Food Habits of Fishes in the Redwood Creek Estuary

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Abstract. The food habits of 11 fish species in the Redwood Creek estuary and an adjacent stream and sloughs were studied during 1980 to identify organisms consumed, seasonal and spatial dietary patterns, and levels of dietary overlap. Fish examined included anadromous species: chinook salmon *(Oncorhynchus tshawytscha),* coho salmon *(O. kisutch),* and steelhead trout *(O. mykiss);* marine species: starry flounder *(Platichthys stellatus),* surf smelt *(Hypomesus pretiosus),* and shiner surfperch *(Cymatogaster aggregata);* freshwater species: prickly scuplin *(Cottus asper),* Sacramento sucker *(Catostomus occidentalis),* and threespine stickleback *(Gasterosteus aculeatus);* and euryhaline species: staghorn scuplin *(Leptocottus armatus)* and tidewater goby *(Eucyclogobius newberryi).* Immature aquatic insects, especially dipterans, were most important in the diets of most fish species. Aquatic crustaceans, particularly two species of the benthic amphipod, *Corophium,* were very important in the summer diet of juvenile steelhead and prickly sculpin in the estuary. Because the diets of the different fish species tended to emphasize different species of prey, dietary overlap was biologically insignificant. Predation of fish on other fish was found to be generally of little importance.

INTRODUCTION

Estuaries of the northwestern United States have been identified as important feeding areas for a variety of fishes, particularly juvenile salmonids (Snyder, 1931; Needham, 1940; Reimers, 1973; Neilson et al., 1985). These estuaries may support, in addition to anadromous species, marine, freshwater, and euryhaline species. Developments within, or modifications to, an estuary may affect its productivity. In 1980 we studied the food habits of fish found in the Redwood Creek estuary, Humboldt

County, California, to better understand the importance of this estuary to the production of fish (for full details see Salamunovich, 1987). We wished to determine the species of fish utilizing the estuary, the seasonal or spatial patterns in their diets, and to compare their diets.

STUDY AREA

Redwood Creek flows through the Redwood National Park and enters the Pacific Ocean approximately 80 kilometers south of the California-Oregon border (Fig. 1). The stream drains approximately 73,000 hectares (Iwatsubo et al., 1976) and has summer flows averaging 1.2 m^3/s (U.S. Geological Survey, 1980, 1981). The stream has historically supported substantial runs of chinook salmon, coho salmon, and steelhead (Ricks and Feranna, 1981).

Because of flood damages, particularly to the community of Orick located about four kilometers upstream from the mouth of Redwood Creek, levees were constructed in 1968 along the lower five kilometers of the stream by the U.S. Army Corps of Engineers (Fig. 2). These levees substantially altered the estuarine habitat by removing riparian vegetation and a major meander of the stream. These alterations to the estuarine habitat, along with logging, road building and grazing, may have contributed to declines in local runs of anadromous salmonids (Winzler and Kelley, 1970; U.S. Fish and Wildlife Service, 1975; Larson et al., 1983).

The character of the Redwood Creek estuary varies seasonally (Gregory, 1982). Salt water intrusion into the estuary is limited in the winter and spring by high stream flows, while low summer and fall flows permit the formation of a sand berm across the mouth of the creek that frequently blocks the interchange of fresh and salt water. During this study, the berm was breached in early July, discharging fish from the embayment into the ocean and disturbing the substrates and benthic fauna in the embayment (Larson et al., 1982, 1983; Larson, 1987).

METHODS

We studied the food habits of fish in lower Redwood Creek throughout 1980 in four separate habitats: (1) the estuary; (2) the stream below the U.S. Highway 101 bridge and immediately above the estuary; (3) the South Slough, which is the remnant of a former stream meander; and (4) the North Slough, which is a former tributary channel with periodic access to the estuary (Fig. 2).

Most fish were collected by seining, with a few caught in a minnow trap. Juvenile stickleback were also collected in dredge and plankton samples. Because the size range of the fish was relatively small, we do not feel that there was any particular selectivity of the fish caught. No effort was made to collect adult anadromous salmonids.

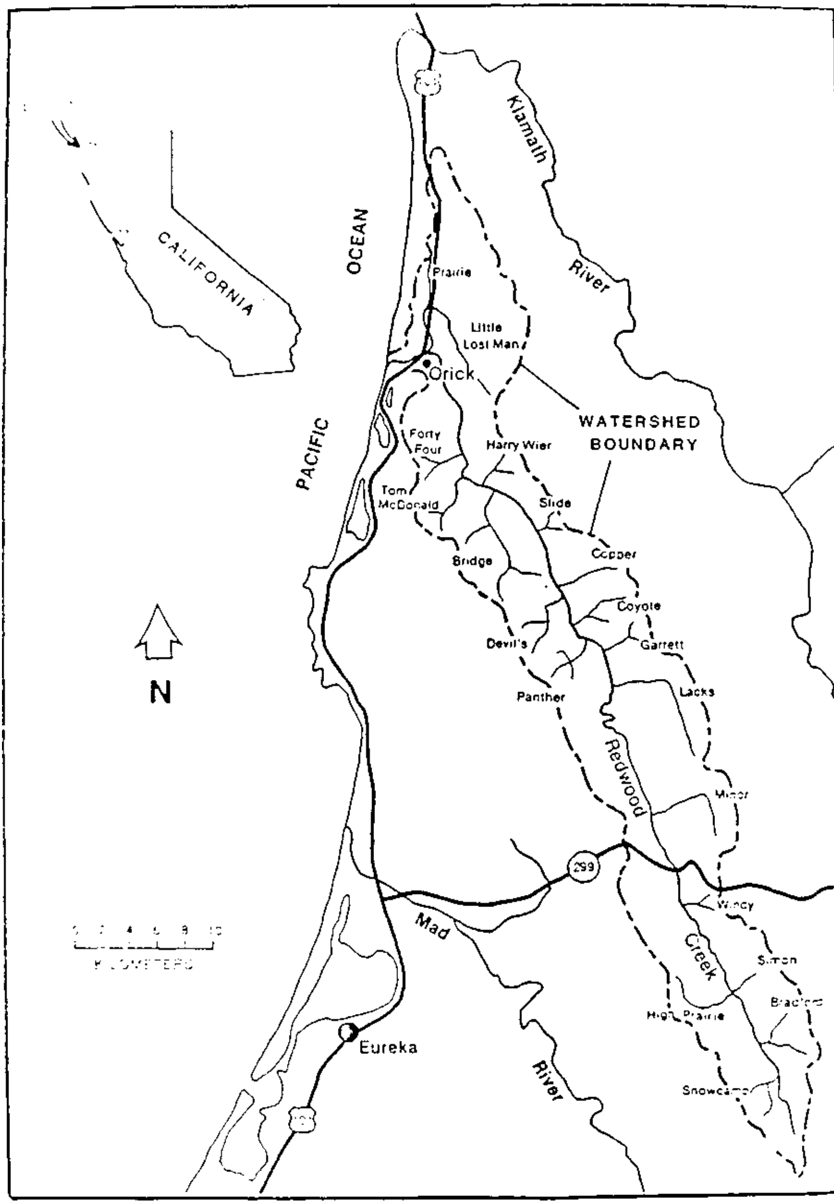

FIGURE 1. Redwood Creek, Humboldt County, California.

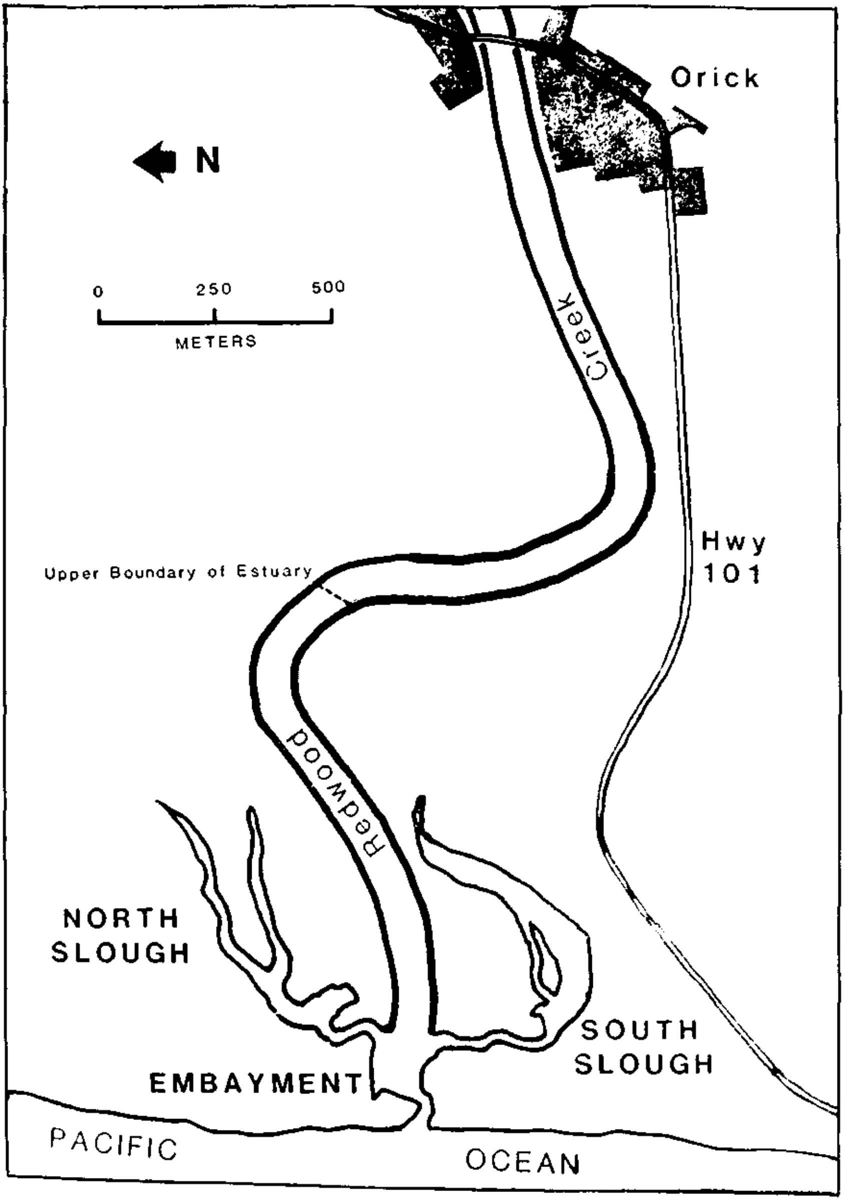

FIGURE 2. Lower Redwood Creek including the stream below the U.S. Highway 101 bridge, the estuary, and the North and South sloughs, Humboldt County, California.

We identified food items to the lowest possible taxon. Diet comparisons were made by using the Index of Relative Importance (IRI) (Pinkas et al., 1971):

$$IRI = (\%N + \%W)(\%F)$$

where N = numerical abundance of a prey item,

W = reconstructed dry weight of a prey item (computed by multiplying the number of individuals by the average dry weight of representative whole organisms), and

F = frequency of occurrence of a prey item.

Schoener's index (a) (Schoener 1970) was used to measure levels of diet overlap:

$$a = 1 - 0.5\ (\Sigma \mid p_x - p_y \mid)$$

where $\sum$ = the sum of the differences over all food categories,

p_x = the percentage, by reconstructed weight, of a particular food in the diet of species x, and

p_y = the percentage, by reconstructed weight, of the same particular food category in the diet of species y.

This index indicates that no food items were consumed in common if a = 0.0; and all food items were consumed in common and in equal proportions if a = 1.0. An a $\geq$ 0.60 was used as the arbitrary boundary to identify biologically significant levels of diet overlap. This level of significance has been used by other investigators (Zaret and Rand, 1971; Mathur, 1977; Johnson, 1981a, 1981b; Johnson and Ringler, 1980; McCabe et al., 1983).

RESULTS

A total of 589 fish, representing 11 species, were collected for this study (Table 1). Sample sizes in some combinations of location and season were too small to allow meaningful comparisons of food habits. High stream flows precluded effective sampling during the winter and woody debris made sampling very difficult in the North Slough. The food habits of all species are presented in this report, but overlap comparisons are limited to situations where there was a sample size of at least four fish of each species for a given location and season. Insect larvae and particularly dipteran larvae and/or pupae were important in the diets of juvenile steelhead trout, juvenile chinook, juvenile coho, prickly sculpin, Sacramento sucker, and threespine stickleback in the area upstream from the estuary during all seasons (Table 2). In all cases, dipterans contributed more than 50% of the IRI except for juvenile coho, for which trichopteran larvae were most important in the spring; and prickly sculpin, for which ephemeropteran nymphs were most important in the summer. Within the estuary, insects, primarily dipterans, dominated the spring and summer diets of juvenile steelhead, juvenile chinook, prickly sculpin, Humboldt sucker, and threespine stickleback (Table 3). Amphipods, *Corophium* spp., were most important in the fall diets of juvenile steelhead and prickly sculpin, and in the diets of starry flounder during all

TABLE 1. Number and size of fish examined for food habits from lower Redwood Creek, Humboldt County, California, February-December 1980.

	Number			Length (mm)	
Species	**Total Number**	**Number with identified food items**	**Percentage with identified food items**	**Mean**	**Range**
Steelhead trout *(Oncorhynchus mykiss)*	79	76	96.2	115.3	28-221(FL) 1/
Chinook salmon *(O. tshawytscha)*	78	78	100.0	72.8	36-111 (FL)
Coho salmon *(O. kisutch)*	5	5	100.0	71.8	33-157 (FL)
Prickly sculpin *(Cottus asper)*	101	89	87.1	63.4	30-140 (TL)2/
Staghorn sculpin *(Leptocottus armatus)*	32	30	93.8	89.0	60-110 (TL)
Starry flounder *(Platichthys stellatus)*	43	35	81.4	25.3	73-254 (TL)
Sacramento sucker *(Catostomus occidentalis)*	41	35	85.4	93.5	44-200 (FL)
Threespine stickleback *(Gasterosteus aculeatus)*	197	182	92.4	44.8	7-77 (TL)
Surf smelt *(Hypomesus pretiosus)*	6	6	100.0	154.0	45-178 (FL)
Tidewater gobie *(Eucyclogobius newberryi)*	5	5	100.0	37.8	31-41 (TL)
Shiner surfperch *(Cymatogaster aggregata)*	2	0	0.0	39.5	39-40 (FL)

l/ FL = fork length.
2/ TL = total length.

TABLE 2. Percentage of the total IRI contributed by the principal prey items found in the stomachs of fish captured upstream from the estuary of Redwood Creek, Humboldt County, California, February-December 1980. (WI = winter, SP = spring, SU = summer, FA = fall).

	Juvenile Steelhead		Juvenile Chinook			Juvenile Coho	Prickly Sculpin			Sacramento Sucker			Threespine Stickleback		
Season... Food Item	SP	SU	WI	SP	SU	SP	WI	SP	SU	WI	SP	SU	SP	SU	FA
Sample size	7	12	2	5	3	4	3	10	15	4	2	5	2	38	5
Acari					1.4									0.4	
Corophium spp.															1.0
Ephemeroptera nymphs		1.1	11.6	5.0	1.8	6.5		3.3		56.2					25.7
Plecoptera nymphs	25.8						32.0			3.3		1.8			
Hemiptera nymphs & adults	1.6					1.2									
Coleoptera larvae	2.0		0.8					2.1		0.8				2.0	
Coleoptera adults				2.6	1.2	0.7	2.1			2.9					
Trichoptera larvae		10.9	7.3	16.7			2.0	6.2	1.1						
Diptera larvae	42.5	46.1	82.7	34.6	29.1	50.7	57.3	55.1	42.2	92.3	93.8	95.4	21.3	64.7	62.9
Diptera pupae	23.7	26.6	0.3	37.3	51.8	33.7				0.8	5.3	2.8	56.6	7.1	36.0
Fish		1.0													
Eggs											0.8				
Terrestrials	0.8	0.7	3.4	6.1	9.1	12.7		35.2					15.4	0.2	

TABLE 3. Percentage of the total IRI contributed by the principal prey items found in the stomachs of fish captured from the estuary of Redwood Creek, Humboldt County, California, February-December 1980. (WI = winter, SP - spring, SU = summer, FA = fall).

	Juvenile Steelhead			**Juvenile Chinook**		**Prickly Sculpin**			**Staghorn Sculpin**			**Starry Flounder**				**Sacramento Sucker**		**Threespine Stickleback**		**Surf-smelt**
Season	SP	SU	FA	SP	SU	SP	SU	FA	SP	SU	FA	WI	SP	SU	FA	SP	SU	SP	SU	FA
Food item / Sample size	6	36	7	10	53	12	23	9	2	9	9	2	5	14	12	2	14	27	28	6
Neanthes succinea						3.4			100.0	0	26.0			3.0	25.2			0.5		
Octopus rubescens										18.2										
Acari					0.6													1.5		
Copepods								3.4								35.9		4.4		61.6
Neomysis mercedis			0.5							6.0	6.0		8.2					1.2		1.1
Gnorimosphaeroma oregonensis			1.8			2.1				1.0		0.9	10.8	4.2				0.3		
Corophium spp.	12.3	25.1	89.6			4.6	5.3	80.5		60.4	10.7	8.8	58.8	66.	74.0			17.4		3.0
Anisogammarus confervicolus			1.1			0.7				1.8	57.3	82.4	4.5		0.4					32.6
Crangon franciscorum									0.2				6.7							
Emerita analoga	22.5																			
Ephemeroptera nymphs	3.4																			
Plecoptera nymphs						1.1						8.0								
Coleoptera larvae						2.1														
Trichoptera larvae	8.4			2.2		1.2														
Diptera larvae	39.3	49.3	1.1	20.6	40.0	84.1	85.6	5.5		8.0			14.1	19.4		64.1	98.9	68.1	98.7	
Diptera pupae	8.7	19.3	1.4	56.9	57.6					1.0							0.8	6.6	0.5	
Fish		4.3	2.7	3.4			1.1	9.8		0.9									0.1	0.5
Eggs							6.6			0.2			3.7							
Terrestrials	1.8	0.4	1.6	15.2	1.4	0.2		0.1		1.5									0.1	0.1

TABLE 4. Percentage of the total IRI contributed by the principal prey items found in the stomachs of fish captured from the South Slough of Redwood Creek, Humboldt County, California, February-December 1980. (WI = winter, SP = spring, SU = summer, FA = fall).

	Juvenile steelhead	Juvenile Chinook	Prickly Sculpin		Staghorn Sculpin			Starry Flounder	Sacramento Sucker	Threespine Stickleback			
Season.	SU	SU	WI	SU	WI	SP	SU	WI	SU	WI	SP	SU	FA
Food Item Sample size	4	5	8	6	5	2	3	2	8	12	16	18	10
Acari												0.1	
Cladocerans		0.5									1.8	1.6	0.6
Ostracods			2.6								0.9		0.1
Copepods				2.2							3.3	10.2	
Neomysis mercedis	0.6	8.9		7.2	26.6	84.0	75.7			46.2	25.8	11.1	91.0
Gnorimosphaeroma oregonensis	1.4	4.0	46.2	82.1	44.3		1.0	63.6	65.3	2.4	8.5	13.1	0.4
Corophium spp.	18.0	53.5	18.0	0.9	15.8	10.5	23.0		19.9	26.1	4.5	46.5	0.5
Anisogammarus confervicolus			29.3					33.7		7.1			
Ischnura cervula naiads		5.5							1.0			1.1	
Plecoptera nymphs		0.9											
Corixid nymphs & adults	54.1										0.4	0.8	
Notonecta shooteri nymphs	2.7								3.0				
Glyphopsyche sp. larvae	1.6	0.7							2.1				
Diptera larvae		1.5	4.0	6.8	2.6	5.5		2.7	7.8	4.2	40.5	6.3	2.1
Diptera pupae	5.1	12.3			0.3					13.9	14.3	3.9	5.3
Fish		4.1										0.5	
Eggs												4.6	
Terrestrials	13.6	4.9											

seasons. Since juvenile chinook left the estuarine embayment when the berm was breached in early July, no information was available to characterize their food habits during the late summer or early fall. Staghorn sculpin fed exclusively on polychaete worms in the spring, predominately on *Corophium* spp. in the summer, and on the amphipod *Anisogammarus* in the fall. Copepods were the primary food of surf smelt in the fall. Although no positive identification was made of the stomach contents of the shiner perch, they appeared to have fed exclusively on algal material.

The South Slough was a relatively stable habitat throughout the study period. The food habits of fish captured in this area varied more than at other sites (Table 4).

Few fish were caught in the North Slough. Threespine stickleback fed primarily on copepods and dipteran larvae and pupae. Tidewater gobies fed primarily on dipteran larvae.

There were only four instances of biologically significant overlap between species and within sites and seasons. The threespine stickleback showed a high degree of overlap with both prickly sculpin and Sacramento sucker in the estuary during the summer. Chironomid larvae was the common food item in both cases. In the estuary during the fall, prickly sculpin and starry flounder both commonly utilized amphipods and isopods such that their diets significantly overlapped. The diets of prickly sculpin and staghorn sculpin in the South Slough significantly overlapped during the winter because both were feeding heavily on *Gnorimosphaeroma.*

DISCUSSION

Most fish in lower Redwood Creek fed upon autochthonous food items. Other investigators have reported similar observations for other Pacific coast estuaries (McCabe et al., 1983; Simenstad, 1983). Except in the sloughs, riparian vegetation within the study area had been largely removed by the construction of the levees, limiting contributions of food from terrestrial sources. Other than juvenile chinook salmon that fed primarily on drift organisms, the fish fed primarily on benthic organisms. McCabe et al. (1983) reported that subyearling chinook salmon in the lower intertidal area of the Columbia River estuary also fed primarily on drift in the form of dipteran adults.

The food habits of the fish did vary between habitats and seasons. McCabe et al. (1983) also reported seasonal and spatial differences in the food habits of fishes captured in the Columbia River estuary. The general characteristics of the food habits of fishes in the lower Redwood Creek habitats would suggest the potential for interspecific competition. However, when food items were precisely identified, there were only four indications of biologically significant dietary overlap between species within a location at a given season. We suspected that food was not a limiting factor in the Redwood Creek estuary during the period of this study because either there were relatively few fish occupying the habitat or there was an abundance of food items. It should be noted that the catastrophic embayment draining was an unusual event. We feel that if the berm had not been breached and the downstream migrating salmonids were concentrated in the embayment throughout the summer, preferred food items such as chironomid larvae or *Corophium* could become limiting and affect fish production, as was observed by Nielson et al. (1985) in the Sixes River.

The construction of the levees has eliminated riparian habitat and cover in the form of cutbanks in the lower reaches of Redwood Creek. Also, the resulting channelization has altered circulation patterns, causing sedimentation within the estuary (Ricks, 1985). The National Park Service policy is to restore the estuary and to enhance its general productivity and, in particular, its productivity with regard to salmonids (Hofstra, 1983). Since the removal of the levees is not practical, other means of increasing the productivity of the area must be considered. A stable estuarine habitat during the summer should enhance the production of the invertebrate fauna upon which the fish depend. Population and growth data have verified that the food resources are adequate to ensure the growth of juvenile salmonids in the estuary through the summer and early fall (Larson et al., 1983). Redwood National Park is presently managing the embayment water levels in the summer and fall. Also, a diversion control structure has been constructed to restore circulation of water through the South Slough to improve water quality and accessibility for fish. In our opinion, these two actions are the most appropriate efforts to maintain and improve the productivity of the Redwood Creek estuary.

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