoring Sites

As discussed previously, 1999 and 2000 were relatively low flow years. Most notably, these years lacked high peak flows of any kind. Mean daily discharge did not rise above 1,000 cfs after September 1998. Even the dry years of 1994 and 1996 had at least 1 day when mean daily discharge exceeded 1,000 cfs. However, 1999 and 2000 were most similar in flow regime to 1994 and 1996 of the past sampling years.

Tables 6, 7, and 8 show the number of seine hauls and numbers of all species collected in the Beaver Dam Wash, Mesquite, and Riverside reaches from April 1998 to May 2000. Woundfin were consistently captured at the Riverside Reach, similar to the study's findings since 1993. A few woundfin were captured at the Mesquite Reach, except in April 1998 when a large number of woundfin that had just been stocked by NDOW were captured. Other native fishes, including Virgin River chub, continued to be common to abundant in the Beaver Dam Wash Reach, while the red shiner population appeared to be smaller in the Beaver Dam Wash Reach, as evidenced by the catch rate of red shiner in the three reaches.

Table 6. Number of seine hauls and all species captured the Beaver Dam Wash Reach (RM 72.00 to 68.50) from January 1998 through June 2000.

DATE	SEINE HAULS	WF ^a	VS	RC	YS	FM	DS	SD	RS	RS (CR)	CC	LB	MF	CP	GS
7/15/98	79	0	0	1	7	198	19	36	292	3.70	0	2	1	0	0
9/30/98	75	0	0	1	0	97	0	154	582	7.76	0	0	0	0	0
4/14/99	98	0	1	3	8,005	16	21	98	914	9.33	0	0	0	0	0
6/25/99	85	0	3	15	0	1,077	357	168	320	3.76	0	8	0	0	0
10/27/99	105	0	0	5	0	256	166	199	1,597	15.2	1	0	23	0	0
5/23/00	103	0	0	2	723	165	138	26	830	8.06	0	0	4	0	0

^aWF = woundfin, VS = virgin spinedace, RC = Virgin River chub, YS = young-of-year suckers, FM = flannemouth sucker, DS = desert sucker, SD = speckled dace, RS = red shiner, CC = channel catfish, LB = largemouth bass, MF = mosquitofish, CP = common carp, GS = green sunfish, CR = the catch rate in # of fish/seine haul.

Table 7. Number of seine hauls and all species captured in the Mesquite Reach (RM 58.00 to 54.50) from January 1998 through June 2000.

REACH	SEINE HAULS	WF ^a	VS	RC	YS	FM	DS	SD	RS	RS (CR)	CC	LB	MF	CP	GS
4/09/98	67	60 (56)	0	1	0	182	49	34	1,298	19.37	0	0	0	0	0
7/14/98	77	2	0	0	0	123	15	21	2,067	26.84	0	1	0	6	0
10/2/98	79	4	0	0	0	48	4	20	1,919	24.29	0	0	0	0	0
4/13/99	94	0	0	0	68	14	1	2	2,568	27.32	0	0	0	0	0
6/23/99	95	1	0	6	0	224	60	3	2,202	23.12	0	6	1	94	0
10/26/99	98	1	0	0	0	94	171	11	5,520	56.33	1	0	0	0	0
5/24/00	109	0	0	0	544	115	42	5	4,220	38.72	1	3	2	5	0

^aWF = woundfin, VS = virgin spinedace, RC = Virgin River chub, YS = young-of-year suckers, FM = flannemouth sucker, DS = desert sucker, SD = speckled dace, RS = red shiner, CC = channel catfish, LB = largemouth bass, MF = mosquitofish, CP = common carp, GS = green sunfish, CR = the catch rate in # of fish/seine haul. Number in parentheses indicates number of woundfin that were tagged.

Table 8. Number of seine hauls and all species captured in the Riverside Reach (RM 49.25 to 45.50) from January 1998 through June 2000.

REACH	SEINE HAULS	WF ^a	VS	RC	YS	FM	DS	SD	RS	RS (CR)	CC	LB	MF	CP	GS
4/10/98	74	7	0	0	0	19	0	1	2,256	30.49	0	1	0	0	0
7/16/98	77	3	0	0	0	66	3	0	1,631	21.18	0	1	0	30	1
10/1/98	107	14	0	0	0	82	7	6	3,271	30.57	7	0	0	3	0
4/15/99	101	8	0	0	0	6	0	0	2,770	27.42	1	0	0	0	0
6/22/99	102	13	0	0	0	7	0	0	1,855	18.18	0	0	4	0	201
10/28/99	111	7	0	0	0	17	3	3	4,753	42.82	0	0	1	2	1
5/25/00	113	4	0	0	96	420	7	1	2,761	24.43	1	2	15	1	0

^aWF = woundfin, VS = virgin spinedace, RC = Virgin River chub, YS = young-of-year suckers, FM = flannelmouth sucker, DS = desert sucker, SD = speckled dace, RS = red shiner, CC = channel catfish, LB = largemouth bass, MF = mosquitofish, CP = common carp, GS = green sunfish, CR = the catch rate in # of fish/seine haul.

DISCUSSION

Red Shiner Removals and Woundfin Stockings

This study showed that a single mechanical removal of red shiner in the spring is sufficient to significantly reduce red shiner numbers, but reproduction rebuilds the red shiner population by late summer. Since red shiner can spawn multiple times from May through September, spring removals may not depress red shiner numbers for any length of time. However, a mechanical removal of red shiner in the fall substantially reduced red shiner numbers and kept them low through the following winter, spring, and spawning period. By the October removal, recruitment of the new red shiner year class was complete, so when large numbers of adult red shiner were removed from the reach, the only red shiner source was from downstream immigration from above the Mesquite Diversion.

The success of past woundfin stockings in the Virgin River was limited. This study showed that 1-year-old woundfin stocked in May did not survive past August, and their numbers began to decline as early as July. Although limited spawning occurred, the extremely low numbers of woundfin collected in the October removal were evidence that the May stocking was unsuccessful. The survival failure of the hatchery-reared woundfin may be a result of the rapid repopulation of the reach by red shiner. However, red shiner numbers did not rebound until August, and the reduction in woundfin numbers was evident by July. The rapid decline in numbers of hatchery-reared woundfin in 1999 suggests that older hatchery-reared fish cannot survive when reintroduced to the river system.

The larger numbers of YOY woundfin introduced in October 1999 survived relatively well and reproduced successfully enough that their YOY outnumbered the adults in catches by June 2000. The catch rate remained relatively constant throughout the winter and spring, except for the May collection, which was much lower than previous trips. The lower May catch rate likely reflects

both increased mortality following spawning and a habitat shift during spawning. During the June removal, large numbers of YOY woundfin at lengths of 18 to 22 mm were found, indicating that spawning had taken place about 4 to 6 weeks earlier. Adults were found clumped in riffle and run/riffle areas. In February, March, and April, 95 to 100% of the woundfin captured were found in run areas, whereas only 43% of the woundfin were captured in runs during the June removal. In June, 56% of the adult woundfin were captured in riffle or riffle/run areas. Greger and Deacon (1982) found that woundfin in an artificial stream spawned in more-shallow, faster areas with coarse gravel and small cobble substrates. By focusing on run habitats during the May sampling period, woundfin aggregated in spawning riffles may have been missed.

The success of the October stocking (through June, 2000) indicates either that the fall removal lowered red shiner numbers to the point that woundfin were able to coexist with them in the reach or that YOY hatchery-reared woundfin may be more adaptable to the food and habitat changes of the riverine environment than 1-year-old woundfin.

The October-stocked fish and their progeny still have to survive the summer in order for the stocking to be a complete success; flows are higher and more consistent throughout the reach in winter. Additionally, temperatures are closer to the final thermal preferendum of 17.5° C for woundfin described by Deacon et al. (1987). The summer months might be the critical time period for woundfin survival. Low flows and temperatures that approach the critical thermal maxima could also be responsible for the loss of stocked fish in the lower river. Therefore, although the October stocked woundfin have survived and reproduced, it remains to be seen whether they will survive the impending increase in red shiner numbers from reproduction and the potentially critical summer flow and temperature conditions.

Standard Reach Monitoring

The results of the standard monitoring of the Beaver Dam Wash, Mesquite, and Riverside reaches are consistent with the results from 1993 to 1997. A small population of wild woundfin continues to persist at Riverside, despite the fact that red shiner numbers are high and numbers of other native fishes are very low. Additionally, a few woundfin are occasionally captured in the Mesquite Reach. However, the woundfin captured in the Mesquite Reach from 1998 to 2000 seem to coincide with stockings in that area. NDOW stocked a total of 21,721 woundfin at the Mesquite Bridge in December 1997, January 1998, and April 1998. The stocked fish and any progeny may account for most of the woundfin caught in the Mesquite Reach during 1998. Downstream migration of fish stocked in the Experimental Reach may account for the single woundfin captured in the Mesquite Reach during both the May 1999 and October 1999 sampling trips. The Beaver Dam Wash Reach continues to be devoid of woundfin, while the increased habitat complexity and more-constant flows in this reach probably account for the higher numbers of native fishes and lower numbers of red shiner.

SUMMARY

The experiments in the lower Virgin River are providing significant information for use in recovery of woundfin throughout their range. Historically, no woundfin stocking, whether in the Virgin, Paria, or other rivers, has been successful. The October 1999 stocking of YOY hatchery-reared fish has shown the best survival of any stocking to date. This is important to future recovery efforts where stocked woundfin may be used to rebuild populations after poisoning or red shiner removal. The use of younger fish appears to be a key to this success. Replication of this experiment is planned for 2000 to 2001, with a stocking in October 2000. The numbers of fish available from Dexter National Fish Hatchery may also be different from those used in 1999, giving the experiment another variation.

The reproduction of woundfin in a reach containing a significant red shiner population also adds new information for the evaluation of woundfin/red shiner interactions. Continued monitoring of this cohort will be important to determine if woundfin can successfully recruit in habitats with a red shiner population. This circumstance may be important for woundfin recovery if long-term red shiner eradication efforts continue to prove unsuccessful.

The woundfin habitat shift that occurred during spawning has been noted by a number of authors, but it is not clearly understood in evaluations of woundfin habitat needs. Holden and Abate (1999) noted the importance of riffles for summer habitat use in the Riverside Reach woundfin population during very low-flow years. Perhaps the presence of the right types of riffles is an important woundfin habitat requirement that needs to be included along with sandy runs in the evaluation of stream reaches for woundfin habitat.

The success of the elastomer dye was encouraging and will provide a number of opportunities to study native fish population size, movements, and habitat shifts. It is an important addition to the study methods in the Virgin River. Since the overall goal of the lower Virgin River studies is to develop self-sustaining populations of native fish in appropriate portions of the river, the first year of studies recommended by the Lower Virgin River Recovery Implementation Team has provided considerable successes in this regard.

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