California Fish and Game 98(1):38-46; 2012

Growing up fast in a small creek: diet and growth of a population of *Oncorhynchus mykiss* in Topanga Creek, California

Jenna M. Krug*, Ethan Bell, and Rosi Dagit

Resource Conservation District of the Santa Monica Mountains, P.O. Box 638, Agoura Hills, California, 91376-0638, USA (JMK, RD)

Stillwater Sciences, 850 G Street, Arcata, California, 95521, USA (EB)

**Correspondent: jkrug@rcdsmm.org*

Key words: diet, growth, *Oncorhynchus mykiss*, rainbow trout, southern California coastal creek, steelhead, Topanga Creek

---

Despite the endangered status of steelhead (*Oncorhynchus mykiss*) in southern California since 1997, few studies have reported on their life history and population dynamics (Tobias 2006, Spina 2007, Bell et al. 2011a, Bell et al. 2011b). As summarized by Boughton et al. (2006) and Boughton et al. (2009), *O. mykiss* is a highly plastic species in terms of phenotypic and life-history variability, and capable of exploiting a wide variety of habitats. A thorough understanding of the mechanisms that allow for the survival and persistence of *O. mykiss* in the southern portion of its geographical range, where highly variable flow regimes, high water temperatures, and frequent isolation from the Pacific Ocean are the norm, is important to better guide management practices and to protect and recover these populations (NMFS 2011).

During nearly a decade of monitoring *O. mykiss* in Topanga Creek, Los Angeles County, California, we have documented the persistence of a population that, despite high summer water temperatures and poor habitat conditions in the lagoon, is characterized by numerous fast growing and large individuals (Bell et al. 2011b). In addition, Bell et al. (2011a) reported that *O. mykiss* smolts in Topanga Creek were of sufficient sizes to expect high rates of marine survival. Understanding the quality and quantity of food available to, and consumed by, *O. mykiss* could help explain the mechanism behind fast growth and survival in the conditions of southern California coastal streams. The goals of this study were to characterize the quantity and diversity of food consumed by *O. mykiss* in Topanga Creek in fall and spring, and to investigate variations in their growth rates and diet between seasons.

Topanga Creek (34° 6' 11" N, 118° 36' 18" W) is a small coastal stream draining a watershed of approximately 47 km^2. The study area stretches from river kilometer (rkm) 1.7 upstream to rkm 6 (Figure 1). Due to the intermittent flow regime and generally low number of *O. mykiss* observed in this area, we excluded the reach from the ocean to rkm 1.7 from the study. Tobias (2006), Dagit et al. (2007), and Dagit and Krug (2011) have provided detailed descriptions of the instream habitat composition, water quality, and vegetation and riparian habitat associated with the creek. During the study period, water year rainfall totals in Topanga ranged from 38.5 cm in 2009 to 80 cm in 2011. Stream temperatures typically range from 9°C to 25°C and average 17°C, however temperatures over 25°C are not uncommon during the summer months (see Dagit and Krug 2011).

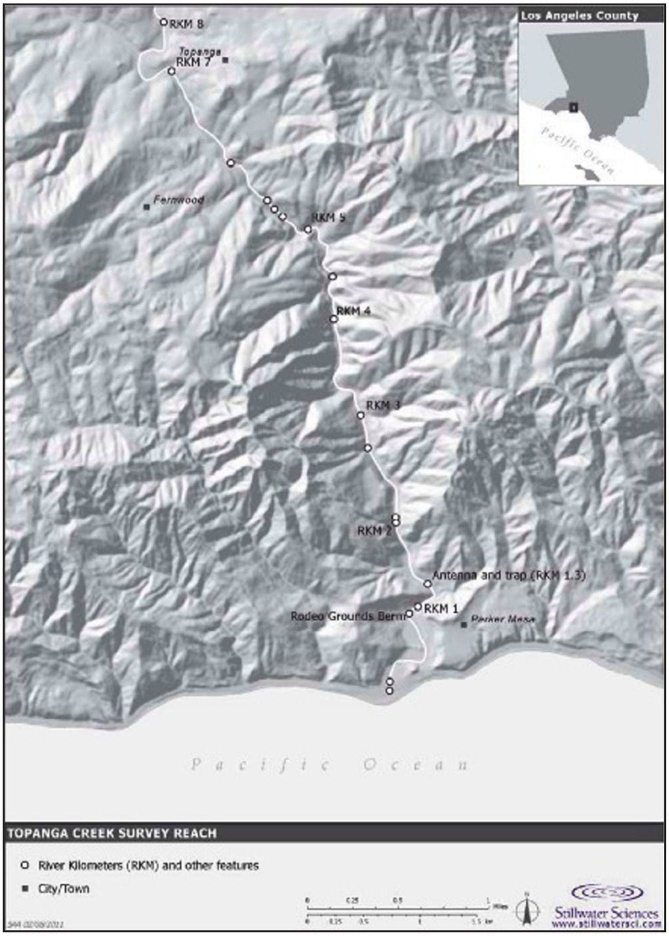

Figure 1.— Location of the study area in Topanga Creek, Los Angeles County, California, 2008-2011.

Oncorhynchus mykiss has the potential for two life history forms, anadromous (steelhead) and resident (rainbow trout). Topanga Creek contains both life history forms and belongs to the federally endangered Southern California Steelhead Distinct Population Segment. Although the two forms are indistinguishable in Topanga Creek, preservation of both life histories is a high priority (NMFS 2011); therefore, information on both forms is of interest to us and, here, we will use *O. mykiss* when referring to either form in our study system. Dagit and Krug (2011) reported detailed information on the spatial and temporal distribution, abundance, and size structure of *O. mykiss* in Topanga Creek based on monthly snorkel survey observations. In addition to *O. mykiss*, the Arroyo chub (*Gila orcutti*) is the only other fish present in our study area, and is often sympatric with *O. mykiss* in southern California streams (Swift et al. 1993). The red swamp crayfish (*Procambarus clarkii*) is the only exotic species, macroinvertebrate or otherwise, to inhabit the creek.

Oncorhynchus mykiss were captured using electrofishing methods over four consecutive days in November of 2008 (*n*=76) and 2010 (*n*=208), three consecutive days in November of 2009 (*n*=71) and 2011 (*n*=136), and two consecutive days in March 2011 (*n*=82). Eighteen individuals were also captured using downstream migrant trapping during storm events in January 2010 (*n*=8) and in February and March of 2011 (*n*=10). Of the 591 total fish captured throughout the study period, 62 (10.5%) were recaptured at least once, and five individuals were recaptured twice. Individuals were recaptured in November of 2009 (*n*=1), 2010 (*n*=11), and 2011 (*n*=37), and in March 2011 (*n*=18).

All captured fish were anesthetized using tricaine methanesulfonate (MS222), and fork length (FL) was measured to the nearest millimeter. *Oncorhynchus mykiss* >110 mm FL were given a passive integrated transponder (PIT) tag, which could subsequently be used to identify recaptures. Scales and fin clips were taken from individuals as well, and results from analyses of these are discussed by Bell et al. (2011a, b). To assess the diet of *O. mykiss*, stomach contents were collected from individuals ranging in size (FL) from 134 mm to 368 mm in November 2010 (fall; *n*=43) and from 150 mm to 239 mm in March 2011 (spring; *n*=13) using the gastric lavage methods described by Giles (1980), which have been shown to have an efficiency of 99.1%. Of those lavaged, 4 were recaptures in November and 2 in March.

Daily growth rate (mm/day) was calculated for each recaptured individual as the change in FL between captures divided by the number of days between captures. For those individuals recaptured twice, daily growth rates were calculated for each individual between the first and second capture as well as for between the second and third capture. Daily growth rates were plotted against initial sizes (mm; FL) in order to obtain a general assessment of the relationship between size and growth. We did not calculate a statistical relationship between initial size and growth rate because of the many different time periods for which growth rates were measured. To assess annual differences in growth rates, mean (±*SD*) daily growth rates were calculated for *O. mykiss* in 2010 (captured in November 2009 and recaptured in November 2010 [*n*=11]), and in 2011 (*O. mykiss* captured in November 2010 and recaptured in November 2011 [*n*=18]). To investigate seasonal differences, mean (±*SD*) daily growth rates were calculated for *O. mykiss* captured in November 2010 and recaptured in March 2011 (winter; *n*=16) and for *O. mykiss* captured in March 2011 and recaptured in November 2011 (spring-summer-fall; *n*=15). Time elapsed between initial mark and first recapture, for all fish that were recaptured at least once during the study, ranged from 116 to 1,090 days. The initial size of fish recaptured at least once ranged from 110 to 250 mm FL. Statistical analyses were not applied to the data due to the low number of samples for each time period; rather, general patterns in seasonal growth were assessed.

Prey items from each lavage sample were sorted, identified, and counted. The percent frequency occurrence (% FO) was calculated for each prey item in order to determine which prey items were being consumed by most *O. mykiss* in fall and spring. Percent FO characterizes the food habits of a population (Cailliet 1977), ranges from zero to 100, and is calculated as the number of stomach samples containing prey item *x* divided by the total number of stomach samples containing food. The % FO of the various prey items was compared between fall and spring samples. We also assessed differences in the types of prey being consumed by *O. mykiss* in fall and spring by calculating the mean percent of each prey type in a sample, which was calculated as the number of individuals from category *x* in sample *n* divided by the total number of prey items in sample *n* and averaged for each season. Prey items were placed into one of three categories: (1) aquatic insects; (2) terrestrial insects; or (3) fish, crayfish, or snails. Differences among the stomach content samples from fall and spring in the number and types of prey items and types of prey observed were assessed; however, statistical analyses were not conducted because of the low and inconsistent sample sizes between sampling periods.

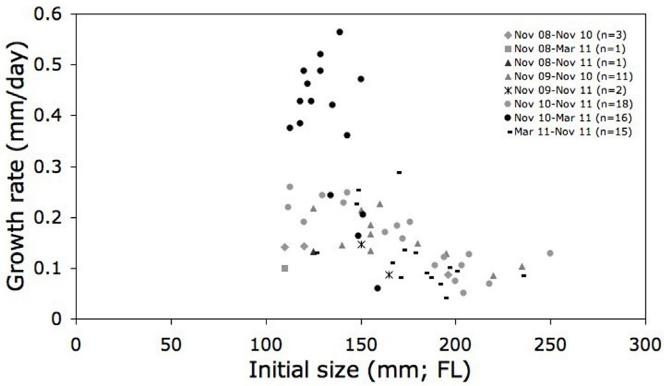

Figure 2.— Initial size (mm; FL) and growth rate (mm/day) between recaptures of pit tagged *Oncorhynchus mykiss* (*n*=67) in Topanga Creek, Los Angeles County, California, 2008-2011.

In general, smaller fish grew at higher rates than larger fish (Figure 2). Daily growth rates ranged from 0.04 to 0.56 mm/day, with a mean (±*SD*) of 0.21±0.13 mm/day. Annual growth rates were similar in 2010 and 2011 (0.16±0.03 mm/day and 0.16±0.07 mm/day, respectively). Mean daily growth rates of the winter group was nearly triple that for the spring-summer-fall group, despite the longer period of time for which growth was measured for the latter group (0.38±0.14 mm/day and 0.13±0.07 mm/day, respectively).

It appeared that dipterans, trichopterans, ephemeropterans (specifically baetids), and hymenopterans were important food sources in both November 2010 and March 2011, as those were the most frequently occurring prey items during those times (Table 1). Adult dipterans were the primary food source in the fall, whereas larval dipterans were the primary food source in the spring. In November, 4.7% and 9.3% of the samples contained Arroyo chub and crayfish, respectively, neither of which was observed in March samples. Algal and plant debris was observed in 60.5% of stomach samples from November compared to <8% of March samples, which corresponds to observed seasonal patterns of benthic algal cover (Dagit and Krug 2011). Although individual prey items in the stomach contents of *O. mykiss* in Topanga Creek were similar between seasons, in general, *O. mykiss* were consuming primarily aquatic insects in March and a more general array of aquatic insects, other invertebrates, and fish in November (Figure 3). March samples contained more than double the number of prey items than those in November (30.7±92.5 and 86.9±62.5, respectively).

The patterns in growth rates observed for *O. mykiss* in Topanga Creek were similar to observations in other coastal California streams. For instance, Hayes et al. (2008) reported that specific growth rates of *O. mykiss* in the upstream habitat of a small central California

Table 1.—Percent frequency occurrence of various prey items in stomach contents of *Oncorhynchus mykiss* in Topanga Creek, California in November 2010 (n=43) and March 2011 (n=13).

	% Frequency Occurrence	
Prey Item	November 2010	March 2011
Aquatic Insects		
Diptera		
Larvae	14	92.3
Pupae	7	7.7
Trichoptera		
Larvae	48.8	69.2
Pupae	2.3	30.8
Ephemeroptera		
Baetidae: subimago	9.3	61.5
Baetidae: nymphs	11.6	69.2
Other	18.6	30.8
Odonata		
Nymphs	11.6	15.4
Larvae	0	7.7
Plecoptera	0	15.4
Coleoptera	34.9	61.5
Hemiptera	25.6	53.8
Terrestrial Insects		
Diptera		
Adult	53.5	53.8
Hymenoptera	34.9	69.2
Lepidoptera	14	38.5
Araneae	23.3	23.1
Fish: Arroyo chub	4.7	0
Crayfish	9.3	0
Snails	34.9	23.1
Amphipoda	23.3	15.4

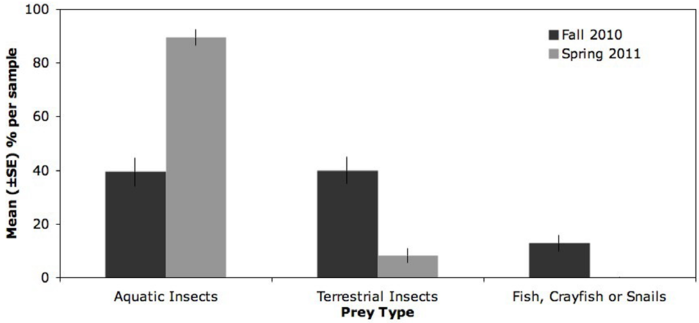

Figure 3.— Mean (±*SE*) percent composition of aquatic, terrestrial, and fish, crayfish, or snails found in *Oncorhynchus mykiss* stomach samples collected from Topanga Creek, Los Angeles County, California in Fall 2010 and Spring 2011.

creek were, on average, higher in winter and spring than in summer and fall. In the lower Mokelumne River, California, Merz (2002) reported growth rates of *O. mykiss* ranged from 0.04 to 0.92 mm/day, and averaged 0.32 mm/day. Overall, growth rates observed in this study were lower than those observed by Merz (2002); however, this could be due to the fact that he observed growth of fish of smaller initial sizes than we did and, similar to our study, he reported that smaller fish tended to grow faster than larger fish. Sogard et al. (2009) reported average growth rates of *O. mykiss* in a small northern California creek to rarely exceed 0.30 mm/day, and also reported highest growth occurred during winter-spring.

In addition, we found that *O. mykiss* in Topanga Creek appeared to be feeding on similar items and at similar times as those in central California creeks. For instance, Rundio and Lindley (2008) reported that terrestrial invertebrates were an important prey source for *O. mykiss* in a Big Sur coastal creek, and that their importance was related both to the relative abundance of aquatic prey and water temperature. Merz (2002) reported that in a central California creek, adult insects were most important in the diets of *O. mykiss* in summer and fall, whereas aquatic insect larvae were most important in spring and winter.

In general, we found that *O. mykiss* in Topanga Creek showed evidence of heightened growth rates during the winter compared to the spring-summer-fall period of the study, suggesting that conditions in the creek, whether it was food availability, reduced thermal stress, or some other factor, were likely conducive to higher growth rates during the cool, wet winter and early spring than the remainder of the year. Our results are consistent with other research that has suggested that growth rates of *O. mykiss* are typically higher in the productive and hydrologically flashy systems in central and southern California when compared to more northerly streams (Satterthwaite et al. 2009). The energetic challenge of overcoming thermal stress during late summer and fall in our study area is further exacerbated by coincidentally low streamflows, which have been shown to reduce input of invertebrate drift and, subsequently, decrease growth (Harvey et al. 2006). Spina (2007), however, reported that southern California *O. mykiss* were able to successfully continue foraging when water temperatures were between 17.4°C–24.5°C. Growth of *O. mykiss* in Topanga Creek appears to be supported by relatively high food consumption or by their ability to generalize their diet, especially during summer and fall when water temperatures are high (>24.5°C).

We observed that *O. mykiss* were feeding at much higher rates (more items/stomach) in March, and were feeding predominantly on an apparently reliable source of aquatic macroinvertebrates that, despite their small size, are relatively nutritious (see Cummins and Wuycheck 1971, Ciancio and Pascual 2006, Johnson et al. 2006). In contrast, during November, fish were feeding at much lower rates and were feeding opportunistically on a wider variety of prey, including non-native crayfish, snails, and Arroyo chub. Snails and crayfish have relatively much lower caloric values than the aquatic macroinvertebrates being consumed in March (Cummins and Wuycheck 1971, Ciancio and Pascual 2006). Fish, however, are a generally and relatively highly nutritious food source (Cummins and Wuycheck 1971, Ciancio and Pascual 2006). Once stream-dwelling salmonids reach large sizes (>250 mm) they must be predominantly piscivorous to grow larger (Keeley and Grant 2001). Although predation on Arroyo chub by *O. mykiss* has not been previously documented, chub appear to be an important food source for *O. mykiss* in Topanga Creek, especially during times when abundance of aquatic macroinvertebrates is limited.

Arroyo chub may also be competing with *O. mykiss* in Topanga Creek for food resources. Chub are opportunistic feeders, and have a benthic diet that shifts between mostly filamentous algae and mollusks, and occasionally drifting invertebrates, depending on food availability (Greenfield and Deckert 1973, Richards and Soltz 1986). Richards and Soltz (1986) observed little dietary overlap or competition between juvenile steelhead and Arroyo chub during most seasons, which they attributed to steelhead being primarily drift feeders, while chub were focused on benthic items. However, there were some periods when invertebrate drift rates were high and diet overlap between juvenile steelhead and Arroyo chub was increased. Consequently, when invertebrate drift rates are high in Topanga Creek, diet overlap and potential competition between juvenile steelhead and chub may be strong. Additional data are warranted to assess whether these two species are competing for food, space, or both.

Lastly, snorkel survey observations indicated that *O. mykiss* >120 mm FL generally were concentrated in pools that contained a relatively deep plunge section and bubble curtain below a cascade, which has been shown to be an area associated with higher prey availability and more successful drift feeding for salmonids (Furukawa-Tanaka 1992), whereas smaller *O. mykiss* were typically found in shallower riffles and runs (see Dagit and Krug 2011). It is possible that *O. mykiss* in Topanga Creek position themselves in such a way to optimize their feeding potential, but further studies are necessary to assess this potential.

This study has contributed information, which was previously limited, on the seasonal growth and diet of *O. mykiss* in a southern California coastal creek. Further work is needed in order to more precisely determine variations in seasonal growth and diet of *O. mykiss* in this system, and to further assess the mechanism supporting their ability to grow and survive in the southern portion of their range, a place where high summer temperatures, low streamflows, and anthropogenic impacts provide relatively challenging conditions for those salmonids.

Acknowledgments

This project was funded by grants from California Department of Fish and Game (CDFG; Contract No. P0850021 and P0950013). Special thanks to M. Larson, D. McCanne, C. Lima, D. Baldwin, and T. Hovey (CDFG), G. Cailliet, J. Bizzarro, and S. Brown for their expert guidance in analysis of fish feeding habits, C. Swift for his continued contributions to our research efforts, the Steele Lab at California State University, Northridge for use of lab space, microscopes and analytical scales, and the administrative and office staff at the Resource Conservation District of the Santa Monica Mountains for logistical support. Field and lab work could not have been completed without extensive assistance from C. Driscoll, B. DeWitt, S. Garcia, R. Beard, G. Warner, the California Science Center, P. Cassells, NMFS, and Topanga Creek Stream team members and volunteers including H. Block, D. Lathers, J. Shuman and S. Williams.

Literature Cited

Bell, E., S. M. Albers, J. M. Krug, and R. Dagit. 2011a. Juvenile growth in a population of southern California steelhead (*Oncorhynchus mykiss*). California Fish and Game 97:25-35.

Bell, E., R. Dagit, and F. Ligon. 2011b. Colonization and persistence of a southern California steelhead (*Oncorhynchus mykiss*) population. Bulletin of the Southern California Academy of Sciences 110:1-16.

BOUGHTON, D. A., P. B. ADAMS, E. ANDERSON, C. FUSARO, E. KELLER, E. KELLEY, L. LENTSCH, J. NIELSEN, K. PERRY, H. REGAN, J. SMITH, C. SWIFT, L. THOMPSON, AND F. WATSON. 2006. Steelhead of the south-central/southern California coast: population characterization for recovery planning. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-394.

BOUGHTON, D. A., H. FISH, J. POPE, AND G. HOLT. 2009. Spatial patterning of habitat for *Oncorhynchus mykiss* in a system of intermittent and perennial streams. Ecology of Freshwater Fish 18:92-105.

CAILLIET, G. 1977. Several approaches to the feeding ecology of fishes. Pages 1-13 *in* C. A. Simenstad and S. J. Lipovsky, editors. Fish food habits studies: proceedings of the 1st Pacific Northwest technical workshop. Washington Sea Grant Program, University of Washington, Seattle, USA..

CIANCIO, J., AND M. PASCUAL. 2006. Energy density of freshwater Patagonian organisms Ecologia Austral 16:91-94.

CUMMINS, K. W., AND J. C. WUYCHECK. 1971. Caloric equivalents for investigations in ecological energetics. Mitteilungen Int Vereinigung fur Theoretische Angewandte Limnol 18:1-158.

DAGIT, R., AND J. M. KRUG. 2011. Santa Monica Bay steelhead monitoring report. Final report prepared for California Department of Fish and Game under Contract No. P0850021. Resource Conservation District of the Santa Monica Mountains, Agoura Hills, California, USA.

DAGIT, R., K. REAGAN AND V. TOBIAS. 2007. Topanga Creek southern steelhead habitat suitability and monitoring summary. Final report. Prepared for California Department of Fish and Game under Contract No. P0450011. Resource Conservation District of the Santa Monica Mountains, Agoura Hills, California, USA.

FURUKAWA-TANAKA, T. 1992. Optimal feeding position for stream fishes in relation to invertebrate drift. Humans and Nature 1:63-81.

GILES, N. 1980. A stomach sampler for use on live fish. Journal of Fish Biology 16:441-444.

GREENFIELD, D. W., AND G. D. DECKERT. 1973. Introgressive hybridization between *Gila orcutti* and *Hesperoleucus symmetricus* (Pisces: Cyprinidae) in the Cuyama River Basin, California: II. Ecological aspects. Copeia 1973:417-427.

HARVEY, B. C., R. J. NAKAMOTO, AND J. L. WHITE. 2006. Reduced streamflow lowers dry season growth of rainbow trout in a small stream. Transactions of the American Fisheries Society 135:998-1005.

HAYES, S. A., M. H. BOND, C. V. HANSON, AND E. V. FREUND. 2008. Steelhead growth in a small central California watershed: upstream and estuarine rearing patterns. Transactions of the American Fisheries Society 137:114-128.

JOHNSON, R. L., S. C. BLUMENSHINE, AND S. M. COGHLAN. 2006. A bioenergetic analysis of factors limiting brown trout growth in an Ozark tailwater river. Environmental Biology of Fishes 77:121-132.

KEELEY, E. R., AND J. W. A. GRANT. 2001. Prey size of salmonid fishes in streams, lakes, and oceans. Canadian Journal of Fisheries and Aquatic Sciences 58:1122-1132.

MERZ, J. E. 2002. Seasonal feeding habits, growth, and movement of steelhead trout in the lower Mokelumne River, California. California Fish and Game 88:95-111.

NMFS (NATIONAL MARINE FISHERIES SERVICE). 2011. Southern California steelhead recovery plan. Southwest Regional Office, Protected Resources Division, National Marine Fisheries Service, Long Beach, California, USA.

Richards, C., and D. L. Soltz. 1986. Feeding of rainbow trout (*Salmo gairdneri*) and Arroyo chubs (*Gila orcutti*) in a California mountain stream. The Southwestern Naturalist 31:250-253.

Rundio, D. E. and S. T. Lindley. 2008. Seasonal patterns of terrestrial and aquatic prey abundance and use by *Oncorhynchus mykiss* in a California coastal basin with a Mediterranean climate. Transactions of the American Fisheries Society 137:467-480.

Satterthwaite, W. H., M. P. Beakes, E. M. Colins, D. R. Swank, J. E. Merz, R. G. Titus, S. M. Sogard, and M. Mangel. 2009. Steelhead life history on California's central coast: insights from a state-dependent model. Transactions of the American Fisheries Society 138:532-548.

Sogard, S. M., T. H. Williams, and H. Fish. 2009. Seasonal patterns of abundance, growth, and site fidelity of juvenile steelhead in a small coastal California stream. Transactions of the American Fisheries Society 138:549-563.

Spina, A. P. 2007. Thermal ecology of juvenile steelhead in a warm-water environment. Environmental Biology of Fishes 80:23-34.

Swift, C. C., T. R. Haglund, M. Ruiz, and R. N. Fisher. 1993. The status and distribution of the freshwater fishes of southern California. Bulletin of the Southern California Academy of Sciences 92:101-167.

Tobias, V. 2006. Groundwater sources and their influence on the distribution of steelhead in Topanga Creek, Topanga, California. M.Sc. thesis, University of Michigan, Ann Arbor, USA.

Submitted 21 February 2012
Accepted 28 March 2012
Associate Editor was K. Shaffer