Transactions of the American Fisheries Society 125:78–86, 1996
American Fisheries Society 1996

Diel Movement and Habitat Use of California Golden Trout in the Golden Trout Wilderness, California

KATHLEEN R. MATTHEWS

U.S. Forest Service, Pacific Southwest Research Station
Box 245, Berkeley, California 94701, USA

Abstract.—I used radio transmitters to determine the diel habitat use and movement patterns of California golden trout *Oncorhynchus mykiss aquabonita* inside and outside cattle exclosures on the South Fork Kern River, Golden Trout Wilderness, California. Twenty-three golden trout were monitored from September 10 to 19, 1993, during 216 diel-tracking hours at four study sites in upper and lower Ramshaw Meadow. No differences in distances moved or home ranges were detected between golden trout inside and outside exclosures. Mean home ranges were 18.5–54.0 m inside the two exclosure sites and 36.0–68.7 m outside the two exclosures. Most golden trout were found within 5 m of their previously recorded location at both upper (93.5% of 521 observations) and lower (92% of 394 observations) Ramshaw Meadow sites. Movement of individual fish varied: five fish moved less than 5 m throughout the 10-d study period, whereas 12 fish moved 100–608 m. Golden trout were active both day and night, and I observed them feeding throughout the night, even when water temperatures were as low as 2°C. At all study sites inside and outside exclosures, golden trout used three macrohabitats (pools, runs, and riffles) but selected pools in higher proportions than the more available runs. Throughout the study, golden trout were associated with nine habitat features (undercut banks, willows, bare banks, collapsed banks, open channel, aquatic vegetation, sedge, boulders, or rootwads) but were most commonly found near sedge and undercut banks.

Despite the status of the golden trout *Oncorhynchus mykiss* as California's state fish, little is known about its behavior or habitat requirements. In the 1960s and 1970s, golden trout were in jeopardy because of competition and predation from nonnative fishes and degradation of their habitat (Pister 1991). In their native habitat within high-elevation streams in the southern Sierra Nevada (Everman 1906; Fisk 1983), chemical treatments eradicated nonnative trout, and rock barriers were constructed to prevent reinvasion from downstream (Pister 1991). The systematics of golden trout are complex, although two major subspecies thought to be most closely related to the rainbow trout–redbanded trout group are generally recognized: Little Kern River golden trout *O. m. gilberti* and the South Fork Kern River or California golden trout *O. m. aquabonita* (Behnke 1992). This paper describes work on the latter subspecies. The California Department of Fish and Game reestablished pure California golden trout in their native streams, and golden trout are currently self-sustaining; their habitat, however, is still in poor condition (Albert 1982; R.A. Knapp and K.R. Matthews, U.S. Forest Service, unpublished).

No ecological studies were conducted when golden trout habitat was pristine, so virtually nothing is known about the fish's ecology under those conditions. Grazing (first sheep and more recently cattle) has occurred for more than 100 years throughout most of the golden trout's range. In this study, I evaluated golden trout habitat associations in one of the golden trout's native streams within the Golden Trout Wilderness, Inyo National Forest, where habitat restoration efforts (cattle exclosures) are underway. This information is necessary for determining the fish's habitat requirements and assessing whether cattle exclosures are effective in restoring required habitat features. Currently, the only opportunity for comparative behavioral and ecological studies of golden trout is between stream segments within cattle exclosures (used as surrogates for restored or less degraded habitat) and adjacent grazed areas.

Using radio transmitters, I determined the diel habitat associations of golden trout in four sites inside and outside of cattle exclosures in Ramshaw Meadow, South Fork Kern River. The objectives of this study were to collect information on the diel movement and home ranges of golden trout, describe the most common habitats used by golden trout, and determine whether there were differences in diel movement and habitat use inside and outside exclosures.

Study Site

I conducted the study at Ramshaw Meadow (36°22'N, 118°15'W; elevation 2,667 m) on the unglaciated Kern Plateau in the Golden Trout Wilderness (GTW), Inyo National Forest (Figure 1). The South Fork Kern River flows through Ramshaw Meadow and is 27 km south of Mt. Whitney. Golden trout are native in this upper portion of the South Fork Kern River, where they were reestablished in 1983 after nonnative brown trout *Salmo trutta* and rainbow trout were removed.

Ramshaw Meadow is underlain by broad, sloping granitic alluvium. Adjacent to the meadows are lodgepole pine *Pinus murrayana* and foxtail pine *P. balfouriana*, and streamside vegetation is primarily willows (*Salix* spp.), sedge (*Carex* spp.), and sagebrush (*Artemisia* spp.). Presumably, the Kern Plateau (eastern Golden Trout Wilderness) was once a diverse high-elevation meadow ecosystem but is now degraded from past and current overgrazing and dominated by sagebrush (Odion et al. 1988).

Because of long, harsh winters at high elevations, meadows in the GTW are characterized by a short growing season from late May through September. Night air temperatures during this period typically fall below freezing. Late-summer snowstorms are not uncommon but did not occur during the radio-tracking study.

The South Fork Kern River is a relatively shallow, low-gradient stream; its bottom consists of unstable sand and occasional gravel and cobble. The stream is characterized by areas of incised channels, sparsely vegetated stream banks, active erosion sites, and the absence of instream cover. In nearby Mulkey Creek, which also has sparse vegetation and a widened stream channel, summer water temperatures may fluctuate 20°C daily (Stefferud 1993).

Cattle exclosures were established in the upper and lower sections of Ramshaw Meadow, each encompassing a portion of the South Fork Kern River. The upper exclosure was established in 1983 and is approximately 1.1 km long (Figure 1). Within this exclosure, some of the stream is recovering; stream variables measured in 1984, 1993, and 1994 chronicle a significant narrowing of the stream (mean widths: 345 cm in 1984, 271 cm in 1993, 230 cm in 1994; analysis of variance of log-transformed data, $P < 0.0001$; Knapp and Matthews, unpublished). In 1993, the stream was narrower (means, 271 versus 402 cm) and the water was deeper (means, 26 versus 22 cm) inside than outside the exclosure (Knapp and Matthews, unpublished). This rectangular structure encloses the stream and the adjacent 100 m of riparian zone on either side.

The lower exclosure, built in 1991, is approximately 2.4 km downstream and approximately 3.2 km long. It is a "drift exclosure"; instead of exclosing a rectangular portion of the stream, it defines upstream and downstream boundaries and is open at the sides. Because this exclosure is newer, less recovery has occurred (Knapp and Matthews, unpublished). For example, mean stream width is similar inside (316 cm) and outside (342 cm), and the mean depth inside and outside is 22 cm. Stream velocity averaged 30 cm/s during August–September of 1993 and did not differ among study sites.

Streamside vegetation also differs inside and outside the exclosures, with more willows inside both exclosures, presumably from replanting and lack of grazing (Knapp and Matthews, unpublished). Also, unvegetated sandbars were more abundant outside the exclosures during the summer of 1993 (A. Dennis, U.S. Forest Service, unpublished data).

Methods

Fish Tagging

I used radio tracking to determine each trout's position in the stream relative to time of day and habitat characteristics. Adult golden trout (>14 cm; 3–9 years old: Knapp and Dudley 1990) were captured by electrofishing and immediately anesthetized in tricaine methanesulfonate (26 mg/L). Once a fish was anesthetized, a transmitter was surgically implanted through an incision in the abdominal cavity just anterior to the pelvic girdle, and the incision was sutured (Supramid[1] HS 23). During surgery, fish were kept immobile on a padded V-shaped tray, and the gills were constantly bathed with anesthetic (6.5 mg/L) flowing from a battery-operated water pump. After surgery and before release, each trout was measured (total length) and allowed to recover for approximately 5 min in a water-filled cooler containing no anesthetic.

Each transmitter (Holohil, Canada) was 16 × 8 × 5 mm, weighed 1.0 g in air, and had an external, nylon-coated, stainless steel antenna. The 20-cm-long external antenna trailed from the closed incision. Golden trout are small fish and the smallest tags available were used. Because of the small tag, the life expectancy of the transmitter was 14–21 d and the study was restricted to less than 10 d. Golden trout were captured, tagged, and then re-

[1] Trade names and commercial enterprises are mentioned solely for information. No endorsement by the U.S. Forest Service is implied.

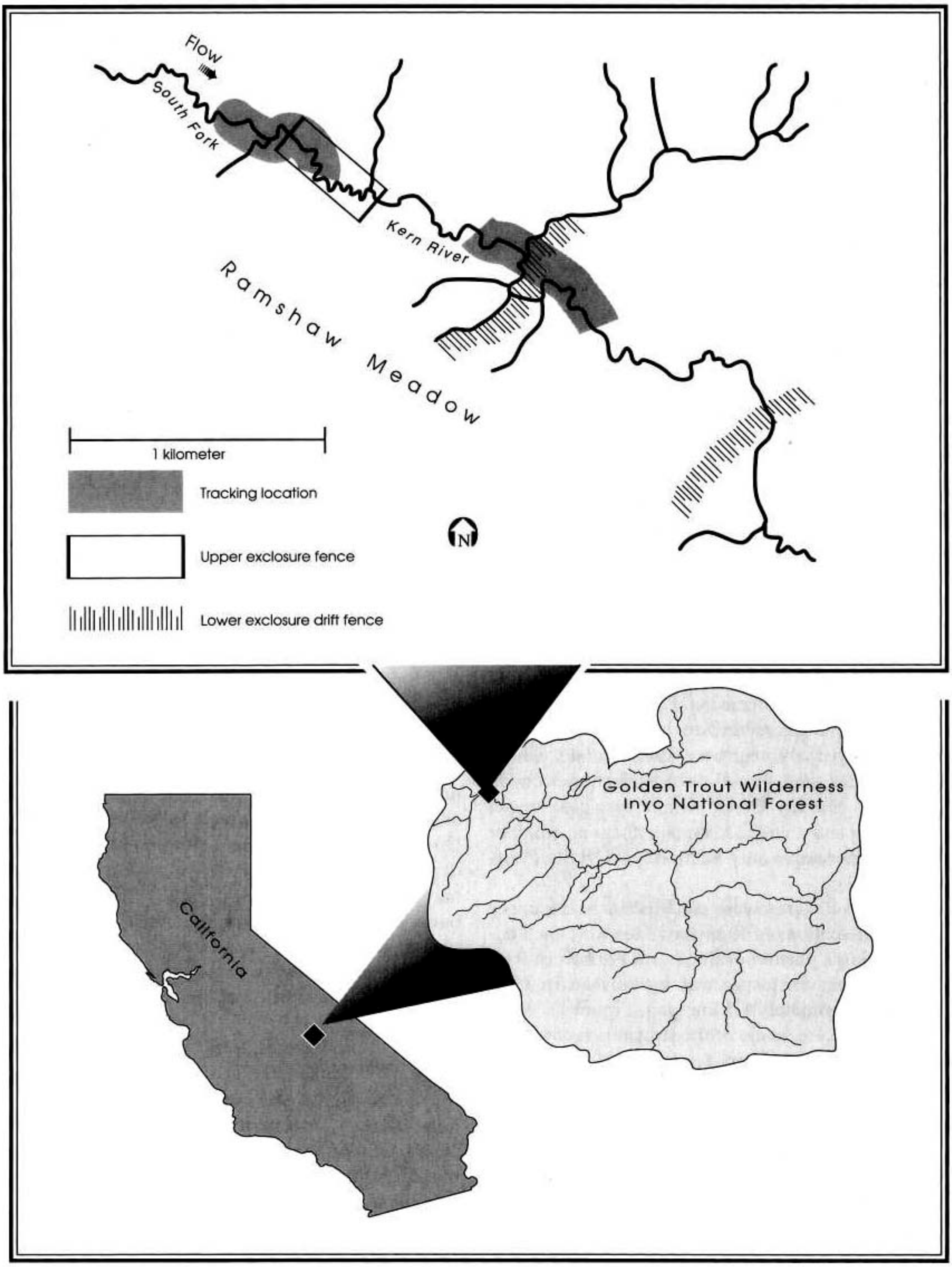

FIGURE 1.—Radio-tracking study sites inside and outside of upper and lower cattle exclosures at Ramshaw Meadow, South Fork Kern River, Golden Trout Wilderness, California.

TABLE 1.—Summary of golden trout tagged during September 1993, including fish number, length, total distance moved, and estimated home range size. Fish were tagged on 9 and 10 September 1993 at upper and lower Ramshaw Meadow, respectively.

Fish number	Length (cm)	Total distance moved (m)	Home range (m)
	Upper Ramshaw, inside exclosure		
1	16.0	101	41.9
2	15.0	<5	6.0
3	18.0	81	68.0
4	15.0	58	16.4
5	14.0	369	137.8
Mean		122	54.0
	Upper Ramshaw, outside exclosure		
6	21.0	456	87.1
7	16.0	301	53.2
8	17.0	187	20.0
9	16.0	270	231.6
10	15.0	<5	1.1
11	15.0	67	19.0
Mean		256	68.7
	Lower Ramshaw, inside exclosure		
12	17.0	124	6.2
13	16.5	<5	11.0
14	16.0	56	48.4
15	15.5	122	18.2
16	16.0	31	11.6
17	15.5	71	15.6
Mean		56	18.5
	Lower Ramshaw, outside exclosure		
18	18.0	299	42.6
19	17.0	608	106.2
20	16.0	394	22.4
21	15.0	<5	3.0
22	15.0	<5	2.0
23	15.0	167	44.0
Mean		244	36.7

leased at the capture site. Equal numbers of fish were tagged and released into each study site (six inside and six outside the lower exclosure, and six inside and six outside the upper exclosure) (Table 1). However, after release, one fish inside the upper exclosure died.

On 9 and 10 September 1993, 24 golden trout were implanted with transmitters, each with individually recognizable frequencies. To locate the tags, I used an ATS Challenger R4000 or AVM LA12-DSE receiver and a hand-held, three-element, collapsible Yagi antenna at the stream's edge. Tagged fish could be detected up to 100 m away. Locations were pinpointed through triangulation, and before data collection, fish trackers practiced locating transmitters. Transmitters were placed in known locations in the stream, and trackers verified their locations to within a 2-m^2 area, primarily because of the lack of streamside complexity (e.g., the absence of vegetation and boulders). I could sometimes see tagged fish out in the open and again verified position of transmitters to within a 2-m^2 area.

After the transmitters were deployed, the following data were recorded (approximately every hour) by teams assigned to upper Ramshaw and lower Ramshaw: (1) water temperature near each fish's location (with a handheld thermometer); (2) longitudinal fish location to the nearest meter (estimated from flagging placed at 25-m intervals on the bank); (3) time of observation; (4) macrohabitat type (pool, riffle, run, or glide); and (5) habitat features (all habitat features where golden trout were found were recorded; they included undercut banks, willows, bare banks, collapsed banks, open channel, aquatic vegetation, sedges, boulders, and rootwads) adjacent to fish location (within the 2-m^2 area). Trackers were also able to record precise locations and habitat associations of tagged fish at night because fish were often out in the open and away from the stream banks when it was dark.

On September 10, 1993, macrohabitat availability was measured in 500-m sections in the four study sites (inside and outside exclosures in upper and lower Ramshaw Meadow). Within each 500-m section, the length of stream containing each macrohabitat was measured, and the proportions (number of meters per 500 m) of pools, runs, riffles, and glides were determined.

Because of the 14–21-d life expectancy of the transmitters, I was unable to allow more than 2 d of recovery before collecting data. However, fish apparently recovered quickly from surgery and tagging, and I had no reason to believe that tagged fish behaved differently than untagged fish. I snorkeled the stream daily to observe the behavior of tagged fish (identified by their external antenna) and untagged fish and to determine the well-being of tagged fish that had not moved. My visual observations of tagged trout indicated no apparent adverse effects from the tag, and I observed fish swimming normally and feeding the same as untagged fish.

Each team was assigned a 12-h "day" (0800–2000 hours) or "night" (2000–0800 hours) shift. Upper Ramshaw fish were tagged on 9 September, and data were recorded during 0900–1900 hours on 11 September, 0800–2000 hours on 12–13 September, 2000–0800 hours on 14–15 September, 2000–0800 hours on 15–16 September, 0800–2000 hours on 16 September, 2000–0800 hours on 16–17, 17–18, and 18–19 September, and 1200–1600 hours on 18 September, for a total of 50 day and 60 night tracking hours. Lower Ramshaw fish were tagged on 10 September, and data were recorded during 1300–1900 hours on 11 September, 0800–2000 hours on 12 September, 0800–2000 hours on 13 September, 2000–0800 hours on 14–15 September, 0800–2000 hours on 15 September, 2000–0800 hours on 15–16, 16–17, 17–18, 18–19 September, and 1200–1600 hours on 18 September, for a total of 46 day and 60 night tracking hours. For lower and upper Ramshaw Meadow, 216 tracking hours were completed.

Water and Air Temperature

In addition to the water temperatures measured when fish were located, water temperatures were also measured at upper Ramshaw Meadow at the top, middle, bottom, and just downstream of the upper exclosure. In addition, air temperatures were taken at the bottom of the Ramshaw exclosure. At each location of water temperature collection, two Omnidata model ES-60 single temperature probes (accurate within ±0.25°C) were placed with the thermistors on the bottom of the stream. Temperature readings were taken every half hour during our study period, September 10–19, 1993. Here, I report the maximum and minimum stream temperatures during the study.

Data Analysis

Analyses and summaries were divided into three categories: habitat use, movement, and home range. Data for upper and lower Ramshaw were compared separately, except where noted. To test whether golden trout used the macrohabitats in different proportions than what was available, I used *t*-tests. I summarized the proportion of observations over the study period for individual fish within each macrohabitat type. Then I computed the mean proportion and standard error using the individual fish as the unit of replication. The means of macrohabitat observations were then compared to the known proportion of the measured macrohabitat within the four study sites. The null hypothesis tested was H_0: mean proportion of golden trout observation in habitat type = measured proportion of habitat type within 500 m (Zar 1974). Individual macrohabitat comparisons were performed only on pools and runs because of the low number of observations in riffles and glides. Mean numbers of observations averaged from individual golden trout in pools or runs were compared inside and outside the exclosure for both day and night.

Because I did not measure relative availability of the habitat features (sedges, boulders, etc.), I could not test whether they were used in significantly different proportions. Instead, I report the proportion of observations during which golden trout were associated with each habitat feature.

Fish movement.—Summaries and analyses of fish movement determined whether there were differences in home ranges or movement for different times or locations. Night was defined as the period with no solar radiation (1800–0800 hours, which included dawn [0600–0800 hours] and dusk [1800–2000 hours]), and day as the period in between (0800–1800 hours).

Distances moved between observations were classified as 0–5 m, 6–25 m, 26–100 m, and greater than 100 m for night and day periods. For the different diel periods, I tested the hypothesis that there was no difference in movement greater than 5 m (log-likelihood ratio for contingency tables, *G*-test, α = 0.05; Zar 1974). I treated only movement greater than 5 m as real because errors in distance estimation were common.

I also totaled the movements for individual fish over the study period. For this summary, the cumulative distances moved per individual fish were summed and averaged for inside and outside of the upper and lower exclosures. The means of the total distance moved over the study period were then compared (*t*-test, α = 0.05) to determine if the mean distance moved differed inside and outside the two exclosures.

To delineate home ranges, I used the "adaptive kernel" method (Silverman 1986; Worton 1989), depicting 90% of the location points recorded for individual fish. First, from the 24-h fish location data, a probabilistic density estimate (PDE) was made along the linear distance of the stream (Silverman 1986) such that each home range estimate represented the linear distance covered by the PDE's central 90%. Using the central 90% minimizes possible outliers resulting from the relatively short sampling period (8 d). Thus, each home range represents the linear distance (m) along the stream where 90% of the 24-h location data points were established for each fish. The home range estimates (m) were compared between fish inside and outside of the exclosures, testing the null hypothesis that there was no difference in home range distance inside and outside the exclosures.

Results

Macrohabitat Use

Runs constituted the largest proportion of macrohabitats inside and outside the exclosure in up-

TABLE 2.—Proportions of measured availability of golden trout macrohabitats from 500-m sections inside and outside exclosures at upper and lower Ramshaw Meadow and the mean proportion of day and night observations during which individual golden trout were found in those macrohabitats. An asterisk indicates a significant difference (t-test, $P < 0.05$) between the available proportion of macrohabitat and the mean proportion averaged over individual fish.

Habitat measure	Pools	Runs	Riffles	Glides
	Upper Ramshaw, inside exclosure			
Available	0.31	0.65	0.05	0
Day use	0.88*	0.11*	0.01	0
Night use	0.89*	0.11*	0	0
	Upper Ramshaw, outside exclosure			
Available	0.33	0.55	0.11	0
Day use	0.89*	0.11*	0*	0
Night use	0.76*	0.24*	0*	0
	Lower Ramshaw, inside exclosure			
Available	0.38	0.44	0.03	0.15
Day use	0.43	0.56	0	0
Night use	0.37	0.63	0	0
	Lower Ramshaw, outside exclosure			
Available	0.33	0.57	0.1	0
Day use	0.82*	0.18*	0*	0
Night use	0.63*	0.38	0*	0

per Ramshaw, but golden trout disproportionately used pools during both day and night (t-test, $P < 0.05$; Table 2). Similarly, runs formed most of the habitat in lower Ramshaw, but use of pools significantly exceeded proportional availability only outside the exclosure (t-test, $P < 0.05$; Table 2). Inside the exclosure, use of runs was greater than use of pools, but there were no significant differences in use and availability.

Use of Habitat Features

Throughout the study, golden trout were associated with nine habitat features (noted in Methods) which were used in different proportions throughout the tracking study. The most commonly used were sedge (38.5% of 2,857 observations) and undercut banks (30.3% of observations).

Upper Ramshaw pools.—During the day in upper Ramshaw pools (619 observations), sedges were the predominant habitat feature used by golden trout both inside and outside the exclosure (Table 3). Inside the exclosure, collapsed banks, aquatic vegetation, willows, and boulders (2% of observations) were the other habitats used. Outside the exclosure, aquatic vegetation, willows, and rootwads were the other habitat features used by golden trout (Table 3).

At night in pools (266 observations), sedge use inside the exclosure increased, and aquatic vegetation and collapsed bank use dropped (Table 3). During the night outside the exclosure, golden trout use of willows increased, and sedge use decreased.

Upper Ramshaw runs.—There were 97 observations of golden trout in runs at upper Ramshaw. Inside the exclosure during the day (29 observations), golden trout were most commonly found near undercut banks (Table 3). Sedges, open channel, and collapsed banks were the other commonly used habitat features. Outside the exclosure (25 observations), golden trout were most commonly

TABLE 3.—Summary of the proportion of all observations in pools and runs during which golden trout were associated with the listed habitat feature inside and outside exclosures in upper and lower Ramshaw Meadow. Bare banks and boulders, although monitored, were seldom used by the fish during observation periods.

	Day				Night			
	Pools		Runs		Pools		Runs	
Habitat feature	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
				Upper Ramshaw				
Sedges	0.58	0.39	0.19	0.0	0.80	0.29	0.46	0.21
Collapsed banks	0.15	0.02	0.07	0.19	0.10	0.02	0.0	0.12
Aquatic vegetation	0.15	0.26	0.0	0.81	0.06	0.14	0.0	0.15
Willows	0.07	0.17	0.0	0.0	0.02	0.35	0.0	0.06
Rootwads	0.0	0.10	0.0	0.0	0.0	0.04	0.0	0.0
Undercut banks	0.01	0.03	0.67	0.0	0.01	0.01	0.08	0.14
Open channel	0.0	0.0	0.07	0.0	0.0	0.0	0.46	0.39
				Lower Ramshaw				
Undercut banks	0.35	0.53	0.58	0.51	0.39	0.42	0.48	0.46
Sedges	0.31	0.25	0.41	0.49	0.28	0.26	0.52	0.53
Aquatic vegetation	0.16	0.06	0.0	0.0	0.28	0.15	0.0	0.0
Collapsed banks	0.16	0.16	0.0	0.0	0.14	0.16	0.0	0.0

TABLE 4.—Movements of golden trout in upper and lower Ramshaw Meadow. Data are separated into distance categories of 0–5, 6–25, 26–100, and >100 m, and into day (0800–1800 hours), and night (1800–0800 hours) observations.

Diel period	Number of observations for distance category (m): 0–5	6–25	26–100	>100	Total
	Upper Ramshaw				
Day	355	11	2	0	368
Night	414	29	12	0	455
	Lower Ramshaw				
Day	249	15	4	0	268
Night	455	31	7	2	495

associated with aquatic vegetation and collapsed banks.

At night in runs (43 observations), golden trout were commonly found in the open channel both inside and outside the exclosure (Table 3). Inside the exclosure, sedges and undercut banks were also used. Outside the exclosure, golden trout also used sedges, aquatic vegetation, collapsed banks, willows, and bare banks (6%).

Lower Ramshaw pools.—Inside the lower exclosure in pools (246 observations), golden trout primarily used four habitat features during the day: undercut banks, sedges, aquatic vegetation, and collapsed banks (Table 3). Outside the exclosure in pools (237 observations), the same habitat features were used but in different proportions. At night in pools (251 observations), undercut banks, sedges, aquatic vegetation, and collapsed banks were the predominant habitat features used by golden trout inside and outside the exclosure (Table 3).

Lower Ramshaw runs.—In both inside (304 observations) and outside (52 observations) the lower exclosure during the day, golden trout were predominately found near undercut banks and sedges (Table 3). Similarly, golden trout were found near sedges and undercut banks both inside and outside the exclosure at night (486 total observations).

Movement Patterns

In both upper and lower Ramshaw Meadow, most tagged golden trout exhibited little movement from one observation to the next (Table 4). Overall, most fish were within 5 m of the previous location during the day (95%) and night (91.4%). Cumulative distance moved per fish did not differ when the mean distance of fish from inside the exclosures was compared to that of fish outside the exclosures (t-test, $P > 0.05$; Table 1).

Some one-time, unidirectional distances (6–226 m) were detected (Table 4). At both upper and lower Ramshaw Meadow, there was no diel difference in the occurrence of these longer-distance movements (G-test, $P > 0.05$; Table 4).

The single longest distance movement was 226 m by fish 9 from outside the upper Ramshaw Meadow exclosure. It was tagged and released at 46 m above the exclosure on 11 September and was stationary until 13 September, when it was found 226 m farther upstream. The fish stayed in this vicinity until tracking was terminated on 19 September.

In contrast to most fish that remained within a narrowly defined location, two golden trout (18 and 19) in lower Ramshaw Meadow moved repeatedly and recurrently used two primary locations. Fish 18 moved 40 m back and forth between two locations; it was typically found at 92 m above the upper drift fence during the day and 132 m above it at night. At night, this fish was observed with aggregations of 20–30 other golden trout in the open channel.

Fish 19 was caught, tagged, and released above the upper drift fence on 10 September, and it was relocated on 11 September 32 m inside the exclosure. It used this as a primary area during the day and, like fish 18, it moved upstream at night—in this case 101 m upstream to an area 69 m above the fence.

Mean home ranges of golden trout (linear distance embracing 90% of locations) ranged from 18.5 to 68.7 m among the four study areas (Table 1). There were no differences (t-test, $P > 0.05$) between home ranges inside the exclosures (range, 6.0–137.8 m) and outside (range, 1.1–231.6 m).

Water and Air Temperatures

During the study period, water temperatures ranged from 2 to 16.5°C in Ramshaw Meadow and typically underwent a diel change of 10°C. Golden trout remained active during low temperatures. No differences in water temperature were detected between reaches inside and outside the upper exclosure (paired t-test, $P > 0.05$). Air temperature during the study ranged from −11.8 to 27.2°C.

Discussion

This is the first study of movements and habitat use by California golden trout in their native habitat. Daily movements and habitat associations of golden trout are critical to our understanding of their habitat requirements and the ongoing restoration efforts. Golden trout were most commonly found in pools near sedges and undercut banks, and these habitat features are typically reduced or lacking in grazed areas (Stuber 1985; Marcus et al. 1990; Platts 1991). Adult trout of other species prefer pools and undercut banks (Campbell and Neuner 1985; Bjornn and Reiser 1991), consistent with what I observed for adult golden trout. During the study, golden trout maintained small home ranges and usually moved little from one observation to the next. No differences in movement distances or home ranges were detected between golden trout inside and outside livestock exclosures.

During the night, golden trout were active and sometimes moved long distances. I also observed aggregations of 20–30 golden trout in the middle of the stream, where they seemed undisturbed by observer presence. Underwater camera and video equipment were placed within centimeters of trout, which did not swim for cover as they often did during the day. Golden trout may actively feed over the entire diel period during the late summer to optimize growth during the short high-elevation growing period. The diel movement behavior of rainbow trout is variable, some populations exhibiting nocturnal activity and others being relatively sedentary (Jenkins 1969; Jenkins et al. 1970; Bisson 1978; Campbell and Neuner 1985; Angradi and Griffith 1990; Matthews et al. 1994). It is unclear why trout are nocturnally active; they do not always exploit nocturnal increases in prey (Bisson 1978; Angradi and Griffith 1990). Nocturnal activity of salmonids may be related to water temperature, and water temperatures were as low as 2°C during this study. Fraser et al. (1993) reported that salmonids switch from diurnal foraging at warmer temperatures to nocturnal foraging as temperatures drop below 10°C. Little was known regarding the nocturnal activities of golden trout before this study, and it is still unknown whether the nocturnal activity I observed is typical or occurs over the entire year. A seasonal analysis of golden trout movement is needed.

Golden trout were found more often near sedges than near willows, even in areas of upper Ramshaw where willows were replanted and are now established inside the exclosure. As in many other restoration plans (Osborne and Kovacic 1993), willows were replanted in the Golden Trout Wilderness with the construction of the exclosures to stabilize stream banks (USFS 1988). It is unknown whether willows were a natural or an important part of the riparian areas on the Kern Plateau before degradation because there are no comparable ungrazed areas. However, sedges were a common habitat feature used by adult golden trout, and current work on the Kern Plateau suggests that sedges may also serve to stabilize the bank (R. Knapp, Sierra Nevada Aquatic Research Laboratory, personal communication). Future research plans include measuring the availability of habitat features to determine whether golden trout are seeking and selecting sedges or undercut banks in preference to other habitat features. In recovered areas inside the exclosure, dense sedge banks narrow the stream width and increase water depth (Knapp and Matthews, unpublished). Thus, for restoration, it is crucial to determine which native plant assemblage is needed to meet the critical habitat requirements of golden trout as well as to stabilize banks.

Acknowledgments

I thank Roland Knapp for introducing me to the incredible golden trout. Phil Pister deserves accolades for his extensive work on golden trout and for alerting the world to their plight. Sara Chubb, former Inyo National Forest Fish Biologist, and Del Hubbs, Range Conservationist, assisted in the logistics of research implementation on the Inyo National Forest. Ed Ballard, Dave Kammerer, Dave Azuma, and Thad Edens performed the grueling fieldwork and assisted with data analysis. Jim Baldwin, Pacific Southwest Station statistician, reviewed the manuscript and assisted in the statistical analysis. Michael K. Young, Peter Moyle, and an anonymous reviewer provided helpful and constructive reviews. The project was funded by the Fish Habitat Relationship Program of the U.S. Forest Service's Region 5 Fish Program. Dennis and Jody Winchester of Cottonwood Packers and their mules endured and moved mounds of equipment, making wilderness fieldwork possible.

References

Albert, C. P. 1982. A survey of factors influencing the condition of the stream zone in Golden Trout Wilderness. Master's thesis. Sonoma State University, Sonoma, California.

Angradi, T. R., and J. S. Griffith. 1990. Diel feeding chronology and diet selection of rainbow trout *Oncorhynchus mykiss* in the Henry's Fork of the Snake River, Idaho. Canadian Journal of Fisheries and Aquatic Sciences 47:199–209.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society Monograph 6.

Bisson, P. A. 1978. Diel food selection by two sizes of rainbow trout (*Salmo gairdneri*) in an experimental stream. Journal of the Fisheries Research Board of Canada 35:971–975.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83–138.

Campbell, R. F., and J. H. Neuner. 1985. Seasonal and diurnal shifts in habitat utilized by resident rainbow trout (*Salmo gairdneri*) observed in western Washington Cascade mountain streams. Pages 39–48 *in* F. W. Olson, R. G. White, and R. H. Hamre, editors. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Western Division and Bioengineering Section, Bethesda, Maryland.

Everman, B. W. 1906. The golden trout of the southern High Sierras. U.S. Bureau of Fisheries Bulletin 25: 1–51.

Fisk, L. 1983. Golden trout of the High Sierra. California Department of Fish and Game, Sacramento.

Fraser, N. H., N. B. Metcalfe, and J. E. Thorpe. 1993. Temperature-dependent switch between diurnal and nocturnal foraging in salmon. Proceedings of the Royal Society of London 252:135–139.

Jenkins, T. M., Jr. 1969. Night feeding of brown and rainbow trout in an experimental stream channel. Journal of the Fisheries Research Board of Canada 26:3275–3278.

Jenkins, T. M., Jr., C. R. Feldmeth, and G. V. Elliot. 1970. Feeding of rainbow trout (*Salmo gairdneri*) in relation to abundance of drifting invertebrates in a mountain stream. Journal of the Fisheries Research Board of Canada 27:2356–2361.

Knapp, R. A., and T. L. Dudley. 1990. Growth and longevity of golden trout, *Oncorhynchus aquabonita*, in their native streams. California Fish and Game 76:161–173.

Marcus, M. D., M. K. Young, L. E. Noel, and B. A. Mullan. 1990. Salmonid-habitat relationships in the western United States: a review and indexed bibliography. U.S. Forest Service General Technical Report RM-188.

Matthews, K. R., N. H. Berg, D. L. Azuma, and T. R. Lambert. 1994. Cool water formation and trout habitat use in a deep pool in the Sierra Nevada, California. Transactions of the American Fisheries Society 123:549–564.

Odion, D. C., T. L. Dudley, and C. M. D'Antonio. 1988. Cattle grazing in southeastern Sierran meadows: ecosystem change and prospects for recovery. Pages 277–292 *in* C. A. Hall and V. Doyle-Jones, editors. Plant biology of eastern California, Mary DeDecker Symposium. University of California, White Mountain Research Station, Los Angeles.

Osborne, L. L., and D. A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. Freshwater Biology 29:243–258.

Pister, E. P. 1991. Golden trout. Pages 280–285 *in* J. Stolz and J. Schnell, editors. Trout. Stackpole, Harrisburg, Pennsylvania.

Platts, W. S. 1991. Livestock grazing. American Fisheries Society Special Publication 19:389–423.

Silverman, B. W. 1986. Density estimation for statistics and data analysis. Chapman and Hall, London, England.

Stefferud, J. A. 1993. Spawning season and microhabitat use by California golden trout (*Oncorhynchus mykiss aquabonita*) in the southern Sierra Nevada. California Fish and Game 79:133–144.

Stuber, R. J. 1985. Trout habitat, abundance, and fish opportunities in fenced vs unfenced riparian habitat along Sheep Creek, Colorado. U.S. Forest Service General Technical Report RM-120:310–314.

USFS (U.S. Forest Service). 1988. Inyo National Forest Land and Resource Management Plan. Inyo National Forest, Bishop, California.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey.

Received June 6, 1994
Accepted June 27, 1995