THE BIOLOGY OF THE JUVENILE STEELHEAD (Oncorhynchus mykiss) IN THE MATTOLE RIVER ESTUARY/LAGOON, CALIFORNIA

by

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ABSTRACT

Downstream migrant steelhead (Oncorhynchus mykiss) were trapped with a fyke net trap placed in the lower Mattole River from late April to October in 1988 and 1989. Young-of-the-year steelhead made up over 97 % of the fish trapped in both years. A resurgence of outmigrating young-of-the-year steelhead occurred from late August to September in 1988.

Juvenile steelhead numbers were determined monthly after lagoon formation using mark/recapture techniques. In 1988, juvenile steelhead numbers remained stable and a temporal and spatial shift from the lower region to the upper region of the lagoon was demonstrated. More steelhead used the lagoon in 1989 even though the lagoon formed nearly two weeks later than in 1988. Numbers of juvenile steelhead declined during the summer of 1989, with the largest decrease occurring in the lower lagoon. Size-class population estimates indicated that most steelhead were yearlings and few steelhead were young-of-the-year or two years of age or older.

Growth was determined monthly for young-of-the-year and yearling steelhead by using length frequency data. Juvenile steelhead growth was greatest in 1989; young-of-the-year steelhead exhibited the greatest growth of the two age classes for both years. Comparisons of steelhead growth to other riverine systems showed that fish reared in the lagoon obtained better growth.

Food habits varied with region of the lagoon and year, and juvenile steelhead generally exhibited a benthic feeding strategy. The major food items consumed by number were Corophium sp., aquatic dipterans, trichopteran larvae, isopods, and ephemeropteran larvae. In both years, highly significant differences occurred in diet between regions of the lagoon; fish from the lower lagoon ate primarily Corophium sp., while fish from the upper lagoon ate primarily trichopteran larvae. In 1989, a highly significant difference was found

between the mean number of major food items ingested by fish less than 100 mm and fish greater than or equal to 100 mm in the upper lagoon region; smaller fish ate primarily Corophium sp., while the larger fish ate primarily trichopteran larvae.

In conjunction with the fisheries work, water quality measurements showed that 1989 had more saltwater overwash and a less variable diel water temperature regime.

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INTRODUCTION

The steelhead (Oncorynchus mykiss) is the most widespread anadromous salmonid in the Pacific Southwest Region and is indigenous to the Pacific Ocean from northern Mexico to Alaska (Barnhart 1986). In addition, this specie shows the most variation in life history strategy regarding freshwater rearing and migration patterns of any anadromous salmonid (Barnhart 1986).

The Mattole River is one of many California drainages that closes off at the mouth to form a coastal lagoon because of low summer flow and long-shore ocean currents. This dynamic phenomenon also occurs in Waddell Creek (Shapovalov and Taft 1954), Big Lagoon (Joseph 1958), and Redwood Creek (Hofstra 1983). After closure, fish emigrating as smolts or adults may become trapped in the lagoon and are forced to rear there during the summer.

Juvenile steelhead using the estuary or lagoon as a rearing area respond to several different factors upstream including: low water flow (Burns 1971), large water temperature fluctuations (Shapovalov and Taft 1954; Wagner 1974), chronic turbidity (Sigler et al. 1984), poor food abundance upstream (Shapovalov and Taft 1954; Chapman 1966), chemical factors (e.g., low oxygen) and increased photoperiod (Shapovalov and Taft 1954; Wagner 1974).

The diet of juvenile steelhead in the lagoon can vary seasonally and between freshwater and brackish-water type areas. During freshwater residence, the main items in the juvenile steelhead's diet include aquatic stages of terrestrial and mature terrestrial insects including: ephemeropterans, dipterans, and trichopterans (Shapovalov and Taft 1954; Royal 1972; Fite 1973; Hiss 1984; Eggers 1987). Steelhead residing in a brackish environment feed on crustaceans such as Corophium sp. (Shapovalov and Taft 1954;

Simenstad 1983; Barnes 1984; Salamunovich 1987), mysid shrimp (Simenstad et al. 1982; Simenstad 1983), and isopods (Needham 1940).

River mouth closure results in the lagoon becoming a nutrient trap, usually resulting in greater productivity and better fish growth (Simenstad et al. 1982). However, Young (1987) and Barnhart et al. (1988) have studied juvenile chinook salmon (O. tshawytscha) in the Mattole River lagoon and demonstrated that even though greater overall productivity may occur, growth of this species can decrease during the warmer months of summer and survival can be low. Juvenile steelhead rearing in the Mattole River lagoon have not been studied in detail by previous investigators and so were the focus of this study.

The following objectives were set forth to provide additional information regarding the importance of this small coastal lagoon as a native steelhead rearing area: (1) determine timing and relative abundance of juveniles migrating into the lagoon; (2) monitor the steelhead population size in the lagoon; (3) determine growth and age class composition of juvenile steelhead in the lagoon; (4) determine spatial and temporal feeding habits of juvenile steelhead in the lagoon; (5) monitor the water quality of the lagoon.

STUDY SITE

The Mattole River basin is located approximately 60 km south of Eureka, California (Figure 1). From its headwaters, the river flows in a northwesterly direction for approximately 105 km before entering the Pacific Ocean at Petrolia. The watershed is approximately 785 km^2 in area and contains 74 tributaries (Barnhart and Young 1985). The climate of this region is characterized as being humid mesothermal with heavy winter rains and summertime coastal fog (California Department of Water Resources 1973). River flow historically ranged from 0.6 to 2,548 cubic meters per second at the Petrolia gauging station (California Department of Water Resources 1973).

The fishery resources of the Mattole River basin have been affected by poor land practices (Barnhart and Young 1985). Logged areas were not replanted and as a result grazing land superseded forested areas. In addition, the land is geologically unstable and susceptible to slumping, erosion and landslides (Barnhart and Young 1985).

During summer, river flow usually decreases enough to allow sand transported by the ocean to accumulate at the mouth of the river forming a berm that separates the river from the ocean and forms a lagoon (Young 1987; Barnes 1984). After closure, lagoon water depth increases until outward seepage through the berm equals that of the river flow into the lagoon. High and low tides also affect the water level in the lagoon, depending on the berm height and weather patterns, by adding saltwater or decreasing the amount of seepage through the spit (Barnhart and Zedonis 1989). Eventually fall rains increase the river flow enough to break open the lagoon. At lagoon formation, emigrating salmonids become trapped (Young 1987; Barnhart and Busby 1986).

Other aquatic inhabitants of the lagoon included threespine stickleback (<u>Gasterosteus aculeatus</u>), Pacific staghorn sculpin (<u>Leptocottus armatus</u>), prickly sculpin (<u>Cottus asper</u>), coast range sculpin (<u>C. aleuticus</u>), Pacific lamprey (<u>Lampetra tridentata</u>),

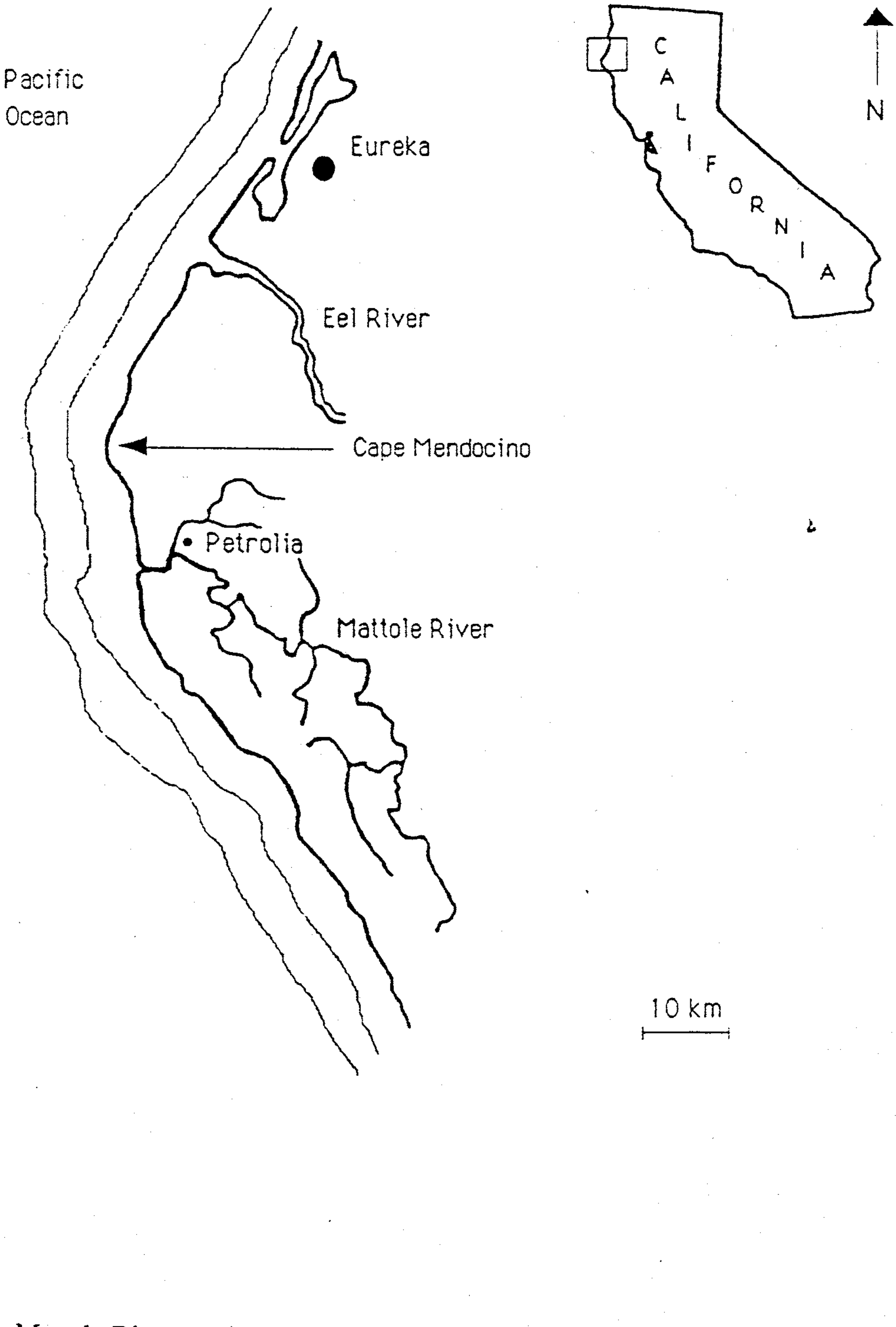


Figure 1. Mattole River Basin

starry flounder (Platichthys stellatus), northern rough skinned newt (Taricha granulosa) and western pond turtle (Clemmys marmorata).

Avian inhabitants such as the great egret (Casmerodius albus), common merganser (Mergus merganser), belted kingfisher (Megaceryle alcyon), great blue heron (Ardea herodias), and terns (Sterna sp.) were commonly observed in the lagoon and were potential predators of salmonids and other fish in the lagoon. A more complete list of vertebrates inhabiting the lagoon area is given in Barnhart et al. (1988).

The lower region of the lagoon has a predominantly sand substrate, with a mixture of boulders along the eastern shoreline, and it also has the greatest depth. The middle and upper lagoon regions have a mostly homogeneous substrate composed of rubble, gravel, sand and silt with a few boulders along the north bank. Water depths vary, and the few deep pools are associated with boulders or woody debris. The north end of the middle and upper regions of the lagoon also have overhanging riparian and submerged vegetation. After lagoon formation, the lower region often develops a thick mat of filamentous algae on the bottom (Young 1987; Barnhart and Busby 1986; Barnhart and Zedonis 1989).

MATERIALS AND METHODS

Juvenile Steelhead Migration

Migration patterns of juvenile steelhead were determined with a downstream migrant fyke trap placed in the lower Mattole River in both 1988 and 1989. The trap mouth was 1.8 m high and 2.4 m wide (mesh size 6.4 mm) and supported with an iron pipe frame. The 7.6 m long nylon net terminated with two screened high-profile live boxes positioned in tandem. Trapping sites were choosen immediately below low gradient riffles and positioned in the center of the channel.

In 1988, and initially in 1989, the trap was placed 4.5 kilometers upstream of the river mouth. In 1988, the trap was located at this site for the entire trapping season. In 1989, the trap was moved from the south channel (Site 1), where it fished from April 30 to May 14, to the north channel (Site 2) where there was greater flow. On July 18, the trap was moved down-stream 0.5 km to trap the entire river and remained there until October 20 (Site 3). Captured fish were anesthetized with Tricaine Methanesulfonate (MS-222), and a subsample of up to 100 fish of each age class was chosen randomly and fork-length (FL) measured to the nearest millimeter. When this condition was met, remaining fish were subjectively aged, counted and released downstream. Fish were placed into one of two age categories: young-of-the-year (YOY), which had been hatched the previous spring; 1+ and older fish, which were fish that had been in the river system for at least one year.

From April to early June, length frequency distributions of YOY and 1+ fish showed no overlap. However, because an overlap in length distribution developed in subsequent months, these age classes were separated by using the following length values: 85 mm from mid-June to mid-July, 90 mm from mid-July to mid-August, 95 mm from mid-August to mid-September, 100 mm from mid-September to mid-October, and 105 mm for the rest of October. Trapping was carried out from evening until early morning (approx. 12 hr), with the exception of June 21, 1989, when the trap was fished from 1100 to 1700 hrs to determine if movement of juvenile salmonids occurred during daylight.

Modifications to the trapping operation were necessary so that the trap would effectively capture down-migrating salmonids. One modification, which was used in both years, was the installation of wingwalls built of redwood weir panels with horizontal slats (2 inch spacing between slats) on both sides of the trap extending to each bank. Steel fence posts were driven into the stream bed to support the weir panels. On the upstream side of the panels, a 6 mm poly-ethylene mesh was placed along the entire wing-wall extending to the bottom to prevent fish from going through the large spacing between the horizontal slats on the weir panels. Excess polyethylene mesh that was located on the end of the innermost weir panels was allowed to enter into the fyke net on both sides, thereby blocking fish passage through the small gap between the end weir panel and the trap frame. Gravel was placed on the mesh at the base of the weir panels to prevent fish from going under the wingwalls. In time, these panels became sealed with organic debris forcing additional water through the trap. These modifications permitted 100 percent of the river to be trapped and presumably the capture of all down-migrating salmonids.

Another modification was the installation of weir panels across the channel 100 meters upstream of the trap to reduce the amount of algae entering the trap. From late April to early June, 1989, trapping became difficult because large amounts of filamentous green algae drifted downstream, which clogged the net and trap boxes often resulting in mortality of juvenile salmonids. Drifting algae decreased markedly by mid-June and the weir panels were removed on June 16. Unlike the modifications made to the immediate area of the trap, the weir panels for collecting algae did not span the entire river channel, and probably did not affect migrating fish.

Lagoon Fish Population Estimation

In both years, a 54.7 m x 4.8 m beach seine of 6.4 mm mesh size was deployed by use of a 4.3 m aluminum boat powered by a 25 horsepower outboard motor in both the upper and lower regions of the lagoon. Juvenile steelhead population estimates were conducted immediately after lagoon formation which occurred July 21 in 1988 and August 4 in 1989.

Prior to beach seining in the upper lagoon region, snorkeling surveys were used to locate areas of greatest fish abundance; seining locations in the lower lagoon region were selected along the spit where boulders were absent (Figure 2). Juvenile steelhead caught in the net were transferred to a holding pen or buckets, and portions of these fish were anesthetized with MS-222 prior to processing. Processed fish were allowed to recover before being released.

A corralling technique where fish were herded into the seine was used successfully to sample the upper lagoon region. The net was set across the lagoon with a stationary end on shore and the rest of the net was let out of the bow of the boat. Excess net was run upstream along the far bank, often several meters. This method of capture required a person(s) to enter the water upstream (approximately 50 meters) from the netting location. The person(s) in the water, termed "scarer(s)", were instructed to create surface disturbance as they approached the net to direct fish towards the net. When the "scarers" approached the net, the boat-end of the net was slowly brought back to the near shore, with the scarers still creating surface disturbance at the mouth of the net to prevent fish escape. Because netting operations in the upper lagoon were often in areas of coarse substrate (i.e., cobble and boulder), it was often necessary to have a person available to get the net free of hang-ups.

Monthly population estimates were made by mark and recapture techniques and calculated by using the Adjusted Petersen estimate (Ricker 1975). The equations used to

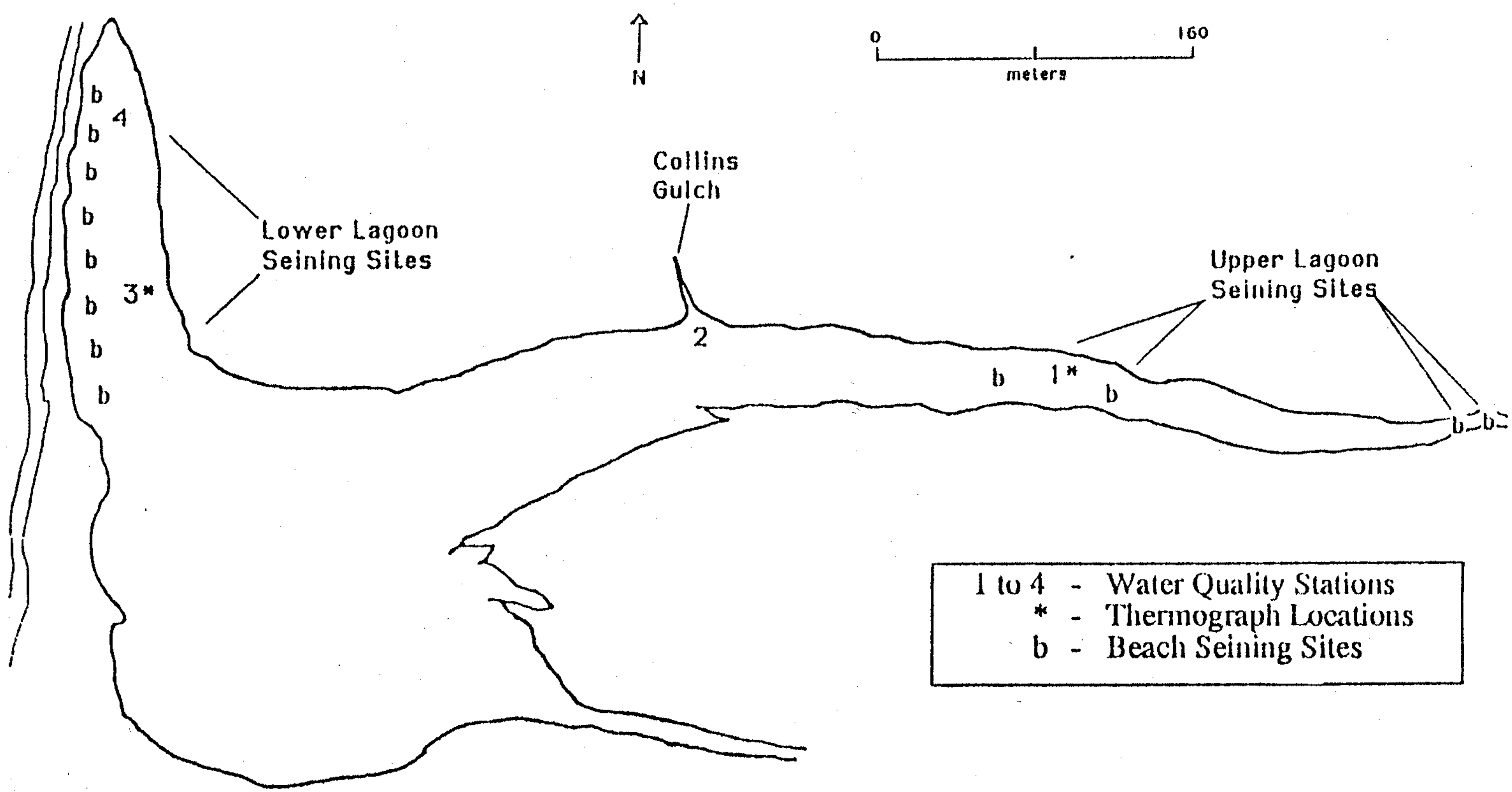


Figure 2. Mattole River Lagoon Showing Upper and Lower Beach Seining Sites, Thermograph Locations, and Water Quality Stations.

calculate the estimated population size (N*), variance (v*), and the 95% confidence interval (CI) were:

$$N^* = \frac{(M+1)(C+1)}{R+1},$$

$$v^* = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)},$$

and $CI = N^* \pm 1.96\, v^{*\,1/2}$,

where M is the number of marked fish, C is the number of fish captured in the sample, and R is the number of marked fish which have been recaptured in the sample. Confidence intervals were determined using a normal distribution (Seber 1982).

For the mark and recapture population estimator to be valid, there were six assumptions or conditions that were essential (Ricker 1975):

1. Marked and unmarked fish must suffer the same natural mortality.
2. Marked and unmarked fish are equally vulnerable to the sampling gear.
3. Fish marked must retain their mark for as long as the censusing period lasts.
4. Marked fish must become randomly distributed in the population.
5. All marks are recognized and reported upon recovery.
6. The population is closed during the time the recoveries are being made.

In both years, population estimates for the upper and lower lagoon regions were calculated separately, then added together to give an estimate of total fish. Confidence intervals for entire lagoon population estimates were determined by adding variance values. Size-class population estimates were attempted in 1989 (e.g., fish from 0 to 90 mm, 91 to 159 mm, and > 159 mm). Catch per unit effort (CPUE) from lower lagoon beach seining was used as an indicator of relative abundance of fish using this region of the lagoon; one unit of effort was equal to one net set. To help ensure that equal effort was applied at each sampling date, the beach seine was regularly checked for holes and tears and repaired. A Panjet dental injection gun (F.H. Wright, Dental Manufacturing Co., Kingsway West, Dundee, Scotland) was used to mark the fish with National Fast Blue, a water soluble dye. All fish that were marked were measured (FL). A white plastic pail lid, inscribed with size-class ranges, facilitated fish size-class separation and also allowed for quick mark identification.

On fish marking dates, a full day (approx. eight hours) and the recapture dates, a half day (approx. four hours) were the effort allotted for each region of the lagoon. During these time periods, I attempted to set as many nets as possible. Factors influencing the efficiency of the netting operation included: the amount of available man power; the number of fish captured; and the abundance of algae, which clogged the net making net retrieval difficult and time consuming.

Fish were marked on different fins or fin lobes for each consecutive population estimate in 1988, but in 1989 the same mark was used for August and September estimates. Additionally, in 1989, a different fin was marked for each lagoon region, except for the October estimate when the same ventral fin was used. Consequently, intermixing of fish from both regions of the lagoon could be monitored during the estimate period. Marking was performed for two consecutive days and fish were allowed to randomly disperse. On the fourth day, fish were recaptured by seining. Deviation from this sampling scheme occurred in October, 1988, when four days separated marking and recapture dates. To prevent catching fish more than once on the recapture date, fish were held in a live box until seining was complete.

Mortality, due to the marking procedure, was determined by holding a sample of fish for at least 24 hours in a live box placed in the upper lagoon. Fish selected for this

1989 test were chosen randomly in the late afternoon from nets set in the upper lagoon. By testing fish at this time of the day, I was assured of the most unfavorable water temperatures and high levels of stress caused by prolonged crowding, which would provide an exaggerated mortality rate. Mortality rates were determined in August and September, but not in October because water temperatures were much cooler and handling mortality should have decreased.

<u>Steelhead Growth and Age-Class Composition</u>

Steelhead growth was calculated approximately every four weeks using length frequency data (Macdonald and Pitcher 1979) usually collected during the marking days for the population estimates. The only exception to this occurred on July 8, 1989, when fish length frequency data from beach seined fish and fyke net trapped fish were pooled. The data were analyzed by the computer program MIX (Version 3.0; Macdonald and Green 1988). A log-normal distribution was used. Histograms were developed using five millimeter grouping intervals. MIX analyzes histograms as mixtures of statistical distributions by the maximum-likelihood estimation method, that is, MIX finds a set of overlapping component distributions that gives the best fit (Macdonald and Green 1988). From the resulting fit, a goodness-of-fit chi-square statistic and an associated P-value were given. For this study, the goodness-of-fit value was given one of two ratings; "poor" ($P < 0.05$) or "good" ($P \geq 0.05$). Although a histogram may have received a poor fit rating, this did not necessarily mean the estimated statistics were not representative of population statistics. This only meant that the difference between expected and observed counts of the distributions determined from MIX and the actual data over all intervals was large enough, given the degrees of freedom, to result in a small P-value (Macdonald and Green 1988).

Juvenile steelhead age class composition in the lagoon was primarily of two age classes, YOY and 1+ fish; older fish (2+ and older) made up a very small percentage of the catch. Scale samples were taken from juvenile steelhead during each netting operation to validate that the modes developed from the length frequency data were accurate. Scale samples were taken above the lateral line and immediately below the dorsal fin after the mucus layer was removed from this area with a knife. Non-regenerated scales were then mounted between two glass slides for ageing. In addition to growth analysis, MIX estimated proportions of each age class that were captured for each sample date.

Steelhead Food Habits

For both years, I attempted to acquire 15 YOY steelhead and 15 older steelhead for each sampling date at each of two lagoon locations. This goal was not always met. Sampling dates were nearly two weeks apart in 1988 and four weeks apart in 1989. Collection of stomach contents began in late August in 1988 and July in 1989, and terminated in late October in both years. Fish that were sacrificed. were randomly chosen, preserved immediately in 10 percent buffered formalin, and later transferred to 70 percent ethanol. The stomachs of fish longer than 90 mm were slit before preservation. Each stomach was examined separately for kinds and numbers of food items. Most organisms were only identified to order, but the more abundant crustaceans were identified to genus. The stomach contents were emptied into a petri dish, inspected under a dissecting microscope, and the contents analyzed using mean number and percent frequency of occurrence. Aquatic invertebrate identification was made possible by using Merritt and Cummins (1984), Usinger (1963), and a reference collection of Mattole River lagoon aquatic invertebrates collected and identified by a previous investigator (Busby 1991).

Because some stomachs had highly digested materials, hard parts of organisms were often used for identification. Trichopteran larvae were assumed to have been consumed if a larval case was present in the stomach. *Corophium* sp. were often identified from their frontal appendages - a pair represented one individual. Partially digested isopods were often identified by their large black eyes; two represented one individual. Dipteran larvae were often identified by a head capsule. Objects that could not be identified or were too digested were placed in an unidentified category. All terrestrials were lumped together into a miscellaneous terrestrial category. To give additional insight into feeding behavior, the presence of algae or pebbles in stomach contents was recorded.

Differences in the relative frequency of the average number of dominant food items consumed by juvenile steelhead were tested by using contingency table analysis as described by Crow (1981) and the G - test statistic (Sokal and Rohlf 1981). For each of the analyses, the null hypothesis (H_O) was that the relative frequency of the average number of dominant food items consumed were the same. A P value of less than 0.05 was determined to be a significant difference and a P value of less than 0.01 a highly significant difference. Tests for diet differences included: (1) between years for a region; (2) between regions for a year; (3) between size-classes for a region of the lagoon for a year (i.e., fish $<$ 100 mm or those $\geq$ 100 mm). To prevent observer bias, this length was arbitrarily chosen prior to analysis.

Lagoon Water Quality

In both years, two Ryan/Peabody Model J thermograph recorders were installed in the lagoon to measure diel temperature fluctuations; one in the lower lagoon (Station 3) and the other in the upper lagoon (Station 1) (Figure 2). In 1989, a third thermograph was placed at the downstream migrant trapping site (river kilometer 4.5). All thermographs were placed in shaded areas.

At four water quality stations (Figure 2), depth profiles of temperature, salinity, and conductivity were monitored using a Yellow Springs Instrument (YSI) Model 33 salinity-conductivity-temperature meter. A YSI Model 51B dissolved oxygen meter was used to obtain oxygen levels throughout the water column at 0.5 m increments. A Hach Model

CA-10 water quality kit and a Cole-Parmer Model 5941-00 pH meter were used to measure pH. Turbidity samples were taken back to the laboratory and measured with a Hach Model 2100A Turbidometer. Water quality station locations were the same in both years.

RESULTS

Juvenile Steelhead Migration

The fyke net trap was effective in capturing down-migrating juvenile steelhead in the lower Mattole River, especially when wing-walls were installed across the entire river. In 1988, 9007 YOY steelhead were captured in 27 nights of effort averaging 334 fish a night. In 1989, 11482 YOY steelhead were captured in 43 nights of effort averaging 267 fish a night. Of the steelhead captured, 98.0 percent in 1988 and 97.4 percent in 1989 were YOY fish (Table 1). The remaining fish captured had resided in the river system for at least one year and their numbers totaled 180 in 1988 and 311 in 1989. No fish larger than 160 mm (probably 2+ fish) were caught in 1988, but in 1989, nine fish between 161 and 212 mm were captured with four captured on the last trapping date, October 20; because of their low numbers, 2+ fish were combined with the 1+ category in Table 1.

Large numbers of YOY steelhead were captured after a freshet, immediately after the wing-walls were installed and when the trap was moved (Table 1). Freshets that resulted in increased numbers of fish entering the trap occurred on May 16 and June 10 in 1988, and on June 29, August 23, and September 30 in 1989. On July 15, 1988, wing-wall installation resulted in the capture of 911 YOY fish, whereas on the previous trapping date (July 12) only seven YOY fish were captured. After July 15, numbers of fish entering the trap decreased. From late August through October a resurgence of down-migrating YOY and 1+ fish occurred.

In 1989, wing-walls were installed twice and on both occasions increased numbers of YOY fish.were captured. On June 14, wing-wall installation resulted in the capture of 421 YOY fish, whereas on the previous trapping date (June 11) only 24 had been captured. On July 19, the trap was moved to a new site (Site 3) and wing-walls were installed

Table 1. Summary of Age-Class Composition and Size Range of Down-Migrating Juvenile Steelhead Captured with a Fyke Net Trap in the Lower Mattole River, California, April to October, 1988 and 1989.

Date	Number 0+	Number 1+	Size Range (FL- mm)	Remark
4/27/88	62	10	26-142	
5/3	27	1	37-65	a
5/12	273	2	28-103	a, b
5/16	1013	7		a
5/21	557	0	29-62	
5/28	195	1	28-114	
6/10	2310	11	32-98	
6/16	780	3	42-89	
6/23	16	0	43-65	
6/29	186	0	43-72	
7/8	79	0	38-62	
7/12	7	1	42-100	
7/15	911	2	43-112	c
7/22	145	0	41-69	
8/4	25	0	41-67	
8/11	55	5	44-138	
8/19	33	1	44-149	
8/27	135	23	40-158	
9/1	122	16	46-143	
9/8	521	33	53-149	
9/15	356	7	46-126	
9/22	335	24	53-150	
9/29	155	8	53-136	a
10/4	275	11	54-140	
10/11	238	2	54-16	a
10/17	138	4	53-119	
10/29	58	8	60-145	
Total	9007	180		

Date	Site	Number 0+	Number 1+	Size Range (FL-mm)	Remark
4/30/89	1	5	0	27-47	
5/14	2	34	1	46-81	
5/17	2	4	0	44-59	
5/21	2	3	0	48-64	
6/7	2	61	3	43-108	
6/8	2	24	0	43-64	
6/11	2	24	2	45-110	
6/14	2	421	2	46-117	c
6/16	2	769	21	49-146	
6/17	2	404	11	52-142	
6/19	2	652	11	48-128	
6/21	2	606	10	53-125	
6/22	2	649	8		
6/26	2	641	3	46-133	
6/28	2	453	1	42-87	
6/29	2	901	4	41-149	a
7/3	2	362	21	45-156	
7/8	2	211	3	52-93	
7/11	2	177	7	53-177	
7/14	2	195	7	52-126	
7/17	2	21	2	57-130	
7/18	2	77	0	53-83	
7/19	3	2191	19	51-138	c
7/23	3	756	13	55-125	
7/25	3	537	12	51-96	
7/27	3	258	4	57-101	
7/30	3	194	10	55-97	
8/1	3	162	11	57-110	
8/4	3	144	3	55-99	
8/6	3	78	3	60-102	
8/8	3	67	1	58-93	
8/11	3	19	1	58-114	
8/23	3	55	5	62-114	a
8/27	3	25	7	61-164	
8/29	3	17	1	60-100	
9/1	3	33	9	48-153	
9/5	3	51	26	61-152	
9/13	3	26	5	67-161	
9/19	3	40	11	55-155	a
9/26	3	31	13	62-165	
9/30	3	83	12	61-125	a
10/10	3	9	6	74-212	
10/20	3	12	22	79-197	
Total		11482	311		

a - Freshet occurred in the previous week

b - Trap boxes dumped over

c - Wing-walls were installed

resulting in the capture of 2191 YOY fish. On the previous trapping date (July 18) only 77 fish had been captured. In 1989, a late resurgence of YOY migrants did not occur.

Other fish captured in the downstream trap included juvenile chinook salmon, juvenile coho salmon (O. kisutch), adult lamprey and ammocoete larvae, sculpins, one green sunfish (Lepomis cyanellus), and threespine sticklebacks (Barnhart and Zedonis 1990).

In 1989, fish mortality associated with downstream migrant trapping was attributed to drifting algae, which clogged the trap boxes and fyke net resulting in suffocated fish. Placement of weir panels above the trap site in the river channel intercepted a small portion of the drifting algae during April and May when green algae abundance was high. When there was a decrease in algae, salmonid mortality associated with the trap boxes dropped from 48.4 percent (n = 64) on May 17 to 3.7 percent (n = 80) on June 7, 1989. During the rest of the trapping period few juvenile salmonid mortalities occurred. Choosing a trap location below a large slack water area, which acted as a settling area for drifting organic debris, reduced the amount of algae entering the trap. In 1988, algae abundance was not as great as in 1989 and mortality of salmonids was insignificant.

Lagoon Fish Abundance and Distribution

During 1988, the number of juvenile steelhead in the lagoon remained fairly constant during the monitoring period, and a spatial and temporal shift in distribution from the lower lagoon to the upper lagoon occurred (Figure 3). In July, the population size of the entire lagoon was estimated to be 23623 fish, and regional estimates indicated that about 16487 fish were in the lower lagoon and 7136 fish were in the upper region. By August, the entire population size was 24208, and regional estimates indicated that 14746 fish were in the upper lagoon and 9462 fish were in the lower lagoon. By September, 26787 fish were located in the upper lagoon, and only 703 fish were in the lower lagoon. Although

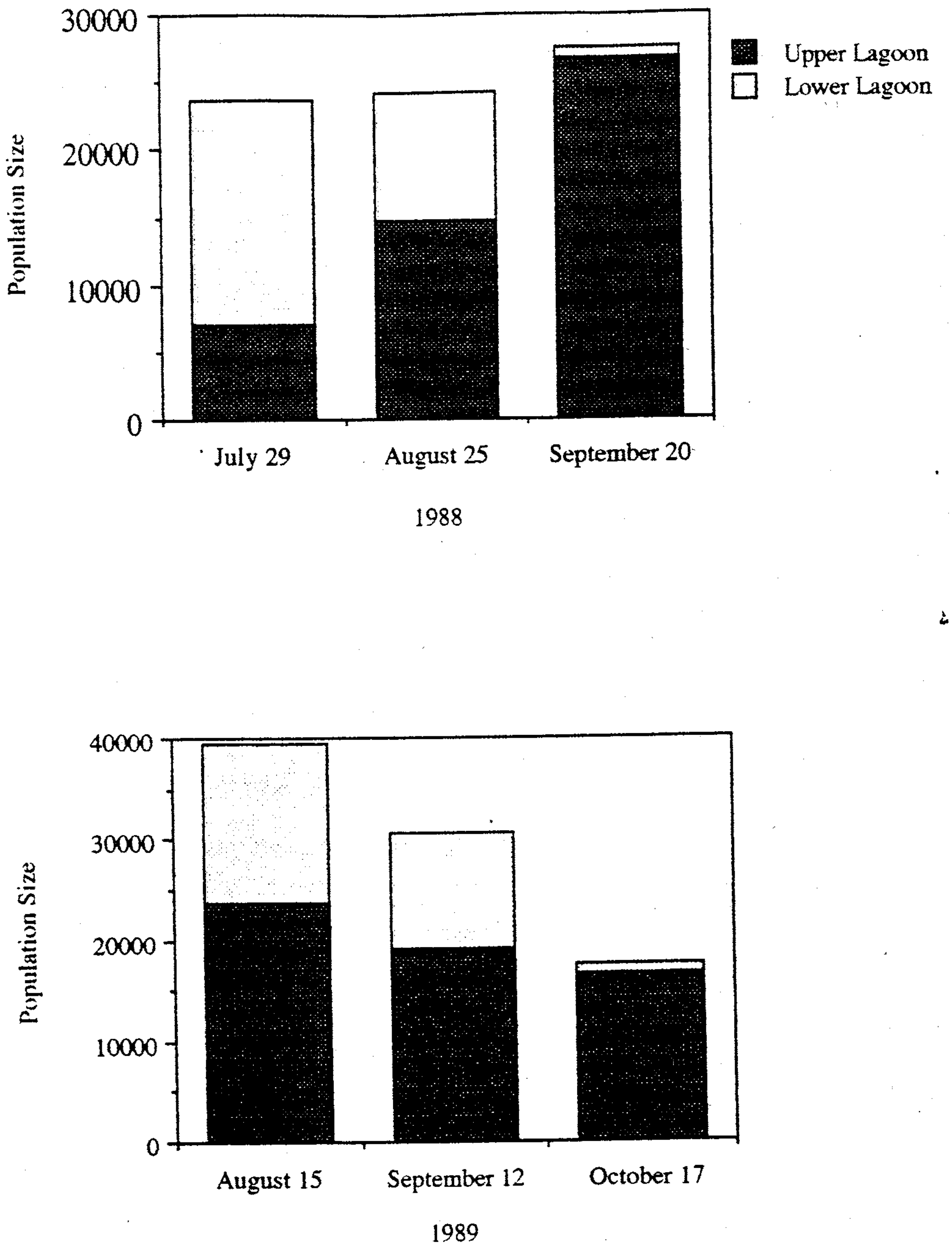


Figure 3. Population Size of Juvenile Steelhead in Two Different Regions of the Mattole River Lagoon, California, 1988 and 1989, Using the Petersen Single Census Method.

not shown in Figure 3, the population size in October was estimated at 185582 fish, and only 465 of these were in the lower lagoon. The October estimate probably did not meet all of the assumptions of the mark/recapture model, and as a consequence, the estimate was high (see Discussion). Refer to Appendix A for confidence intervals, fin mark location, number of seine hauls, and number of fish marked, captured, and recaptured.

In addition to population estimates that indicated a decrease in the number of fish in the lower lagoon, CPUE values, calculated from marking day effort, indicated decreasing numbers of juvenile steelhead using the lower lagoon: 189 in July, 80 in August, 17 in September, and 6 in October.

During 1989, the number of fish in the lagoon decreased monthly in both regions, but the lower lagoon region showed a more pronounced reduction in fish numbers (Figure 3). On August 15, the population size of the entire lagoon was estimated at 39519 fish. Of this total, the upper lagoon region contained 23784 fish and the lower lagoon 15735 fish. The size-class breakdown for lagoon regions indicated that by number, fish from 51 to 90 mm were the most abundant in the upper lagoon and fish from 91 to 159 were most the most abundant in the lower lagoon (Figure 4). In the upper lagoon, 15630 fish were from 51 to 90 mm, 8069 fish were from 91 to 159 mm, and 85 fish were larger than 159 mm. In the lower lagoon, 2358 fish were from 51 to 90 mm, 13181 fish were from 91 to 159 mm, and 196 fish larger than 159 mm. Refer to Appendix B for confidence intervals, fin mark location, number of seine hauls, and number of marked, captured, and recaptured fish.

The September population estimate indicated a decline of nearly 9000 steelhead from the August census. Of the 30653 fish present, 19215 fish were in the upper lagoon region and the remaining 11438 fish were in the lower lagoon region. Size-class estimates revealed that fish from 100 to 159 mm were the most abundant size-class in both lagoon regions (Figure 5). In the upper lagoon 6673 fish were from 65 to 99 mm, 11607 fish

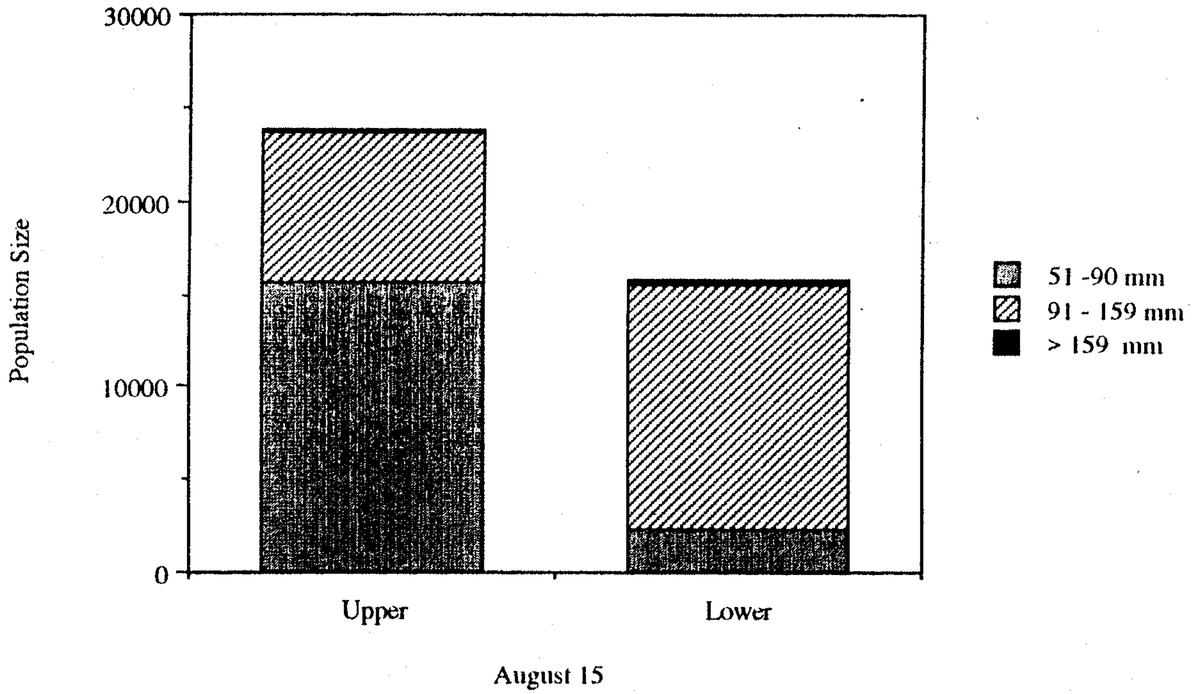


Figure 4. Population Size of Three Different Size-Classes of Juvenile Steelhead in Two Different Regions of the Mattole River Lagoon, California, August 15,1989.

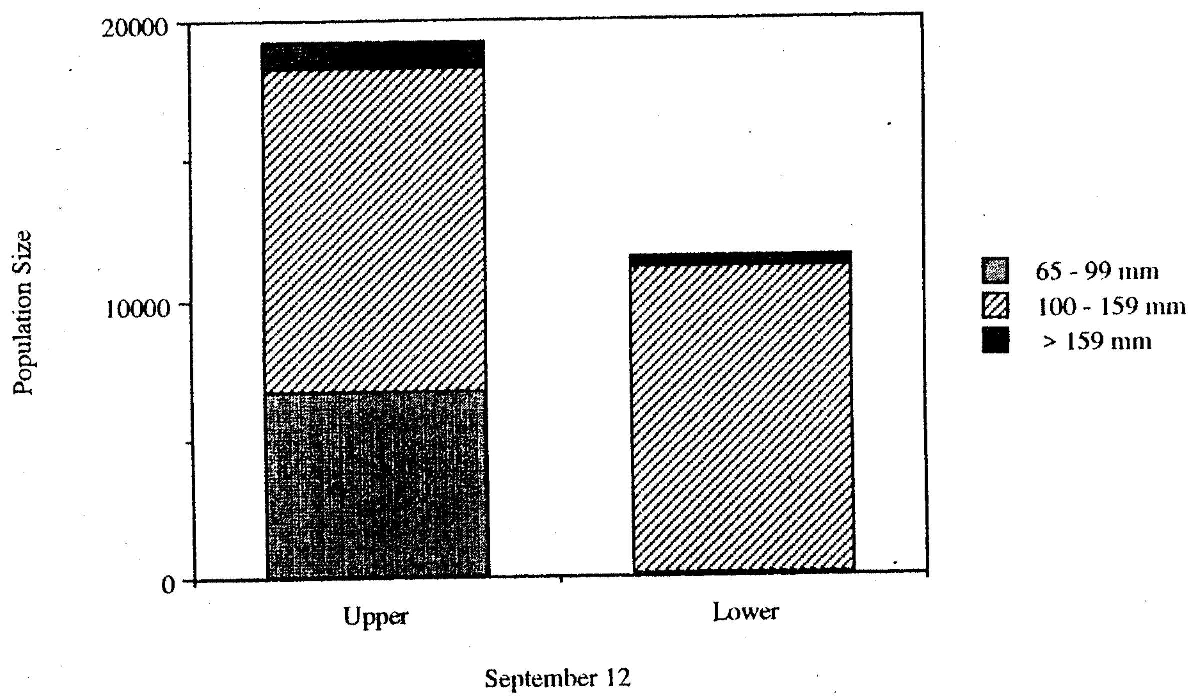


Figure 5. Population Size of Three Different Size-Classes of Juvenile Steelhead in Two Different Regions of the Mattole River Lagoon, California, September 12, 1989.

were from 100 to 159 mm. and 935 fish were larger than 159 mm. In the lower lagoon 80 fish from 65 to 99 mm, 11012 fish were from 100 to 159 mm, and 346 fish were larger than 159 mm. Refer to Appendix C for confidence intervals, fin mark location, number of seine hauls, and number of marked, captured, and recaptured fish.

The October population estimate indicated a decline of 13000 fish from the September census. Of the 17484 fish present, 16653 fish were in the upper lagoon region and 831 fish were in the lower lagoon region. Size-class estimates indicated that fish from 83 to 169 mm were the most abundant in both regions (Figure 6). In the upper lagoon, 16007 fish were from 83 to 169 mm and 500 fish were larger than 169 mm, while in the lower lagoon, 810 fish were from 83 to 169 mm and 21 were greater than 169 mm. Refer to Appendix D for confidence intervals, fin mark location, number of seine hauls, and number of marked, captured, and recaptured fish.

Similar to 1988, CPUE values calculated from marking day effort indicated monthly decreases in numbers of steelhead using the lower lagoon; 191 in August, 80 in September, and 11 in October. Decreasing CPUE values with time for salmonids in the lower region of the Mattole River lagoon were also reported by Young (1987) in 1985, Barnhart and Busby (1986) in 1986, and Barnhart et al. (1988) in 1987.

Some intermixing of juvenile steelhead between upper and lower lagoon regions did occur. During the August 1989 population estimate three fish, marked in the upper lagoon, were recaptured twenty-four hours later in the lower lagoon. Alternately, three fish, marked in the lower lagoon, were recaptured forty-eight hours later in the upper lagoon. During the September 1989 estimate, fish movement was more pronounced, five juvenile steelhead, marked in the upper lagoon, were recaptured twenty-four hours later in the lower lagoon. Alternately, 124 juvenile steelhead, marked in the lower lagoon, were recaptured forty-eight hours later in the upper lagoon.

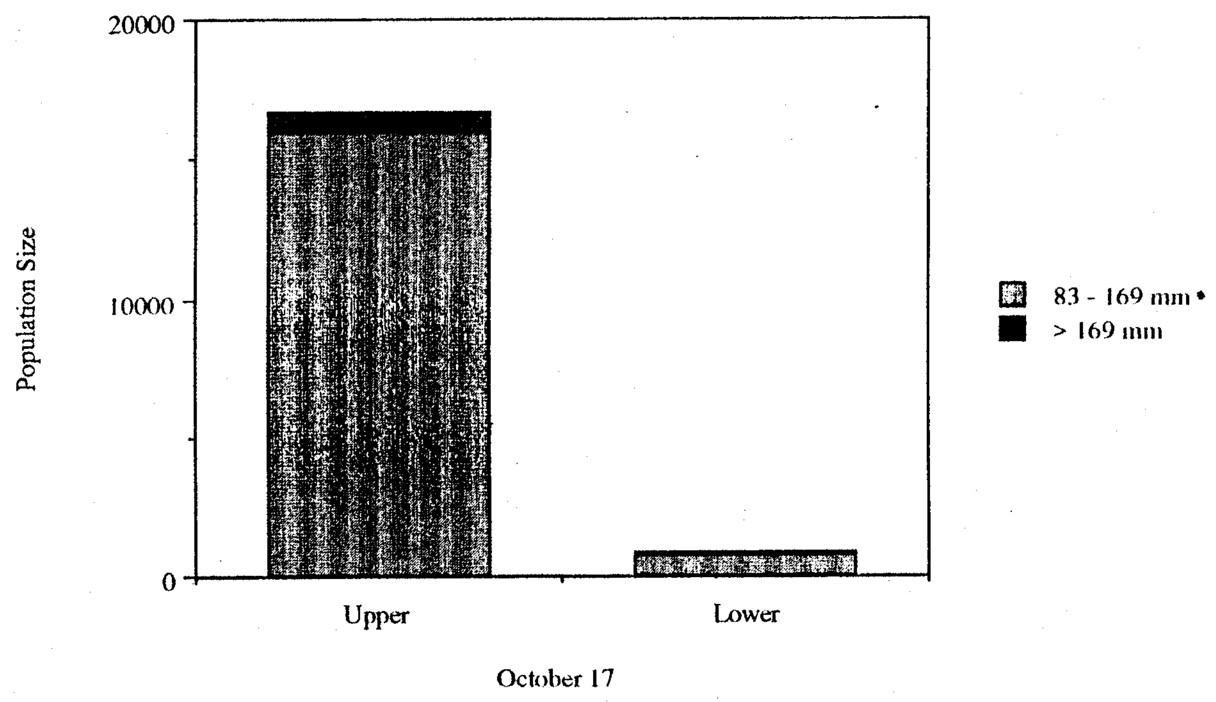


Figure 6. Population Size of Two Different Size-Classes of Juvenile Steelhead in Two Different Regions of the Mattole River Lagoon, California, October 17, 1989.

Mortality of juvenile steelhead, due to the marking procedure, was only determined in 1989, and it appeared to be correlated with water temperature. On August 13, steelhead mortality was 2.1 percent when 94 steelhead of various age classes were held for 36 hours with a maximum water temperature of 23.3 °C. On September 10, 56 fish were held for 24 hours and no mortality occurred when the maximum water temperature of 19.5 °C was reached. The mortality rate in October was not determined but was probably low because of the cooler water temperatures (maximum of 15 °C).

Steelhead Age-Class Composition

In 1988, a steady decline in the percentage of YOY steelhead captured by beach seining occurred from July to September, then an increase occurred in October (Figure 7). This increase in October was corroborated by downstream migrant trapping data, which indicated a resurgence of migrating YOY steelhead. The percentage of 1+ fish captured increased from July to September and then decreased in October. Numbers of 2+ and older fish captured were greatest in August and September, and represented less than 1.0 percent of the catch. Standard error values associated with age class proportions are given in Appendix E.

Similar to 1988, the percentage of YOY steelhead beach seined in 1989 decreased with time and the percentage of 1+ fish steadily increased (Figure 7). Contrary to 1988, no increase in YOY fish numbers was recorded in October, and this was also corroborated by downstream migrant trapping data. Numbers of 2+ fish captured were greatest in July and accounted for approximately 1.0 percent of the catch. Standard error values associated with age class proportions are given in Appendix J.

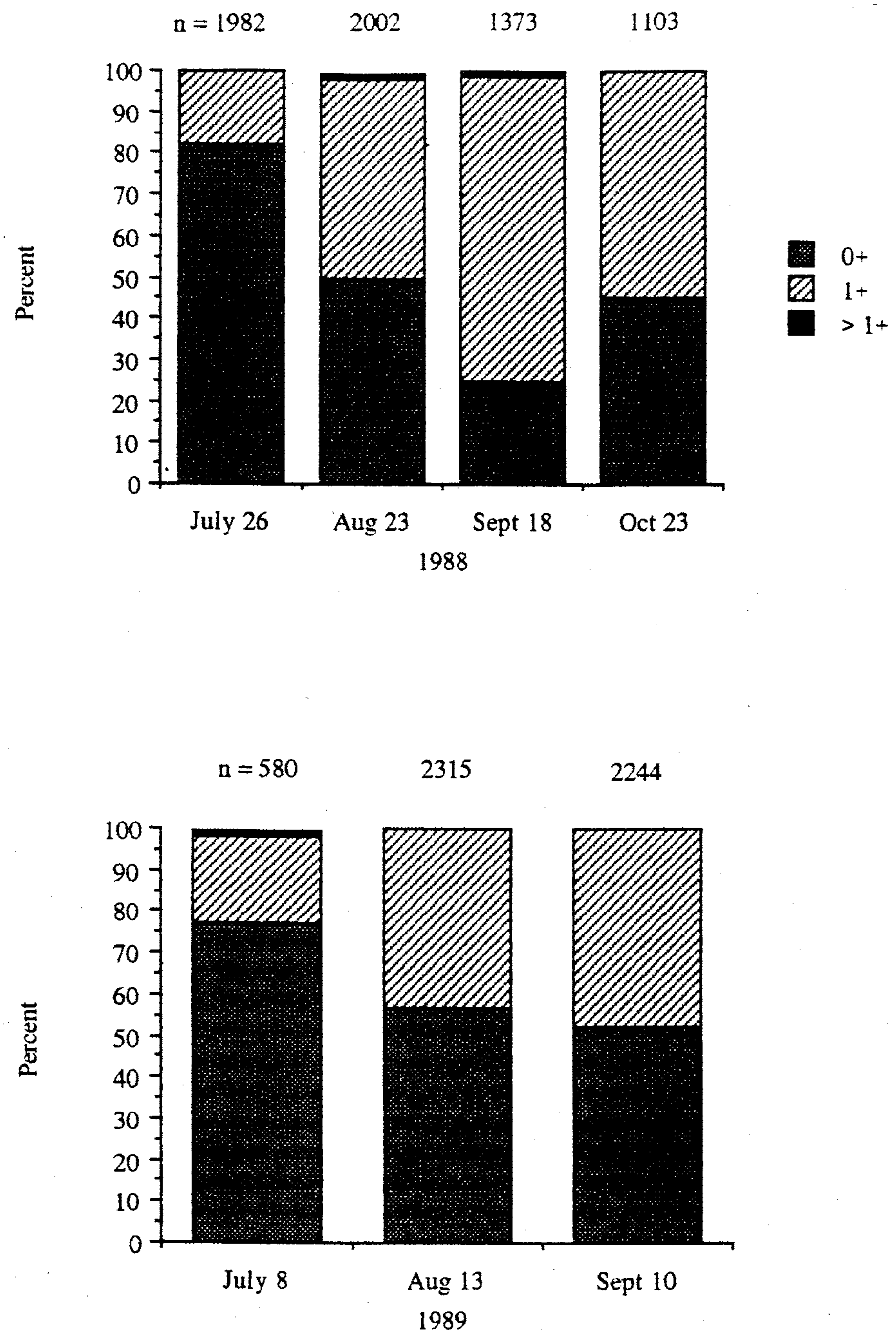


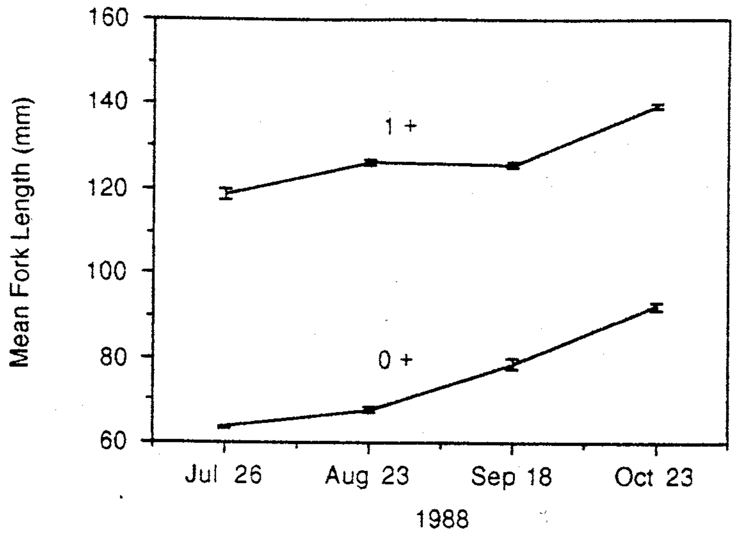
Figure 7. Age Class Composition of Juvenile Steelhead Beach Seined in the Mattole River Estuary/Lagoon, California, in 1988 and 1989. Values Determined from Length Frequency.Data (n is Sample Size).

Steelhead Growth

In 1988, the growth rate of juvenile steelhead was greater for YOY fish compared to 1+ fish from July to October (Figure 8). From July 26 to October 23, mean length increased 28.6 mm for YOY fish and 21.2 mm for 1+ fish. Growth of both age classes was least from July 26 to August 23. During this four week period, yearlings grew 7.5 mm and YOY fish grew 4.0 mm. From August 23 to September 18, an increase in length of 11.0 mm was exhibited by YOY fish, while a 0.5 mm decrease in length was exhibited by 1+ fish. From September 18 to October 23, an increase in mean length of 13.6 mm was exhibited by YOY fish and 13.9 mm by 1+ steelhead.

From length frequency data collected on the marking dates, and analyzed by MIX, goodness-of-fit ratings varied from month to month (Appendix E). On July 26, the mean length was 63.6 mm for YOY fish and 118.5 mm for 1+ fish and the goodness-of-fit chi-square statistic resulted in a poor fit (P = 0.0106). On August 23, the mean length was 67.7 mm for YOY fish and 126.3 for 1+ fish, and the goodness-of-fit chi-square statistic resulted in a good fit (P = 0.8196). On September 23, the mean length was 78.7 mm for YOY fish and 125.8 mm for 1+ fish, and the goodness-of-fit chi-square statistic resulted in an poor fit (P = 0.0003). Finally, on October 23, the mean fork-length was 92.3 mm for YOY fish and 139.7 mm for 1+ fish, and the goodness-of-fit chi-square statistic resulted in a good fit (P = 0.4104). Standard error values for mean fork-lengths are given in Appendix E. Length-frequency histograms from July to October are presented in Appendixes F, G, H, and I.

In 1989, the growth rate of juvenile steelhead was nearly constant for both age classes from July 8 to September 10, but as in 1988, YOY fish exhibited more growth; 32.8 mm compared to 16.8 mm for 1+ fish (Figure 8). From July 8 to August 13, the increase in mean length was 15.7 mm for YOY fish and 6.0 mm for 1+ fish. Increase in average fish length from August 13 to September 10 was 17.1 for YOY fish and 10.8 mm



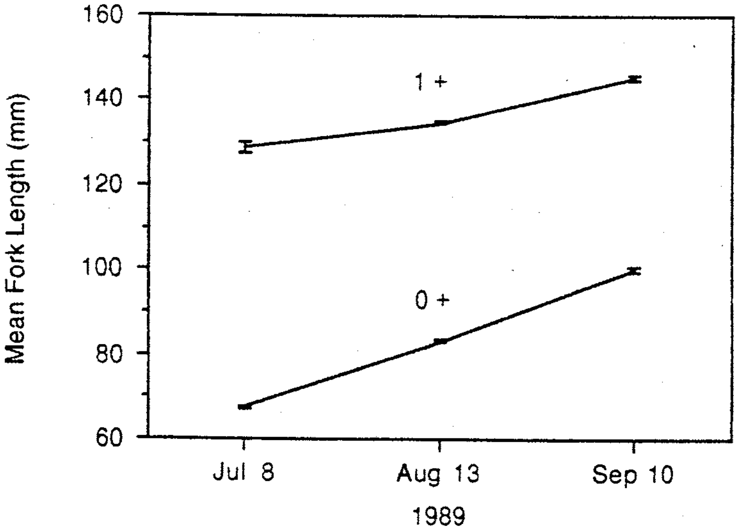


Figure 8. Mean Fork Lengths of Young-of-the-Year (0+) and Yearling (1+) Steelhead in the Mattole River Estuary/ Lagoon, California, 1988 and1989. Verticle Bars Represent Standard Error.

for 1+ fish. October growth rates were not estimated because the length frequency distribution indicated only one distinct mode (see Appendix N).

In 1989, similar to 1988, ratings for goodness-of-fit values varied from month to month (Appendix J). On July 8, mean fork-length was 67.4 mm for YOY fish and 128.7 mm for 1+ fish, and the goodness-of-fit chi-square statistic resulted in a poor fit (P = 0.0401). On August 13, mean fork-length was 83.1 mm for YOY and 134.7 mm for 1+ fish, and the goodness-of-fit chi-square statistic resulted in a poor fit (P = 0.0017). On September 10, mean fork-length was 100.2 mm for YOY fish and 145.5 for 1+ fish, and the goodness-of-fit chi-square statistic resulted in a good fit (P = 0.2451). Standard error values for mean fork-lengths are given in Appendix J. Length-frequency histograms for July to October are presented in Appendixes K, L, M, and N.

For comparative purposes, a list of juvenile steelhead mean fork-lengths for various northern California streams for various years in September are given in Table 2. From these data, it appears that the Mattole River lagoon is a favorable environment for juvenile steelhead growth.

Steelhead Food Habits

Mean number of food organisms and their percent frequency of occurrence in stomach contents by region of the lagoon are given in Appendix O for 1988 and Appendix P for 1989. Mean number of food organisms and their percent frequency of occcurrence in stomach contents for combined dates for a lagoon region for each year are presented in Appendix Q. Mean number and percent frequency of occcurrence of food items in stomach contents for two size-classes of juvenile steelhead for both lagoon regions are presented in Appendix R for 1988 and Appendix S for 1989.

In 1988, 179 stomach samples were collected over a two month period, from late August to late October. Of these, 128 samples were taken from the upper region and the

Table 2. Mean Fork Lengths of Juvenile Steelhead in September from Various Northern California Streams.

Source	Location	Year	Age	Length (mm)
Zedonis	Mattole River	1988	0	78.7
			1	125.8
		1989	0	100.2
			1	145.5
USFWS (1987a)	Upper Trinity River	1986	0	72
			1	113
USFWS (1987b)	Grass Valley Creek	1987	0	72
Pennington (1986)	Manzanita Creek	1974	0	70 - 80
Reeves (1979)	E. Fork of the N. Fork, Mad River	1977	0	61
Cross (1975)	Singley Creek	1969-1970	0	65
Burns (1971) [a]	N. Fork Caspar Creek	1967-1969	0	51 - 54
			1	108 - 123

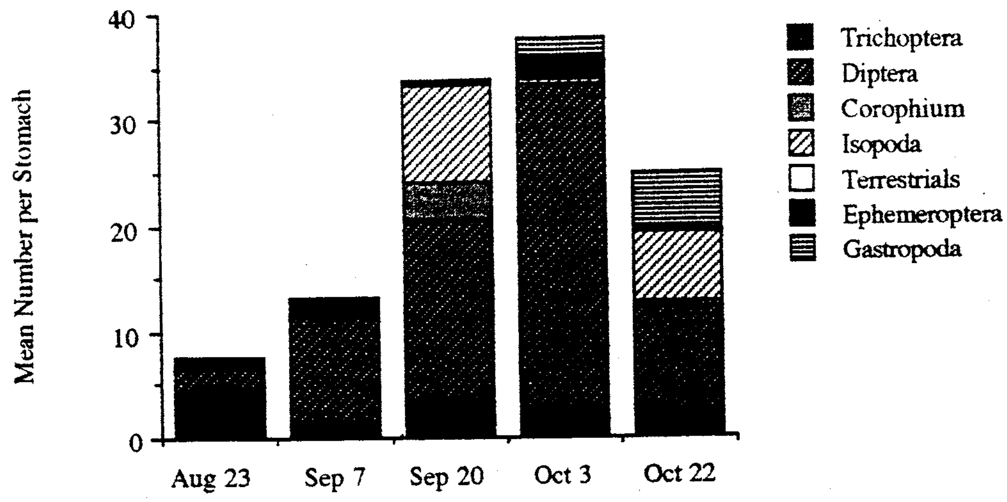
[a] - indicates October sampling period

remaining 51 samples were from the lower region. Fish from the upper lagoon region ate similar food items on all sampling dates, but the quantity and frequency of occurrence varied (Figure 9). In late August, Trichoptera was the dominant food item by number followed by aquatic Diptera, but Diptera occurred more frequently. Terrestrials and Ephemeroptera were observed in 20% of stomachs examined, but were not eaten in large numbers. Less important food items included: Corophium, plecopterans, coleopterans, hemipterans, water mites, nematodes and threespine sticklebacks. In addition, nearly 68% of fish stomach contents contained algae or pebbles, and 26% of stomachs had unidentifiable items and two stomachs were empty.

In early September, aquatic Diptera were the most abundant and common food item followed by Ephemeroptera and Trichoptera. Isopods (Gnorimosphaeroma oregoniensis) and terrestrials were among the least abundant food items, and no Corophium were present. Other food items that were represented in low numbers were plecopterans, coleopterans, hemipterans, gastropods, and water mites. Nearly 62% of stomachs contained algae or pebbles, and 41% had some unidentifiable items.

In late September, aquatic Diptera dominated by number followed by isopods, but isopods occurred more often. Trichoptera and Corophium were the next most important food items which were about equally abundant and common. Less important food items were: terrestrials, ephemeropterans, plecopterans, coleopterans, hemipterans, gastropods, gammarid amphipods (Eogammarus confervicolus), and nematodes. During this sampling date, only 14.3% of stomachs examined contained algae or pebbles, and 21% contained some unidentifiable items.

In early October, Diptera was the dominant food item by number and frequency of occurrence followed by Trichoptera and Ephemeroptera. Gastropods had a mean number value similar to Ephemeroptera, but had a much lower frequency of occurrence. Less important food items were Corophium, isopods, and terrestrials, plecopterans, coleop-



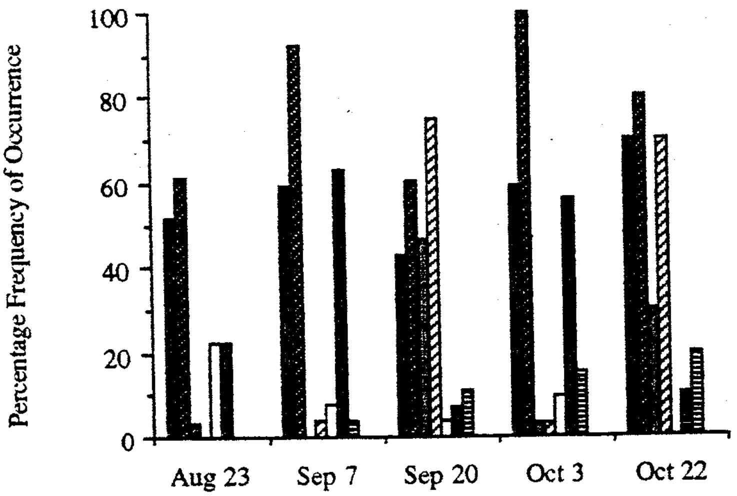


Figure 9. Mean Number and Frequency of Occurrence of Major Food Items from Juvenile Steelhead Stomach Contents Collected on Five Sampling Dates from August to October in the Upper Region of the Mattole River Lagoon, California, 1988.

terans, hemipterans, lepidopterans, ostracods, gastropods, water mites, and nematodes. Algae or pebbles were present in 21.9% of stomachs examined. In addition, 69% of stomach contents examined contained unidentifiable food items.

In late October, aquatic Diptera was the dominant food item by number and frequency of occurrence followed by isopods and Trichoptera. As in October, gastropods were present in relatively large numbers, but had a low frequency of occurrence. Corophium were consumed in low numbers as were Ephemeroptera, and no terrestrials were eaten. Other less abundant food items included coleopterans, and ostracods. Algae or pebbles were present in 30% of stomachs examined, and 40% of stomachs had unidentifiable food items.

Fish from the lower lagoon region also ate similar food items on all sampling dates, but the quantity and frequency of occurrence varied with sampling date (Figure 10). In late August, Trichoptera larvae were the most abundant food item, and Corophium had the highest frequency of occurrence value of any food item. Other important food items by number and frequency of occurrence, in order of importance, were isopods, Corophium, dipterans, and terrestrials. Less important food items were hemipterans, other gammarid amphipods, water mites, and nematodes. Algae or pebbles were present in 13.8% of stomachs examined, and 26% of stomach contents had unidentifiable food items. In addition, three stomachs were empty.

In late October, isopods were the most abundant and common food item followed by Diptera and Corophium. Terrestrial insects and trichoptera larvae became a less important component in the diet. Other food items that were present in low numbers were other gammarid amphipods, gastropods, and threespine sticklebacks. On one occassion, a juvenile steelhead caught by an angler had a smaller steelhead in it's throat. Algae or pebbles were present in 38% of stomachs examined and 14% had unidentifiable food items.

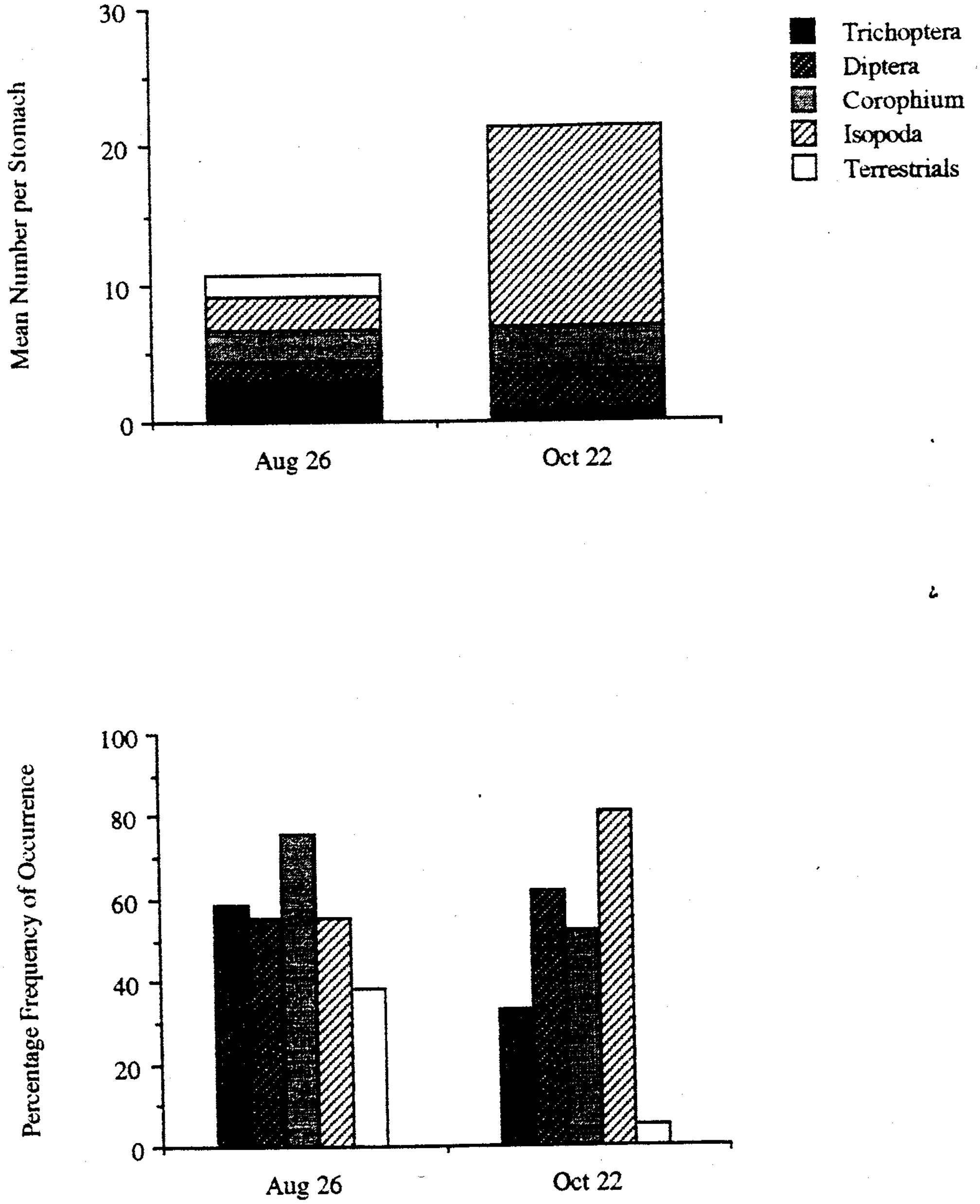


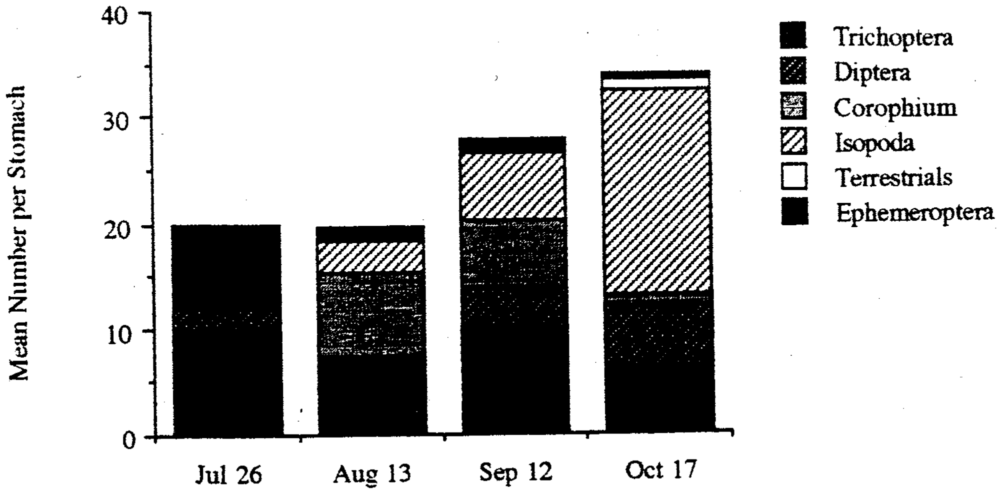
Figure 10. Mean Number and Frequency of Occurrence of Major Food Items from Juvenile Steelhead Stomach Contents Collected on Two Sampling Dates from August to October in the Lower Region of the Mattole River Lagoon, California, 1988.

In 1989, a total of 148 stomachs were collected from late July to late October. Of these, 89 samples were taken from the upper lagoon, and the remaining 59 were from the lower lagoon. In the upper lagoon similar food items were eaten on most sampling dates, but the number and frequency of occurrence varied (Figure 11). In late July, the dominant food items by number and frequency of occurrence were Trichoptera and Ephemeroptera. Diptera made up the next most important food item by number and frequency of occurrence followed by Corophium, isopods, and terrestrials. Less important food items were coleopterans and nematoda. Algae or pebbles and unidentifiable food items were present in 45% of stomachs examined.

In August, the dominant food item by number was Corophium, followed by trichopterans, and isopods. The most frequently found food item was the trichopteran larvae followed by Corophium, isopods, ephemeropterans, and terrestrials. Food items that had low representation in stomach contents were: plecopterans, hemipterans, and water mites. Of the stomachs examined, 33% contained algae or pebbles and only 5% contained unidentifiable food items, and six were empty.

In September, Trichoptera was also the dominant food item by number and percent frequency of occurrence followed by isopods. Corophium and Diptera were the next most important food items by number, and Corophium had a lower frequency of occurrence than Diptera. Ephemeropterans and terrestrials were among the least important food items of major prey types. Other less important food items included: coleopterans, hemipterans, and water mites. Nearly 23% of the stomachs examined contained algae or pebbles and 10% contained unidentifiable food items.

In October, isopods dominated by number and percent frequency of occurrence followed by Trichoptera, Diptera, Corophium and Terrestrial insects. Less important food items were ephemeropterans, coleopterans, hemipterans, ostracods, a gammarid amphipod, gastropods, water mites, and mysid shrimp (Neomysis sp.). Of the stomachs examined,



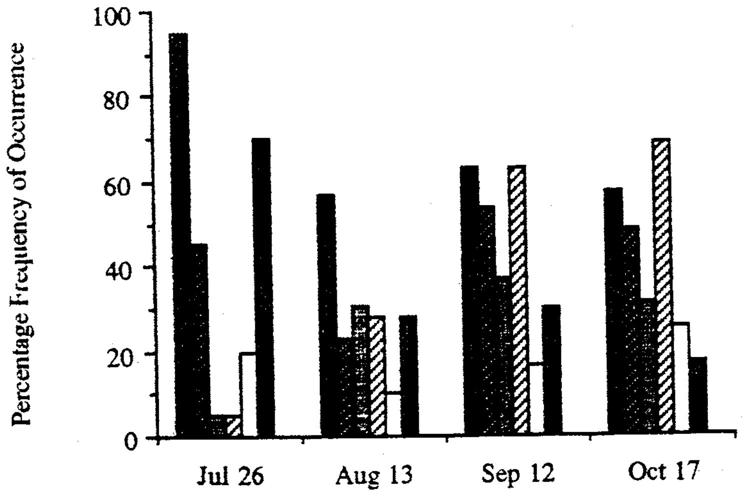


Figure 11. Mean Number and Frequency of Occurrence of Major Food Items from Juvenile Steelhead Stomach Contents Collected on Four Sampling Dates from July to October in the Upper Region of the Mattole River Lagoon, California, 1989.

51% contained algae or pebbles, 31% contained unidentifiable food items, and four were empty.

Fish in the lower lagoon region also ate similar food items on all dates, but the number and frequency of occurrence varied (Figure 12). In August, Corophium was the dominant food item by number and percent frequency of occurrence followed by Trichoptera. aquatic Diptera, isopods, and terrestrials. Less important food items included coleopterans and hemipterans. Of the stomachs examined, 63% contained algae or pebbles and only 3% had unidentifiable food items.

In September, Corophium and isopods were eaten almost exclusively. Less numerous and common food items were: aquatic dipterans, trichopterans, ephemeropterans, terrestrial insects, other amphipods, gastropods, hemipterans, mysid shrimp, and threespine stickleback. Algae and pebbles were present in 72% of stomachs examined, and 31% had unidentifiable food items.

In October, Corophium, terrestrials, and Diptera were eaten in large numbers and occurred in 100% of stomachs examined. Neomysis was also important by number and frequency of occurrence, occurring in 90% of the stomachs examined. Isopods were not consumed in large numbers by individual fish, but were found in 80% of stomachs examined. Less important food items by number and frequency of occurrence included: trichopteran larvae, ephemeropterans, hemipterans, gammarid amphipods, and gastropods. Algae or pebbles were present in 70% of stomachs examined and 20% of stomachs contained unidentifiable food items.

Results of statistical comparisons of mean numbers of Trichoptera larvae, Ephemeroptera larvae, aquatic Diptera, Isopoda, and Corophium in fish stomachs resulted in some significant differences (Appendix T). A highly significant difference in diet resulted between years for the upper lagoon ($P = 0.0015$). The major sources of variation

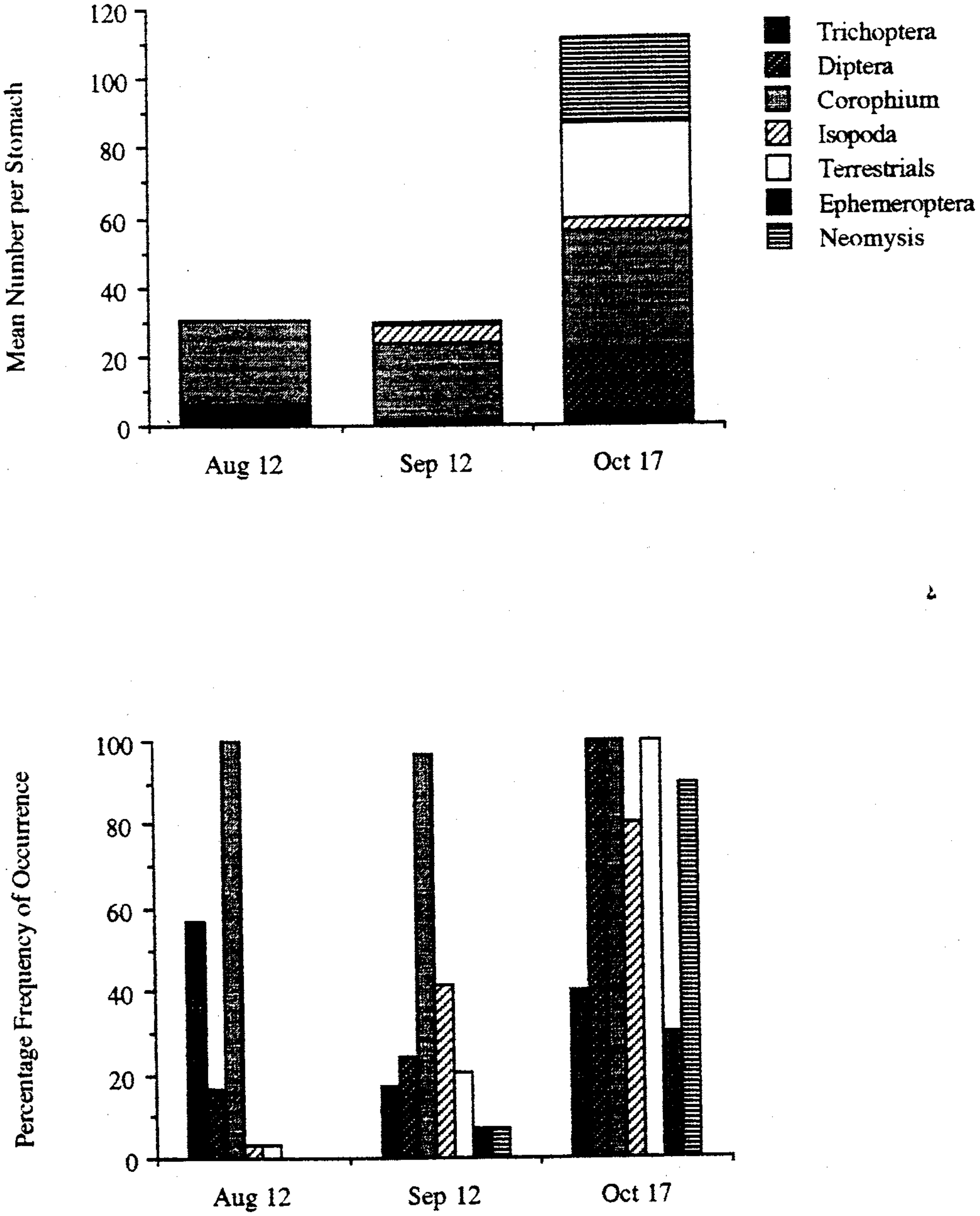


Figure 12. Mean Number and Frequency of Occurrence of Major Food Items from Juvenile Steelhead Stomach Contents Collected on Three Sampling Dates from August to October in the lower Region of the Mattole River Lagoon, California, 1989.

were associated with Diptera, which were eaten more in 1988, and Trichoptera, which were eaten more in 1989. Together they accounted for 62.8% of the variation.

Similarily, a significant difference in diet resulted between years for the lower lagoon (P = 0.0178). In this region, most of the variation was associated with Corophium and Isopoda (81.6%); in 1988 fish consumed more isopods and in 1989 fish consumed more Corophium.

Comparisons between regions of the lagoon in both years resulted in significant differences between relative frequencies of major food items eaten. In 1988, a highly significant difference resulted (P = 0.0084). Most of the variation was associated with aquatic Diptera (48%), which were more abundant in stomach contents from the upper lagoon. In 1989, a highly significant difference also occurred (P = 0.0076). Corophium and Trichoptera numbers accounted for most of the variation (76%), with Corophium being more abundant in stomach contents of fish from the lower lagoon and trichopteran larvae being more abundant in stomachs from the upper lagoon.

Comparisons of food habits between two size-classes for the upper and lower lagoon in 1988 did not result in any significance differences (P = 0.9838 and 0.0892). In 1989, no significant difference was found between size-classes for the lower lagoon. However, a highly significant difference in the diet of the two size-classes in the upper lagoon in 1989 did occur (P = 0.0072). The major sources of variation were associated with Trichoptera larvae (mean number for fish less than 100 mm in length was 4.9 compared to 13.6 for fish larger than or equal to 100 mm), which were preyed upon more frequently by larger fish, and Corophium, which were preyed upon more frequently by smaller fish (mean number = 9.53) as compared to larger fish (0.42). Together, the differences between mean numbers of trichopteran larvae and Corophium present in stomach contents of the two size-classes accounted for 64.4% of the variation.

Predation

Piscivorous birds were commonly observed fishing the lagoon. Direct evidence that fish were susceptible to predation was obtained during the beach seining operation; YOY, 1+, and to a lesser extent older fish showed signs that they had been attacked by predators (i.e., lacerations or missing caudal fin lobes). In September and October in 1988, and to a lesser extent in 1989, mergansers, egrets, and herons congregated in the upper lagoon where most of the fish were located.

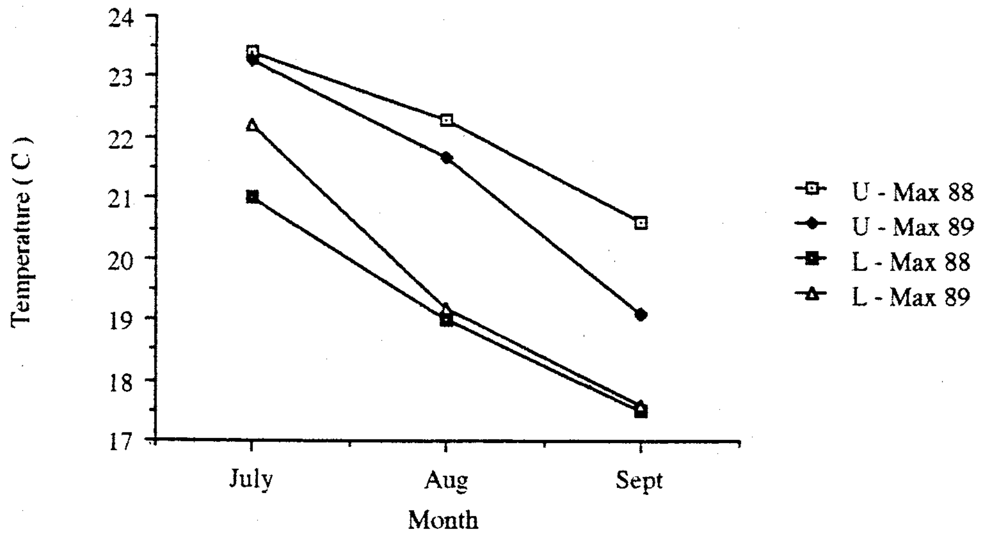
Fin Marks

Quality of fin marks varied with the fin used and location on the fin. Marks on the ventral fins were best. These marks were easily recognized because of the contrast between mark and the clear to white ventral fins. The caudal fin was not as good for marking, but was used with success in 1988. The dorsal fin was used in October 1988, but did not show marks well. Quality of marks also varied with how close the mark was to the body of the fish; the closer the better. Retention and recognition of fin marks were recorded for up to two months. The blue dye mark I used turned black in about two weeks.

Water Quality

Water Temperature

Lagoon mean monthly water temperatures varied with location (Figure 13). The upper lagoon had warmer temperatures reflecting upstream river water temperatures. The warmest temperature recorded in both years was 26 ^{o}C, which occurred in the upper lagoon, only once, and on the same date - July 17. Daily water temperatures for 1988 and 1989 are given in Barnhart and Zedonis (1989, 1990). The mean maximum water temperatures peaked in the upper lagoon in July in both years with values of 23.4 ^{o}C in 1988 and



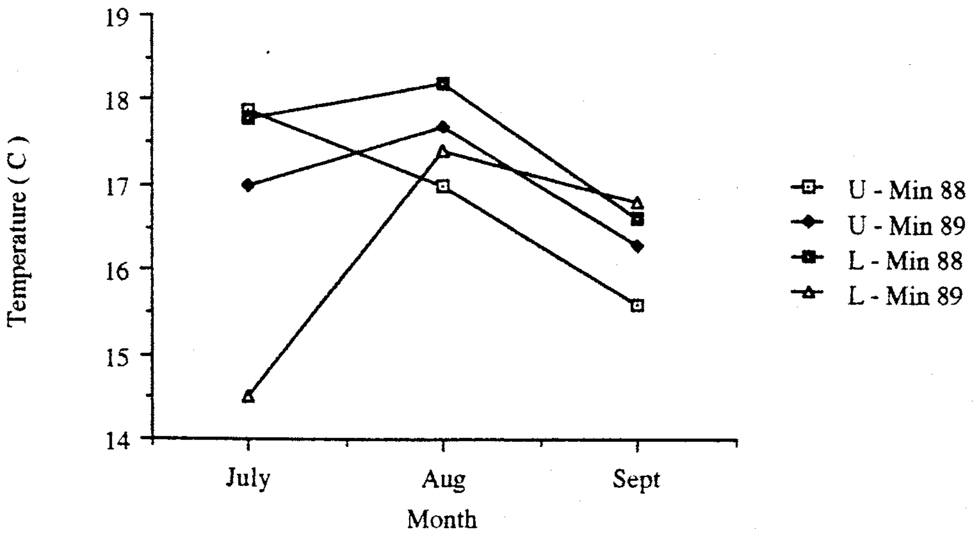


Figure 13. Mean Maximum and Mean Minimum Monthly Water Temperatures (°C) at Two Different Regions (U-Upper, L-Lower) of the Mattole River Lagoon, California, 1988 and 1989.

23.3 ^{o}C in 1989, and decreased in subsequent months. Cooler water temperatures in the lower lagoon were attributed to the predominant cool northwestern wind and saltwater overwash.

Mean monthly minimum water temperatures increased from July to August in the lower region in both years and in the upper lagoon in 1989. In 1988, water temperatures in the upper lagoon decreased from July to August. By September water temperatures decreased in both regions in both years.

Temperature statification occurred irregularly (Barnhart and Zedonis 1990). Due to strong onshore winds, the water column was usually thoroughly mixed. However, on calm sunny days the lower lagoon showed some stratification. Saltwater intrusion also caused stratification; on July 21, 1988, the surface temperature was 20.1 ^{o}C and the temperature of the bottom saline water was 17.0 ^{o}C. On October 29, a high tide washed a substantial quanitity of saltwater into the lagoon and saline water was detected up to water quality station 1. Solar heating of this dense layer of saline water created a temperature inversion (meromixis); the surface water temperature was 14.9 ^{o}C and the bottom layer was 17.0 ^{o}C.

From June 6 to September 23, 1989, the lower lagoon thermograph recorded 50 occassions when saltwater overwash was pronounced enough to be detected; indicated by sharp drops in water temperature. These sharp drops were not recorded in 1988. In 1989, meromixis occurred on September 1, at stations 1, 2, and 4; the bottom saline water was as much as 5.3 ^{o}C warmer than the surface water.

Salinity and Conductivity

Conductivity of river water ranged from 190 to 210 micromhos, and lagoon water ranged from 190 to 17200 micromhos (Barnhart and Zedonis 1989, 1990). Conductivity varied with lagoon location, with stations 3 and 4 having the highest values. Occasionally high levels of conductivity were found when high tides breached the sand berm. The presence of a recent saltwater intrusion could be detected by using a salinity meter, but the conductivity meter was a more sensitive indicator of salt ions. Other indications of sea-water overwash were the presence of marine plants such as kelp (Macrocystis sp.) and marine animals such as starry flounder, staghorn sculpins, and sea stars (Pisaster sp.).

Dissolved Oxygen

Dissolved oxygen levels in the lagoon were measured 11 times in 1988 and 4 times in 1989. In 1988, dissolved oxygen levels ranged from 8.7 to 10.4 ppm in the lower lagoon, and 8.5 to 9.6 ppm in the upper lagoon (Barnhart and Zedonis 1989). In 1989, dissolved oxygen levels ranged from 9.2 to 10.2 ppm in the upper lagoon and from 9.3 to 10.2 ppm in the lower lagoon (Barnhart and Zedonis 1990). These values represented near 100% saturation of oxygen in water for the given water temperature and atmospheric pressure, and were well within the limits to support aquatic life as set by the United States Environmental Protection Agency (1977).

Turbidity and pH

In both years, the mean high values for turbidity were detected at water quality station number 4 and were 0.75 and 1.2 NTU (Nephelometric Turbidity Units) for 1988 and 1989, respectively. These values were due to wind driven mixing (Barnhart and Zedonis 1989, 1990). In both years, the lowest turbidity readings were taken from water quality station 1.

The pH ranged from 7.4 to 8.5 depending on the method used. The Cole/Palmer pH meter was used once and resulted in a value of 7.4. The Hach Model CA-10 water quality kit resulted in a pH value of 8.5 for all other sampling periods.

DISCUSSION

Juvenile Steelhead Migration

There is a lack of information regarding timing of smolt migration and the predominant age at which smoltification occurs for Mattole River steelhead. Numerous investigators have indicated that steelhead emigration occurs in the spring usually at age two (Shapovalov and Taft 1954; Maher and Larkin 1955; Chapman 1957; Withler 1966). I trapped few Mattole River two year old steelhead from late April to October. Additionally, age class composition determined from size-class population estimates indicated that of the nearly 40000 steelhead in the lagoon, only a few hundred were two years of age or older. The two year old steelhead had probably emigrated to saltwater in March and early April before I began trapping.

Salmonids migrate at night (Shapovalov and Taft 1954; Northcote 1962; Pennington 1986). Although daytime sampling was limited, migration patterns in the Mattole River appeared to be similar. Some fish were captured during afternoon sampling, but few compared to night sampling.

Trapping results indicated that YOY steelhead were the primary age class moving downstream from late April to late October. Young (1987) also found primarily YOY steelhead moving downstream in the lower Mattole River in 1985 during the same time frame, as did Shapovalov and Taft (1954) for lower Waddell Creek, California. Bjornn (1971) recorded non-smolt steelhead entering his trap year round in two Idaho streams. These fish were probably migrating in response to decreased river flow which resulted in less available habitat or an exceeded carrying capacity (Allen 1969; Burns 1971; Cross 1975).

Numbers of YOY steelhead captured were greater per unit of effort in 1988 than 1989, and a resurgence of YOY migrants was recorded from late August to October 1988.

The lower Mattole River may have had a more successful steelhead spawning season in 1988. Steelhead as large as 50 mm were trapped in late April and fish as small as 29 mm were captured a month later. This variation in length may have indicated that steelhead had a more extended spawning season in 1988. In addition, a portion of the late winter steelhead run may have been absent in 1989. Jerry Lapacek (pers. comm.), a fishing guide on the Mattole River, indicated that few late-run steelhead were caught by anglers in 1989.

Freshets and the installation of trap wing-walls influenced the number of juvenile steelhead captured. Shapovalov and Taft (1954) found that freshets increased the number of salmonids trapped on Waddell Creek. Chapman (1957) recorded increased numbers of steelhead immediately after wing-walls were installed and attributed this to increased trap efficiency. In both years, when I installed wing-walls, I recorded a substantial increase in the number of salmonids trapped. I believe that this was not only a result of increased efficiency, but also because of changing hydraulic conditions above the trap. When wing-walls were installed and subsequently became clogged with organic debris, the water level above the trap rose from 10 to 15 cm. This altered the velocity in the low gradient riffle, which is an area of greatest YOY steelhead abundance at low summer flow (Hartman 1965; Cross 1975), so that additional fish moved downstream into the trap. Water velocity has been reported to be an important component of habitat used by juvenile salmonids (Moyle and Baltz 1985; Gatz et al. 1987; Taylor 1988).

Edmundson et al. (1968) indicated that steelhead became inactive at night-time usually selecting areas inshore and of low water velocity, and during the day selected areas of moderate velocity. Since the trap was placed immediately below a low gradient riffle, an area of moderate velocity, fish may have been moving downstream to find resting areas and were subsequently captured. Although fish were released downstream of the trap and the trap was not fished every night, fish may have moved up to the riffle during the day so that

I was merely recapturing them. However, catch data from 1988 indicated an increase in the percentage of YOY fish in the lagoon which indicated that fish were moving downstream.

Downstream migrant trapping during the summer months indicated few migrating yearlings. Yet, 1+ fish were the primary age class found in the lagoon. Perhaps these 1+ fish migrated downstream during the spring or were the previous years YOY that resided in the lower river or lagoon through the previous winter. Beach seining in the estuary in conjunction with downstream migrant trapping during the winter and spring may provide information to substantiate this hypothesis.

Lagoon Fish Abundance and Distribution

Population estimates in 1988 indicated that the numbers of juvenile steelhead remained constant from late July to August, and increased in late September and October. The large increase in fish numbers in October was probably an overestimation. The mark location chosen for this census period was the dorsal fin and mark identification was difficult. As a result marked fish that were recaptured may not have been detected. Although downstream migrant trapping from September 20 to October 29 indicated some fish moving downstream, these numbers did not reflect a change in population size of that magnitude.

Intermixing of fish between lagoon regions during the census period was recorded in 1989 and probably also occurred in 1988. Consequently, regional population estimates were probably biased. Because fish predominantly moved from the lower region to the upper lagoon, the actual number of marked fish would be lower than reported in the lower lagoon and higher than reported in the upper lagoon. Therefore, the estimates for the lower lagoon would be overestimates while the upper lagoon estimates would have been under-estimates. However, the effects of this bias on the observed trends is believed to be low.

Another bias which was probably present, but probably did not affect the observed trends was a low number of recaptured fish for lower region and size-class estimates. Ricker (1975) suggests that the number of recaptures be at least four otherwise statistical bias may result.

In 1989, numbers of fish residing in the lagoon steadily declined in each succeeding month; this was also reported by Barnhart et al. (1988), Barnhart and Busby (1986), and Young (1987) for the Mattole River juvenile chinook residing in the lagoon. CPUE for both years in the lower lagoon decreased as the season progressed. It appeared that juvenile steelhead migrated to the upper lagoon area. This spatial and temporal shift in steelhead distribution can probably be attributed to two factors; changes in salinity and changes in water temperature. The amount of saltwater overwash into the lower lagoon was substantial in 1989. These periodic and often abrupt changes in water quality probably caused fish to move to the upper lagoon region where more favorable conditions persisted. Bassindale (1943) emphasized that the magnitude and rate of the salinity change in an estuary can have detrimental effects on aquatic organisms; if salinity changes gradually, adaptation can take place, otherwise mortality may occur. Salinity has also been reported as the most important factor influencing an organism's ability to cope with an estuarine environment (McLusky 1989).

Meromictic conditions probably also influenced the distribution and/or mortality of steelhead in the lagoon. When these conditions were present, the more dense saltwater on the bottom was much warmer than the surface water creating adverse chemical and physical conditions for salmonids and invertebrates. Young (1987) hypothesized that if overwash was frequent, meromixis might effectively remove the lower lagoon as a rearing area for juvenile chinook salmon; this also appeared to be the case for juvenile steelhead. In 1989 the carrying capacity of the lagoon system may have been exceeded as a result of high initial numbers of steelhead being subjected to declining habitat quality. This was first speculated by Young (1987).

The nutrient rich environment in the lower lagoon resulted in the formation of dense algae mats. Dissolved oxygen levels may have become low enough during the night to cause mortality and/or movement of salmonids. Barnhart et al. (1988) found dissolved oxygen levels below the limits set by the United States Environmental Protection Agency (1977) during one night in September, 1987. Steelhead densities remained higher in the upper lagoon in 1988 compared to 1989 and no mass mortality was detected, indicating that space was probably not a limiting factor, and food was probably adequate (Chapman 1966).

Predation

Predation could account for some of the losses in numbers of juvenile steelhead during lagoon residence. Merganser predation on juvenile salmonids can be significant (Wood 1987a; Wood 1987b). In addition, larger steelhead preyed on smaller salmonids, but they did not appear to consume large numbers. Piscivory by larger steelhead has also been reported to be low by other investigators (Busby 1991; Young 1987; Salamunovich 1987; Shapovalov and Taft 1954).

Steelhead Growth

In both years, the mean lengths of juvenile steelhead using the lagoon exceeded those of juvenile steelhead from various riverine habitats for the same time period (Table 2). This indicated that the lagoon is a productive rearing habitat. Reimers (1973) indicated that a survival advantage was gained by chinook salmon that reared to a larger size in the Sixes River estuary in Oregon, and Shapovalov and Taft (1954) noted that juvenile steelhead made the most rapid growth in lagoon and tidewater areas of Waddell Creek, California.

In both years, YOY fish exhibited continuous good growth during the monitoring period. Yearlings, however, grew slowly between August and September, 1988 (Figure 8). While MIX indicated a good fit for the August sample, the fit for the September data was poor, even though the sample size was large (n=1361). September MIX mean length values may have been inaccurate, thus explaining the apparent reduction in growth rate. Length frequency data did, however, indicate distinct modes for both age classes. Why YOY fish did not exhibit a similar reduction in growth is unclear.

Reduced growth of yearling fish during this period was probably related to warm water temperatures. The United States Environmental Protection Agency (1986), lists the maximum weekly average temperature for growth of rainbow trout during the summer to be 19°C, which was exceeded more times between August and September in 1988 than in 1989. Steelhead of both age classes were several millimeters longer in 1989 compared to the same age classes in 1988 at about the same time periods indicating that growth conditions during winter and spring in 1989 were probably better.

Steelhead Food Habits

Fish in the lower lagoon region ate different numbers and kinds of food items than fish in the upper lagoon probably because of dissimilar environments (Needham 1940; Shapovalov and Taft 1954; Salamunovich 1987; Busby 1991). Corophium was the major food item by percent frequency of occurrence and mean number eaten by fish in the lower lagoon for combined years, indicating a relatively homogeneous feeding regime (Hyslop 1980). Shapovalov and Taft (1954) indicated that steelhead in brackish water relied on crustaceans for food in the Waddell Creek lagoon. Young (1987) and Barnhart et al. (1988) also indicated that Corophium was an important dietary component for juvenile chinook salmon in the Mattole River lagoon as did Salamunovich (1987) for steelhead in the Redwood Creek estuary. Busby (1991) found Corophium to be the most abundant epibenthic organism in the lower lagoon in 1986; it was not as abundant in the upper lagoon. Needham (1940) reported that Corophium was the second most abundant food in Waddell Creek lagoon, but it was not found in any of the stomach contents of juvenile steelhead. He postulated that this species of amphipod had secretive habits. The frequent changes in salinity concentration and water temperature in the lower lagoon probably caused Corophium to become available to fish. Busby (1991) found decreased numbers of epibenthic organisms in the lower lagoon for one month in 1986 and attributed the decline to meromictic conditions.

Trichopteran larvae, aquatic dipterans, and Corophium were important food items for fish of both the upper and lower regions of the lagoon. However, because hard parts (i.e., larval cases, head capsules, and exoskeletons) were used to identify these food items, their importance may be overemphasized compared to more easily digested organisms (Hyslop 1980). Softer food items such as oligochaetes, which were abundant at times in benthic samples in 1986 (Busby 1991), but not found in stomachs in 1988 or 1989, may also have been an important component of the diet.

The upper lagoon showed more variation in different food items ingested probably because of the more stable riverine type environment. Busby (1991) found significantly larger numbers of epibenthic organisms in the upper lagoon compared to the lower lagoon. Although this area had abundant overhanging vegetation, few terrestrials were eaten by steelhead. However, since the density of fish was so great in this area, the number of terrestrials eaten per individual fish would probably not comprise a large component of the diet. Conversely, in the lower lagoon, which had few fish, the steelhead diet had larger frequency of occurrence and mean number of terrestrials.

Significant differences in food item selection by the two size-classes of fish in the upper lagoon in 1989 was probably related to differences in mouth size (Glova 1984) and size of abundant and available prey organisms; larger fish preyed on the larger trichopteran larvae and smaller fish preyed on the smaller Corophium. This same trend was not evident in the upper region of the lagoon in 1988 probably because food item abundance and availability differed from 1989 (both size-classes ate primarily aquatic dipterans). This inference was made because steelhead are considered opportunistic feeders (Shapovalov and Taft 1954; Fite 1973; Salamunovich 1987). Therefore, stomach content analysis should have reflected the relative abundance and availability of these organisms in the lagoon.

The large number of fish stomachs containing algae and pebbles and epibenthic invertebrates indicated that Mattole lagoon steelhead were primarily exhibiting a benthic type feeding strategy. Salamunovich (1987) found the same in Redwood Creek estuary.

In summary, the Mattole River lagoon offered a productive yet hostile rearing environment for juvenile steelhead. While rearing in the lagoon, fish were subjected to continuously changing water quality conditions that affected not only their distribution and probably survival, but also affected the distribution and survival of prey organisms. The overall importance of the lagoon to the survival of the Mattole River steelhead stock(s) is relatively unknown. However, because large numbers of fish reared in the lagoon, and obtained good growth here, it is likely that lagoon rearing is an important component of the early life history of the Mattole River steelhead.

REFERENCES CITED

Allen, K.R. 1969. Limitations on production in salmonid populations in streams. Pages 3 -18 in T. G. Northcote (ed.) Salmon and Trout in Streams. Univ. British Columbia, Vancouver, Canada.

Barnes, R.S.K. 1984. Estuarine biology. (2nd edition). Edward Arnold Publishing, Baltimore, MD. USA. 76 pp.

Barnhart, R.A. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) - steelhead. U.S. Fish Wildl. Serv. Biol. Rep. 82 (11.60). U.S Army Corps of Engineers, TR EL-82-4. 21 pp.

Barnhart, R.A., and M.S. Busby. 1986. Chinook salmon populations and related biological parameters Mattole River lagoon, California, June 1986 to October 1986. Summary Report, California Cooperative Fisheries Research Unit, Humboldt State University, Arcata, California. 38 pp.

Barnhart, R.A., M.S. Busby, and P.P. Petros. 1988. Natural resources of the Mattole River estuary, California, 1987. Natural Resources and Habitat Inventory Summary Report, California Cooperative Fisheries Research Unit, Humboldt State University, Arcata, California. 81 pp.

Barnhart, R.A., and D.A. Young. 1985. An investigation of the Mattole River estuary, May 1984 to March 1985. Bureau of Land Management, Arcata, California. 26pp.

Barnhart, R.A., and P.A. Zedonis. 1989. Biological parameters and salmonid populations (emphasis on steelhead), Mattole River lagoon, California, July to October 1988. Summary Report, California Cooperative Fisheries Research Unit, Humboldt State University, Arcata, California. 42pp.

Barnhart, R.A., and P.A. Zedonis. 1990. Biological parameters and salmonid populations (emphasis on steelhead), Mattole River lagoon, California, July to October, 1989. Summary Report, California Cooperative Fisheries Research Unit, Humboldt State University, Arcata, California. 29 pp.

Bassindale, R. 1943. A comparison of the varying salinity conditions of the Tees and Severn estuaries. Journal of Animal Ecology 12: 1-10.

Bjornn, T.C. 1971. Trout and salmon movements in two streams as related to temperature, food, stream flow, cover and population density. Transactions of the American Fisheries Society 100: 423-438.

Burns, J.W. 1971. The carrying capacity for juvenile salmonids in some northern California streams. California Fish and Game 57: 44-57.

Busby, M.S. 1991. The abundance of epibenthic and planktonic macrofauna and feeding habits of juvenile fall chinook salmon (Oncorhynchus tshawytscha) in the Mattole River estuary/lagoon, Humboldt County, California. M.S Thesis, Humboldt State University, Arcata, CA.

California Department of Water Resources. 1973. Character and use of rivers. Mattole River. State of California Resources Agency. Department of Water Resources. 145 pp.

Chapman. D.W. 1957. Studies on age, growth, and migration of steelhead trout (Salmo gairdneri gairdneri) in the Alsea River, Oregon. M.S. Thesis. Oregon State College, Portland, Oregon. 96pp.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. American Naturalist. 100: 345-357.

Cross, P. D. 1975. Early life history of steelhead trout (Salmo gairdneri) in a small coastal stream. M. S. Thesis. Humboldt State University, Arcata, California. 44 pp.

Crow, M. E. 1981. Some statistical techniques for analyzing the stomach contents of fish. Pages 8 - 11 in Cailliet, G. M. and C. A. Simenstad (ed.) Proceedings of the Third Pacific Workshop on Fish Food Habits. Washington. Sea Grant.

Edmundson, E., F.E. Everest, and D.W. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 25: 1453 - 1464.

Eggers, S.D. 1987. Seasonal fluctuation in food availability and feeding of juvenile steelhead trout (Salmo gairdneri) in a small coastal stream. M.S. Thesis. Humboldt State University, Arcata, California. 100 pp.

Fite, K.R. 1973. Feeding overlap between roach and juvenile steelhead in the Eel River. M.S. Thesis. Humboldt State University, Arcata, California. 38 pp.

Gatz, A.J., Jr., M.J. Sale, and J. M. Loar. 1987. Habitat shifts in rainbow trout: Competitive influences of brown trout. Oecologia 74: 7-19.

Glova, G.J. 1984. Management implications of the distribution and diet of sympatric populations of juvenile coho salmon and coastal cutthroat trout in small streams in British Columbia, Canada. Progressive Fish Culturist 46: 269-277.

Hartman, G.F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 22: 1035-081.

Hiss, J.M. 1984. Diet of age-0 steelhead trout and speckled dace in Willow Creek, Humboldt County, California. M.S. Thesis. Humboldt State University, Arcata, California. 48 pp.

Hofstra, T.D. 1983. Management alternatives for the Redwood Creek estuary. Redwood National Park management plan, March 1983, Redwood National Park, Arcata, California.

Hyslop, E.J. 1980. Stomach content analysis - a review of methods and their applications. Journal of Fish Biology 17: 411-429.

Joseph, J. 1958. First annual report of the Big Lagoon project volumes 1 and 2. Humboldt State University, Arcata, California. 163 pp.

Macdonald, P.D., and P.E. Green. 1988. User's guide to program MIX: an interactive program for fitting mixtures of distributions. Icthus Data Systems, Hamilton, Ontario. 60 pp.

Macdonald, P.D., and T.J. Pitcher. 1979. Age-groups from size-frequency data : a versatile and efficient method of analysing distribution mixtures. Journal of the Fisheries Research Board of Canada 36: 987-1001.

Maher, F.P., and P.A. Larkin. 1955. Life history of the steelhead trout of the Chilliwack River, British Columbia. Transactions of the American Fisheries Society p. 27-38.

McLusky, D.S. 1989. The estuarine ecosystem (2nd edition). Chapman and Hall Publishing Company, Inc., New York, NY. 215 pp.

Merritt, R.W., and K.W. Cummins, editors. 1984. An introduction to aquatic insects of North America, 2nd edition. Kendall / Hunt Co., Dubuque.

Moyle, P.B., and D.M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: Developing criteria for instream flow determinations. Transactions of the American Fisheries Society 114: 695-704.

Needham, R.R. 1940. Quanitative and qualitative observations on fish foods in Waddell Creek lagoon. Transactions of the American Fisheries Society 69: 178-186.

Northcote, T.G. 1962. Migratory behabiour of juvenile rainbow trout, Salmo gairdneri, in outlet and inlet streams of Loon Lake, British Columbia. Journal of the Fisheries Research Board of Canada 19: 201-269.

Pennington, H.M. 1986. Emigration and mortality of juvenile steelhead in a nursery stream. M.S. Thesis. Humboldt State University, Arcata, California. 55 pp.

Reeves, G.H. 1979. Population dynamics of juvenile steelhead in relation to density and habitat characteristics. M.S. Thesis. Humboldt State University, Arcata, California. 67 pp.

Reimers, P.E. 1973. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Oregon Fish Commission, Research Report 4 (2), Portland.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Journal of the Fisheries Research Board of Canada, Bulletin 191. 382 pp.

Royal, L.A. 1972. An examination of the anadromous trout program of the Washington State Game Department. Wash. State Dep. Game, Final Rep. AFS-49, Olympia. 176 pp.

Salamunovich, T.J. 1987. Fish food habits and their interrelationships in lower Redwood Creek, Humboldt County, California. M.S. Thesis. Humboldt State University, Arcata, California. 173 pp.

Seber, G.A.F. 1982. Estimation of animal abundance and related parameters. 2nd ed., John Wiley, New York. 654 pp.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game, Fish Bull. 98. 375 pp.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelhead and coho salmon. Transactions of the American Fisheries Society 113: 142 -150.

Simenstad, C.A. 1983. The ecology of estuarine channels of the Pacific Northwest coast: A community profile. United States Department of Interior, Fish and Wildlife Service FWS/OBS-83/05. 181 pp.

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: An unappreciated function. Pages 343-364 in V. Kennedy (ed.), Estuarine Comparisons. Academic Press, New York, NY. USA.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry. 2nd edition. W.H. Freeman and Company, San Fransisco, California. 859 pp.

Taylor, E.B. 1988. Water temperature and velocity as determinants of microhabitats of juvenile chinook and coho salmon in a laboratory stream channel. Transactions of the American Fisheries Society 117: 22-28.

United States Environmental Protection Agency. 1977. Quality criteria for water. Office of Water and Hazardous Materials, United States Environmental Protection Agency, Washington D. C. 256 pp.

United States Environmental Protection Agency. 1986. Quality criteria for water 1986. EPA 440/5-86-001. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington DC. 235 pp.

U.S. Fish and Wildlife Service. 1987a. Progress report on Grass Valley Creek studies. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, California.

U.S. Fish and Wildlife Service. 1987b. Trinity River Flow Evaluation Study. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, California. 157 pp.

Usinger, R.L., ed. 1963. Aquatic insects of California. Univ. of California Press, Berkely, California. 508 pp.

Wagner, H.H. 1974. Photoperiod and temperature regulation of smolting in steelhead trout (Salmo gairdneri). Canadian Journal of Zoology 52: 219-234.

Withler, I.L. 1966. Variability in life history charcteristics of steelhead trout (Salmo gairdneri) along the Pacific coast of North America. Journal of the Fisheries Research Board of Canada 23: 365-393.

Wood, C.C. 1987a. Predaton of juvenile Pacific salmon by the common merganser (Mergus merganser) on Eastern Vancouver Island. I: Predation during the seaward migration. Canadian Journal of Fisheries and Aquatic Sciences 44: 941 - 949.

Wood, C.C. 1987b. Predaton of juvenile Pacific salmon by the common merganser (Mergus merganser) on Eastern Vancouver Island. II: Predation of stream-resident juvenile salmon by merganser broods. Canadian Journal of Fisheries and Aquatic Sciences 44: 950 - 959.

Young, D.A. 1987. Juvenile chinook salmon abundance, growth, production and food habits in the Mattole River lagoon, California. M.S. Thesis. Humboldt State University, Arcata, California. 73 pp.

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Appendix A. Population Estimates and Confidence Limits for Juvenile Steelhead in the Mattole River Lagoon, California, July to October, 1988.

Date	July 29		August 25		September 20		October 28	
Fin Marked	Lower Lobe Caudal		Upper Lobe Caudal		Anal Fin		Dorsal Fin	
Region of Lagoon	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Number of Seine Hauls	3	4	2	8	3	8	4	7
Marked (M)	1375	755	1004	640	2669	134	1026	44
Number of Seine Hauls	2	4	3	7	2	5	4	7
Captured (C)	974	566	1525	678	2146	98	1441	30
Recapture (R)	187	25	103	45	213	18	7	2
Population Estimates (N)	7136	16487	14746	9462	26787	703	185117	465
95% CI [a] Limits	± 849	± 5969	± 2578	± 2516	± 3259	± 257	± 120136	± 418
Combined Region Estimates (N)	23623 ± 6029		24208 ± 3603		27490 ± 3269		185582 ± 120137	

a - confidence intervals determined using a normal distribution

Appendix B. Population Estimates and Confidence Limits for Juvenile Steelhead in the Mattole River Lagoon, California, August 15, 1989.

Region of Lagoon	Upper	Lower	
Fin Marked	Caudal	Anal	
Marked (M)			
Number of Seine hauls	1	5	
51 - 90mm	859	87	
91 - 159mm	479	847	
160mm or larger	14	20	
Captured (C)			
Number of Seine hauls	1	7	
51 - 90mm	1253	133	
91 - 159mm	352	885	
160mm or larger	16	27	
Recapture (R)			
51 - 90mm	68	4	
91 - 159mm	20	56	
160mm or larger	2	2	
Population Estimates (N) (95% CI) [a]			Combined
51 - 90mm	15630 ± 3414	2358 ± 1798	17988 ± 3858
91 - 159mm	8069 ± 3197	13181 ± 3169	21250 ± 4502
160mm or larger	85 ± 68	196 ± 168	281 ± 181
Region Population Estimates (N)	23784 ± 4678	15735 ± 3648	39519 ± 5932

a - confidence intervals determined using a normal distribution

Appendix C. Population Estimates and Confidence Limits for Juvenile Steelhead in the Mattole River Lagoon, California, September 12, 1989.

Region of Lagoon	Upper	Lower	
Fin Marked	Caudal	Anal	
Marked (M)			
Number of Seine hauls	1	8	
65 - 99mm	537	9	
100 - 159mm	990	566	
160mm or larger	80	62	
Captured (C)			
Number of Seine hauls	1	7	
65 - 99mm	582	15	
100 - 159mm	1791	873	
160mm or larger	126	10	
Recapture (R)			
65 - 99mm	46	1	
100 - 159mm	152	44	
160mm or larger	10	1	
Population Estimates (N) (95% CI) [a]			Combined
65 - 99mm	6673 ± 1729	80 ± 76	6753 ± 1731
100 - 159mm	11607 ± 1612	11012 ± 2974	22619 ± 3383
160mm or larger	935 ± 470	346 ± 349	1281 ± 585
Region Population Estimates (N)	19215 ± 2411	11438 ± 2995	30653 ± 3845

a - confidence intervals determined using a normal distribution

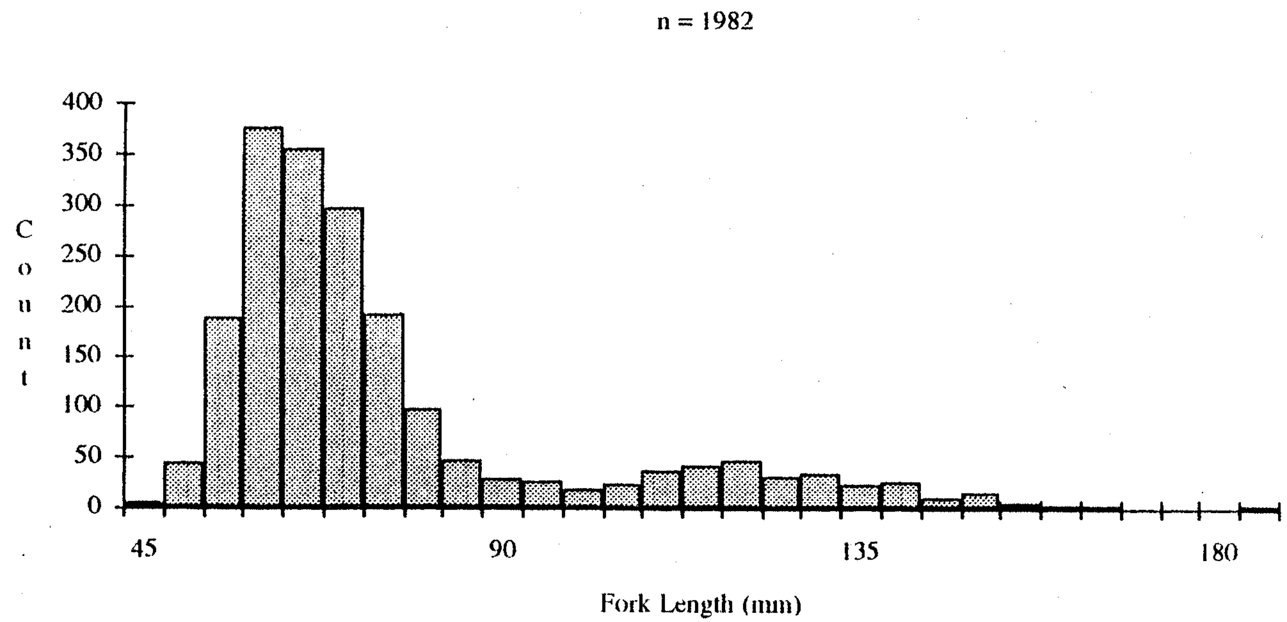
Appendix D. Population Estimates and Confidence Limits for Juvenile Steelhead in the Mattole River Lagoon, California, October 17, 1989.

Region of Lagoon	Upper	Lower	
Fin Marked	Pelvic	Pelvic	
Marked (M)			
Number of Seine hauls	3	9	
83 - 169mm	1420	89	
170mm or larger	112	6	
Captured (C)			
Number of Seine hauls	2	8	
83 - 169mm	1745	8	
170mm or larger	39	2	
Recapture (R)			
83 - 169mm	154	0	
170mm or larger	6	0	
Population Estimates (N) (95% CI) [a]			Combined
83 - 169mm	16007 ± 2264	810 ± 857	16817 ± 2422
170mm or larger	646 ± 328	21 ± 22	667 ± 394
Region Population Estimates (N)	16653 ± 2298	831 ± 860	17484 ± 2453

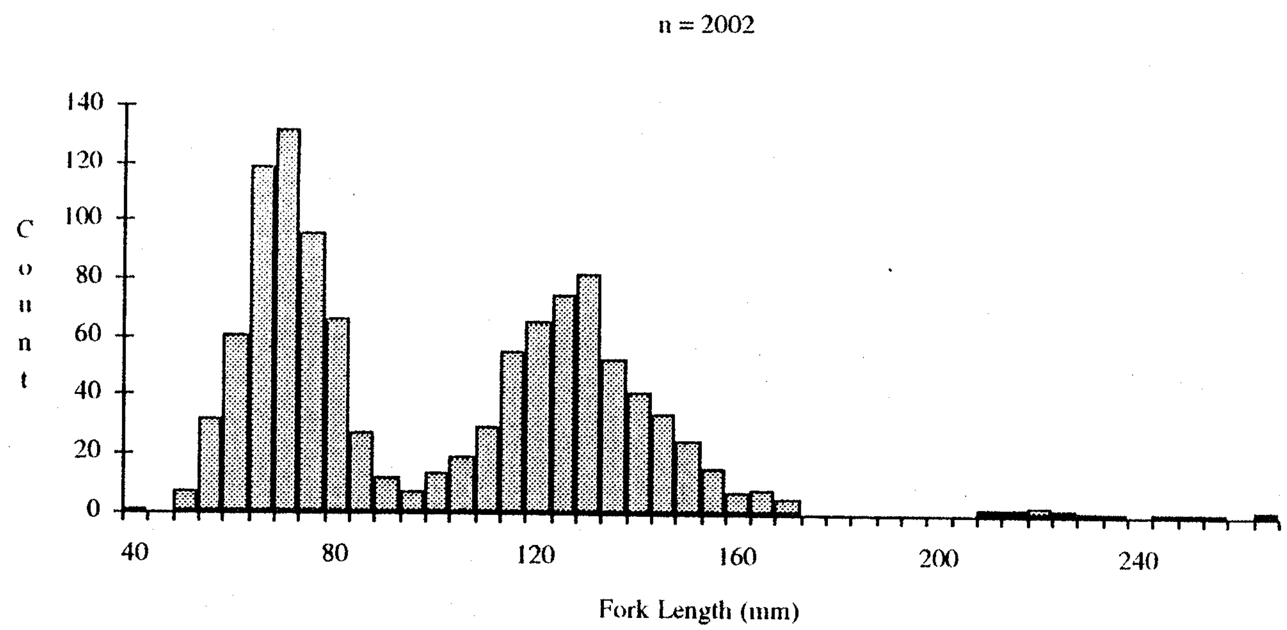
a - confidence intervals determined using a normal distribution

Appendix E. Statistics Generated by MIX 3.0 from Juvenile Steelhead Length Frequency Data, Mattole River Estuary/Lagoon, California, 1988.

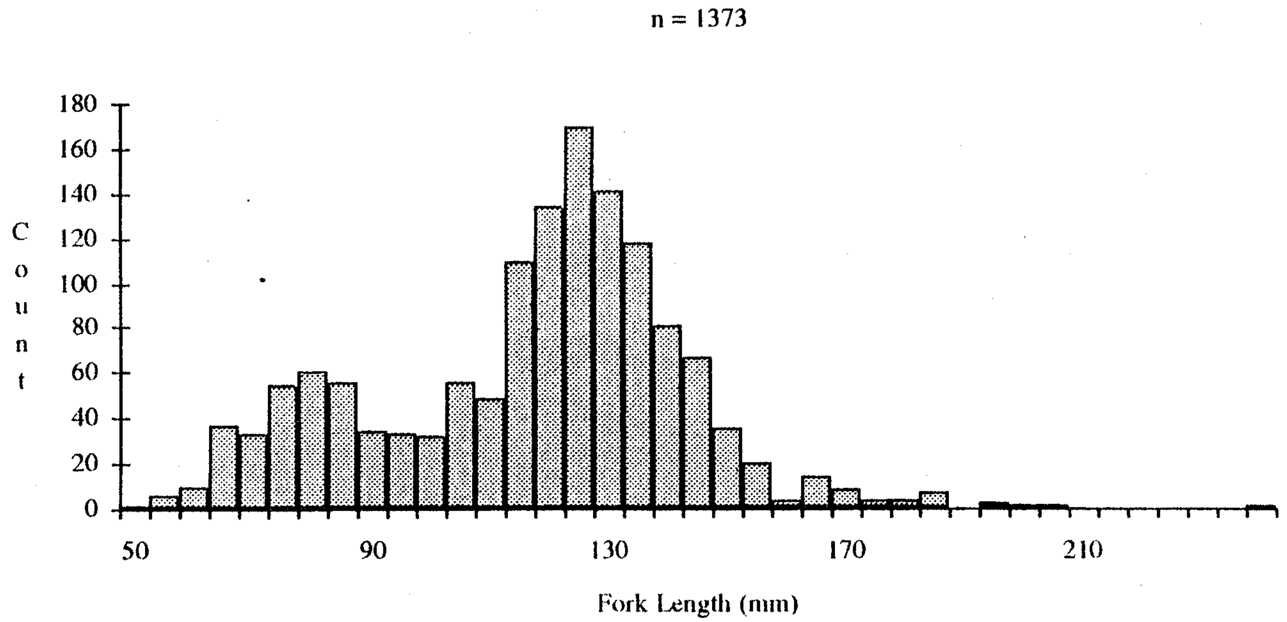
Date	7/26/88		8/23/88		9/18/88		10/23/88	
Total Sample Size	1979		1087		1361		1095	
Distribution	Lognormal		Lognormal		Lognormal		Lognormal	
Age Class	0+	1+	0+	1+	0+	1+	0+	1+
Proportion	0.82198	0.17802	0.51345	0.48655	0.25833	0.74167	0.44908	0.55092
Standard Error	0.00913	0.00913	0.01539	0.01539	0.01585	0.01585	0.01904	0.01904
Mean	63.6545	118.5365	67.7203	126.3263	78.7348	125.8076	92.2805	139.7447
Standard Error	0.2316	1.0669	0.3994	0.6757	1.2251	0.5502	0.8076	0.7954
Sigma	8.5125	17.2125	8.7601	14.9048	12.7099	14.1526	11.5827	14.7656
Standard Error	0.1899	0.8666	0.3255	0.5322	0.9928	0.4166	0.6542	0.5963
Degrees of Freedom	19		19		21		20	
Chi-square Statistic	35.9841		13.3603		50.7154		20.7768	
Probability	0.0106		0.8196		0.0003		0.4104	



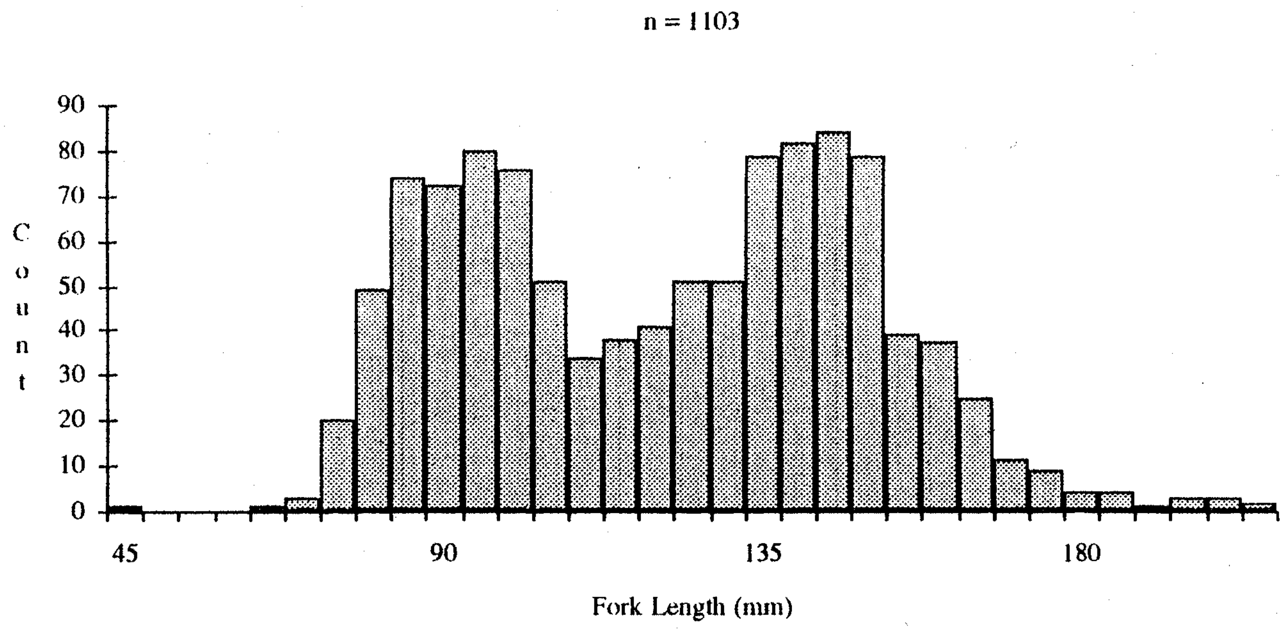
Appendix F. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Lagoon, California, July 27, 1988.



Appendix G. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Lagoon, California, August 23, 1988.



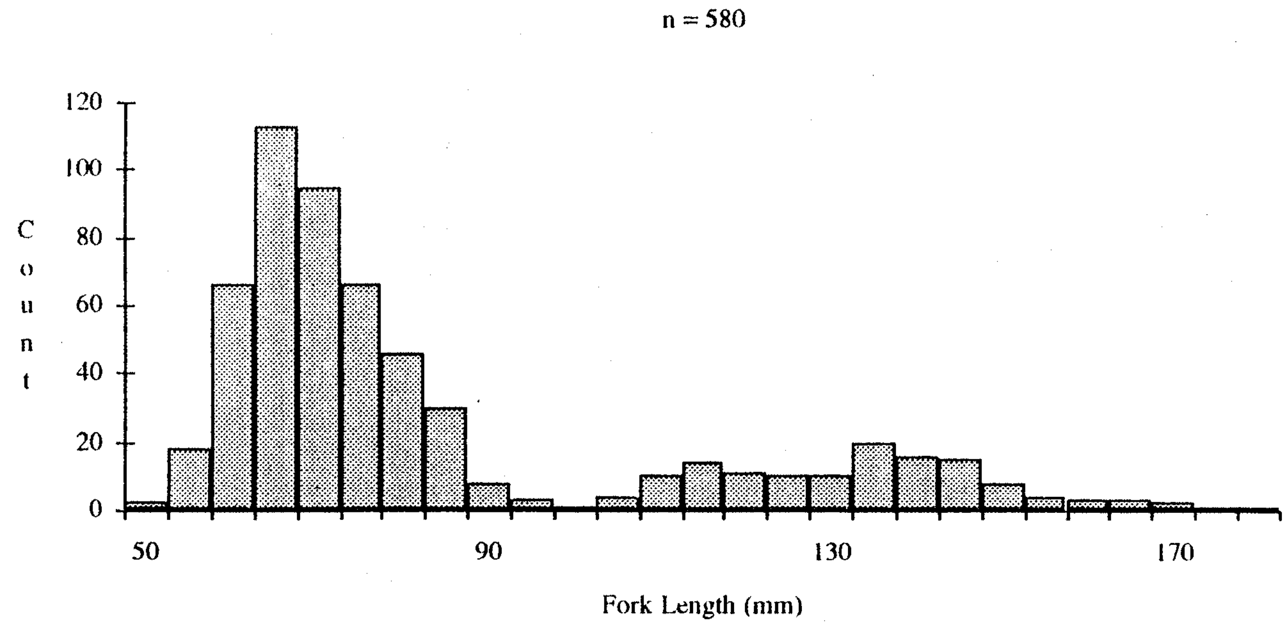
Appendix H. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Lagoon, California, September 18, 1988.



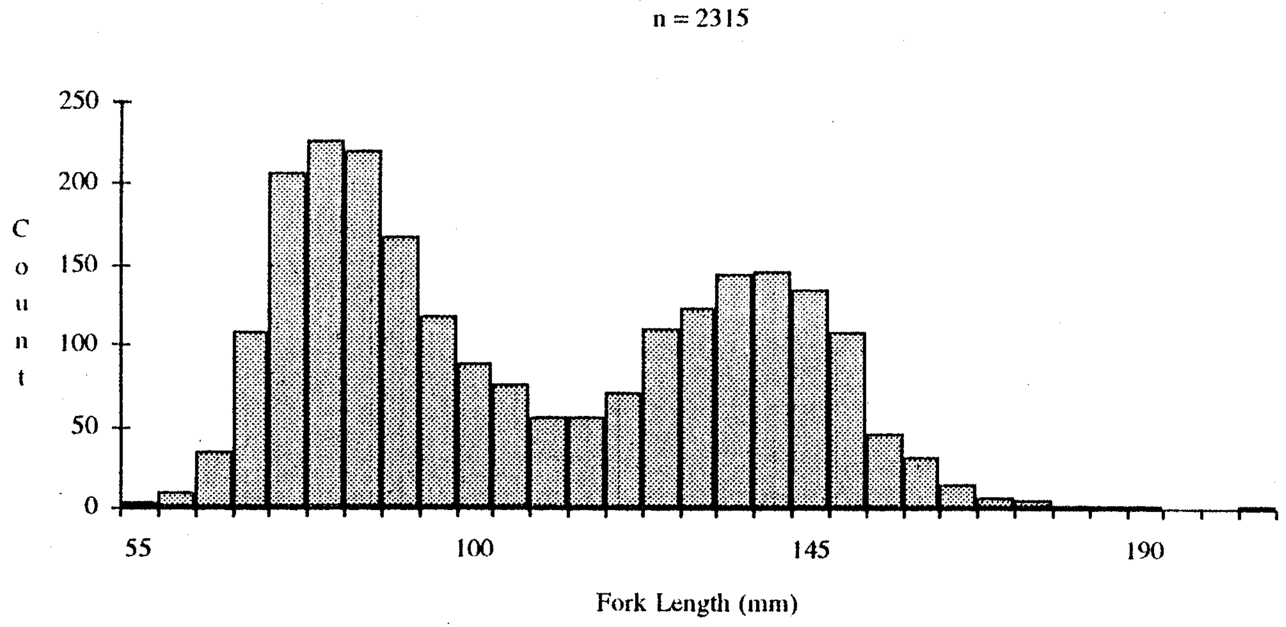
Appendix I. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Lagoon, California, October 24, 1988.

Appendix J. Statistics Generated by MIX 3.0 from Juvenile Steelhead Length Frequency Data, Mattole River Estuary/Lagoon, California, 1989.

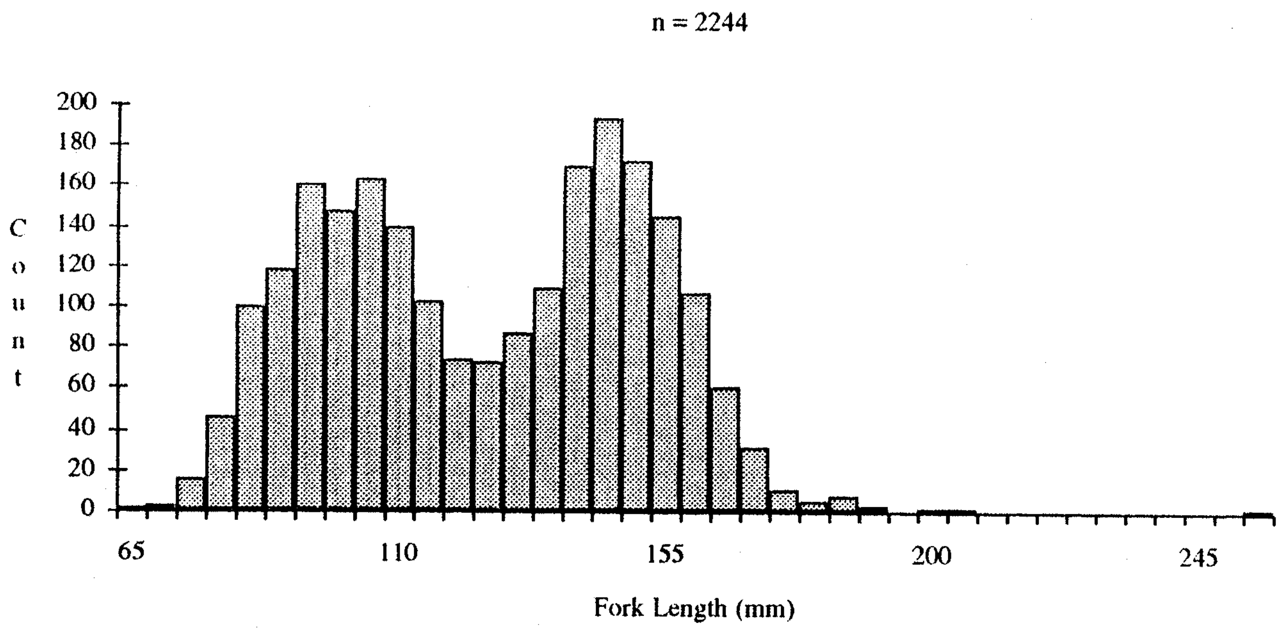
Date	7/8/89		8/13/89		9/10/89	
Total Sample Size	573		2312		2241	
Distribution	Lognormal		Lognormal		Lognormal	
Age Class	0+	1+	0+	1+	0+	1+
Proportion	0.78015	0.21985	0.57081	0.42919	0.51636	0.48364
Standard Error	0.01747	0.01747	0.01132	0.01132	0.01397	0.01397
Mean	67.376	128.6686	83.1096	134.7193	100.2279	145.5101
Standard Error	0.4108	1.3809	0.4091	0.4833	0.6547	0.4861
Sigma	8.3597	14.8447	11.902	12.9269	13.8723	11.7976
Standard Error	0.3226	1.1242	0.3461	0.3737	0.5343	0.3537
Degrees of Freedom	17		20		20	
Chi-square Statistic	28.4314		43.5783		23.9378	
Probability	0.0401		0.0017		0.2451	



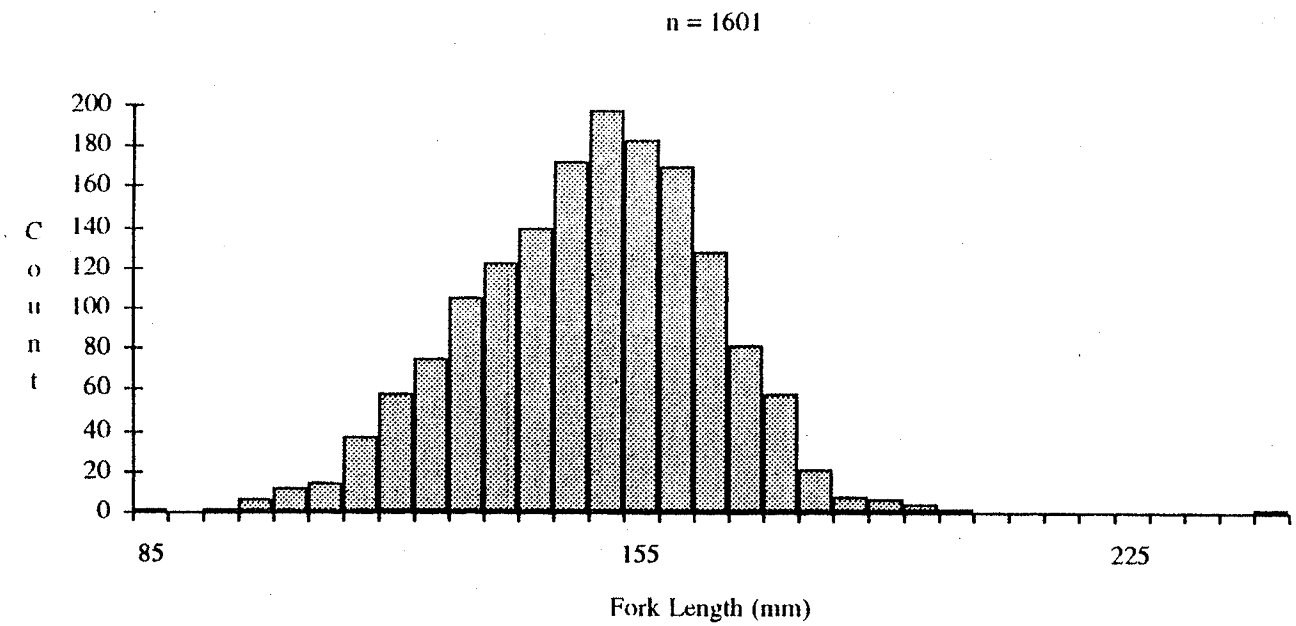
Appendix K. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Estuary, California, July 8, 1989.



Appendix L. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Lagoon, California, August 13, 1989.



Appendix M. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Lagoon, California, September 10, 1989.



Appendix N. Length Frequency Distribution for Juvenile Steelhead Captured by Beach Seining in the Mattole River Lagoon, California, October 15, 1989.

Appendix O. Mean Number and Percent Frequency of Occurrence (FO) of Food Items of Juvenile Steelhead in the Mattole River Lagoon, California, 1988.

Date	8/23		8/26		9/7		9/20		10/3		10/22		10/22	
Lagoon Region	Upper		Lower		Upper		Upper		Upper		Upper		Lower	
Sample size (n)	31		29		27		28		32		10		21	
Fish														
Size Range (mm)	56 -135		52 -134		52 -148		42 -178		64 -168		65 -115		68 -146	
Mean Length (mm)	92.3		92.5		87		102.57		104.4		84.8		102.1	
Std. Dev.	28.53		25.67		29.83		30.43		29.51		18.55		25.37	
Empty Stomachs	2		3		0		0		0		0		0	
Food Item	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO
Trichoptera	4.55	51.6	2.87	58.6	1.48	59.3	3.64	42.9	2.78	59.4	2.6	70	0.71	33.3
Ephemeroptera	0.39	22.6	-	-	1.52	63	0.11	7.1	1.97	56.2	0.1	10	-	-
Plecoptera	0.06	6.5	-	-	0.04	3.7	0.14	7.1	0.21	15.6	-	-	-	-
Diptera	2.16	61.3	1.6	55.2	10.11	92.6	16.89	60.7	30.47	100	9.6	80	2.95	61.9
Coleoptera	0.55	9.7	-	-	0.19	18.5	0.21	14.3	0.09	6.2	0.2	10	-	-
Hemiptera	0.06	6.5	0.1	10.3	0.11	7.4	0.11	10.7	0.56	18.7	-	-	-	-
Lepidoptera	-	-	-	-	-	-	-	-	0.22	12.5	-	-	-	-
Terrestrial	0.39	22.6	1.47	37.9	0.15	7.4	0.18	3.6	0.12	9.4	-	-	0.1	4.8
Corophium sp.	0.16	3.2	2.27	75.9	-	-	3.64	46.4	0.06	3.1	0.5	30	3.24	52.4
other Gammarid Amphipods	-	-	0.03	3.4	-	-	0.07	7.1	-	-	-	-	0.1	9.5
Isopoda	-	-	2.47	55.2	0.04	3.7	9.32	75	0.53	3.1	6.7	70	14.43	81
Neomysis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracoda	-	-	-	-	-	-	-	-	0.03	3.1	0.2	20	-	-
Gastropoda	-	-	-	-	0.04	3.7	0.14	10.7	1.72	15.6	5.5	20	0.05	4.8
Watermite	0.03	3.2	0.07	6.9	0.15	14.8	-	-	0.12	6.2	-	-	-	-
Nematoda	0.03	3.2	0.03	3.4	-	-	0.04	3.6	0.09	6.2	-	-	-	-
Stickleback	0.06	6.5	-	-	-	-	-	-	-	-	-	-	0.38	4.8
Unidentified	0.29	25.8	0.37	37.9	0.96	40.7	0.43	21.4	2.66	68.8	1.1	40	0.19	14.3
Algae / Pebbles		67.7		13.8		51.9		14.3		21.9		30		38.1

Note: Empty stomachs were included in calculating FO.

Appendix P. Mean Number and Percent Frequency of Occurrence (FO) of Food Items of Juvenile Steelhead in the Mattole River Lagoon, California, 1989.

Date	7/26		8/12		8/13		9/12		9/12		10/17		10/17	
Lagoon Region	Upper		Lower		Upper		Lower		Upper		Upper		Lower	
Sample size (n)	20		30		39		29		30		35		10	
Fish														
Size Range (mm)	56 - 140		75 - 144		55 - 154		78 - 164		81 - 160		81 - 184		127 - 178	
Mean Length (mm)	81.4		104.8		99.3		114.6		112.5		148.4		136.3	
Std. Dev.	22.93		20.98		29.77		23.78		25.24		18.93		25.85	
Empty stomachs	0		0		6		0		0		4		0	
Food item	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO
Trichoptera	10.05	95	6.1	56.7	6.77	56.4	0.48	17.2	10.03	63.3	6.17	57.1	3.3	40
Ephemeroptera	7.45	70	-	-	1.23	28.2	0.31	6.9	1.03	30	0.48	17.1	0.8	30
Plecoptera	-	-	-	-	0.18	2.6	-	-	-	-	-	-	-	-
Diptera	2	45	0.37	16.7	0.56	23.1	0.76	24.1	3.73	53.3	5.91	48.6	18.3	100
Coleoptera	0.05	5	0.03	3.3	-	-	-	-	0.4	20	0.86	14.3	-	-
Hemiptera	-	-	0.2	16.7	0.03	2.6	0.03	3.4	0.07	6.7	0.14	5.7	0.1	10
Lepidoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Terrestrial	0.25	20.0	0.2	3.3	0.15	10.3	0.38	20.7	0.23	16.7	0.91	25.7	27.7	100
Corophium sp.	0.05	5.0	23.9	100	8.03	30.8	22.72	96.6	6.27	36.7	0.86	31.4	34.5	100
other Grammarid Amphipod	-	-	-	-	-	-	0.1	10.3	-	-	0.03	2.8	0.3	30
Isopoda	0.05	5.0	0.03	3.3	2.95	28.2	5.28	41.1	6.5	63.3	19.51	68.6	3.3	80
Neomysis sp.	-	-	-	-	-	-	0.1	6.9	-	-	0.03	2.8	23.9	90
Ostracoda	-	-	-	-	-	-	-	-	0.13	3.3	0.06	5.7	-	-
Gastropoda	-	-	-	-	-	-	0.21	13.8	-	-	0.31	8.6	0.8	30
Watermite	-	-	-	-	0.03	2.6	-	-	0.07	3.3	0.06	2.8	-	-
Nematoda	0.05	5	-	-	-	-	-	-	-	-	-	-	-	-
Stickleback	-	-	-	-	-	-	0.03	3.4	-	-	-	-	-	-
Unidentified	0.70	45.0	0.03	3.3	0.05	5.1	0.66	31	0.1	10	1.00	31.4	0.2	20
Algae / Pebbles		45.0		63.3		33.3		72.4		23.3		51.4		70

Note: Empty stomachs were used in calculating FO.

Appendix Q. Mean Number and Percent Frequency of Occurrence (FO) of Food Items in Juvenile Steelhead Stomachs Combined for Both Years and Separated by Region, Mattole River Lagoon, California , 1988 and 1989.

Lagoon Region	Upper						Lower					
Year	1988		1989		Combined		1988		1989		Combined	
Sample size (n)	128		89		217		51		59		110	
Food Item	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO	Mean	FO
Trichoptera	2.33	55.5	8.62	67.4	4.91	60.4	1.98	47.1	3.41	39	2.75	42.7
Ephemeroptera	0.92	34.4	2.56	39.3	1.59	36.4	-	-	0.24	3.4	0.13	1.8
Plecoptera	0.1	7.8	0.08	1.1	0.09	5.1	-	-	-	-	-	-
Diptera	14.57	78.1	1.93	37.1	9.39	61.8	2.16	56.9	0.56	18.6	1.3	36.4
Coleoptera	0.26	12.5	0.15	7.9	0.22	10.6	-	-	1.7	1.7	0.01	0.9
Hemiptera	0.2	10.2	0.04	4.5	0.14	7.8	0.06	5.9	0.14	13.6	0.1	0.1
Lepidoptera	0.05	3.1	-	-	0.03	1.8	-	-	-	-	-	-
Terrestrial	0.2	10.2	0.2	14.6	0.2	12	0.9	25.5	0.29	11.9	0.57	18.2
Isopoda	2.74	23.4	3.49	33.7	3.05	27.6	6.04	62.7	3.76	27.1	4.82	43.6
Neomysis sp.	-	-	-	-	-	-	-	-	0.05	3.4	0.03	1.8
Ostracoda	0.02	2.3	0.04	1.1	0.03	1.8	-	-	-	-	-	-
Corophium sp.	0.89	14	5.64	27	2.84	19.4	4.04	66.7	22.17	98.3	13.76	83.6
other Gammarid Amphipod	0.02	1.6	-	-	0.01	1	0.06	5.9	0.05	5.1	0.05	5.5
Gastropoda	0.9	8.6	-	-	0.53	5.1	0.02	2	0.1	6.8	0.06	4.5
Watermite	0.07	5.5	0.04	2.2	0.06	4.1	0.04	3.9	-	-	0.02	1.8
Nematoda	0.04	3.1	0.01	1.1	0.03	2.3	-	-	-	-	-	-
Stickleback	-	-	-	-	0.01	1	0.16	2	0.02	1.7	0.08	1.8
Unidentified	0.95	35.2	0.21	15.7	0.65	27.2	0.39	35.3	0.34	16.9	0.36	25.5
Algae / Pebbles		22.9		33.7		28.9		23.5		67.8		47.3

Appendix R. Mean Number and Percent Frequency of Occurrence (FO) of Food Items in Juvenile Steelhead Stomachs Separated by Region and Size-Class for All Months Combined, Mattole River Lagoon, California, 1988.

Lagoon Region	Upper				Lower			
Sample size (n)	70		58		26		25	
Size-Class	< 100 mm		≥ 100 mm		< 100 mm		≥ 100 mm	
Food Item	Mean	FO	Mean	FO	Mean	FO	Mean	FO
Trichoptera	1.48	44.3	3.34	69	0.54	34.6	3.48	60
Ephemeroptera	0.81	30	1.05	39.7	-	-	-	-
Plecoptera	0.07	7.1	0.13	8.6	-	-	-	-
Diptera	9.83	80	20.3	77.6	2.77	69.2	1.52	44
Coleoptera	0.14	10	0.41	15.5	-	-	-	-
Hemiptera	0.06	4.3	0.38	17.2	0.08	7.7	0.04	4
Lepidoptera	0.09	4.3	0.02	1.7	-	-	-	-
Terrestrial	0.3	14.3	0.07	5.2	1.42	38.5	0.36	12
Isopoda	2.17	25.7	3.43	20.7	8.38	73.1	3.6	52
Neomysis sp.	-	-	-	-	-	-	-	-
Ostracoda	0.01	1.4	0.03	3.4	-	-	-	-
Corophium sp.	0.34	11.4	1.55	17.2	2	73.1	6.16	60
other Gammarid Amphipods	0.01	1.4	0.02	1.7	0.04	3.8	0.08	8
Gastropoda	0.01	1.4	1.97	17.2	0.04	3.8	-	-
Watermite	0.09	5.7	0.05	5.2	0.08	7.7	-	-
Nematoda	0.06	4.3	0.02	1.7	-	-	-	-
Stickleback	-	-	0.03	3.4	-	-	0.32	4
Unidentified	0.57	31.4	1.41	39.7	0.62	53.8	0.16	16
Algae / Pebbles		22.9		-		11.5		36

Appendix S. Mean Number and Percent Frequency of Occurrence (FO) of Food Items in Juvenile Steelhead Stomachs Separated by Region and Size-Class for All Months Combined, Mattole River Lagoon, California , 1989.

Lagoon Region	Upper				Lower			
Sample size (n)	51		38		23		36	
Size-Class	< 100 mm		≥ 100 mm		< 100 mm		≥ 100 mm	
Food Item	Mean	FO	Mean	FO	Mean	FO	Mean	FO
Trichoptera	4.9	58.8	13.6	78.9	0.35	21.7	5.36	50
Ephemeroptera	2	41.2	3.32	36.8	-	-	0.39	5.6
Plecoptera	-	-	0.18	2.6	-	-	-	-
Diptera	2.57	43.1	1.08	28.9	0.3	13	0.72	22.2
Coleoptera	0.16	5.9	0.13	10.5	-	-	0.03	2.8
Hemiptera	0.04	3.9	0.05	5.3	0.09	8.7	0.17	16.7
Lepidoptera	-	-	-	-	-	-	-	-
Terrestrial	0.22	15.7	0.18	13.2	0.22	8.7	0.33	13.9
Isopoda	4.47	35.3	2.18	31.6	4	21.7	3.61	30.6
Neomysis sp.	-	-	-	-	-	-	0.08	5.6
Ostracoda	0.08	2	-	-	-	-	-	-
Corophium sp.	9.53	35.3	0.42	15.8	22.6	100	21.9	97.2
other Gammarid Amphipods	-	-	-	-	-	-	0.08	8.3
Gastropoda	-	-	-	-	-	-	0.17	11.1
Watermite	0.08	3.9	-	-	-	-	-	-
Nematoda	0.02	1.9	-	-	-	-	-	-
Stickleback	-	-	-	-	-	-	0.03	2.7
Unidentified	0.33	23.5	0.05	5.3	0.18	13	0.44	19.4
Algae / Pebbles		21.6		50		56.5		75

Appendix T. Summary of Statistics Generated from Contingency Table Analysis from Comparisons Between Years, Regions, and Size-Classes of Average Number of Major Food Items (Tricopteran Larvae, Aquatic Diptera, Corophium sp., Isopods, and Ephemeropteran Larvae) Consumed by Juvenile Steelhead in Two Regions of the Mattole River Lagoon, California, 1988 and 1989.

Comparison	Year	Region	DF	G Statistic	Probability [a]
Between Years	-	U	4	19.543	0.0015
	-	L	3	10.031	0.0178
Between Regions	1988	-	3	12.647	0.0084
	1989	-	4	14.693	0.0076
Between Size-Class	1988	U	4	0.399	0.9838
	1988	L	3	6.915	0.0892
	1989	U	4	16.146	0.0072
	1989	L	3	5.172	0.2305

[a] Probabilities were determined by the Chi-Square Distribution