OBSERVATIONS ON THE ECOLOGY OF COLORADO SQUAWFISH (*Ptychocheilus lucius*) IN THE YAMPA RIVER, COLORADO, 1982

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OBSERVATIONS ON THE ECOLOGY OF COLORADO SQUAWFISH (*PTYCHOCHEILUS LUCIUS*) IN THE YAMPA RIVER, COLORADO, 1982

WRFSL Report No. 83-7

by

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September 1983

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Endangered Wildlife Investigations
Job Progress Report
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SUMMARY

Twelve Colorado squawfish were surgically implanted with radio-transmitters on the Upper Yampa River between river kilometer (km) 86 and 172 in March and April, 1982. Five fish exhibited highly mobile migrations of 200-350 km by migrating from the Upper Yampa downstream to spawning areas in the lower 32 km of Yampa Canyon, with at least four returning to the Upper Yampa near points of original capture. The major movement into Yampa Canyon occurred in late June and early July. Three fish of the sample population did not migrate. Radio contact was lost with three other fish in June and July.

A chute channel with rubble gravel substrate at river km 26.4 was the only site at which squawfish were observed by radiotelemetry to exhibit spawning behavior. Aggregations of ripe fish captured with nets at several locations throughout the lower 32 km of Yampa Canyon suggest spawning at other sites. The river within the spawning area is characterized by large meandering bends, unique pool-riffle-pool sequences, and large braided rubble (cobble) bars.

From July 2 through August 7, 40 Colorado squawfish were captured between river km 33 and km 8.2. Additional pre- and postspawning samples resulted in the capture of 30 squawfish. Ten fish were recaptured during the sampling season. Capture/recapture information supplemented radiotelemetry data to show that (1) fish from the Yampa, White, and Green rivers use the Yampa Canyon spawning area then return to their resident home ranges; (2) recruitment of adult Colorado squawfish into the Upper Yampa River likely originates from nursery

areas in the middle and lower Green River, downstream from Jensen, Utah; and (3) squawfish that establish residency in the Yampa River tend to remain within their home range throughout the year except to spawn.

Twelve larvae were captured below river km 18, indicating successful Colorado squawfish reproduction in the Lower Yampa River. Our collections and those of others suggest that larvae tend to drift or move down the Yampa River and into and down the Green River.

Habitat use varied seasonally based on flow and habitat availability. During high flows, squawfish tend to move out of the main river into low-velocity eddies and backwaters. At low flow they tend to move back into the main river, using pools and runs. Flooded backwater habitats used by Colorado squawfish during runoff may play an important role in preconditioning fish for spawning by providing warmer water and feeding or resting areas.

Water temperature is a primary factor influencing spawning time. Migration occurred as fish temperatures approached 16°C. Fish were in the spawning area as temperatures approached 19°C and spawning behavior was observed after fish temperatures exceeded 19°C. Alterations of Yampa River flow and temperature regimes could affect the reproductive success of Colorado squawfish spawning within the boundaries of Dinosaur National Monument.

INTRODUCTION

The Yampa River originates on the western slope of the Rocky Mountains near Yampa, Colorado. It is the largest tributary to the Green River. The Yampa flows first in a northerly and then in a westerly direction to its confluence with the Green River in Dinosaur National Monument (Fig. 1). The Yampa River can be characterized as a system of extreme hydrologic events. Dramatic seasonal fluctuations in flow create equally dramatic changes in temperature, turbidity, conductivity, and quantity of allochthonous material. These seasonal variations in flow and water quality also exhibit long-term pulses caused by annual variations in precipitation and accumulation of snow in mountainous regions of the river watershed. Amid these hydrologic extremes the endemic Colorado squawfish evolved a unique migratory reproductive strategy.

Historically, migration of Colorado squawfish (*Ptychocheilus lucius*) was considered a predictable summer event in many of the rivers of western Colorado (Sigler and Miller, 1963; Joseph et al., 1977; Behnke and Benson, 1980). However, neither origin nor destination of the migrants was documented. It was assumed that the migration was related to spawning.

Recent studies, conducted by the U.S. Fish and Wildlife Service (USFWS), Colorado Division of Wildlife (CDOW), and Utah Division of Wildlife Resources in the Upper Colorado River basin (Wick et al., 1981; Haynes and Muth, 1982; Miller et al., 1982a,b, 1983b; Tyus et al., 1982a,b; Radant et al., 1983) produced new data regarding the movements

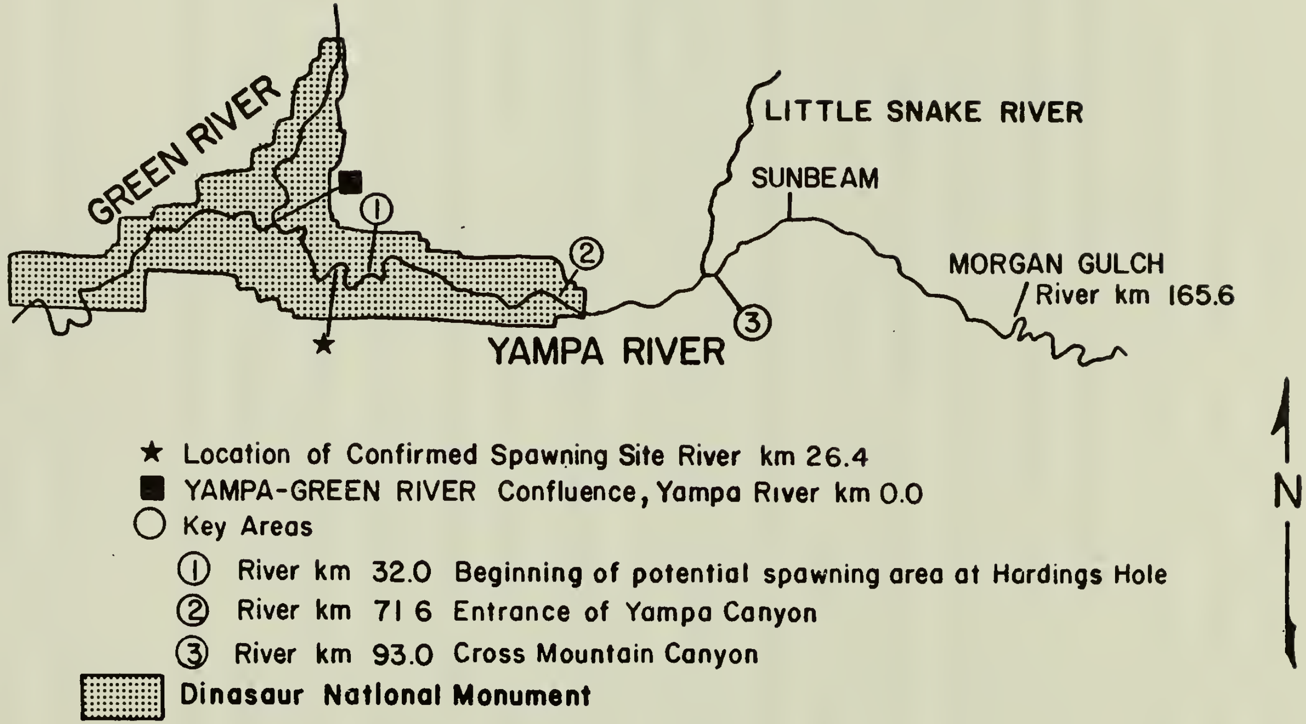

Fig. 1. Yampa River study area, 1982

and reproductive strategy of the Colorado squawfish. These studies have led to preliminary revisions regarding hypotheses presented by Vanicek and Kramer (1969), Seethaler et al. (1976), Holden (1977, 1980), Seethaler (1978), Joseph et al. (1977), and Behnke and Benson (1980) on the distribution of successfully reproducing Colorado squawfish populations, habitat requirements and the general ecology of this endangered species.

The purpose of this study was to collect data on prespawning, spawning and postspawning movements of Colorado squawfish in the Yampa River (Fig. 1) and to expand the findings of previous studies. In addition to movement patterns and habitat utilization, temperature preferences of the Colorado squawfish were investigated.

METHODS

Radiotelemetry

Twelve Colorado squawfish, greater than 550 millimeter (mm) total length (TL), were collected from the Yampa River during March and April, 1982, for radiotransmitter implantation. Collections were made during these months when cool water temperatures minimized the chances of infection due to field surgical procedures. Six fish were collected above Juniper Springs Canyon river km 146.4 (mile 91), 3 above Cross Mountain Canyon river km 93.3 (mile 58) and 3 below Cross Mountain Canyon river km 85.3 (mile 53) using electrofishing gear and experimental gill nets as described by Wick et al. (1981).

Electrofishing efforts were continued until July 8, 1982, from river km 177 to 72.4 (mile 109.9-45). This extended sampling was conducted in preferred habitats, indicated by the presence of radiotagged squawfish, to verify habitat preference data and to provide additional marked fish. All fish captured during this period were measured to the nearest millimeter (mm) total length (TL), weighed to the nearest gram (g), marked with a numbered Carlin dangler tag, and released. The 12 fish captured in March and April were anesthesized with a solution of unbuffered MS222, and surgically instrumented with radiotransmitters. The surgical procedure used was similar to the one discussed in Bidgood (1980) and used by Tyus et al. (1981). Lateral incisions, approximately 1.5 centimeters (cm) in length, were made anterior, and dorsal to the insertion of the pelvic fins and closed with 3 to 4 individual sutures. The suture material used was non-absorbable, black monofilament nylon attached to an FS-1 cutting needle. Following surgery each implanted fish was also marked beneath the dorsal fin with a numbered Carlin dangler tag. The fish were then held in a flow through live car until they had recovered from the anesthetic and then released.

The transmitters were approximately 4.3 cm in length, 1.8 cm in diameter and weighed 11.8 to 12.3 g in the air. The operating frequency was in the 30 MHz band. The transmitters were powered with Lithium cells and had an expected life of 270 days. Eleven of the transmitters were temperature sensitive. Temperature data were transmitted as a function of transmitter pulse frequency. Calibration points of temperature, 0 to 40°C, and transmitter pulse frequency were used to derive regression equations for temperature versus pulse frequency for each unit. The pulse frequency data collected in the field were then used in the equations to obtain temperature. The high, low and mean temperatures of the fish and water temperature of their habitat were plotted for each fish.

Two techniques of monitoring were used, general survey and continuous diel monitoring patterned after USFWS studies (Miller et al., 1982b,c; Tyus et al., 1982a). The general survey method was an attempt to locate a maximum number of radiotagged fish at random times throughout a 3 to 5 day period. The diel technique was an effort to monitor fish activities continually during three time periods, 0800-1600, 1600-2400, 2400-0800 hr. All radiotagged fish were monitored systematically according to a study plan. The two monitoring systems were usually conducted concurrently by two field teams. The procedure for data collection was the same for both methods. The general location of a fish was first determined using a Custom Electronics receiver with an omni-directional whip antenna, with a nominal range of 800 meters (m). When a fish was located a directional loop antenna was used to triangulate the actual position of the fish. The nominal range was 250 m. When the position of a fish had been determined, the river (km), movement pattern, habitats utilized, river substrate, river water temperature and transmitter pulse frequency data were recorded. Habitat was identified according to modified definitions used by the CDOW (Wick et al., 1981; Appendix A). Intensive monitoring of the radiotagged fish began on April 26 and continued until August 28, 1982. In addition, the general survey technique was used during late August, early October, and November to obtain postspawn data.

Squawfish Sampling During Migration

When squawfish began extensive migrations and spawning was likely, potential spawning sites and areas inhabited by radiotagged fish were sampled with trammel nets. When conditions permitted, trammel nets were used as seines over gravel bars and through runs and pools. Sex and spawning condition of all captures were noted. Males running milt were usually tuberculated over the entire body and easily sexed. Fish were considered possible females if they were not tuberculated or were only slightly tuberculated on the head and had swollen genital papillae or distended abdomens. Fish were listed as indeterminant sex if none of the above indicators were present.

Larval Fish Sampling

The Yampa River was intensively sampled every 8 km for larval squawfish from river km 195 (mile 121) to its confluence with the Green River. The sampling was conducted August 12-28, 1982, approximately 2 weeks after the major spawning period. Dipnet and seine (pore size 0.8 to 1.6 mm) samples were taken from specific habitat types. Samples were fixed in 10% formalin and taken to the Larval Fish Laboratory, Colorado State University, Fort Collins, for sorting, identification, and curation.

RESULTS

Migratory Movement

Of the 12 fish in the radiotagged sample population, five (numbers 1, 4, 5, 9, and 10) migrated to or near the previously identified spawning area at river km 26.4 (mile 16.4), and at least four of them returned to the general vicinity of their premigratory residence (Fig. 2). Fish number 1, a ripe male, was captured in a trammel net at river km 26.7 (mile 16.6), July 10, with an inoperable transmitter. Fish numbers 2, 6, and 8 (Fig. 3), were considered nonmigrants; they were recorded only in the general vicinity of their original capture, had operational transmitters after the spawning period, and were not found in Yampa

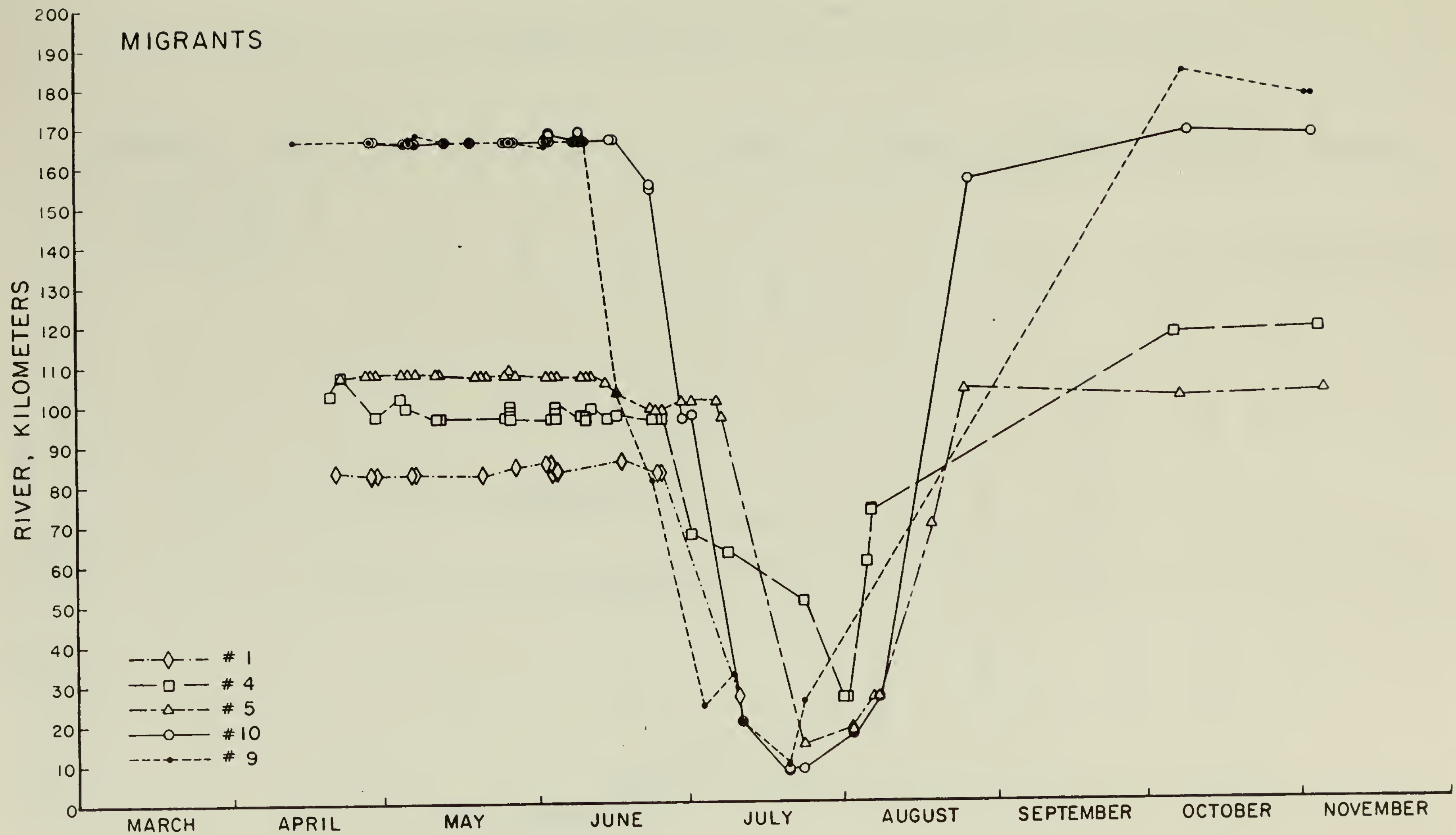

Fig. 2. Long-term movements and contact dates of migrating radiotelemetered Colorado squawfish on the Yampa River, 1982

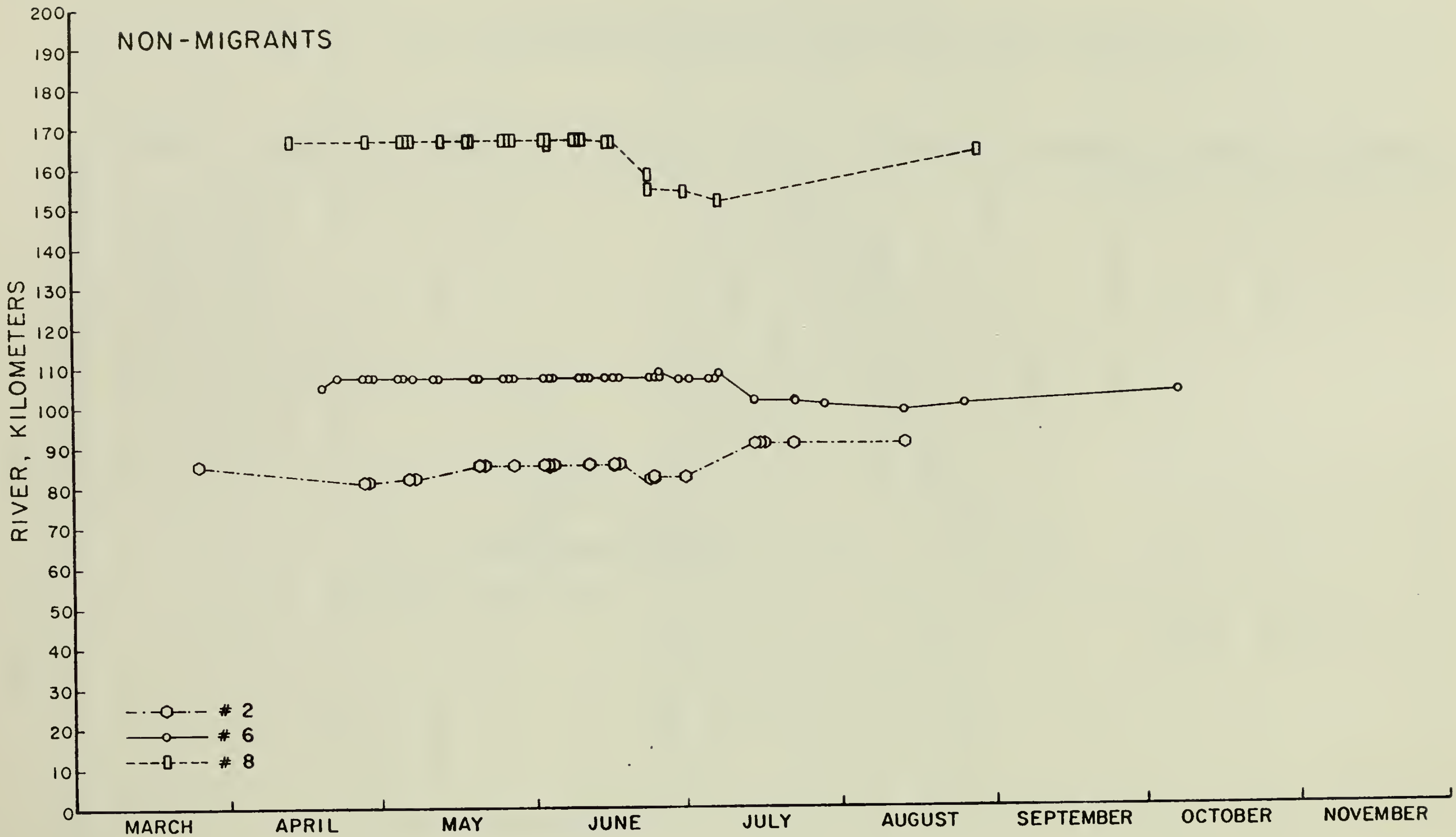

Fig. 3. Long-term movements and contact dates of nonmigrant radiotelemetered Colorado squawfish on the Yampa River, 1982

Canyon. Contact with fish numbers 3, 11, and 12 was lost between June 11 and July 7 (Fig. 4), after some migratory tendencies had been noted. Radiotagged fish number 7 was presumed dead after several weeks of sedentary behavior. After water levels receded, this fish was located by triangulation and was apparently buried in a sand bar. Recovery attempts were unsuccessful.

General Habitat Use

Changes in habitat use throughout the year are illustrated in Fig. 5. [This figure was prepared from monthly summaries of our observations of habitat use (Appendix B).] In April, as water levels were beginning to rise, main channel run habitat was most frequently used, followed by tributary stream backwaters and eddies. Four of the twelve fish radiotagged were originally captured in the flooded mouth of Morgan Gulch, a tributary stream at river km 166.5 (mile 103.4). As runoff flows increased in early May through mid-June backwater and eddy habitats were frequently used. In May, backwater habitat use was evenly divided between backed-up tributary streams (natural) and flooded, dike-off side channels (man-made), identified in this report as main channel backwaters. In June, fish were observed predominantly in the tributary stream backwaters and main channel eddies. In July, as water levels dropped, fish moved into main channel habitats. Run habitat was used most frequently. In August, secondary side and chute channels were used more extensively. Shoreline, run, and riffle habitats were equally used in August, when much attention was given to the spawning area below river km 32 (mile 20). During October and November, pool habitat was utilized most extensively, followed by run, eddy and shoreline habitat.

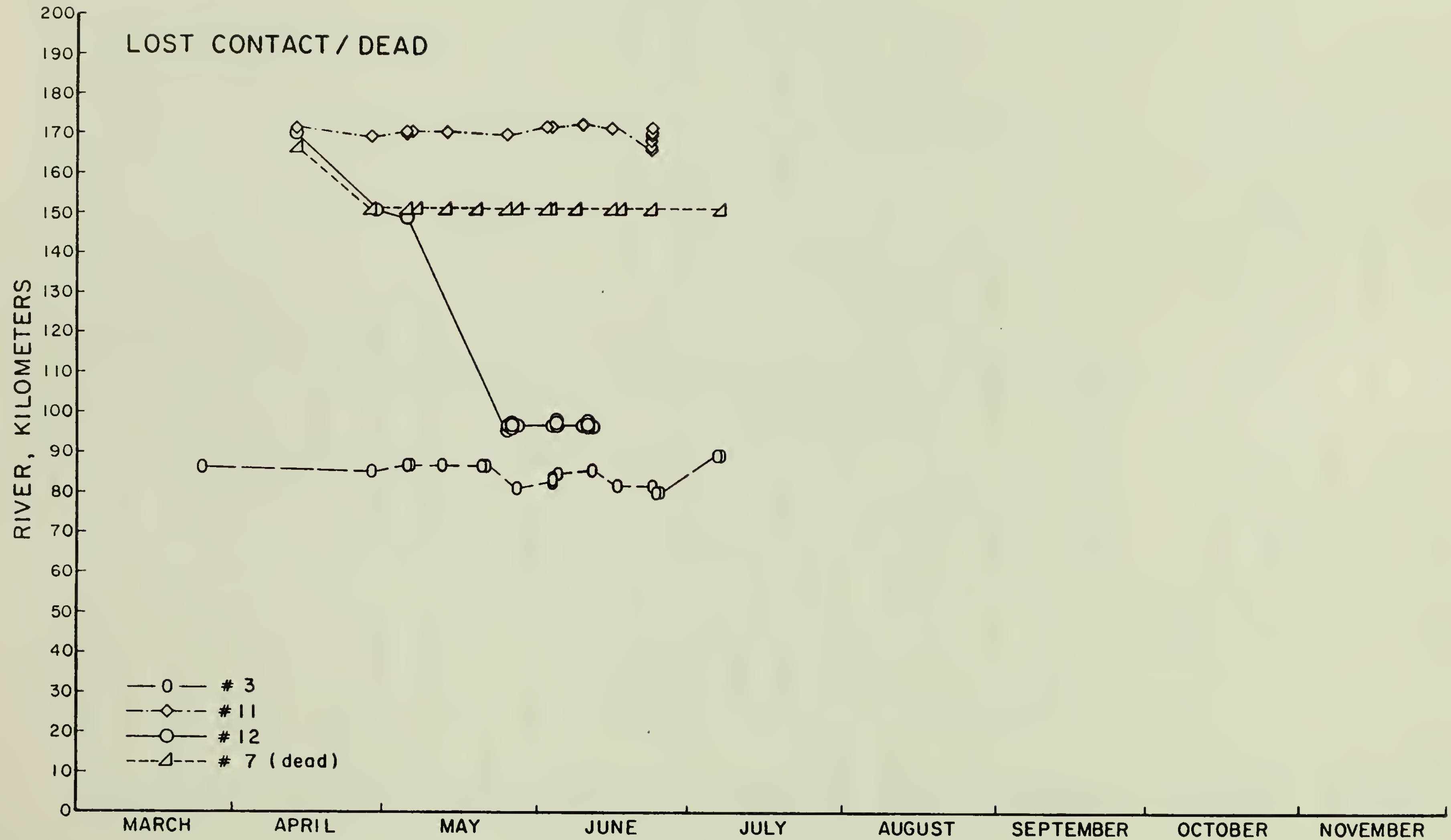

Fig. 4. Contact dates and movement of radiotelemetered Colorado squawfish with which contact was last on the Yampa River, 1982

Fig. 5. Monthly frequency of habitat use based on 1424 observations (all records) of radiotagged Colorado squawfish in the Yampa River, 1982. Major habitat (MH) records are given when no specific habitat could be determined. Definitions of habitat types are given in Appendix A. Observations on individual fish are provided in Appendix B.

Temperature Observations

The high, low, and mean temperatures of fish with temperature-sensitive transmitters and water temperatures recorded near their locations are presented in Figs. 6-15. These data reflect the range of temperatures available and utilized by each fish. Fish numbers 4, 8, 9, 10, and 12 had the most notable fluctuations in fish temperature during the months of May and June. This can be related to their use of backwater habitats during this period (Appendix B, Tables 3 and 4). Use of backwater habitat resulted in exposure to higher temperature and appears to have influenced spawning time among migrant fish. Migrant fish numbers 4, 9, and 10 used backwater habitats quite extensively during runoff in May and June, but fish number 5 was not recorded in a backwater until early July. Fish 4, 9, and 10 began migrating before number 5 did. Fish number 4 exhibited spawning behavior patterns at river km 26.4 (mile 16.4), one week before fish number 5 did. Fish numbers 4 and 5 were tagged in the same river reach on the same day (river km 102.2-102.7, mile 63.5-63.8).

Ripe males were captured in the vicinity of the spawning site (river km 26.4) during the week of July 11 through 17, when the mean water temperature was 18.5°C. Ripe males and females were captured at the same locations between July 29 and August 8. The mean water temperature recorded in the field during this period was 22.7°C. Based on observations of radiotagged fish at the spawning area, the interval of July 23 through August 8 was identified as the major spawning period in 1982.

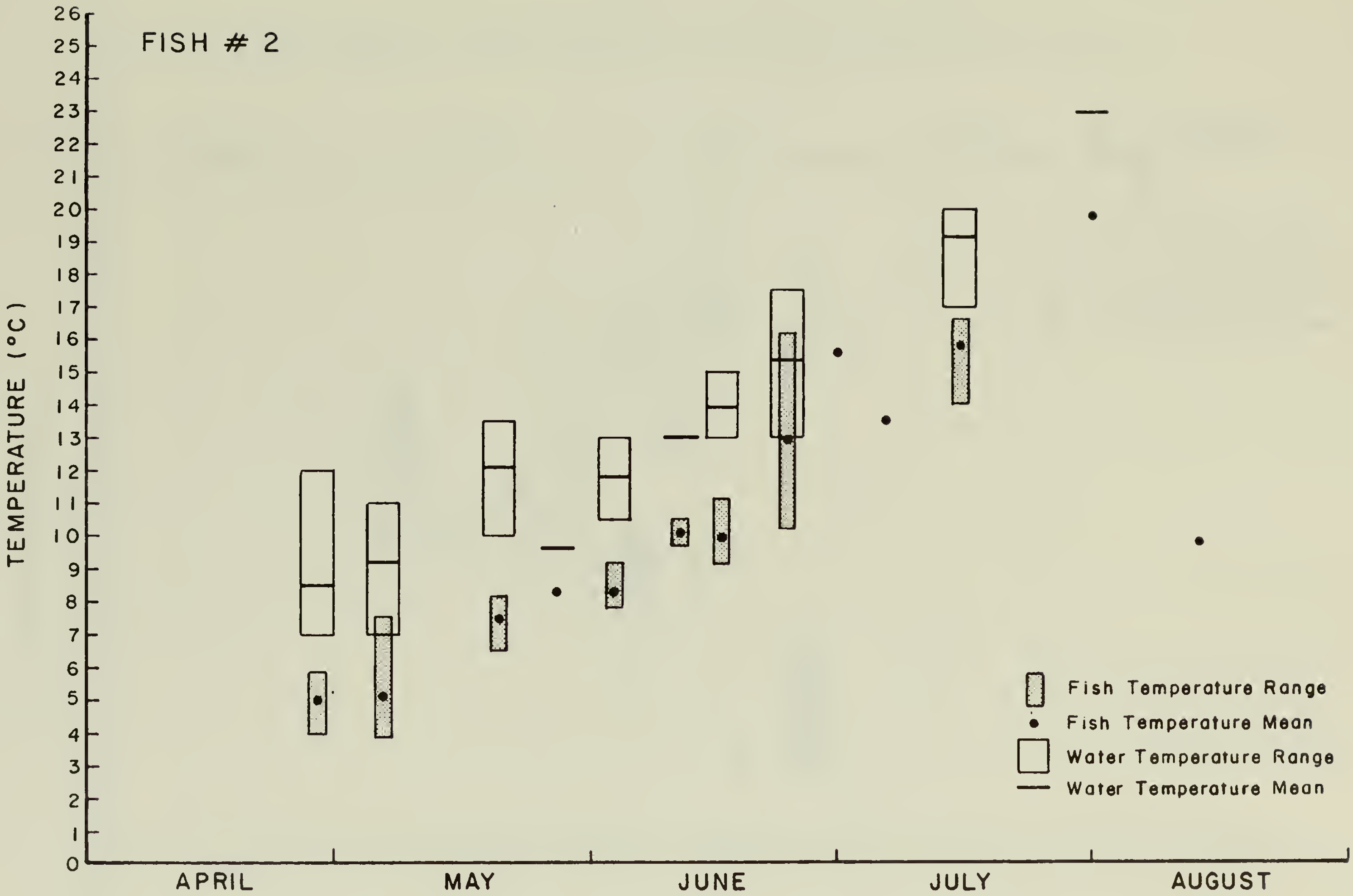

Fig. 6. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 2 in Yampa River, 1982

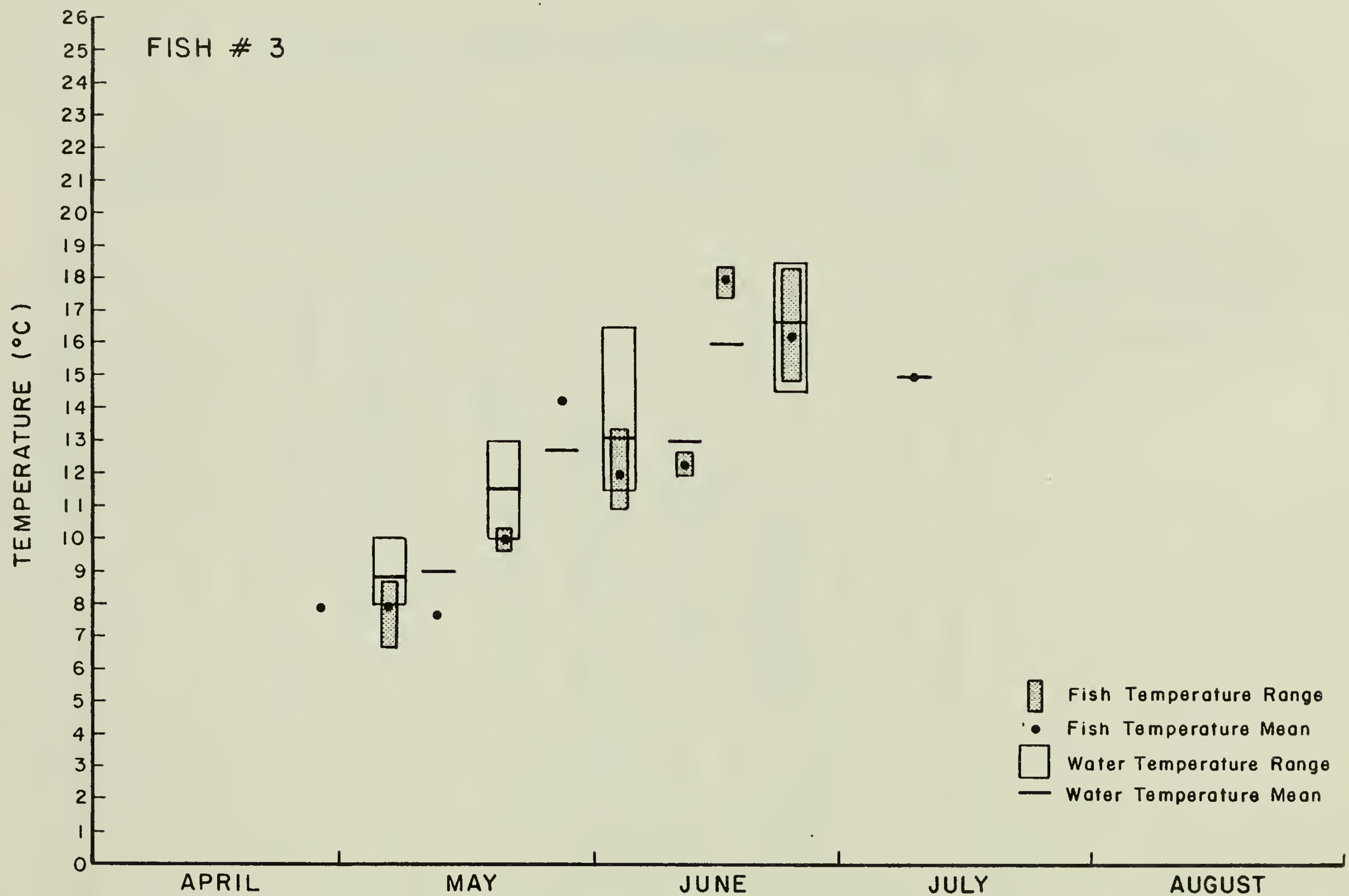

Fig. 7. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 3 in Yampa River, 1982

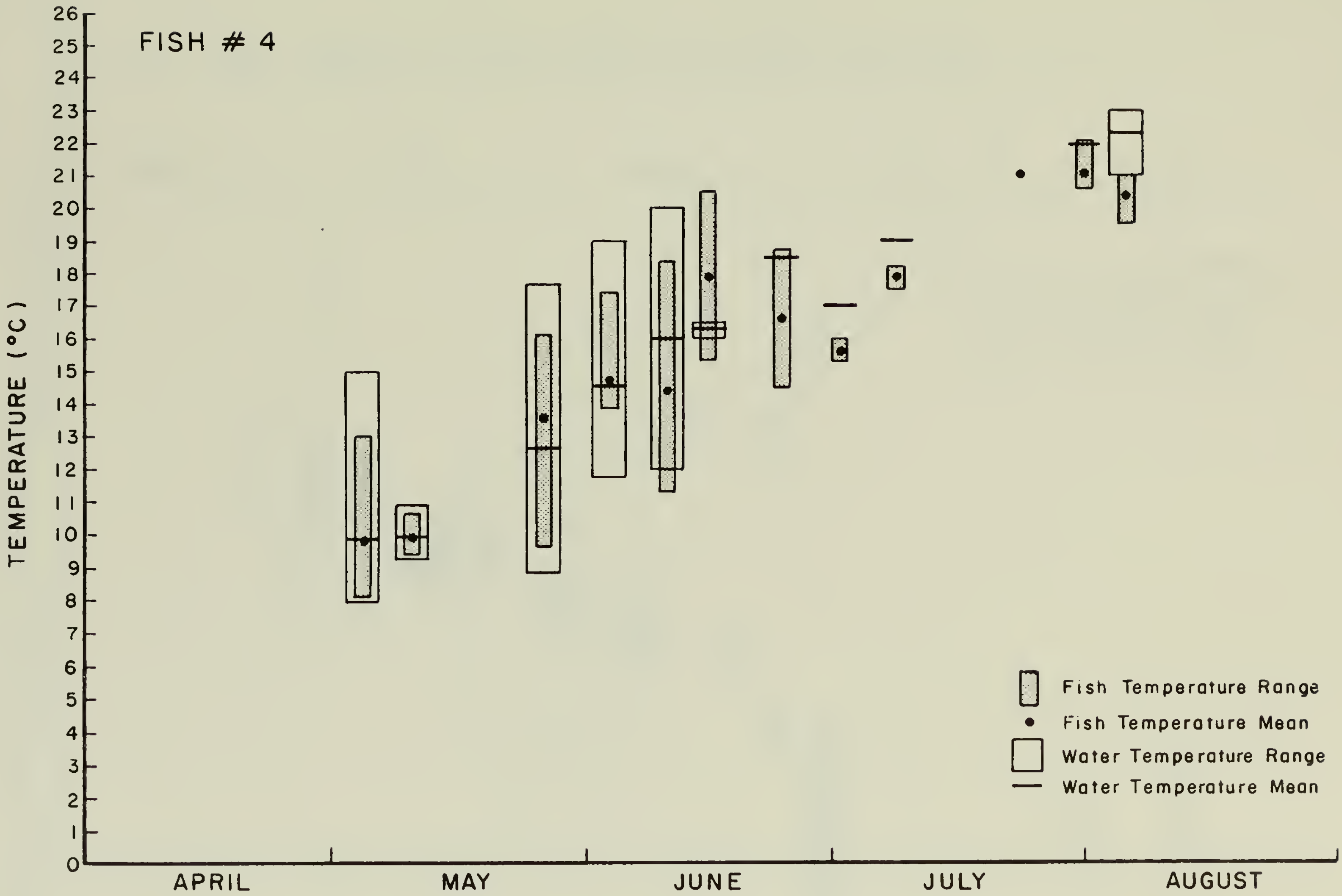

Fig. 8. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 4 in Yampa River, 1982

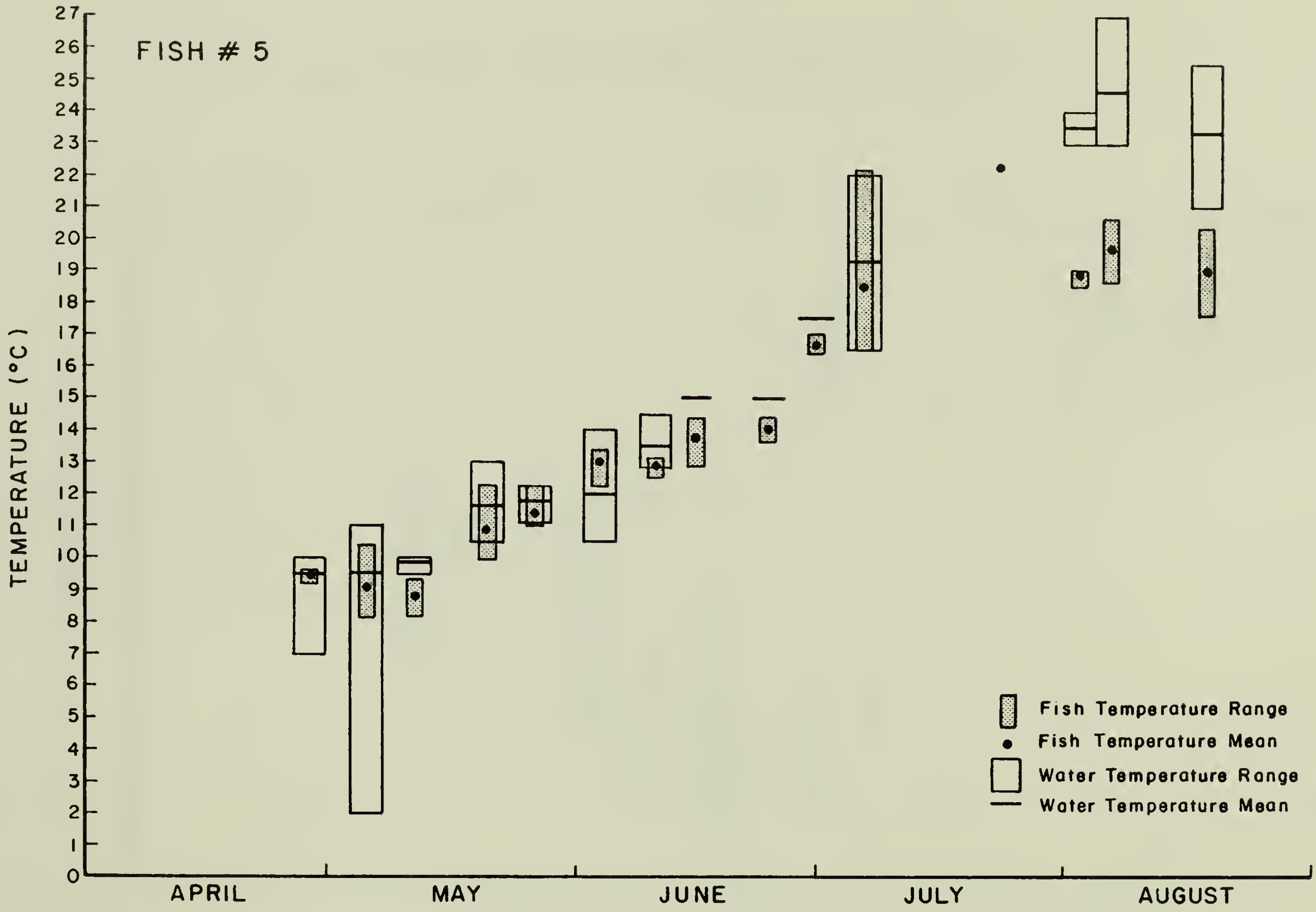

Fig. 9. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 5 in Yampa River, 1982

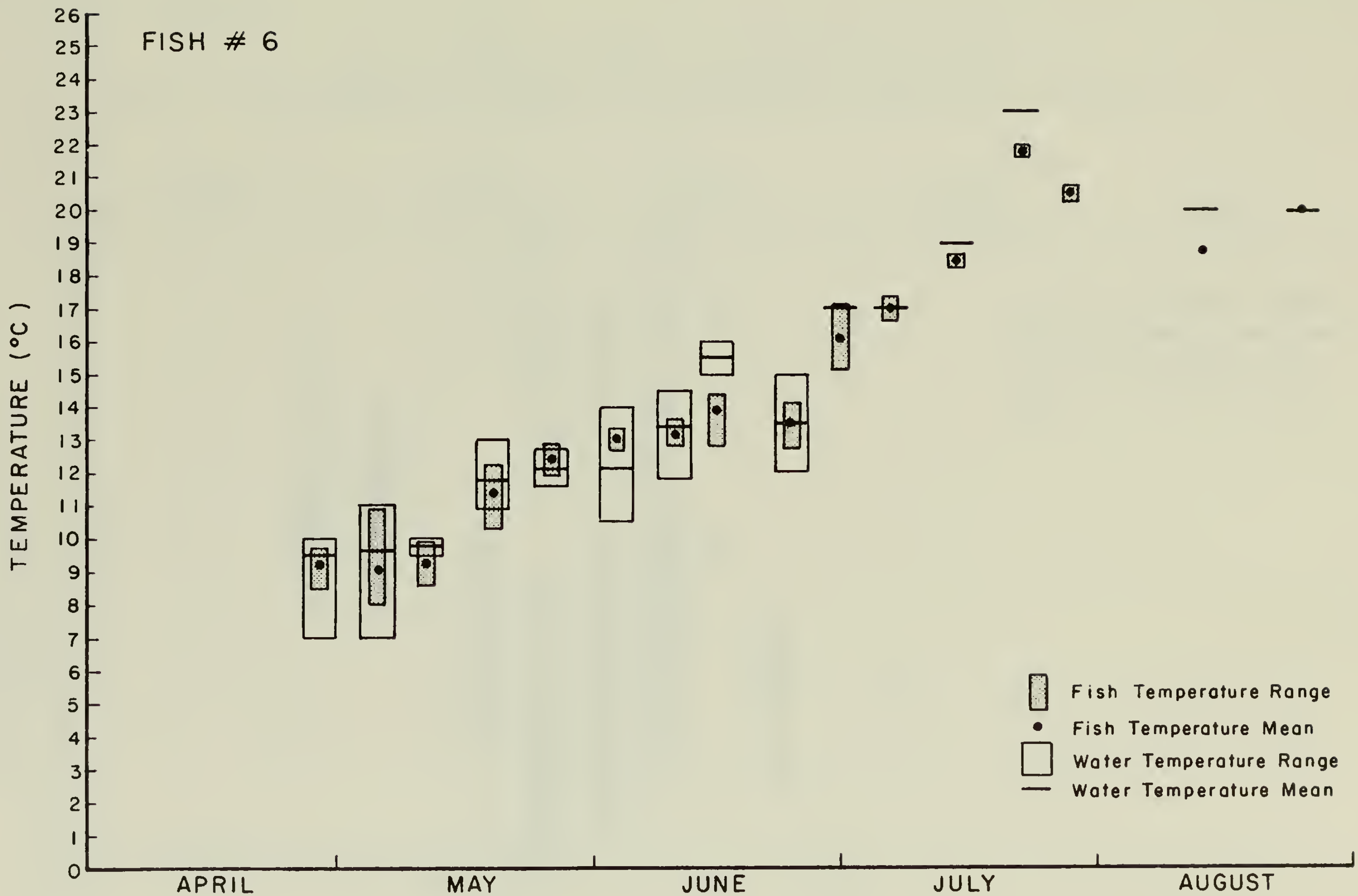

Fig. 10. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 6 in Yampa River, 1982

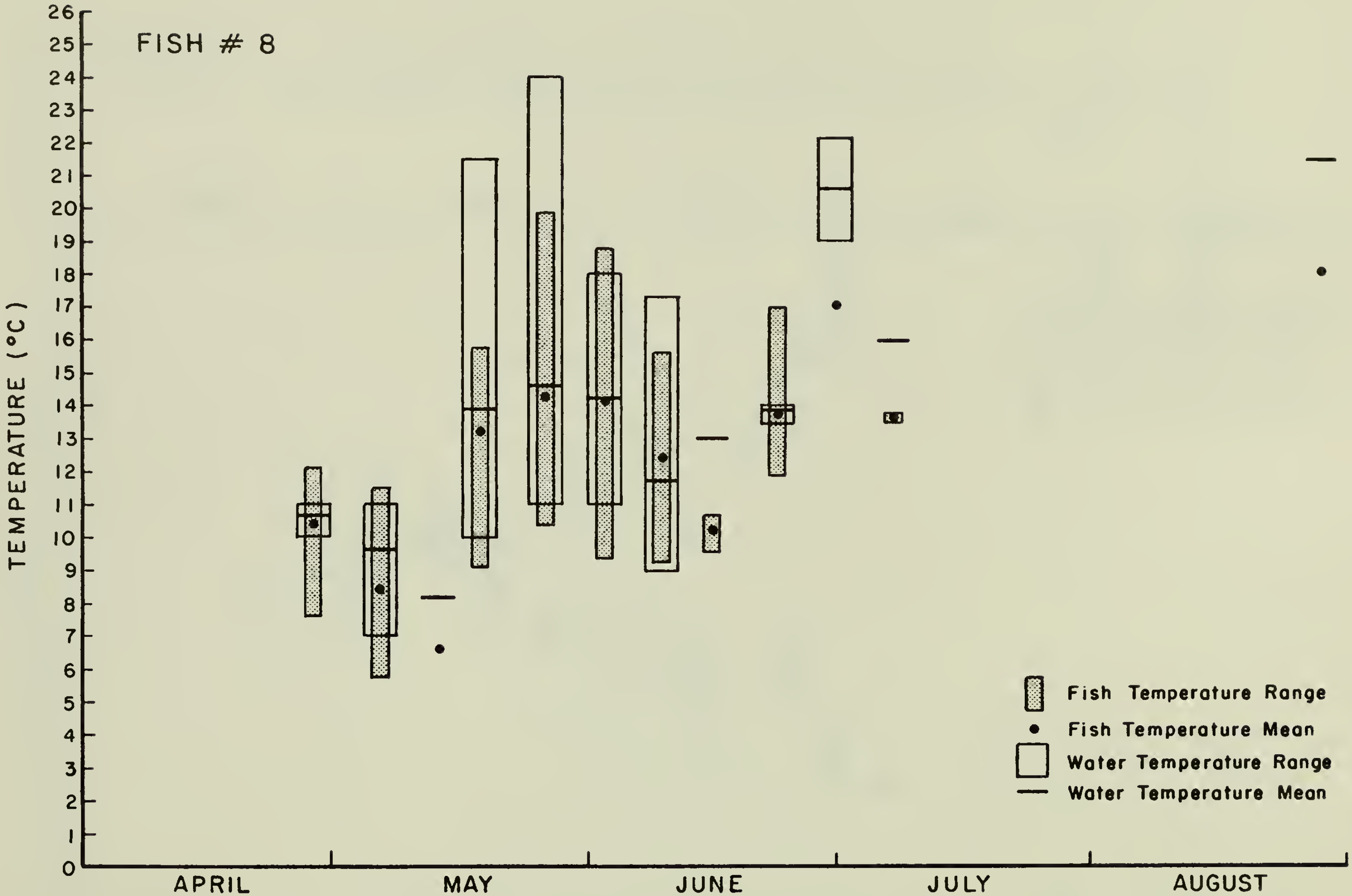

Fig. 11. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 8 in Yampa River, 1982

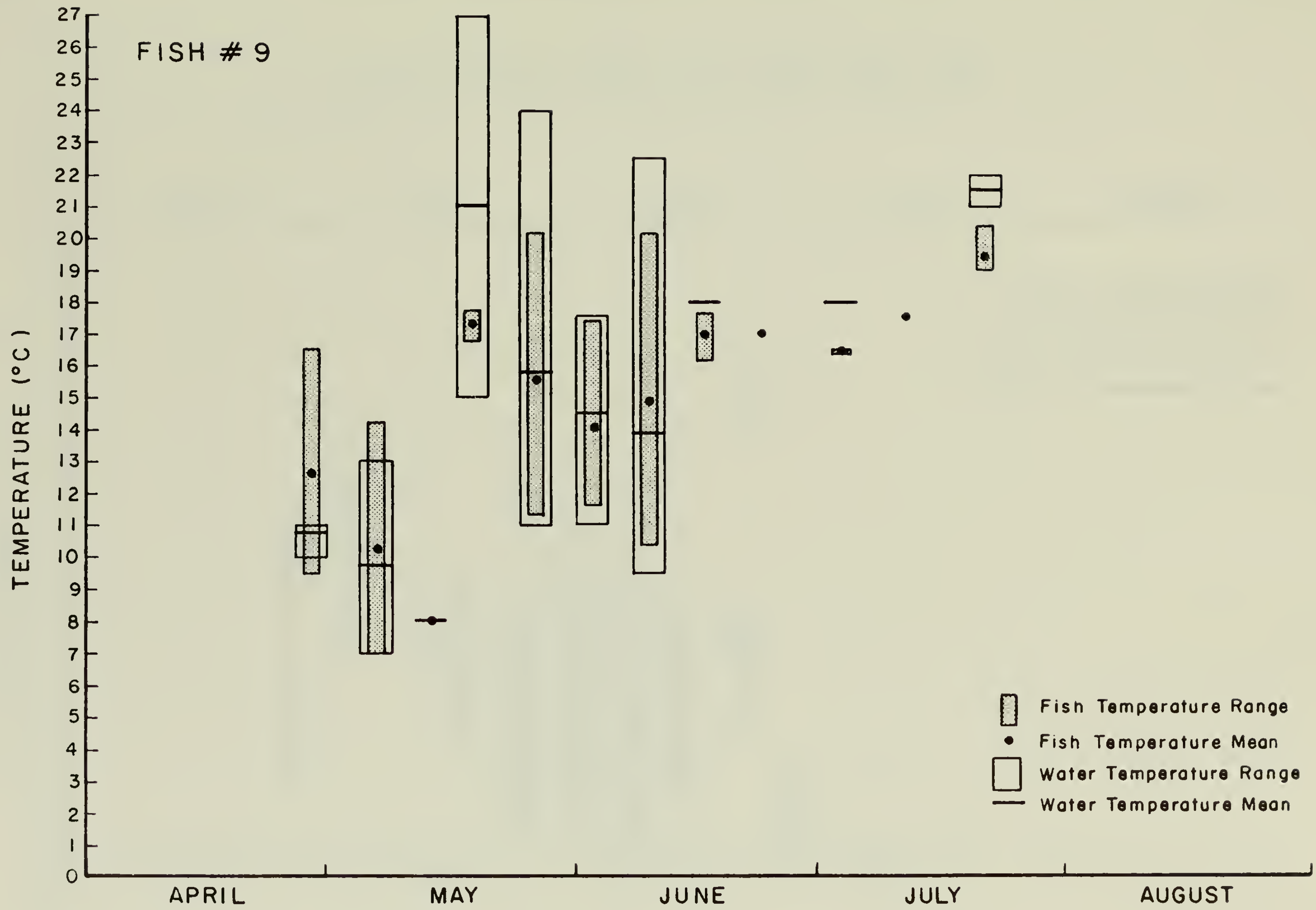

Fig. 12. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 9 in Yampa River, 1982

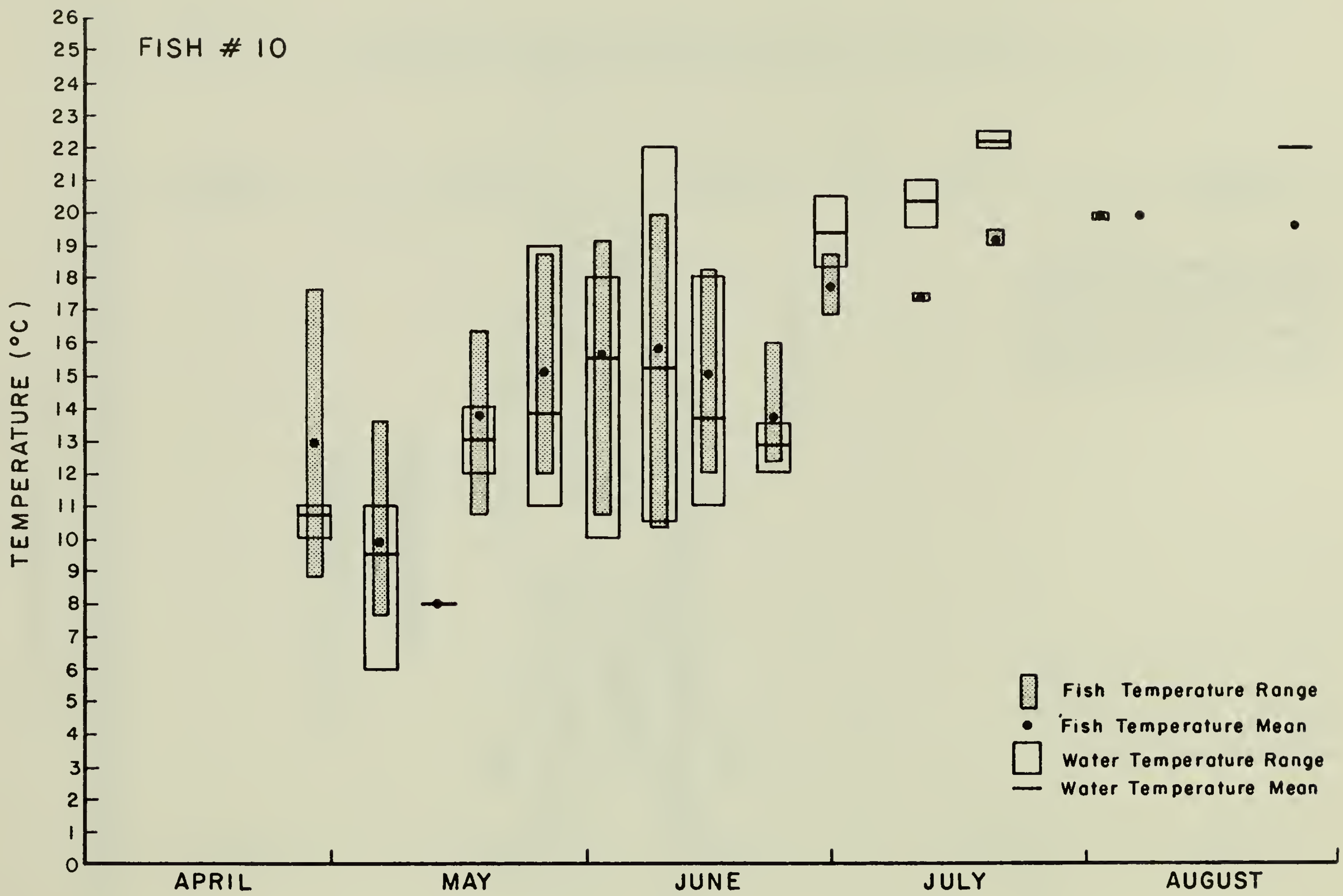

Fig. 13. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 10 in Yampa River, 1982

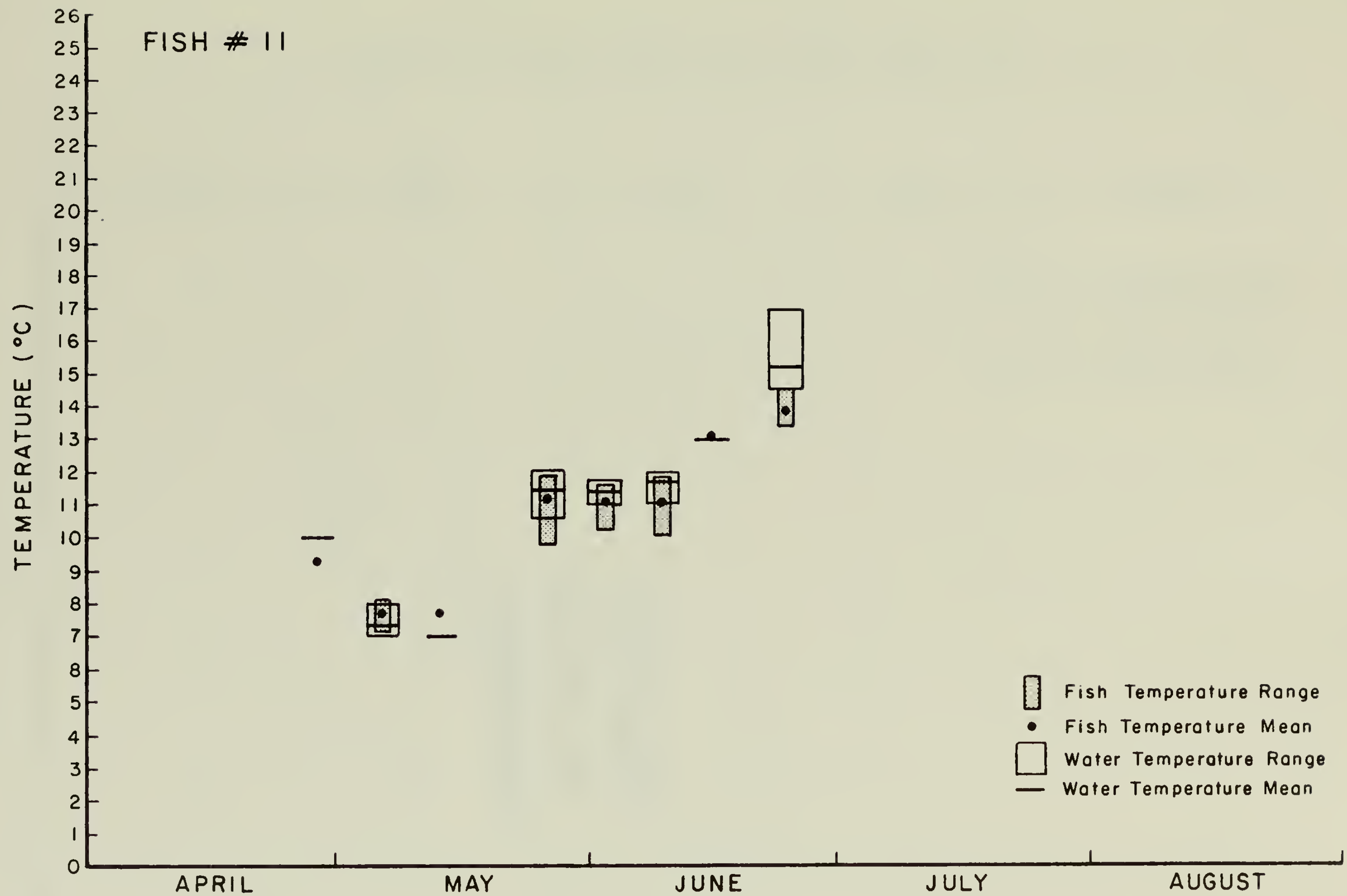

Fig. 14. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 11 in Yampa River, 1982

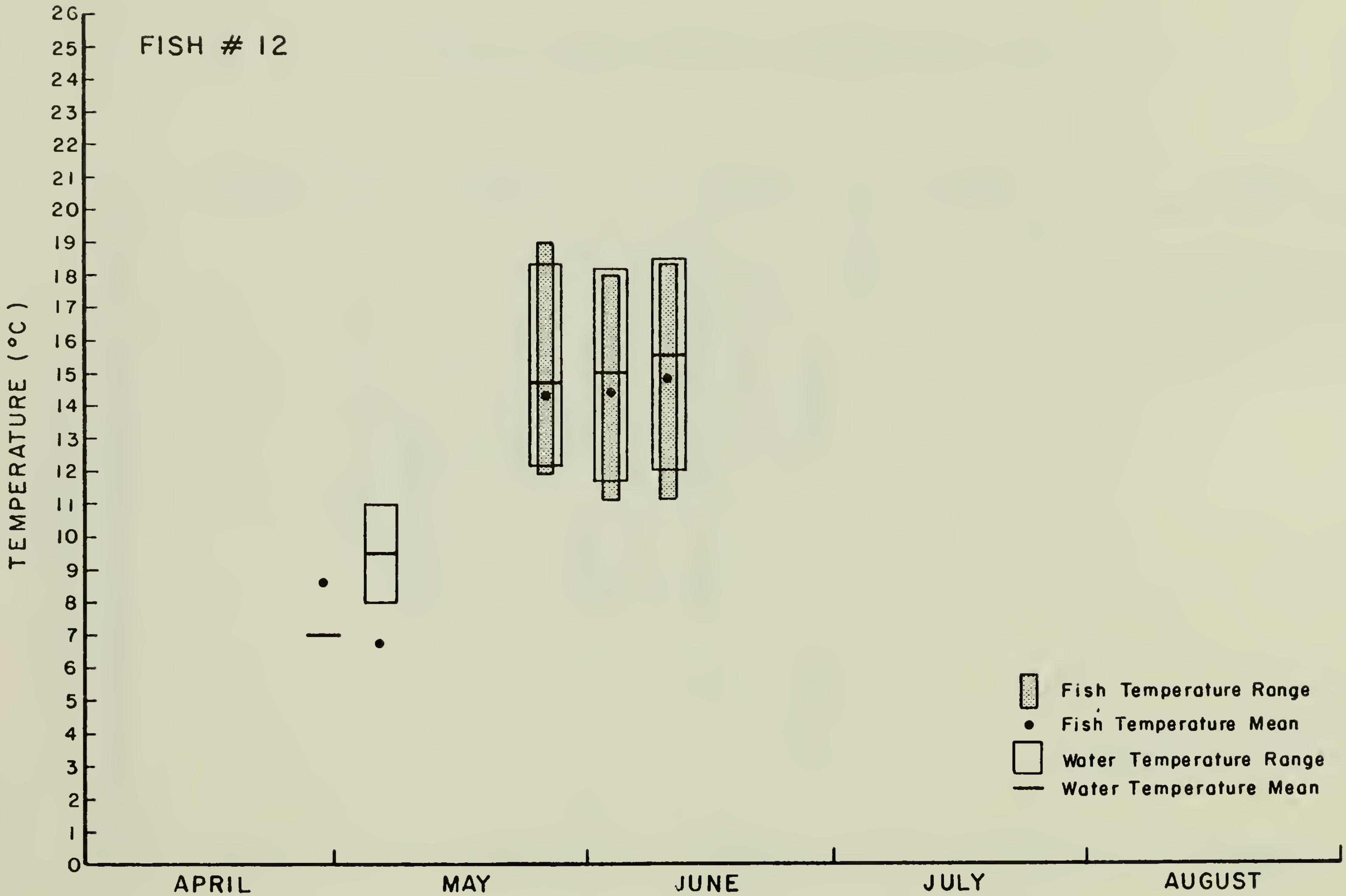

Fig. 15. Fish temperature range and associated water temperatures recorded for Colorado squawfish number 12 in Yampa River, 1982

Spawning Observations

On July 31, at 2020 hours (hrs), contact was made with radiotagged fish number 4 at river km 26.4 (mile 16.4) in a chute channel. The fish was monitored throughout the night and showed local movement of 27-46 m (30-50 yds.) within the chute channel. On August 1, at 0945 hrs., fish number 4 was located in the chute channel "run" habitat. During the next 4 hrs, the fish was observed by radiotelemetry to exhibit a large range of movement. The fish moved first to the base of the upper riffle along the eddy interface and then moved abruptly down the channel "run" about 46 m (50 yds.). This movement pattern was observed several times. Most movement occurred between 1030 and 1200 hrs. The fish frequently moved into lower-velocity eddy and shoreline habitats between its abrupt movements in the channel. The fish was not observed moving into the shallow riffle. Approximately one week later, on August 6, radiotagged fish number 5 was located in the same chute channel at river km 26.4 and exhibited a behavioral pattern very similar to that of fish number 4.

Spawning Habitat

The braided reach between river km 26.7-26.1 (mile 16.6-16.2) offers diverse riffle/pool habitat. The river reach above, at river km 26.7 to 26.4 (mile 16.6-16.4), is characterized by a long, low-velocity pool with sand substrate giving way to rubble gravel as it approaches the braided channel. There were three secondary channels at river km 26.4 (Fig. 16). The chute channel on river right was unique from the other side channels in that a deep, high-velocity channel had been cut into the riffle's far right side. The riffle was 0.3 to about 0.6 m (1-2 ft.) deep, and the cut channel was estimated to be more than 1 m (3 ft.) deep. Below the channel, a small rapid was formed, which gave way to a laminar flowing run with depth estimated at more than 2 m (6 ft.). A large eddy was located next to the run and below the riffle on the island side of the channel. Because of an inoperable velocity meter, exact velocity readings were not obtained. However, velocities were estimated to range from 1.8-2.4 m/sec (6-8 ft/sec) in the deep riffle chute. This fast current also made it impossible to safely obtain accurate depth measurements along the channel. Channel substrate consisted of rubble and gravel with some sand deposition within the eddy.

Endangered Fish Captures

Spawning site captures

A floating trammel net pull from river km 26.7-26.4 (mile 16.6-16.4) on August 1 resulted in the capture of two Colorado squawfish (Fig. 16; seine haul B). This was the same area in which the USFWS captured 13 ripe Colorado squawfish on July 5, 1981 (Miller et al., 1983b). These two fish were females in spawning condition.

On August 1 at 1210 hrs, two attempts were made to capture radio-tagged fish number 4 with a trammel net pulled seine-fashion from a raft and walked along the shore (Fig. 16, seine haul A). The net was pulled through eddy and run portions of the channel; and seven Colorado squawfish, all in spawning condition, were captured. One of the fish was a possible female [Carlin tag #1863(B)], which had been originally tagged on June 2, 1982, within a man-made backwater at river km 103.0 (mile 64.0). Another less efficiently pulled net resulted in the capture of only two additional Colorado squawfish, both males in spawning condition.

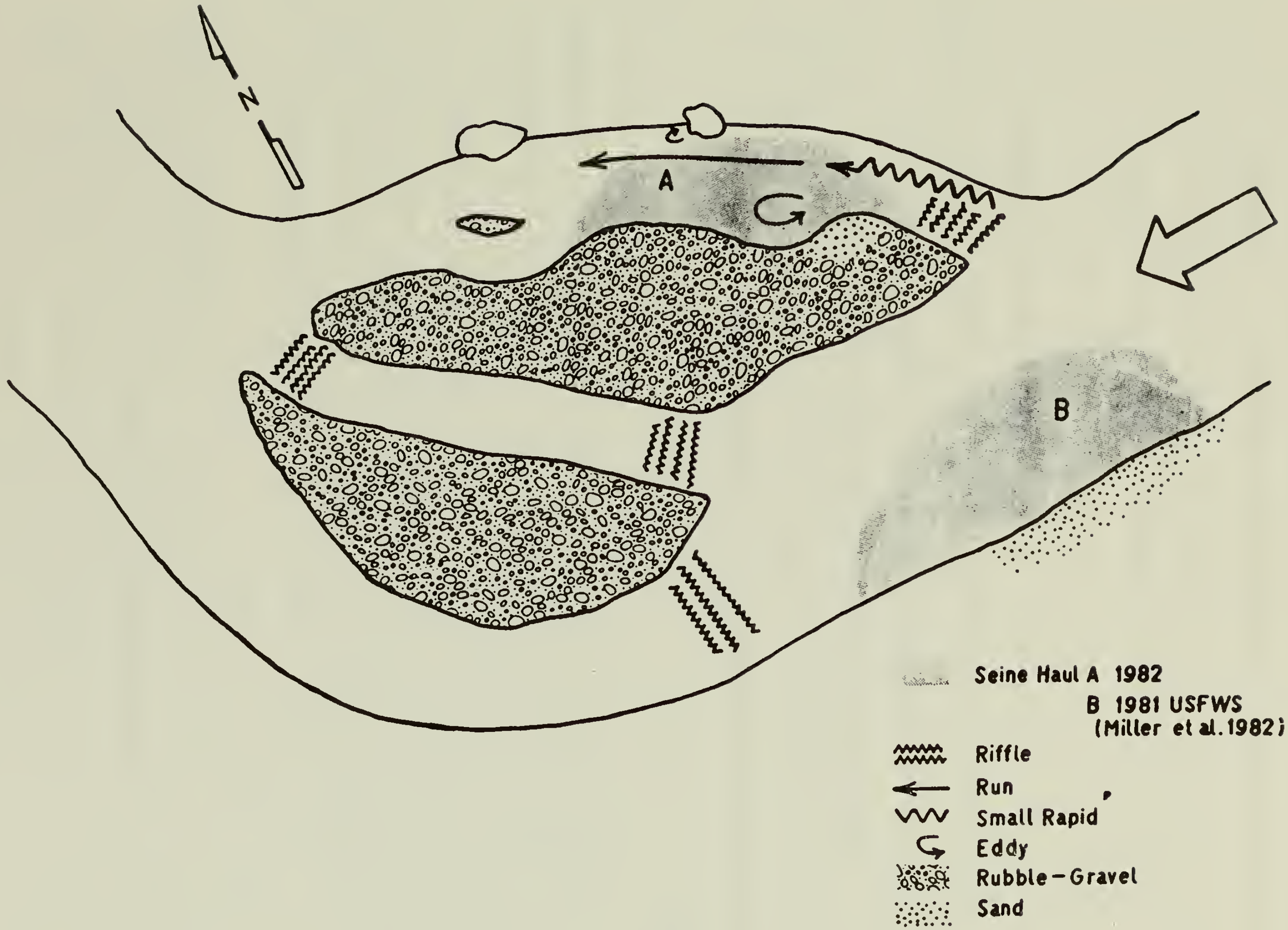

Fig. 16. Map of Yampa River reach at km 26.4 (mile 16.4), 1982

Just before sampling the channel, a large fish (possibly a squawfish) was noted at the surface within the eddy. During the net haul, many large squawfish (>500 mm) jumped and swam away from the moving net. Many fish probably avoided capture by outswimming the net or going around, over, or under it, since the net's depth (2 m) was not as great as that of the water sampled. Radiotagged fish number 4 was not captured.

On August 7, radiotagged fish numbers 5 and 10 were observed at river km 26.4 (mile 16.4) and river km 26.2 (mile 16.3). An unsuccessful attempt to catch fish number 5 resulted in capture of five male squawfish in spawning condition from the chute channel mentioned above. Prior sampling in this general area (Fig. 16, seine haul B) on July 19 resulted in capture of only one ripe male squawfish.

Recaptures

The capture-recapture effort yielded three recaptures of squawfish at km 27.5 (mile 17.3) on the Yampa on July 31, 1982. One recaptured, Carlin-tagged fish [#1102 (Y)] had been originally captured 1 km (0.6 miles) upstream the previous day. Another [#1182 (Y)], was originally tagged at Yampa River km 89.4 (mile 55.5) on October 6, 1981. The third [#1804 (B)], was originally tagged by the CDOW in the White River at river km 218.8 (mile 136) in 1981.

A recapture of significant importance occurred on July 10 at river km 26.7 (mile 16.6) when radiotagged fish number 1 was recaptured and was discovered to have a transmitter that had stopped functioning. The fish appeared to be in excellent health and in spawning condition. Original site of capture was river km 83 (mile 51.5) on April 21.

Carlin-tagged fish #1166 (Y) was originally captured on the spawning bar at river km 26.4 (mile 16.4) by the USFWS on July 5, 1981 (Miller et al. 1983b). This fish was recaptured on March 25, 1982 and implanted with radiotag number 3. On May 27, 1982, three recaptured Carlin-tagged squawfish were among eight squawfish captured in a large man-made backwater at river km 152 (mile 99), 6.4 km above Juniper Canyon. Two of these fish were originally caught in pool habitat inside Juniper Canyon, river km 146.5 (mile 91) in October 1980 and 1981 by the CDOW (Wick et al., 1981). Finally, recapture #1138 (Y) at river km 123 (mile 76.3) on August 24, 1982, was originally captured at river km 18.5 (mile 11.5) on July 1, 1981 by the USFWS (Miller et al., 1982b).

Extended pre- and postspawning electrofishing resulted in capture and tagging of 30 Colorado squawfish, all greater than 400 mm TL above the entrance to Yampa Canyon. From July 2 through August 7, 40 fish were captured between river km 33 and km 8.2 (mile 20.5 to 5.1), including five recaptures that were not originally Carlin-tagged within Yampa Canyon in 1982. There were 25 males, 11 possible females and 4 fish of indeterminate sex. Fifty-five percent of the above fish from Yampa Canyon were captured within 0.8 km (0.5 mile) of the spawning site at river km 26.4 (mile 16.4). All migrant radiotagged fish were at some time observed within this area.

Larval fish collections

The 1982 larval fish collections contained larval Colorado squawfish only from below river km 20.8 (mile 12.9), below the known spawning site at km 26.4 (mile 16.4), on the Yampa River. All endangered fish (adults and larvae) sampled during this study are listed in Appendix C.

DISCUSSION

Migratory Movement

Five radiotagged fish of the sample population exhibited a highly mobile migration of 200-350 km by migrating from the Upper Yampa downstream to spawning areas in the lower 32 km of Yampa Canyon, and at least four returned to the Upper Yampa near points of original capture. Similar observations of migratory movement were documented by the USFWS in 1981 (Miller et al. 1982a,b; Tyus et al. 1982a,b, 1983).

Timing of migration in 1981 and 1982 was similar with the major movement into Yampa Canyon occurring in late June and early July. However, water levels in 1982 were considerably higher than in 1981. Peak flows in 1982 were approximately 15,000 cfs compared to 6,000 cfs in 1981 (Miller et al., 1982b). Flows during migration into Yampa Canyon were 7,000-10,000 cfs in 1982 compared to 1,000-2,000 cfs in 1981. These observations from two dramatically different water years suggest that the timing of spawning migration of Colorado squawfish is directly related not to flow levels alone but to other environmental factors. Since squawfish evolved in a system of highly variable flow, it is logical that they adapted to migrating and spawning at different flow levels. Factors controlling timing of migration and spawning are likely related to the annual flow cycle and temperatures to which fish are exposed.

In 1981, all of the seven fish radiotagged on the Yampa River migrated to the spawning area (Miller et al., 1982b). In 1982, three fish in the radiotagged sample population did not appear to migrate.

The daily plots of these fish show them remaining in the vicinity of their original capture (Fig. 3). Close contact throughout the spawning period in the Upper Yampa River was not made with all these fish because of intense tracking efforts inside Yampa Canyon. We assumed that these fish, which had operational tags through mid-August did not migrate into Yampa Canyon, since no contact was made within Yampa Canyon during the spawning period. The sizes of the nonmigratory fish were 554 mm (#8), 565 mm (#6), and 566 mm (#2) TL. Miller et al. (1983b) reported that the average size of four nonmigrants tagged on the Green and White rivers was 476.5 mm TL and that average size of 11 migrants from the Yampa, White, and Green rivers was 565 mm. Seethaler (1978) reported 100% sexual maturity in 11 female and 48 male Colorado squawfish over 503 mm TL. Hamman (1981) reported that hatchery reared Colorado squawfish became mature at age V for males 317-376 mm TL and age VI for females 425-441 mm TL. The mean total length of nonmigrants in 1982 was 562 mm. According to reports cited above, these fish were probably sexually mature. However, because of either small numbers of fish examined, different conditions under which fish were reared, and different rivers in which squawfish were tagged in the above studies, no firm conclusions can be drawn regarding sexual maturity of Yampa River nonmigrants in 1982.

Another explanation of why these fish did not migrate is that they spawned "in place." However, larval and young-of-the-year (YOY) Colorado squawfish have not been collected above Harding Hole, river km 34, indicating that successful reproduction does not take place above Yampa Canyon. Another possibility is that all Colorado squawfish do not spawn every year. This could be because they spawned the previous year and are reconditioning. It is also possible that the fish were in poor condition or were stressed by surgery. However, behavior of these nonmigrant fish during the premigratory period did not appear abnormal, since their local movements were similar to those of other squawfish radiotracked in 1982 and 1981. Still another possibility is that the proper environmental stimuli were not experienced by the fish. This possibility will be discussed later, in the temperature section.

Migratory movement was noted in radiotagged fish number 12 prior to losing contact on June 11. It moved from its upstream capture site river km 170, (mile 105.5) to river km 96.6 (mile 60). Fish number 11 was also tagged at river km 170 (mile 105.5), and contact was lost June 23 after noting a downstream movement of 8 km to river km 166.5 (mile 103.4). The last contact with fish number 3 was July 7 at river km 89.5 (mile 55.6); this fish was originally tagged at river km 86.5 (mile 53.7).

Spawning Areas

River km 26.4 (mile 16.4) was the only site at which Colorado squawfish were observed by radiotelemetry to undergo spawning behavior. However, this is not the only site at which spawning may occur. In 1981, similar behavior, presumably spawning, of radiotelemetered squawfish was observed at river km 29.8 (mile 18.5). In addition, four larval squawfish were collected at river km 28.8 (mile 17.9) in 1981, providing conclusive evidence that spawning occurred upstream of river km 26.4 (mile 16.4) (Haynes and Muth, 1982). Aggregations of ripe fish captured at several locations throughout the lower 32 km of Yampa Canyon suggest spawning at other sites. It is also possible that individual squawfish might spawn at several sites within the lower 32 km of Yampa Canyon. In 1981 and 1982, ripe Colorado squawfish were also located in areas where physical parameters were similar to those at river km 26.4. These areas at river km 31.4-26.6 (mile 19.5-16.5) and km 18.4-14.0 (mile 11.4-8.7) were also highly diverse and characterized by side channels and rubble gravel bars amid a unique riffle-pool habitat sequence.

Endangered Fish Captures

Radiotelemetry and capture-recapture information indicate that Colorado squawfish exhibit fidelity to the Yampa River. The recapture of five Carlin-tagged squawfish reinforced telemetry data on migratory movement between Yampa Canyon and upper reaches of the Yampa River. In July 1981, USFWS captured two squawfish [#1166(Y) and #1138(Y)] near the spawning area. These fish were recaptured in March and August of 1982 in the upper reaches above Yampa Canyon. Two other squawfish [#1182(Y) and #1863(B)] originally captured in the Upper Yampa in 1981 and 1982 were subsequently recaptured near the spawning area in July and August 1982. The USFWS also reported fish recaptures between the upper and lower reaches of the Yampa River (Miller et al., 1982b). Two recaptures on the spawning area in 1981 were originally Carlin-tagged on the Upper Yampa.

Adult capture information indicates that suitable adult habitat exists throughout the Yampa River up to Milk Creek at river km 191.9 (mile 119.2) (Holden and Stalnaker, 1975; Seethaler, 1978; Wick et al., 1981; Miller et al., 1982b). Spawning habitat appears to be restricted to the lower 32 km (20 miles) of Yampa Canyon. Young-of-the-year (age

0-I, ≦ 60 mm TL) squawfish occur only in the lower 32 km (20 miles) of Yampa Canyon (Haynes and Muth, 1982; Miller et al., 1982b). Few, if any, juvenile squawfish (age I-IV, 60-400 mm TL) have been collected in the Yampa River. The largest documented concentration of juvenile squawfish near the Yampa River spawning area is in the Jensen-Ouray area of the Green River (Holden, 1977; Miller et al., 1982a). Adult Colorado squawfish (age V+, >400 mm TL) were captured throughout the Yampa River study area. Current records indicate that no adult squawfish originally Carlin-tagged in the Yampa River above Yampa Canyon have been recaptured in other rivers. However, recaptures in the Yampa have yielded fish originally Carlin-tagged on the Green and White rivers (Miller et al., 1982b). These observations lead to the following conclusions:

1. Fish from the Yampa, White, and Green rivers use the Yampa Canyon spawning area and then return to their resident home range.
2. Recruitment of adult Colorado squawfish (>400 mm TL) into the Upper Yampa River likely originates from nursery areas in the middle and lower Green River, downstream from Jensen, Utah.
3. Squawfish that establish residency in the Yampa River tend to remain within their home range throughout the year except to spawn.

Larval fish collections

The larval collection effort yielded a total of 12 individuals, 9.5-21 mm in length, only below the known spawning areas (Appendix C). Larger individuals (mean length 17.6 mm) were collected from isolated pools in backwater areas below river km 1.0. Smaller individuals (mean length 12.6 mm) were collected from areas nearer the spawning site. These observations coupled with similar observations in past years suggest that, as larvae grow, they tend to drift or move downstream to the confluence of the Yampa and Green rivers and on down the Green River.

General Habitat Use

The habitats used by radiotelemetered Colorado squawfish in the Yampa River varied considerably throughout the study period (April to November). This coincides with observations of Miller et al. (1982b) and Holden and Wick (1982), who also noted seasonal variations in habitat use. River-specific variations in habitat use were also noted by Miller (1983b).

In general, habitat use by Colorado squawfish appears related to flow and habitat availability in a given river reach. The Upper Yampa River above Cross Mountain Canyon is an area of diverse habitats. For example, canyon areas near Duffy Mountain (river km 172, mile 106.8) and Juniper Canyon (river km 147, mile 91.3) provide deep pool habitats for Colorado squawfish at low flows, while several small tributary streams form backwater habitats, which are used at high flow. This river reach also contains several man-made backwaters, created by diking off the upper end of former side channels. These habitats, at river km 159, 155, 103 and 97, are open to the river and used by squawfish at high water. Squawfish leave these habitats as water levels recede. Island areas also provide diverse habitats for squawfish at both high and low flow levels. During high flow, squawfish are often located in eddies below island tips and in shallow, low-velocity areas with vegetated shoreline. During low flows, squawfish are often located in backwaters formed by former sidechannels or in channel runs at island areas.

In contrast, the river reach below Cross Mountain Canyon contains few backwater habitats. The Little Snake River enters the Yampa at river km 82 (mile 51) and provides numerous eddies, sand islands and bars. The Yampa River between the confluence with the Little Snake and the entrance to Yampa Canyon (river km 74, mile 46) is characterized by sand deposition and braided channels. Fish numbers 1, 2 and 3 implanted below Cross Mountain Canyon used predominantly eddy, run, and side channel habitats. The fish implanted above Cross Mountain Canyon, where more backwater habitats are located, accounted for the high percentage of backwater use reflected in Figure 5.

In 1982, work conducted by the U.S. FWS on the Colorado River indicated that gravel pits, similar hydrologically to some backwater habitats, were used by both Colorado squawfish and razorback sucker (Miller et al., 1983a). Thirty-six Colorado squawfish were collected from four gravel pits, 23 were captured in Walter Walker Wildlife Area (WWWA), just west of Grand Junction, where most collecting efforts were concentrated. In late June and early July, when water levels began to recede, 13 Colorado squawfish were captured in fyke nets as they were apparently leaving WWWA. When significant reductions in water levels threatened to isolate the gravel pits, squawfish left the habitat as evidenced by lack of squawfish in collections in isolated gravel pits or connected pits during low water. Movement patterns of 16 radiotagged Colorado squawfish were monitored in the Grand Junction area by USFWS in 1982. Twelve fish were collected in gravel pit and backwater habitats while four were collected in river habitats. The fish from WWWA exhibited the most dramatic movement patterns migrating both upstream and downstream. These observations on habitat use and subsequent migratory movement are similar to those observed in man-made backwater and flooded tributary habitats on the Yampa River.

Temperature Observations

Most radiotagged fish in the migrant group began to move downstream in late June and early July, when their temperatures rose to 16°C. These fish were present in the spawning area when their temperatures approached 19°C. However, spawning behavior was noted only after their temperatures exceeded 19°C. Hamman (1981) observed captive Colorado squawfish (wild fish captured in the Upper Colorado River system and not induced by hormonal injection) spawning at water temperatures of 20-21°C. In addition, 1982 Yampa River data indicate that several fish in the migrant group moved below the known spawning site on the Yampa River and then returned upstream to spawn. The same pattern was observed by the USFWS in 1981 (Miller et al., 1982b,c). These movements could be related to selection of physical conditions (temperature and spawning habitat) that are suitable for spawning. Fish may migrate downstream from the Upper Yampa in search of suitable spawning habitat or a familiar scent. Once a site is located, migrating fish may go into a holding pattern until proper temperatures physiologically prepare them for spawning. This type of pattern was noted in fish numbers 5, 9, and 10. Fish also recognize spawning habitat from downstream as evidenced by migrants from the Green and White rivers. This suggests a mechanism of scent imprinting similar to that of salmon (Hasler, 1971). As larvae, squawfish may imprint the odor of the Yampa spawning area and later, as migrating adults, recognize this odor and detect it in downstream waters (upstream migrants) or as they pass through the spawning area (downstream migrants).

The temperature graphs (Figs. 6-15) indicate narrower ranges of fish and water temperatures in July and August, when squawfish move into main channel habitats. Minor variations in temperature are very important to spawning of the northern squawfish, a congener of the Colorado squawfish (Beamesdefer and Congleton, 1981). Spawning began, in the St. Joe River, Idaho, when water temperatures reached 14°C. Spawning stopped, abruptly, when a cold rain caused water temperatures to fall below 14°C and resumed when the water temperature returned to 14°C and above. This observation, in conjunction with others (Jeppson and Platts, 1959; Hill, 1962), supports the hypothesis that specific temperature requirements are needed by Colorado squawfish for spawning.

Temperature and photoperiod influence fish behavior and physiology in several ways (Magnuson et al., 1979). The interaction of these two environmental stimuli triggers gonadal maturation, which ensures that fish will spawn during periods when environmental conditions are most favorable (Schwassmann, 1971).

This environmental influence is hypothesized to occur in two stages. In the initial stage, physical stimuli act through the "brain-pituitary-gonad axis" to release hormones, which initate gonadal maturation. This is a relatively slow metabolic process that is activated by cumulative exposure to environmental changes. The second stage, triggered by the occurrence of the first stage and additional environmental changes, is final maturation of the gonads; this may occur relatively fast compared with the first stage (Liley, 1969).

One possible explanation for several adult-size squawfish not migrating may be related to inadequate stimuli to trigger the initial process of gonadal maturation. Our data indicate that this triggering mechanism may be highly sensitive to temperature. Comparison of temperature data in Figs. 9 and 10 shows that the temperatures of fish 5 and 6 are very similar. Fish number 5 (608 mm) migrated, fish number 6 (565 mm) did not. These fish were located very close together from mid-April to mid-June; then fish 5 moved downstream a few kilometers and finally entered a large backwater in early July. Then a large temperature fluctuation occurred with fish number 5, and this temperature change may have triggered migration. It is interesting to note that fishes 2 and 6 of the nonmigrant group were never found in backwater habitats (Appendix B). The temperature of fish number 2 was consistently cooler by several degrees than that of the environment. This might have been caused by an original calibration error or a sensing-unit failure. Fish number 8, located in the farthest upstream group used backwaters quite extensively at times but was never located on the spawning area. Fish number 8 showed cooler temperatures in late April and again in mid- to late June than fish numbers 9 and 10, which were migrants and originally tagged in the same upstream area. Cooler temperatures of fish number 8 reflect its location near the mouth of the tributary stream backwater, where cooler river temperatures were an influence.

These observations suggest a delicate relationship between habitat use and temperature that may or may not trigger spawning in individual fish in a given year and given river reach. The upper sections of the study area now represent the upstream distributional range for Colorado squawfish. During high-water years temperatures can be colder for extended periods in the main channel than in low-water years, when temperatures can rise quite rapidly. During higher, colder water years, use of warm backwater habitat may be important in triggering gonadal development, especially in upper distributional ranges. In low-flow years, main-channel temperatures may be sufficient to trigger gonadal development even in extreme upstream areas. The effect of cooler water temperatures in 1982 was also evident in that spawning time was almost a month later than in 1981.

The effect of colder river temperatures on native fish reproduction in general was dramatically evident on the Green River below Flaming Gorge Dam. Holden and Crist (1978) reported that reproduction of two native suckers, the flannelmouth sucker (Catostomus latipinnis) and the bluehead sucker (Catostomus discobolus), was curtailed in the tailwaters of Flaming Gorge Dam downstream to the confluence with the Yampa River. These fish reproduce earlier in the year and at cooler temperatures than do Colorado squawfish. After inlet modifications to Flaming Gorge Dam, reproduction resumed for these species in lower sections of the Green River up to Ladore and Alcove Brook (upstream from the Yampa River confluence).

Seethaler (1978) reported large numbers of adult-size Colorado squawfish congregating below Flaming Gorge Dam just after closure in 1962. However, as tailwaters cooled, adult Colorado squawfish abundance declined dramatically in the Green River reach between Flaming Gorge Dam and the Yampa River confluence and no reproduction was evident. After the dam inlet modification in June 1978, adult squawfish responded to the warmer temperatures by returning to the lower segments of this river reach (Holden and Crist, 1978). Radiotagged squawfish were tracked into this segment of the Green in 1982 by the USFWS (Miller et al., 1983). The inconsistent migration patterns noted in USFWS Colorado squawfish radiotelemetry studies on the Upper Green River 1979-1982 may be caused by the highly altered and changing flow and temperature regimes occurring on the Green River after inlet modification in 1978. Since the decline of squawfish numbers in the river reach between Flaming Gorge Dam and the Yampa River was probably temperature related, one can logically expect changing fish behavior patterns resulting from changes in temperature regimes due to inlet modification. The reproductive behavior of Colorado squawfish in the Upper Green has very likely been in an altered and often changing state for the last 20 years.

CONCLUSION

The Green River Basin below Flaming Gorge Dam is now the most productive refuge remaining for Colorado squawfish. Largely because of the Yampa River and its amelioratory effects on the Green River, this refuge provides the most pristine aquatic habitat available to squawfish.

The Colorado squawfish is historically the top predator in the Colorado River system. Throughout its life cycle, this relatively long-lived and wide-ranging fish requires a variety of habitats and, as with most top predators, requires considerable territory. Adults live and travel throughout the basin, sometimes migrating more than 350 kilometers. Adults migrate either upstream or downstream and between different rivers, if necessary, to specific spawning sites, then return to their prespawning locations. Larvae drift or migrate downstream from the spawning grounds to nursery areas in lower portions of the basin. As they grow, juvenile fishes expand their range, and just before adulthood some move up tributary rivers and establish residency.

The history of extirpation in the Lower Colorado River Basin is evidence of the vulnerability of Colorado squawfish to (1) disruptions in migratory routes; (2) alterations in temperature, flow, and habitat;

and (3) introductions of non-native species. Extinction in the Green River Basin could result from similar disruptions. A major portion of squawfish habitat in the Upper Green River has already been eliminated by Flaming Gorge Dam. Below the dam, significant seasonal alterations in temperature and flow occur, and daily fluctuations in water levels probably impact young-of-the-year and juveniles in nursery areas. Introduced species, such as walleye and northern pike, could prey on young and compete with adults for the remaining habitat and resources in the Green and Yampa rivers. Recently approved dams on the White River will further reduce habitat and range.

Efforts must be made to mitigate the damage already done. We need to better anticipate, understand, and mitigate the cumulative impacts of future development to ensure survival of the Colorado squawfish. Effects of altered temperature and flow regimes must be better understood. The importance of adequate flushing flows for maintenance of spawning habitat must not be overlooked. Quality habitat must be preserved for all life history stages, along with sufficient distributional range, to maintain a healthy population. Our observations suggest important relationships between temperature, habitat use, and reproduction in the upper portions of the basin. We need to build on this work to confirm and better define these relationships.

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A helicopter crash occurred while radiotracking on July 23, just as spawning activity was starting. Fortunately, only minor injuries were incurred in the accident, although the helicopter was destroyed. Steve Zary, a passenger on the downed helicopter, displayed exceptional calm and quick thinking at the crash site, which reassured other injured crew members and aided the rescue. Thanks are extended to the many persons who showed concern and provided support during this time.

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Appendix Table A. Definitions of habitat types used for radiotelemetry and larval fish studies on Yampa River, 1982 (modified from Arnette, 1976 and Wick et al., 1981)

Habitat type (abbreviation code)	Definition
Primary Habitat Type	
Main channel (MC)	The primary river course that carries the major water flow.
Chute channel (CC)	A secondary channel, with upper sections characterized by high gradient and large substrate size often followed by a deep pool. Lower sections often have reduced gradient with smaller substrate sizes.
Side channel (SC)	A secondary channel, often in a braided river reach, that may carry appreciable flow during high water but during low flow often provides low-velocity or backwater habitat. Gradient and substrate are similar to those in main channel.
Tributary stream (TS)	A small permanent or ephemeral stream entering the main river.
Gravel pit (GP)	Body of water resulting from gravel-mining excavation and periodically or permanently connected to the main river.
Offstream impoundment (OI)	A body of water isolated from the main river.
Specific Habitat Type	
Backwater (BA)	A body of water with no measurable velocity, created either by a drop in water level, which cuts flow through a secondary channel, or by high water levels, which flood low-lying areas or former river channels. Access to the main river is not blocked. [Note: Backwaters include habitats formed during high water, either when a lower section of a tributary stream is flooded and backed up or when a former river channel that has been altered by man is flooded. Usually, the upper portions of side channels are diked to protect fields or provide watering areas.
Isolated pool (IP)	A backwater that has had access to the main river blocked by falling water levels.
Embayment (EM)	Elongated pocket of water connected to the main river and formed by turbulence of back currents associated with shoreline obstructions or irregular substrate, resulting in depressions in the river bed. Distance across mouth (where connected to river) is less than length of embayment.
Concavity (CO)	A low- to no-velocity pocket of water in a shoreline indentation often resulting from irregular shoreline and substrate. Distance across mouth is equal to, or greater than, length of concavity.
Shoreline (SH)	The shallow, low- to negligible-velocity waters next to shore.
Puddle (PU)	Isolated on-shore bodies of water created by falling water levels, not isolated pools in secondary channels.
Rubble flat (RF)	Quiet water areas among rubble- and boulder-size substrates often found at upstream end of island areas and along chute channels.
Riffle (RI)	A shallow rapid in open river where the water surface is broken into waves by obstructions or irregular substrate wholly or partly submerged.
Run (RU)	A stretch of relatively deep, fast-flowing water with the surface essentially nonturbulent.
Rapid (RA)	A relatively deep, fast-flowing area characterized by standing waves and whitewater caused by channel constriction or obstructions.
Pool (PO)	A portion of stream that is deep and quiet relative to the main current.

Appendix Table B-1. Frequency of habitat use by radiotagged Colorado squawfish in the Yampa River during April 1982; cumulative data given as percentages of the total number of observations. Definitions of habitat types are in Appendix A

Fish	Specific habitat:	BA			SH			ED			RU			PO			RI			No specific habitats determined			
no.	Primary habitat:	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	Total no. obs.
1					1				3		1	1											6
2									4			1									9		14
3																				1			1
4		1									1												2
5											16												16
6											16												16
8										13													13
9				7																			7
10				13																			13
11					2																		2
12											2												2
Total		1		20	3				7	13	36	2								1	9		92
Percent		1		22	3				8	14	38	2								1	10		

Appendix Table B-2. Frequency of habitat use by radiotagged Colorado squawfish in the Yampa River during May 1982; cumulative data given as percentages of the total number of observations. Definitions of habitat types are in Appendix A

Fish	Specific habitat:	BA			SH			ED			RU			PO			RI			No specific habitats determined			Total
no.	Primary habitat:	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	no. obs.
1									22		2	2									10		36
2								17	13			2								2	21		55
3								8												16			24
4		65			1			2			6												74
5					13			39												7			59
6								56												5			61
8				42				1		46													89
9				44	4			1		2												4	55
10				50	2			12		13										1			78
11								23			6												29
12		74									2												76
Total		139		136	20			159	35	61	16	4								31	31	4	636
Percent		22		21	3			25	6	10	3	1								5	5	1	

Appendix Table B-3. Frequency of habitat use by radiotagged Colorado squawfish in the Yampa River during June 1982; cumulative data given as percentages of the total number of observations. Definitions of habitat types are in Appendix A

Fish	Specific habitat:	BA			SH			ED			RU			PO			RI			No specific habitats determined			
no.	Primary habitat:	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	Total no. obs.
1					2			6			1									12			21
2						1		56	1		4									4			66
3					3			6			6									3			18
4		27							3		1									6			37
5					2			15			3												20
6								22			2									1			25
8		2		100				3		1	4												110
9		2		37	1			1			3									3			47
10		2		65	2			3		4	4									4		2	86
11				6	2			16			7												31
12		30			1			2			3									5			41
Total		63		208	13	1		130	4	5	38									38		2	502
Percent		13		41	3	*		26	1	1	8									8		*	

*Less than 0.5%

Appendix Table B-4. Frequency of habitat use by radiotagged Colorado squawfish in the Yampa River during July 1982; cumulative data given as percentages of the total number of observations. Definitions of habitat types are in Appendix A

Fish	Specific habitat:	BA			SH			ED			RU			PO			RI			No specific habitats determined			Total
no.	Primary habitat:	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	no. obs.
1								1															1
2					2						1			2						9	1		15
3																				2			2
4								2			7									5	4*		18
5		1						2			1									1			5
6					2			4			7									3			16
8											1									1			2
9					1						4									8			13
10		4			4			2			4									3			17
11																							
12																							
Total		5			9			11			25			2						32	5		89
Percent		6			10			12			28			2						36	6		

*Chute channel habitat used.

Appendix Table B-5. Frequency of habitat use by radiotagged Colorado squawfish in the Yampa River during August 1982; cumulative data given as percentages of the total number of observations. Definitions of habitat types are in Appendix A

Fish no. — Specific habitat:	BA			SH			ED			RU			PO			RI			No specific habitats determined			Total no. obs.
Primary habitat:	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	
1																						
2										2												2
3																						
4				3	9*		1			1	4*					2			3	7		30
5				3	2		6			4	4*		1			2	18**		2	1*		43
6										3												3
8													1									1
9																						
10				1			1				1								3	1		7
11																						
12																						
Total				7	11		8			10	9		2			4	18		8	9		86
Percent				8	13		9			12	10		2			5	21		9	10		

*Chute channel habitat used.

**Chute channel habitat used; riffle habitat recorded during this time period may have been more accurately described as small rapid habitat.

Appendix Table B-6. Frequency of habitat use by radiotagged Colorado squawfish in the Yampa River during October and November 1982; cumulative data given as percentages of the total number of observations. Definitions of habitat types are in Appendix A

Fish no.	BA			SH			ED			RU			PO			RI			No specific habitats determined			Total no. obs.
Specific habitat: / Primary habitat:	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	MC	SC	TS	
1																						
2																						
3																						
O 4													2									
N													2									4
O 5											1											
N		1																				2
O 6				2																		
N																						2
8																						
O 9							1															
N							1			1				5								8
O 10													1									
N										2												3
11																						
12																						
Total		1		2			2			3	1		5	5								19
Percent		5		11			11			16	5		26	26								

O = October, N = November

Appendix C. Yampa River Endangered Fish Sampled - 1982

Species	Sex	Tag Number (Color) [3]	Total Length (mm)	Weight (g)	Location (RM)	Date	Radio Tag Number	Water Temperature (°C)	Habitat [4]	Substrate
P. lucius		1079 (Y)	566	1446	53.7	3/25/82	02	--	MCPO	SARU
P. lucius	M	Recap.[1] 1166 (Y)	550	1698	53.7	3/25/82	03	--	MCPO	SARU
P. lucius		3294 (O)	570	1600	106.7	4/13/82	11	9	TSBA	SISA
P. lucius		3284 (O)	681	2970	105.8	4/13/82	12	8	MCSH	SIRU
P. lucius		3282 (O)	680	3000	103.4	4/13/82	10	--	TSBA	SISA
P. lucius		3257 (O)	662	3200	103.4	4/13/82	09	--	TSBA	SISA
P. lucius		3256 (O)	554	1320	103.4	4/13/82	08	--	TSBA	SISA
P. lucius		3267 (O)	628	2320	103.4	4/13/82	07	--	TSBA	SISA
P. lucius		Obs.[2] --	--	--	81.6	4/14/82	--	--	MCSH	SIBO
P. lucius		3286 (O)	565	1380	65.5	4/19/82	06	6	MCSH	SISA
P. lucius		3280 (O)	608	1950	63.5	4/19/82	05	6	SCSH	SISA
P. lucius		Obs. --	--	--	81.6	4/20/82	--	5	MCSH	SIBO
P. lucius		3265 (O)	742	3790	63.8	4/20/82	04	0	MCSH	SISA
P. lucius	M	3295 (O)	636	2550	51.5	4/21/82	01	5	MCSH	SISA
P. lucius		--	550	1600	106.6	5/26/82	--	11	TSBA	SISA
P. lucius		--	493	1000	106.6	5/26/82	--	11	TSBA	SISA
P. lucius		Obs. --	--	--	98.7	5/27/82	--	--	MCBA	SISA
P. lucius		Recap. 1006 (Y)	564	1580	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		Recap. 1141 (Y)	635	2400	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		Recap. 1380 (Y)	589	2008	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		1822 (B)	604	2300	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		1821 (B)	552	1460	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		1896 (B)	575	1620	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		1820 (B)	641	2400	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		1870 (B)	540	1620	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		Obs. --	--	--	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		Obs. --	--	--	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		Obs. --	--	--	94.7	5/27/82	--	13	MCBA	SISA
P. lucius		Obs. --	--	--	94.7	5/27/82	--	13	MCBA	SISA
P. lucius	F(?)	1863 (B)	680	3100	64.0	6/ 2/82	--	18	MCBA	--
P. lucius		1067 (Y)	582	1100	106.7	6/ 9/82	--	18	TSBA	SISA
P. lucius		1866 (B)	558	1580	98.6	6/ 9/82	--	20	MCBA	SISA
P. lucius		1861 (B)	689	3180	98.6	6/ 9/82	--	20	MCBA	SISA
P. lucius		1874 (B)	549	1740	98.6	6/ 9/82	--	20	MCBA	SISA
P. lucius		1883 (B)	533	1560	98.6	6/ 9/82	--	20	MCBA	SISA
P. lucius		1887 (B)	574	1720	98.6	6/ 9/82	--	20	MCBA	SISA
P. lucius		1174 (Y)	527	--	17.5	7/ 2/82	--	19	MCED	SISI
P. lucius		1080 (Y)	535	--	16.6	7/10/82	--	--	MCED	SARU
P. lucius	M	1132 (Y)	555	--	16.6	7/10/82	--	--	MCED	SARU
P. lucius	M	Recap. 3295 (O)	636	2550	16.6	7/10/82	01	--	MCED	SARU
P. lucius	M	1176 (Y)	545	1600	19.4	7/18/82	--	20	MCRU	SASI
P. lucius		1122 (Y)	594	1820	18.0	7/18/82	--	--	MCED	SASI
P. lucius	M	1066 (Y)	540	1400	18.0	7/18/82	--	--	MCED	SASI
G. cypha		1135 (Y)	330	290	17.5	7/18/82	--	20	MCED	SASI
P. lucius	M	1112 (Y)	508	1100	16.3	7/19/82	--	20	MCRU	RUSA
P. lucius		1157 (Y)	471	800	9.3	7/19/82	--	--	MCRU	RUSA
P. lucius	M	1129 (Y)	620	1860	5.1	7/20/82	--	--	MCED	SASI
P. lucius	F(?)	1183 (Y)	503	960	20.5	7/29/82	--	23	MCED	SARU
P. lucius	M	1093 (Y)	553	1400	17.8	7/30/82	--	--	MCED	RUSA
P. lucius	M	1102 (Y)	511	980	17.8	7/30/82	--	--	MCED	RUSA
P. lucius	F(?)	1414 (Y)	715	3260	17.2	7/31/82	--	23.5	MCRI	RUGR
P. lucius	F(?)	1084 (Y)	558	1480	17.2	7/31/82	--	23.5	MCRI	RUGR
P. lucius	M	Recap. 1182 (Y)	520	1130	17.2	7/31/82	--	23.5	MCRI	RUGR
P. lucius	M	Recap. 1102 (Y)	511	980	17.2	7/31/82	--	23.5	MCRI	RUGR
P. lucius	M	Recap. 1804 (B)	592	1620	17.2	7/31/82	--	23.5	MCED	SARU
P. lucius	F(?)	1098 (Y)	618	2100	17.0	7/31/82	--	23.5	MCRU	RUSI
P. lucius	F(?)	1195 (Y)	634	2100	17.0	7/31/82	--	23.5	MCRI	RUGR
P. lucius	M	1114 (Y)	549	1220	16.7	7/31/82	--	24	MCRI	RUGR
P. lucius	F(?)	1198 (Y)	688	2720	16.7	7/31/82	--	24	MCRI	RUGR
P. lucius	F(?)	1172 (Y)	817	5120	16.6	8/ 1/82	--	25	MCRU	RUGR
P. lucius	F(?)	1171 (Y)	652	2260 (?)	16.6	8/ 1/82	--	25	MCRU	RUGR
P. lucius	F(?)	Recap. 1863 (B)	679	2500	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1190 (Y)	645	2280	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	F(?)	1181 (Y)	557	1290	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1180 (Y)	559	1440	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1197 (Y)	567	1600	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1173 (Y)	643	2240	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1440 (Y)	548	1280	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1447 (Y)	585	1590	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1465 (Y)	570	1300	16.4	8/ 1/82	--	25	CCED	RUGR
P. lucius	M	1430 (Y)	554	1200	16.1	8/ 1/82	--	24	MCRU	RUSA
P. lucius	M	1475 (Y)	570	1220	16.1	8/ 1/82	--	24	MCRU	RUSA

Appendix C. Continued.

Species	Sex	Tag Number (Color) 3/	Total Length (mm)	Weight (g)	Location (RM)	Date	Radio Tag Number	Water Temperature (°C)	Habitat 4/	Substrate 5/
P. lucius	F(?)	1476 (Y)	531	1080	8.8	8/ 3/82	--	22.5	MCRU	GRRU
P. lucius	M	1042 (Y)	524	1000	16.4	8/ 7/82	--	24	CCRU	RUGR
P. lucius	M	1160 (Y)	558	1140	16.4	8/ 7/82	--	24	CCRU	RUGR
P. lucius	M	1107 (Y)	652	2250	16.4	8/ 7/82	--	24	CCRU	RUGR
P. lucius	M	1184 (Y)	484	775	16.4	8/ 7/82	--	24	CCRU	RUGR
P. lucius	M	1134 (Y)	594	1940	16.4	8/ 7/82	--	24	CCRU	RUGR
P. lucius		--	10	--	10.9	8/21/82	--	20	MCEM	SIRU
P. lucius		--	14	--	9.9	8/21/82	--	25	SCPO	SASI
P. lucius		--	16	--	9.9	8/21/82	--	25	SCPO	SASI
P. lucius		--	11	--	3.2	8/21/82	--	24	MCCO	SASI
P. lucius		--	21	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius		--	18	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius		--	20	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius		--	13	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius		--	18	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius		--	18	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius		--	13	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius		--	20	--	0.3	8/22/82	--	25	SCIP	SI
P. lucius	M	Recap. 1138 (Y)	508	900	76.3	8/24/82	--	23	MCRU	RU
P. lucius		1406 (Y)	566	1380	71.9	8/24/82	--	23	MCRU	RU
P. lucius		Obs. --	--	--	79.5	8/24/82	--	21	MCRU	RUSA
P. lucius	F(?)	3201 (O)	832	6500	76.0	10/ 6/82	01	8	MCSH	RU
P. lucius		Obs. --	--	--	93.0	10/ 8/82	--	6.5	MCSH	GRSA

1/ Recap. = recaptures

2/ Obs. = observed fish not captured

3/ Color Y = Yellow
O = Orange
B = Blue

4/ Habitat (see definitions in text)

Primary Habitat Types
- MC = main channel
- SC = side channel
- TS = tributary stream
- CC = chute channel

Specific Habitat Types
- PO = pool
- SH = shoreline
- BA = backwater
- RU = run
- ED = eddy
- RI = riffle
- EM = embayment
- IP = isolated pool

5/ Substrate
- SA = sand
- SI = silt
- RU = rubble
- GR = gravel
- BO = boulder

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