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Fisheries Elements of a Garcia River Estuary Enhancement Feasibility Study

By Patrick Higgins

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FINAL REPORT

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Introduction

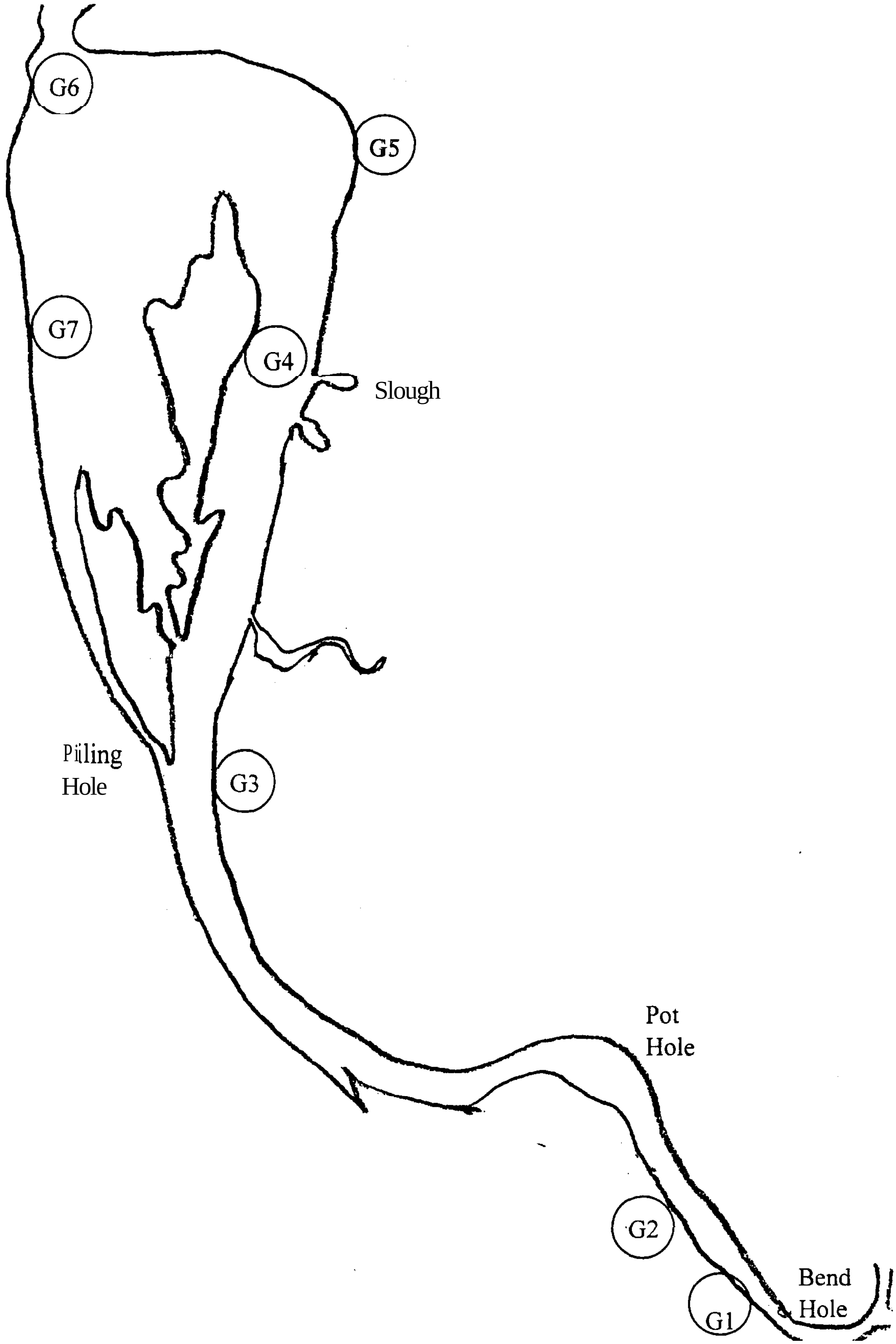
The Garcia River has long been noted for its production of salmon and steelhead. Intensive land use management has lead to increased erosion, however, which has caused profound changes in stream beds and the estuary and a related decrease in fish populations. The river has been inundated by waves of sediment, first from logging around the turn of the century and failure of a splash dam and then from logging and floods following World War II (MCRCD, 1992). The estuary, according to accounts of local residents, has been greatly diminished in depth. Chinook salmon are thought to be extinct in the basin and coho salmon at remnant levels. However, winter steelhead trout populations have held their own and now seem to be on the rise. Currently, the Garcia River is in recovery from past impacts and the site of a watershed- wide fishery restoration program (MCRCD, 1992). Estuaries are important to anadromous salmonids (Reimers, 1971; Busby, 1988; Murphy et al., 1984; Tschaplinski, 1982) and this study is to determine whether the restoration of the Garcia estuary can be accelerated to benefit salmon and steelhead.

Samples of fish were collected from the Garcia River estuary for this study from June-August 1995 and the habitat types of the estuary categorized. This study was conducted to demonstrate how salmonids use various habitat types within the estuary and to help assess whether the habitat manipulations in the estuary suggested by the Garcia River Watershed Enhancement Plan (MCRCD, 1992) would achieve the goal of increasing production of salmonids.

Methods

The fishes of the Garcia River estuary were sampled during the summer of 1995 on June 5, July 12 and August 8. Seven sampling stations were chosen that were thought to be representative of all habitat types within the estuary, from riverine to marine (Figure 1). The upper most sampling station (Gl) was the Bend Hole (Photo #l, Appendix A), just below Hathaway Creek, which is the upstream end of tidal influence. A run habitat approximately 150 yards downstream of Bend Hole served as station G2, the second riverine sampling station (Photo #2). The third sampling station chosen was at the Piling Hole (G3), a considerable distance downstream. The main channel of the river just downstream of the mouth of the lowest slough served as the fourth sampling station (G4). The area just above where the estuary channel is deflected to the south by the sand berm separating it from the ocean served as the fifth station (G5). The mouth of the estuary, which is a marine environment, served as station G6. The last station (G7) was

Figure 1. Beach seine sampling stations in the Garcia River estuary from June-August 1995.



just north of the Lighthouse Bluffs in an area that has little flow of fresh water because gravel bars upstream have deflected the river flow. Sampling slough habitats with the beach seine was not feasible until the river level dropped; therefore, only one slough sample was collected in August.

Samples were collected using a 100 foot long, by eight foot high beach seine with l/2 inch mesh. The center of the seine also had a bag eight feet by eight feet with a mesh of 3/8 inch. Seine nets have float lines along the top and lead lines along the bottom. The net was deployed by boat or by wading, dependent on the depth of water (Photos #3 and #4). The technique employed was devised by field assistant Steve Cannata (Personal Communication), who has employed similar methods in collecting over 300 samples for his Master's Thesis study in the Eel River estuary. Direct observation by diving was also employed as a supplementary tool to assess fish use of areas with snags or substantial riparian cover where the net could not be deployed. The fork length (measurement from the nose to the cleft in the tail) of all species of fish were measured to the nearest millimeter (mm). A representative sample ofjuvenile salmonids were also weighed and scales taken to determine age.

Water temperature, salinity and conductivity were measured at each station either immediately before or after each sample was taken, using a YSI Model 33 TSC meter. Measurements were taken at the surface, at one meter and at two meters if water depth was sufficient. Time was also recorded so that tide level could also be ascertained. Habitat types within the Garcia River estuary were measured on August 7 using the technique of Starr (1979) as modified from Cowardin (1978). In addition to salinity, depth and substrate type were measured to determine habitat types. Starr (1979) found it most useful to separate Oregon estuaries into four distinct habitat subsystems: marine, bay, slough and riverine(Table 1). The **marine** subsystem is the area near the mouth which is characterized by high wave or tidal energy, course sand or rocky substrate and high salinity. The portion of the estuary characterized as **riverine** is often a narrow, subtidal river channel that may be only seasonally influenced by salt water or may be completely freshwater throughout the year. **Bay** subsystems often have mud (silt and clay) substrate, high salinities during summer and may have extensive intertidal areas harboring eel grass beds or marshes. **Sloughs are** narrow arms that extend off the estuary that usually are intertidal areas with fine sediment as substrate.

Results

Beach Seine Results: A total of ten species of fish were collected throughout the sampling period (Table 2). No chinook salmon or coho salmon juveniles were captured, however, steelhead trout juveniles were sometimes abundant. The fish samples collected on June 5 were dominated by steelhead juveniles except at stations G6 and G7. Three-spine stickleback and staghorn sculpin were found at many stations with one prickly sculpin collected at the Piling Hole (G3). The highest number of steelhead captured was 130 at station G4 with station G5 yielding the second largest total (30). Freshwater flows were sufficient at this date to restrict salt influence to within 100 yards of the mouth of the

Table 1. **Estuarine habitat classification system taken from Starr (1979).**

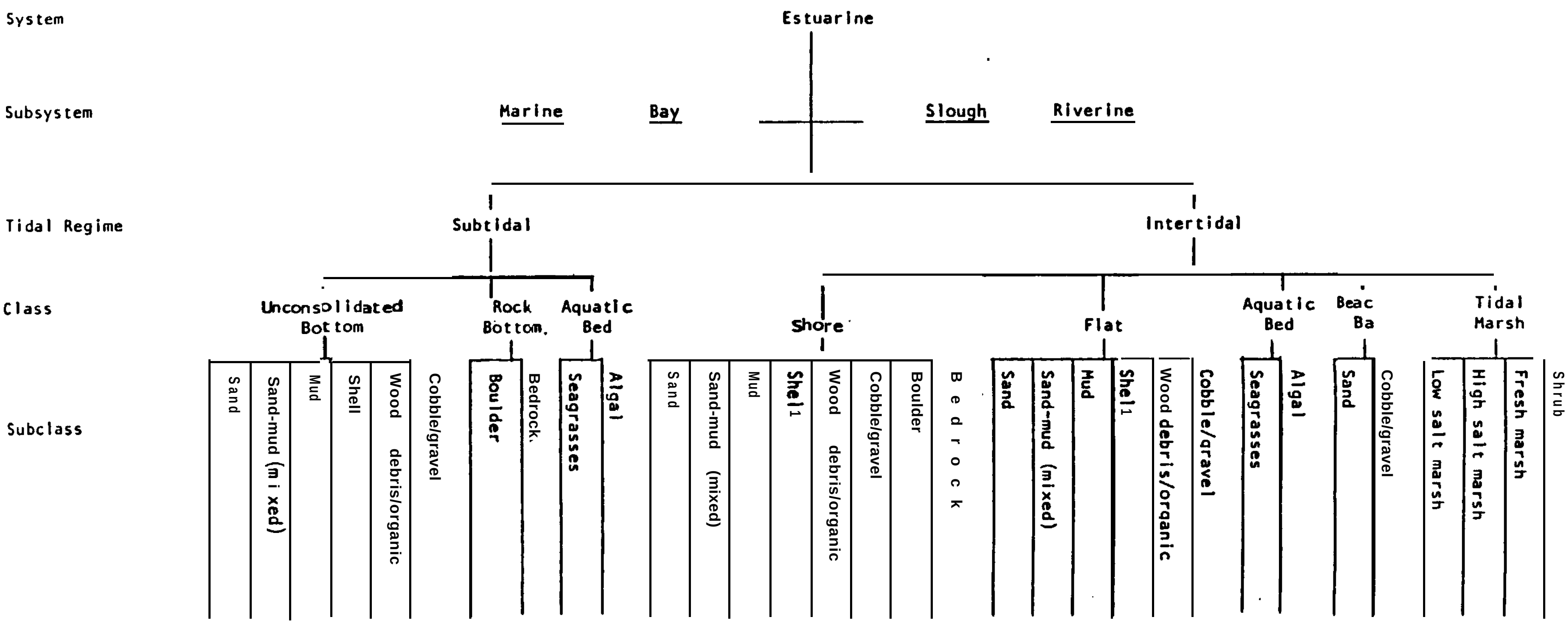


Table 2. Common and scientific names of fish species collected in the Garcia River estuary during June, July and August 1995.

steelhead trout	Oncorhynchus mvkiss
Pacific herring	Clupea harengus
surf smelt	Hypomesus nretiousus
bay pipefish	Sygnathus ariseolonealus
shiner surfperch	Cymatoaaster aggregata
silver surfperch	Hyperprosooon ellipticum
starry flounder	Platichthys stellatus
saddleback gunnel	Pholis omata
prickly sculpin	Cottus asper
staghom sculpin	Leptocottus armatus
three-spined stickleback	Gasterosteous aculeatus

estuary in the main channel of the river, below station G5. Sampling took place during high tide at the mouth and only two staghom sculpins were found in the full strength sea water (33.5 parts per thousand). Station G7 yielded two steelhead juveniles on June 5 but 82 shiner perch, one staghom sculpin and one bay pipe fish were also captured, reflecting salt water influence (15 ppt at 1 m in depth).

Fish samples collected on July 12 showed a precipitous decline in steelhead at stations G4 and G5. The highest number of steelhead juveniles captured was 43 at the Bend Hole (Gl). Stickleback were present in samples at stations Gl, G2 and G3. The sample collected at the Piling Hole (G3) also showed increasing use by marine fishes, with 18 juvenile shiner surfperch and one surf smelt captured. Only four steelhead were captured at station G-4. The station where the river channel turns south along the beach sand berm (G5) had changed to salt influence and sampling there yielded two bay pipe fish as well as five staghom sculpin. Four surf smelt, one juvenile silver surfperch and four staghom sculpins were found at the mouth of the estuary (G6). Station G7 against the light house bluffs showed the typical mix of fishes with one steelhead, one staghom sculpin and five surf smelt captured on July 12.

By August 8, salt influence had reached upstream to just below station G2. No steelhead were captured at station Gl but no motor was available for the boat used for sampling on this date; therefore, it is likely that at least some of the older age juvenile steelhead in the Bend Hole eluded capture. Eight stickleback and 20 prickly sculpin were collected at Gl, however. Station G2 remained consistent across all sampling periods and produced 13 steelhead and five stickleback on August 8. The Piling Hole (G3) continued to produce a mix of steelhead, stickleback, prickly sculpin, juvenile surfperch and surf smelt. Station G4 had abundant algal beds by August 8 and had numerous prickly and staghorn sculpins, a bay pipefish and 22 juvenile shiner surfperch. Although one steelhead was collected at station G5, six bay pipefish, a juvenile greenling and a saddleback gunnel showed strong salt water influence. One Dungeness crab was also collected at station G5. Eight starry flounder juveniles were captured at the mouth of the estuary (G6) along with staghorn sculpins. Only staghorn sculpins were collected at station G7 on August 8.

On August 8, the lowest slough arm had a sufficient flat area at its mouth to allow a beach seine haul. The sample included prickly sculpin, staghorn sculpin, bay pipefish and over 1000 juvenile herring (50-55mm). A complete list of fish captured by station is available in Table 3.

Other Fish Observations: Direct dive observations were used to supplement net samples. On June 5, a school of approximately 50 yearling and two year old steelhead were observed in the pool at the mouth of Hathaway Creek. A similar number of fish was also sighted at the same site on July 12. Because of the low number ofjuvenile steelhead captured in the seine haul at the Bend Hole on June 5, a dive was undertaken. No additional steelhead juveniles were seen, confirming low abundance at the site as opposed to low sampling efficiency. A similar dive effort on August 8 also showed that few juvenile steelhead were present in the Bend Hole.

Dives took place in the Pot Hole during each sampling period. Few or no steelhead were observed in this hole until August 8 when between 30 and 40 juvenile steelhead were observed near over hanging riparian vegetation. These fish were predominantly yearling and two year old fish. An adult starry flounder was observed holding in the riffle below the Pot Hole on August 8 as well. On the same date, one seine haul was attempted along the bluffs just upstream of the mouth of the estuary but only one striped surfperch was captured.

Habitat Typing Observations: The habitat inventory of the Garcia River estuary was conducted on August 9. This late summer date was chosen to show greater habitat diversity. An earlier sampling date would have shown the estuary to be dominated by freshwater and largely riverine which would not have been representative of conditions as freshwater flows dropped. Below is a description of estuarine physical habitat parameters using the fisheries sampling stations as land marks for orientation.

Station Gl *(Bend Hole):* The maximum depth at the Bend Hole just after high tide was approximately 10 feet. No salinity or elevated conductivity was evident during any sampling period. Therefore, the Bend Hole sampling station falls under the category of river-me. The point bar across from the hole pinches the river into a tight channel that is narrow but deep (Photo #l) and forms several holes upstream and downstream of the Bend Hole. Riparian willow and alder trees extend well over the water providing excellent cover for steelhead juveniles.

The substrate of the exposed gravel point bar was a mixture of cobble and gravel with several large dead alder trees deposited by the floods of March. The bottom of the stream channel was covered with gravel in riffle areas but fine sediment predominated in the depth of pools. Mud also was deposited in quiet water back water areas near shore in the pools.

Table 3.- Water quality and catch data collected at sampling stations in the Garcia River estuary June - August, 1995.

										CATCH											
STATION	DATE	TIME	TEMP SURFACE	SALINITY SURFACE	TEMP 1M	SALINITY 1M	TEMP 2M	SALINITY 2M		STEELHEAD	STICKLEBACK	PRICKLY SCULPIN	STAGHORN SCULPIN	SHINER SURPERCH	SILVER SURFPERCH	STARRY FLOUNDER	SURFSMELT	PACIFIC HERRING	BAY PIPEFISH	SADDLEBACK GUNNEL	DUNGENESS
G1	JUN 5 - 95	1205	16	0	16	0	16	0		12	2										
	JUL 12-95	1505	19	0	19	0	19	0		43	3										
	AUG 8-95	1015	16.5	0	16.5	0	16.5	0			8	20									
G2	JUN 5 - 95	1120	16	0	15.5	0				13	2		1								
	JUL 12-95	1420	18.5	0	18.5	0				12	3										
	AUG 8-95	1055	17.5	0	17.5	0				13	5										
G3	JUN 5 - 95	1335	17	0	17	0	17	0		14	3	1	2								
	JUL 12-95	1320	18.5	0.5	15	30	14.5	30.5		13	1		1	18			1				
	AUG 8-95	1200	19	1	14	32	14	32		5	2	2		2			1				
G4	JUN 5 -95	1620	18	0	18	0				126											
	JUL 12-95	1240	18	3	14	28				4											
	AUG 8-95	1310	19	6	15	33					6	5	17	22					1		
G5	JUN 5 - 95	1425	17.5	0	17.5	0	17.5	1		30			2								
	JUL 12-95	1215	13	33	13	32.5	13	32.5					5						2		
	AUG 8-95	1355	19	5.5	14.5	33	14.5	33		1	3	1	8						6	1	1
G6	JUN 5 - 95	1505	13	32	13	31							2								
	JUL 12 -95	1130	13	32.5	12.5	33.5							4		1		4				
	AUG 8-95	1420	20	5.5	17	31							4			8					
G7	Jun 5 - 95	1545	17	8	17	12.5				2			1	82					1		
	JUL 12-95	1050	15.5	6	13	30.5				1			1				5				
	AUG 8-95	1510	20	13.5	19	32.5							7								
SLOUGH	AUG 8-95	1615	18	31.5	15	32	14	33				2	2					1000	1		

The deep hole at the convergence of the Garcia River with Hathaway Creek was 10.5 feet deep and the stream bottom was entirely covered with fines. Between the Bend Hole and Station G2, the river thalweg shifts from the south bank to the north bank with a maximum depth of approximately four feet. However, two isolated scour pockets around embedded logs, of six feet and seven feet in depth, were noted near the south bank in this reach. The bottom was covered with a mixture of gravel and mud and heavily colonized by filamentous algae.

Station G2: The channel width at this station was 95 feet and would be classified as a run habitat. The depth ranged from very shallow near the south bank to three feet from mid-channel to the north bank. Cover near the north bank was provided by willow and alder trees over-hanging the stream (Photo #2). The bottom was covered with mud but a gravel and cobble layer was only a few inches below the surface. Approximately 30% of the bottom was covered with filamentous algae. No salinity or elevated conductivity was detected at this station during any sampling period.

The riffle 100 yards downstream of Station G2 was the upper limit of salt intrusion on August 9. The substrate in the riffle was clean gravel but it was almost 100% covered with a luxuriant growth of filamentous algae. Cattle have extensive access to the river at this site and nutrient enrichment may in part promote the algae growth.

The Pot Hole was measured at 8.5 feet deep two hours before low tide. This pool is well developed and remained 6 feet deep to within a short distance of the gravel bar. Approximately 20% of the pool's surface has cover from overhanging riparian vegetation. The substrate in the pool was gravel at the front, edges and rear but fine sediment and organic material at depth. The salinity was zero at the surface but was near full strength sea water (32 ppt) at depths greater than one meter when measured on August 9 just before low tide.

The riffle below the Pot Hole had gravel substrate approximately 2 inches in diameter on average. The stream bottom remained gravely at the top of the area that formerly was the site of the Miner Hole (Photo #5). Depth in the thalweg of the river along the bluffs increased from one to four feet and substrate in the deeper areas was composed of fine sediment. Gravel in shallower areas was about 40% colonized by the salt tolerant algae, Cladophera sp. and Enteromorpha sp.. The latter species is the dominant algae in most of the estuary influenced by salt water and attaches to rock surfaces and traps air within its stalk or thallus. The plant floats vertically toward the surface when submerged by high tides. The gravel bar exposed by low tide was covered with extensive algal growth and cattle waste.

Station G3 (Piling Hole): The maximum depth at the Piling Hole one hour before low tide was seven feet near the large pile of woody debris that forms this feature. Course gravel was the dominant substrate in shallower areas, while a pea gravel and mud mixture covered deeper areas. Enteromorpha sp. had colonized about 30% of the gravel surface in shallower areas. In June, there was no salinity measured at this station but by July salt water was intruding as river flows dropped. On August 8, the surface of the Piling Hole was nearly fresh (1 ppt) but 3 3.5 ppt at depths below one meter approximately one hour before low tide.

Below the Piling Hole in the main channel of the estuary, 90% of the stream bottom was covered with algae. In addition to Enteromorpha, Ulva sp. was also abundant. The thalweg shifted from the south side of the channel at the Piling Hole to the north side with a maximum depth of four to five feet.

Station G4: The habitat at station G4 would again be characterized as a run with a maximum depth of approximately four feet. Mud and fine sediment were mixed gravels at this station and algae covered about 50% of the bottom. Below Station G4, the thalweg of the channel increased in depth to about 5.5 feet and the substrate in the thalweg showed an increasing amount of fine sediment. Areas less than three feet in depth with gravel substrate were heavily colonized by algal beds (Photo #6). The salinity was zero in June and was heavily salt influenced by July. On August 8, the surface salinity was measured at 6 ppt but at one meter it was 33 ppt.

Station G5: This station had a sandy bottom and a maximum depth of 4.5 feet. Salinity trends were similar to those describing Station G4 as were readings on August 8. Substrate across the channel toward the tip of the island included more gravel with about 40% of the substrate covered by Enteromorpha. The estuary channel swings due south along the sand berm below Station G5. The channel attained a maximum depth of approximately four feet along the berm. Substrate in the thalweg was sand but nearer to the island, the estuary bottom was completely carpeted with detritus.

Station G6 (the mouth): Sand dominates the substrate of the Garcia River estuary bottom near the mouth. Salinity was approximately 33.5 ppt during all sampling periods except measurements were taken on August 8 at low tide when surface salinity was 5.5 ppt. Depth in the immediate vicinity of the spit at the mouth had decreased to less than three feet by August 8. During earlier sampling periods, the deep water area near the mouth was much larger. The greatest depth in the estuary was 15 feet along the Lighthouse Bluffs just in from the mouth at low tide on August 8. The water remains deep along the bluffs for several hundred feet further east with maximum depth ranging between 5-9 feet (Photo #7).

Station G7: The bottom shallows quickly away from the mouth and the bluffs in the quiet water area that forms the southern portion of the Garcia River estuary. Sand bars upstream shunt most of the freshwater flows away from this area when the river drops. This station was heavily influenced by sea water even in June. Average maximum depth at low tide for much of this area was 2-3 feet at low tide on August 8. Substrate at Station G7 was a mixture of mud, sand and gravel. Approximately 20% of the substrate was covered with Enteromorpha.

Arms of the southern portion of the estuary had substrate of mostly gravel except in the thalweg of channels where fine sediments had been deposited. Algal growth covered about 40% of gravely areas. Maximum depth in the channels was three feet at low tide.

Sloughs: The slough areas of the Garcia River are relatively small areas with steep sides and fine sediment as substrate. Maximum depth was 4.5 to 5 feet and algal beds covered areas near the edges or up slough arms (Photo #8).

Discussion

The nature of the habitat and use by fishes changed dramatically over much of the Garcia River estuary as freshwater flows decreased and salt water intruding from the ocean increased. As of June 5, the majority of the estuary was riverine and the fish samples were dominated by steelhead. In August, when habitat typing took place, much of the riverine channel was so influenced by salt and had developed such extensive algal beds that it fit more under the category of the bay subsystem. Species diversity increased in this latter period as marine fish juveniles colonized.

Changes in Steelhead Abundance and Use of Habitat By Other Fish Species

Smith (1966) stated that most fish occurring in estuaries are of marine origin with a few anadromous species also using these habitats. He also asserted that, as a consequence, species diversity will decline in an upstream direction in an estuary. This generalization certainly held true in the Garcia River estuary and could also be applied on a temporal scale: as salt water influx increased during summer, species diversity went up.

Steelhead trout juveniles were surprisingly abundant in lower areas of the estuary that had little depth or cover on the June 5 sampling date. In retrospect, it seems that these fish were feeding in the main river channel, but staging for ocean entry. The size trend between sampling stations was that larger juvenile steelhead were collected nearer to the mouth. Fish in this lower reach were often quite silvery and had lost their parr marks which is typical when anadromous salmonids are staging to enter the ocean. The substantial reduction in steelhead juveniles at stations G3, G4 and G5 from June to July suggests that as salt water intruded into the north channel of the estuary that many steelhead entered the ocean. Two factors suggest that steelhead juveniles were staged nearer to the estuary mouth in June in preparation of ocean entry. Larger juveniles would be more fit to enter the ocean and in fact size of fish increased in the lower estuary (Figure 2). Also, steelhead nearer to the ocean were very silver and often lacked parr marks, which is a sign of smolting, while steelhead captured upstream often retained parr marks. Dive observations and net samples did not uncover any large concentrations of steelhead that had moved back upstream in response to the salt water in either July or August.

Steelhead captured during all three months of summer showed a growth trend that indicates that conditions in the estuary were good. The length/frequency graphs shown

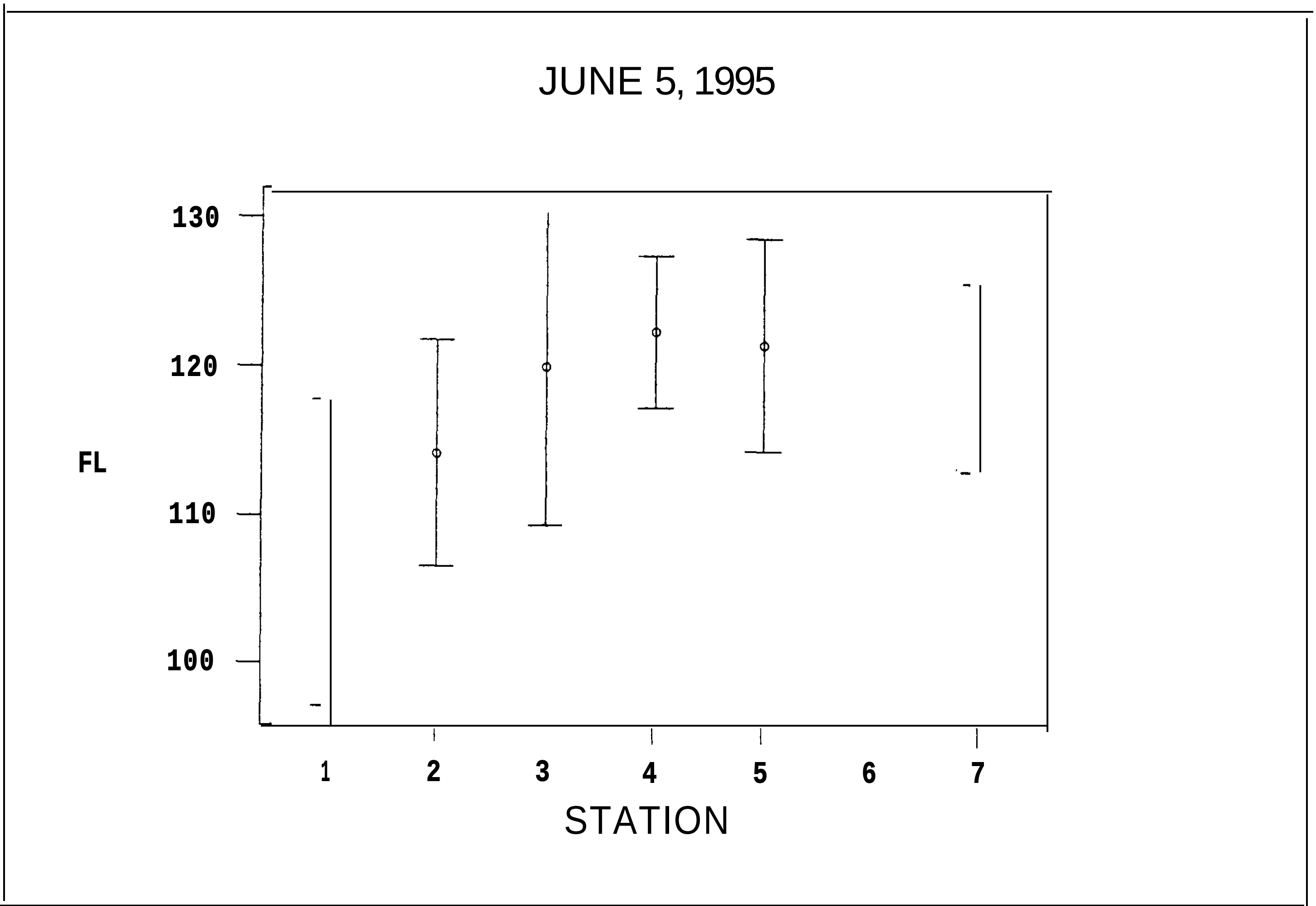


Figure 2. Fork length mean and 95% confidence intervals for steelhead captured at Garcia River Estuary beach seine sampling stations.

as Figure 3 show an increase in the most frequent length in samples from 110 mm in June to 120 mm in July. So few fish steelhead were captured in August that it was difficult to confirm this trend and but the mode of larger fish was 140-150 mm. The smaller fish in the length frequency histogram for August suggests that young of the year steelhead numbers in the estuary were increasing in late summer.

The majority of steelhead captured were yearlings according to scale samples analyzed. In addition to scales, size classes were compared to reference samples analyzed by Shapavalov and Taft (1938) to determine age. Fish over 160 mm in length were probably two year old steelhead according to comparisons with this data base. In early samples, not many young of the year steelhead were captured, but those in the 70-80 mm size class were probably of this age class.

Steelhead in the riverine subsystem of the upper estuary showed preference for deeper pool features with good cover, as was found during extensive dive observations conducted by Peterson (MCRCD, 1992). The large number of steelhead captured during July at the Bend Hole and large school ofjuvenile steelhead seen in the Pot Hole in August, using direct dive observation, confnmed this preference. However, steelhead in the estuary in June were distributed across all habitats, with no noticeable increase in areas with greater depth or cover. The largest number of steelhead collected during the June sampling period were at Stations G4 and G5 where the water depth was less than four feet and no large wood or other cover.

Variations in capture or in dive observations in the Bend Hole and Pot Hole during various sampling periods may be owing to other factors. A well worn trail into the riparian thicket at the convergence of Hathaway Creek and the Garcia River suggests that a family of otters may live there. Hunting otter families may cause considerable changes in the way steelhead may disperse to avoid predation. Anglers were seen fishing for “trout” during our June sampling period and hooks and lines were found in the bushes or on snags on subsequent trips. Angling may also have changed the distribution and abundance of steelhead juveniles in the riverine habitat of the estuary.

The area of the estuary near the mouth and off of Lighthouse Bluffs harbored marine or euryhaline fishes, such as sculpin, during all sampling periods. The sampling stations further up the main river channel, however, showed a dramatic change as salt water gained influence. Algae heavily colonized the bottom, in some areas as much as 90%, and shiner surfperch used the algal beds as a nursery. Prickly and staghom sculpins and bay pipefish also strongly favored these habitats. Surf smelt ranged into the estuary where ever salt water was present and were captured as far up as the Piling Hole.

Sloughs in the Garcia River estuary are so steep sided that sampling with the seine was not possible until August. It is likely that the sloughs stay salty after river flows drop and sea water first intrudes in early summer. In addition to bay pipefish and sculpin, one thousand juvenile herring were captured. The timing of herring spawning may vary in different estuaries along the Caliiornia coast. The small size of the young herring

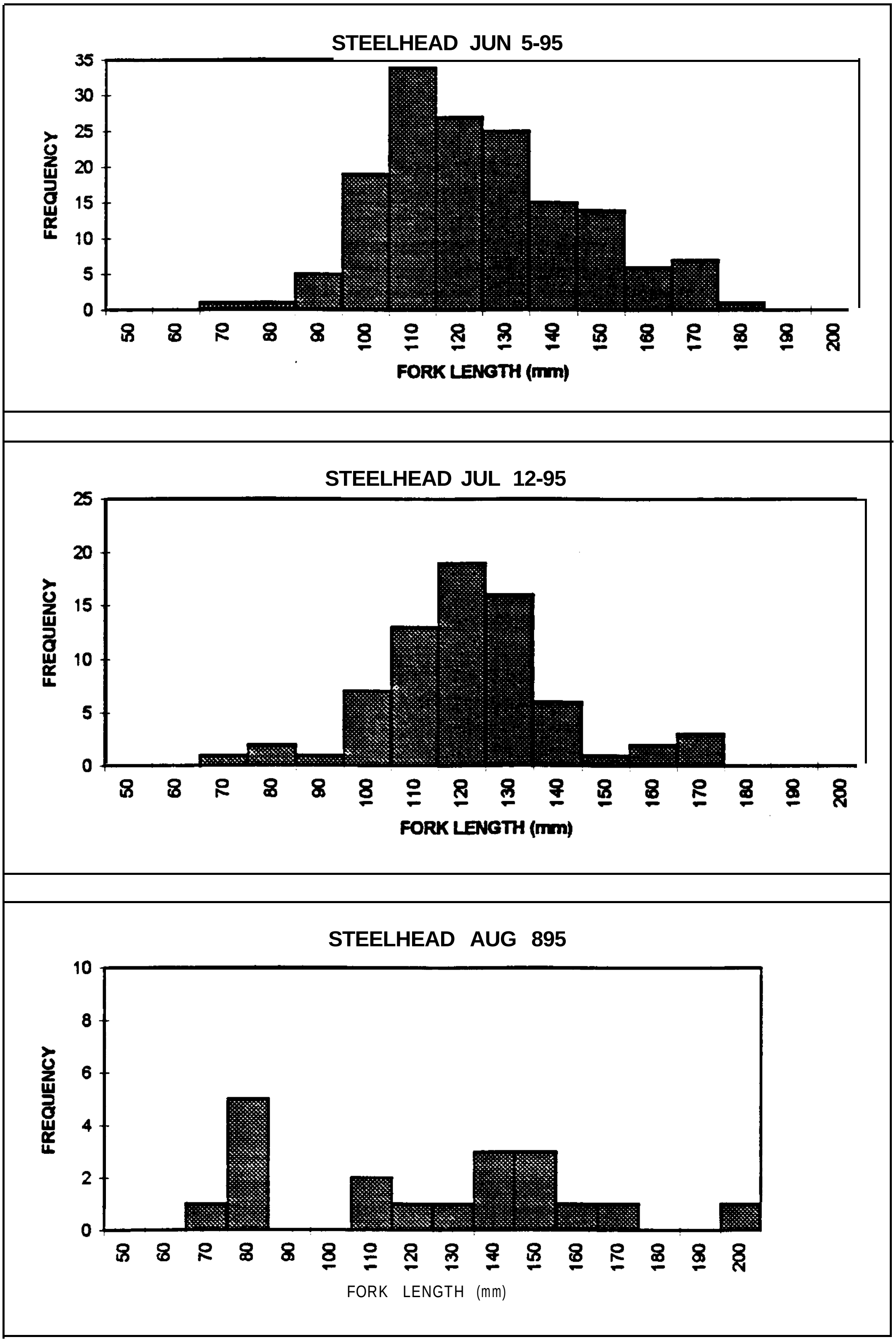


Figure 4. The frequency of the most abundant size class of juvenile steelhead sampled in the Garcia River estuary rose from 110 mm in June to 120 mm in July 1995. Sample size in August was small, but yearling steelhead seem to have increased in size to 140-l 50 mm.

would indicate that spawning took place late in the Garcia estuary, as herring are often spring spawners in California bays and estuaries (Steve Cannata, personal communication). The male bay pipefish captured in the slough had a well developed pouch which harbored thousands of larvae.

The lack ofjuvenile chinook salmon and coho salmon in the Garcia River estuary is not surprising. Although local residents contend that chinook salmon runs were still present on the river in the 1950's, the chinook population in the Garcia River is functionally extinct. Occasionally, chinook salmon are still caught or sighted in the river (Craig Bell, personal communication), however, these fish may actually be strays from other rivers basins. The estuary as currently configured would probably be capable of rearing some chinook salmon juveniles if they were present. The loss of chinook salmon in the Garcia River basin is probably owing to other factors, such as decreased spawning gravel quality, rather than diminished estuarine habitat carrying capacity. Coho salmon are still present in the Garcia River, although in very low numbers. Young coho in California spend their first year in fresh water and are not known to use estuaries extensively in summer months.

Changes in Habitat Types in the Garcia River Estuary During Summer 1995

In June, high freshwater flows prevented sea water from reaching further than a few hundred yards into the main river channel that forms the northern part of the estuary (Figure 4). By early August, salt water had profoundly influenced estuarine habitat upstream as far as the Pot Hole. This resulted in a large shift in the aggraded portions of the river channel to become more like a bay subsystem than one described as riverine (Figure 5). The following is a break down of habitats of the Garcia River estuary as of August 8, 1995 under the system devised by Starr (1979).

Marine: The area immediately adjacent to the mouth of the estuary and the deep water area extending eastward along Lighthouse Bluffs comprised the marine subsystem. The substrate was coarse sand near the entrance with small patches of bedrock near the bluffs. Salinity at this station typically ranged from 3 1 to 33.5 ppt during sampling periods, however, the surface salinity at low tide on August 8 was 5.5 ppt. The deep water area around the mouth seemed to fill in during the course of the summer. Most of the marine subsystem is sub-tidal with only rock wall exposed or submerged with rising and falling tides (Photo #7). Barnacles and other invertebrates characteristic of tide pools inhabited the rock faces in this area.

Riverine: As of June 5, the majority of the Garcia River estuary was riverine. Freshwater flows prevailed even as far down stream as 100 yards from the mouth. By August 8, much of the aggraded lower river channel had been extensively colonized by salt tolerant algae and more closely resembled a bay habitat. Consequently, that habitat in the Garcia estuary that could still be categorized as riverine was restricted to the area from Pot Hole upstream. Most of the riverine habitat is sub-tidal with gravel substrate.

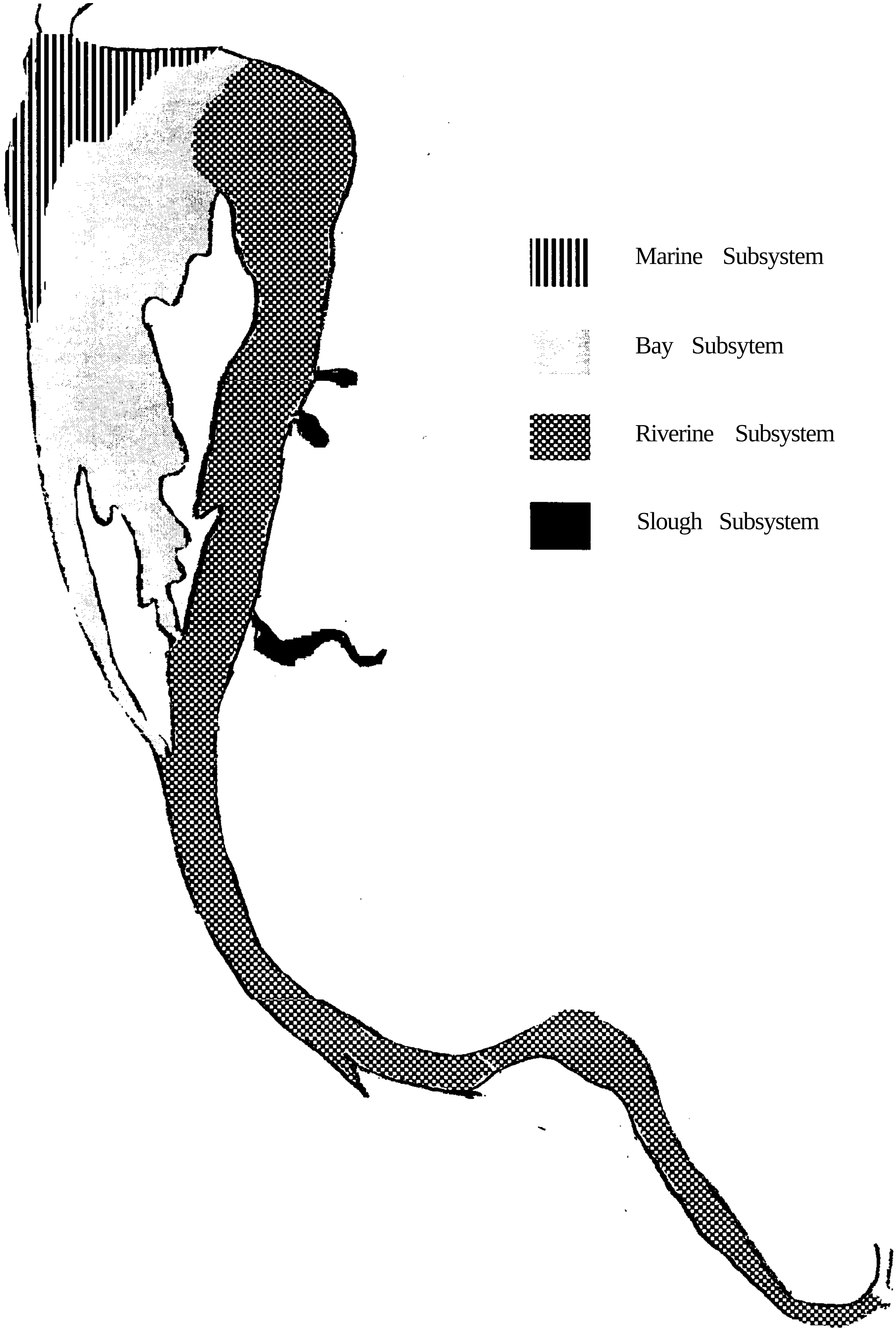


Figure 5. Map of Garcia River estuarine habitat types, according to Starr (1979), on June 5, 1995.

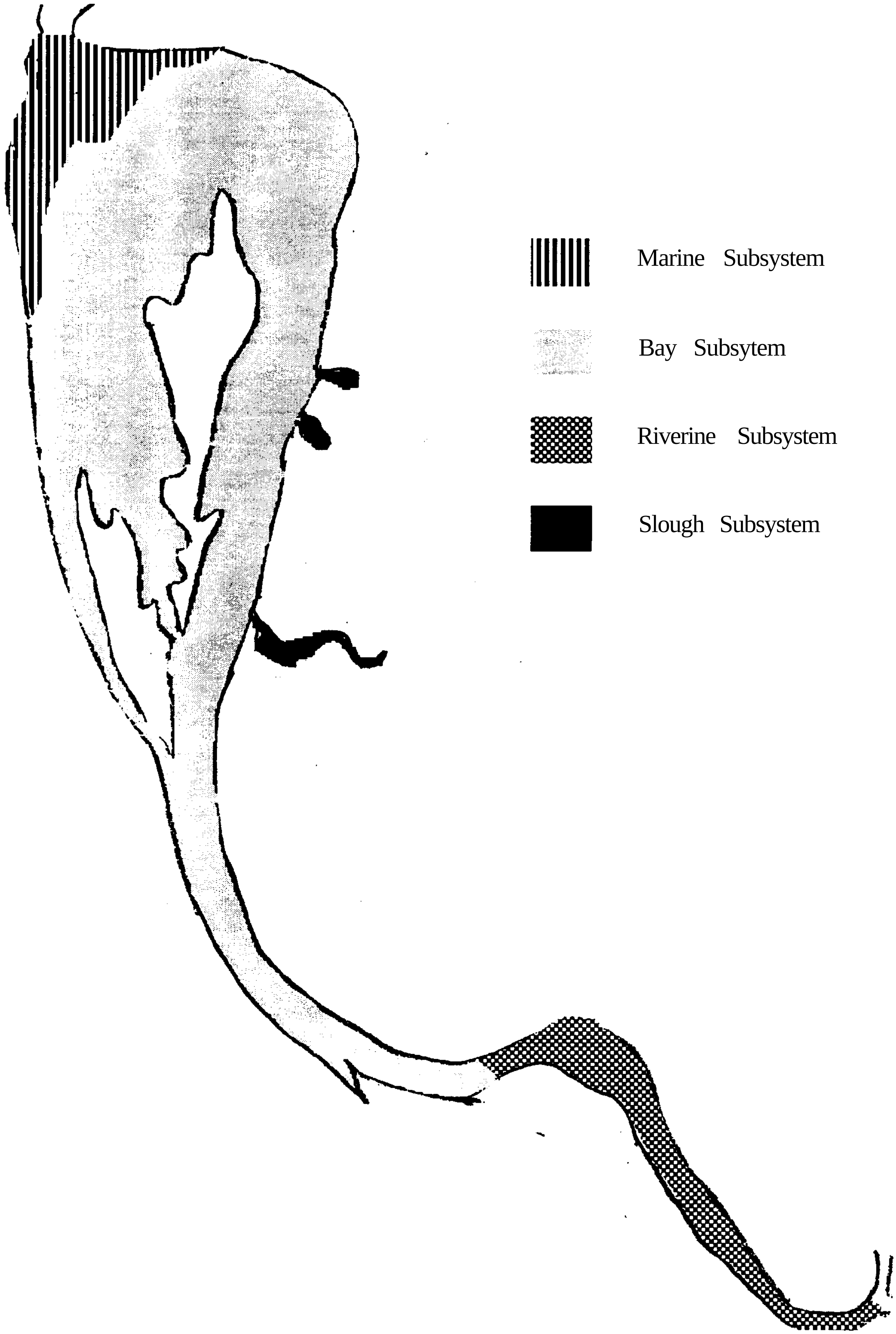


Figure 6. Map of Garcia River estuarine habitat types, according to Starr (1979), on August 8, 1995.

The gravel in shallow riffles was colonized heavily by freshwater filamentous algae. Substrate in runs and pools also included patches or layers of mud. The upper riverine habitats at Bend Hole and Station G2 never showed measurable salinity, but Pot Hole did show salinity at depth on August 8.

Bay: The Garcia River estuary does not have a truly developed bay system because it lacks intertidal eel grass beds or salt marsh areas. However, the salt-influenced southern area of the estuary was best described under this habitat type because it was heavily influenced by salt water during all sampling periods and had extensive seasonal algal beds (Photo #6). Much of the substrate in this area was mud and fine sand, which is also typical of bays. In arms formed by over flow channels at the upper end of this area, gravel dominated the substrate except in the deepest portion of channels where mud had been deposited.

The shallow, aggraded, lower reaches of what was considered riverine channel in early June had changed sufficiently to be reclassified as part of the bay subsystem by August 8. Extensive algal beds colonized the shallow water in this reach, creating a habitat similar in some respects to bay flats. The bay pipe fish, marine fish juveniles and euryhaline species also would be characteristic of bay habitats.

Substrate varied in these formerly riverine areas of the bay subsystem. Gravel and mud were interspersed in the area formerly occupied by Minor Hole down through the Piling Hole. Areas of gravel were heavily colonized by Enteromorpha, often leading to greater than 40% algae cover. Below the Piling Hole, algae covered 90% of the stream bottom which was predominantly gravel. The reach between Stations G4 and G5 was more depositional and mud covered nearly half the bottom. At Station G5 the substrate changed to sand, probably as a result of blowing sand from the dunes. In a quiet water area off the island as the estuary channel bends south, the bottom was covered with dead plant material and other detritus over an extensive area.

Sloughs: There are only three small slough areas that extend off the Garcia River estuary. They are characterized by fine substrate and relatively steep sides. After river flows receded and salt water was pushed in by the tide, it is likely that the sloughs remained salty. This created an environment that was optimal for herring to spawn and for bay pipefish to reproduce. Most of the channels were subtidal but heavily colonized by algal beds. Sculpin were noted to be in abundance in weed beds that extended up the most well developed slough arm.

A complete map of substrate types throughout the Garcia River estuary can be found as Figure 6.

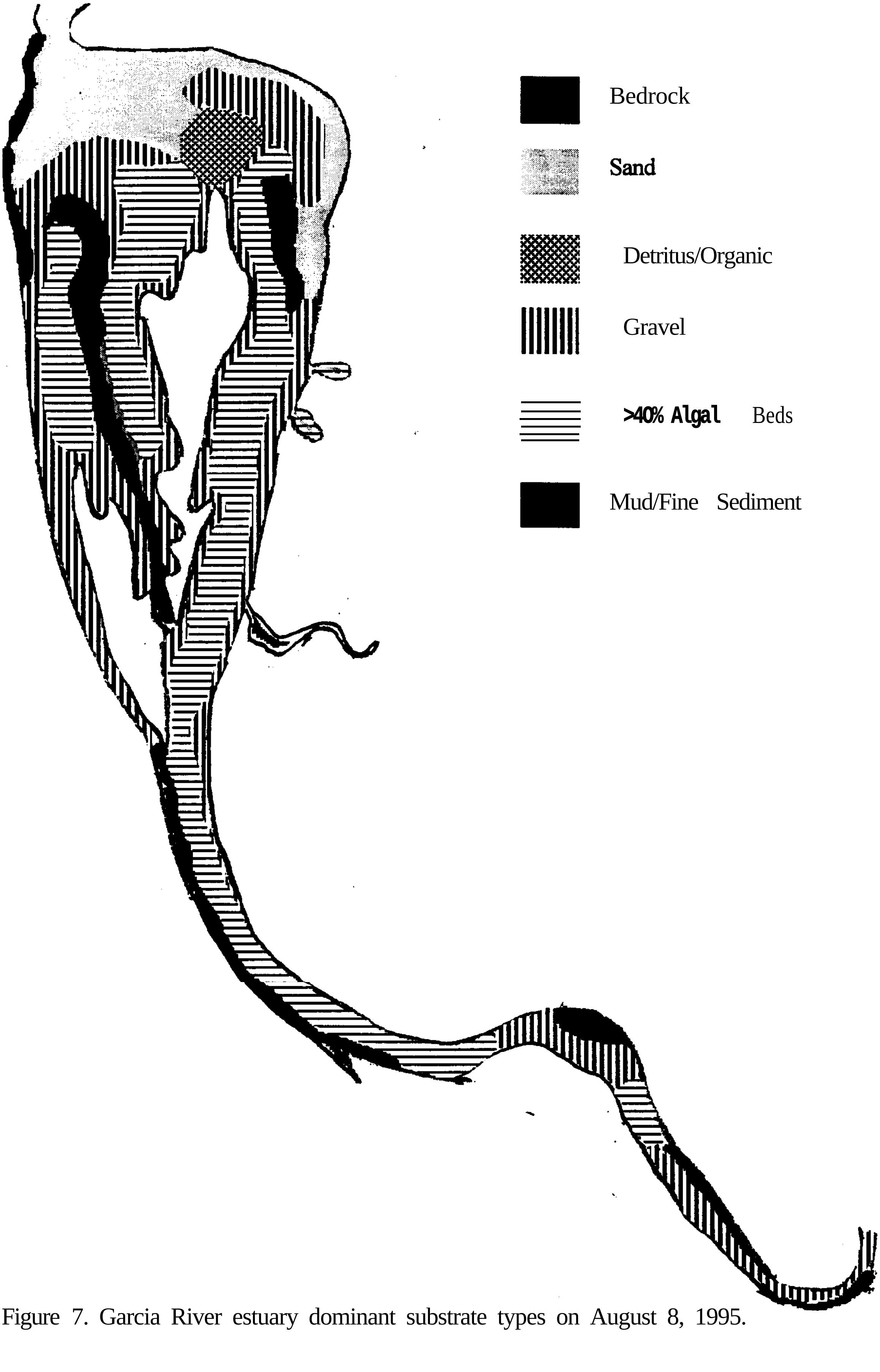


Figure 7. Garcia River estuary dominant substrate types on August 8, 1995.

A Comparison of Findings on Salmon and Steelhead Use of the Garcia River Estuary and Other Northern California Estuaries

To discover whether the Garcia River was impaired in some regard with respect to production of salmonids, reports on other estuarine systems were reviewed. One difficulty in this approach is that there are no undisturbed estuaries in northern California with which to make comparisons. The Big River estuary was found to be highly aggraded as a result of repeated timber harvest in the basin (Warrick and Wilcox, 1981). The report described "substantial decreases in the width of the estuary, the filling of tidal sloughs and the . .. colonization of mud flats by salt marsh vegetation." Because the Big River estuary is several miles long and up to 30 feet deep in places, it was still instructive to compare use of habitat by various fish species with that in the Garcia River estuary. Fish sampling for the Big River study was fairly extensive with 22 species collected. The greater number of species captured may reflect year-around sampling effort or may have been a result of the more varied habitats.

War-rick and Wilcox (198 1) found coho salmon juveniles in the Big River estuary, primarily in spring, while adult coho were trapped as they entered the estuary in fall. They noted that both steelhead and coho salmon juveniles were more widely distributed throughout the estuary during periods of high freshwater runoff in spring. War-rick and Wilcox (1981) did note use of the upper estuary by coho salmon juveniles during summer, but noted that a large California Department of Fish and Game hatchery plant had taken place above the sampling site in spring. Jennifer Nielsen (1993), during studies of coho salmon behavior on Mendocino coastal streams, found use of upper estuarine areas by coho salmon during summer as well.

Many more steelhead juveniles were captured in the freshwater portions of the Big River estuary during summer than in salt water influenced areas (Warrick and Wilcox, 1981) similar to Garcia River estuary samples collected for this study. Although areas of the Big River estuary are 30 feet deep, these pools were not heavily used by salmonids once they became dominated by salt water. Curiously, numerous western suckers were netted in the upper Big River estuary but none were captured in the Garcia River estuary.

A study of the Russian River estuary (Sonoma County, 1993) failed to provide much enlightenment because the estuary is so unlike the Garcia's and few salmonids were collected. No coho juveniles were captured and only one dead steelhead was found. Eleven chinook salmon juveniles were collected from April through June, but none collected during later sampling periods. The Russian River mouth closes and a salt wedge develops at depth. When lower portions of the water column are not mixed, they also develop very low dissolved oxygen conditions which sets up hostile conditions for most fish.

The Eel River estuary was extensively sampled by Puckett (1977). He found that coho salmon passed through the upper estuary in April and May. Steelhead were found throughout the riverine habitat in the upper estuary, however; they were only infrequently sampled in brackish or salt influenced areas. Chinook salmon also showed an early season peak in the Eel River estuary, with freshwater stations showing peaks during June and July. Some extended chinook rearing was noted, however.

The Mattole River estuary changes to a lagoon as flows recede in spring or early summer and the mouth closes. Busby (199 1) found that the survival of juvenile chinook salmon was extremely low over summer in the Mattole River lagoon. Zedonis and Bamhart (1990) found that steelhead survival was variable in the same ecosystem, with some years showing increasing steelhead numbers over summer and other years showing a pattern of decline.

Conclusion

Steelhead trout were the only anadromous salmonid species using the estuary extensively during this study. The primary factor limiting the distribution and abundance of this species during late summer in the Garcia River estuary was a negative response to salt water. Studies from the Big River estuary show that deep water habitats there are not used by steelhead once salt water intrudes. Therefore, these findings call into question the assumption put forth in MCRCD (1992) that creating more deep water habitat in the Garcia River estuary will benefit production of anadromous salmonid juveniles. While this is true of freshwater pools at the top of the estuary, there is no evidence that this strategy would work in areas where salt water intrudes.

Another factor to consider with regard to manipulation the Garcia River estuary is that the system seems to be recovering naturally from past problems related to high sediment transport. The main channel of the upper estuary increased in depth in response to the very large storm events that occurred during January and March 1995 (McBain and Leopold, 1995). Although dredging of the Pot Hole was recommended in the Garcia Watershed Restoration Plan (MCRCD, 1992) the storms of January and March 1995 caused this hole to reform as a result of natural processes.

While some juvenile coho salmon use estuaries for rearing in British Columbia and Alaska (Tschaplinski, 1982, Murphy et al., 1984) this life history is not well documented for California. It is not prudent to manipulate or enhance the estuary to benefit coho salmon juveniles given their absence during our sampling period and because it has not been established that an estuary-rearing life history trait is present in the remnant population of coho remaining in the Garcia River basin. However, creating deep water holding areas and providing additional cover with large logs would probably provide improved holding habitat for adult coho salmon that return to the estuary during low flow periods in fall.

While chinook salmon do use estuarine habitat extensively (Reimers, 1971) no viable population of chinook salmon exists in the Garcia River basin. The current limiting factors are probably more related to poor habitat quality elsewhere in the Garcia River watershed. It makes little sense to improve estuarine habitat to improve conditions for chinook salmon juveniles at this time.

The Mendocino Resource Conservation District may decide to re-route the estuary along Lighthouse Bluffs, as recommended by Moffatt & Nichol Engineers. This activity would probably result in the loss of the Piling Hole. Fish sampling during summer did not indicate that there was any unique fisheries resources associated with this particular feature.

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Appendix A

Photos of the Garcia River Estuary Fisheries Study

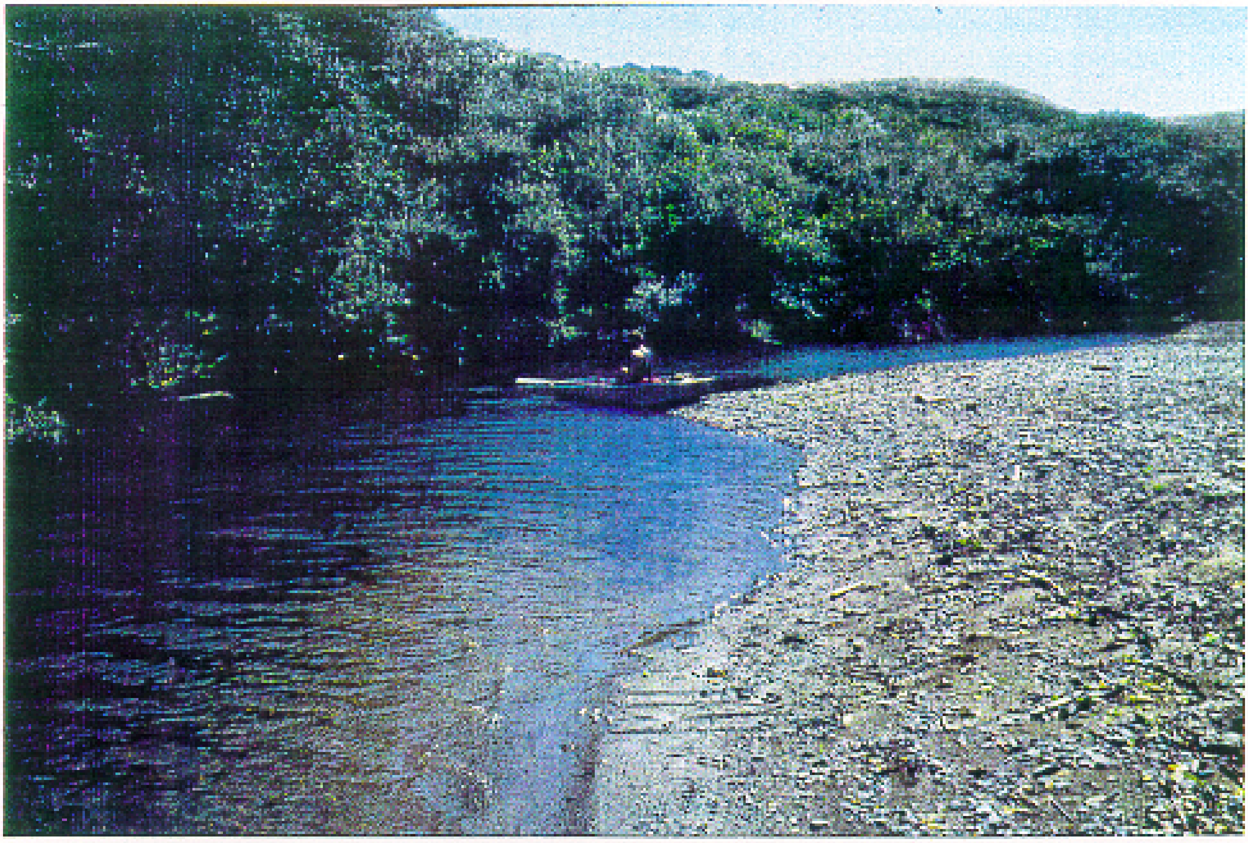

Photo #1. Sampling station G1 at the Bend Hole just below Hathaway Creek near the upstream limit of the Garcia River estuary. Note the excellent cover provided by willows.

Photo #2. Looking upstream in the riverine reach of the Garcia River estuary toward sampling station G2 at gravel bar on the right.

Photo #3. Steve Cannata feeds beach seine over the bow of the boat in the Bend Hole while Craig Bell runs the motor in reverse to complete a successful set.

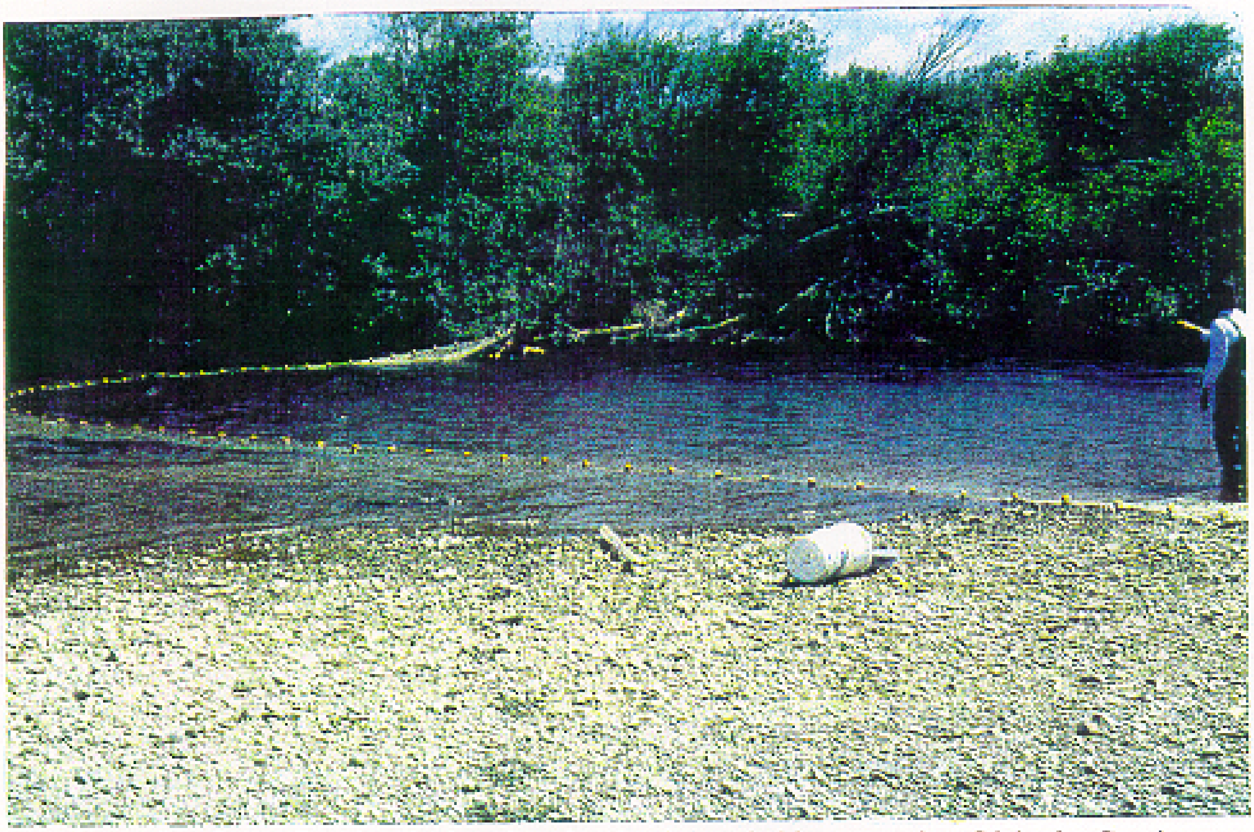

Photo #4. Steve Cannata deploys beach seine in run habitat at station G2 in the Garcia River estuary on June 5, 1995.

Photo #5. Run or shallow pool habitat in the vicinity of what was once the Miner Hole. Note the extensive algal growth in shallow areas where Enteromorpha has attached to gravel.

Photo #6. Photo taken at tip of island across from Garcia River estuary sampling station G5 on August 8, 1995. Note extensive algal beds.

Photo #7. Sample at the Piling Hole (G3) yields a steelhead, a surf smelt and a shiner surf perch. Note the very silver color of the large juvenile steelhead.

Photo #8. Yearling steelhead on measuring board still has prominent parr marks which suggests that it may not be ready for ocean entry.

Photo #9. Slough arm of the Garcia River estuary with extensive algal beds.

Photo #10. Bay pipe fish captured in slough during August 1995. Note the small elongate, red juvenile bay pipe fish on the palm of the hand in picture.