Introduction
In central California, coho salmon (Oncorhynchus kisutch) are listed as endangered and steelhead (O. mykiss) as threatened, under the U.S. Endangered Species Act. Continued declines of central California salmonids are attributed to degradation/loss of habitat and diversion of water for human use. Other factors, however, may limit recovery of depressed populations, including variation in ocean primary productivity and predation (Anderson et al. 2004, Good et al. 2007). Salmonids are eaten by a variety of piscivorous birds, fish, and mammals, and are vulnerable to predation during all life history stages (e.g. Collins et al. 2001, Weise & Harvey 2005, Wright et al. 2007). Mortality of juvenile salmonids during freshwater rearing has a disproportionate effect on numbers of returning adults, compared with mortality during other life stages (Kareiva et al. 2000). In systems where piscivorous birds and salmonids co-occur, predation of juveniles can be substantial (Cairns, 1998). Recent studies in Scott Creek (Santa Cruz County) indicate that predation of coho and steelhead by piscivorous birds may be limiting recovery of these species. The extent to which juvenile salmonids are susceptible to predation depends on abundance of predators, overlap in space and time between predators and prey, and consumption of alternate prey. The objective of our study was to use stream surveys to determine species identity, abundance, and annual trends in distribution of piscivorous birds in Scott Creek to assess susceptibility of juvenile salmonids to predation by avian species.

Methods
Between 2008 and 2010 we conducted surveys (N = 55) 7-14 days apart (T = 12 days) in 10 stream reaches randomly selected using a General Randomized Tessellation Stratified (GRTS) sampling program. Surveyed reaches were representative of all habitat types within Scott Creek and encompassed 40% habitat available to anadromous salmonids.

Scott Creek watershed, with survey sections color coded. The upper watershed is dominated by a coastal redwood forest; willow and alder dominate the canopy of the lower mainstem. The watershed terminates in a small estuary which is connected to the ocean during winter months; during summer months sandbar formation blocks the creek mouth from the ocean forming a freshwater lagoon.

Stream reaches were grouped into 5 fixed-width strip transects (referred to as stream sections) with the stream corridor selected as the transect width because we were concerned with the number of birds available for eating salmonids. During surveys, two observers walked stream sections and recorded species identity, location, and time of observation. We assumed all birds present in stream sections were seen. The order in which sections were surveyed was randomized and all surveys began 2 hours after sunrise to minimize effects of daily patterns of bird activity on observations.

Diversity indices (species richness, Simpson’s Index) were calculated for each stream section. Simpson’s Index was chosen as a measure of diversity because it weights common species more heavily than rare species, and common species are more likely to have a greater impact on salmonid populations. Using a Generalized Linear Model with a quasi-poison distribution and a log link function, we examined whether bird counts related to river mile (station), day of the year, and seasonal cycle (sin transformed days of year) varied among stream sections, with the greatest number of birds in the lagoon/estuarine habitat (Section 1, A). Mean number of birds decreased with increasing distance from the estuary. However, there was no seasonal variability in bird distribution. For all sections, counts of birds were greater during Year 2 than Year 1. The significant effect of sinDay means that distribution. For all sections, diversity was slightly greater during Year 1 (Dec 2008- Nov 2009) than Year 2 (Dec 2009- Nov 2010). Diversity decreased with increasing distance from the lagoon.

We found that stream surveys were an effective method of assessing predation pressure faced by salmonids in a small, coastal watershed. Predation pressure was greatest in the estuary, where species abundance and diversity were greatest. Predation pressure also varied seasonally, with peaks in predator abundance occurring in the spring (Feb-Mar) and Autumn (Sept-Oct). These periods correspond with migration of juvenile salmonids to the ocean (Spring) and the lagoon rearing period for juvenile steelhead (Autumn). Predators may be responding to increased availability of fish in the lagoon during these periods, however, other explanations must be ruled out (e.g. changes in bird abundance because of breeding or migration). Fish densities and growth rates are lower in the oligotrophic upper watershed than in the nutrient rich estuary, which may explain the greater bird abundance/diversity in the estuary. Based on published estimates of energetic requirements, a kingfisher can eat ~ 6 juvenile salmonids per day (Fetham 1995). Mean annual smolt production in Scott Creek (wild and hatchery) was ~ 3,000 coho and 11,500 steelhead (2003-2009). On a diet of salmonids, only a merganser and one kingfisher could consume 9.5% of the mean annual smolt production in one month. Stickleback, sculpin and invertebrates represent alternative prey for birds in Scott Creek (Langford unpubs data). Inclusion of these species in predator diets will reduce overall impact of predation on juvenile salmonids, however, the data presented here indicate that predation by birds likely represents a significant source of mortality and may limit recovery of federally listed salmonids in Scott Creek, and should be accounted for in management and recovery strategies.

Conclusions

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References: