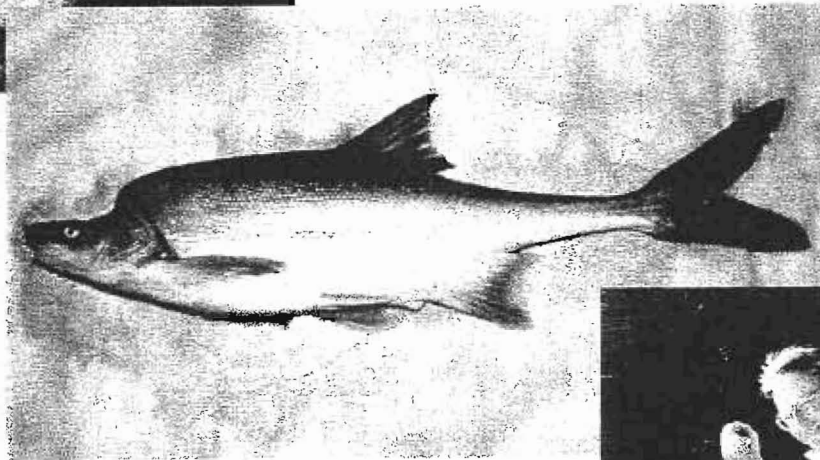
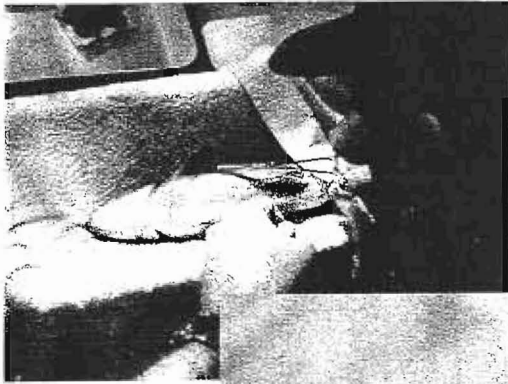


**Spring-Summer Movements of Bonytail in a  
Colorado River Reservoir,  
Lake Mohave, Arizona and Nevada**

Open File Report 99-103



**Bonytail** (*Gila elegans*)

U.S. Department of the Interior  
U.S. Geological Survey

Prepared Jointly with Arizona State  
University.

**U.S. DEPARTMENT OF THE INTERIOR**

**U.S. GEOLOGICAL SURVEY**

**Spring-Summer Movements of Bonytail in a  
Colorado River Reservoir,  
Lake Mohave, Arizona and Nevada**

By

<sup>1</sup>Paul C. Marsh, Arizona State University-Dept. Of Biology  
and

<sup>2</sup>Gordon Mueller, U.S. Geological Survey-MESC

Open-File Report 99-103

Prepared jointly with Arizona State University, Department of Biology.

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<sup>1</sup>P.O. Box 871501, Tempe, Arizona 85287

<sup>2</sup>P.O. Box 25007, D-8220, Denver, Colorado 80225

## TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY .....	ii
INTRODUCTION .....	1
METHODS .....	2
RESULTS and DISCUSSION .....	6
Patterns of Movement and Distribution .....	7
Individual Tracking Histories .....	8
Spatio-temporal Aspects of Fish Locations .....	11
Fish Captures Associated with Tagged Bonytail .....	12
CONCLUSIONS and RECOMMENDATIONS .....	13
ACKNOWLEDGMENTS .....	14
REFERENCES .....	14
APPENDIX A, 1996 Telemetry Tables and Figures .....	20
APPENDIX B, 1997 Telemetry Tables and Figures .....	24

## TABLES

<u>Number</u>		<u>Page</u>
1	Capture, implant, release and tag data for 5 pond-reared and 5 wild-caught bonytail, Lake Mohave, Arizona-Nevada, 1996. Pond-reared fish were 1994-year class volunteer spawn Willow Beach National Fish Hatchery Arizona, and wild-caught fish were captured from the reservoir as indicated. ....	3
2	Capture, implant, release and tag data for 3 pond-reared and 7 wild-caught bonytail, Lake Mohave, Arizona-Nevada, 1997. Pond-reared fish were 1995-year class volunteer spawn from Dexter National Fish Hatchery New Mexico reared at Cibola National Wildlife Refuge Arizona, and wild-caught fish were captured from the reservoir as indicated. ....	4
3	Contacts (number of observations) with cove-reared and wild-caught, sonic tagged bonytail in Lake Mohave, Arizona-Nevada, relative to time of day and proximity to shore, 14 May to 29 July 1996. ....	12

## FIGURES

<u>Number</u>		<u>Page</u>
1	Map of Lake Mohave, Arizona and Nevada, showing numbered waypoints 1-71 and reservoir zones 1-5. ....	5

## EXECUTIVE SUMMARY

The bonytail *Gila elegans* is a large-river minnow (Cyprinid) endemic to the Colorado River system of western North America. The species is federally listed as endangered, its biology poorly understood, and relatively little is known of its movements. Two short-term telemetry studies were conducted during 1996 and 1997 to assess spring-summer temporal and spatial movement patterns in Lake Mohave, Arizona and Nevada, where the largest remaining population of bonytail persists. A total of 20 bonytail were implanted with 90-day sonic transmitters. Ten fish (5 wild-caught from the Lake and 5 cove-reared: 5 females and 5 males) were implanted in May 1996 and additional 10 (7 wild-caught and 3 pond-reared: 2 females and 8 males) were implanted in April 1997, released into the lake immediately after surgery, and tracked approximately weekly through August of both years.

Eight fish dispersed immediately after release in 1996, two moved up- and six moved down-lake. The five wild-caught fish moved down-lake as much as 42 km, and four of these (all males) remained in the lower most 5 km while the other (female) occupied an area about 10 km below the release site. Two cove fish moved up lake 15 and 43 km, respectively, while a third moved 4 km down-lake. Two fish were never contacted. Most locations were in shallow water along shorelines, in some instance within inundated stands of riparian vegetation.

In 1997, three pond fish were surgically implanted with transmitters and released at Cottonwood Cove, Nevada. Two were not contacted again, and the other was lost 12 days post-release after moving approximately 1.4 km across the lake. Seven wild fish were captured and released at two sites in the lower portion of the lake, and all moved to downstream areas where they remained for the duration of study. Contact was lost with one fish after 3 days and another remained stationary after 13 days; the five others were tracked for 62 to 119 days. These last fish remained in the lower lake and had net movement (displacement from release site to last contact location) that averaged 5.4 km and ranged from 4.7 to 6.9 km. All net displacements were downstream. Cumulative distance traveled averaged 28.9 km and ranged from 19.9 to 33.0 km. Most fish locations during daylight hours were in deep water adjacent to the steep Nevada shore, while nighttime locations were in shallow water along gently sloping Arizona shorelines.

Bonytail can move substantial distances in a short time (10s of km in a few days). Fish in both years apparently favored the same areas, where they may remain for weeks. Unmarked bonytail were observed or captured by setting nets in places favored by tagged fish, a significant result since future use of the technique may enhance our ability to monitor reintroductions, locate and document spawning, examine habitat use, and acquire desperately needed brood stock for this critically imperiled species. External tagging techniques developed for juvenile razorback sucker may provide a method of minimizing telemetry induced stress while allowing us to focus sampling on congregation sites.



## INTRODUCTION

The native "big-river" fish fauna of the western North America's Colorado River is comprised of three endemic minnows (Cyprinidae): bonytail (*Gila elegans*), humpback chub (*Gila cypha*), and Colorado pikeminnow (*Ptychocheilus lucius*), and one endemic sucker (Catostomidae): razorback sucker (*Xyrauchen texanus*). In the lower Colorado River basin (below Lees Ferry, Arizona), humpback chub historically was found primarily above Black Canyon (present site of Hoover [Boulder] Dam, while the other three species were widespread in the Colorado River mainstream and its major tributaries including the Gila, Salt, and Verde rivers (Minckley 1973, Holden 1980a, b; Holden and Minckley 1980).

Water development in the lower Colorado River basin during the past century has involved construction of dams and diversions, creation of impoundments, and channelization that has modified aquatic habitats and altered natural hydrography (Fradkin 1968, Minckley 1979, Worster 1985). Coincident with this development was the intentional or accidental introduction of a suite of non-native fishes (U.S. Fish and Wildlife Service [USFWS] 1980). These structural, hydrologic, and biological changes were coincident with and continue to be associated with declines in native fishes of the region (Dill 1944, Miller 1961, Minckley 1973, Minckley and Deacon 1991). In Arizona, for example, more than half the 30 native fish species are now federally listed as threatened or endangered (Johnson 1987); the four "big-river" fishes all fall into the latter category.

Most native species that historically occupied springs, smaller streams, and cienegas still persist in isolated "strongholds" where habitats maintain a semblance of their natural states and are relatively free of non-native fishes (Minckley 1985). This is not the case for the "big-river" forms, which now are restricted to only a few places, all of which are occupied by an abundance of alien kinds (Miller et al. 1982, USFWS 1982). The big rivers of the region, without exception, have been modified by the activities of technologic man.

Bonytail remains only in lakes Mohave (Arizona and Nevada) and Havasu (Arizona and California), and is reliably captured only in the former locale (Marsh and Minckley 1992). Humpback chub is restricted to the Colorado and Little Colorado Rivers in Grand Canyon, where a relatively large population persists (Minckley 1991). It also is found in several canyon-bound segments of the Green, Colorado, and Yampa Rivers in the upper Colorado River basin (Tyus and Karp 1989). Colorado pikeminnow is extirpated from the lower basin (Minckley 1973), and persists upstream only in portions of the Colorado-Green River system (Tyus 1991). Razorback sucker is extirpated from the Gila River system (Minckley 1983), and is widely scattered elsewhere in the upper and lower basins (McAda and Wydoski 1980, Marsh and Minckley 1989); the largest remaining population inhabits Lake Mohave (Marsh 1994).

Remnant populations of big-river fishes all appear to suffer from recruitment problems. Bonytail and razorback sucker are not known (few exceptions with razorback sucker) to recruit to

reproductive size/age anywhere in the wild (Mueller and Marsh 1995), humpback chub does so only within a few river reaches in and upstream of Grand Canyon (Minckley 1991), and Colorado pikeminnow recruitment apparently occurs only within limited stream reaches of the upper Green River basin (Tyus 1991).

Although a suite of factors are cited as responsible for declines and local/regional extirpations of the big river fishes (e.g., Miller 1961, Minckley and Deacon 1991), direct and indirect impacts associated with construction and operation of main stem dams and interaction with non-native fishes are considered most significant (Marsh, in press a and b; Mueller and Marsh 1995).

The present study was developed to provide information on dispersal, distribution, and habitat use of bonytail in Lake Mohave. In part, the effort was to replicate and hopefully corroborate findings of a similar study performed in 1996 (Marsh 1997b). Both endeavors were to enhance our understanding of the life history of wild bonytail in the reservoir, and to provide management insights that might be useful in implementing and assessing an ongoing repatriation program.

## METHODS

Ten adult bonytail were implanted with sonic transmitters in both May 1996 and April 1997 (Tables 1 & 2). Both wild-caught and pond-reared fish were used. Seven were produced in hatchery ponds and reared in captivity, and 13 were wild-caught, or resident fish from Lake Mohave. The pond fish were 1994-95 year-class spawn of F1 adults (Lake Mohave stock) at Dexter, New Mexico and came from either Willow Beach National Fish Hatchery or from ponds at Cibola National Wildfire Refuge, Arizona. Pond-reared fish used in 1996 included 4 females that were 35.5 to 42.7 cm total length (TL) and a male 36.3 cm long. All pond-reared fish (3) used in 1997 were male, and they were 35.4, 39.0 and 42.0 cm TL.

Lake fish were either wild or repatriated individuals captured in trammel nets set in vicinity of Arrowhead, Bill Gayes, Dandy, and Yoke Coves. Four males (43.0-46.5 cm TL) and one female (46.1 cm TL) were used in 1996 compared to two females (46.9 and 47.5 cm TL), and five males (46.8 to 48.8 cm TL) used in 1997. Size of implanted pond fish was substantially smaller, however, lake fish were similar in size to wild-caught individuals captured from the reservoir between 1980 and 1996 (Tables 1 & 2; Marsh 1996, 1997a).

Cylindrical sonic tags (Sonotronics Inc, Tucson Arizona part number MT-95-2) measured approximately 32 mm long x 8-mm diameter, were encased in inert ABS plastic, and weighed 5 gm. These were surgically implanted into fish anaesthetized with 125 mg/L MS-222 (tricane methane sulfonate), through a 12-15 mm-long medial incision through the abdominal musculature into the peritoneal cavity a few mm off the ventral midline just anterior to the pelvic girdle. Anesthesia was maintained by continuous irrigation of the gills, and a damp towel to prevent drying covered the body. A Passive Integrated Transponder (PIT) tag (codes in Tables 1 & 2) was inserted with each sonic tag, and the incision was closed with 2-3 sutures of 2-0 metric

(Dermalon) monofilament nylon. Time from initial immersion in anesthesia to removal to fresh water never exceeded 8 minutes, and fish were released after 2-5 minutes recovery in fresh water.

Table 1. Capture, implant, release and tag data for 5 pond-reared and 5 wild-caught bonytail, Lake Mohave, Arizona-Nevada, 1996. Pond-reared fish were 1994-year class volunteer spawn from Dexter, New Mexico and supplied by Willow Beach National Fish Hatchery, Arizona, and wild-caught fish were captured from the reservoir as indicated.

Capture Date	Capture Location	Implant Date	Release Location	TL (cm)	Sex	Tag Code Frequency	PIT tag Number	Comment
POND REARED FISH								
14 May	North AJ <sup>a</sup>	14 May	1st N Carp <sup>b</sup>	36.3	M	2-3(74)	7F7D223042	ASU trammel
14 May	North AJ <sup>a</sup>	14 May	1st N Carp <sup>b</sup>	39.6	F	3-4(74)	7F7D1B7315	ASU trammel
14 May	North AJ <sup>a</sup>	14 May	1st N Carp <sup>b</sup>	42.7	F	5-5(74)	7F7D18437E	ASU trammel
15 May	North AJ <sup>a</sup>	15 May	North AJ	42.2	F	4-4(72)	One of 3	ASU trammel
23 May	WBNFH <sup>c</sup>	23 May	1st N 116 <sup>d</sup>	35.5	F	2-2(74)	7F7D132B70	Hatchery
WILD CAUGHT FISH								
15 May	Bill Gayes	15 May	Acr CWC <sup>e</sup>	46.2	M	2-6(72)	2024607666	ASU/FWS
16 May	Bill Gayes	16 May	Levi Cove	46.1	F	3-3 (74)	None	ASU/FWS
14 May	Arrowhead	16 May	1st N 116	43.0	M	2-5 (72)	7F7F32170F	AZGFD
14 May	Arrowhead	16 May	1st N 116	45.5	M	3-5 (72)	7F7F317603	AZGFD
14 May	Dandy	16 May	1st N 116	46.5	M	2-4 (74)	7F7F320E2A	USBR

<sup>a</sup> North Arizona Juvenile backwater Arizona

<sup>b</sup> First small cove north of Carp Cove Arizona

<sup>c</sup> US Fish and Wildlife Service Willow Beach National Fish Hatchery Arizona

<sup>d</sup> First cove north of Copper Basin Cove Nevada (US National Park Service number 116)

<sup>e</sup> On the Arizona side directly across the reservoir from Cottonwood Cove Nevada

Table 2. Capture, implant, release and tag data for 3 pond-reared and 7 wild-caught bonytail, Lake Mohave, Arizona-Nevada, 1997. Pond-reared fish were 1995-year class volunteer spawn from Dexter, New Mexico reared in ponds at Cibola National Wildlife Refuge, Arizona, and wild-caught fish were captured from the reservoir as indicated.

Capture date	Capture location	Implant date	Release location	TL (cm)	Sex	Tag code frequency	PIT tag number	Comment
POND REARED FISH								
01 Apr	Cibola <sup>a</sup>	02 Apr	CWC NV <sup>b</sup>	35.4	M	3-4 (70)	2038596966	ASU/FWS trammel
01 Apr	Cibola	02 Apr	CWC	42.0	M	3-6 (70)	7F7A062475	ASU/FWS trammel
01 Apr	Cibola	02 Apr	CWC	40.6	M	3-5 (70)	7F7A08123E	ASU/FWS trammel
WILD CAUGHT FISH								
15 Apr	Yoke Cove	15 Apr	S Pt KPC <sup>c</sup>	47.5	F	2-3 (70)	1F77734F28	ASU/BRD trammel
15 Apr	Yoke Cove	15 Apr	S Pt KPC	46.8	M	2-4 (70)	201D616200	ASU/BRD trammel
15 Apr	Yoke Cove	15 Apr	S Pt KPC	47.0	M	3-3 (70)	7F7A08272A	ASU/BRD trammel
15 Apr	Yoke Cove	15 Apr	S Pt KPC	48.8	M	4-6 (70)	1F78375161	ASU/BRD trammel
16 Apr	Yoke Cove	16 Apr	Beaver Cv <sup>d</sup>	48.8	M	4-5 (70)	2038587E52	ASU/BRD trammel
18 Apr	Yoke Cove	18 Apr	S Bas Lt Cv <sup>e</sup>	48.5	M	4-4 (70)	2037107029	ASU/BRD trammel
18 Apr	Yoke Cove	18 Apr	S Bas Lt Cv	46.9	F	5-6 (70)	1F7A346E45	ASU/BRD trammel

<sup>a</sup> US Fish and Wildlife Service Cibola National Wildlife Refuge, Arizona

<sup>b</sup> Cottonwood Cove Resort & Marina Beach, Nevada (US National Park Service [NPS] cove number 107)

<sup>c</sup> South Point of Katherine Powerline Cove, Arizona (NPS no. 39)

<sup>d</sup> Beaver Cove, Arizona (NPS no. 20)

<sup>e</sup> South Basin Light Cove, Arizona (NPS no. 77)

Tracking was performed using an USR-5W receiver and DH-2 hydrophone (Sonotronics, Inc, Tucson, Arizona), with signals amplified and audibilized through a dual speaker headset. Tags were programmed to operate at a frequency in the 70 kHz range and modified by extending pulse interval to 1.7 sec to extend nominal life expectancy from 47-90 days. Sonic signal detection range depends on tag power, obstructions and other underwater structure, turbulence, wave action, watercraft activity, power generation status (when near dams), and other factors, and during this study typically was > 500 m and approached 1000 m under ideal listening conditions.

Nominal, routine monitoring consisted of stops at each of 71 listening stations or "waypoints" (WP) designated at approximately 1.6-km intervals and forming a grid that provided approximately 85% surface area coverage of the reservoir (Fig. 1). In practice, most listening was done at ½ WP or shorter (0.5-0.8 km) intervals. Location and repetitive relocation of each

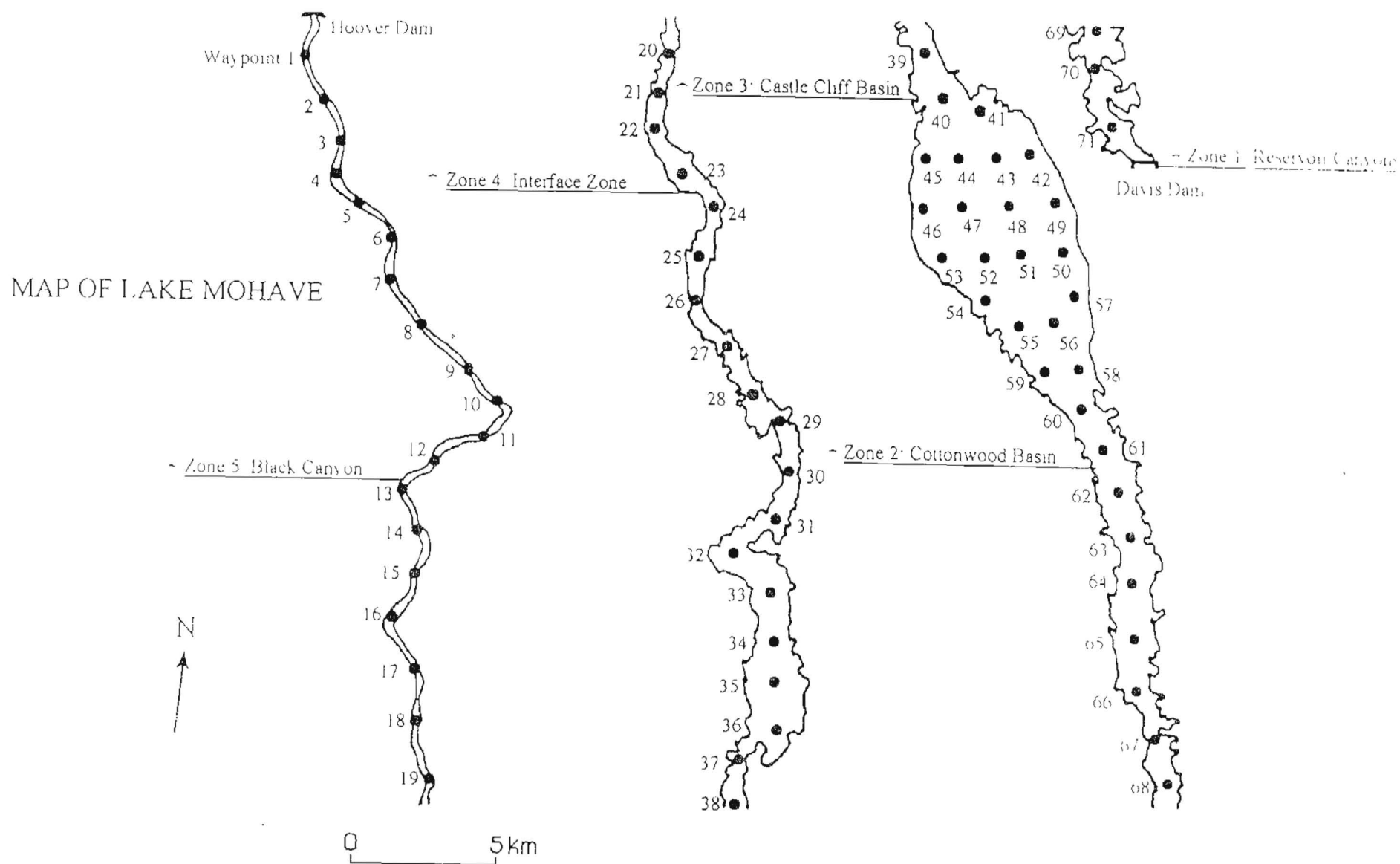


Figure 1 Map of Lake Mohave, Arizona and Nevada, showing numbered waypoints 1-71 and reservoir zones 1-5

WP was accomplished by use of a Magellan NAV 5000 DX Geographical Positioning System (GPS) instrument. Once a signal was detected, the fish location was determined by triangulation, identified by GPS output, and recorded as degrees, minutes and seconds of latitude and longitude (later translated into UTM's for graphical interpretation). A visual estimate was made of distance to shore, and anecdotal notes also were recorded.

The reservoir was examined in entirety (all 71 WPs) at least once every 2 weeks from fish release (Appendixes A & B, Table 1) until tag expiration. In addition, several complete or partial "cove surveys" were conducted that examined all or a portion of the lakes coves and shorelines. These latter surveys were performed in an attempt to locate fish/tags in places from which signals might not propagate well, such as the backs of long coves.

The reservoir was sub-divided into 5 zones or areas, each characterized by similar limnological and morphological features (Figure 1). Designated areas were Black Canyon (Hoover Dam to WP 13), Interface (WP 13 to 24), Castle Cliff Basin (24 to 40), Cottonwood Basin (40 to 61), and Reservoir Canyon (WP 61 to Davis Dam). These correspond with zones used by Foster et al. (1997), Knowles (1997) and Marsh (1997b), but not by Marsh (1997c).

Fish movement was assessed quantitatively on the basis of point-to-point distance (the linear distance in km between successive contacts), net distance (the total linear distance between point of release and each successive contact), and cumulative distance (the sum of all point-to-point distances). We plotted each contact location on a map of Lake Mohave and examined direction of movement (up- or down-lake) and movement between reservoir zones.

Lake Mohave surface elevation varied slightly less than 2 m (6+ ft) from 194.65 to 196.52 m (638.63 to 644.75 ft) MSL, daily discharge from Hoover Dam averaged 471 and 500 CMS (16,633-17,675 CFS) (range 189 to 736 CMS [6,670 to 26,000 CFS]), and daily release from Davis Dam averaged 462 and 498 CMS (16,313 CFS) (range 270 to 603 CMS [9,520 to 21,300 CFS]) during the study period between April and September 1996 and 1997 (U.S. Bureau of Reclamation, unpublished data).

## **RESULTS and DISCUSSION**

All fish survived the anesthesia and surgery, and swam vigorously away when released into the lake. All releases were in quiet, protected coves. Nine fish were released in 1995 between WP 36 and 40 in the lower portion of Castle Cliff Basin and one was released in Cottonwood Basin, at Arizona Juvenile backwater, Arizona. In 1997 three pond-reared fish were released from the campground beach at the back of Cottonwood Cove, Nevada, in Castle Cliff Basin immediately upstream from the Cottonwood Basin transition, and the seven wild-caught fish were released between Beaver and South Basin Light Coves, Arizona in the Reservoir Canyon portion of the lake. Tracking was conducted from the first releases (14 May-1996/ 02 April-1997) for

approximately 4 months (August 1996-September 1997), after which time batteries presumably expired (no contacts were made during the last comprehensive, reservoir wide survey). Individual fish were contacted once (at time of release) to two dozen times over monitoring period (Appendix A & B: Table 1A-J, Figures 2-11).

### **Patterns of Movement and Distribution**

1996 - Generally, wild-caught fish moved downstream into the lowermost portion of the Reservoir Canyons zone (Appendix A, Table 3A-E and Figures 1-6), and, if a pattern existed, cove-reared fish moved upstream (Appendix A, Table 3F-J and Figures 7-11).

Four of five wild-caught fish moved down-lake about 56 km from release locations near WP-35-38 to positions in the lowermost portion of the reservoir between WP 67 and 71. This movement was accomplished in the first 4 to 14 days after release, and all fish remained in the lower reaches of the Reservoir Canyon area until contact was lost up to 10 weeks later. This reach is characterized by a relatively narrow channel (100s of m), steep, rocky shorelines with extensive development, and the deepest water anywhere in the lake (to near 40 m during the survey period). Summertime water surface temperatures in this portion of the reservoir exceeded 25 °C and may approach 30 °C, while those below 10 m depth may remain near 15 °C (Paulson et al. 1980).

There were no other evident patterns. The other wild-caught fish moved down-lake about 14 km immediately after release and remained mostly near-shore within a few km of WP 54 for the next 5-plus weeks until contact was lost. Among cove-reared fish, one moved down-lake approximately 14 km and the other two moved up-lake 16 and 48 cm, respectively. At no time were the latter two fish found in proximity to one another; for example, they were separated by more than 11 km when both were contacted on 21 May.

There was no post-release contact with two fish; both cove-reared. Explanations include immediate failure of the tag, or removal of the fish from the system (for example, by avian predators or scavengers such as bald eagles, ospreys or ravens, or by coyotes). There is no information to support or refute either alternative.

1997 - Generally, wild-caught fish with which contact was maintained moved downstream from their respective release sites into the lowermost portion of the Reservoir Canyon zone (Appendix B, Table 2D-H and Figures 6-10). This pattern of movement and distribution was consistent for both years. This gross movement in both years was accomplished in the first 4 to 14 days after release, and all fish remained in the lower reaches of the Reservoir Canyon area until contact was lost up to 17 weeks later).

Most contacts were made during evening hours and little information on diel changes in



distribution is available from this study. However, contacts made during daylight were generally with fish in deep water associated with the steep Nevada shoreline, while during evening fish were found in a variety of habitats and depths, often in shallow water along the Arizona shoreline. Similar results were reported by Marsh (1997b) for bonytail tracked during 1996.

Two or more tagged bonytail were contacted in close proximity on several occasions, and visual contact was made during one such encounter. Previous speculation that tagged fish might lead researchers to other, unmarked bonytail was confirmed in 1996 (see Marsh 1997b), and similar efforts were expended during spring-summer 1997 as part of this study. Indeed, wild-caught bonytail used here were obtained primarily from the same sites occupied by fish that were tagged and tracked during 1996. Only non-native species were otherwise captured in net sets made during 1997, however, effort was limited to relatively few nets deployed on only a few dates. The capture of unmarked bonytail adults in an area used by marked fish remains a significant result because it suggests a potential mechanism to enhance sampling efforts in behalf of brood fish acquisition.

### **Individual Tracking Histories**

**1996** - Refer generally to Appendix A, Figure 1 for WP locations, and to Appendix A, Table 1A-J, and Appendix A, Figures 2-11 for data on each fish. Individuals are identified by their source (i.e., wild-caught or cove-reared) and sonic tag code number.

Wild 2-4. Released 16 May 1996 at the first cove north of Copper Mountain Cove, Nevada in the lower portion of Castle Cliff Basin. Contacted upstream <1 km near WP 35 on day 8, then downstream 31.5 km at WP 67.5 in the lower Reservoir Canyons on day 15. Fish remained there (contact between WP 68 and 70.3 on 12 occasions from day 19 to day 75. Last contact was on 29 July. Maximum linear displacement downstream from point of release was 35.3 km, and total cumulative point to point distance moved was 42.7 km.

Wild 2-5. Released 16 May 1997 at the first cove north of Copper Mountain Cove, Nevada in the lower portion of Castle Cliff Basin. Next contacted 31.3 km downstream near WP 68 in the lower Reservoir Canyons on day 15. Fish remained in vicinity at WP 67-69.3 on days 19-21, 28 and 33. Last contact was 17 June. Maximum linear displacement downstream from point of release was 32.9 km, and total cumulative point-to-point distance moved was 36.4 km.

Wild 2-6. Released 16 May 1996 on the Arizona side directly across the lake from Cottonwood Cove Marina in the Lower portion of Castle Cliff Basin. Contacted 32.6 km downstream near WP 71 on day 5, then 2.1 km further downstream days 6 and 8 at WP 70 in the lower Reservoir Canyons. Fish remained there (contacted at WP 70.5 on day 16). Last contact was on 30 May. Maximum linear displacement downstream from point of release was 32.6 km, and total cumulative point-to-point distance moved was 34.6 km.



Wild 3-3. Released 16 May 1996 at Levi Cove, Arizona upstream from WP 39 in the lower portion of Castle Cliff Basin. Contacted 7.8 km downstream near WP 53 on day 4, on the Nevada shoreline of lower Cottonwood Basin. The fish remained in the vicinity of WP 52-54, where it was recontacted 8 times between days 5 and 43. Lake contact was on 27 June. Maximum linear displacement downstream from point of release was 9.9 km, and total cumulative point-to-point distance moved was 18.1 km.

Wild 3-5. Released 16 May 1996 at the first cove north of Copper Mountain Cove, Nevada in the lower portion of Castle Cliff Basin. Next contacted 2.4 km upstream near WP 34 on day 3. Fish moved 24 km downstream and was contacted near WP 62 in the lower Reservoir Canyons on day 5, and 10.3 km further downlake near WP 68 on day 7 where it was recontacted on day 15. Last contact was on 30 May. Maximum linear displacement downstream from point of release was 31.9 km, and total cumulative point-to-point distance moved was 36.7 km.

Wild 5-5. Released 14 May 1996 from the first cove north of Carp Cove AZ (due E of WP 40), in the lower portion of Castle Cliff Basin. Contact 15.3 km upstream at WP 29 on Day 8, and 11.5 km back down the lake at WP 36 on day 10. Last contact was on 23 May. Maximum linear upstream displacement from point of release was 15.3 km, and total cumulative point-to-point distance moved was 26.8 km.

Cove 2-2. Released 23 May 1996 from the first cove north of Copper Mountain Cove, Nevada in the lower portion of Castle Cliff Basin. No post-release contact.

Cove 2-3. Released 14 May 1996 from the first cove north of Carp Cove, Arizona (due E of WP 40), in the lower portion of Castle Cliff Basin. Contacted upstream at WP 36 on day 8, 17.5 (day 36), 19.3 (day 37), 9.3 (day 46), and there after at WP 17 (days 57, 64, and 72). The tag malfunctioned by 16 July and last contact was on 24 July. Maximum linear upstream displacement from point of release was 55 km, and total cumulative point-to-point distance moved was 75 cm.

Cove 3-4. Released 14 May 1996 from the first cove north of Carp Cove, Arizona (due E of WP 40), in the lower portion of Castle Cliff Basin. No post-release contact.

Cove 4-4. Released 15 May 1996 at "North Arizona Juvenile" backwater (on the Arizona shore E of WP 50) in the lower portion of Cottonwood Basin. Contacted across the lake and 4 km downstream near WP 59 on day 29. Last contact was on 12 June. Maximum linear upstream displacement from point of release was 4 km, and total cumulative point-to-point distance moved was 26.8 km.

**1997** - Refer generally to Figure 1 for WP locations and reservoir zones, and to Appendix B, Tables 1A-J, and Figures 2-11 for data on individual fish. Individuals are identified by their

source (i.e., wild-caught or cove-reared) and two-digit sonic tag code number.

Pond-reared 3-4. Released 02 April 1997 at the campground beach at Cottonwood Cove Resort and Marina, Nevada, in the lowermost portion of Castle Cliff Basin. Contacted twice on day 12: first in mid-channel ca. 1 km from the release site, and later near the Arizona shore adjacent to WP 38.75 at Airport Cove. Last contact was on 13 April. Maximum linear displacement from point of release was 1.60 km, and total cumulative point to point distance moved was 2.02 km. Either the tag failed or this fish died and was removed from the system after April 13. There were no obvious indications of mortality factors during the surgical procedure or at time of release.

Pond-reared 3-5. Released 02 April 1997 at 1997 at the campground beach at Cottonwood Cove Resort and Marina, Nevada, in the lowermost portion of Castle Cliff Basin. There was no post-release contact with this fish. Either the tag failed or this fish died and was removed from the system after April 2. There were no obvious indications of mortality factors during the surgical procedure or at time of release.

Pond-reared 3-6. Released 02 April 1997 at the campground beach at Cottonwood Cove Resort and Marina, Nevada, in the lowermost portion of Castle Cliff Basin. There was no post-release contact with this fish.

Wild-caught 2-3. Released 15 April 1997 at Katherine Powerline Cove, Arizona adjacent to WP 66.6 in the Reservoir Canyon portion of the lake. Contacted about 4.8 km downstream near WP 69.5 on day 7, along the Arizona shoreline. The fish remained in vicinity of WPs 66-71 in the Reservoir Canyon, where it was re-contacted on 17 occasions between days 17 and 80. This fish was detected in deep water along the Nevada cliffs, in open water of mid-channel, and in shallow water near the Arizona shore. It was visually contacted on day 28 on the south point of Yoke Cove, Arizona (near WP 68.1), where it was accompanied by wild-caught 3-3 (see below). On day 37, this fish and wild-caught 4-5 were detected in close proximity to each other near WP 70.4. Last contact was on 03 July. Maximum linear displacement from point of release was 6.78 km downstream, and total cumulative point to point distance moved was 32.35 km.

Wild-caught 2-4. Released 15 April 1997 at Katherine Powerline Cove, Arizona adjacent to WP 66.6 in the Reservoir Canyon portion of the lake. Next contacted 5.7 km downstream in mid-channel near WP 70 on day 17. Fish moved only locally thereafter, and was contacted on 11 occasions between days 17 and 98 near WPs 67-71 in the lower Reservoir Canyon. It was detected along with wild-caught 3-3 in shallow water near WP 68 on day 23, and with 3-3 and 4-4 inside Telephone Cove, Arizona on day 98. This fish occupied a variety of depths and habitats over the 3+ months of contact. Last contact was on 21 July (day 98). Maximum linear displacement downstream from point of release was downstream 8.35 km, and total cumulative point-to-point distance moved was 31.32 km.

Wild-caught 3-3. Released 15 April 1997 at Katherine Powerline Cove, Arizona adjacent to WP 66.6 in the Reservoir Canyon portion of the lake. This fish was first contacted on day 7 about 5.6 km downstream from the release site about 50 m off the Nevada shore adjacent to sheer cliffs near WP 70. Most movements thereafter were of relatively shore distance. The fish was re-contacted on 19 subsequent occasions between WPs 68 and 71, almost always in association with the Arizona shoreline. It was detected on day 28 along with wild-caught 2-4 in shallow water along the south point of Arrowhead Cove, Arizona, with 4-4 in 10-12 m depth in Telephone Cove, Arizona on day 91, with 2-4 and 4-4 in the same area on day 98, and again with 4-4 near shore along the north point of Telephone Cove, Arizona on day 119. Last contact was on 11 August (day 119). Maximum linear displacement from point of release was 7.24 km downstream, and total cumulative point-to-point distance moved was 27.57 km.

Wild-caught 4-4. Released 18 April 1997 at South Basin Light Cove, Arizona (adjacent to WP 60) in the lower portion of Cottonwood Basin, immediately upstream from the Reservoir Canyon transition. Contacted on day 4 downstream 8.30 km in deep water near WP 71 near the mouth of Davis Cove, Arizona. The fish was subsequently contacted on 13 occasions between days 14 and 116. It remained between WPs 69 and 71 and was detected on both sides of the river, in deep and shallow water. On 11 August (day 116) it was associated with wild-caught 3-3 near WP 69.5 in 5-6 m of water fewer than 15 m from the Arizona shore. Last contact was on 11 August (day 116). Maximum linear upstream displacement from point of release was 8.30 km, and total cumulative point-to-point distance moved was 19.88 km.

Wild-caught 4-5. Released 16 April 1997 at Beaver Cove, Arizona, near WP 69.25 in the Reservoir Canyon portion of the lake. The fish moved downstream about 2.5 km by day 6, when it was contacted in mid-channel near WP 68. It was detected on 12 subsequent occasions between WPs 67 and 71. It was found on both the Arizona and Nevada sides of the reservoir, in coves and open water, and both shallow and deep. The fish was associated with wild-caught 2-3 on day 36 in deep water near WP 70.4. Last contact was on 16 June (day 62) inside the cove at Katherine Landing, Arizona. Maximum linear displacement from point of release was downstream 6.85 km, and total cumulative point-to-point distance moved also was 32.97 km.

Wild-caught 4-6. Released 15 April 1997 at Katherine Powerline Cove, Arizona adjacent to WP 66.6 in the Reservoir Canyon portion of the lake. Last contact was on 17 April (day 3) adjacent to the Arizona shore near WP 60. Maximum linear displacement from point of release was downstream 7.5 km, and total cumulative point-to-point distance moved also was 7.5 km.

Wild-caught 5-6. Released 18 April 1997 at South Basin Light Cove, Arizona (adjacent to WP 60) in the lower portion of Cottonwood Basin, immediately upstream from the Reservoir Canyon transition. The fish apparently moved after release into mid-channel, where it either died or shed the tag. The immobile signal was contacted on 6 occasions (not shown in Table 2-J) at the same location (WP 60).

## Spatio-temporal Aspects of Fish Locations

Tagged bonytail tended to be found near shore more often than not. Among all contacts, 76% were associated with shoreline habitat; 24% were in deeper, open waters of the reservoir (Table 3, Appendix A, Figures 2-11). All cove-reared fish contacts were near shore while wild-caught fish were found 70% along shore and the remainder were pelagic.

Most contacts with tagged bonytail were during daylight or darkness; relatively few contacts were made during crepuscular periods (none during dawn and only 6 of 45 [13%] during dusk; see Table 3 for definitions). However, this may have been simply an artifact of when surveys were conducted rather than a true indication of fish dispersal in space. Regardless, for both cove-reared and wild-caught bonytail, about half of all contacts were during daylight and half during darkness (Table 3).

On the other hand, when day and shore orientation are considered simultaneously there was a clear indication that wild-caught bonytail spend most of the daylight hours in deeper, open waters (73% of deep water contacts were during the day) and most of their night or low-light hours (69% of shore contacts were at night or during crepuscular periods) in shallow water along shore (Table 3). This observation was made repeatedly for several individuals (e.g., sonic codes 2-4, 2-5, and 3-3) and seemed a general pattern of behavior and habitat use.

Table 3. Contacts (number of observations) with cove-reared and wild-caught, sonic tagged bonytail in Lake Mohave, Arizona-Nevada, relative to time of day and proximity to shore, 14 May to 29 July 1996.

	Number of Observations				
	Near shore		Deep water		
Time of day <sup>a</sup>	cove	wild	cove	wild	Totals
Dawn	0	0	0	0	0
Day	4	8	0	8	20
Dusk	1	5	0	0	6
Night	3	13	0	3	19
Totals	8	26	0	11	45

Dawn = 0430-0559 hrs MST, Day = 0600-1859 hrs MST, Dusk = 1900-2029 hrs MST, Night = 2030-0429 hrs MST.

## Fish Captures Associated with Tagged Bonytail

Tagged fish were used to direct net sets in an area used by sonic tagged bonytail along Arizona

shoreline near WP 67 (vicinity of Arrowhead Cove, Gasoline Alley, and Yoke Coves). Two, wild-caught bonytail (codes 2-4 and 2-5, see Appendix A, Tables 2 and 3) were located by telemetry in shallow water fewer than 20 m from shore on a gravel point between Gasoline Alley and Yoke Cove on the evening of 03 June, and again on 04 June 1996. Trammel nets (100-m long, 2.5 cm inter and 30-cm outer meshes) were set at about 2030 hrs on 04 June along the N points of Arrowhead and Yoke Coves (perpendicular to shore) and inspected at 1200 M, 0300, and 0600 hrs. A total of 4 unmarked, adult bonytail were captured in these two, shore-term sets. Fish were transported to Willow Beach National Fish Hatchery, Arizona and turned over to USFWS personnel.

The capture of unmarked bonytail adults in an area used by marked fish is a significant result because it suggests a potential mechanism to enhance sampling efforts in behalf of brood fish acquisition. Additional sampling should be conducted in areas frequented by tagged bonytail (e.g., Arrowhead Cove-Gasoline Alley-Yolk Cove, Arizona area, Nine-Mile to Nellis Coves, Nevada, and as indicated by future telemetry work).

## **CONCLUSIONS AND RECOMMENDATIONS**

Results of previous investigations (Minckley 1983, Marsh and Minckley 1992) are corroborated in that bonytail captures were along shallow, gravel points. However, most captures prior to 1988 were during stormy periods in winter-early spring, and until the past decade little sampling has been conducted during warmer, late-spring to summer months. And, most earlier sampling was concentrated in the upper portion of Cottonwood Basin (for example, Carp Cove to Cottonwood East, Arizona and Tequila to Hog Farm Coves, Nevada). Sampling in these "traditional" areas now is augmented by efforts in the lower portions of the Reservoir Canyons (NFWG, unpublished data). Telemetry results clearly go hand in hand with existing information to provide a clear picture of bonytail habitat use, in a general sense, and should prove valuable in obtaining additional brood stock of the critically imperiled species.

To this end we recommend that future attempts to capture additional wild fish be directed toward shallow points and gravel bars along the Arizona shoreline in the lowermost Reservoir Canyon zone of Lake Mohave. Other areas of the lake also deserve attention in this regard, since bonytail are not found exclusively in the lower lake.

While a recommendation of additional studies may seem trivial, important questions nonetheless remain without answers. Foremost is the need for information on post-stocking dispersal, distribution, and habitat use of hatchery-produced bonytail, which is necessary to provide management recommendations and to assess repatriation program success. Telemetry work can contribute to filling this information gap.

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## REFERENCES

- Dill, W. A. 1944. The fishery of the lower Colorado River. *California Fish and Game* 30: 109-211.
- Foster, D. K., P. C. Marsh, and G. Mueller. 1997. Bonytail chub telemetry in Lake Mohave, Arizona and Nevada. *Proceedings of the Desert Fishes Council* 29(1997).
- Fradkin, P. L. 1968. *A River No More. The Colorado River and the West.* University of Arizona Press, Tucson. 360 p.
- Holden, P. B. 1980a. *Gila elegans* Baird and Girard Bonytail chub. Page 167 in D. S. Lee, C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. (editors). *Atlas of North American Freshwater Fishes.* North Carolina Biological Survey, Raleigh.
- Holden, P.B. 1980b. *Xyrauchen texanus* (Abbott) Humpback sucker. Page 435 in D. S. Lee, C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. (editors). *Atlas of North American Freshwater Fishes.* North Carolina Biological Survey, Raleigh.
- Holden, P. B. and W. L. Minckley. 1980. *Gila cypha* Miller Humpback chub. Page 165 in D.S. Lee, C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. (editors). *Atlas of North American Freshwater Fishes.* North Carolina Biological Survey, Raleigh.
- Johnson, J. E. 1987. *Protected fishes of the U.S. and Canada.* American Fisheries Society, Bethesda, MD. 47 p.

- Knowles, G. W. 1997. Movements of adult razorback suckers *Xyrauchen texanus* in Lake Mohave, Arizona-Nevada. Master of Science Thesis, Arizona State University, Tempe.
- Marsh, P. C. 1994. Abundance, movements, and status of adult razorback sucker in Lake Mohave, Arizona and Nevada. Proceedings of the Desert Fishes Council 25(1993):65.
- Marsh, P. C. 1996. Bonytail *Gila elegans* stocking records for Lake Mohave, Arizona and Nevada. Report, U.S. Bureau of Reclamation, Boulder City NV, Order Number 1425-96-PG-30-07870. Arizona State University, Tempe.
- Marsh, P. C. 1997a. Age estimation from otoliths of bonytail chub *Gila elegans* from Lake Mohave, Arizona and Nevada. Report, U.S. Fish and Wildlife Service, Parker AZ, Order Number 22340-5-0033. Arizona State University, Tempe.
- Marsh, P. C. 1997b. Sonic telemetry of bonytail in Lake Mohave, Arizona and Nevada. Report, U.S. Geological Survey, Denver Colorado, Cooperative Agreement 1445-0009-94-1108, task 2. Arizona State University, Tempe.
- Marsh, P.C. 1997c. Razorback sucker monitoring in Lake Mohave, Arizona and Nevada, for the period 01 November 1995 to 31 October 1996. Report, U.S. Bureau of Reclamation, Boulder City, Nevada, order number 1425-97-PG-30-06390. Arizona State University, Tempe.
- Marsh, P. C. In press, b. Threatened fishes of the world: *Xyrauchen texanus* (Abbott), 1860 (Catostomidae). Environmental Biology of Fishes.
- Marsh, P. C. In press, a. Threatened fishes of the world: *Gila elegans* Baird and Girard 1853 (Cyprinidae). Environmental Biology of Fishes.
- Marsh, P. C. and W. L. Minckley. 1992. Status of bonytail (*Gila elegans*) and razorback sucker (*Xyrauchen texanus*) in Lake Mohave, Arizona-Nevada. Proceedings of the Desert Fishes Council (1991): 18-23.
- McAda, C. W. and R. S. Wydoski. 1980. The razorback sucker, *Xyrauchen texanus*, in the upper Colorado River basin, 1974-1976. U.S. Fish and Wildlife Service Technical Paper 99: 1-15.
- Miller, R. R. 1961. Man and the changing fish fauna of the American southwest. Papers of the Michigan Academy of Arts, Science and Letters 46: 365-404.



- Miller, W. H., H. M. Tyus, and C. A. Carlson. 1982. Fishes of the upper Colorado River system: Present and future. American Fisheries Society, Bethesda, MD. 131 pages.
- Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix. 293 pages.
- Minckley, W. L. 1979. Aquatic habitats and fishes of the lower Colorado River, southwestern United States. U.S. Bureau of Reclamation Contract 14-06-300-2529, Arizona State University, Tempe. 478 pages.
- Minckley, W. L. 1985. Native fishes and natural aquatic habitats of U.S. Fish and Wildlife Service Region II, west of the continental divide. U.S. Fish and Wildlife Service Interagency Personnel Act Agreement, Arizona State University, Tempe. 185 pages.
- Minckley, W. L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the lower Colorado River basin. Southwestern Naturalist 28: 165-187.
- Minckley, W. L. 1991. Native fishes of the Grand Canyon region: An obituary? Pages 124-177 in Colorado River Ecology and Dam Management. National Academy Press, Washington, DC.
- Minckley, W. L. and J. E. Deacon, editors. 1991. Battle Against Extinction: Native Fish Management in the American West. University of Arizona Press, Tucson. 517 pages.
- Mueller, G. and P. C. Marsh. 1995. Bonytail and razorback sucker in the Colorado River basin. Pages 324-326 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran and M. J. Mac, editors. Our living resources: A report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.
- Tyus, H. M. 1991. Ecology and management of Colorado squawfish. Pages 379-402 in W.L. Minckley and J. E. Deacon, editors. Battle Against Extinction: Native Fish Management in the American West. University of Arizona Press, Tucson.
- Tyus, H. M. and K. A. Karp. 1989. Habitat use and streamflow needs of rare and endangered fishes, Yampa River, Colorado. U.S. Fish and Wildlife Service Biological Report 89(14): 1-27.
- U.S. Fish and Wildlife Service (USFWS). 1980. Aquatic study of the lower Colorado River. U.S. Water and Power Resources Service Contract 9-07-30-X0066, U.S. Fish and Wildlife Service, Phoenix, Arizona. 278 pages.



U.S. Fish and Wildlife Service (USFWS). 1982. Part 2, Colorado River fishery project, final report field investigations. U.S. Bureau of Reclamation Contract 9-06-40-L-1016, U.S. Fish and Wildlife Service, Salt Lake City, Utah. 365 pages.

Worster, D. 1985. Rivers of Empire. Water, Aridity and the Growth of the American West. Pantheon Books, New York. 402 pages.

## **APPENDIX A**

**1996**

### **Telemetry Tables and Figures**

Appendix A, Table 1. Individual tracking summaries for sonic telemetry of bonytail in Lake Mohave, Arizona and Nevada, 14 May to 12 August 1996. Fish are individually identified by their source (i.e., pond-reared or wild-caught) and two digit sonic tag code number (see Table 1 for additional information). Waypoints (WP) as in Figure 1. Distances in km are between successive contact points (Pt to pt), net displacement from release site (net), and cumulative distance traveled, the sum of all point to point distances (cumulative).

A. Cove reared 2-2 Released 23 May 1996 at 1st cove N of Copper Basin Cove NV						
Date	Day	Location	Pt to pt	Net	Cumulative	
23 May	1	1st N 116	no post-release contact			.
B. Cove-reared 2-3. Released 14 May 1996 at 1st cove N of Carp Cove AZ						
Date	Day	Location	Pt to pt	Net	Cumulative	
14 May	1	1st N Carp				
21 May	8	WP 36	5.6	5.6	5.6	
18 June	36	WP 17.5	35.3	40.9	40.9	
19 June	37	WP 19.3	3.8	37.1	44.7	
28 June	46	WP 9.3	17.9	55.0	62.6	
09 July	57	WP 17	12.4	42.6	75.0	
16 July	64	WP 17	0	42.6	75.0	
24 July	72	WP 17	0	42.6	75.0	
C. Wild-caught 2-4. Released 16 May 1996 at 1st cove N of Copper Basin Cove NV						
Date	Day	Location	Pt to pt	Net	Cumulative	
16 May	1	1st N 116				
23 May	8	WP 35	0.9	0.9	0.9	
03 June	19	WP 67.5	31.5	31.5	32.4	
04 June	20	WP 67.5	0.8	31.3	33.2	
05 June	21	WP 68	0	31.3	33.2	
12 June	28	WP 68.3	0.5	31.9	33.7	
17 June	33	WP 69	1.2	33.1	34.9	
25 June	41	WP 68	1.8	31.3	36.7	
27 June	43	WP 68.3	0.6	31.9	37.3	
30 June	46	WP 68	1.2	33.1	38.5	
09 July	55	WP 70.3	2.2	35.3	40.7	
17 July	63	WP 69.7	2.0	33.3	42.7	
22 July	68	WP 69.7	2.0	33.3	42.7	
29 July	75	WP 69.7	2.0	33.3	42.7	

D. Wild-caught 2-5. Released 16 May 1996 at 1st cove N of Copper Basin Cove NV

Date	Day	Location	Pt to pt	Net	Cumulative
16 May	1	1st N 116			
30 May	15	WP 68	31.3	31.3	31.1
03 June	19	WP 67	1.6	32.9	32.9
04 June	20	WP 68	1.6	31.3	34.5
05 June	21	WP 68	0	31.3	34.5
12 June	28	WP 68.3	0.4	31.7	34.9
17 June	33	WP 68.3	1.5	33.2	36.4

E. Wild-caught 2-6. Release 15 May 1996 across from Cotton Wood Cove NV.

Date	Day	Location	Pt to pt	Net	Cumulative
15 May	1	Acr CWCN			
19 May	5	WP71	32.6	32.6	32.6
20 May	6	WP70	2.1	30.5	33.7
22 May	8	WP70	0	30.5	33.7
30 May	16	WP70.5	0.9	31.4	34.6

F. Wild-caught 3-3. Released 16 May 1996 at Levi Cove AZ.

Date	Day	Location	Pt to pt	Net	Cumulative
16 May	1	Levi Cove			
19 May	4	WP 53	7.8	7.8	7.8
20 May	5	WP 52	1.5	7.9	9.3
22 May	7	WP 53	1.5	8.1	10.8
30 May	15	WP54	2.1	9.9	12.9
03 June	19	WP53	1.8	8.1	14.7
05 June	20	WP53	0	8.1	14.7
12 June	28	WP 47-52	1.8	7.4	16.5
17 June	33	WP 53.3	1.6	8.8	18.1
27 June	43	WP 53.3	0	8.8	18.1

G. Cove-reared 3-4. Release 14 May 1996 at 1st cove N of Carp Cove AZ

Date	Day	Location	Pt to pt	Net	Cumulative
16 May	1	1st N 116	no post-release contact		

H. Wild-caught 3-5. Release 16 May 1996 at 1st cove N of Copper Basin Cove NV.

Date	Day	Location	Pt to pt	Net	Cumulative
16 May	1	1st N 116			
18 May	3	WP 34	2.4	2.4	2.4
20 May	5	WP 62	24.0	21.6	26.4
22 May	7	WP 68	10.3	31.9	36.7
30 May	15	WP 68	0	31.9	36.7

I. Cove-reared 4-4. Release 15 May 1996 at North Arizona Juvenile backwater AZ

Date	Day	Location	Pt to pt	Net	Cumulative
16 May	1	North AJ			
12 June	29	WP 58	4.0	4.0	4.0

J. Cove-reared 5-5. Release 14 May 1996 at 1st cove N of Carp Cove AZ

Date	Day	Location	Pt to pt	Net	Cumulative
14 May	1	1st N Carp			
21 May	8	WP 29	15.3	15.3	15.3
23 May	10	WP 36	11.5	5.1	26.8

Lake Mohave  
Bonytail Tag No. 2-4  
465 M/Wild

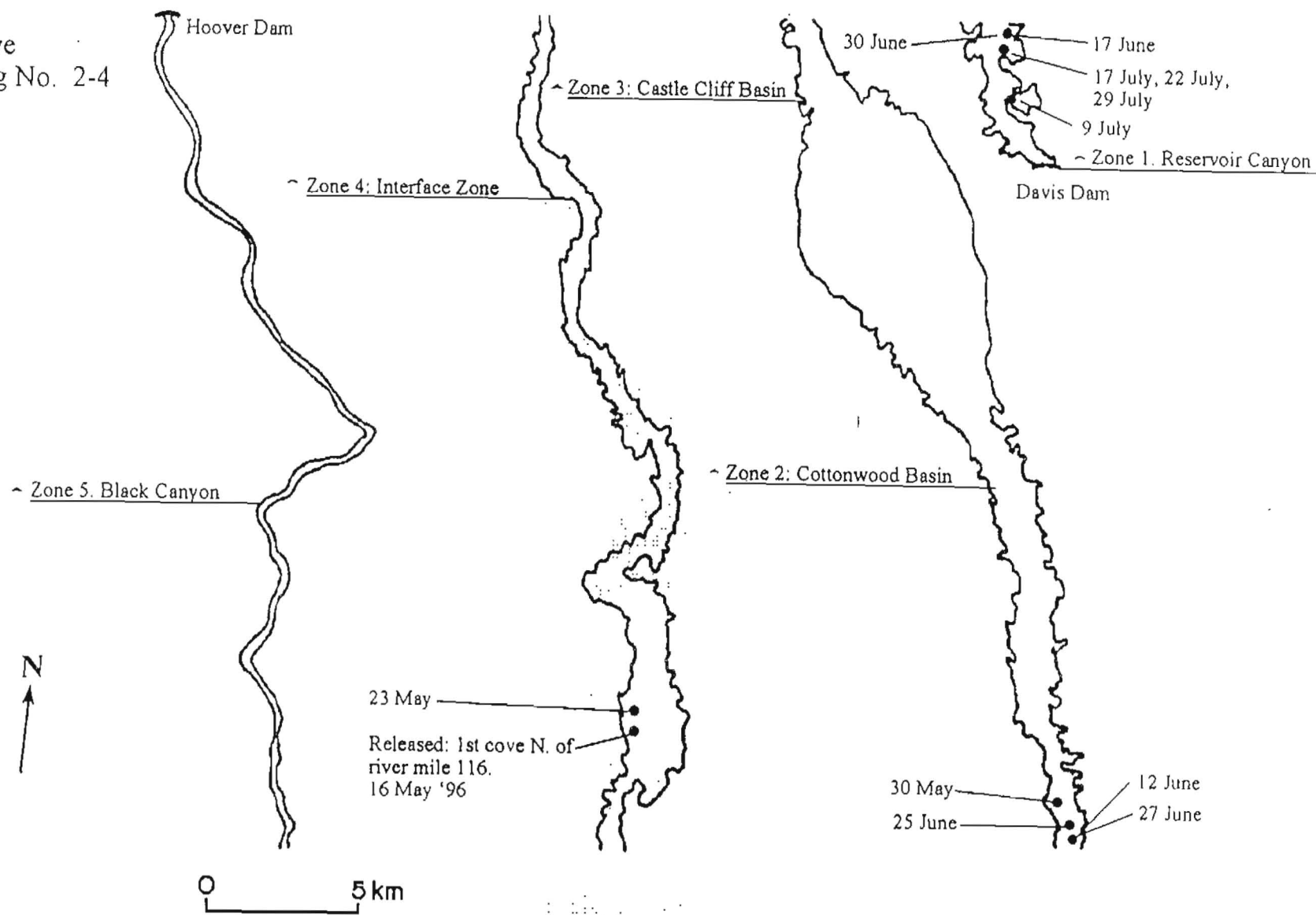


Figure 2. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Wild-caught fish, tag number 2-4, total length 46.5 cm, sex M.

Lake Mohave  
Bonytail Tag No. 2-5  
430 M/Wild

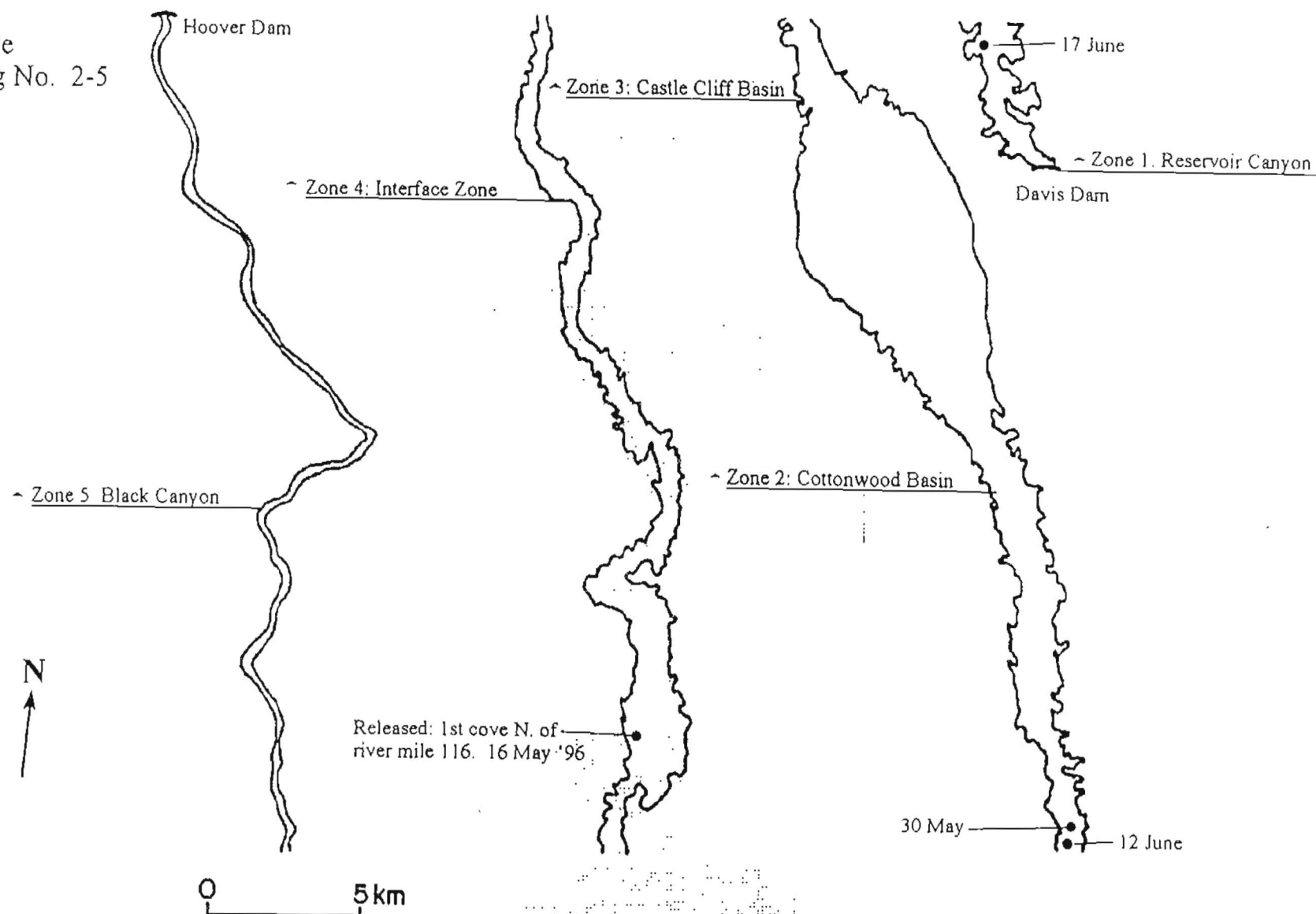


Figure 3. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Wild-caught fish, tag number 2-5, total length 43.0 cm, sex M.

Lake Mohave  
Bonytail Tag No. 2-6  
462 M/Wild

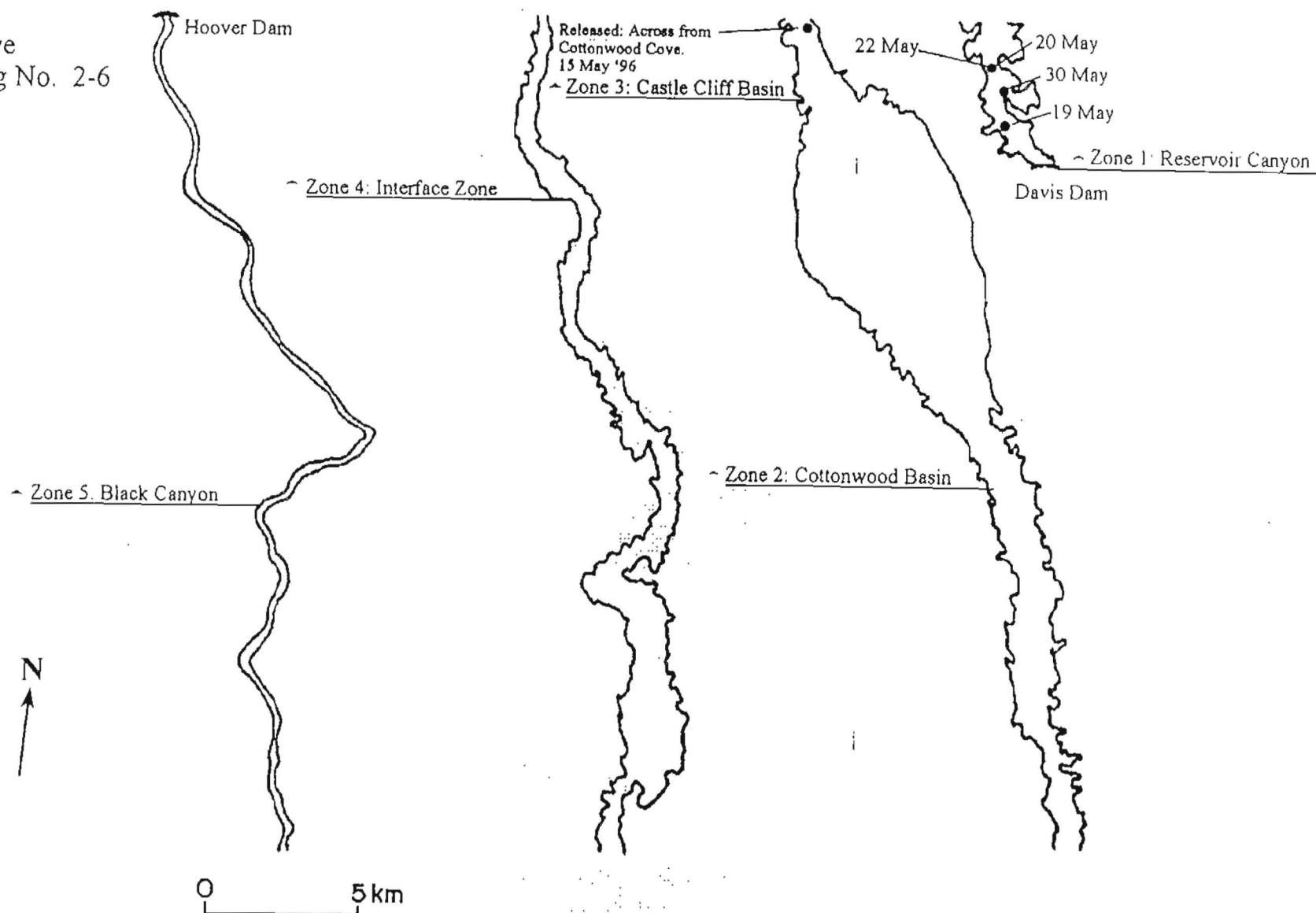


Figure 4. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Wild-caught fish, tag number 2-6, total length 46.2 cm, sex M.



Lake Mohave  
Bonytail Tag No. 3-3  
461 F/Wild

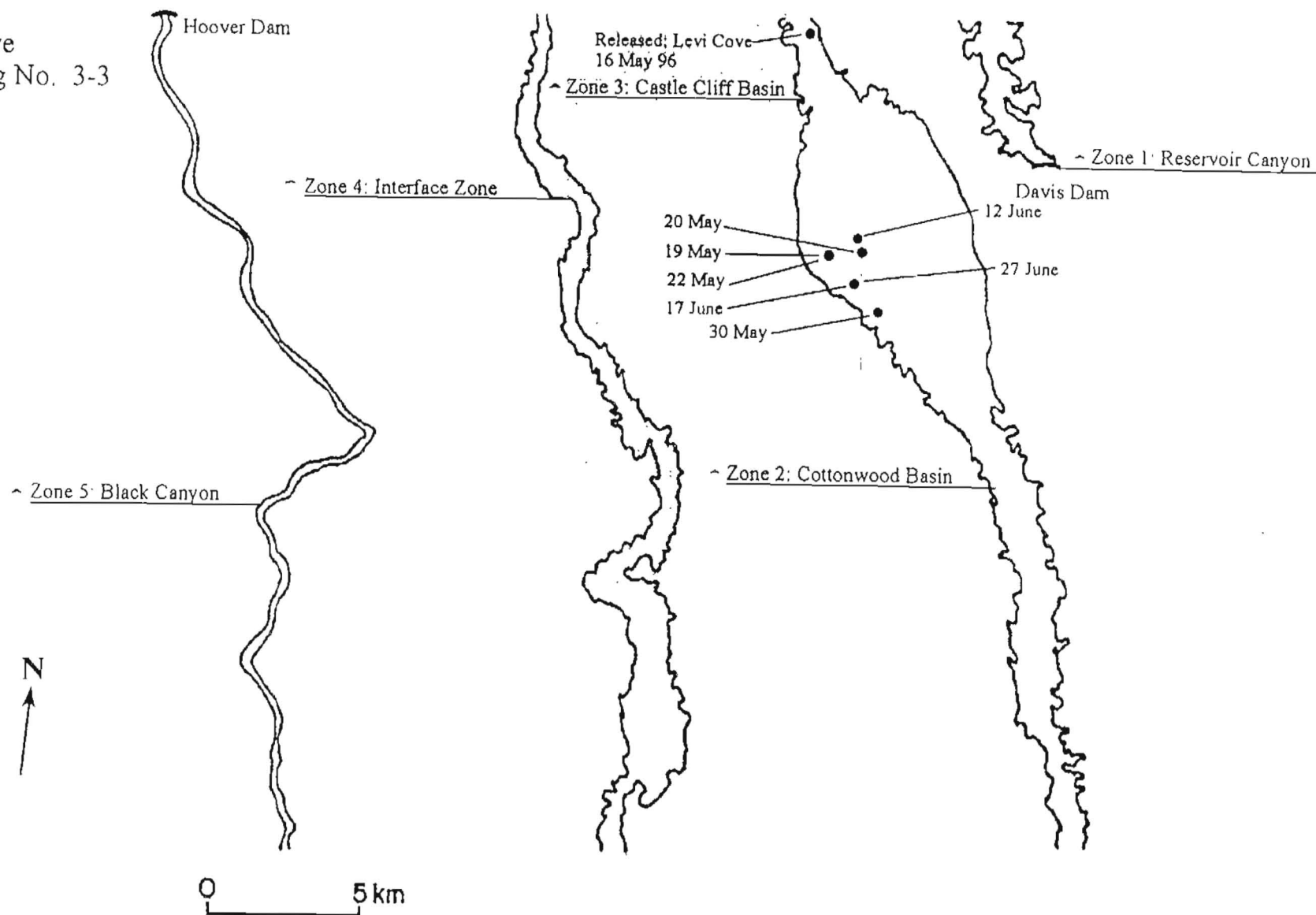


Figure 5. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Wild-caught fish, tag number 3-3, total length 46.1 cm, sex F.

Lake Mohave  
Bonytail Tag No. 3-5  
455 M/Wild

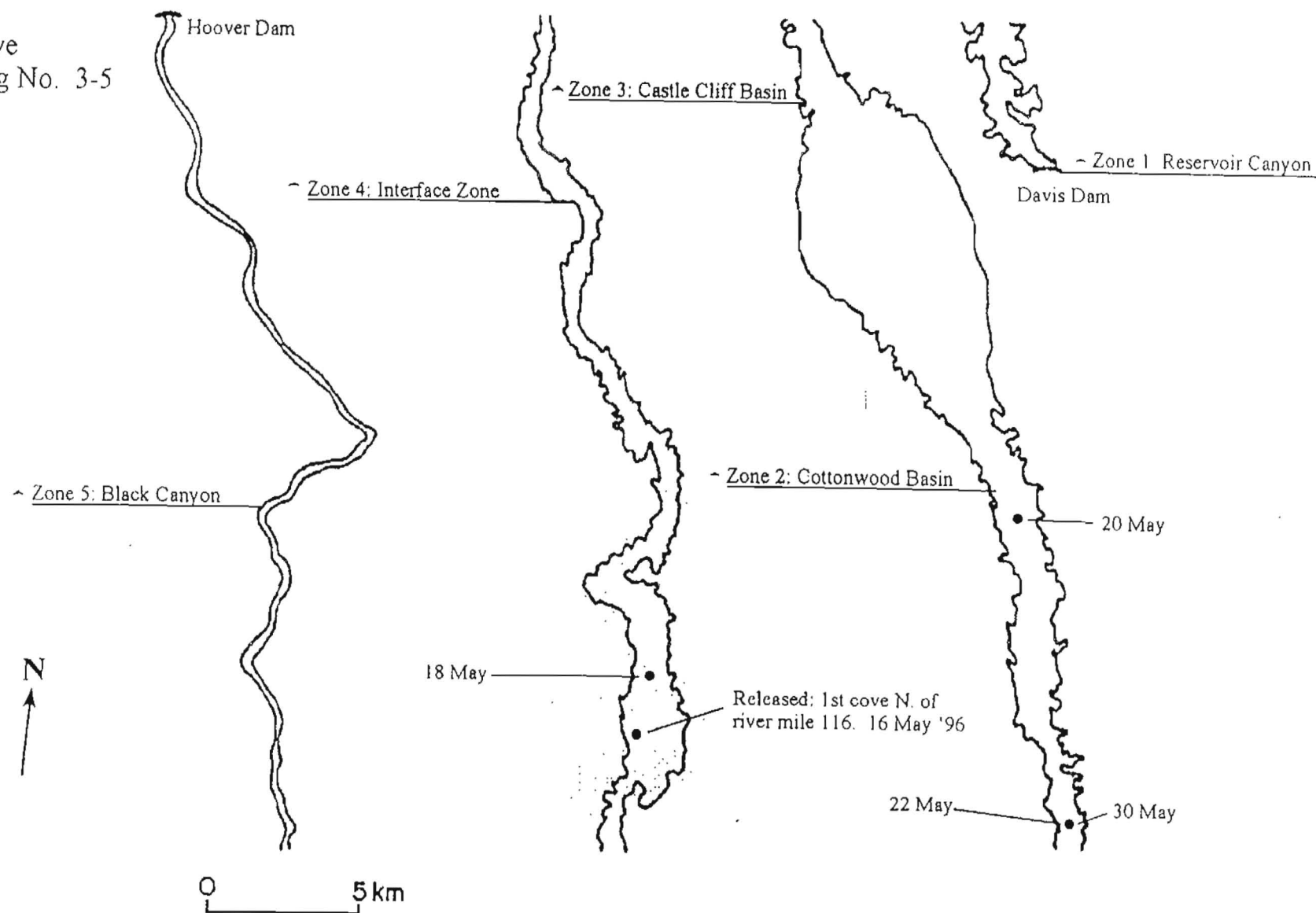


Figure 6. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Wild-caught fish, tag number 3-5, total length 45.5 cm, sex M.

Lake Mohave  
Bonytail Tag No. 2-2  
355 F/Cove

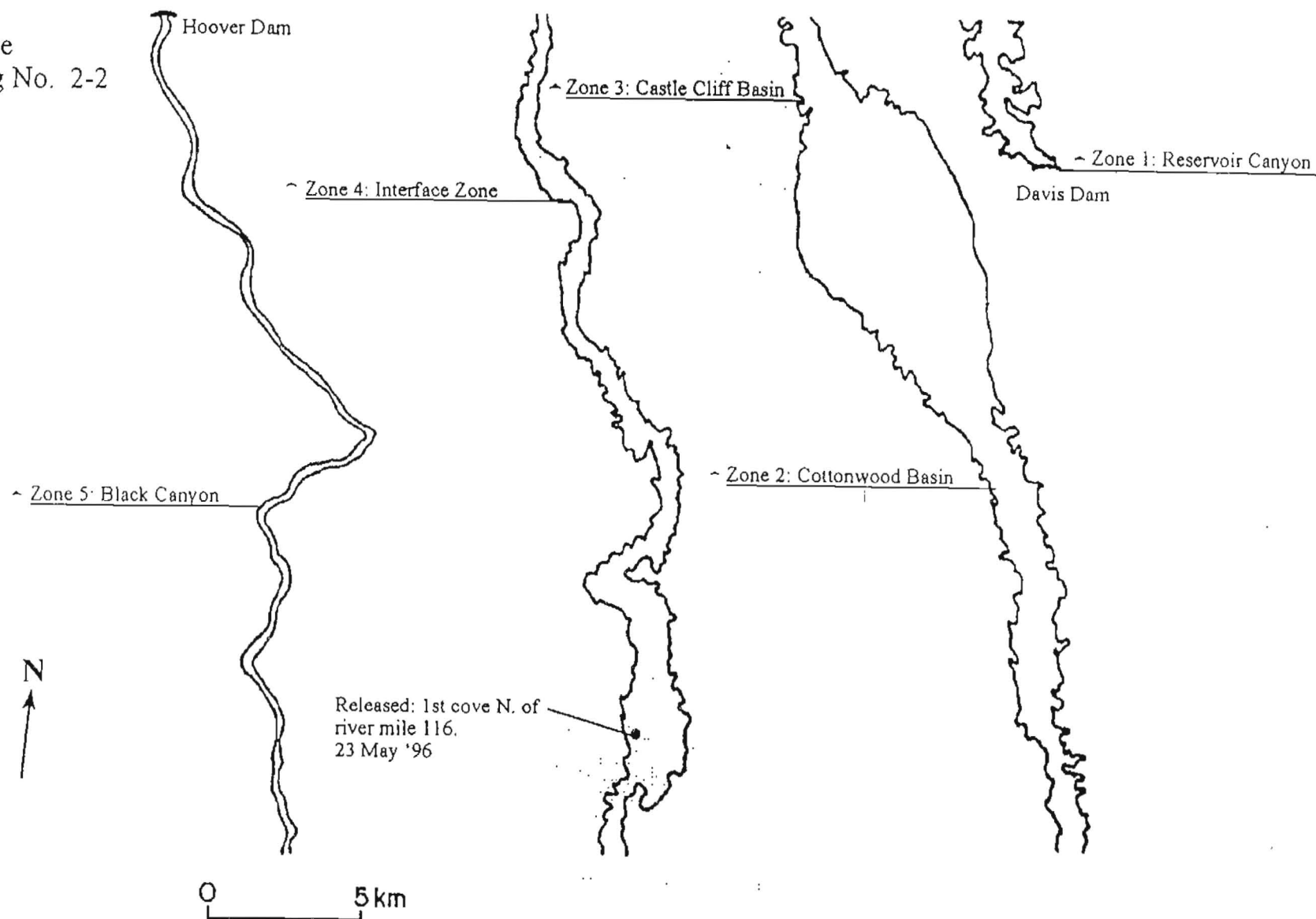


Figure 7. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Cove-reared fish, tag number 2-2, total length 35.5 cm, sex F.

Lake Mohave  
Bonytail Tag No. 2-3  
363 M/Cove

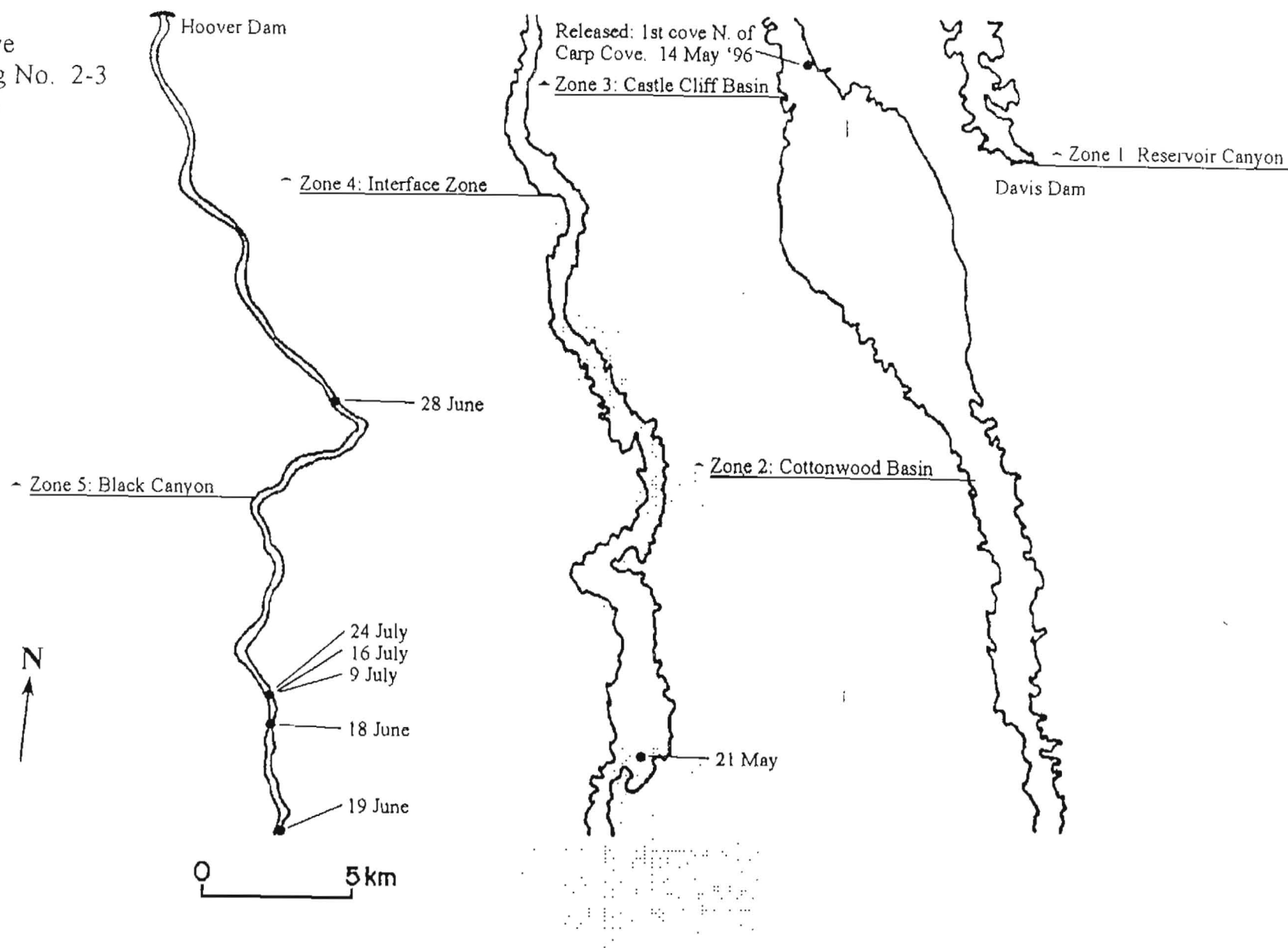


Figure 8. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Cove-reared fish, tag number 2-3, total length 36.6 cm, sex M.

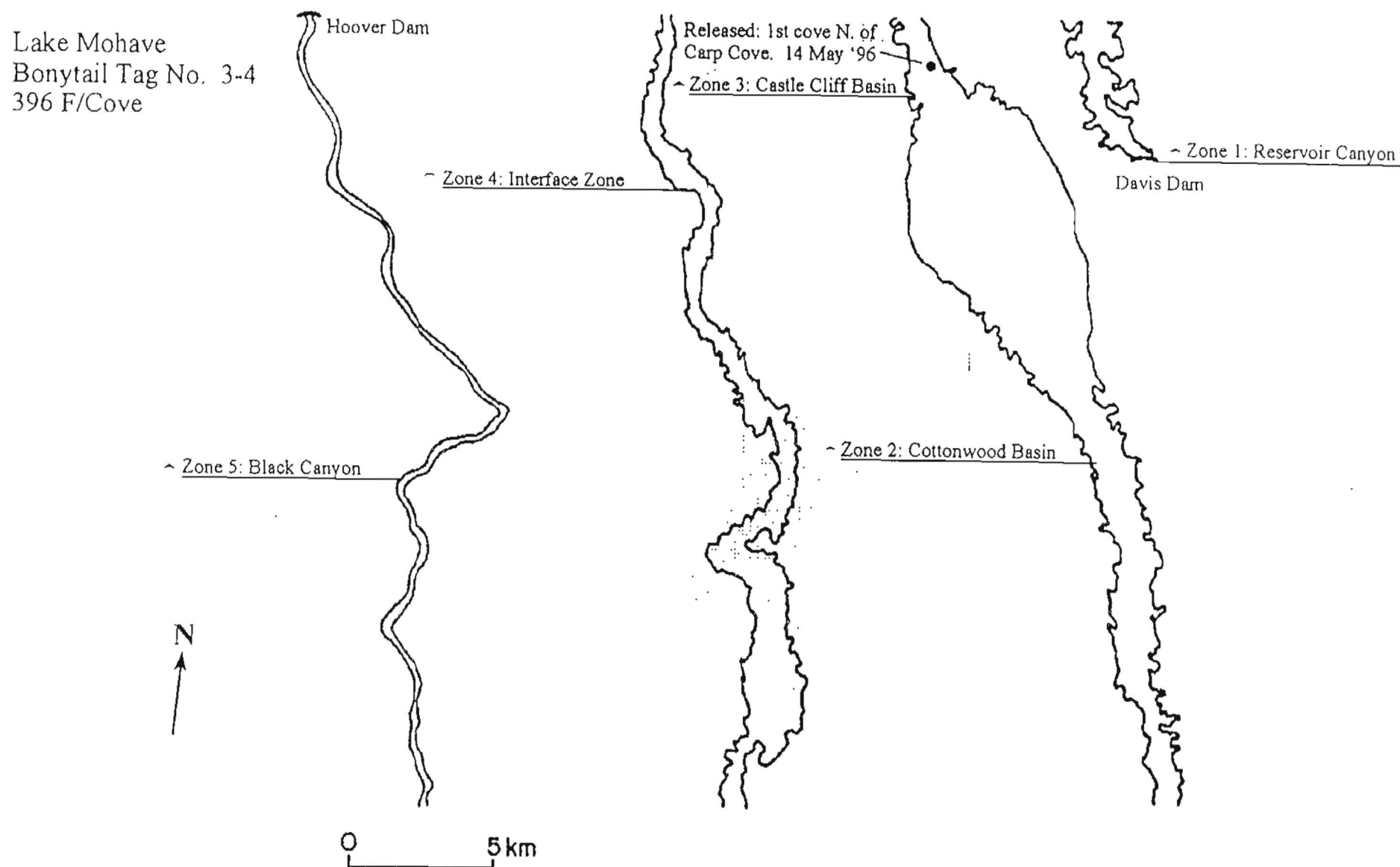


Figure 9. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Cove-reared fish, tag number 3-4, total length 39.6 cm, sex F.

Lake Mohave  
Bonytail Tag No. 4-4  
422 F/Cove

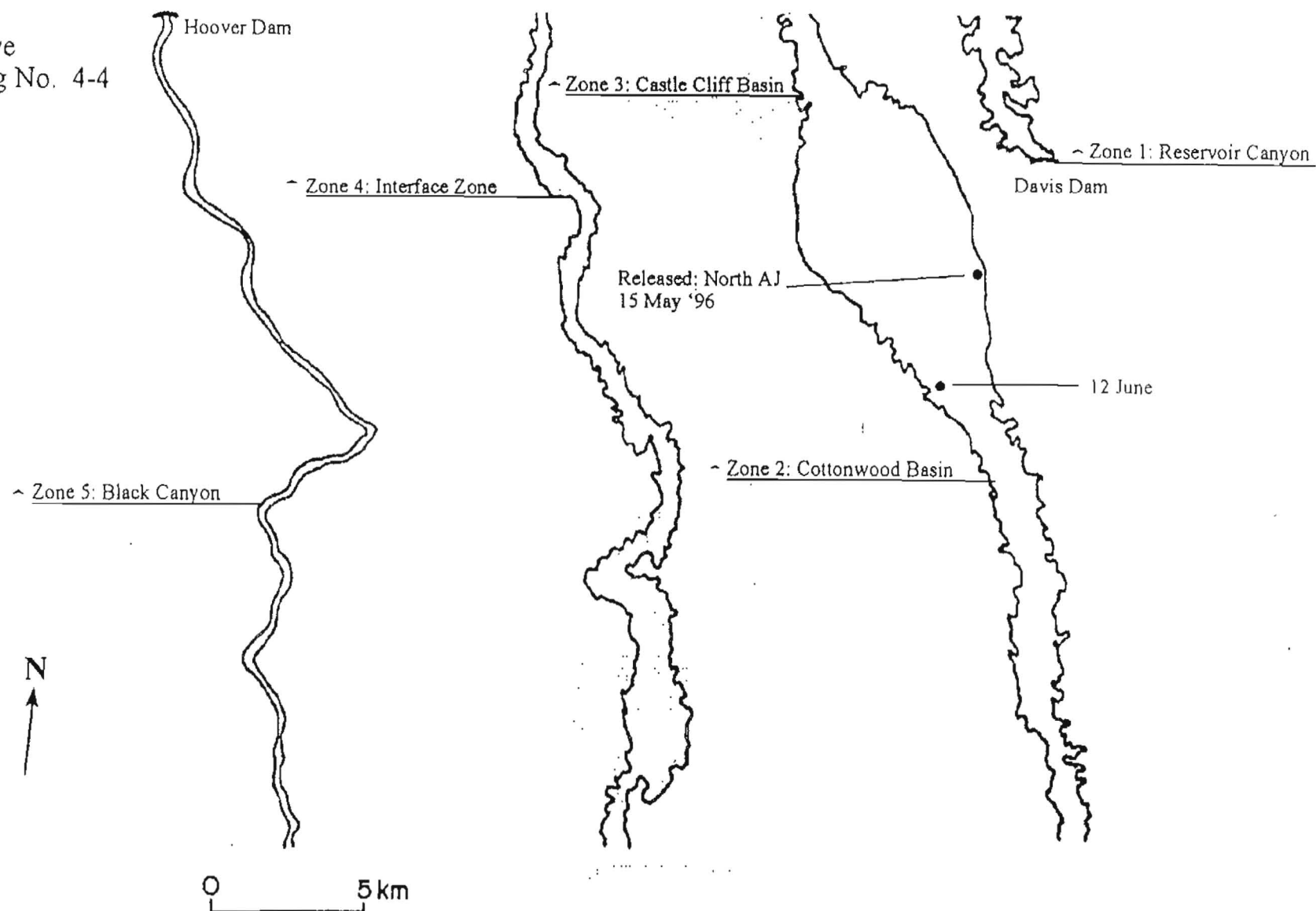


Figure 10. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Cove-reared fish, tag number 4-4, total length 42.2 cm, sex F.

Lake Mohave  
Bonytail Tag No. 5-5  
427 F/Cove

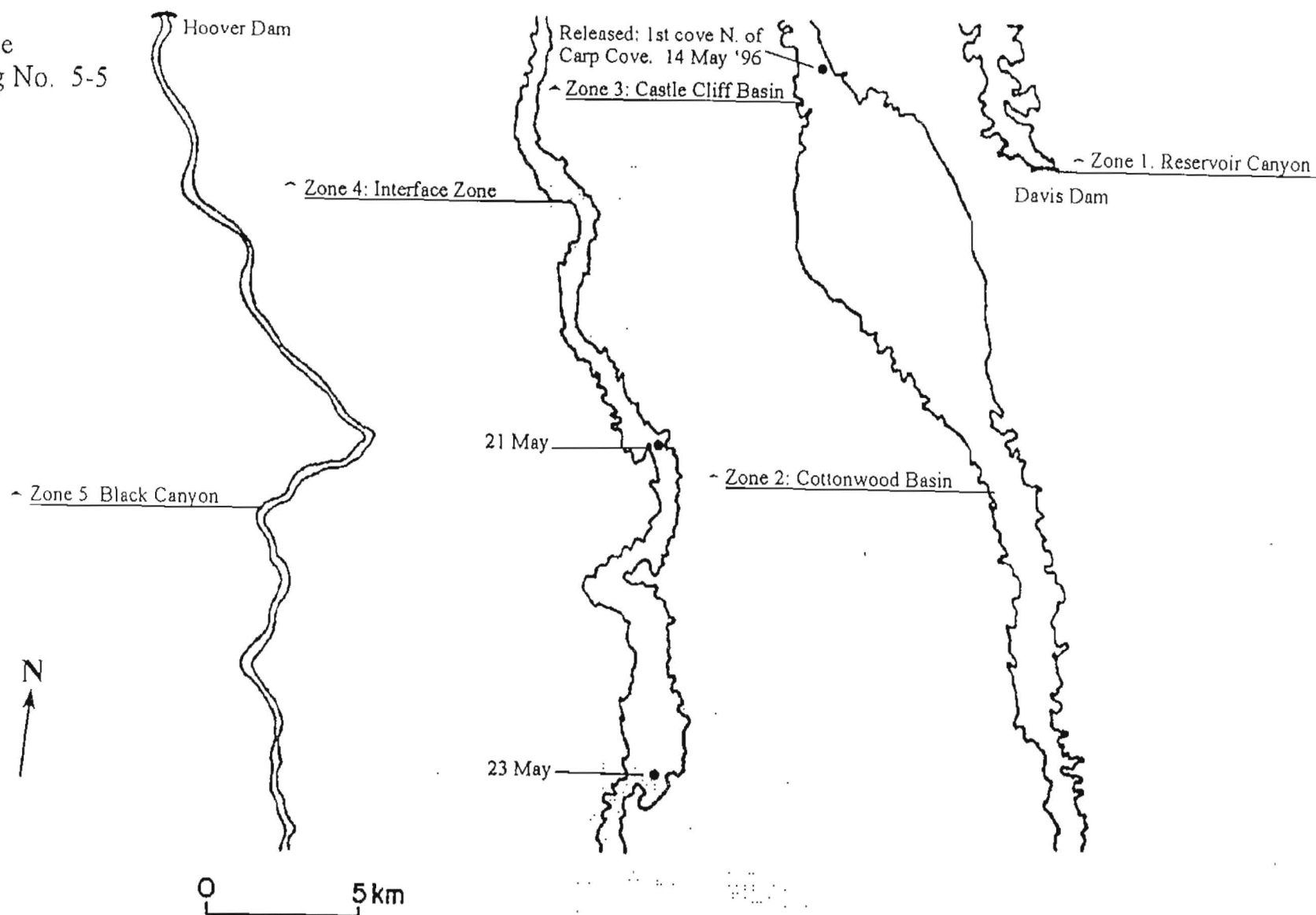


Figure 11. Map of Lake Mohave, Arizona and Nevada, showing locations of bonytail *Gila elegans* determined by sonic telemetry between 14 May to 12 August 1996. Release location and date, and location(s) and date(s) of subsequent telemetry contacts indicated on map. Cove-reared fish, tag number 5-5, total length 42.7 cm, sex F.

## **APPENDIX B**

**1997**

### **Telemetry Tables and Figures**



Appendix B, Table 1. Individual tracking summaries for sonic telemetry of bonytail in Lake Mohave, Arizona and Nevada, 02 April to 28 September 1997. Fish are individually identified by their source (i.e., pond-reared or wild-caught) and two digit sonic tag code number (see Table 1 for additional information). Waypoints (WP) as in Figure 1. Distances in km are between successive contact points (Pt to pt), net displacement from release site (net), and cumulative distance traveled, the sum of all point to point distances (cumulative).

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A. Pond-reared 3-4. Release 02 April 1997 at Cottonwood Cove NV

Date	Day	Pt to pt	Net	Cumulative
02 Apr	1	0	0	0
13 Apr	12	1.4	1.4	1.4
13 Apr	12	0.6	1.6	2.0

Last contact: WP 38.75 at Airport Cove AZ

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B. Pond-reared 3-5. Release 02 April 1997 at Cottonwood Cove NV

Date	Day	Pt to pt	Net	Cumulative
02 Apr	1	0	0	0

No post-release contact

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C. Pond-reared 3-6. Release 02 April 1997 at Cottonwood Cove NV

Date	Day	Pt to pt	Net	Cumulative
02 Apr	1	0	0	0

No post-release contact

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D. Wild-caught 2-3. Release 15 April 1997 at Katherine Powerline Cove AZ

Date	Day	Pt to pt	Net	Cumulative
15 Apr	1	0	0	0
21 Apr	7	4.8	4.8	4.8
01 May	17	3.0	1.8	7.8
01 May	17	0.4	1.5	8.2
09 May	25	0.9	2.4	9.2
09 May	25	0.3	2.6	9.4
09 May	25	0.7	3.2	10.1
09 May	25	0.8	2.5	10.9
12 May	28	1.1	1.5	12.0
Date	Day	Pt to pt	Net	Cumulative
21 May	37	5.4	6.8	17.3
21 May	37	5.7	1.2	23.0
22 May	38	0.4	0.8	23.4
22 May	38	0.3	0.5	23.7
27 May	43	3.6	4.1	27.4
27 May	43	0.6	4.7	28.0

02 June	49	1.5	6.2	29.5
16 June	63	0.4	6.6	30.0
23 June	70	0.2	6.7	30.1
03 July	80	2.2	4.7	32.4

Last contact: 0.17 km N of N point at Telephone Cove AZ

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E. Wild-caught 2-4. Release 15 April 1997 at Katherine Powerline Cove AZ

Date	Day	Pt to pt	Net	Cumulative
15 Apr	1	0	0	0
01 May	17	5.7	5.7	5.7
01 May	17	2.6	3.0	8.3
07 May	23	0.9	2.2	9.2
09 May	25	6.1	8.4	15.3
09 May	25	2.9	7.2	18.2
12 May	28	1.4	5.7	19.6
12 May	28	0.3	5.5	19.9
21 May	37	0.3	5.8	20.2
22 May	38	4.9	1.0	25.1
14 June	61	4.7	5.6	29.7
23 June	70	1.4	5.3	31.1
21 July	98	0.2	5.4	31.3

Last Contact: Back (east end) of Telephone Cove AZ

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F. Wild-caught 3-3. Release 15 April 1997 at Katherine Powerline Cove AZ

Date	Day	Pt to pt	Net	Cumulative
15 Apr	1	0	0	0
21 Apr	7	5.6	5.6	5.6
01 May	17	2.6	3.1	8.2
01 May	17	0.8	2.4	9.0
07 May	23	0.1	2.3	9.0
09 May	25	0.1	2.1	9.2
09 May	25	0.3	2.5	9.5
09 May	25	0.4	2.7	9.9
12 May	28	0.7	2.1	10.6

Date	Day	Pt to pt	Net	Cumulative
21 May	37	5.2	7.2	15.8
21 May	37	3.2	4.1	19.0
27 May	43	1.7	2.4	20.7
02 June	49	0.3	2.4	20.9
14 June	61	0.4	2.6	21.4
16 June	63	1.4	4.0	22.7
23 June	70	1.8	2.3	24.5
03 July	80	1.7	4.0	26.2
14 July	91	0.8	4.8	27.0
14 July	91	0.4	4.8	27.3
21 July	98	0.1	4.9	27.4
11 Aug	119	0.2	5.0	27.6

Last contact: N point of Telephone Cove AZ

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G. Wild-caught 4-4. Release 18 Apr 1997 at South Basin Light Cove AZ

Date	Day	Pt to pt	Net	Cumulative
18 Apr	1	0	0	0
21 Apr	4	8.3	8.3	8.3
01 May	14	3.6	4.0	11.9
01 May	14	0.9	4.8	12.7
09 May	22	0.9	4.9	13.6
09 May	22	0.9	5.6	14.5
12 May	25	0.4	6.1	14.9
21 May	34	0.4	5.7	15.3
21 May	34	0.3	5.8	15.6
27 May	40	1.7	4.1	17.3
27 May	40	1.0	5.1	18.3
16 June	60	0.3	4.8	18.6
14 July	88	0.3	4.9	18.9
21 July	95	0.8	5.4	19.7
11 Aug	116	0.2	4.8	19.9

Last contact: N point of Telephone Cove AZ

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H. Wild-caught 4-5. Release 16 April 1997 at Beaver Cove AZ

Date	Day	Pt to pt	Net	Cumulative
16 Apr	1	0	0	0
21 Apr	6	2.5	2.5	2.5
01 May	16	4.2	6.6	6.6
07 May	22	4.2	2.5	10.8

Date	Day	Pt to pt	Net	Cumulative
09 May	24	0.7	2.4	11.5
12 May	27	0.9	3.2	12.4
12 May	27	0.3	3.6	12.7
21 May	36	3.0	6.8	15.7
21 May	36	0.4	6.4	16.1
22 May	37	2.1	5.1	18.2
27 May	42	3.6	3.2	21.8
02 June	48	2.6	5.8	24.4
14 June	60	3.8	2.1	28.2
16 June	62	4.8	6.9	33.0

Last contact: Inside Katherine Landing AZ

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I. Wild-caught 4-6. Release 15 April 1997 at Katherine Powerline Cove AZ

Date	Day	Pt to pt	Net	Cumulative
15 Apr	1	0	0	0
17 Apr	3	7.5	7.5	7.5

Last contact: WP 60 (FLR "2") AZ

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Wild-caught 5-6. Release 18 April 1997 at South Basin Light Cove AZ

Date	Day	Pt to pt	Net	Cumulative
18 Apr	1	0	0	0
14 July	88	0	0	0

Last contact: WP 60 AZ side (no post release movement detected)

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# Lake Mohave Bonytail Movements River Mile 1 - 6

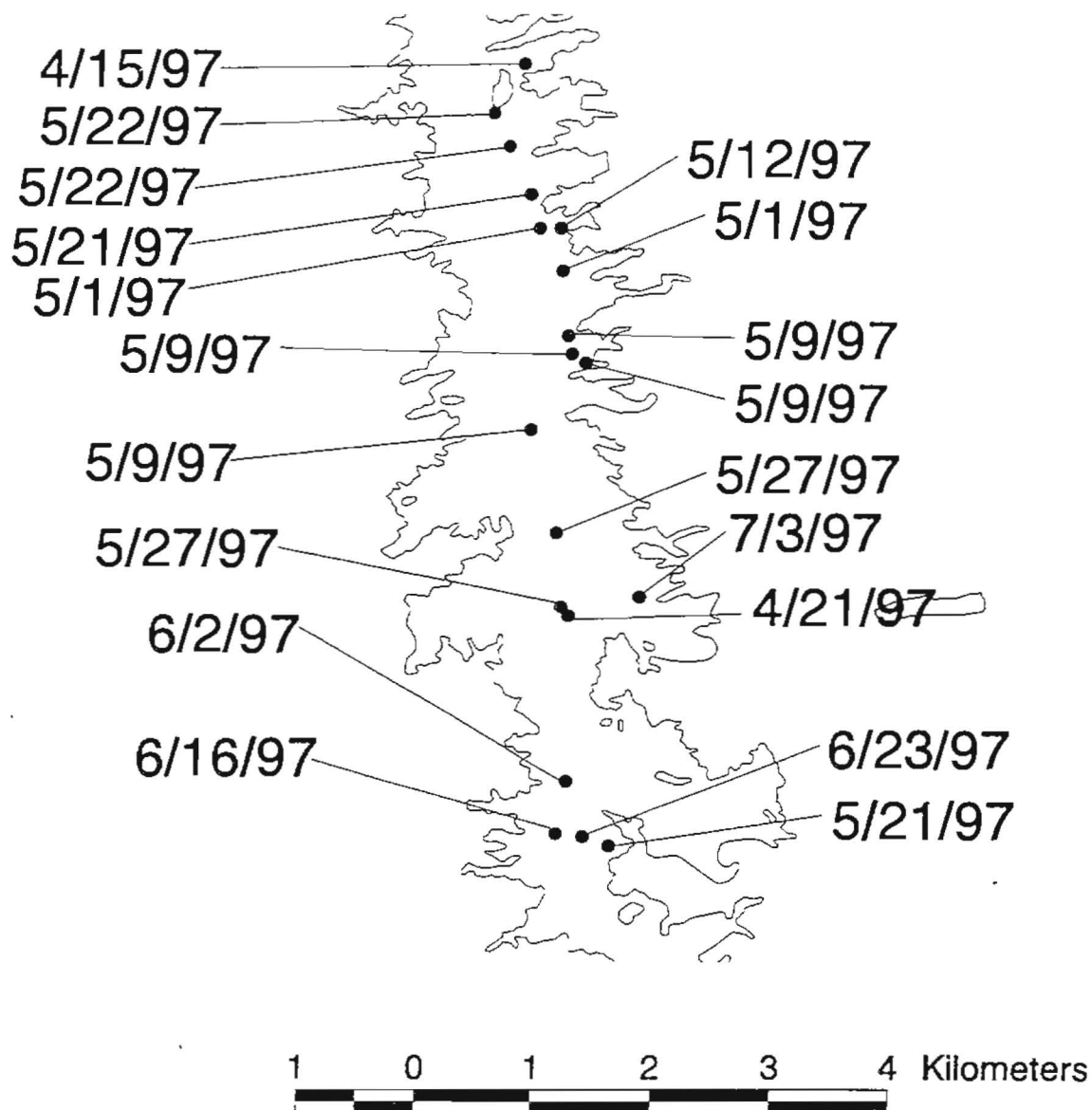
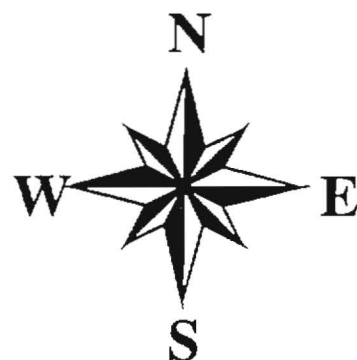


Figure 2. Map of lower Lake Mohave, Arizona and Nevada, showing post-release locations and dates for wild-caught bonytail 2-3 determined by sonic telemetry during spring-summer 1997. See Table 1 for release data.



# Lake Mohave Bonytail Movements River Mile 1 - 6

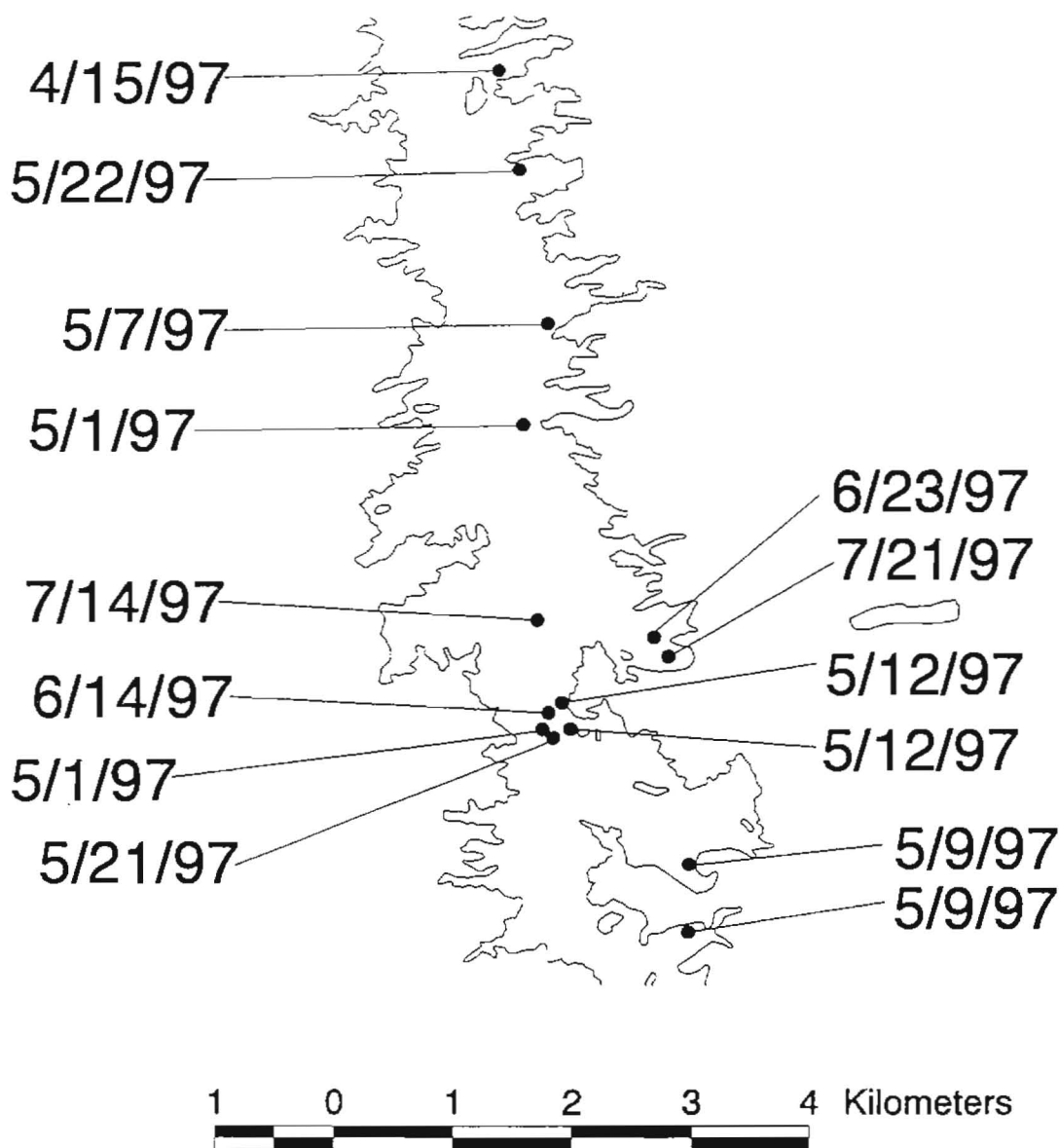
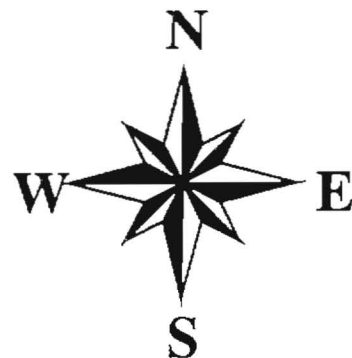


Figure 3. Map of lower Lake Mohave, Arizona and Nevada, showing post-release locations and dates for wild-caught bonytail 2-4 determined by sonic telemetry during spring-summer 1997. See Table 1 for release data.



# Lake Mohave Bonytail Movements River Mile 1 - 6

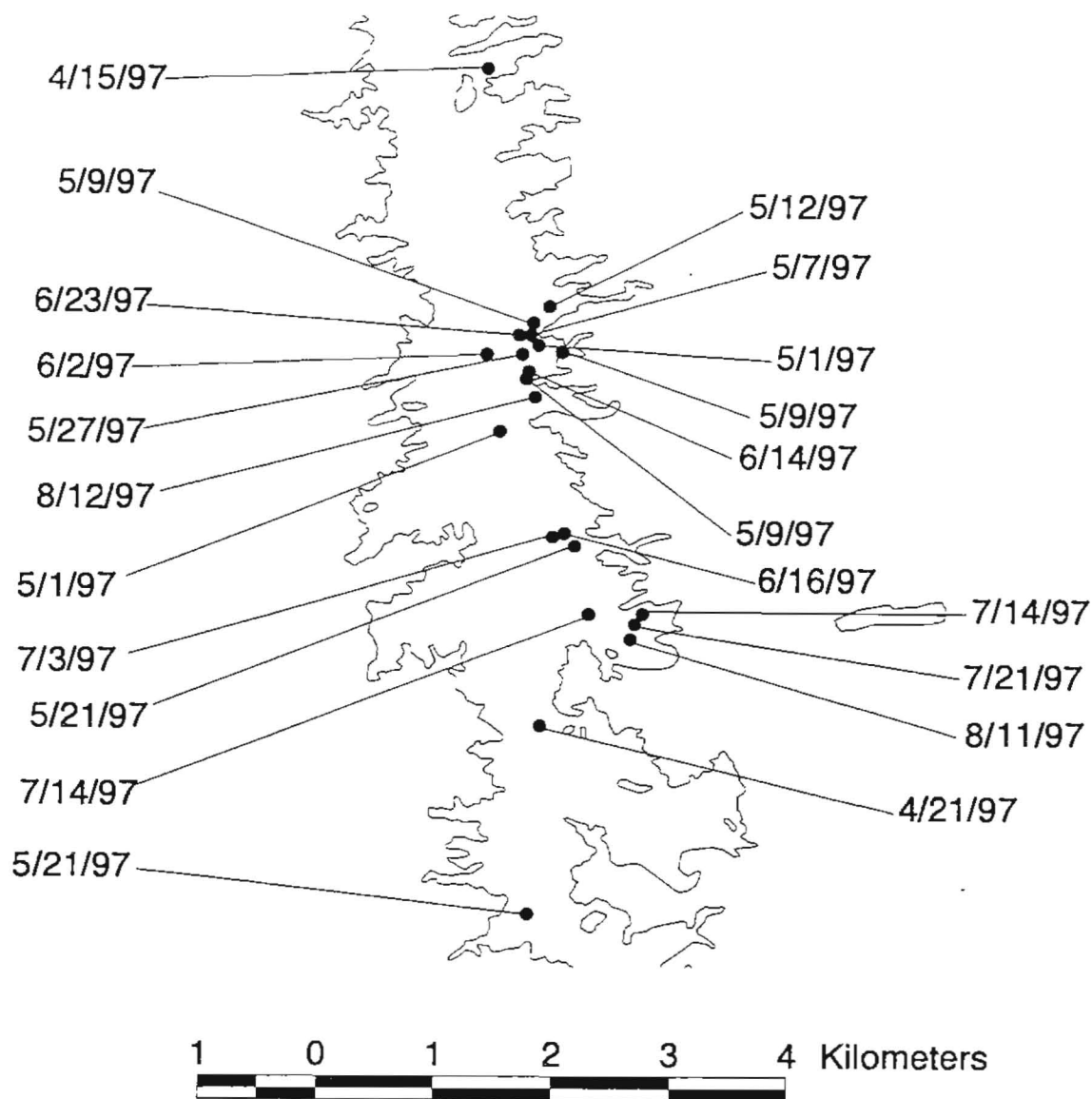
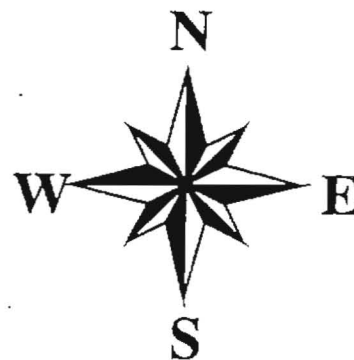


Figure 4. Map of lower Lake Mohave, Arizona and Nevada, showing post-release locations and dates for wild-caught bonytail 3-3 determined by sonic telemetry during spring-summer 1997. See Table 1 for release data.



# Lake Mohave Bonytail Movements River Mile 20 - 22

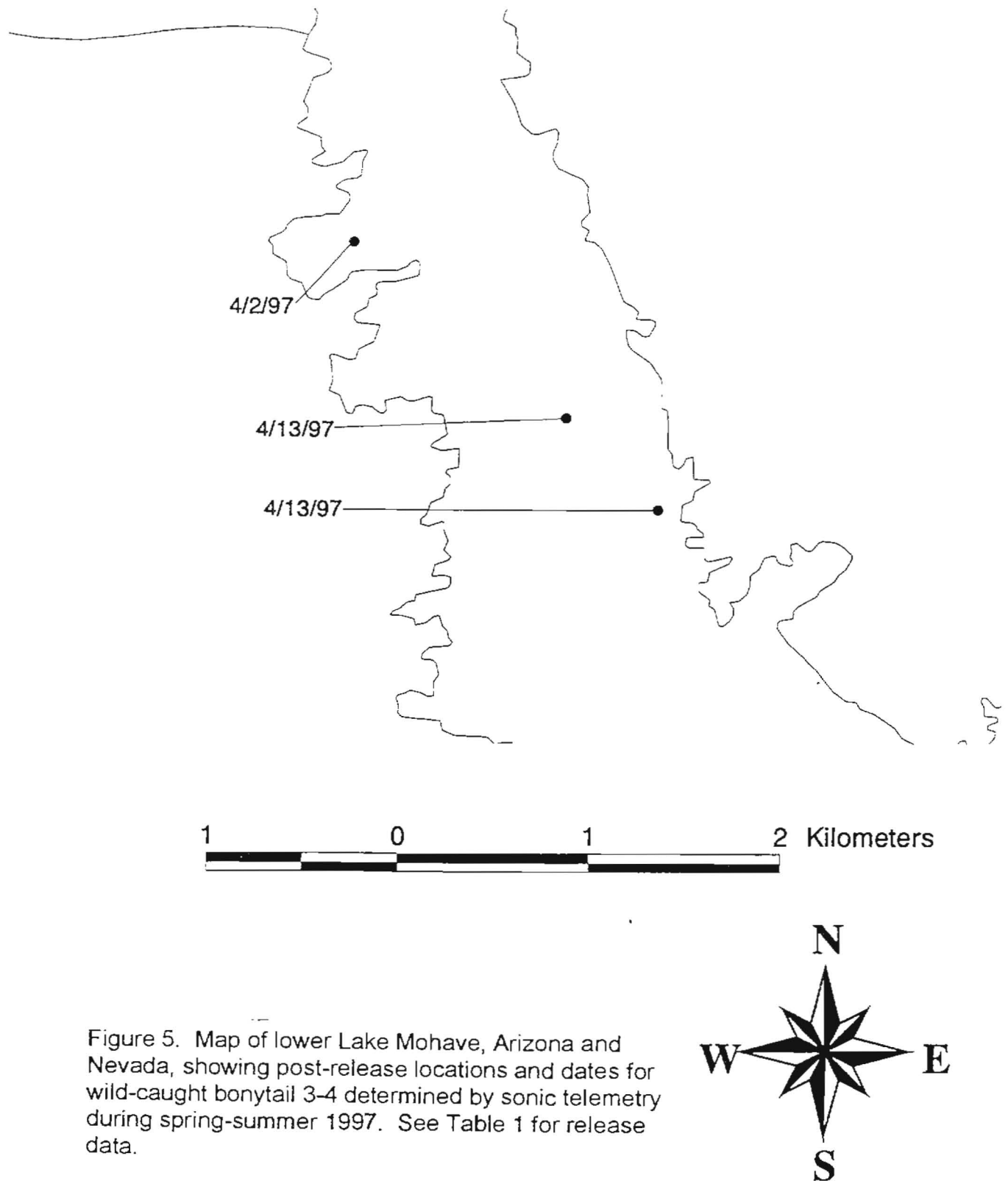


Figure 5. Map of lower Lake Mohave, Arizona and Nevada, showing post-release locations and dates for wild-caught bonytail 3-4 determined by sonic telemetry during spring-summer 1997. See Table 1 for release data.



# Lake Mohave Bonytail Movements River Mile 1 - 6

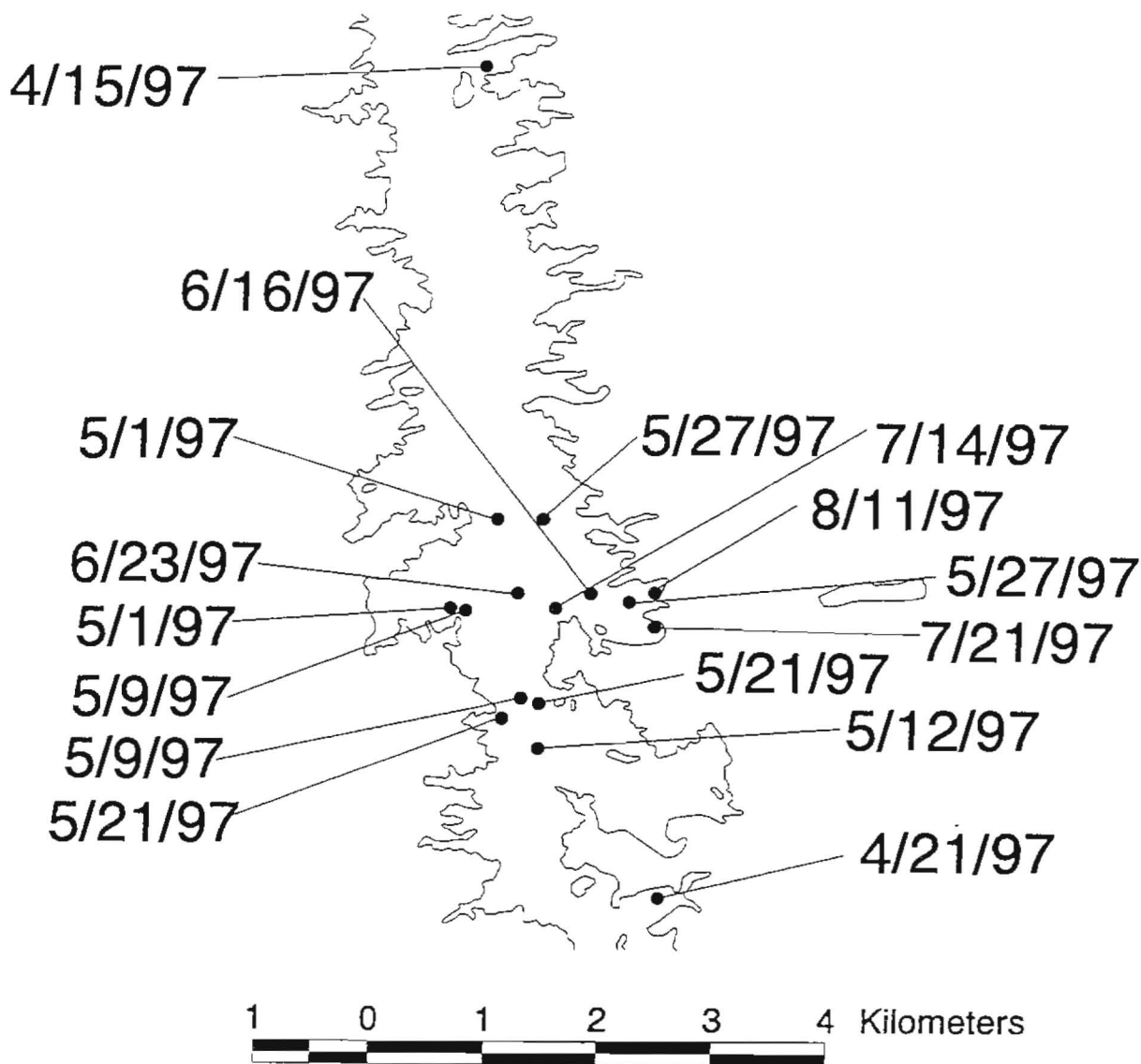
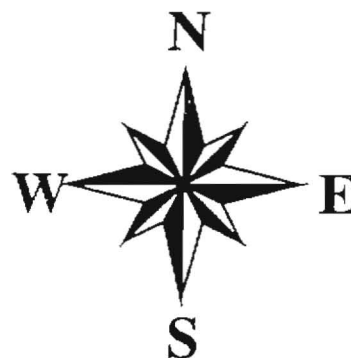


Figure 6. Map of lower Lake Mohave, Arizona and Nevada, showing post-release locations and dates for wild-caught bonytail 4-4 determined by sonic telemetry during spring-summer 1997. See Table 1 for release data.



# Lake Mohave Bonytail Movements River Mile 1 - 6

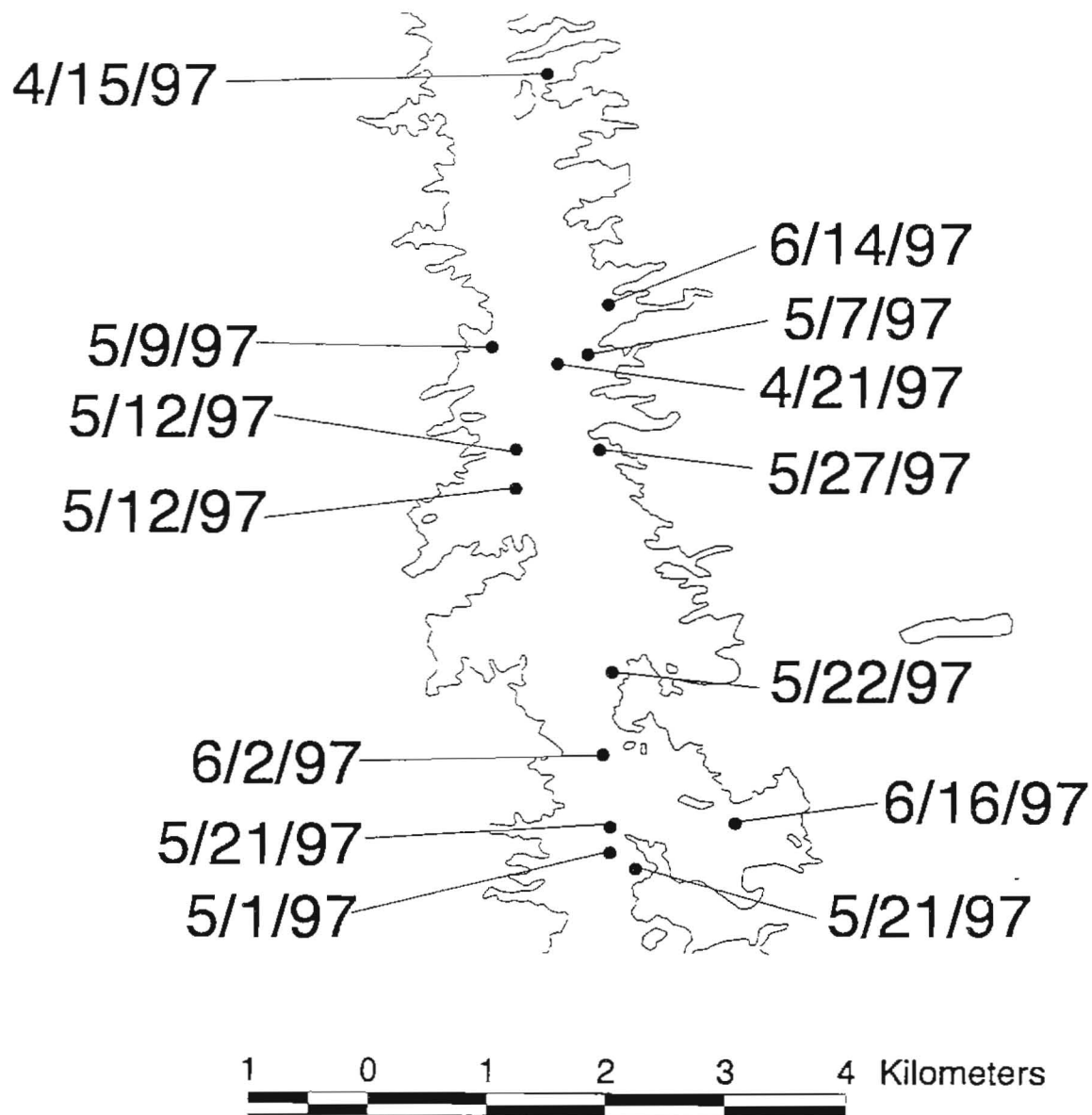


Figure 7. Map of lower Lake Mohave, Arizona and Nevada, showing post-release locations and dates for wild-caught bonytail 4-5 determined by sonic telemetry during spring-summer 1997. See Table 1 for release data.

