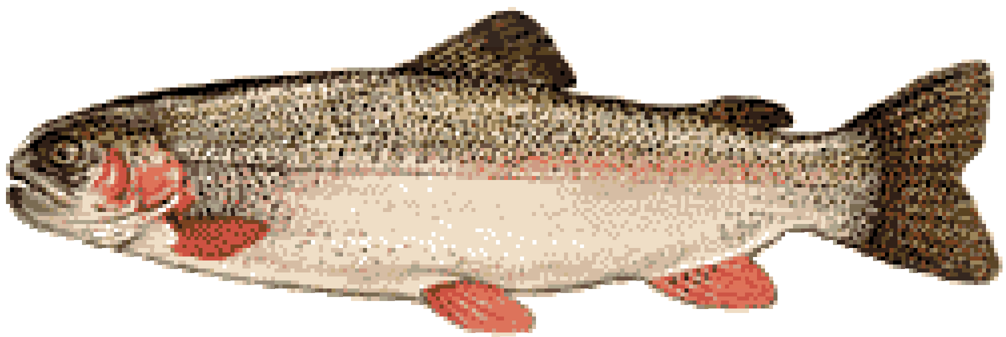
Steelhead *(Oncorhynchus mykiss)* Habitat Assessment Along the Arroyo Seco River



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Preface

This is an under-graduate student report. The opinions and conclusions presented do not necessarily reflect the final material to be presented as the outcome of the Salinas Sediment Study (2000-1 contract). Nor do they necessarily reflect the opinions or conclusions of the Central Coast Regional Water Quality Control Board, who funded the work, or any of its staff.

Having said that, I hope you enjoy the report. It is the product of an extra-ordinary level student dedication to the science of bettering the environment of the Central Coast while recognizing the social and economic importance of its agriculture and industry.

Dr. Fred Watson
Project leader.
Student Capstone Advisor

Abstract:

Salmon populations are in decline in the Western Pacific. Locating existing populations and protecting them is becoming increasingly important. One species of local interest is the *Oncorhynchus mykiss,* or steelhead. With the Carmel River being listed as the southernmost major steelhead run (Dettman and Kelley, 1986), it is hoped that suitable spawning habitat exists in the nearby Salinas River watershed. Using a habitat assessment developed in part by Dave Dettman, this study assessed 3 sites along the Arroyo Seco River. Two of the sites were on the Arroyo Seco and one site was located along Piney Creek, a tributary between the two main stem Arroyo Seco sites. This study found that there is a high potential for steelhead to spawn and rear fry in portions of Piney Creek and the Arroyo Seco River, a major tributary to the Salinas River. Potential fish densities were calculated to be between 13.99 and 14.67 fish/meter^2, at the Upper and Lower Arroyo Seco sites, respectively, while Piney Creek, a small tributary to the Arroyo Seco River yielded an approximate potential fish density of 3.28 fish/meter^2. Potential young of the year populations were calculated to be in the hundreds of thousands, for both of the Arroyo Seco study sites and slightly less, still in the hundreds of thousands, for the Piney Creek site. From these results, policies concerning habitat mitigation, landuse, and California Fish and Game codes are discussed.

Introduction:

The Salinas River plays an important role as a resource by providing water for human use, such as drinking water and water for irrigation, and by providing ecological value. At present, these are conflicting roles. Agriculture, one of the largest water users, which draws water from the Salinas River system, produces in excess of $4 billion in crops a year. This is accomplished through the pumping of water from below the ground, which is partially recharged by the Salinas River. Compare that with the ecological needs of a single species of fish, the *Oncorhynchus mykiss*, or steelhead which spawn in fast water in main-stem rivers and medium to large tributaries (Whitman, 1999). The total abundance of steelhead in the South Central Coastal California Evolutionary Significant Unit (ESU) is extremely low and decreasing every year. Risk factors for this ESU include habitat deterioration due to sedimentation and flooding due to land management practices (Busby, et al., 1996). Based on anecdotal reports, and historical readings, there is evidence that suggests a steelhead run could still exist on the Arroyo Seco River (Franklin, 1999). The purpose of this project is to determine if the Arroyo Seco would make good spawning and rearing grounds for the endangered steelhead.

The steelhead, is a protected species, having been listed as a threatened species under the Federal Endangered Species Act of 1973. The California Department of Fish and Game (CDFG) defines a steelhead as "any rainbow trout larger than 16 inches, found in any of California's anadromous waters (NMFS, 1996)." Presently 24 salmon and steelhead runs in the Pacific Northwest are protected, accounting for approximately 157,000 square miles, nearly double that of the spotted owl (Brinckman, 1999). Thirtyeight percent of the combined area of Washington, Oregon, Idaho, and California have protected steelhead or salmon populations in their waterways (Ellis, 1996).

Section 9 of the Endangered Species Act (ESA) prohibits any person from taking a listed species (Ellis, 1996). A person is defined to include any individual, state, or political subdivision of a state. The definition of “take” includes “harm”. Harm is defined to include “an act which actually kills or injures wildlife. Such acts may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (Ellis, 1996).” In June 1999, the National Marine Fisheries Services released its’ 4-d rules, which explain in detail the activities which are prohibited under the Endangered Species Act (NMFS,1996). The penalty for harming a threatened or endangered species, or damaging its’ habitat is a federal crime punishable by up to 6 months imprisonment and an fine of up to $25,000 (Brinckman, 1999).

Background:

Steelhead Life Cycle:

Steelhead have traditionally made 2 runs to spawn, one in the spring months, March-early June, and a fall run, September-November. Those that do not make their way up the rivers in the spring, make their way up the rivers in the fall and early winter. However, in the Salinas River, there is only a winter run (Busby, et al., 1996), as a sandbar separates the Salinas River from the ocean most of the year. These runs are a steelheads’ chance to spawn and pass on its’ unique genetic code before it dies even though spawning does not necessarily mean death to the steelhead as it does with other salmonid species.

A steelhead begins its spawning journey in the ocean, where they spend the majority of their lives, but come spring, if the rivers have enough water to make it to the sea, some steelhead begin to migrate up the rivers to spawning grounds. Once the steelhead enters a river its sole purpose is to find suitable spawning grounds, mate, and either turn around to head back to the ocean, or die.

Spawning for a steelhead is not an easy task. To begin with, there has to be enough water in all the waterways in order for them to migrate to their spawning grounds. Next, they have to survive a gauntlet of predation, pollution, and obstructions to make it to their spawning grounds. Once they have made it that far, they then require a very specific set of conditions in order for them to spawn. They first have to locate an appropriate habitat in which to lay their eggs and build a nest, known as a redd.

The area that steelhead use to spawn in is located at the downstream end of a pool structure, or at the beginning of a glide (Bratovich and Kelley, 1988). It is at this point that the least amount of sediment is moving or being deposited, so that it will not cover their eggs and prevent them from hatching, or suffocate the young (Newcombe, 1997). The steelhead seem to prefer types of substrate in the area in which they use to build their redds. Spawning habitat can be limited by available gravel, too much sand or cobble, or by low flow (Dettman and Kelley, 1984).

Steelhead prefer a gravely substrate, with little to no fine sediment (Dettman and Kelley, 1984). Once this is located, a female will turn her body on its' side so that it lays parallel to the waters surface, and lift its' tail toward the surface of the water. By doing this, she creates a bit of suction beneath her body, which moves the gravel aside, creating a small depression, in which she will lay her eggs (Hagar, 1996). Once the eggs are lain, the male will fertilize the eggs inside the depression. The female then covers the redd with gravel large enough to protect the redd from predators, and also from mobilization should the water velocity increase. She does this by moving slightly upstream from the depression she previously created, and performs the same task. This time the gravel that is mobilized moves down and covers the eggs (Bratovich and Kelley, 1988). By using gravel, instead of sand, the steelhead insures that water will still flow through the redd bringing the much needed oxygen to the eggs so that they may survive (Newcombe, 1997).

Upon emerging from the egg and the gravel nest, the young steelhead will spend a year or more in the waterway in which it was hatched growing in size until it is large enough to begin the journey downstream to the ocean (Dettman and Kelley, 1984). There they will live for many years before returning to the grounds from which they were hatched, to spawn themselves and return to the ocean or eventually die, completing a cycle that has been going since the end of the last ice age (Dettman and Kelley, 1986). Within a waterway, there may be resident populations of rainbow trout, which mature, spawn, and complete their a life cycle within about 300 feet of the site of their birth in addition to anadromous steelhead which would have returned from the ocean after a journey spanning several thousand kilometers (Encyclopedia Brittanica, 2000).

It is during this first year that habitat is such an important component. If there is not enough in-stream cover for the young fish, or fry, predation will be very high and survivability very low. If there is not enough vegetative cover over the water, it is possible that the water temperature would climb high enough that it would be unable to carry sufficient levels of oxygen for the fry to survive. Substrate material is another important factor for the fry. While substrate composition is important for spawning and hatching, once the fry emerge, the young fish rarely use the substrate for cover (Dettman and Kelley, 1986). Should the suspended sediment levels be high it can affect the fry's ability to forage (Newcomb, 1997). While this is not measured in the habitat assessment, it is a consideration that needs to be explored when investigating environmental factors that would impact these fish.

If the fry have survived, and grown to a size large enough to weather the trials that lay before them, they will begin to migrate down to an estuarine environment in autumn months, after the first rains when rivers begin to flow once again. There they will begin to acclimate themselves to a saltwater environment. Should the waterway not be open to the ocean, a fry will remain in the estuarine environment, undergoing smoltification, until enough water is flowing down the channel to break through the barrier to the ocean, and a flood of young smolt will enter into their home for the next several years. Should the river not carry enough continuous flow to allow for downmigration, smoltification in the estuary is impossible.

Steelhead may spend up to 7 years in freshwater and up to 3 years in saltwater before their first spawning (Busby, et al., 1996). Anecdotal reports lay claim to sightings of mature steelhead on the Arroyo Seco, a major tributary to the Salinas River, as recent as this October 2000 (Franklin, 1999). It is known that a winter steelhead run existed in the Salinas River in years past. In 1986 there were published reports of open steelhead fishing on the Salinas River, as far south as Camp Richards (Anonymous, 1986), and that the fishing outlook was listed as “fair, at best” (Anonymous, 1986). It is also believed that spawning grounds are located along the Arroyo Seco. It has been published that the California Department of Fish and Game released more than 10,000 steelhead from the Mad River stock into the Arroyo Seco in 1994 (Busby, et al., 1996). What wasn’t known was the present quality of the spawning grounds. Using a method of habitat assessment, developed by Dave Dettman (Dettman, 2000), I undertook the task of determining the quality of potential steelhead spawning and rearing grounds on the Arroyo Seco River.

Methods:

The Dettman (2000) method for surveying habitat has been used to assess salmon and steelhead habitat in places such as Lagunitas Creek in Marin County, Soquel Creek in Santa Cruz County, and the Carmel River in Monterey County. The process involves breaking the waterway into various components (pools, riffles, glides, and runs) and making measurements within each component. This requires classifying vegetation cover and type, measuring both the size and the embeddedness of the substrate, as well as approximating the percent cobble and roughness, and measuring the velocity for each structure.

Three study sites were chosen to survey for this project based on the accessibility of the river. All three sites were located along the Arroyo Seco River, which lies in the northern end of the Santa Lucia Coastal Range of coastal Central California. The Arroyo Seco begins its' journey to the Pacific Ocean in the Los Padres National Forest, on the Eastern side of the Santa Lucia Range. From there the river travels in a northeasterly direction until it joins the Salinas River, which also flows in a Northerly direction before finally ending at the Pacific Ocean approximately 32 kilometers North of Monterey, California as shown in Appendix I.

There are 4 major structures in the river that were to taken into account for the assessment of steelhead habitat. Those structures included riffles, runs, glides, and pools (See Appendix II). These structures can be broken down into more detailed structures, but for the purpose of this survey method, these four basic structure types are sufficient.

Riffles are areas of fast moving, turbulent water, usually quite shallow with a large rocky substrate. These structures are important as they help to oxygenate the water for downstream aquatic organisms. As the water slows its' descent, and becomes less turbulent as it enters into a lower velocity regime and larger sediment is deposited. This is how I defined a run for the purpose of on-site surveying and habitat assessment, and it was evident in the field as a steep slope change and change in substrate from sand to a courser substrate. The run structures were typically found immediately after a riffle as a transition to a pool. Pools are areas of deep, slow moving water where fine sediment is deposited. These structures tend to be more permanent, and due to their depths, usually have lower water temperatures, which are beneficial to young steelhead in the summer months. Finally there are glides. Glides are where the depth of the water becomes less and the velocity begins to increase as it leaves a pool structure. The water here is fast moving, but not yet turbulent, and tends to have a laminar flow pattern as it reaches critical velocity. It is in the glides that fine sediments are once again mobilized and transported down stream. In the field this was physically evident by a steep slope change underfoot, and by a drastic change in substrate from gravel and larger size substrate to a finer sand bottom. It is possible that glides are chosen as spawning grounds because these locations are relatively stable at high, scouring flows (Bratovich and Kelley, 1988).

The surveying process begins with visiting a site, in this case the Arroyo Seco, and walking the riverbed taking measurements along the way using the method described below to gather data sets which are then entered into a computer modeling program developed by Dave Dettman. The 3 sites surveyed were Piney Creek, Upper Arroyo Seco, and Lower Arroyo Seco, as seen in Appendix I. All three of these sites had good access to the river, and did not require the crossing of private property to gain river access.

Study Sites:

Site 1: Piney Creek

Piney Creek is a small tributary to the Arroyo Seco that runs year round and is sparsely inhabited by local residences. According to Busby, Piney Creek represents some of the best-known habitat for both spawning and rearing of steelhead (Busby et. al., 1996). Piney Creek flows in a southerly direction until it joins with the Arroyo Seco. This site is situated between the two Arroyo Seco sites.

Site2: Upper Arroyo Seco

This site was located within the Los Padres National Forest, less than 1 mile downstream from the Arroyo Seco Campground. This survey site began at a spillway, the result of a concrete river crossing to 10 or so residences. This is the uppermost section of the river surveyed, and the Westernmost as well.

Site 3: Lower Arroyo Seco

This third and final survey site is located approximately 900 meters downstream of the green bridge (Arroyo Seco Road) at the large right-angled bend in the river, as it takes a more Northern direction. This site was surrounded by private property, primarily used as grazing land for cattle.

After an initial scouting of the areas to be surveyed, a starting point for the survey needs to be determined. This point can be as simple as an access point, or as complex as a change in hydraulic regime. Once a suitable starting point has been established for surveying, the flow of the waterway should be determined as supplemental information to the habitat survey. This is done one of two ways. The first is to gain the discharge information from a local USGS gauging station close to the assessment site. The second option is to use a flow meter, and perform a traditional transect of the waterway, which at the termination of the transect, a volumetric flow will be established. For the two Arroyo Seco sites, the volumetric flow was acquired from nearby USGS gauging stations. The volumetric flow is used as supplementary information to give a baseline for the amount of water flowing through a habitat at each assessment. This information is supplementary to the data collection and not needed to complete the model calculations, but does provide useful reference data.

Moving upstream established pools, glides, runs, and riffles are noted. Depending on the size of each of these segments, they are possibly broken down into smaller segments for the purpose of measurement. First, the length and width of each segment is measured and recorded. Next, the approximate velocity of the water in the segment is measured using wooden dowels and a pre-measured length of PVC pipe, using a stopwatch as a timing device. Then, the depth is taken at no less than 5 places within each structure, or sub-structure, at random, to give an average depth. Next, substrate particle size is measured using a ruler and placed into 1 of 4 categories: sand (0-2mm), gravel (2-45mm), cobble (45-128mm), and boulder (128mm+). Then the embeddedness of the substrate is determined. This is done by picking up a cobble-sized particle from the substrate at random, and measuring the height of the line at which it is embedded in the substrate and an approximate percentage of embeddedness will be recorded. This is repeated five times per area measured in order to gain an average embeddedness figure that is then used in the computer model. The embeddedness is an important parameter to measure as it directly affects the health of the eggs in a redd, and can determine the placement of redds. Roughness, or topography of the bed is then visually assessed and rated between –1, 0, and 1, with –1 being a flat, featureless bed.

Cobble abundance is the next variable measured. This is a visual survey of the structure in question in which the percentage of the substrate being cobble-sized particles is approximated. The cobble-sized particles in the structure are of importance to the young fry as they provide shelter from predators and areas from which to forage. Finally, vegetation is taken into account. This is done by noting the presence or absence of aquatic and terrestrial vegetation that provides shelter, and/or shade for the potential Steelhead that may inhabit that particular stretch of the waterway. The vegetation cover is ranked on a scale of 0-2. Zero being little to no vegetation in or over the water providing minimal or no cover for Steelhead. A ranking of 2 would mean that the vegetation provides a lot of cover and shelter for Steelhead, and a ranking of 1 would lie somewhere in between.

From these measurements Rearing Indexes (RI's) for "young of the year" and "yearlings" was calculated using a computer program (Dettman, 2000). From these Rearing Indexes, a potential population of both young of the year and yearlings can be extrapolated. These Rearing Indexes have historically been checked against visual population surveys to ensure the validity of the models' output (Dettman, 2000).

The model uses a three-dimensional lookup table based on the average embeddedness of the substrate, the cobble abundance, and the velocity (see Appendix III)(Dettman, 2000) within each structure to give a quality rating (Q_1). This quality rating (Q_1) ranges from 0-8. This quality index is added to another quality rating (Q_2), 0-1 based on the average depth in a given structure to give a third quality rating (Q_3).

$Q_3=Q_1+Q_2$. From there the quality rating (Q_3) is modified with "if-else" clauses concerning the roughness. If the quality rating (Q_3) is other than 0 or 1 then the new quality index (Q_4) is equal to $Q_3+2^{(Roughness-1)}$. If Q_3 is equal to 0, then $Q_4=Q_3$, but if Q_3 is equal to 1 then $Q_4=1$. Once Q_4 has been calculated, another quality index must be calculated. This is done based on the structure type and its' distance upstream to the next riffle. If the structure is a pool or a glide and the distance is greater than 100 meters, then Q_5 is equal to Q_4-2. If the structure is a pool and the distance to riffle is less than 50 meters, then Q_5 is equal to Q_4+2. If Q_5 is greater than 8, then Q_6=8, but if Q_5 is less than 0, Q_6=0. From Q_6 a fish/m2 (Q_7) can be calculated using the simple mathematical equation: $Q_7=(1/(12*0.0254))^2$. Now that a fish/m^2 is known, a Rearing Index (RI) for a reach can be calculated in the following manner: $RI=(\Sigma(Area*Q_7))/Length$. Finally, from the Rearing Index (RI) a fish density (D) is calculated. This is done by using this equation: $D=0.25+0.014*RI$. This equation gives a total number of complete fish per meter.

Results:

Piney Creek

Beginning in mid-march, habitat assessment was conducted beginning at the Arroyo Seco confluence, and moved upstream for approximately 800 meters. The average width of the stream was 3.5 meters. The substrate varied from structure to structure, but was overwhelmingly large cobble and boulder size rocks. The banks were primarily vegetated with young willow trees, though there were stands of older, larger willows as well. The slope of the creek is unknown, but can be best described as steep, because the creek exhibited a riffle-run/glide sequence with few pools.

The survey site was broken into various reaches based on changes in landuse, cover, major obstructions, or geologic features. At the confluence with the Arroyo Seco, the adjacent land was alluvial floodplain deposit containing primarily sand and other fine sediments, sparsely vegetated with few young willows transforming into a boulder armored bank further inland from the waters edge. Moving upstream and away from the confluence, the adjacent land contained stands of riparian vegetation, sometimes 5-6 meters deep. Further upstream, the walls of the canyon that contained Piney Creek became steeper, until at one point, the creek flowed along a 7 meter tall sheer wall of Monterey Shale Formation, for over 50 meters. The typical vegetation was young willow stands, with some grasses lining the floodplain, and the occasional larger, established willow tree. Close to the confluence with the Arroyo Seco, there were 2 small dirt roads crossing the creek. Both of these crossings took place in wide, shallow areas with cobble sized substrate. Piney Creek had a potential fish density much lower than that of either site on the Arroyo Seco River at 2.89, 3.59, and 3.37 fish/meter^2 for each of the 3 reaches surveyed. This calculated out to 30,984, 89,264, and 33,196 potential fish yields respectively for a combined total of 153,444 potential fish in the 0.31 ha portion of the creek covered by this survey.

Upper Arroyo Seco

The spillway at the starting point of this reach measured approximately 1.5 meters tall by 1 meter wide and 30 meters long. The downstream side of the spillway was broken concrete with exposed rebar protruding from the structure. Above the spillway the width of the river very closely matched the length of the spillway, with large, deep pools, established willow and cottonwood trees, and typically sandy banks. The substrate was primarily course sand in the pools, with cobbles and boulders being found in the runs/glides and riffles. Residences lined the North bank, though they were set back approximately 50 meters from the current waters edge. The floodplain was wide and had a shallow slope along the North side, while the South side was steep and uninhabited above the spillway. The South side of the river ranged from crumbling, sheer walls to vegetated slopes upwards of 60 degrees. The end of the survey site was marked by the downstream bridge support of the Arroyo Seco Road just past a U.S. Forest Service kiosk. The Upper Arroyo Seco was found to have a potential fish density of 13.99 fish/meter^2, this calculated out to a 402,161 potential fish yield in the 2.46 ha section surveyed.

Lower Arroyo Seco

There was a large floodplain on either side of the river, extending as much as 30 meters on either side. The southern side of the river sustained thick (5-10 meters) riparian vegetation containing large willows, blackberry brambles, and poison oak. The Northern side of the river butted against steep canyon walls of varying material (sandstone to soil). The floodplain on this side of the river was limited to the Western end of the survey site, and averaged about 5 meters in width. The substrate ranged from course sand, typically in the slower velocity areas of the pools and ends of glides, to large boulders in the faster water structures of riffles and runs. A United States Geological Survey (USGS) stage plate, located beneath the green bridge marks the end of the survey site. As seen in Chart 1 the Lower Arroyo Seco site was found to have a 14.67 fish/meter^2 potential fish density, which calculated out to a potential yield of 848,801 fish in the 11.6 ha survey site.

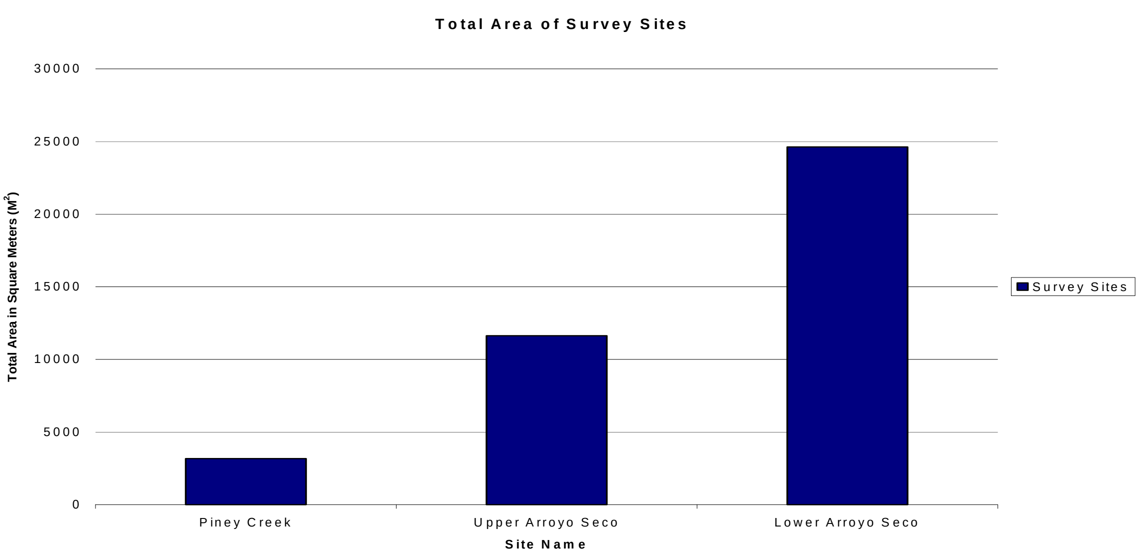
Chart 1. Reach Indices as given by modified index calculating program.

ReachIndices

Stream	*RchID*	*Rch#*	*StartLoc*	*Leader*	*Length (m)*	*Area (m2)*	*# of quasi-fish*	*Metric RearingIndex (quasi-fish per metre)*	*Density (fish per metre)*
Lower Arroyo	13	0	North Bend	Brian Londquis	858.13	418.75	348801.08	989.13	14.67
Upper Arroyo	12	0	Spillway	Brian Londquis	427.48	512.74	102161.64	940.77	13.99
Piney Creek	16	0	Sheer cliff	Brian Londquis	186.30	691.59	33916.92	182.06	3.37
Piney Creek	15	0	concrete driveway	Brian Londquis	450.61	680.62	89264.73	198.10	3.59
Piney Creek	14	0	Confluence with Arroyo	Brian Londquis	209.70	636.29	30984.35	147.76	2.89
Carmel River	10	0		Dave Dettman	26.22	115.13	5875.65	224.09	3.96
Carmel River	9	0		Dave Dettman	34.59	106.26	7335.82	212.06	3.79

While the Lower site is nearly 5 times the size of the Upper site (see Chart 2), the difference in potential number of fish between the two sites differ by only a factor of 2 (2.11), and the Lower site is greater than the Piney Creek site by better than 5 times (5.56). This difference in size between the sites can be attributed to the average width of each study site.

Chart 2. This graph shows the difference in areas between the three survey sites.



There was a marked difference in the substrate makeup between the Piney Creek site and both of the Arroyo Seco sites. While Piney Creek was dominated by large cobble and boulder substrate, with very little sand sized particles, the Arroyo Seco sites abounded with sand. The sand was primarily found in the pool structures, of which the Piney Creek site was lacking in number when compared to the number of riffles and glides. The average embeddedness for the whole of Piney Creek was 42%, while the Upper and Lower Arroyo Seco sites measured in at 56% for the Lower site and 46% for the Upper site.

Cobble abundance was another source of variation between the sites. Piney Creek was dominated by large boulder sized substrate and had an average cobble abundance of 30%. The Lower and Upper Arroyo Seco sites both contained higher averages of cobble abundance at 39% and 45% respectively.

The width of the waterways varied greatly from site to site, but especially between the two Arroyo Seco sites and Piney Creek. The average width of the waterway was nearly 26 meters for the Arroyo Seco sites, and only 3.5 meters for the Piney Creek site

Chart 3. Number of structures recorded by survey site.

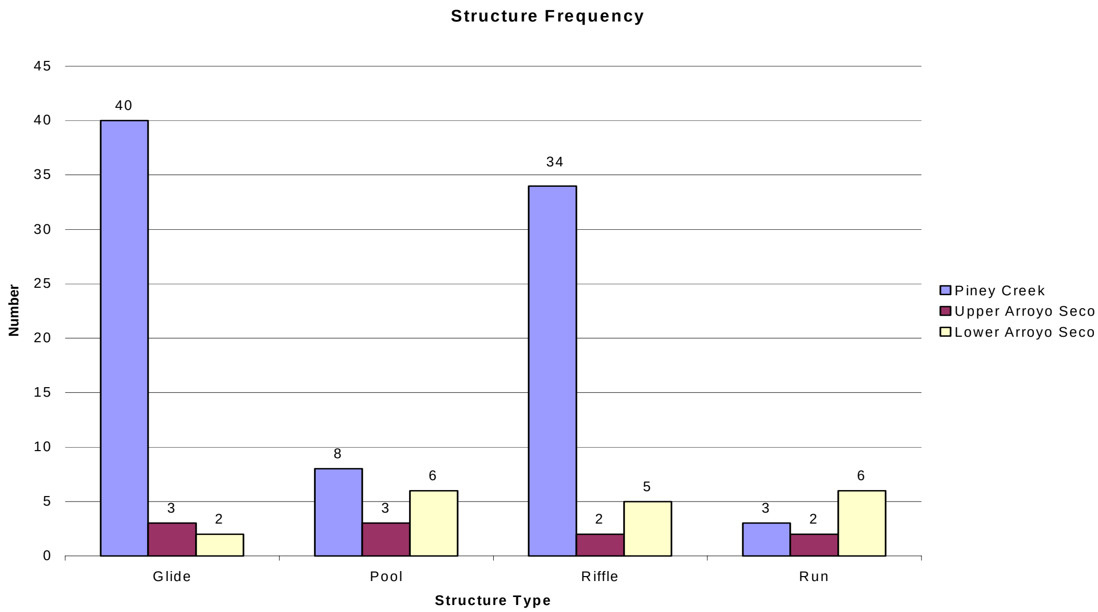


Chart 3 shows the numbers of structures recorded at each study site. In both the Upper and Lower Arroyo Seco sites, the ratios between structures was nearly on a one to one basis, while the Piney Creek structures revealed themselves to have a much high ratio by containing many glides and riffles.

Discussion:

Based on the rearing numbers produced using the Dettman assessment method and the program designed to analyze the parameters collected by that method, it is reasonable to assume that the Arroyo Seco could and does support steelhead. With possible fish support numbers being in the hundreds of thousands of fish for both of the Arroyo Seco study sites and for Piney Creek, it can easily be seen that if the steelhead could reach the Arroyo Seco to spawn, the emerging fry would be supported in great number. The level of fry supported, according to the metric rearing index, is over 10 times that of the Carmel River, where much work has been put into restoring and protecting the steelhead run.

The numbers produced by the survey of the 2 Arroyo Seco sites are far greater those that have been produced by other waterways in the area of the Central Coast. The Carmel River for example, returned potential fish densities of 3.79 and 3.96 fish/meter^2 for two survey areas. These densities are much closer to the 2.89, 3.59, and 3.37 fish/meter^2 returned for the Piney Creek site. The Arroyo Seco, on the other hand, returned densities of 14.67 fish/meter^2 for the Lower site and 13.99 fish/meter^2 for the Upper site.

Perhaps the difference between the densities can be explained by the large difference in areas between the Arroyo Seco Sites and the Piney Creek site. The Arroyo Seco sites are 4 and 8 times the area of the Piney Creek site. While the Piney Creek site was far longer than that of the Arroyo Seco sites, the area is much less. In the model, length is an important input as it is used in the calculation of the Rearing Index. The greater the length, the smaller the Rearing Index. The Rearing Index is then used directly to calculate the potential fish densities. So if the Rearing Index were a small number, as would be the case with a long, narrow section, then the Density would also be much smaller. If, on the other hand, the length was not so great but the total area was high, the Rearing Index would be high, and therefor so would the density. I believe that this is the case in the Arroyo Seco sites. The area was quite large, but the ratio of length to average width is lower than that of Piney Creek, whose ratio of average width to length was rather large.

One of the pitfalls to using this method of habitat survey is the subjectiveness involved in almost every aspect of the surveying process. From the quality of the vegetative cover to the roughness, everything relies on the surveyors' perspective. Even in the measurement of the width and length, each surveyor is going to have different perceptions of where a structure begins and ends, as well as what features define a structure. To try and reduce the amount of subjectiveness in the team that surveyed the Arroyo Seco and Piney Creek, a portion of time was set aside to calibrate each of the members' perceptions to one another. Time was spent collaborating and conversing about the quality of cover over various portions of stream within the survey group to once again calibrate the team members to one another. This process was continued until all aspects of the surveying procedure had been discussed and all team members were of similar mindset as to the final numbers recorded at each site. This whole process worked to reduce the variance within the group, but not between groups on different waterways. So therein lies one of the greatest sources of error and discrepancy between surveys.

Another source of variance between surveys would be in the data processing. The program used for this study was adapted from the original program, and as such is not exactly the same. Test data sets have shown there to be about a 3% difference in the number of potential fish between the original program results and the modified programs' results (Hager, 2001). This model was calibrated using survey information collect by Dave Dettman, and checking model outputs between the adapted program and the original program. It is thought that the discrepancy lies in the ever evolving surveying method (Hager, 2001). This small difference, however could result in a large difference between reaches that are producing high quantities of fish.

Conclusion:

Since a large Rearing Index number was returned for both the "Young of the Year" steelhead, it can be concluded that should steelhead be able to reach these stretches of the Arroyo Seco, they could be used for both spawning and rearing. This finding points to the potential implementation of various state and federal laws and codes. For instance, the California Fish and Game Code 2786(e), which stipulates that, "funds allocated under California Wildlife Protection Act of 1991 (CWPA) may be used for acquisition, restoration, or enhancement of aquatic habitat for spawning and rearing of anadromous salmonids and trout resources (NMFS, 1996)." This would allow for the state to allocate funds to purchase land in and around these spawning and rearing grounds for the purpose of protecting them.

California Fish and Game Code 2786(e) could be a useful piece of legislation should the State of California decide to oust a local gravel mining operation located between the Lower Arroyo Seco site and the Piney Creek and Upper Arroyo Seco sites. The gravel mine annually extracts 30,000 tons of material, with a proposal to increase that amount to 300,000 tons (Sullivan, 2000). The gravel mine has downstream effects of reducing downstream water quality, and habitat destruction for fish, birds, and reptiles, as well as disturbing natural hydraulic patterns both up- and down-stream (Hayward, 2000).

Protection of the natural broodstock is an important thing to consider, and as such the State of California has created regulations designed to do so. The Trout and Steelhead Conservation and Management Planning Act of 1979 impacts the recreational fishing industry (NMFS,1996). This plan calls for the state to develop angling regulations to protect wild trout and steelhead stocks though natural production (NMFS, 1996). In 1999, the rules for recreational fishing in California were changed so that there is a zero bag limit on steelhead, though on some waterways, an angler can keep 1 hatchery fish. The hatchery fish can be distinguished from natural born steelhead by their clipped adipose fin (Richey, 1999).

These spawning and rearing grounds could also lend themselves to the Steelhead Trout Catch Report-Restoration Card (Assembly Bill 2187), which as of 1991, requires anglers to purchase and complete a $3.15 card when fishing for steelhead in the Arroyo Seco (NMFS, 1996). This money could then be used in accordance with California Fish and Game Code 2786(e) to purchase more land, or to fund protection, restoration, or enhancement projects. These report cards could also be used to track the information on the number of steelhead that visit, or reside in the Arroyo Seco as well.

The money collected from these angler report cards could be used to fund projects such as the one on the Hamma Hamma River, in Washington State. This project involves hand collecting eggs from redds in the Hamma Hamma River, incubating these eggs and raising the fish to a projected adult size of 10 pounds. Once the fish reach this size, they will be released, in 2002, back into the Hamma Hamma River, in hopes that they will head out to sea and return to spawn and revive the dwindling run (Hughes, 2000). There is the option of large scale production facilities on the Salinas, or hatcheries, though none are currently in place anywhere on the Salinas or any of it's tributaries (Busby, et al., 1996).

Though many efforts are underway to try and rehabilitate the stocks of Steelhead, there are different ways to go about it. Most projects work under the assumption that the natural processes that have historically supported these fish, can be re-created and controlled by humans. For example, many projects are based on simply placing more fish in the waterways. The belief is that this would result in more adult spawners, and that production would be increased. This approach doesn't take into account the downstream conditions of the rivers, the oceans, or estuarine environments (Anonymous, 1998). This also doesn't account for the minute nuances that fish from different waterways, or stocks exhibit. For example, those fish that have historically been spawned in a river that flows to the ocean year round, are not going to behave as a fish that has been spawned in a river that does not always flow to the ocean, such as the Salinas River. The timing of their spawning may be off, resulting in a zero return for those transplanted fish. Studies have shown that anadromous fish, transplanted from one waterway to another rarely persist for more than 2 generations without assistance, due to the lack of appropriate adaptations to their new environment (Higgins, et. al., 1992).

There is also evidence that suggests that the mixing of hatchery fish with wild stock may have detrimental effects on the population as a whole. Juvenile salmonids spawned by stray hatchery fish and wild salmonids have lower survival rates and may lack resistance to diseases, or other traits critical to their survival in the wild (Higgins, et al, 1992). The impacts of stock transfers increase dramatically if non-native anadromous salmonids are planted on top of wild populations for several generations (Higgins, et al, 1992). This transferring of genetic material between native and non-native stocks could result in the loss of local adaptations, and the extinction of a population (Higgins, et al, 1992).

In an attempt to protect individual stocks of steelhead, the California Department of Fish and Game (CDFG) has adopted the policy of returning rescued juvenile steelhead to their natal streams. This rescue effort is only to be undertaken when the fish can be held until habitat conditions improve, which includes securing the necessary in-stream flows to support the steelhead. The CDFG also works under the policy that existing steelhead habitat will not be diminished without offsetting mitigation of equal or greater long-term habitat benefits, and that resident fish will not be planted in the drainage of steelhead waters if it has been determined that it would interfere with steelhead populations (NMFS, 1996).

Locating spawning and rearing grounds could also affect the landuse adjacent to the Arroyo Seco and its tributaries. Since different landuse practices produce different sediment yields, it is conceivable that those landuses that produce larger sediment yields be restricted to land away from the waters edge, or that catchment basins be installed in an attempt to reduce the amount of sediment entering into the habitat. There is a particular concern about sedimentation and channel restructuring due to floods, which partially result from poor land management practices, such as gravel mining (Busby, et al., 1996).

Landuse also includes the creation and use of roadways, and other such transportation pathways. To account for the construction of roads, bridges, and other such necessities in, over, and around waterways, the state government passed the Cal Trans Environmental Enhancement and Mitigation Program. This program calls for the annual allocation of $10 million to be provided through the California Resources Agency for the acquisition, restoration, or enhancement of resource lands (natural areas, wetlands, forests, woodlands, meadows, streams, or other areas that contain fish or wildlife habitat) (NMFS, 1996).

A great effort would be needed in order to increase the number of spawning steelhead in the Salinas River watershed. This study has shown that spawning and rearing habitat exists, but the sad fact of the matter is that very few steelhead, less than 100 return each year to use it (NMFS, 1996). Some of the obstacles that need to be reduced for the fish migration would include increasing overhanging vegetative cover on the waterways. This would lower the temperature of the water and make it more habitable to the migrating fish. Removal of dams, diversions, and other such obstructions would also aid in the ease of migration for the steelhead. Presently there are 17 dams that block waterways within the Salinas River watershed (CRA, 1997).

In addition to the removal of obstructions such as dams, and increasing the vegetative cover over the waterways of the Salinas River watershed, reducing the amount of pesticide, herbicide, and sediment yields would greatly improve the health of the waterways. By improving the overall health of the waterways, the more likely it would be that organisms beneficial to the steelhead would increase.

It is my belief that focusing efforts in these areas would begin to bridge the gap between the potential yield of steelhead fry and the actual number of steelhead fry residing in the waterways. Protecting and cultivating the broodstock that is known to exist in the watershed would help ensure that future generations will be seen, and hopes for sustaining and increasing steelhead populations will live on.

All of these things considered, it is going to take the cooperation of more than just the governmental agencies to restore the steelhead population to what it once was. It is going to require that land users adjacent to the river take an active role in rehabilitating the waterways. This rehabilitation may take several forms, from planting riparian vegetation and allowing it to grow to a size and depth that it shades the water and proved cover for fry, to changing landuse, and ultimately sediment runoff into the waterways. While the various government agencies have the intention of restoring and rehabilitating all the waterways in the West, it may not be enough to elevate the population of steelhead to a healthy level because it has already dropped so low. What we have, we need to protect and preserve so that a valuable resource is not lost as so often happens.

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The discharge for the Upper Arroyo Seco site at the time of the habitat assessment was 285cfs, and 370cfs for the Lower site (USGS, 2001).

Appendices:

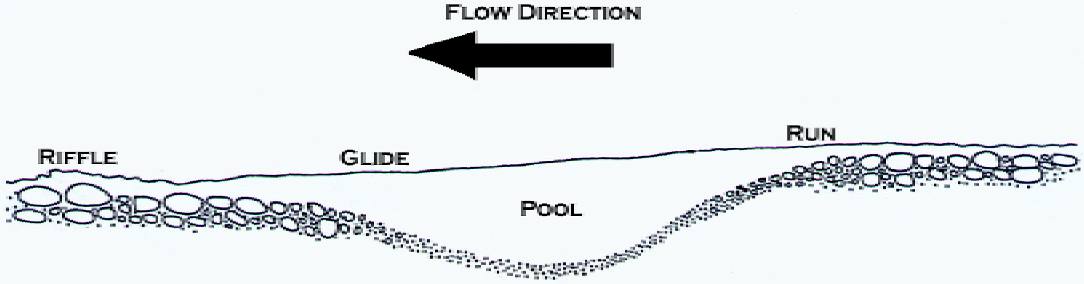
I Study Site Map

II In Stream Structure Illustration

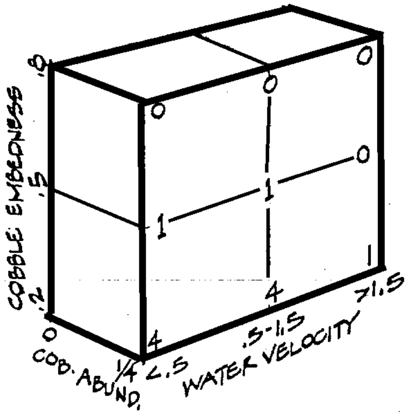
III Quality Index Lookup Table (modified from Dettman, 2000)

IV Recorded Data Sets

Appendix I



Appendix II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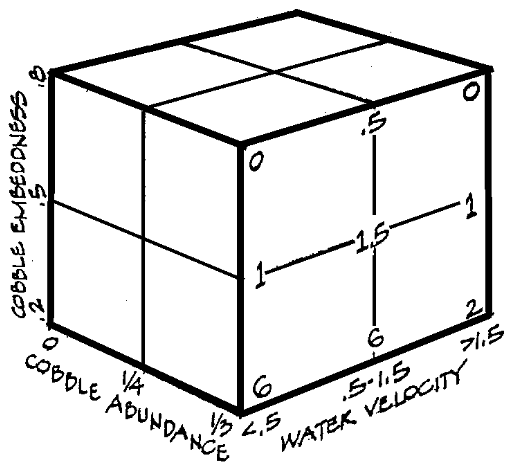
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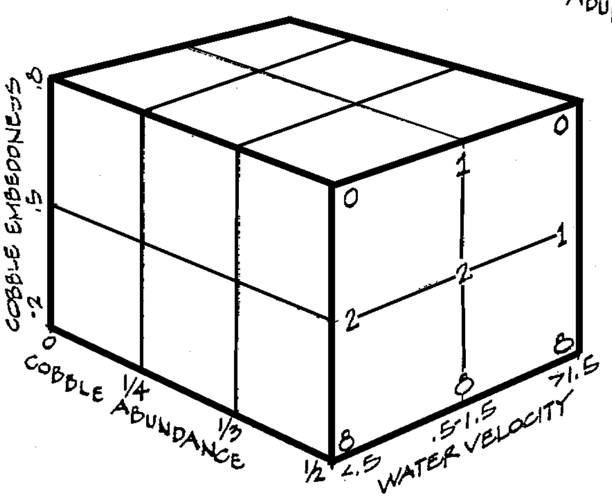
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