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727 West Eleventh Street
Claremont, California 91711

FINAL REPORT

AN EXAMINATION OF POTENTIAL RELOCATION SITES OF THE MOHAVE TUI CHUB

(*Gila bicolor mohavensis*)

Prepared by: C. Robert Feldmeth and David L. Soltz
Ecological Research Services

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Riverside, CA

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C. Robert Feldmeth and Associates
Ecological Analysis and Environmental Assessment
(714) 621-8190

An Examination of Potential Relocation Sites for the Mohave Tui Chub (*Gila bicolor mohavensis*)

by

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Introduction

The Mohave tui chub, *Gila bicolor mohavensis*, is native to the Mohave River drainage in San Bernardino County, California. During the early part of this century the arroyo chub, a closely related species, *Gila orcutti*, was introduced into Mohave River headwaters and subsequently hybridized with the Mohave tui chub within the lower reaches of the Mohave River (Hubbs and Miller, 1943). A small population of genetically pure Mohave tui chubs currently persists in isolated ponds at Soda Springs, where the Mojave River terminates into Soda Lake. This fish is listed as Endangered by both the U.S. Fish and Wildlife Service and the State of California. Other than the Soda Springs population it only exists in the Lark Seep at China Lake and in a small pond near the town of Hinkley, California. The Army Corps of Engineers have proposed a modification to the Mohave Forks Dam in the Victorville area which could lower the aquifer level at Soda Springs. If the Mohave tui chub is to be preserved, additional populations need to be established, especially in habitats within the Mohave River drainage and nearby areas, to bring about the recovery of this protected subspecies (U.S. Fish and Wildlife Service Recovery Plan for the Mohave tui chub, 1984).

Although a number of transplants of this species have been attempted, most have failed (St. Amant and Hoover, 1975). From a recent study of the

physiological tolerance and ecology of Mohave tui chub at Lark Seep, we have found that this species does not tolerate temperatures above 35 C, or salinities greater than 10 parts per thousand (Feldmeth, et al., 1984). Any potential refugium must thus be carefully analyzed for water quality characteristics, especially during mid-summer when temperatures and salinity (and/or alkalinity) are likely to be the highest.

The following study was made of five potential refugia sites in order to analyze their physical and chemical characteristics, with the objective of determining which sites might provide potential habitats for the future Mohave tui chub transplants.

METHODS

Two pools were examined along the Mojave River in Afton Canyon (Campground Pond and Railroad Pond). Two springs located on the northeast slope of the San Bernardino Mountains in Lucerne Valley (Rattlesnake Spring and Dove Spring) were also examined. The final area surveyed was Owl Hole Spring, located just east of Death Valley National Monument near its southernmost boundary.

Each study site was examined over a 24 hour period to collect data on daily fluctuations in temperature and dissolved oxygen. Other parameters, including pH, salinity, specific conductance and alkalinity were also measured. A 2 liter water sample collected from each study site was subjected to thorough chemical analysis at the Edward S. Babcock Laboratory in Riverside, California. The following substances were analyzed: sodium, calcium, magnesium, manganese, potassium, chloride, sulfate, nitrate, carbonate, bicarbonate, boron, fluoride, iron, hydroxide, and phosphate. Measurements of color, odor, turbidity, total hardness, total alkalinity, electrical conductivity and total dissolved residue were also taken.

Information on the physical aspects of each study site was collected. Lengths and widths of each pool or pond was measured using a transect line calibrated at 5 m intervals. Pond depths were measured at 5 meter intervals along the long axis of each study site. Water flow into or out of each site was also measured whenever possible. A map of each site was drawn noting all emergent and riparian vegetation. The presence of both shade and cover are an extremely important aspect in most desert aquatic habitats.

Biological aspects were determined by sampling for zooplankton, benthic invertebrates and aquatic invertebrates using standard methods. An 8 inch diameter net (no. 25 bolting silk) was used to collect plankton. General tows were taken only in Campground Pond and Dove Spring. The smaller size of the other habitats necessitated using a technique where 5 buckets of water (50 liters total) were passed through the same plankton net. All organisms captured using both methods were preserved in 10% formalin.

Benthic invertebrates were sampled using an Ekman grab. All material obtained was then washed through a 0.9 mm screen at the site. Organisms were picked from the screen and preserved in 70% alcohol. Aquatic invertebrates were sampled with dip nets and also preserved in alcohol.

Fish were collected using either 10 or 20 foot minnow seines (1/8 or 1/4 in. mesh). All fish were measured (standard length), a small number of each species were preserved for confirming identification, and all other fish were returned live to the area from which they were collected.

Results

Afton Canyon

The two ponds studied in Afton Canyon were probably formed in past times by stream meander of the Mojave River. The water level of each pond

is apparently related to ground water levels. Observation of the banks and shorelines indicated that water levels had decreased considerably prior to the time of our visit in late July.

The Campground Pond (Figure 1) is a long, narrow water body which abuts the steep north canyon wall approximately 0.5 miles east of the Bureau of Land Management campground. The surface area of this pond covers 1340 square meters (0.3 acres). Mean depth is 85.8 cm (Table 1). The western shoreline is choked with a dense stand of cattails (see Figure 1). Remaining shoreline pond vegetation includes tamarisk (Tamarix spp.) and arrow weed (Pluchea serica). Adjacent mesic vegetation consists of stands of reeds (Juncus spp.) and bulrush (Distichlis spp.).

Water quality of Campground Pond is good when compared to other most desert aquatic habitats without active spring flow (Table 2). The pond supports a large population of native and exotic fishes including: green sunfish (Lepomis cyanellus), black bullhead (Ictalurus melas) and possibly Mohave chub - Arroyo chub hybrid (Gila orcuttix bicolor).

Water chemistry parameters measured in the field indicate a salinity of 3.6 ppt, a specific conductance of 7,000 umhos/cm, a pH of 8.15 and a total alkalinity of 804 ppm (Table 2). Laboratory analysis indicates that water mineral content is dominated by sodium, chloride and sulfate ions, with relatively high concentrations of both boron and fluoride, (Table 3).

Invertebrate population sampling also indicated that the Campground Pond is rich in aquatic life. Zooplankton samples provided an abundance of rotifers, cladocerans and copepods (Table 4). Benthic invertebrates and other swimming or epibenthic forms such as amphipods, damselflies and backswimmers were also numerous (Table 4).

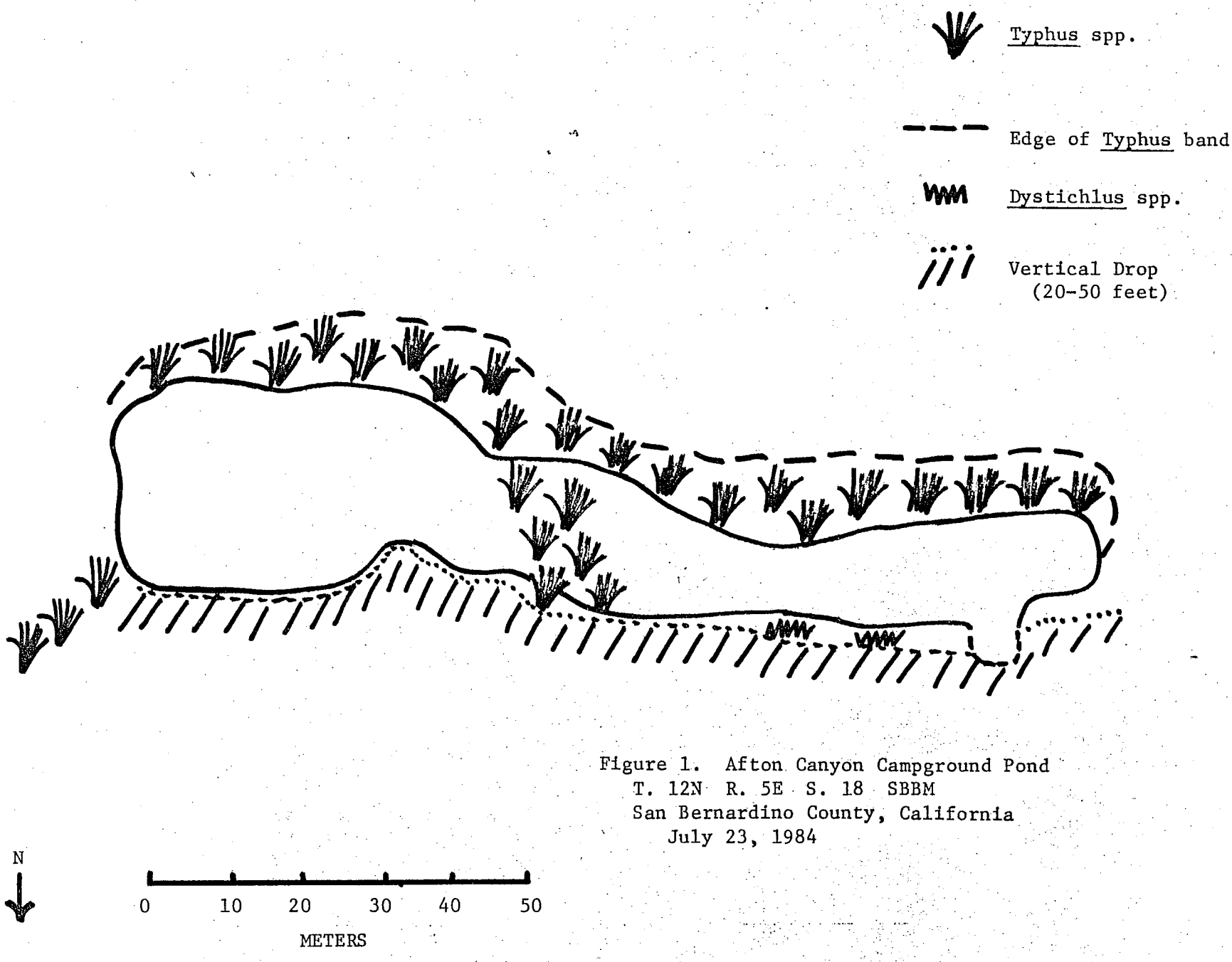


Figure 1. Afton Canyon Campground Pond
T. 12N R. 5E S. 18 SBBM
San Bernardino County, California
July 23, 1984

Table 1. Physical Data for the Potential Mohave Tui Chub Relocation Sites

Location Name	Pond Length (m)	Average Width (m)	Surface Area (m^2)	Mean Depth (cm)	Outflow Rate (liters/hr)	Volume (m^3)
Campground Pond	145	7.8	1340	85.8	none	1149
Dove Spring	50	19.8	995	71.2	480	708
Rattlesnake Spring	8.7	5.1	44	52.3	426	23
Owl Hole Spring	28.5	2.9	67.8	46.3	32	31

Table 2. Water Quality Characteristics Obtained by Field Analysis of Potential Mohave Tui Chub Relocation Sites

Location	Date 1984	Maximum Water Temperature (C)	Specific Conductance (umhos/cm)	Salinity (ppt)	pH	Carbonate (ppm)	Bicarbonate (ppm)	Total (ppm)
Afton Canyon								
Campground Pond	7/23/84	31.0	7,000	3.6	8.15	80	724	804
Railroad Pond	7/24/84	34.6	149,000	12.5	8.80	380	380	1536
Johnson Valley								
Rattlesnake Spring	8/7/84	27.2	1,530	0.8	7.17	0	50	50
Dove Spring	8/8/84	26.1	780	0.2	9.07	23	72	95
Death Valley								
Owl Hole Spring	10/11/84	21.0	2,580	1.4	8.40	60	236	296

Table 3. Water Quality Characteristics Obtained Through Laboratory Analysis of Potential Mohave tui Chub Relocation Sites

(Laboratory Water Chemistry Analyses performed by Edward S. Babcock and Sons, Inc.)

CATIONS (mg/1)		ANIONS (mg/1)		OTHER WATER QUALITY MEASUREMENTS (mg/1)	
AFTON CANYON					
Campground Pond					
Sodium	- 1850	Chloride	- 1300	Tot. Hard. as CaCO	- 90
Calcium	- 26	Sulfate	- 1140	Total Alkalinity	- 990
Potassium	- 22	Nitrate	- 0.02	Elec. Conductivity	- 7780
Magnesium	- 6	Hydroxide	- 0	Dissolved Solids	- 4700
Boron	- 16	Phosphate	- 13	Color	100 units
Iron	- 0.62	Flouride	- 14	Odor	4 ton
Manganese	- 0.14			Turbidity	5.5 NTU
Railroad Pond					
Sodium	- 4900	Chloride	- 4289	Tot. Hard. as CaCO	- 200
Calcium	- 20	Sulfate	- 2780	Tot. Alkalinity	- 1,440
Potassium	- 80	Nitrate	- 1	Elec. Conductivity	- 18,700
Magnesium	- 36	Hydroxide	- 0	Dissolved Residue	- 12,700
Boron	- 33	Phosphate	- 13	Color	100 units
Iron	- 0.07	Flouride	- 25	Odor	32 ton
Magnesium	- 0.02			Turbidity	7 NTU

Table 3 (continued)

CATIONS (mg/1)		ANIONS (mg/1)		OTHER WATER QUALITY MEASUREMENTS (mg/1)	
LUCERNE VALLEY					
Dove Spring					
Sodium	- 99	Chloride	- 28	Tot. Hard. as CaCO	- 193
Calcium	- 27	Sulfate	- 248	Tot. Alkalinity	- 103
Potassium	- 8	Nitrate	- 1	Elec. Conductivity	- 830
Magnesium	- 30	Phosphate	- 0.5	Dissolved Solids	- 510
Boron	- 0.1	Hydroxide	- 0	Color	10 units
Iron	- 0.05	Flouride	- 1.8	Odor	4 ton
Manganese	- 0.01			Turbidity	0.5 NTU
Rattlesnake Spring					
Sodium	- 270	Chloride	- 59	Tot. Hard. as CaCO	- 193
Calcium	- 72	Sulfate	- 664	Tot. Alkalinity	- 50
Potassium	- 6	Nitrate	- 1	Dissolved Residue	-1070
Magnesium	- 12	Phosphate	- 0.4	Color	10 units
Boron	- 1	Hydroxide	- 0	Odor	4 ton
Iron	- 0.08	Flouride	- 7	Turbidity	0.5 NTU

Table 4: Afton Canyon
Aquatic Invertebrates
July 22 - 23, 1984

Campground Pond and Railroad Pond:

- Class Insecta
  - Order Odonata
  - Order Hemiptera
    - Family Gerridae
  - Order Coleoptera
    - Family Dystiscidae
  - Order Diptera
    - Family Tabanidae
    - Family Chironomidae
- Class Crustacea
  - Order Amphipoda
    - Genus Hyallella
  - Order Cladocera
    - Genus Daphina
  - Order Copepoda
    - Genus Cyclops

Rattlesnake Spring:

- Class Insecta
  - Order Ephemeroptera
  - Order Odonata
    - Suborder Anisoptera
    - Suborder Zygoptera
      - Genus Enallagma
      - Genus Coenagrion
  - Order Hemiptera
    - Family Belastomatidae
    - Family Notonectidae
      - Genus Notonecta
    - Family Gerridae
  - Order Trichoptera
    - Family Limnephilidae
  - Order Coleoptera
    - Family Elmidae
  - Order Diptera
    - Family Dixidae
    - Family Chironomidae
- Class Crustacea
  - Order Ostracoda

Table 4 (continued)

Dove Spring:

- Class Insecta
  - Order Ephemeroptera (immature nymph)
  - Order Odonata
  - Order Hemiptera
    - Genus Notonecta (immature)
  - Order Coleoptera
    - Family Elmidae
- Class Crustacea
  - Order Ostracoda

Owl Hole Spring:

- Class Insecta
  - Order Hemiptera
    - Family Notonectidae
  - Order Odonta
    - Suborder Zygptera
  - Order Coleoptera
    - Family Dystiscidae
  - Order Diptera
    - Family Chironomidae
- Class Rotifera
- Class Crustacea
  - Order Copepoda
    - Genus Cyclops

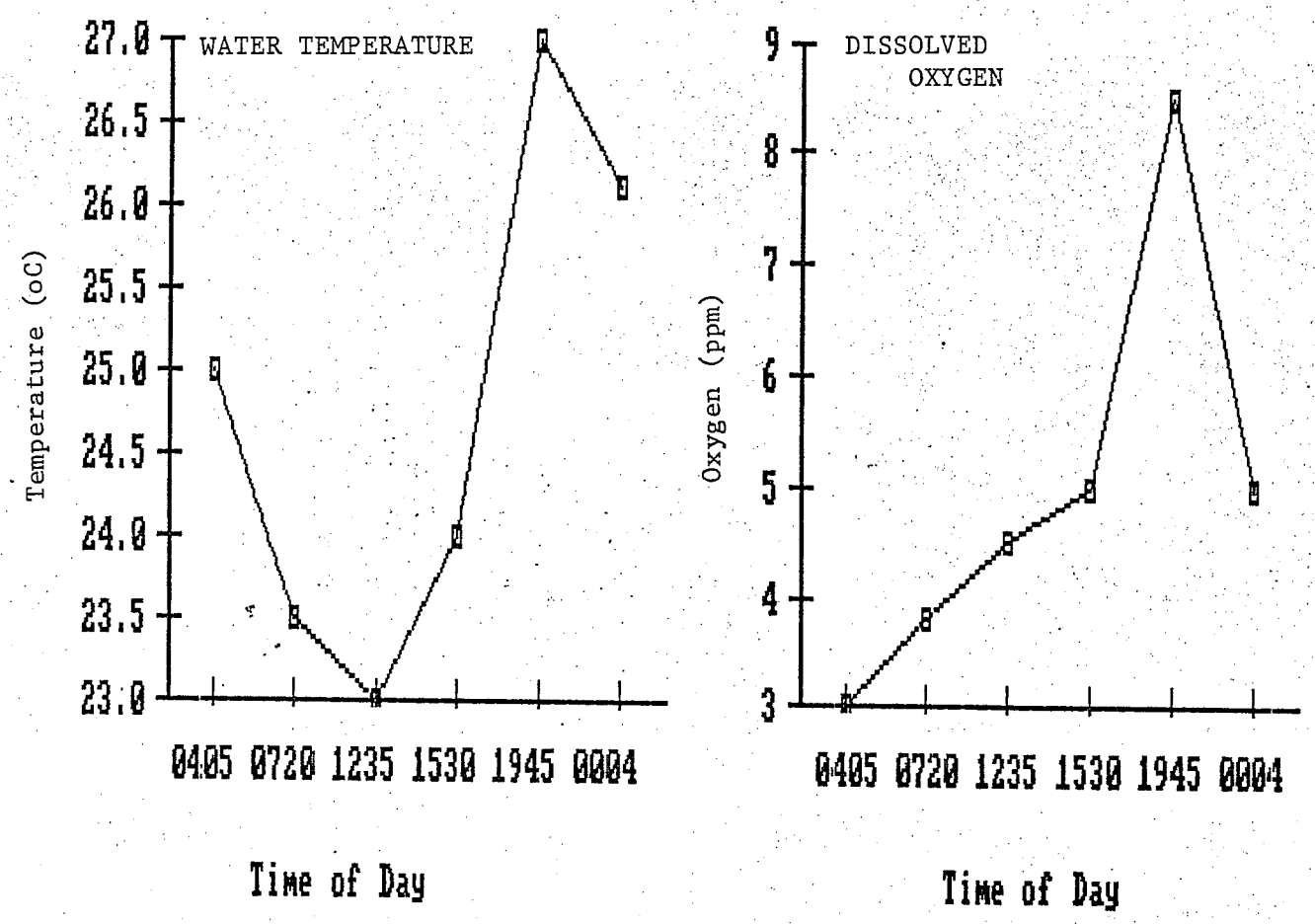


Figure 2. Campground Pond Temperature and Oxygen Study

The fish fauna clearly show that a large population of several exotic species have become established in this pond (Table 5). Mid-summer extremes in water temperature and dissolved oxygen concentration apparently do not limit either growth or reproduction of these fish. Data indicate that temperatures ranged between 27.0 C and 23 C. Dissolved oxygen ranged between 8.5 ppm (1745 hrs) and 3.0 ppm (0110 hrs) (Figure 2). An anomolously low dissolved oxygen value of 1.9 ppm occurred at 1005 hrs after the pond was seined for fish.

Railroad Pond

A second pond is located one mile to the southeast of the Campground Pond, where the railroad berm has dammed an old portion of the river channel. The water level of the Railroad Pond on July 24, 1984 had decreased to a point that it water was clearly an unsuitable habitat for fish. The maximum water temperature was 34.6 C, the salinity was 12.5 ppt and the specific conductance was 149,000 umhos/cm (Table 2). A decision was made to continue the planned water chemistry measurements but physical measurements on pond size and depth were not made. The maximum depth was less than 50 cm and most areas were less than 10 cm. A rough map of the pond is presented in Figure 3. Burush is present around the pond as are a few small tamarisk trees.

The dissolved oxygen concentration of the Railroad Pond was very low, and water appeared to be filled with decomposing algae (Figure 4). No fish and few insects were present (Table 4).

Lucerne Valley

Two seperate ponds were examined on the northern slope of the San Bernardino Mountains, and south of Old Woman Springs Road. Dove Spring is located at an elevation of 4200 feet, 0.5 miles east of Round Mountain and about 2 miles southeast of Old Woman Springs Road. Rattlesnake Spring is

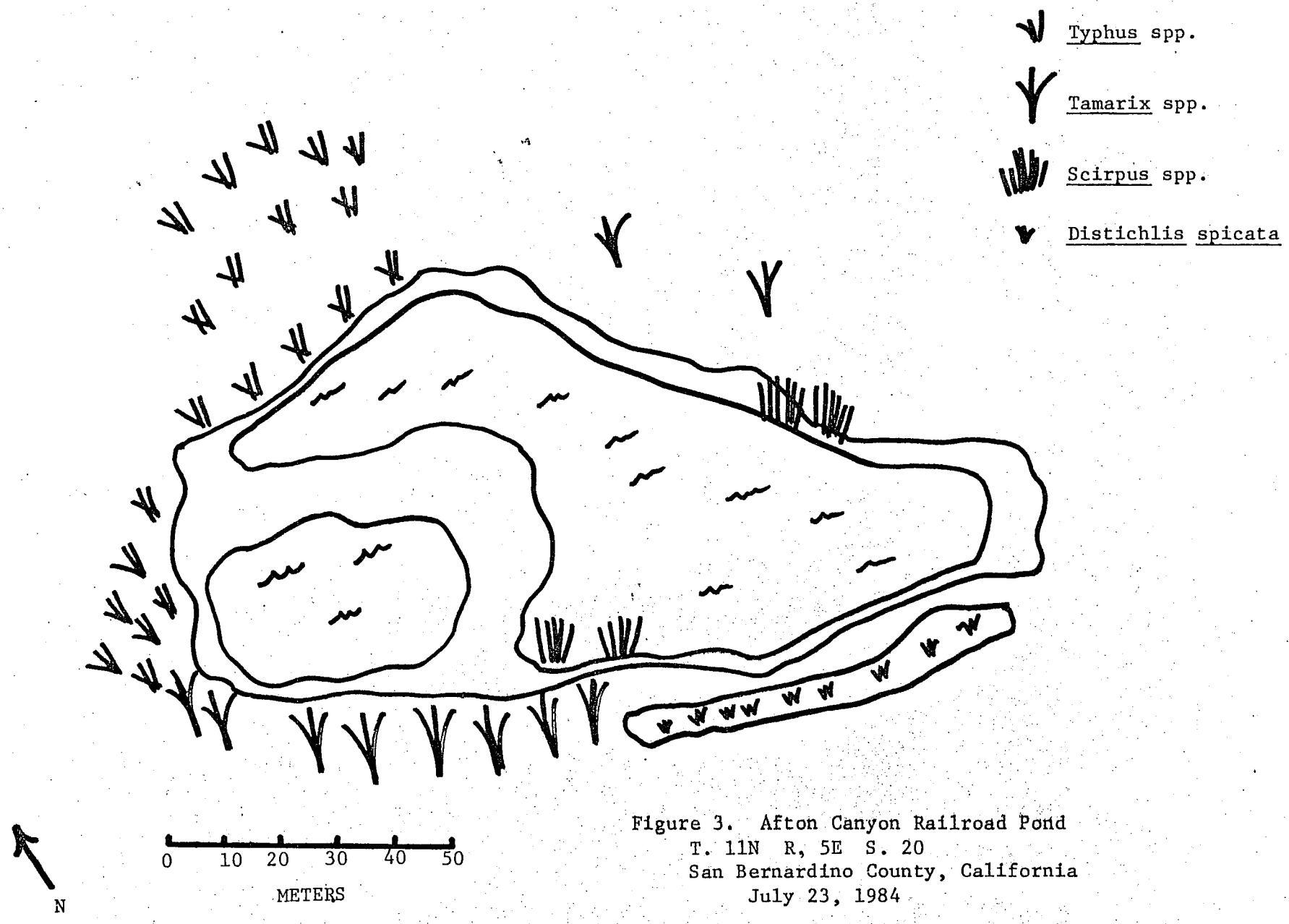


Figure 3. Afton Canyon Railroad Pond
T. 11N R, 5E S. 20
San Bernardino County, California
July 23, 1984

Table 5. Fish Fauna of Campground Pond, Afton Canyon

Common Name	Scientific Name	Number	Size Range
Arroyo Chub	Gila orcutti	8	8.0-9.1 cm
Black bullhead	Ictalurus melas	29	13.0-20.0
Green Sunfish	Lepomis cyanellus	23	9.2-12.5

1. The chubs did not resemble Mohave chub but may have some intermediate characteristics between both species.

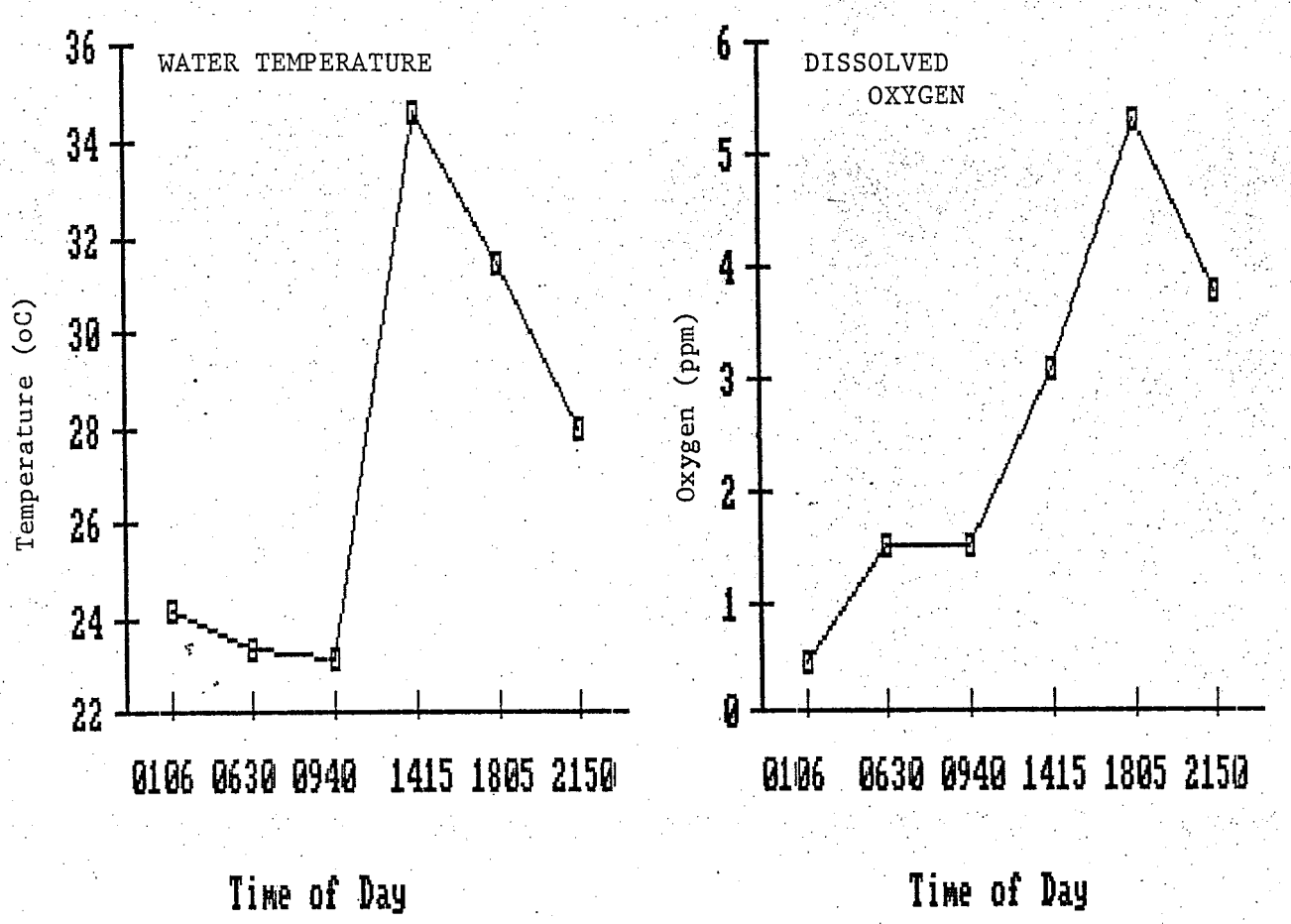


Figure 4. Railroad Pond Temperature and Oxygen Study

located about 1.5 miles to the east of Dove Spring in Rattlesnake Canyon at an elevation of 3600 feet.

Dove Spring

Dove Spring is a pool approximately 50 m long with a mean depth of 71.2 cm (Figure 4). The presence of an outflow pipe in a dam at one end of the pool yielded a flow rate of 480 liters per hour. The water in this pond is relatively clear and the bottom was covered with a dense carpet of Stonewart (Chara sp.). Dove Spring has an average width of 19.8 m, a surface area of 995 m (0.25 acres) and a total volume of 708 m .

The water in Dove Spring has a low specific conductance (780 umhom/cm) and a low total alkalinity (95 mg/l, see Table 2). Laboratory chemical analysis reveals the water is very low in most salts and of excellent quality when compared to other desert aquatic habitats (Table 3). Measured water temperatures over a 24 hour period ranged between 17 and 25 degrees celcius; dissolved oxygen tanged between 4.8 and 13.4 ppm.

No fish were present in this pond and there was a typical, although sparse assemblage of aquatic insects (Table 3). Plankton samples yielded rotifers and a few copepods (Cyclops sp.).

Rattlesnake Spring

This spring is located in Rattlesnake Canyon just to the west of Dove Spring. The spring head was completely surrounded and totally shaded by cattails (Typha spp) (Figure 7). The pool of water was completely filled with Chara and water is being piped to two adjacent cattle tanks.

The spring pool had a mean depth of 52.3 cm with a bottom consisting of a soft ooze of anaerobic mud under the dense submergent vegetation. Outflow into the two cattle tanks was measured at 426 liters per hour.

Chemical analysis of Rattlesnake Spring indicated a water of generally

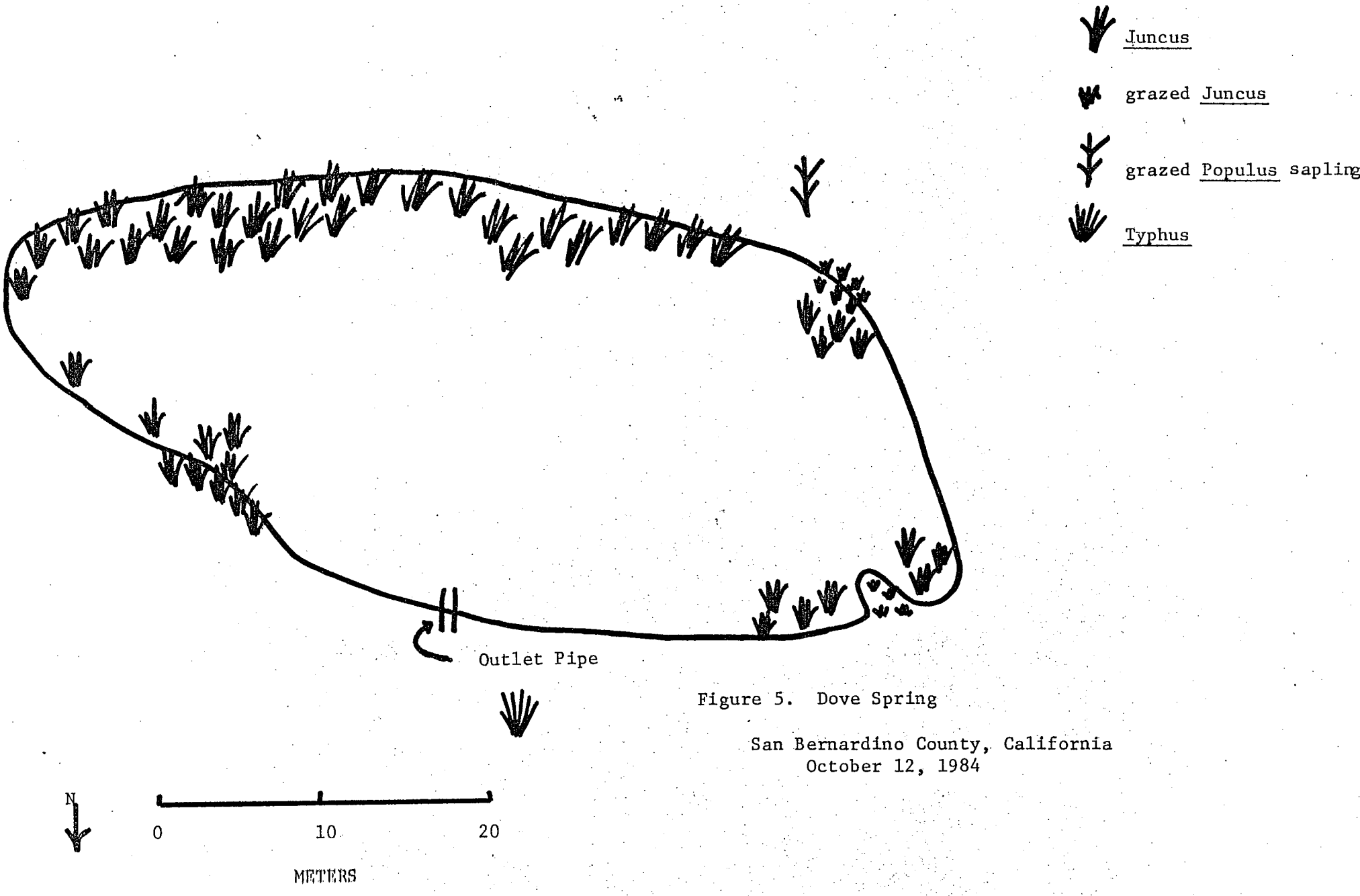


Figure 5. Dove Spring

San Bernardino County, California
October 12, 1984

low mineral and salt content, but with a specific conductance about twice that of Dove Spring (Table 3). The total dissolved residue was also about 2 times as high as Dove Spring. Major differences of water quality characteristics were in the cations sodium and calcium and the anions chloride and sulfate. The low surface area (44 m) and small volume (23 m) make this spring the smallest of the five study sites.

A 24 hour oxygen and temperature analysis provided extremely low oxygen levels during the night and early morning hours (Figure 8). Temperatures ranged from 19.5 to 26.5 degrees celcius.

No fish were present in Rattlesnake Spring. A very surprising finding, however, was the presence of a large number of aquatic insect species here when compared to the larger Dove Spring (Table 3). No plankton samples were taken as no open water habitat was present.

Owl Hole Spring

Owl Hole Spring is located at an elevation of 1920 feet in the Owlshead Mountains, 2.8 miles southwest of Death Valley National Monument.

The spring is a rectangular pool 28.5 m in length with an average width of 2.9 m (Figure 7). It is associated with a mine and mineral claim and there are numerous old concrete and wooden structures surrounding the site. The surface area is 67.8 square meters and the pool is shallow with mean depth of 46.3 cm and with a total volume of only 31.4 cubic meters. Outflow was measured as 32 liters per hour.

Water quality characteristics of this spring indicate water of generally low mineral and salt content (Tables 2 and 3). The specific conductance was 2580 umhos/cm which is intermediate between the Afton Canyon and SanBernardino Mountains slope sites. A 24 hour temperature and oxygen analysis indicated the spring pool had a temperature range from 14.5 to 18.0 C and a dissolved oxygen range from 2.6 to 8.8 ppm (Figure 10).

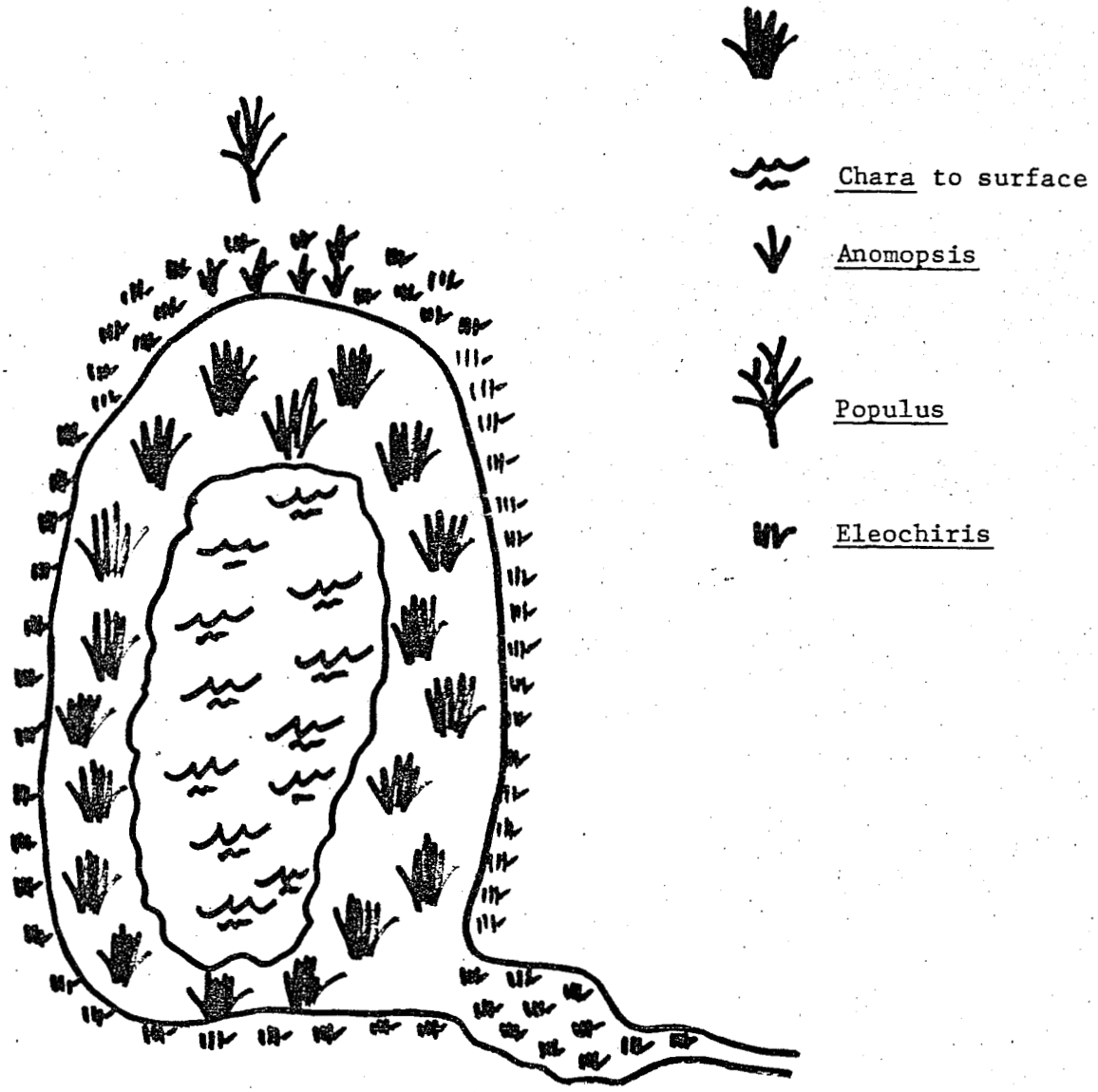


Figure 7. Rattlesnake Spring
San Bernardino County, California
October 12, 1984

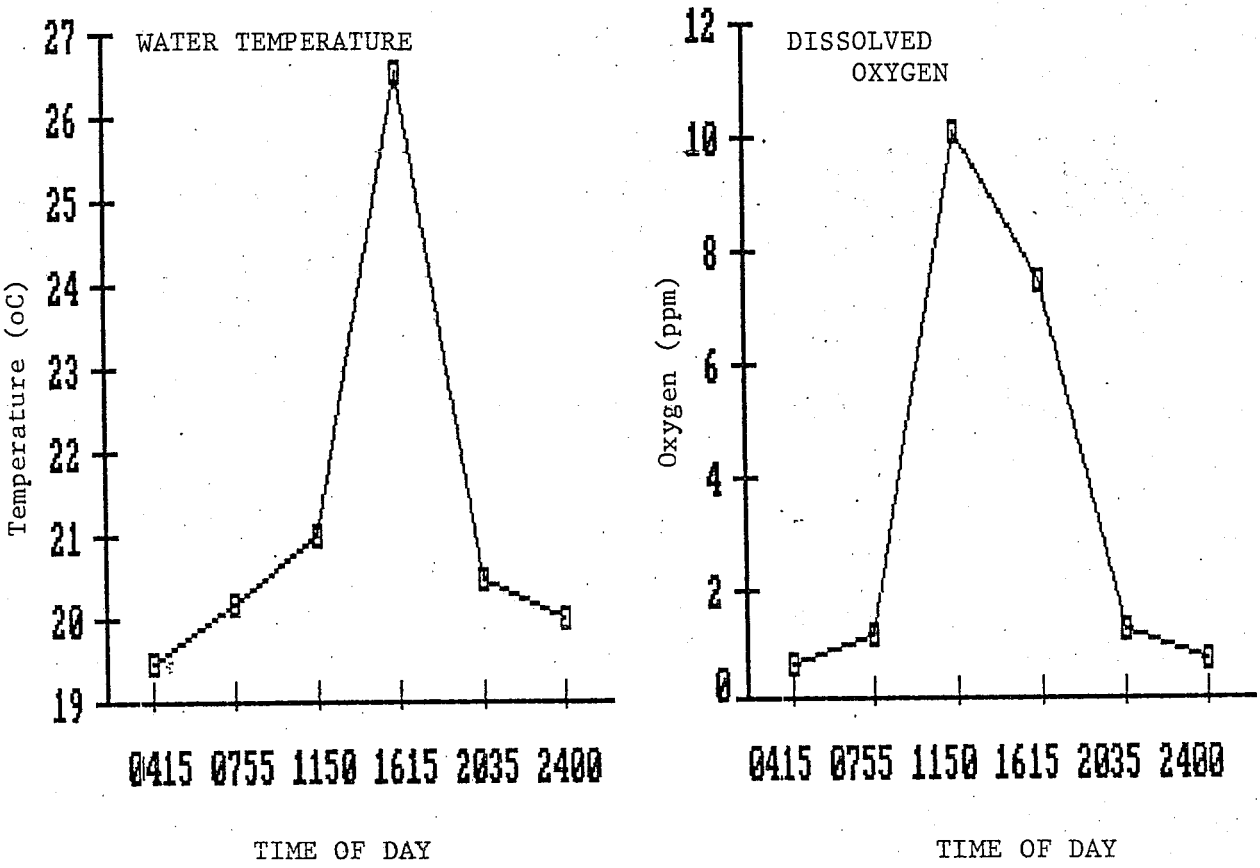


Figure 8. Rattlesnake Spring Temperature and Oxygen Study

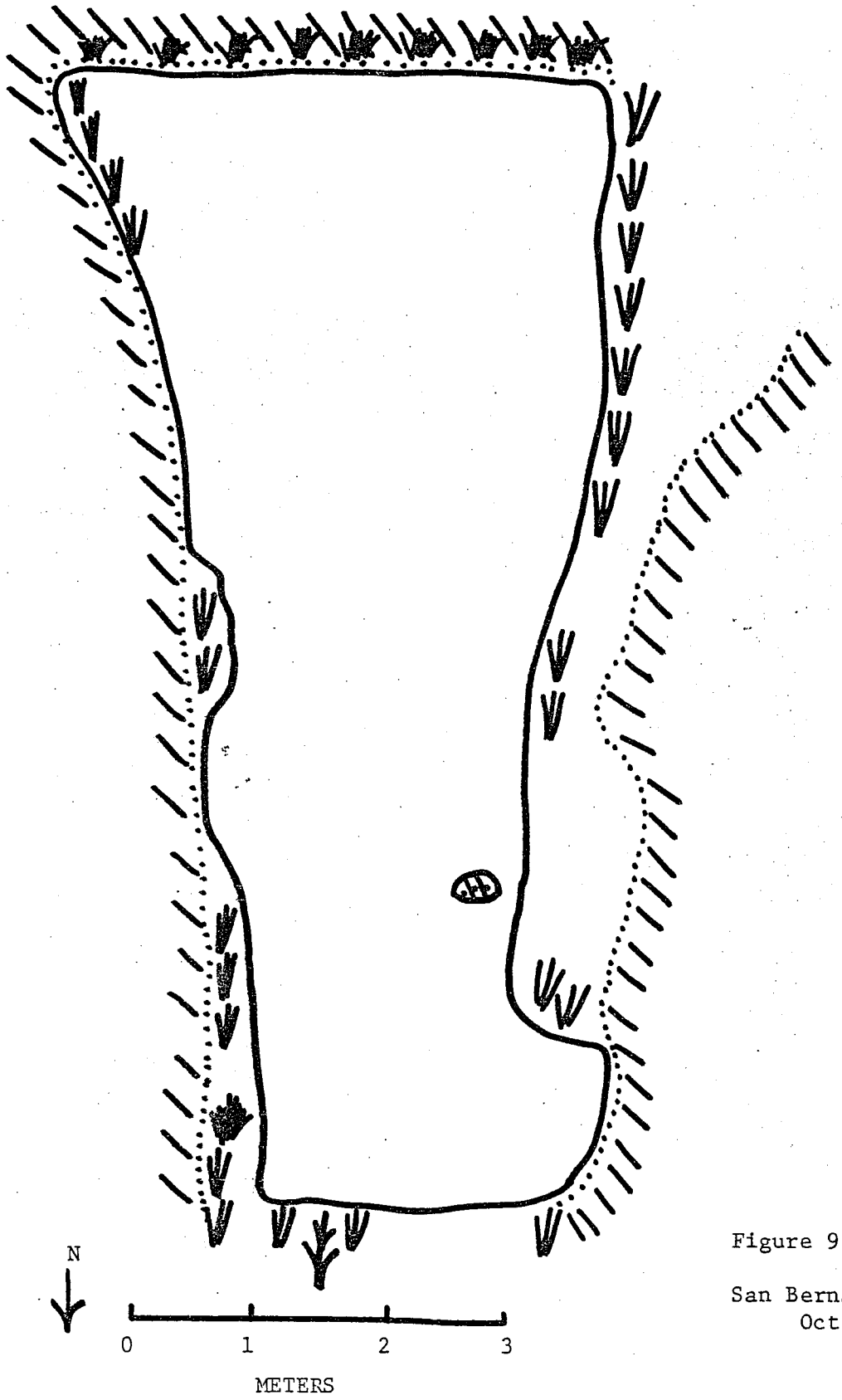


Figure 9. Owl Hole Springs

San Bernardino County, California
October 12, 1984

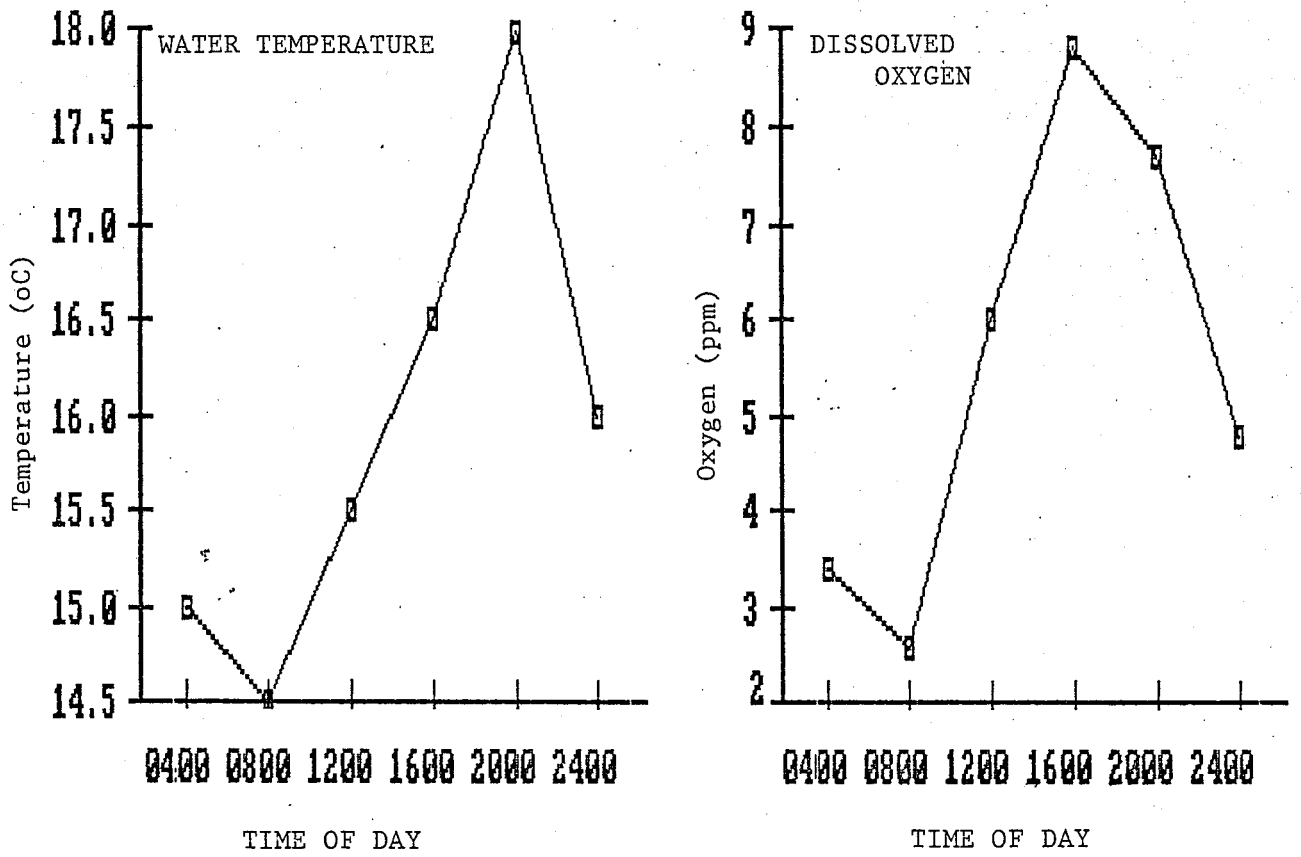


Figure 10. Owl Hole Spring Temperature and Oxygen Study

No fish were present in Owl Hole Spring and although many aquatic insects were present, comparatively few species were represented (Table 3). Backswimmers and diving beetles were numerous in open water habitats, while benthic insect larvae included midges and damselflies.

DISCUSSION

In an evaluation of potential relocation habitats for the Mohave tui chub, a number of factors must be taken into consideration. From previous studies conducted by Vickers (1972), Soltz (1978) and Taylor (1981), environmental conditions at Soda Springs can be examined. Recent work on the Mohave tui chub population at Lark Seep on the China Lake Naval Weapons Center (Feldmeth, et al, 1984) provides additional information on habitat conditions and oxygen, temperature and salinity tolerance limits for this endangered species.

From these data it appears that the Mohave tui chub is not extremely tolerant of either high temperature or high salinity, nor of low oxygen. Water temperatures above 35 C and salinities greater than 10 ppt cannot be tolerated by this fish (McClanahan, et al., in press). Soltz (1978) found fish died overnight in minnow traps in the dense cattail stand in Lake Tuendae at Soda Springs. Dissolved oxygen dropped to 1 ppm during the night in these areas (Soltz, 1978). These physiological tolerance regimes must be fundamental points for consideration when attempting to establish additional chub populations.

In aquatic environments in desert areas, unless there is a continual flow of water, evaporation will increase salinity above chub tolerance levels. Temperatures of shallow, non-flowing waters in low elevations of the eastern Mohave Desert could easily exceed lethal tolerance levels. Conversely, shallow pools could become so cold in winter that winter chub

kill is also possible.

In ponds that become densely vegetated with submerged aquatic plants such as Typha, Ruppia and Chara, dissolved oxygen levels could drop to potentially lethal levels at night if fish cannot move into surrounding areas of higher oxygen concentration. Cattail stands are areas that have been shown to produce low dissolved oxygen levels; however these plants along with other submerged aquatic vegetation also provides cover and areas of reduced water temperature, especially important for young fish. Cattails and other aquatic vegetation also provide substrate for aquatic invertebrates which provide food for the chub.

All of these factors need to be considered in evaluating habitats as potential relocation sites for the Mohave chub. Each pond or spring studied will be discussed in terms of physical, chemical and biological parameters. The habitats will then be ranked as to their potential as refuges for the chub. A final section will examine management recommendations for each habitat.

Campground Pond, Afton Canyon

This pond lies within a portion of the Mojave River where surface flow is perennial. The banks of this pond are not breached by floodwaters each year; however, flooding does occur during years of abundant rainfall.

Flooding will alter the vegetation around the pond and could also introduce sediment that would decrease its volume. The long narrow basin of the pond appears to have been scoured by water action by the river during the past.

Flooding would also continue to reintroduce other exotic fish species into the pond. The presence of green sunfish, black bullhead, and a chub which appears to be the Arroyo chub probably indicates colonization by

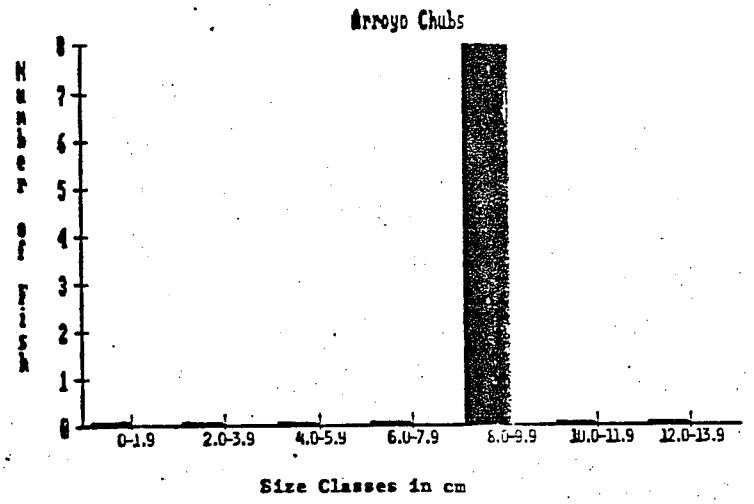
floodwaters, although the bullhead and sunfish may have been planted. The pond chubs were all very similar in size and may represent a one year class which was washed into the pond during recent flooding (see Figure 11) .

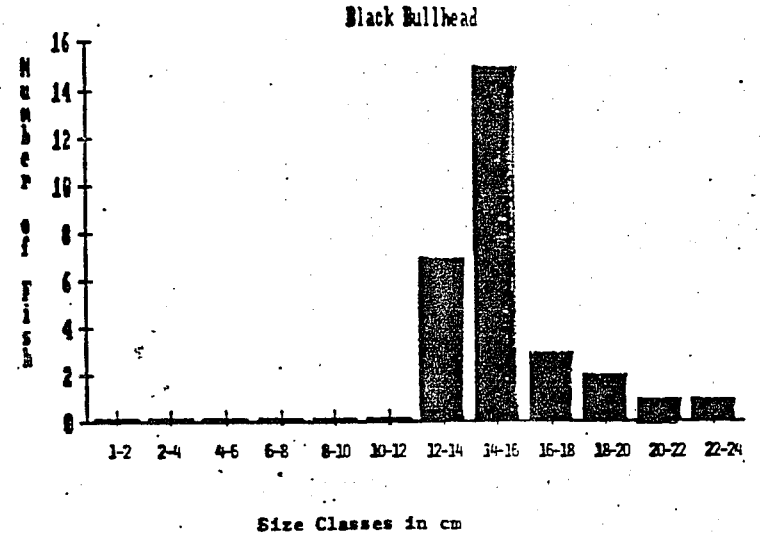
The physical conditions of Campground Pond are very suitable for maintaining fishes. Pond waters appear to be replentished by the lateral movement of subsurface river water. A considerable decrease in water level of the pond was noted between early June and late July.However, a corresponding increase in water salinity did not occur. Specific conductance of 6500 umos/cm was measured in early June (Soltz, field notes). In late July, the specific conductance was only slightly higher (7000 umhos/cm, see Table 2). The depth of the pond and the shade provided both by vegetation and the steep canyon wall probably keep the maximum water temperatures below 34 C. A maximum water temperature of 31 C was measured on July 23, 1984.

The presence of large numbers of zooplankton, aquatic insects and amphipods provide an abundant source of food for the fish population. The Campground Pond was the only site studied with any fish present. Its proximity to the BLM campground makes it vulnerable to the introduction of exotic species.

The Campground Pond provides an excellent habitat for the Mohave tui chub. Water salinity is 3.6 ppt, and although both boron (16 mg/l) and fluoride (14 mg/l) are rather high, they do not seem to adversely affect exotic fish fauna of this pond. It was probably in habitats similar to this that this endangered species survived over the preceeding 11,000 years.

The major drawback to its use as a relocation site for the Mohave tui chub are the threat of introductions of exotic fish by campground visitors,





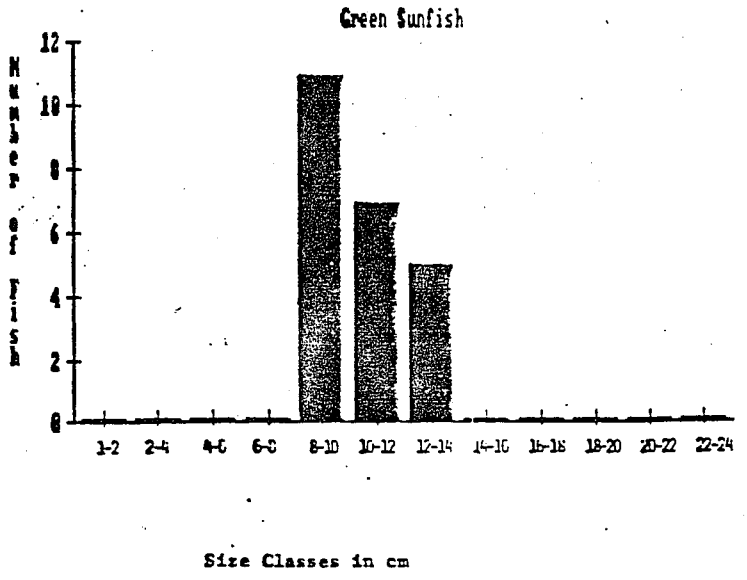


Figure 11. Size Class Structure of Fish Species from Sampling of the Afton Canyon Campground Pond

and the "natural" colonization of exotic fishes via floods along the Mojave River.

Another perplexing aspect of this site is the lack of reproduction of the chub population. There were no young chubs present at a season when they are abundant at Soda Springs and Lark Seep, and the chubs present were all of a single, small adult size class. The lack of successful reproduction could be due to several causes including: 1) lack of appropriate subtrate, 2) an unusual chemical parameter that is lethal to eggs and/or fry but not adults, 3) complete egg and/or fry predation by the carnivorous species in the diverse and abundant invertebrate community in the pond, and 4) complete predation of year classes as fry or juveniles by the exotic predatory fish species in the pond. Alternatives 1 and 2 are considered unlikely due to the apparent high quality of the habitat as discussed above. A combination of 3 and 4 are the probable causes of no effective recruitment in this small chub population which would have a rather low total reproductive output.

Railroad Pond, Afton Canyon

Railroad Pond can be removed from consideration as a potential relocation site because of poor water quality. It was apparent that the water level of this pond dropped several feet between May and July. Chemical analysis reveals a considerable ion concentration had occurred during this time. High levels of sodium, chloride and sulfate ion make this site unsuitable for the chub. Dissolved oxygen dropped as low as 0.45 ppm, a lethal level for most fish species.

This pond appears to form in an old portion of the Mohave River which was isolated by construction of the railroad berm. Groundwater from the river channel and runoff from a small basin surrounding Railroad Pond probably serve to fill the pond in the late winter or early spring.

Subsequent evaporation and lowering of the ground water in the adjacent river bed cause the water level to substantially decrease in the late spring and summer months.

Dove Spring, Lucerne Valley

Dove Spring appears to be a rather recently created pond habitat. It occurs in a relatively steep hillside where a shallow basin has been scooped out and a small earth dam constructed in order to create a water supply for cattle. Another small spring and pool located about 100 m to the east indicates water rises to the surface in at least two locations on this otherwise dry, creosote bush scrub covered slope.

The water in the pond at Dove Spring is relatively clear and the maximum temperature measured was only 26.1 C even in August when air temperatures reached 32.5 C. The pond supports a considerable amount of aquatic vegetation and a cattail stand along the south shoreline which would provide adequate cover for fish.

Chemically, the water quality is very good. Low salinity, alkalinity and specific conductance values even in mid-summer indicate that this habitat remains very much a freshwater environment all year.

Biologically, the pond does not seem to be very productive. Five plankton tows were taken with an 8 in. diameter net and yet only a few copepods (Cyclops) were collected. Many rotifers were present but they are probably too small to provide food for chubs. Aquatic insects were also not very prevalent. Only four species of insects were collected indicating a relatively depauperate fauna in terms of species diversity. Total standing crop biomass, as indicated by insect numbers sampled, also appears to be low.

The Dove Spring pond is probably relatively new and the low rate of

insect colonization in this arid area has not allowed a diverse aquatic insect fauna to become established. Another possible factor is the low levels of minerals which would tend to indicate the waters would not be very productive. By contrast, nearby Rattlesnake Spring which is much smaller, supported 11 species of insects. The water source in Rattlesnake Spring is higher in overall mineral content and this habitat may be much older. Another potential drawback to Dove Spring is the fact that winter water temperatures probably drop as low as 5C and snow is present at this elevation after exceptionally cold winter storms. The Mohave tui chub, which becomes less active in the winter months in its present habitat near the floor of Soda Lake, may not be able to tolerate the cold water temperatures present in Dove Spring in winter.

No sign of disturbance by campers or swimmers was present, although the pond is readily accessible from a major paved road. Disturbance is a possibility here but no more so than any other spring or pool habitat near well traveled roads in San Bernardino County.

Rattlesnake Spring, Lucerne Valley

Rattlesnake Spring is not a suitable habitat for Mohave chubs at present. The spring pool is small and completely surrounded by a dense stand of cattails (Typha). The open water portion is so entirely filled with vegetation that almost no area for fish would be present. Also, low oxygen levels at night (we measured 0.7 ppm at 0415 hrs) would certainly be lethal to any fish transplanted here.

The spring produces an outflow similar to Dove Spring, and with some major alterations it could become suitable as a relocation site for the chub (see Management Recommendations). Although it is located in a small canyon that might be subject to flooding, it is situated high enough above

the floor of the wash to escape major flood damage.

Both the chemistry of the spring water and the biological diversity and productivity suggest that a viable refugium could be developed at Rattlesnake Spring. Disturbances to the spring would mainly be by cattle. The area is adjacent to a very poor road that it unlikely to be traveled by most vehicles.

Owl Hole Spring

This small pool is located just off the gravel road which runs westward from the south end of Death Valley National Monument.

Owl Hole Spring has good water quality characteristics and it is high enough in elevation so that water temperatures probably do not exceed lethal levels for the chub.

The pond has an insect population that would support a small chub population. Insect diversity was not high in terms of species, but the abundance of insects was great. The remote location of this spring and the lack of other aquatic habitats in the vicinity, make this spring difficult for flying insects to find and the transfer of aquatic organisms by water birds is unlikely.

The only negative aspect of Owl Hole Spring as a potential relocation habitat of the Mohave chub is its small area, shallow depths and hence low volume. Perhaps 50 to 100 chubs could survive in Owl Hole Spring.

Very little signs of human disturbance were observed in the area. Mining activities could be resumed and because the water of the spring appears to have been used for some mining process, water drawdown for mining could be a potential problem. The pond is also somewhat protected by its location; it is not visible from the nearest road and therefore easy to bypass.

Ordinal Ranking of the Prospective Chub Relocation Sites

In order to rank the five habitats studied, a numerical rating system was developed for a series of categories that were analysed in this study. These categories included water chemistry, temperature, oxygen, food, habitat (cover, pond depth, etc), and disturbance (flooding, human or predators). A value of "5" indicates the best possible habitat conditions for the Mohave tui chub, while a value of "1" would indicate the least suitable or very poorest habitat quality.

The following numerical scoring for the various habitats takes the above factors or characteristics into account:

	Campground	Railroad	Dove	Rattlesnake	Owl Hole
Chemistry	3	1	5	4	4
Temperature	3	1	3	3	4
Oxygen	4	1	5	1	5
Food	5	3	2	3	4
Habitat	4	1	3	1	4
Disturbance	2	4	4	4	4
Mean Values	3.5	1.8	3.7	2.7	4.2

From the above table it appears that the ordinal ranking for the habitats we examined as potential relocation sites for the Mohave tui chub would be Owl Hole Spring, Dove Spring, Campground Pond, Rattlesnake Spring and Railroad Pond. Of the five habitats, Rattlesnake Spring and Railroad Pond are unsuitable in their present form. Improvements, mentioned in the following section, to Rattlesnake Spring could make it a viable refugium but Railroad Pond should be eliminated from any future consideration as a fish habitat.

Owl Hole and Dove Springs are both likely candidates for an introduction of chubs without any habitat modification or study. Owl Hole Spring will not support a large population of chubs but 50 to 100 fish could be introduced there at any time. Dove Spring, is a more suitable habitat in terms of habitat (size, depth, cover) but has far fewer aquatic invertebrates and hence it scores lower in terms of food. It also may be too cool for the chubs and so it has a lower value for temperature than Owl Hole Spring.

Management Recommendations

Although it was ranked third, Campground Pond could provide habitat for establishing a population of the Mohave tui chub if certain management measures were adopted. Exotic fishes would have to be removed from the pond through poisoning. Some procedure to protect the pond from encroachment of floodwaters in the Mojave River would be required. A breach in the river bank immediately upstream from Campground Pond could be closed with crib-cage or rip-rap to prevent the reestablishment of exotic fishes from the Mojave River system through flooding. A 50-year flood, however, would probably overwhelm any constructed barrier. This would not preclude the introduction of fishes such as bass, sunfish and catfish by the public, but it is unlikely that they would introduce the arroyo chub (Gila orcutti). With the potential of hybridization removed from Campground Pond, the Mohave tui chub may do very well here, assuming the water table is not altered.

A modification of the Mojave Forks Dam (Army Corps of Engineers Information Bulletin, July 1984) has been proposed. The dam is on the Mojave River, just downstream from the junction of Deep Creek and the West Fork of the Mojave River, 14 miles upstream of Victorville. The Army Corps of Engineers is presently studying a plan to install a gate on the dam for

water conservation purposes. This will alter the water regime in Afton Canyon and thus reduce the water available to Campground Pond. If water flow to the lower Mohave River is restricted by alterations to the Mojave River Dam, Campground Pond should not be considered as a relocation site for the Mohave tui chub.

Rattlesnake Spring would need to be physically altered by a mechanical effort that probably would involve excavation with a back-hoe. The Spring could be enlarged to form a pool of about 500 m^2 (about the half size of Dove Spring). A float valve would also have to be installed in the existing troughs to provide for continued cattle use while minimizing water diversion from the spring source. The water supply and chemistry would probably allow for a good habitat to be constructed at Rattlesnake Spring. The access road to the site is very rough and some alterations would be required to get equipment to the spring.

Cattle use the area extensively and their continued use of this area as a water source may take some additional management. Perhaps a cattle watering area could continue to be present downstream from the newly created pool habitat. The pool would have to be deep enough (greater than 4 feet) to prevent the encroachment of cattails. The present spring head is fenced to keep cattle out, but as a result of removing grazing pressures the cattails have almost totally filled this habitat.

As stated earlier, no management recommendations are needed for either Owl Hole Spring or Dove Spring. They are suitable at present for the introduction of Mohave chub. The cold winter temperatures at Dove Spring should preclude any transplant attempts during the winter months.

CONCLUSIONS

Of the five sites examined as potential relocation habitats for the endangered Mohave tui chub (Gila bicolor mohavensis), two appear suitable for introduction at this time. Both Owl Hole Spring, in the Owlshead Mountains just west of Dealth Valley National Monument and Dove Spring, on the eastern slope of the San Bernardino Mountains in Lucern Valley appear to be good potential relocation sites for the chub.

Water chemistry parameters, temperature, dissolved oxygen levels, and biological factors all are favorable for the chub. Both habitats are not used for recreational purposes and hence human disturbances would be minimal. Both are accessible by road and no problems with the transport or relocation of fish would exist.

Campground Pond in Afton Canyon was ranked third in terms of suitability. Removal of exotic fishes and the alteration of the river channel to provide flood protection would have to take place before this pond could be used as a refugia.

Rattlesnake Spring would need more major modification, as the existing spring pool is too small and choked with vegetation at present. There is good potential here, however, for a chub habitat in terms of water supply and quality.

Railroad Pond in Afton Canyon is unsuitable as a fish habitat in terms of water quality and habitat. This ponds becomes quite stagnant during the summer months and the volume decreases with evaporation. We do not consider this as viable fish habitat and no future management efforts here are recommended.

Any refuge site will require periodic vegetation removal and dredging of sediments such as has occurred at Soda Springs, to maintain an area of open water of sufficient volume and quality to maintain a viable chub

population. The cost of such habitat maintenance should be estimated and included in any cost analysis of establish refugia.

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