USAGE OF LOWER REDWOOD CREEK AND BIG LAGOON BY JUVENILE COHO SALMON AND STEELHEAD

INTRODUCTION

The Redwood Creek watershed is a coastal drainage in southern Marin County, California. It covers 7.5 square miles (PWA *et al*. 1994). Before discharging into the ocean, Redwood Creek joins with its last tributary, Green Gulch, to form Big Lagoon, an intermittent tidal lagoon approximately 2.2 acres, and associated backwater areas. Barring uncharacteristic hydrologic events, Big Lagoon is connected to the Pacific Ocean during winter and spring months and closed during the remainder of the year.

Historically, Big Lagoon was a 30-acre wetland complex consisting of a freshwater lagoon, seasonal wetlands, dunes, and an intermittently tidal lagoon (PWA *et al*., 1994). This historic habitat was degraded through channelization, levee construction, filling, dune removal, and accelerated sedimentation (PWA *et al*., 1994). The historic wetlands were likely characterized by emergent vegetation such as sedges, tules, and cattails along the periphery and open water habitats.

The existing Big Lagoon complex harbors several sensitive aquatic species. The California red-legged frog *(Rana aurora draytonii*), a federally proposed species, has been found in the wetlands and backwater areas associated with Big Lagoon. The western pond turtle (*Clemmys marmorata*), a federal candidate species, is known to occur in the backwater area of lower Redwood Creek.

In addition, the Redwood Creek watershed supports self-sustaining runs of anadromous coho salmon *(Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*). Both species have been petitioned for listing under the Endangered Species Act and coho salmon in this area have been proposed for threatened status.

Past efforts to improve habitat quality and quantity for aquatic animals within the Redwood Creek watershed have resulted in reduced water diversions, elimination of Park Service septic systems, improved land management through

the reduction of grazing and cessation of logging, and changes in instream removal of woody materials.

In addition, future actions are underway to further improve freshwater habitat conditions for aquatic species within Redwood Creek. A major restoration project, funded by the California Department of Transportation and the Golden Gate National Park Association, is planned for Big Lagoon at the mouth of Redwood Creek, in part to benefit anadromous fisheries (PWA *et al*. 1994). Implementation of the preferred restoration alternative would enlarge and deepen Big Lagoon to its approximate historic configuration.

Purpose:

The study objectives were as follows:

1) To determine habitat use (cover type) by juvenile salmonids during the late-winter in Big Lagoon.

2) To estimate juvenile salmonid abundance between late-winter and fall in Big Lagoon and lower Redwood Creek.

Implementation of the preferred restoration alternative could result in the conversion of existing creek habitat between the Pacific Way bridge and the pedestrian bridge at Big Lagoon into an open water/freshwater marsh habitat. Therefore, the intent of the study was to document existing use of this area by coho and steelhead juveniles between late winter and fall, as well as to document existing use of open water area/marsh habitat of Big Lagoon. In addition, habitat features associated with occurrence of juvenile coho and steelhead could be used to shape restoration design details.

Study Area

For the purposes of this project, lower Redwood Creek and Big Lagoon were divided into the following sections:

1.) The area considered as "Big Lagoon" is the main channel pool from the mouth of the creek to just below the willow riparian and emergent cattail portion downstream of the pedestrian bridge (Figure 1). This area changed greatly in size over the year. The habitat is characterized by sandy bottoms with large concrete rubble. Nearshore areas are vegetated primarily by sedges.

2.) The area considered “Lower Redwood Creek” consists of the creek above the confluence with the backwater area upstream of the pedestrian bridge at Muir Beach to below the Pacific Way bridge crossing (Figure 1). Above the pedestrian bridge, lower Redwood Creek is heavily shaded by willow riparian cover. The stream habitat is dominated by pools with overhanging branches and instream woody materials. A mixture of pool, flatwater and riffle habitats extend along Redwood Creek between the portable latrines in the parking lot to the Pacific Way Bridge.

Past Work

Several investigators have sampled Big Lagoon and lower Redwood Creek to determine abundances of steelhead trout and coho salmon juveniles. Between February and June of 1986, portions of lower Redwood Creek and Big Lagoon were sampled with beach seines by Dr. Johnson Wang in order to assess the impacts of a recent oil spill on fish life (Wang and Keegan 1987). Abundances of steelhead and coho peaked on the May and April sampling dates respectively. Arnold (1971) collected 1+ coho and steelhead within Big Lagoon and lower Redwood Creek in January 1968. No information regarding the length of residence, correlation with hydrologic events, or habitat use information was obtained from the field.

Work by Dr. Jerry Smith for Philip Williams and Assoc. focused on the suitability of Big Lagoon and lower Redwood Creek as summer rearing habitat for coho and steelhead. His completed work mirrors observations by Arnold (1971) and others that poor summer water quality conditions impair rearing by coho and steelhead. In particular, Dr. Smith found a drastic decline in steelhead numbers between July and October 1994 sampling periods, particularly in the lower mile of the creek (Smith Dec. 1994).

METHODS

The original purpose of the study was to determine the use of Big Lagoon during the winter and spring of 1995 by coho and steelhead smolts. Estimation of outmigration using beach seines was abandoned after two separate sampling events with beach seines (Febuary 14 and 23, 1995). No coho or steelhead were captured in repeated seinings. The seine was often stuck on rocks on the bottom. Similarly, seining by Dr. Smith (San Jose State) also did not capture salmonids effectively in areas with an uneven bottom (Dr. J. Smith pers. comm., 1995).

Habitat Utilization

Based on preliminary sampling by electrofishing, collected coho and salmon in Big Lagoon were associated with bank or rubble cover. Snorkel surveys were conducted on March 30, 31 and April 2, 1995 to determine cover type association by juvenile salmonids during the late-winter in Big Lagoon. Cover types included none, undercut banks, cobble size materials or larger, woody debris, emergent vegetation, overhanging vegetation, and undercut roots. The cover type(s) within one meter of the fish were recorded.

Physical Habitat Information

Recorded physical information included stream discharge, air and water temperature, length, area, and volume of the sampled unit. On occasions when stream discharge was not directly measured, gage height readings were taken from the nearest gage. The length of the sampled areas was measured along the deepest portion of the channel. Width estimates were obtained at a minimum of three or more equidistant locations. Depth measurements were obtained at these same locations. On two occasions, a GPS system was used to map the sampling area; area estimates were computed using this GPS unit.

Fish Information

The sampled areas were snorkeled in a single pass using a two person team. Estimates based on an average of repeated passes were attempted on several occasions, but proved difficult because of poor water clarity following the first pass. Recorded information included water visibility, length class, species, and abundance. A rigorous calibration of snorkel estimates with other, more accurate, methods of determining abundance and

length class was not conducted. However, two-pass electrofishing data was collected by Dr. Jerry Smith in Lower Redwood Creek (Section 2) two days after one snorkel event.

Table 1: Sample dates.

Sample Dates	Location	Gear
February 14, 1995	Big Lagoon	Beach seine
February 23, 1995	Big Lagoon	Beach seine, E-fishing (B. Cox)
March 1, 1995	Big Lagoon, Lower Redwood	Snorkel
March 30,31, April 2, 1995	Big Lagoon, Lower Redwood	Snorkel
May 9,11 1995	Lower Redwood	Snorkel
August 21, 1995	Lower Redwood	Snorkel
August 23, 1995	Lower Redwood	E-fishing (J. Smith)
October 30,31 1995	Big Lagoon, Lower Redwood	Snorkel

Personnel

Several people assisted in the various sampling events including Dan Howard (Cordell Banks NMS, NOAA), Maya Khosla (VIP), Chris Mobley (NMFS), Arnie Petersen (VIP), and Denise Vore (NPS). NPS personnel and volunteers assisted Dr. Jerry Smith (San Jose State Univ.) and Bill Cox (CDFG) during electrofishing surveys.

RESULTS

Big Lagoon

Although the focus of the surveys was juvenile coho salmon and steelhead, several other species were observed. In Big Lagoon, we observed or collected (via seines and electrofishing) topsmelt (*Atherinops affinis*), Pacific staghorn sculpin (*Leptocottus armatus*), striped bass (*Morone saxatilus*), threespine stickleback (*Gasterosteus aculeatus*), steelhead juveniles (*Oncorhynchus mykiss*), and coho salmon juveniles (*Oncorhynchus kisutch*).

Throughout the three snorkel survey dates, the densities of coho juveniles in Big Lagoon remained relatively low (Table 2). Maximum densities of juvenile coho (0.05 fish/m^2) were observed on March 30. Flood flows or competition for resources in upstream areas may have resulted in the young-of-the-year coho observed in Big Lagoon during the spring. Coho fry in Carnation Creek, a coastal stream in British Columbia, were produced in excess of that stream's carrying capacity, causing the seaward movement of large numbers of fry during the spring and summer (Hartman *et al*. 1981).

It is doubtful that juvenile coho currently utilize the existing lagoon for summer rearing. No juvenile coho were present in the later October 31 survey. In the PWA report, water quality (periodic high temperatures and low dissolved oxygen levels) was deemed unsuitable during the summer and fall for rearing. During the October survey in Big Lagoon, large amounts of filamentous green algae and decaying algae were present on the bottom sediments.

All of the observed coho within Big Lagoon were young-of-the-year. The fate of the young-of-the-year coho that entered Big Lagoon during the spring is unknown. Wading birds such as great blue herons were seen foraging in the shallows of Big Lagoon during the spring and summer and likely consumed many a coho juvenile. It is also possible that some coho could have moved upstream to more favorable rearing areas. It is more likely that many were swept into the ocean following storm events where it is doubtful that many would survive to adulthood. All of the young-of-the-year coho observed in March were less than 35 cm. Survival to adult is positively associated with size; young-of-the-year coho that enter the sea in spring or summer generally do not survive to become adults (Sandercock 1991). The threshold size for

survival is 70-80 mm (Sandercock 1991).

Low numbers of steelhead (>1+ years) were present in Big Lagoon during an electrofishing survey in February (2 smolts- 178 and 147 mm) and during the March 30 and October 31 snorkel surveys. All of the steelhead were found in the deeper water areas (approximately 1 m) that contained rubble cover.

Lower Redwood Creek (above confluence)

Upstream of Big Lagoon, in the lower Redwood Creek section, prickly sculpin (*Cottus asper*), coastrange sculpin (*Cottus aleuticus*), and unidentified adult newts were found in addition to threespine stickleback and juvenile coho and steelhead.

The main channel pool above the confluence of lower Redwood Creek and the backwater does not appear to support large numbers of juvenile coho throughout the summer. Although large numbers of young-of-the-year coho were observed during the spring, only one coho was seen in the fall survey (Table 2). Interestingly, the surveyed area appeared to be suitable habitat for summer rearing by coho juveniles. The main channel pools in this section were relatively deep (range of October 31st mid-channel depths=> 0.25 to 0.9 m) with dense overhanging vegetation and abundant instream woody debris for cover. However, riffle areas, which are usually associated with the production of instream macroinvertebrates, were not present in this area.

As with Big Lagoon, low numbers of steelhead juveniles that have spent more than 1 year in freshwater were present in this area. Most were found near the bottom and in dense cover. It likely that the snorkel surveys greatly underestimated the numbers of these steelhead because of low light conditions and behavior patterns.

Lower Redwood Creek (above portable toilets)

Unlike the section just downstream, an interspersion of pool, flatwater, and riffle habitats were present in this section. Very little change in the numbers of coho juveniles occurred between the May 11 and August 21 dates (Table 2). However, densities decreased in half by the October 31 date. Nevertheless, densities of both coho and steelhead juveniles were much greater than both Big Lagoon and the main channel pool above the confluence.

Spring Cover Type Association

Young-of-the-year coho and their associated cover types were observed on March 30,31, April 2, 1995. Seventy-four percent of the observed young-of-the-year coho were associated with emergent vegetation or overhanging cover (Figure 2). Many of the 1797 coho were associated with more than one cover type. Although constituting a major proportion of the available perimeter, particularly in Big Lagoon, few coho were associated with the no cover (e.g. sandy bottoms).

Temperature

Water temperatures were recorded for 1995 at the pedestrian bridge to Muir Beach (Figure 1) with an Onset Stowaway data logger placed initially 0.75 m below the water surface. tHE Average water temperatures exceeded 18^{o} C a few times in July (Figure 3). The preferred temperature range for juvenile coho is 12-14^{o} C with an upper lethal temperature of 25^{o} C (Sandercock 1991).

DISCUSSION

Snorkel surveys appeared to be less effective than electrofishing estimates in determining the number of young-of-the-year steelhead in riffle, flatwater, and pools lacking cover. Two days after snorkel counts were conducted in Lower Redwood Creek (site "Pool 2"), two-pass electrofishing was conducted at the same location. Dr. Jerry Smith estimated of 54 coho/100 feet and 142.5 steelhead/100 feet. Snorkel counts produced 50 coho/100 feet and 78 steelhead/100 feet. Although termed "Pool 2," portions of the pool contained shallow flatwater habitat that were too shallow to snorkel effectively, yet sufficiently deep for young-of-the-year steelhead. The efficiency of electrofishing is not adversely affected by shallow water conditions. However, snorkel counts appeared to work in habitats, such as Pool 1, that contained complex instream cover and depths that restrict the effectiveness of electrofishing techniques. However, many of the deep pools, particularly above the confluence of Redwood and the backwater area, were so well shaded that detection of elusive one-two year old steelhead was difficult.

The proposed restoration project would extend the area of presumably shallow water habitat bordered by emergent wetland and riparian willow habitat. It is likely that the nearshore vegetated areas of the restored wetland would be heavily used during the spring by recently emerged coho. It is unclear how valuable open water areas would be for coho juveniles during the summer. Such areas would likely be shallow and lack cover. No coho juveniles were observed in fall snorkel counts in Big Lagoon. Also, work by Dr. Jerry Smith in the pools above Big Lagoon during the late summer/early fall in 1992 and 1993 noted very few coho and steelhead juveniles (Smith 1995).

The proposed project would also create a loss of a riffle, flatwater, and pool sequence in Lower Redwood Creek between the portable toilets and the Pacific Way Bridge that appears to be providing rearing habitat throughout the summer. This area contained higher densities of coho juveniles at the end of summer than Big Lagoon or the deep, heavily shaded pools above the confluence of Lower Redwood Creek and the backwater. Although the main channel pool above the backwater appears to provide little summer rearing habitat for young-of-the-year coho, the areas were consistently used by one/two year-old steelhead. It is unclear how the proposed restoration of the historic channel alignment will create the heavily shaded pools with complex cover that currently exists now.

Although the benefits of the proposed restoration project as summer rearing habitat for coho juveniles is unclear, the proposed restoration project will increase the habitat available to other native fishes and amphibians, such as threespine stickleback and California red-legged frog. Yet, the most attractive feature of the restoration project would be the creation of suitable habitat conditions for the endangered tidewater goby (*Eucyclogobius newberryi*). The proposed restoration alternative would create shallow, open water habitats with fine grained sandy bottoms. Such substrates are necessary for the establishment of nests. Appropriate food resources are present for the goby. Benthic invertebrate surveys by PWA noted the presence of a *Corophium* amphipod and other possible goby food resources. Also, gobies are likely more tolerant of warmer water temperatures and dissolved oxygen levels than more cold-tolerant salmonids. Also, if salinities remain relatively low throughout the year, it is likely that the tidewater goby would have a competitive advantage against some non-native gobies (e.g. yellow-fin goby) that are adapted to higher salinities.

Although no tidewater gobies have been found in recent surveys, gobies may have been extirpated earlier by historic land-use practices and water quality problems. Because of their apparent limitations in dispersal, recolonization of extirpated sites would be difficult to achieve. Therefore, introduction of tidewater gobies would be required. Any introduction of listed species would require authorization by the U.S. Fish and Wildlife Service.

The benefits of establishing a population of tidewater gobies are prodigious. Currently, Rodeo Lagoon is the only existing population within the greater San Francisco region. All other sites (e.g. Lake Merritt, Aquatic Park, Corte Madera Creek) have no reported gobies. Establishment of a viable population at Big Lagoon would create an insurance policy in case natural disaster extirpates or severely reduces the goby population at Rodeo Lagoon. Furthermore, it would be unlikely that development activities would significantly threaten an established goby population. Big Lagoon is under NPS management authority and most watershed lands are managed by either federal and state resource agencies. Finally, a potential source of gobies, Rodeo Lagoon, is in a nearby watershed and is under NPS management.

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