necessary for the wise stewardship of our natural resources and wildlands. We welcome our new partners and pledge our full support to both the new and old agencies. The papers presented here—and past research efforts in national parks—provide an important stepping stone to the future. While many of us will be transferred administratively to the National Biological Survey, our emotional ties to the National Park Service mission of preserving resources for future generations will remain with us forever.

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Status of Summer Steelhead Trout in Redwood Creek, Redwood National Park, California

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Abstract. Summer steelhead (*Oncorhynchus mykiss*), a declining stock of rainbow trout in Redwood National Park, have been monitored in Redwood Creek by snorkelers since the summer of 1981. The adult fish migrate upriver in spring, hold in pools during summer, and spawn during winter. Large and numerous pools have been filled in as a result of record floods and land-use activities. The resultant high water temperatures ($\leq 25°$ C) and lack of pool habitat and cover have restricted the distribution of summer steelhead in Redwood Creek. Schools of fish are rare and observed only in pools adjacent to tributaries where cooler water enters Redwood Creek. A 25.9-km reach of the creek's best habitat was used to index trends in the population. Numbers of fish observed peaked at 44 in 1984–85 but have since declined. Summer steelhead face several problems: habitat degradation, poor water quality, sport-fishing and poaching, and small population size. The prospect for recovery of the summer steelhead of Redwood Creek is poor and long-term.

Key words: Habitat, *Oncorhynchus mykiss*, summer steelhead, stock decline, Redwood Creek, water temperature.

Summer steelhead (*Oncorhynchus mykiss*) are an anadromous race of rainbow trout. Their life cycle differs from that of the more numerous winter-run steelhead. Adult summer steelhead ascend the rivers in spring, hold over in deep pools in summer, then spawn during winter. This cycle isolates them both spatially and temporally from winter-run fish. Because adult summer steelhead hold in freshwater for 8–10 months (Roelofs 1983), they are vulnerable to detrimental environmental and human-caused factors including high water temperatures, low summer flows, and poaching.

Redwood National Park personnel have been monitoring the status of adult summer steelhead in Redwood Creek since 1981. To ascertain that the fish we observed were summer-run fish, two females were sacrificed in 1986. Their gonads were in an immature state of development, and they had a low gonad to body weight ratio indicative of summer steelhead.

Approximately 25 summer steelhead populations are known in California. In 1990, almost 1,900 adults were counted; over half were observed in two rivers (E. Gerstung, California Department of Fish and Game, personal communication). Most rivers had less than 100 adults. The species, though not federally or state listed as threatened or endangered, is classified as a sensitive species by the U.S. Forest Service and as a species of special concern by the California Department of Fish and Game. Roelofs (1983) and, most recently, the summer steelhead management advisory committee (under the auspices of the California Department of Fish and Game) have documented the status of summer steelhead populations in California.

Study Area

The 108-km-long Redwood Creek drains a 730-km^2 watershed in Humboldt County, California (Fig. 1). The basin is steep-sided and narrow with a total basin relief of 1,616 m. The climate is Mediterranean, with an estimated average precipitation of 203 cm per year (Janda et al. 1975). Mainstem stream flow is lowest between August and October. Vegetation in the basin consists of coast redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*) forests, their associated flora, and ridge-top prairies (Janda et al. 1975). Commercial timber harvest is one of the major land use practices in the basin. By 1978, 66% of the basin drainage, composing 81% of the original conifer forests, had been logged (Best 1984). Logging no longer occurs in the lower one-third of the watershed, site of Redwood National Park. The park was established in 1968, and its boundaries were expanded in 1978 to protect park resources.

Methods

A 25.9-km reach (Fig. 1), 24% of Redwood Creek, is surveyed by snorkelers during summer, usually around the first week of August, to index the population. This reach includes a majority of the deep pool habitat in Redwood Creek. Expanded surveys showed that almost all summer steelhead were within the reach during the period of observation. Of the 25.9 km, 16.1 km is in Redwood National Park, and 9.8 km is upstream of the park on private property commercially harvested for timber. The reach was divided into smaller sections and surveyed in 3–4 days. Following procedures of Roelofs (1983), crews of three–five people dove in the creek using mask and snorkel to count adult summer steelhead trout. While proceeding downstream, the swimmers looked under ledges, root wads, and other large organic debris; at the base of boulders; and in the bubble curtains of turbulent water. Numbers and locations of fish observed were recorded on waterproof U.S. Geological Survey topographical maps. Water temperatures (°C) were obtained where summer steelhead were observed and where tributaries enter Redwood Creek.

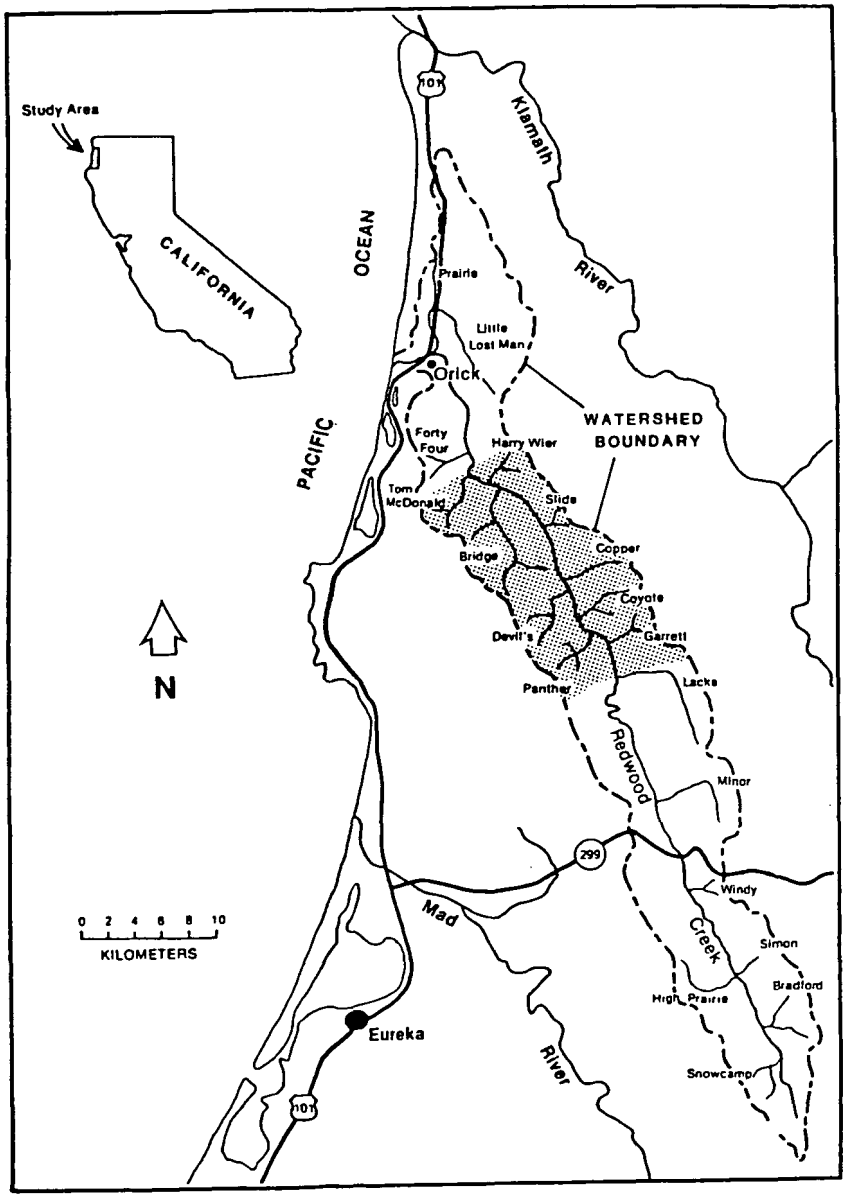

Fig. 1. Redwood Creek, Humboldt County, California. *Shaded area* represents the stream reach surveyed by snorkel swimmers as a population index for summer steelhead.

Results

Numbers of fish observed over the 11 summers of surveys declined from 44 in mid-decade to 0 in 1989 (Fig. 2). The observation of 15 fish in 1991 was the highest recent count.

Summer steelhead numbers and estimated depths of pools where fish were observed for seven of the surveys indicate an avoidance of shallow (30–60-cm) and mid-depth (275–400-cm) pools (Fig. 3). Other variables, including cover provided by boulders and large organic debris and nearby low-temperature tributaries (with cooler water temperatures than the mainstem), influence their occurrence.

Mainstem and tributary water temperatures from the 1990 summer steelhead survey were representative of conditions measured in previous surveys. The highest water temperatures, ranging from 20.5 to 24.5° C were measured in mainstem Redwood Creek. East-side tributaries were cooler, with a mean of 18.0° C (n = 8) and ranging from 15.5 to 20.0° C. West-side tributaries were coolest, with a mean of 15.2° C (n = 17) and ranging from 12.0 to 18.0° C.

Discussion

The majority of summer steelhead were observed in pools. Forty-five percent of the fish were sighted where a deep pool and inflow of cooler water from a tributary occurred together. The highest concentration of fish was usually in a pool at the confluence of one large west-side tributary and Redwood Creek. Otherwise, fish were generally found singularly and not in schools.

In the 3 years (1981, 1983, 1987) the survey was expanded to include more of Redwood Creek, 92% of summer steelhead were found in the index reach. This reach represented the best habitat in the stream for summer steelhead trout. Suitable holding pools were generally lacking in the upper and lower reaches of Redwood Creek, presumably because of sedimentation, lack of cover, or both.

Summer steelhead in Redwood Creek face several problems: habitat degradation, water quality, sportfishing and poaching, and population size. Geologically, the Redwood Creek basin is highly erodible (Janda et al. 1975). Also, large portions of the Redwood Creek basin have been logged. Together, the combined effects of timber harvest (i.e., removal of forest cover and road building) and significant storms have deposited large amounts of sediment in Redwood Creek and degraded fish habitat. Both erosion and hillslope mass wasting caused sedimentation of the mainstem that filled deep pools, the preferred habitat of summer steelhead. Major flood events like the record flood of 1964 caused significant channel adjustments—channel widening, aggradation, and bank erosion. The resultant widened streambed and accompanying shallow riffles provided little or no cover for fish.

The stream received more insolation with less riparian canopy cover over a wider channel, with an accompanying increase in water temperature and a decrease in water quality. Summer mainstem water temperatures are well above the preferred temperature range reported by Reiser and Bjornn (1979) for

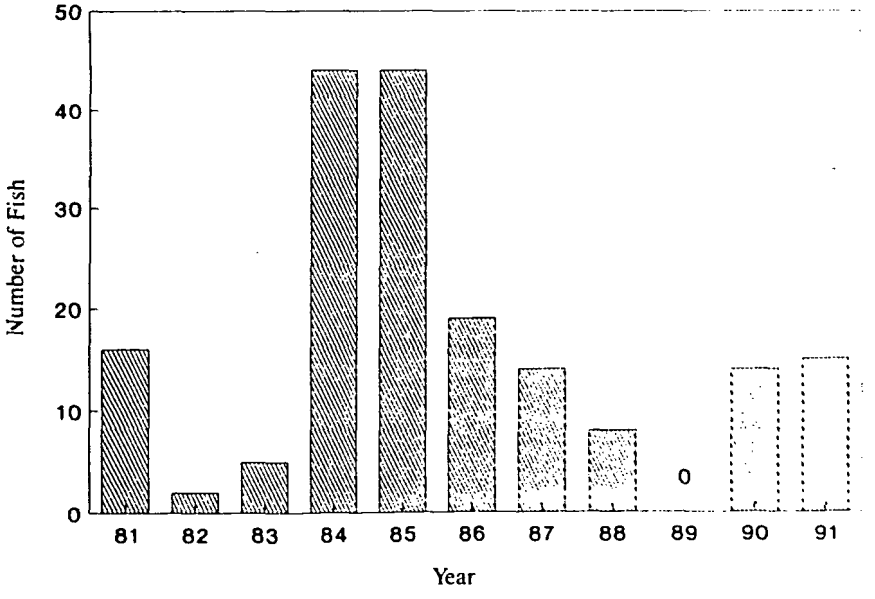

Fig. 2. Numbers of summer steelhead observed each summer since 1981 on a 25.9-km reach of Redwood Creek, Humboldt County, California.

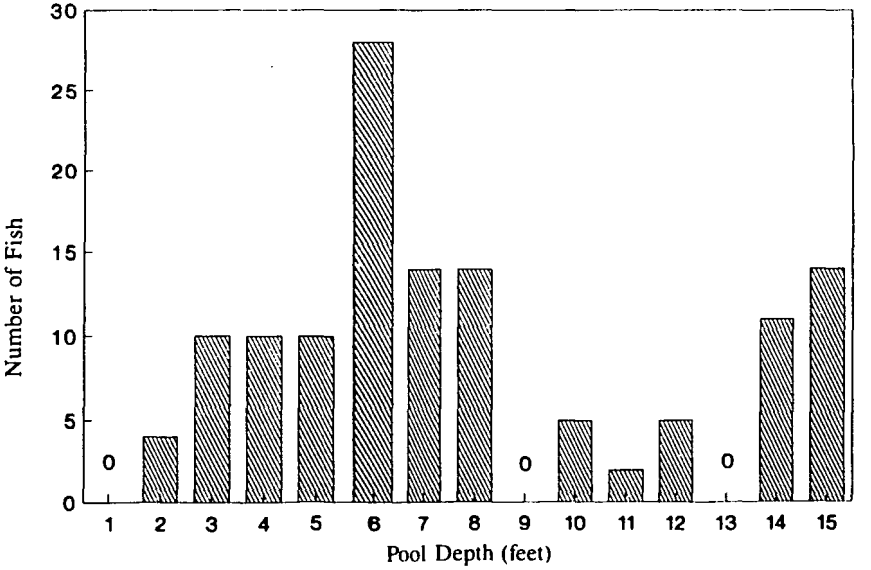

Fig. 3. Summer steelhead numbers and estimated pool depths where fish were observed for seven of the snorkel surveys of Redwood Creek, Humboldt County, California.

steelhead of 7.3–14.6° C. Greater numbers of steelhead were found where water at 15° C entered Redwood Creek from a major west side tributary. The entering flow cooled portions of the pool. This 'cold' pool area was partially thermally stratified because the cooler water sank to the bottom. Though not meeting the definition of a typical cold pool—where physical features such as a gravel bar isolate large volumes of cool water from the warmer mainstem (Ozaki 1988)—the resulting cooler water in the pool provided habitat for summer steelhead.

Sportfishing may be adversely affecting the summer steelhead population. Though the pools are somewhat inaccessible, a few knowledgeable people could deplete the small population present. Further, fishing in the lower river adversely affects the numbers of fish that can migrate in spring to the holding areas upstream. The extent of poaching on this reach of Redwood Creek is unknown. The holding pools are remote and not patrolled, and poaching activities have not been detected but, because of the small population size, poaching would have an inordinate effect on summer steelhead.

A factor making summer steelhead susceptible to poaching is its hiding behavior. When approached by a diver in the water, it may only partially hide. For example, its head will be under a log but its body will be visible, or it may rest in the open on the substrate at the base of a boulder. The fish is easy to approach and usually does not move until touched. This behavior makes it susceptible to spearfishing.

Most summer steelhead in California are found in remote canyons not readily accessible to people (P. B. Moyle and M. D. Morford, California Fish and Game Commission, unpublished data). On Redwood Creek, a hike of approximately 9 km is necessary to reach the holding pools, and on the private timber land, public access is restricted. This may indicate that, besides habitat distribution, public access and the accompanying fishing pressure may influence their distribution.

The small population size and potential concomitant loss of genetic diversity of the summer steelhead of Redwood Creek may also affect their chances for recovery. The optimum effective size of the population for the long-term survival of this run needs to be determined.

The small population size makes this run more prone to be severely affected should a catastrophic natural or human-caused event occur—an event from which the population would not recover. The natural recovery of this population would also be longer because of a catastrophe. In their review of salmonid stocks at risk, Nehlsen et al. (1991) rated the summer race of steelhead of Redwood Creek at a high risk of extinction, based primarily on the small adult escapement and threats of further habitat destruction and overutilization of the fish.

The likelihood of recovery of summer steelhead of Redwood Creek is poor and long term. The National Park Service has invested 15 years and approximately $11 million in a comprehensive watershed rehabilitation program of erosion control and rehabilitation of timber-harvested lands in the Redwood Creek basin and in restoration projects on Redwood Creek, its tributaries, and its estuary. These programs will benefit the fish in the long run by decreasing

erosion and sedimentation and increasing in-stream cover and spawning gravels. However, changes in present fishing regulations and watershed management practices are necessary in the interim. Closing the index reach to fishing and implementing more restrictive angling regulations downstream, including catch-and-release, would increase upstream migration and immediately protect summer steelhead.

Most of the basin is already logged, and vegetative recovery needed to decrease insolation and erosion will be slow. Upstream of the park, better timber-, road-, and erosion-management practices to protect the inner gorge area and riparian canopy are needed to maintain and conserve the remaining habitat.

The California Department of Fish and Game is writing a statewide summer steelhead management plan to address problems facing these fish and to aid their recovery. Creating additional holding pools by installing in-stream structures and implementation of artificial propagation using small on-site hatch-box programs have been proposed. These proposals will need to be evaluated for their potential effectiveness in Redwood Creek and their appropriateness in a national park (Meffe 1992).

The future for the summer steelhead is uncertain. The situation on Redwood Creek is not an isolated one. Most summer steelhead stocks in California are at risk. Decisions, some unpopular, that further protect the stocks and their habitat may be the answer.

Acknowledgments

I thank the many Redwood National Park employees, volunteers, and California Department of Fish and Game personnel that participated in summer steelhead surveys over the past 11 years. I also appreciate access to private land permitted by the Stover family and Simpson Timber Company.

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Nine Thousand Years of Coastal Prehistory on Santa Rosa Island, California: A Radiocarbon Chronology for CA-SRI-1

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Abstract. Twenty-five years ago, Phil Orr described several shell middens on Santa Rosa Island he believed dated to the late Pleistocene. The existence of Pleistocene middens on Santa Rosa Island would have major implications for a number of current anthropological issues, including the possibility of an early coastal migration route for the peopling of the New World. In this paper, we discuss Orr's claims in the context of our recent field work at CA-SRI-1 (Garanon Point), an archaeological site where shell-bearing strata have now been dated to about 2,000, 7,150, and 9,050 years ago. The earliest of these dates, on marine shell of probable cultural origin, took place well within the age range of known coastal California sites. Natural processes, including the transport of shellfish by carrion-eating birds, may account for occasional marine shells found in Pleistocene terrestrial sediments along the California coast.

Key words: Archaeology, Santa Rosa Island, shell midden, Pleistocene.

From 1947 to 1968, Phil Orr of the Santa Barbara Museum of Natural History studied archaeological and paleontological sites of Santa Rosa Island,

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Cover photo: Yosemite Valley in Winter, Yosemite National Park, California.

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Proceedings of the Fourth Conference on Research in California's National Parks

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