STANISLAUS RIVER
SALMONID DENSITY AND DISTRIBUTION
SURVEY REPORT (2002-2004)

Final Draft

Fishery Foundation of California

Prepared for
The U.S Bureau of Reclamation
Central Valley Project Improvement Act

Prepared by
Trevor Kennedy
Thomas Cannon

October 2005

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Abstract

Snorkel surveys were conducted on the lower Stanislaus River from October 2002 to October 2004 to determine the distribution, abundance, and habitat use patterns of juvenile Chinook salmon and rainbow trout. Young Chinook salmon were abundant in late winter and spring throughout most of the river from Goodwin Dam downstream to Oakdale. Their distribution shifted downstream through the spring and their numbers declined sharply from mid April to mid May coincident with the Vernalis Adaptive Management Program experimental storage releases from New Melones Reservoir. This pattern was also evident in the 2000 and 2001, which is strong support for the theory that spring flow pulses such as those provided by the VAMP experiment encouraged young salmon to leave the river and migrate to the estuary. The exodus of smolts in spring is also evident in lower river screw trap collections. Young trout were abundant from late spring through the fall throughout the river in 2003 and 2004; however, as in 2000 and 2001 their abundance progressively increased in the upstream direction through the summer. Yearling trout were concentrated in the upper portion of the river below Goodwin Dam where summer water temperatures were consistently below 16^{o}C, whereas water temperatures in the lower reaches were 18-20^{o}C during portions of the summer. Young salmon and young and yearling trout were found in significantly higher densities in experimental sites where gravel had been placed in the river to create riffle habitat. Small numbers of adult salmon were observed during the summer, including several in June that had recently spawned. Young Chinook were observed in low numbers over summering in the river upstream of Lovers Leap. Striped bass and American shad adults were also observed in the lower reaches during the summer, and were potential predators on young salmon and trout.

Introduction

With funding from the Central Valley Project Improvement Act (CVPIA[1]) in 2000-2001 and the U.S. Bureau of Reclamation in 2002-2005 the Fishery Foundation of California (Foundation) conducted snorkel surveys of Chinook salmon and rainbow/steelhead trout in the lower Stanislaus River downstream of Goodwin Dam from water years (October 1-September 30) 2000, 2001, 2003, 2004, and 2005. This report represents the results of surveys for water years 2003 and 2004. Results for survey years 2000 and 2001 are presented in Cannon and Kennedy (2002). The 2003 and 2004 surveys were conducted from October 18, 2002 to October 7, 2004. The snorkel surveys documented juvenile salmonid distribution, abundance, and habitat use patterns that are useful in evaluating habitat improvements and the effects of fishery flow releases from upstream storage reservoirs.

Purpose

Surveying juvenile salmonids in the lower Stanislaus River provides information about their spatial and temporal distribution within the river, as well as on their abundance and habitat use patterns, especially related to spawning and rearing in areas where gravel has been added to improve habitat. Such information assists in determining fishery water needs in the Stanislaus River in accordance with CVPIA objectives. The CVPIA has funded habitat improvement projects and "fish friendly" flow release trials from reservoir to the lower Stanislaus River to increase salmon and steelhead populations in the River. Snorkel surveys also provide data to evaluate the benefits of habitat improvements and flow releases. Snorkel surveys help determine habitat use patterns of juvenile salmonids under different flow regimes occurring over the year. Understanding what habitats juvenile salmonids use will help determine future habitat improvement needs. Understanding how juvenile salmonids respond to specific flow and habitat changes will help evaluate the importance of flow in triggering changes in juvenile salmonid distribution and emigration patterns in the river.

Objectives/Questions Addressed by Study

- Collect information on the life history of anadromous salmonids in the lower Stanislaus River.
- Determine the seasonal distribution and relative abundance of juvenile salmonids.
  - How are Chinook salmon and trout distributed within the Stanislaus River?
  - Are certain reaches or habitat types used disproportionately?
  - Do juvenile Chinook salmon and trout shift their distribution within the river in response to changes in habitat conditions (temperature, flow, predators, competitors, physical habitat, etc)?
- Collect information that can be used to evaluate the need for and benefits of habitat improvements.
- Relate distributions and relative abundance of different life stages of juvenile salmonids and other fishes to habitat conditions (river flow, water temperature, turbidity, velocity, cover, vegetation, substrate, geomorphology, predators, aquatic invertebrates, etc).
  - Determine habitat factors related to fish distribution and habitat use.
  - Determine response of juvenile Chinook salmon to changes in flow and water temperature.
- Document changes in juvenile salmonid distribution and abundance patterns as a consequence of supplemental spring flows of the Vernalis Adaptive Management Program (VAMP).
- Develop conceptual models of the life history, distribution and relative abundance, and habitat use patterns of juvenile salmonids to define fishery needs on the Stanislaus River and help plan, select, and evaluate habitat improvement actions.
- Determine factors that may limit growth and survival, and downstream movements of juvenile anadromous salmonids, particularly factors that affect young salmon reaching smolt size sufficiently early to allow successful migration through the Bay-Delta estuary before it warms and becomes intolerable for successful migration to the ocean.

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[1] The CVPIA provides for the mitigation, protection, and restoration of fish and wildlife resources and associated habitats within California's Central Valley.

- Determine juvenile Chinook emigration cues such as water temperature or river flow.

- Evaluate the extent of over-summering juvenile Chinook salmon and the potential contribution of this life history type based on on-going distribution and abundance surveys.
  - Is there a significant reduction in salmonid densities over the summer and if so what factors are related to that reduction?
  - Are there any differences in abundance between years and if so what factors might contribute to these differences?
- Determine life history types that contribute to anadromous salmon and steelhead escapement to the river based on distribution and abundance survey data.
- Evaluate the adequacy of lower river habitat for growth and survival of juvenile anadromous salmonids, especially fry and fingerling Chinook salmon.
- Relate the findings of the study to those of other studies documented in the scientific literature.

Sampling Sites

Eight sampling reaches were selected from one-fourth mile below Goodwin Dam downstream to the vicinity of Oakdale (Figure 1). Two to four sites were surveyed per reach for a total of twenty-two sites covering a range of habitat types within and among reaches. Sites consisted of subreaches of varying length with specific target habitat conditions. Access to the river was a consideration in site selection. The eight sampling reaches were Goodwin Dam (RM 58.3), Two-Mile Bar (RM 56.6), Knight's Ferry (RM 54.5), Lovers Leap (RM 52.2), Honolulu Bar (RM 49.6), Orange Blossom (RM 46.9), Valley Oak (RM 44.5), and Oakdale (RM 40). Two basic subreach/site categories were selected for surveying in each reach: a low velocity (Slow) site and a higher velocity (Fast) site of relatively fast moving water. A third subreach/site type (Experimental) was added for reaches that had recent gravel augmentations to enhance salmonid spawning and rearing habitat. Whenever possible, subreaches with slackwater pool margins were selected for the low velocity sites. In instances when no pool habitat was available, flatwater habitat with low velocity margins were selected to represent slow-water habitat in a reach. Riffle or higher velocity glide habitats were selected to represent fast-water habitat. Areas near the downstream end of high gradient riffles or narrow reaches of glide habitat where velocities are higher relative to other glide habitat area were selected as fast-water habitat. Experimental sites where habitat has been improved with gravel augmentation were generally riffle habitat, but often also had some slow water habitat. Experimental sites were included based on observations made in the 2000-2001 surveys that juvenile salmonid densities were significantly higher at these sites and the fact that the sites represent a unique habitat for the present-day lower Stanislaus River. A more detailed description of the sampling sites is provided in Table 1. GPS coordinates are shown in Table 2.

Table 1. Survey reaches and sampling sites for snorkel surveys of the Stanislaus River in 2002-03 and 2003-04.

	Sites			
Reach	**Slow**	**Fast**	**Exp 1**	**Exp 2**
Goodwin Dam (RM 57.5)				
Length (m)	22	55	70	45
Average width (m)	26.7	21.7	25	17.4
Average depth (m)	2.2	1.55	.68	.40
Habitat type	Lateral scour pool[2]	Riffle	Gravel glide	Riffle
Two-Mile Bar (RM 56.6)				
Length (m)	66	65	36	
Average width (m)	36	24.3	29.5	
Average Depth (m)	1.6	1.2	.65	
Habitat type	Pool	Fast glide/riffle	Gravel glide	
Knights Ferry (RM 54.5)				
Length (m)	62	55	70	
Average width (m)	30.1	24.5	40.1	
Average Depth (m)	1.8	1.5	0.6	
Habitat type	Slow glide/pool	Fast glide	Tailout/riffle	
Lovers Leap (RM 52.2)				
Length (m)	70	84	98	
Average width (m)	24.6	19.6	39.1	
Average Depth (m)	1.4	1.6	0.7	
Habitat type	Slow glide/lat. Scour	Fast glide/lat. scour	Mid-glide gravel bar	
Honolulu Bar (RM 49.6)				
Length (m)	72	68	45	
Average width (m)	28.2	21.7	28.3	
Average Depth (m)	0.9	0.6	.77	
Habitat type	Slow glide	Fast glide/riffle tailout	Gravel glide	
Orange Blossom (RM 46.9)				
Length (m)	46	49	43	
Average width (m)	31.2	26.8	26.4	
Average Depth (m)	1.1	0.8	0.5	

	Sites			
Reach	**Slow**	**Fast**	**Exp 1**	**Exp 2**
Habitat type	Slow glide	Fast glide	Tailout riffle & lateral scour	
Valley Oak (RM 44.5)				
Length (m)	57	74	49	
Average width (m)	23.9	24.5	25	
Average Depth (m)	1.4	0.95	.60	
Habitat type	Slow glide/lat. Scour	Fast glide	Gravel glide	
Oakdale (RM 40.0)				
Length (m)	57	74		
Average width (m)	23.9	24.5		
Average Depth (m)	1.4	0.95		
Habitat type	Slow glide/lat. Scour	Fast glide		

[2] Classification per DFG 1998.

Table 2. Midpoint coordinates for 2002-03 and 2003-04 Stanislaus River snorkel survey sites.

Site Name	Latitude	Longitude
Goodwin Slow	N37.85755	W120.63558
Goodwin Fast	N37.85880	W120.63547
Goodwin Exp	N37.85842	W120.63559
Two-Mile Bar Fast	N37.84334	W120.64355
Two-Mile Bar Slow	N37.84504	W120.64341
Two-Mile Bar Exp	N37.84315	W120.64320
Knights Ferry Slow	N37.81851	W120.66632
Knights Ferry Fast	N37.81817	W120.66537
Knights Ferry Exp	N37.81885	W120.66731
Lovers Leap Slow	N37.80880	W120.69317
Lovers Leap Fast	N37.80840	W120.69219
Lovers Leap Exp	N37.80912	W120.68100
Honolulu Bar Slow	N37.80027	W120.72658
Honolulu Bar Fast	N37.80027	W120.72658
Honolulu Bar Exp	N37.80027	W120.72658
Orange Blossom Slow	N37.78947	W120.76343
Orange Blossom Fast	N37.78873	W120.76296
Orange Blossom Exp	N37.78807	W120.76250
Valley Oak Slow	N37.78550	W120.80112
Valley Oak Fast	N37.78550	W120.80112
Valley Oak Exp	N37.78550	W120.80112
Oakdale Slow	N37.77080	W120.87089
Oakdale Fast	N37.77091	W120.87019

Figure 1. Location of sampling sites in lower Stanislaus River

Methods

As in the 2000 and 2001 surveys, sampling at each survey site consisted of two divers swimming upstream along the stream margin on opposite banks. Divers were positioned so that the maximum lateral area could be observed (~1.5 m from the river margin depending on visibility – Figure 2). In addition to the two upstream margin transects, a mid-stream transect was also surveyed swimming downstream parallel to the two margin transects.

Figure 2. Diver moving upstream along sampling site.

Observations were recorded on dive slates. Variables recorded include fish species and length. Divers were trained to distinguish between young salmon and trout, as well as non-salmonid species such as pike minnow, sac-suckers, bass, etc. Size was determined by training the divers to visually estimate the size of standard-length, painted, lead weights. For large groups of fish, size distribution was estimated as percentage by size category. Individual large trout were counted and sized independently of smaller trout and salmon. For each sampling date and sampling site, indices of abundance were calculated for juvenile salmon and trout. The number of each species and life stage per 100 square meters surveyed for the entire site was calculated to provide an index of abundance for each species and age group (salmon and trout). Because the area surveyed differed among the 23 sites, total observations were standardized to a 100 square-meter index.

Water temperature was recorded at each site at the start of each survey. Recordings were made at approximately the same time of day at each site within a reach for temporal consistency among sites. Survey data on water temperature was supplemented by continuous recording thermometers data available from DFG.

Results

Stream Flows

Flows at Orange Blossom Bridge in the 2002-03 survey period, October 1 2002 through October 31, 2003, ranged from 175 to 1,291 cfs (Figure 3). Spring–time flows ranged from 1,131 to 1,275 cfs during April 25 to May 3 and 1,005 to 1,255 cfs during May 29 to June 30. These spring high flows correspond to reservoir releases generally referred to as the Vernalis Adaptive Management Program (VAMP) releases, which vary depending on the water year type. VAMP releases generally occur from mid-April to mid-May, or in some years early April to late May. VAMP releases are generally 1200-1500 cfs. Summer releases above 300 cfs are generally for meeting Vernalis flow standards or Ripon dissolved oxygen standards. By mid-August flows had declined to near 300 cfs and remained in this range for the remainder of the summer through the winter. Non-VAMP reservoir releases are generally in the 250-300 cfs range, except when higher releases are needed for water quality. There was a short period of higher releases during the fall Chinook salmon attraction flow from October 20-29, 2004 when flows reached 762 cfs.

Flows at Orange Blossom Bridge in the 2003-04 survey period, November 1, 2003 through October 31, 2004, ranged from 175 to 1,291 cfs (Figure 3). Spring-time VAMP reservoir release peaked at 1,291 cfs between April 28 and May 17. Again, by mid-August flows had declined to near 300 cfs and remained at this level through the end of the survey period.

Stream Habitat

As observed in 2000-2001 (Kennedy and Cannon 2002), stream habitat is considerably different under the two basic flow regimes: 250-400 cfs and 1,000-1,500 cfs. Differences were noted in the amount of low-velocity, high-cover margin habitat, particularly in the fast-water sites of the upper four reaches of the river. During the higher flow periods, flooded vegetation is abundant at all sites. As flows recede in late spring, the margin habitat recedes as well. Flooded margin habitat under the 250-400 cfs base flow regime is only about 10% of that at 1500 cfs or higher based on visual observations. Side channels at the Honolulu Bar and Oakdale sites became disconnected from the main channel at flows less than 500 cfs. The side channels remain watered via inter-gravel flow after they become disconnected from the main channel

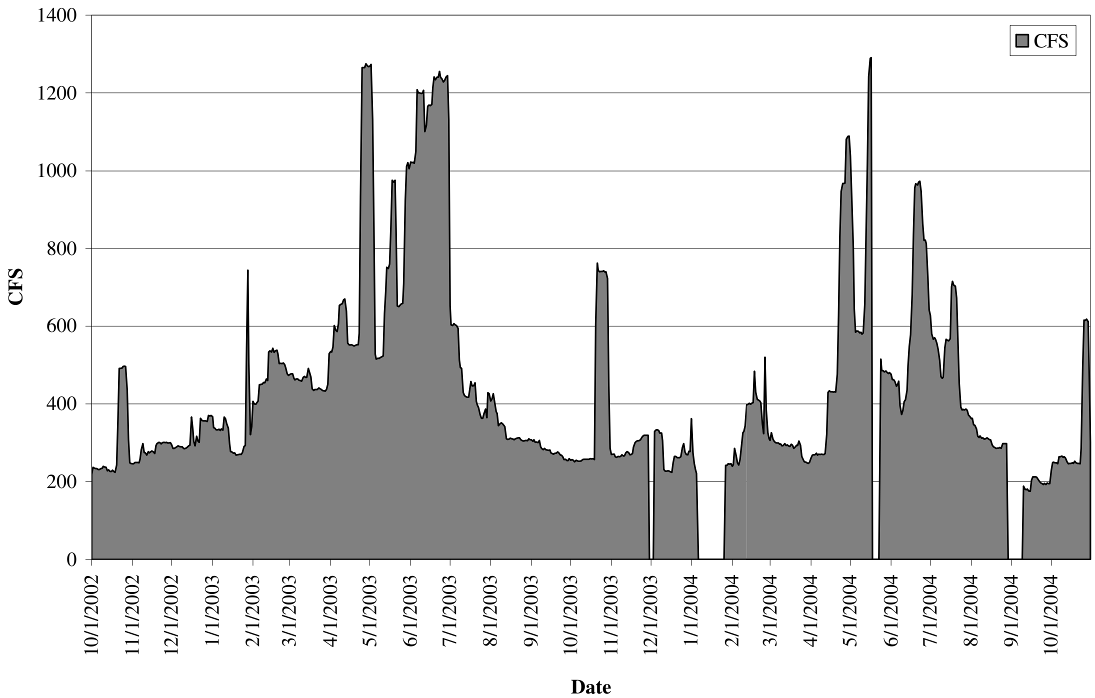

Figure 3. Daily Stanislaus River flow measured at Orange Blossom Bridge from October 1, 2002 to October 31, 2004. Zero flow days were caused by gauge malfunction. (Source: CDEC).

Water Temperature

Water temperature measured by CDFG at Orange Blossom Bridge varied from 9 to 17.5°C during the two survey years (Figures 4 and 5). Temperatures exceeded 16°C from early July through late September 2003 and from late July through mid September 2004. Temperatures reached a minimum in late December 2002 (2003 survey period) and in early January 2004 (2004 survey period).

Water temperatures collected at snorkel survey sites in the two years ranged from 9 to 18°C, reaching their minimum in January at Goodwin and their maximum in July at Oakdale (Figure 6). Temperatures at Goodwin, the most upstream survey site were generally lower than downstream sites throughout the survey period, ranging from 9 to 14°C. Temperatures at the most downstream survey site, Oakdale ranged from 10 to 18°C. The peaks in temperature at Oakdale of 17-18°C occurred when flows were below 400 cfs from spring through fall. Water temperature reached or exceeded 16°C from Honolulu Bar and downstream during the summer after flows fell below 400 cfs.

In both survey years, water temperatures remained below 16°C throughout the study period in the upper reaches including Goodwin, Two-Mile bar, Knights Ferry, and Lovers Leap. Temperatures of 16°C and higher were recorded during the summer and early fall

2003/2004 and spring 2004 surveys in the lower reaches including Honolulu-Bar, Orange Blossom Bridge, Valley Oak and Oakdale.

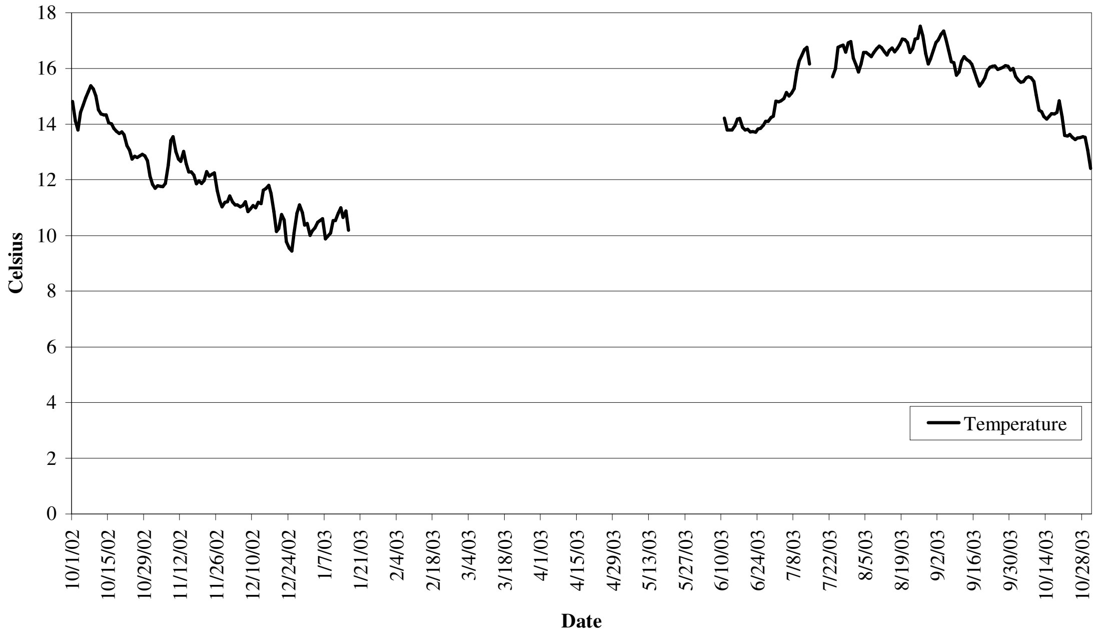

Figure 4. Mean Daily water temperature (celcius) measured at Orange Blossom Bridge on the Stanislaus River from October 1, 2002 to October 31, 2003. Source: CDFG data from CDEC.

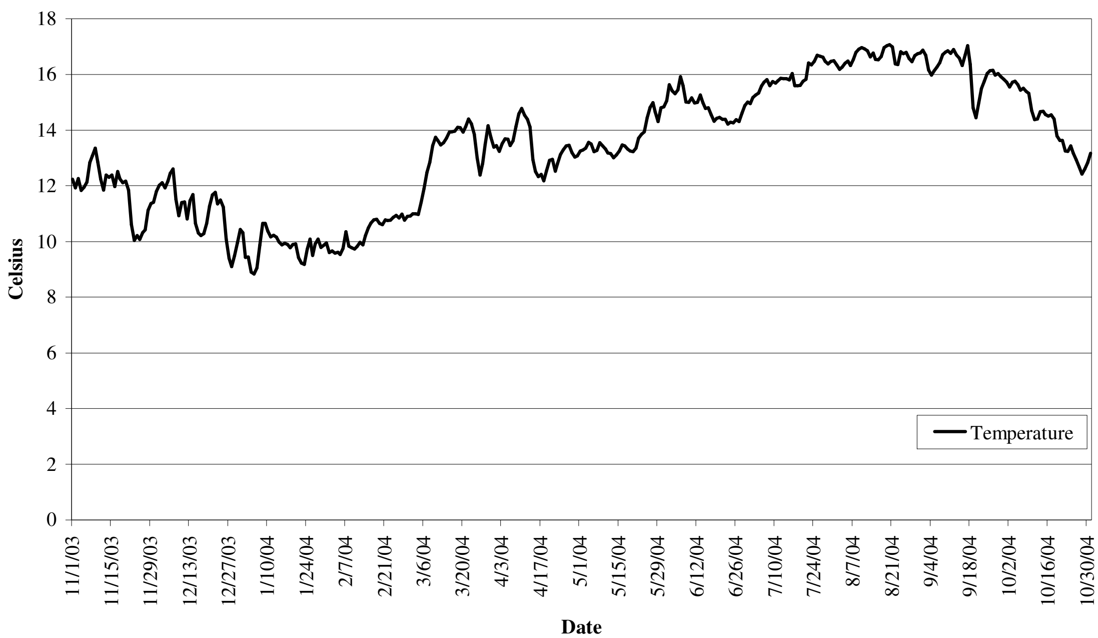

Figure 5. Mean daily water temperature (celcius) measured at Orange Blossom Bridge on the Stanislaus River from November 1, 2003 to October 31, 2004. Source: CDFG data from CDEC.

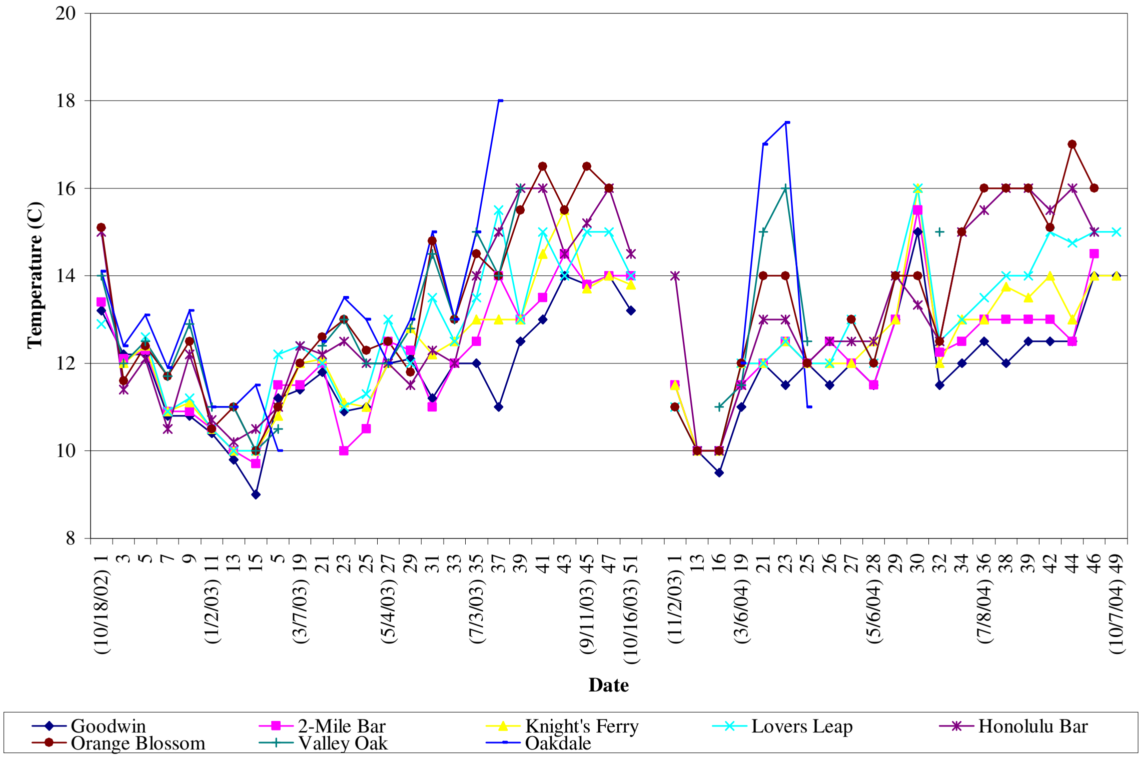

Figure 6. Water temperature (C) measured at snorkel survey sites on the Stanislaus River from October 2002 to October 2004.

Salmonid Distribution

Density of juvenile Chinook salmon and 0+ and 1+ age trout in fast water, slow water and gravel augmented habitats was averaged for each survey site and species or age class. The resulting average density at each site over the survey period is presented here. Appendix A contains density data broken down by species and age class for each of the three habitat types.

Chinook Salmon

<u>Survey Year 2002-03</u>

Surveys began in mid-October 2002. Young Chinook salmon were observed in appreciable densities starting early January 2003 (Figure 7). Peak abundance occurred from late January to mid March, with densities reaching up to 227 fish per $100m^2$ at Orange Blossom. During peak abundance, the middle reaches had higher densities than the upper and lower reaches. Goodwin had the lowest peak density and Orange Blossom the highest.

Chinook densities declined in late March with few observed after June 2. However, densities at Goodwin remained steady and higher through the end of May than at the other sites perhaps due to cooler water temperatures in the upper portion of the river.

From June 18 to October 16, Chinook were most abundant between Goodwin and and Lovers Leap.

Survey Year 2003-04

Surveys began in early November in 2003. Overall densities of young Chinook salmon were lower than in the previous survey year. Young Chinook were observed in appreciable numbers starting in late January and densities peaked during weeks from mid February to mid March (Figure 8). The highest density was 76 fish per 100m2 at Orange Blossom and the lowest peak density was 8 fish per 100m2 at Goodwin. Young Chinook were least abundant in the upper reaches especially at Goodwin and most abundant in the middles reach from Lovers Leap to Orange Blossom. Density declined sharply after mid April. Density was very low by May 25. As in the previous years of surveys density at Goodwin remained higher as downstream densities dwindled in late spring.

Chinook emergence (2002-2004)

Observations of Chinook emergence differed between sites and years. In the 2003 survey Chinook fry were observed as early as December 2002. In the 2004 survey Chinook fry were not observed in any site until the end of January. Below is a list of the dates the first Chinook fry were seen at each site for both years.

	03' Survey	04' Survey
Goodwin Dam	1/2/2003	1/29/2004
Two-mile Bar	12/12/2002	1/30/2004
Knights Ferry	12/12/2002	1/29/2004
Lovers Leap	12/12/2002	1/30/2004
Honolulu Bar	1/3/2003	1/29/2004
Orange Blossom	1/2/2003	1/29/2004
Valley Oak	1/16/2003	2/9/2004
Oakdale Rec.	1/16/2003	2/9/2004

Trout Young (Age 0)

Survey Year 2002-03

Young trout began to appear in early April from Goodwin Dam downstream to Lovers Leap (Figure 9). They did not appear in appreciable numbers in downstream reaches below Lovers Leap until mid July but even then only to Orange Blossom. Densities peaked in the upper reach at Goodwin, Two-Mile Bar and Knights Ferry from mid June to mid October. Densities ranged from 1.27 fish per 100m2 at Knights Ferry to 14 fish per 100m2 at Goodwin. Densities declined by mid November and were at their lowest by mid December. Densities were lowest throughout the survey period in the middle and lower reaches.

Survey Year 2003-04

Young trout began to appear in mid April in the upper river reach at Goodwin, Two-Mile Bar and Knights Ferry (Figure 10). They began appearing in appreciable numbers in the lower reaches in early May. Densities were highest in the upper reach from late May to early October, with highest density of 10 fish per 100m2 at Goodwin. Densities declined starting late January with lowest densities during the period mid February to early April. Densities were lowest throughout the survey period in the middle and lower reaches.

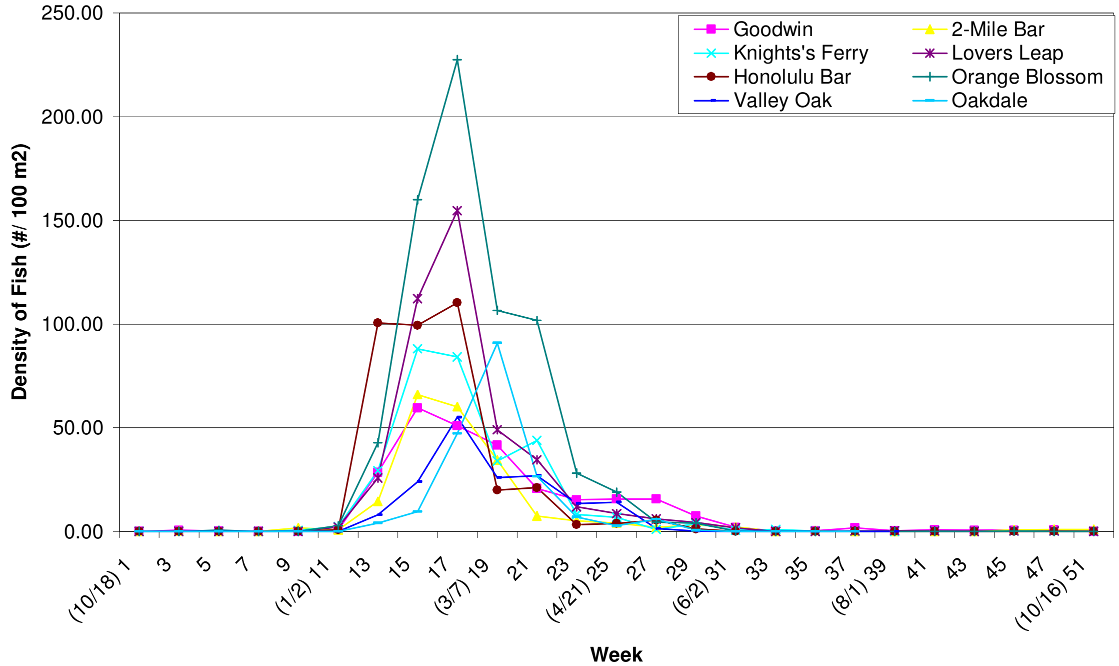

Figure 7. Average density of young Chinook salmon in surveys of fast water, slow water, and gravel augmented habitat. 2002-03 survey.

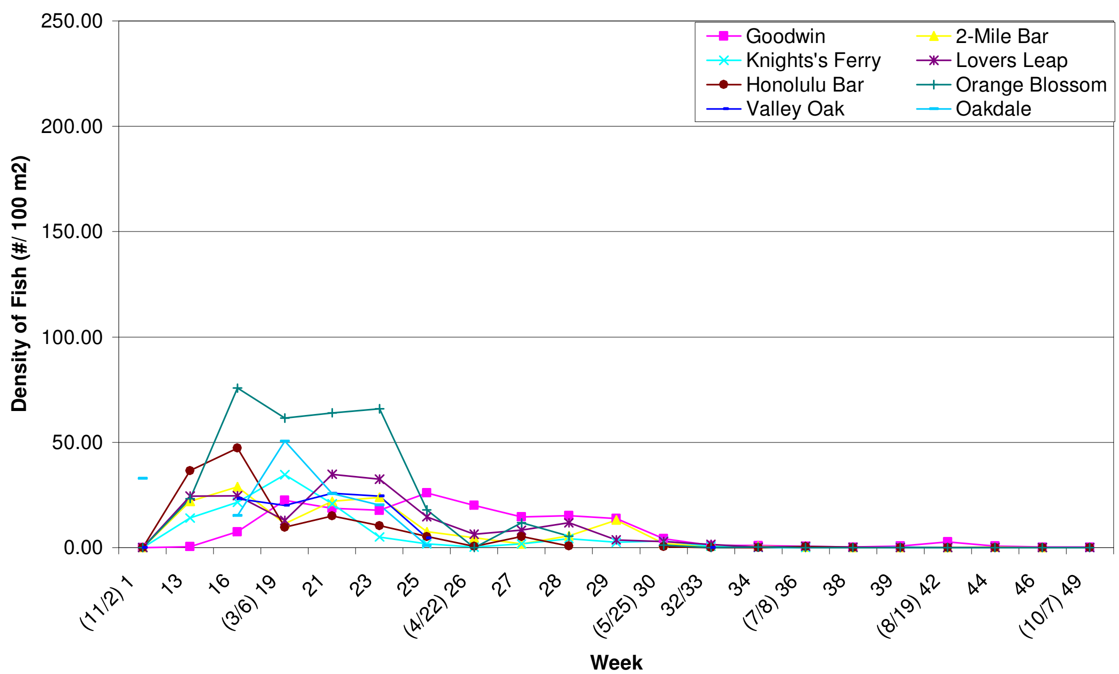

Figure 8. Average density of young Chinook salmon in surveys of fast water, slow water, and gravel augmented habitat. 2003-04 survey.

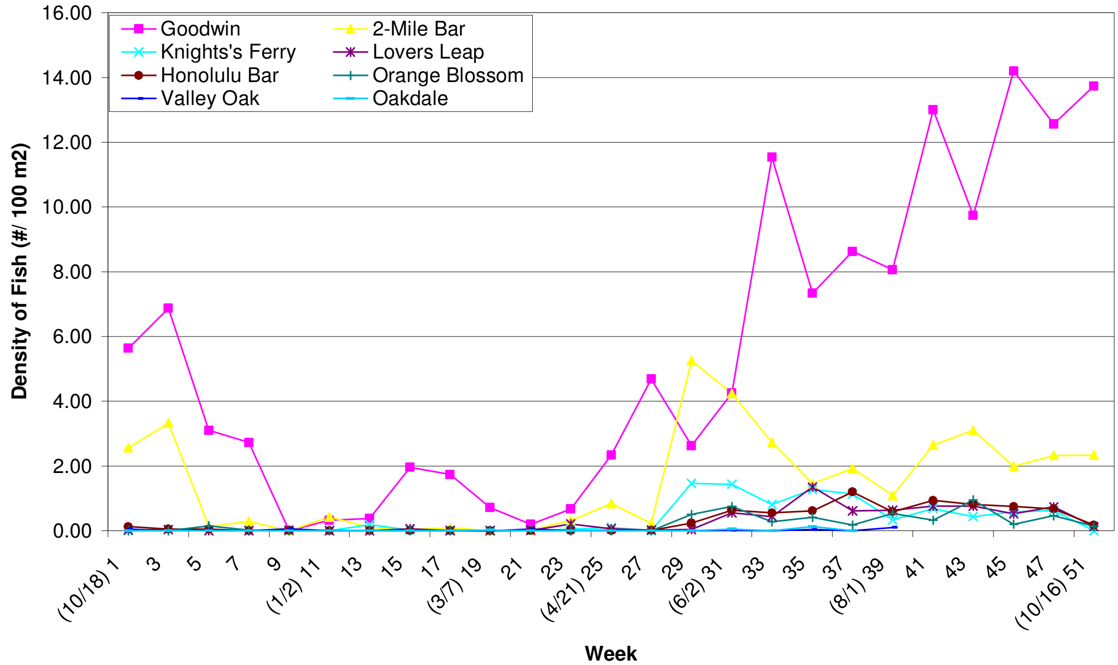

Figure 9. Average density of 0+ steelhead trout in surveys of fast water, slow water, and gravel augmented habitat. 2002-03 survey.

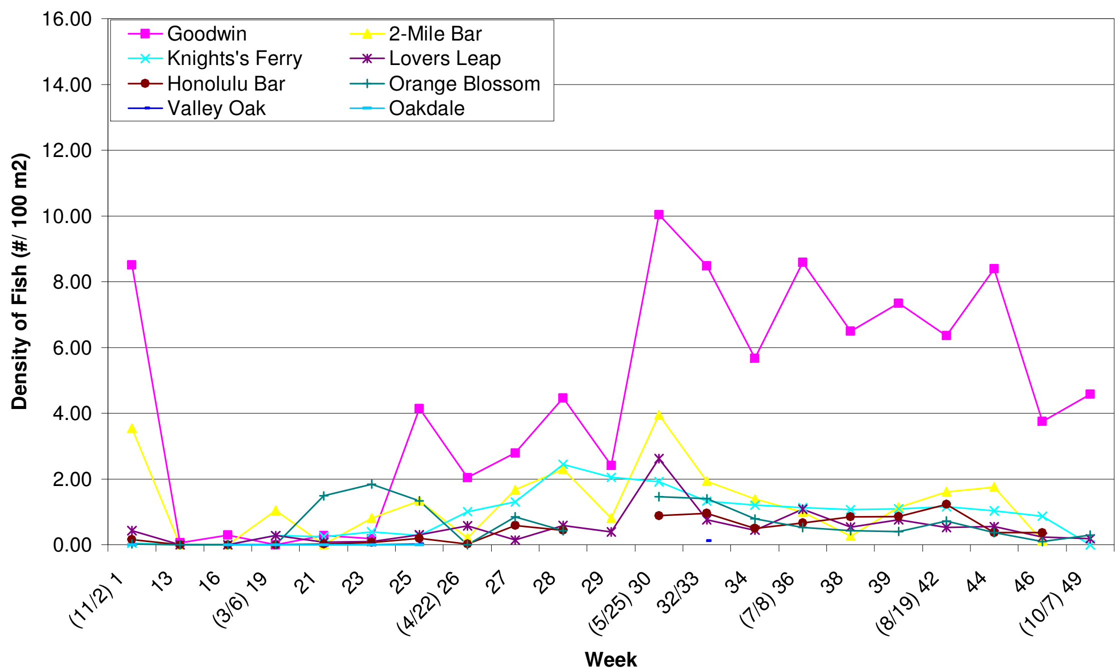

Figure 10. Average density of 0+ steelhead trout in surveys of fast water, slow water, and gravel augmented habitat. 2003-04 survey.

Trout Yearlings (Age 1+)

Years 2002-2003

Yearling trout were observed throughout the survey period in 2002-2003 and were most abundant in the upper reach. Yearling trout densities increased in the upper river reach at Goodwin in mid May (Figure 11). Densities at Two-Mile Bar and Knights Ferry were much lower than in the previous year. They began appearing in higher densities in the lower reaches in early June. Densities were highest in the upper reach from mid May to late September, ranging from 0 to 5 fish per 100m2. Densities declined starting in mid December with lowest densities from early January to mid May.

Trout Yearlings (Age 1+)

Years 2003-2004

Yearling trout were observed throughout the survey period and were most abundant in the upper reach. Yearling trout densities were highly variable in the upper river reach at Goodwin, but remained higher than any other site throughout the survey period (Figure 12). Yearling trout began appearing in higher densities in the lower reaches in early June. Densities were highest in the upper reach from late April to early October, ranging up to 8 fish per 100m2. Densities at Two-Mile Bar declined starting in late January. Densities at all sites below Goodwin generally remained below 1 fish per 100m2 throughout the survey period.

Trout Emergence (2002-2004)

Below is a list of dates that Trout fry were first observed at each site. An asterisk represents no fry observed at that reach, the first juvenile trout seen were in the size range of 40-60mm .

	03' Survey	04' Survey
Goodwin Dam	3/21/2003	4/18/2004
Two-mile Bar	3/21/2003	3/6/2004
Knights Ferry	4/16/2003	3/6/2004
Lovers Leap	4/31/2003	3/6/2004
Honolulu Bar	*	4/1/2004
Orange Blossom	5/17/2003	3/17/2004
Valley Oak	3/21/2003	*
Oakdale Rec.	*	*

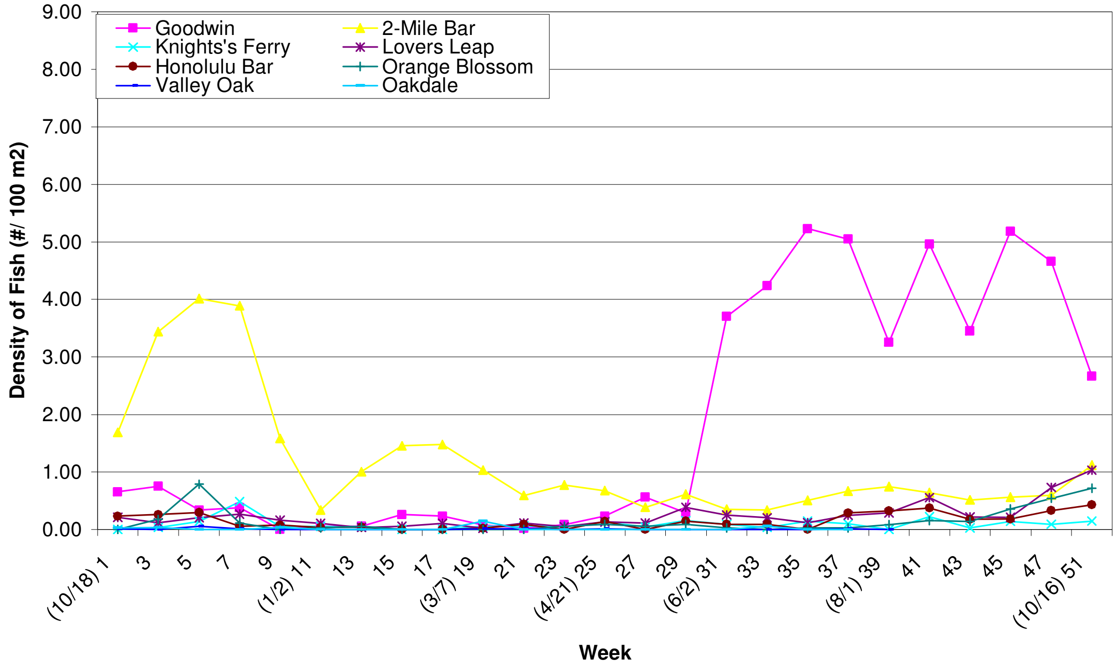

Figure 11. Average density of 1+ steelhead trout in surveys of fast water, slow water, and gravel augmented habitat. 2002-03 survey.

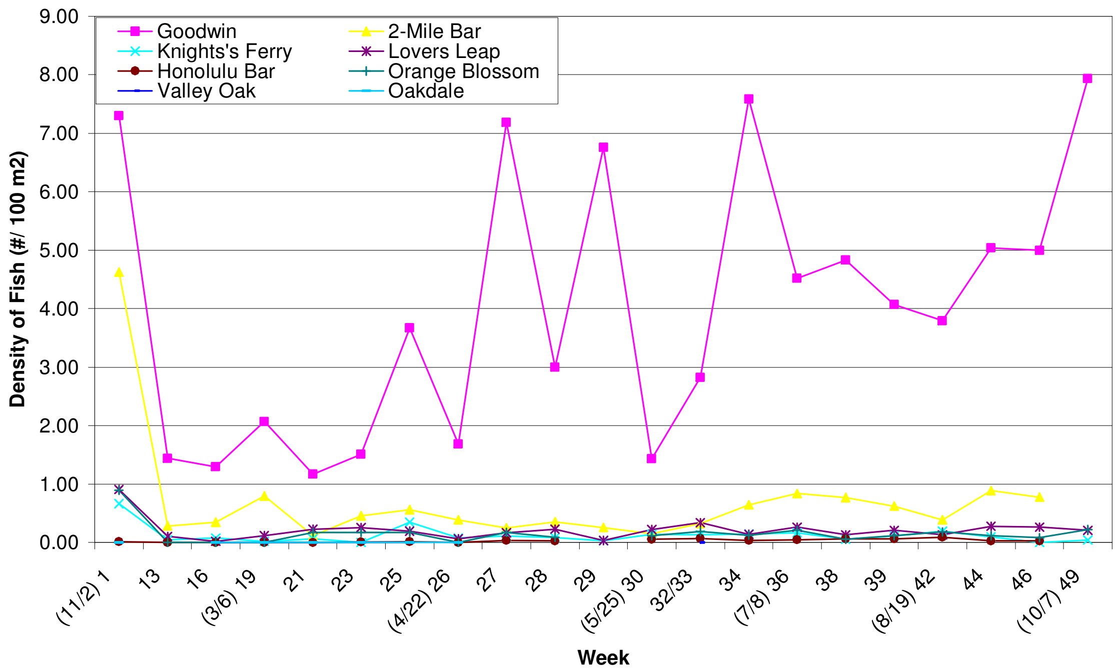

Figure 12. Average density of 1+ steelhead trout in surveys of fast water, slow water, and gravel augmented habitat. 2003-04 survey.

Observations of Adult Chinook

Summertime surveys were conducted weekly from Goodwin Canyon to Lovers Leap. Focused SCUBA surveys were conducted below Matterhorn Falls to observe any over summering spring run Chinook holding in the deep pools in that area. Snorkel surveys were used from Two Mile bar to Lovers Leap to observe any adult Chinook in that area. Adult Chinook were observed on four dates from Goodwin Dam downstream to Lovers Leap:

- **18 June 2003 -** Two adult Chinook salmon were observed in the Two-Mile Bar to Lovers Leap reach.
- **17 July 2003 -** One adult Chinook salmon was observed between Goodwin Dam and and Two-Mile Bar.
- **1 August 2003 –** No Chinook observed from Goodwin Dam to Two-mile Bar.
- **15 August 2003 –** No Chinook observed from Two-mile Bar to Knights Ferry.
- **28 August 2003 –** No Chinook observed from Knights Ferry to Lovers Leap.
- **10 June 2004 -** Six adult Chinook salmon were observed between Goodwin Dam and and Two-Mile Bar.
- **16 September 2004 -** One adult Chinook salmon was observed between Goodwin Dam and and Two-Mile Bar.

Observations of Adult Rainbow Trout

During the summertime surveys from Goodwin Canyon to Lovers Leap, adult rainbow trout including some that appeared to be steelhead (over 400mm) were observed sporadically in the river. Fifteen large trout sized 400-500 mm and two 500-600 mm size trout were observed on June 10, 2004 in the Goodwin Dam to Two-Mile Bar reach. Twenty-one 400-500 mm size trout were observed on September 16, 2004 in the Goodwin Dam to Two-Mile Bar reach.

Salmonid Length-Frequency

Chinook Salmon
Salmon length frequency was consistent from year to year with fry (30-50mm) dominating in January and February, fingerlings (50-70mm) in March, and smolts (70mm+) by May (Appendix B-1). Some over-summering smolts were observed in the upper river of each year.

Trout
Trout length frequency was consistent from year to year with young entering the population in April and May (Appendix B-2). Yearling and older trout were present year-round.

Non-Salmonid Distribution

Except for the upper river at Goodwin, gravel introduction sites (experiment) sites generally had less non-salmonid fish than fast or slow water sites (Appendix C). Slow water sites generally had the highest densities of non-salmonids. Non-salmonids were predominantly Sacramento sucker and pikeminnow, and tule perch. Striped bass and American shad were also observed in small groups during the late spring and summer.

Discussion

Distribution of Juvenile Salmon in Lower Stanislaus River

Fry salmon were abundant throughout the survey area by January. Density of fry salmon was lowest in the upper sites below Goodwin Dam. Exploratory dives in the reach between Goodwin Dam and Two-Mile Bar found the reach was made up of deep, slow pools and high gradient riffles with little spawning habitat. Pool tailouts within this reach were highly scoured and possessed mainly angular cobble substrate with diameters in excess of three inches (median axis). Although salmon redds have been observed in this reach, it generally lacks spawning gravels. The otherwise favorable spawning and rearing conditions observed in this reach throughout the year make it a prime candidate for spawning habitat restoration. Maximizing the spawning potential within this reach for salmon and trout would allow for a greater amount of spawning habitat and better utilization of the optimal rearing habitat of the upper reaches, which together should increase smolt production in the river.

Abundance of juvenile salmon declined rapidly throughout the river upon commencement of VAMP storage releases in mid to late April of both 2003 and 2004, as it had in 2000 and 2001 (Kennedy and Cannon 2002). This decline is likely indicative of active emigration of fingerling and smolt salmon downstream into the lower river, the San Joaquin River, and the Bay-Delta. Such an emigration is also indicated in smolt (primarily 80-90 mm) catch in the screw traps monitored at Caswell in April and May (Figure 13).

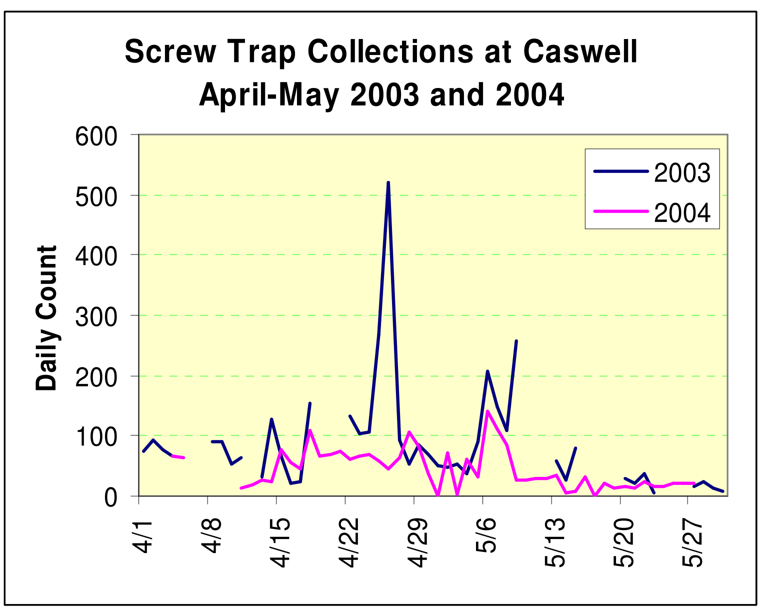

Figure 13. Daily counts of salmon smolts in screw traps at Caswell in 2003 and 2004. (Source: http://www.stanislausriver.com)

Small numbers of juvenile salmon (about 5% of the number of salmonids observed) were observed through the summer in the upper reaches as they were in 2000 and 2001 where water temperatures remained low at 11-14°C.

Distribution of Juvenile Trout in Lower Stanislaus River

Young trout began to emerge from the gravel at the upper river sites by April and were abundant from May through September. They were most abundant in the upper reaches from Goodwin down to Orange Blossom where water temperatures were consistently in the optimal 14-16°C range. Young trout reached the lower river sites by July in small numbers, But were virtually absent from the Oakdale and Valley Oak sites the remainder of the summer where water temperatures typically reached marginal levels of 18°C or above.

As in 2000 and 2001, by December the density of young trout observed fell by over 90% as water temperature fell to 10°C or below. With four years of this consistent pattern, we believe that a combination of (1) emigration from the river after the first fall rains in November, and (2) young trout seeking refuge under larger substrate because of the low water temperature were the reasons for the decline in density. A sharp increase in density in spring when water temperature rose above 10°C indicates the latter was a key factor. The disappearance of young salmonids into substrate cover at temperatures at or below 10°C is well documented in the literature (e.g., Bjornn 1971; Rimmer et al. 1983). This is also the point when many juvenile salmonids emigrate from their natal rivers after over-summering (e.g., Rimmer et al. 1983).

Yearling and post-yearling trout were concentrated in the upper river in the Goodwin and Two-Mile Bar reaches in both 2003 and 2004, as they were in the 2000 and 2001 surveys. Small numbers were observed in the middle reaches particularly within experimental sites (Knight's Ferry, Lovers Leap, and Orange Blossom). As in 2000 and 2001, the density of yearling and older trout increased over the summer at the upstream sites, while densities declined at downstream locations, which may indicate a positive upstream movement of yearling and older trout into the cooler waters of the upper river.

Movement and Factors Related to Movement

A relatively high proportion of juvenile salmon likely emigrate from the Stanislaus River as fry during the winter of wet years as in other Central Valley rivers. This pattern is apparent in the downstream shift in fry densities over the winter that we observed in all four years of surveys as well as in screw trap surveys (http://www.stanislausriver.com). The relatively low densities of young salmon observed in 2000 and 2004 as compared to 2001 and 2003 is possibly due to high winter emigration during higher flows in 2000 and 2004; whereas, flows were lower through the winter of 2001 and 2003. Another explanation for the higher densities of salmon in some years is that greater escapement of adult salmon occurred in the fall of some years, which resulted in greater production of young the next spring, as available stock-recruitment data indicate a significant positive relationship between spawners and escapement two years later (Figure 14)..

As discussed earlier, in each survey year including 2000 and 2001 it appeared that a large proportion of remaining juvenile salmon migrated from the river during VAMP storage releases. As designed, VAMP pulse flows in spring appear to trigger emigration of juvenile salmon from the river based on the coincidence of timing and general theory, although no surveys have been conducted in absence of a VAMP flow release.

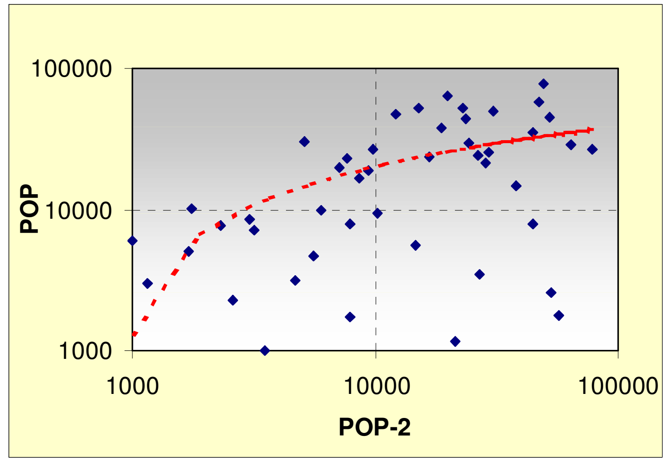

Figure 14. Log of San Joaquin salmon escapement 1958-2003 versus log of escapement two years earlier.

VAMP storage releases from mid April through mid May or mid June may also trigger downstream dispersal of age 0 trout into the lower reaches especially in years when the only pulse of flow for the year is the VAMP flow. This dispersal pattern was evident in each of the four survey years.

The VAMP flows may thus serve to not only aid dispersal and emigration, but also to minimize competition between young salmon and trout by making room for the trout when the salmon leave the river as observed by Everest and Chapman (1972) in Idaho streams.

Habitat Use by Juvenile Salmon and Trout in the Lower Stanislaus River

Soon after emergence in winter, fry salmon were observed concentrated in slow-water, margin habitats of the entire study reach. As they grew through the spring they were more abundant in faster water and were often observed sharing feeding lanes on current seams with young, yearling, and adult trout.

Throughout the spring and summer, velocity appeared to play a more important role in where salmonids were in a given habitat unit as they were often observed in higher velocity areas without vegetation and less often observed in low velocity, vegetated areas where they concentrated as fry. Likewise, under lower summer flow, juvenile salmonids sought out higher velocity water towards the head or tail of pools.

Both salmon and trout showed a strong preference for habitat of the experimental gravel introduction sites in the upper reaches of the river. Reaches with experimental sites had more young salmon and trout, and there were generally higher densities at experimental sites than slow and fast-water sites. The experimental sites were generally much shallower than other sites, as experimental sites generally consisted of areas where large amounts of gravels were introduced into reaches and sites within reaches that were otherwise deep water. These results are consistent with those of Baltz et al. (1987) who found shallow depths important in macrohabitat choice of juvenile rainbow trout. At the non-experimental sites water depths are much greater based on our observations because of apparent channel incising and gravel mining, as well as an obvious lack of gravel recruitment because of the presence of upstream dams. The gravel additions at the experiment sites add more than gravel, they fill the channel and provide proper depths and geomorphic conditions (per Lanka et al. 1987) as well as substrate for young salmonids. Moyle and Baltz (1985) found young trout preferred water depths of about 36 cm, while yearlings and adults preferred 63 and 82 cm, respectively. All of these depths are generally more prevalent at the experimental sites. Water column velocities and substrates may also be more optimal for trout at the experimental sites. The fact that young salmon and trout, as well as yearling and older trout all preferred the experimental sites in the river is an indication that the more optimal habitats are lacking in the lower Stanislaus River. Concentrations of young trout and salmon in the limited experimental sites may be an indication of intense competition or even predation (by yearling and older trout on young trout and salmon). Under such circumstances the production of young salmon and trout is likely limited by the competition and predation as suggested by Hearn (1987). For Chinook salmon populations that are already depressed from historical levels as in the case of the Stanislaus River population, such competition and predation could be a limitation to recovery (Link 2002), and that restoration of optimal habitat should lead to an increase in the population.

Fry salmon and trout often selected flooded vegetation in the river channel as it provided velocity refuge, overhead cover, and protection from predators.

The classic winter shift of trout and salmon from faster shallower water to slower deeper pool water (Bustard and Narver 1975) was not readily apparent in this survey. Only at Goodwin did the slower water site have similar or higher densities of trout through the year.

Segregation of different size-age groups of trout and salmon (Baltz and Moyle 1984) was readily apparent. Young trout and salmon tended to use the slower sheltered waters while yearling and older trout used faster waters. Young salmon appeared to move downstream during the winter and spring and were less abundant in the upper reaches where yearling and older trout densities were greatest.

Young salmon also used the river predominantly in late winter and spring, whereas, young trout were predominant in late spring, summer, and fall. This pattern was also evident in 2000 and 2001 (Kennedy and Cannon 2002).

In general, the habitat use patterns observed appears complicated by the continued growth of individual fish and changes in habitat (e.g., flow and water temperature) through the seasons, as observed in many previous studies (Hearn 1987).

Predation and Competition

Non-salmonids, particularly Sacramento sucker, Sacramento pikeminnow, and tule perch were resident in the lower Stanislaus River. Smaller numbers of striped bass and American shad were seasonally present. Lower densities of non-salmonids and higher density of salmonids at all the gravel introduction sites and higher gradient upstream sites (especially Goodwin) may indicate that gravel introductions and habitat enhancements may favor salmonids over non-salmonids. As in past years, striped bass and American shad have been observed nearly 30 miles upstream from the mouth of the river, and may pose a predation threat to salmonids.

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Appendix A

Goodwin (Figure A-1)

Juvenile Chinook Salmon

Chinook densities were consistently about 50% higher in experimental gravel introduction sites and slow water sites than in fast water in 2003 and 2004. As observed in other reaches where gravel had been introduced in 2000 and 2001, winter fry densities were significantly higher in the experimental gravel introduction site at Goodwin winter of 2003, but less so in 2004. Higher density in gravel introduction areas of fry may simply be related to proximity to spawning areas. Densities peak at nearly 1 per m^2 in 2003, but were less than half that in 2004. In spring, fingerling and smolt densities remained higher in gravel introduction and slow water sites. Peak densities were at sites from late January to early March 2003 and from mid March to mid May in 2004. Densities dropped sharply in late May.

Age 0 Trout

Age 0 trout were first observed in late March in 2003 and 2004. They remained abundant through the spring and summer of both years, and through the fall, as well. Densities were low in winter when water temperature fell to 10ºC or below. Generally, experimental gravel introduction sites had higher densities than slow and fast water sites in 2003; however there we no apparent differences in the three sites in 2004 except that slow water sites had higher densities in summer and fall.

Age 1+ Trout

Age 1 and older trout were present year-round in both survey years. Densities were significantly higher by about 50% in slow water sites than experimental or fast water sites. Density was lowest in winter when water temperatures fell to near or below 10ºC.

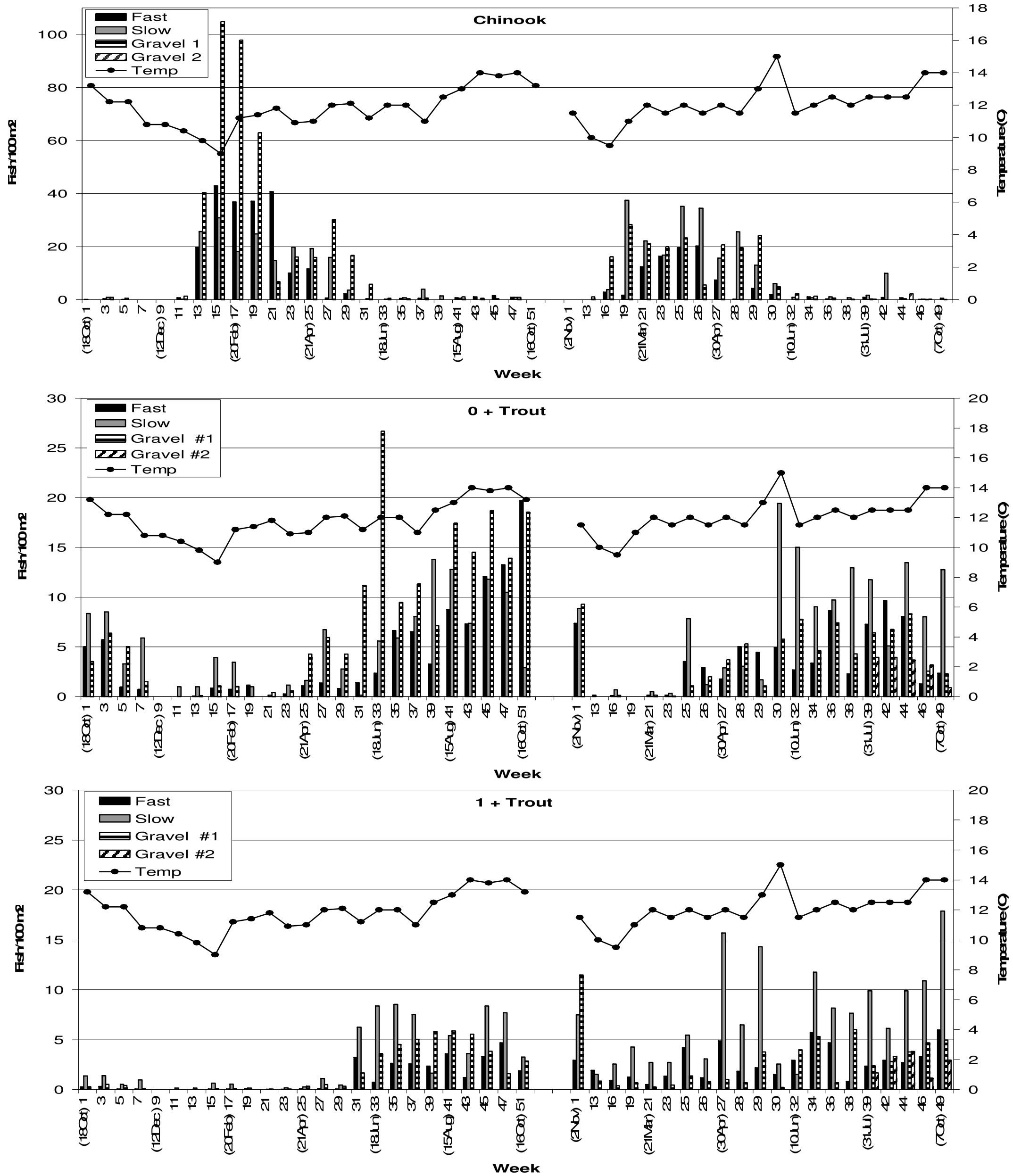


Figure A-1. Density of juvenile Chinook salmon, 0+ steelhead trout, and 1+ steelhead trout in fast water, slow water and gravel augmented habitats at Goodwin: 2002-03 and 2003-04 survey periods.

Two-Mile Bar (Figure A-2)

Juvenile Chinook Salmon

Peak Chinook densities were in fast water sites in early February 2003 and generally highest in fast water sites in 2004. As overall densities declined in spring and salmon grew to fingerling and smolt sizes, densities were highest in gravel introduction and fast water sites. In 2003 density declined initially in early March coincident with an increase in flow to 500 cfs. In 2004 the density declined initially in mid April when flows increased to 500 cfs.

Age 0 Trout

Age 0 trout first appeared in abundance in April 2003 and April 2004. They were observed during the summer and fall of the 2003 and 2004 surveys with the greatest densities observed at gravel introduction and fast water sites.

Age 1+ Trout

Age 1 and older trout were relatively abundant year-round with highest densities from mid October to late February 2003 and during the first week of the 2004 monitoring (early November 2003) at gravel introduction and fast water sites. Highest densities were observed at gravel introduction sites. Densities were markedly higher in 2003 than 2004.

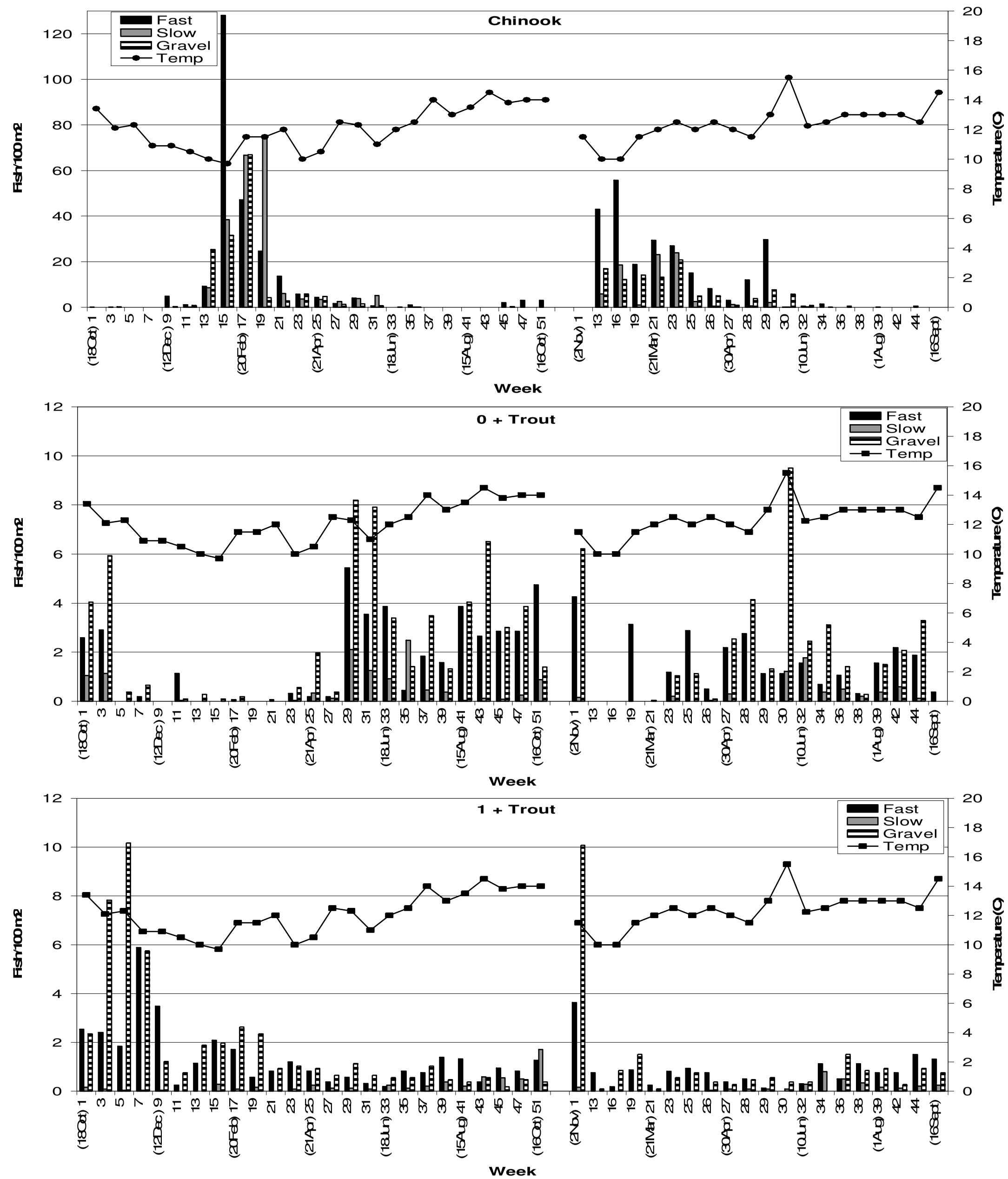


Figure A-2. Density of juvenile Chinook salmon, 0+ steelhead trout, and 1+ steelhead trout in fast water, slow water and gravel augmented habitats at Two-Mile Bar. 2002-03 and 2003-04 survey periods.

Knights Ferry (Figure A-3)

Juvenile Chinook Salmon

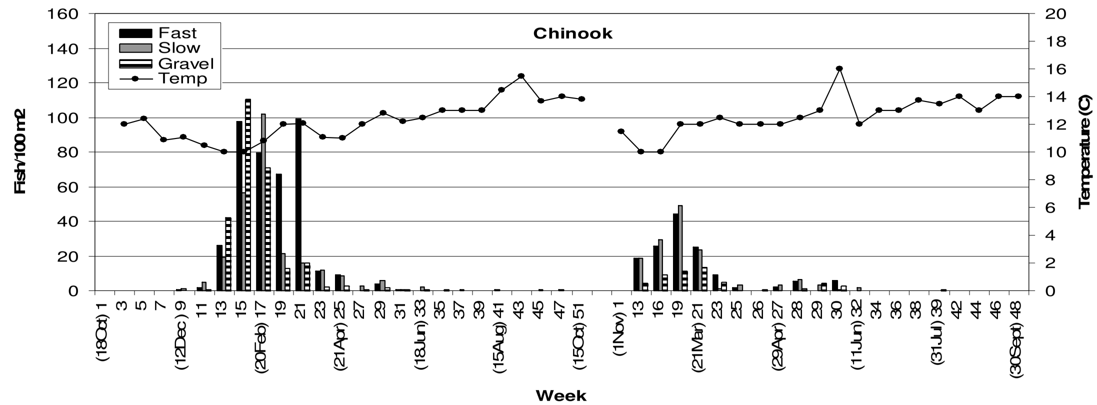
Chinook salmon densities were higher in 2003 than 2004 as at the Goodwin and Two-Mile Bar sites. Peak Chinook densities were highest in gravel and fast water sites from early January to early March in 2003 and in fast and slow water sites from early February to late March in 2003-2004. As overall densities declined by late March in both years. Young salmon were generally observed in low densities in all three habitat types.

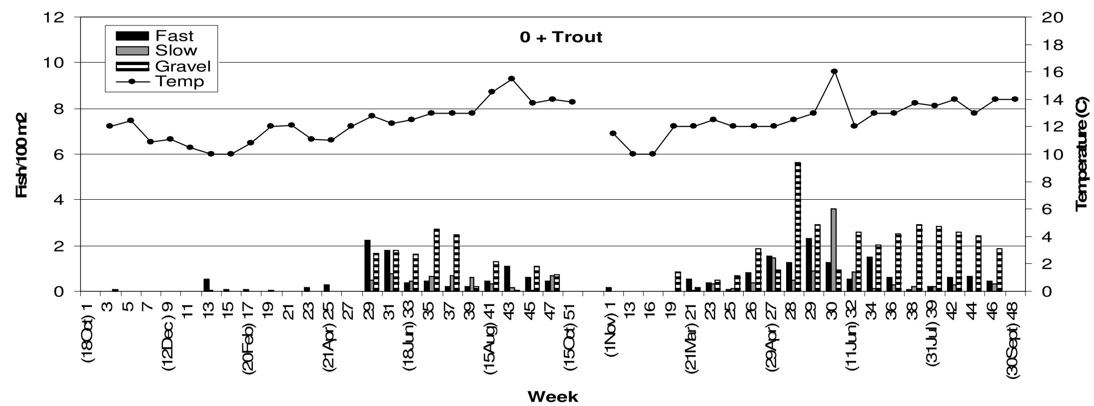
Age 0 Trout

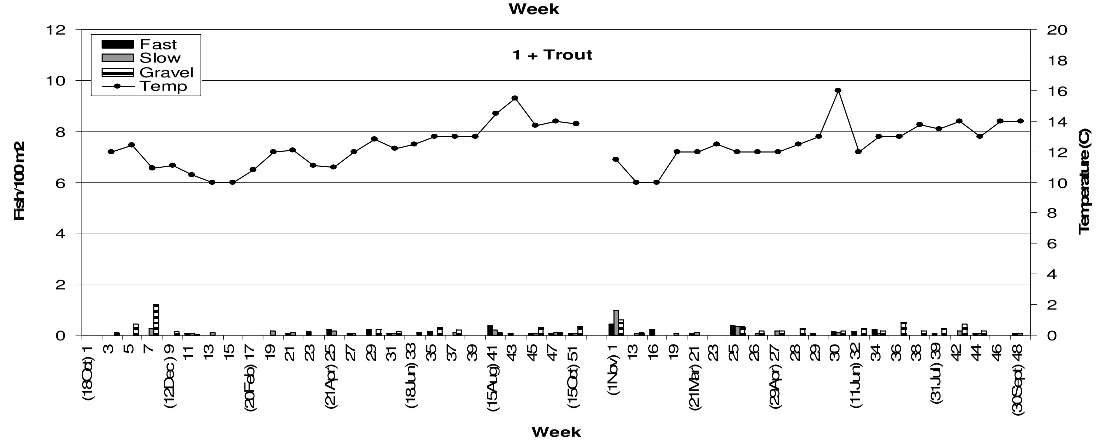
Age 0 trout first appeared in abundance in May 2003 and March 2004. They were significantly more abundant at experimental gravel introduction sites in both 2003 and 2004.

Age 1+ Trout

Age 1 and older trout were captured in significantly lower numbers at Knights Ferry than at upstream sites in both 2003 and 2004. Densities were generally higher at the gravel introduction sites.


Chinook
Fast
Slow
Gravel
Temp
Fish/100 m2
Temperature (C)
Week


0 + Trout
Fast
Slow
Gravel
Temp
Fish/100 m2
Temperature (C)
Week


1 + Trout
Fast
Slow
Gravel
Temp
Fish/100 m2
Temperature (C)
Week

Lovers Leap (Figure A-4)

Juvenile Chinook Salmon

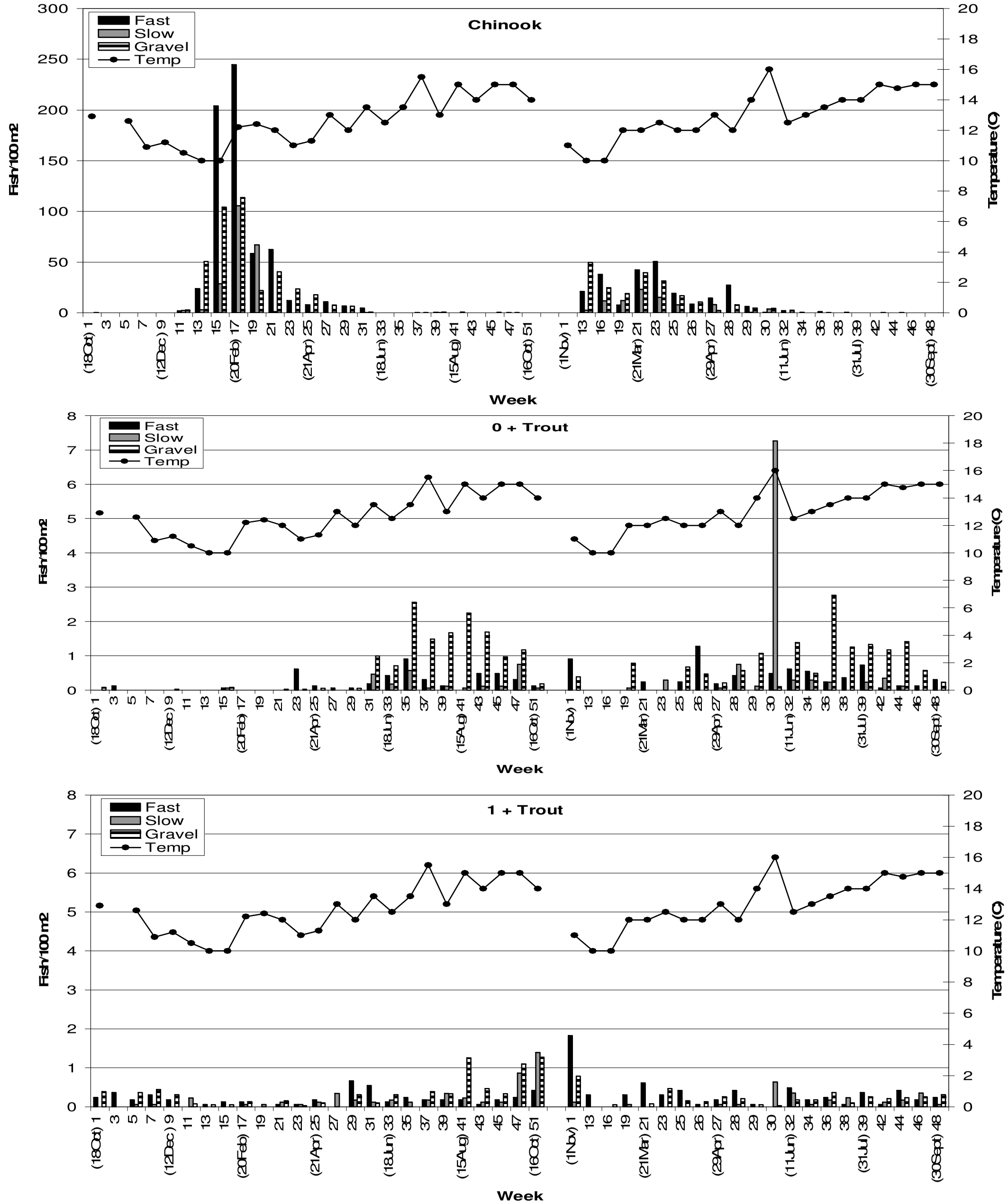
As at the upper sites, density was higher in 2003 than 2004. Peak Chinook densities were highest in gravel introduction and fast water sites from early February to late February 2003 and from early February to late March 2004. As overall densities declined in late spring, fish density remained higher in gravel and fast water sites. Density declined in late March in 2003 and mid April of 2004 coincident with increases in flow to near 500 cfs.

Age 0 Trout

Age 0 trout first appeared in abundance in May 2003 and March 2004. As at Knights Ferry, young trout were significantly more abundant at the gravel introduction site.

Age 1+ Trout

Age 1 and older trout were captured in low numbers through most of the two survey periods. Densities were generally higher at the gravel introduction and fast water sites.


Chinook
0 + Trout
1 + Trout
Fast
Slow
Gravel
Temp
Fish/100 m2
Temperature (C)
Week
(18Oct) 1
(12Dec) 9
(20Feb) 17
(21Apr) 25
(18Jun) 33
(15Aug) 41
(16Oct) 51
(1Nov) 1
(21Mar) 21
(29Apr) 27
(11Jun) 32
(31Jul) 39
(30Sept) 48

Honolulu Bar (Figure A-5)

Juvenile Chinook Salmon

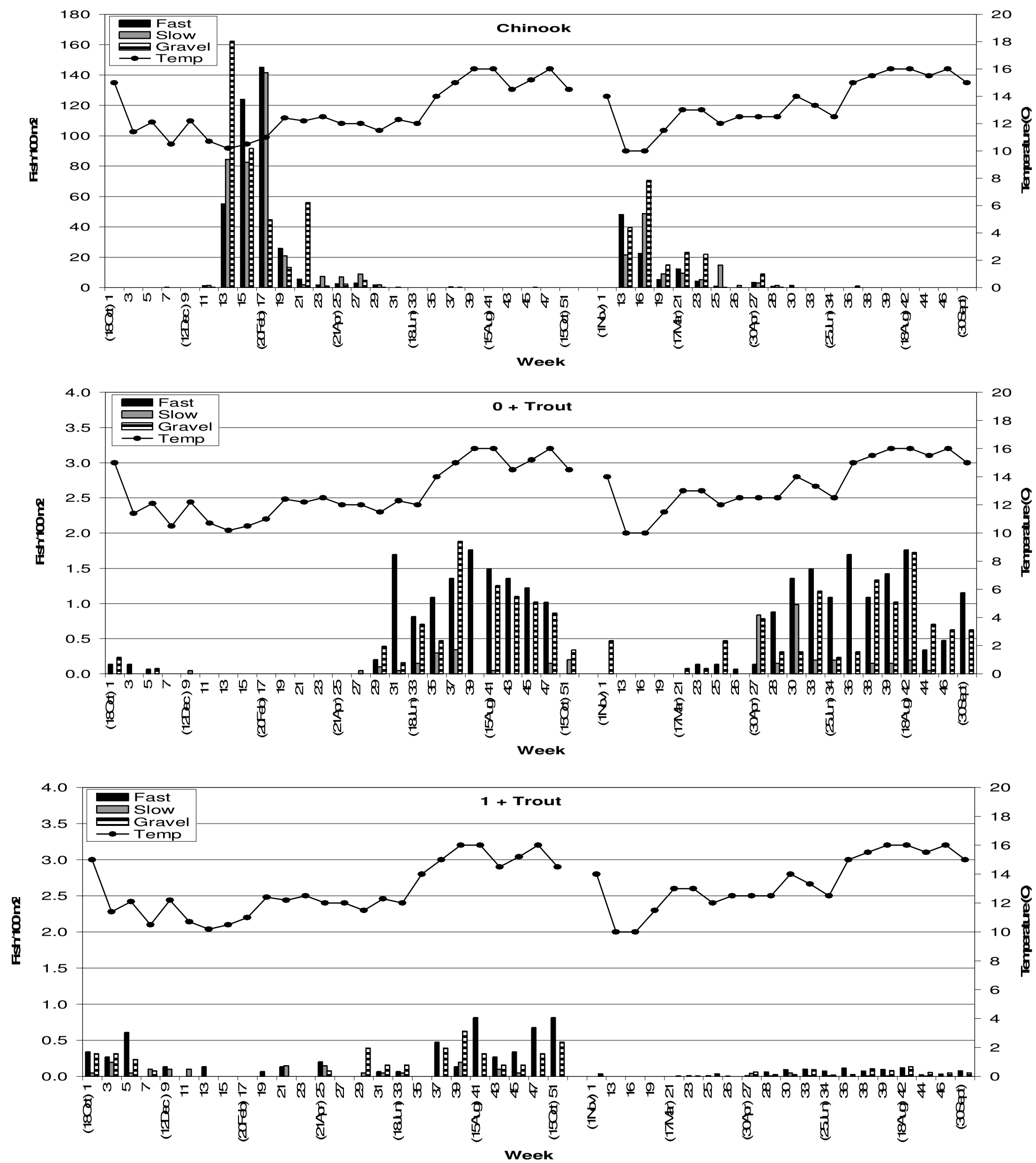
Peak Chinook densities were highest from early January to mid February 2003 and from early February to early March 2004. Densities were high in all sites in 2003 and slightly higher in the gravel introduction sites in 2004. Overall densities declined in late spring, fish were generally observed in low densities at all sites. The decline was in early March in 2003 and mid May in 2004 coincident with the first significant increases in river flow.

Age 0 Trout

Age 0 trout first appeared in abundance in May. Densities were significantly higher in gravel and fast water sites than the slow water site.

Age 1+ Trout

Age 1 and older trout were captured in low numbers through most of the two survey periods, with highest density in summer and fall. Densities were significantly higher in gravel introduction and fast water sites than slow water sites.



FigureA-5. Density of juvenile Chinook salmon, 0+ steelhead trout, and 1+ steelhead trout in fast water, slow water and gravel augmented habitats at Honolulu Bar. 2002-03 and 2003-04 survey periods.

Orange Blossom (Figure A-6)

Juvenile Chinook Salmon

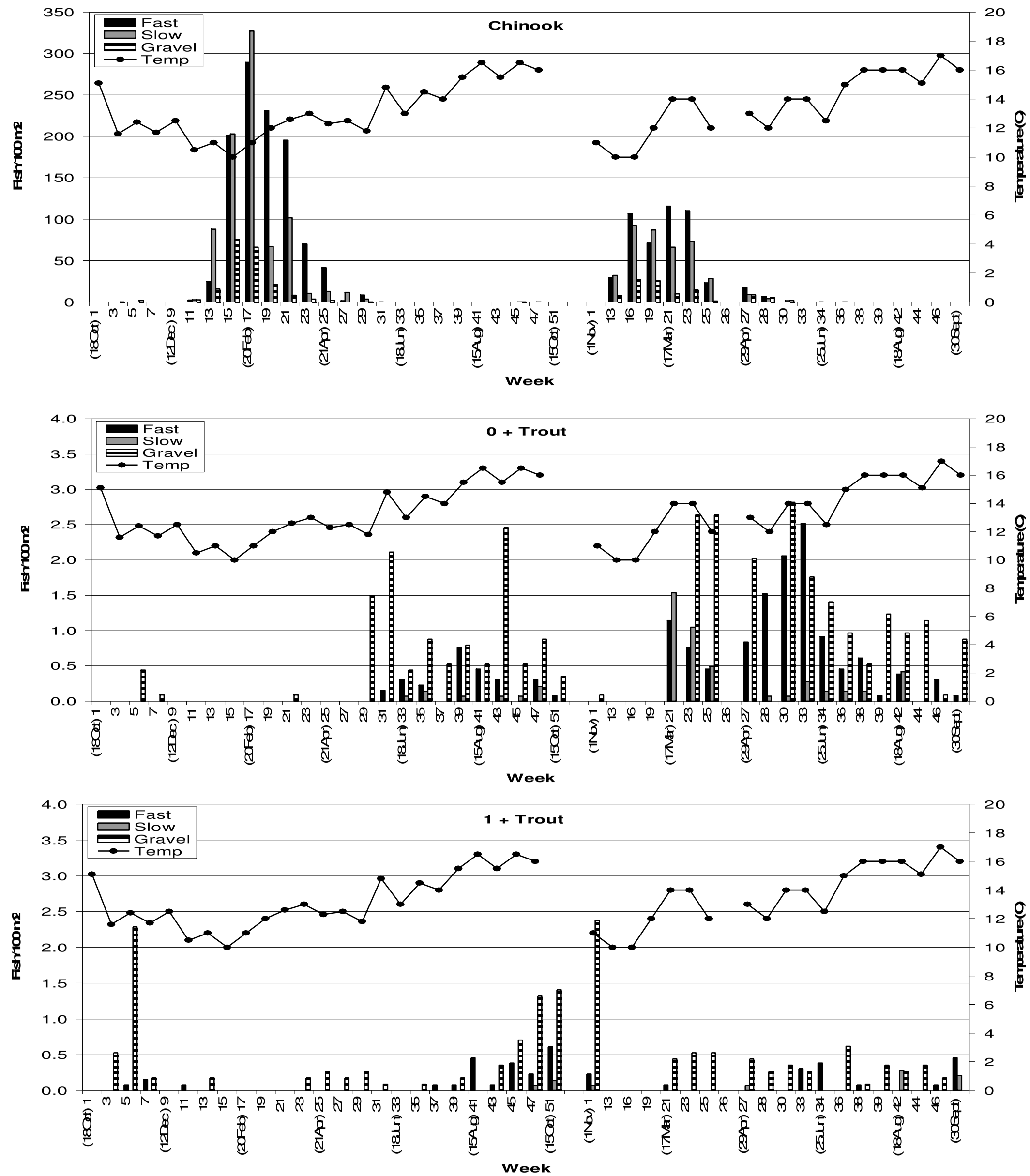
Peak Chinook densities were highest in fast and slow water sites from early February to last March 2003 and from late February to late March 2004. As overall densities declined in late spring, fish were generally observed in fast and slow water sites, and significantly less abundant in the gravel introduction site. Density declined sharply in mid April of both years at the beginning of the VAMP flow pulse period.

Age 0 Trout

Age 0 trout first appeared in abundance in May 2003 and March 2004. Densities were significantly higher at the gravel introduction site during summer and fall of 2003 and from early spring through early fall of 2004.

Age 1+ Trout

Age 1 and older trout were captured sporadically and in low numbers through both 2003 and 2004 at Orange Blossom. Yearling densities were significantly higher at the gravel introduction site.



FigureA-6. Density of juvenile Chinook salmon, 0+ steelhead trout, and 1+ steelhead trout in fast water, slow water and gravel augmented habitats at Orange Blossom. 2002-03 and 2003-04 survey periods.

Valley Oak (Figure A-7)

Juvenile Chinook Salmon

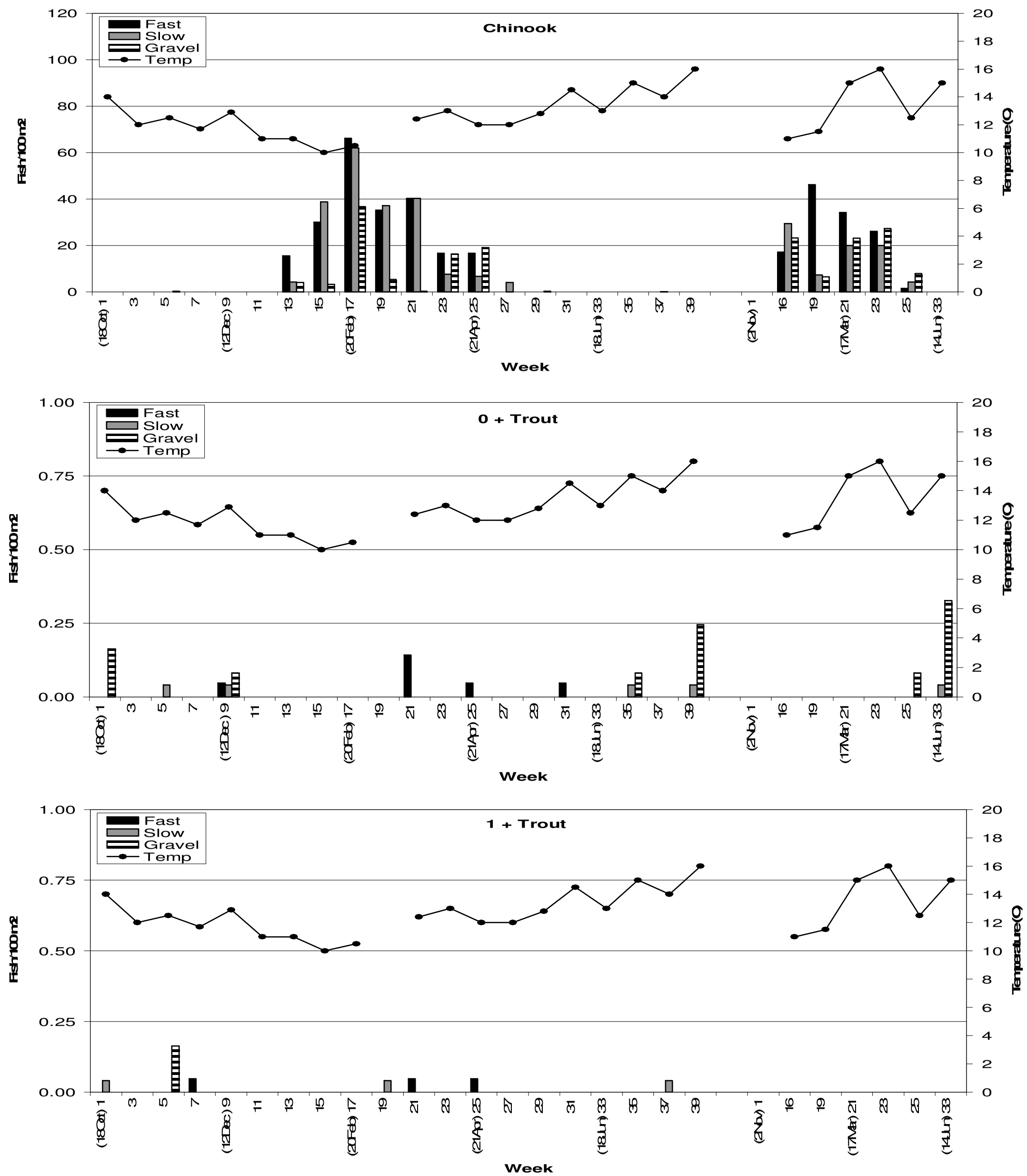
Chinook densities were similar at the three sites during peak density from early February to late March 2003 and from mid February to late March 2004. Chinook densities declined sharply in late April in both 2003 and 2004.

Age 0 Trout

Age 0 trout were observed in very low numbers during both 2003 and 2004 with highest densities found at the gravel introduction sites.

Age 1+ Trout

Age 1 and older trout were also rarely observed during both survey years.



FigureA-7. Density of juvenile Chinook salmon, 0+ steelhead trout, and 1+ steelhead trout in fast water, slow water and gravel augmented habitats at Valley Oak. 2002-03 and 2003-04 survey periods.

Oakdale (Figure A-8)

Juvenile Chinook Salmon

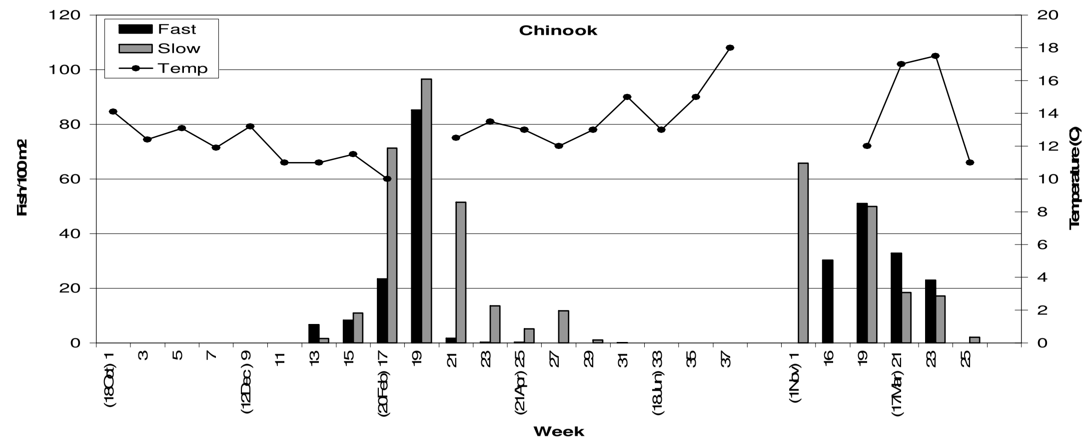
Chinook peak density occurred from mid February to early March 2003 and from late February to mid March 2004. Chinook densities declined in late April in both years. Densities were similar at the slow and fast water sites. There were no gravel augmented sites at Oakdale.

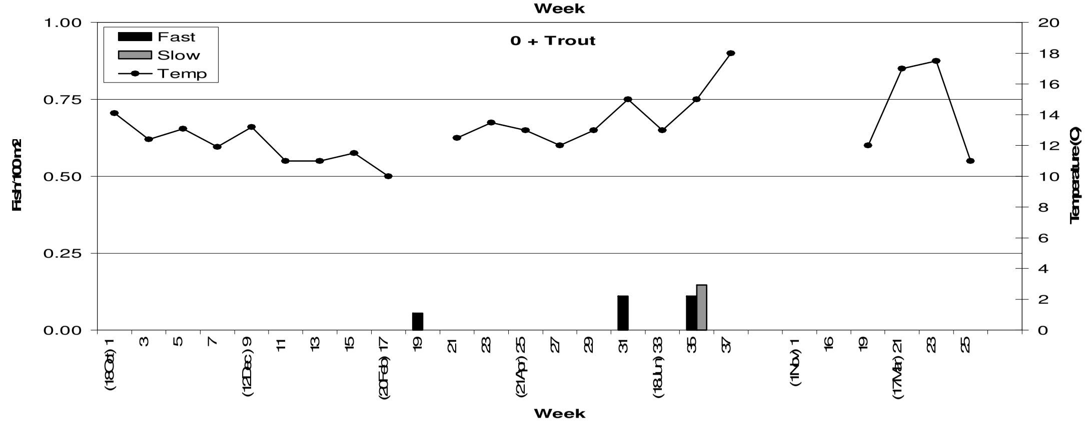
Age 0 Trout

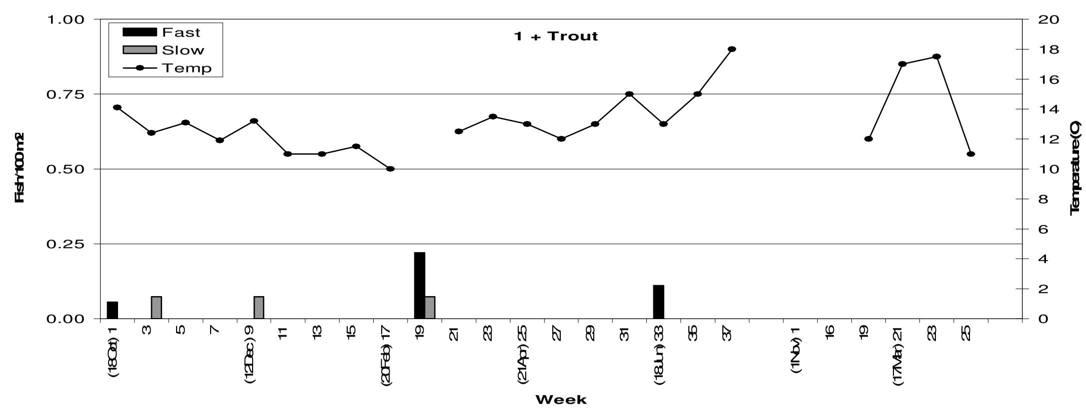
Very few age 0 trout were observed.

Age 1 Trout

Very few age 1 or older trout were observed.

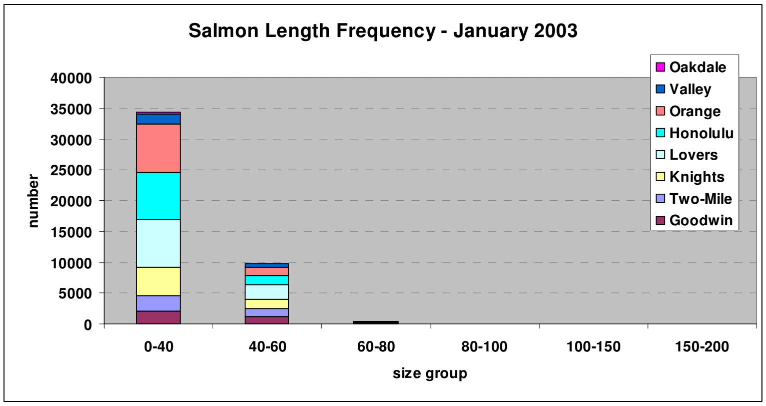

Chinook
Fast
Slow
Temp
Fish/100 m2
Temperature (C)
Week
(18Oct) 1
(12Dec) 9
(20Feb) 17
(21Apr) 25
(18Jun) 33
(1Nov) 1
(17Mar) 21

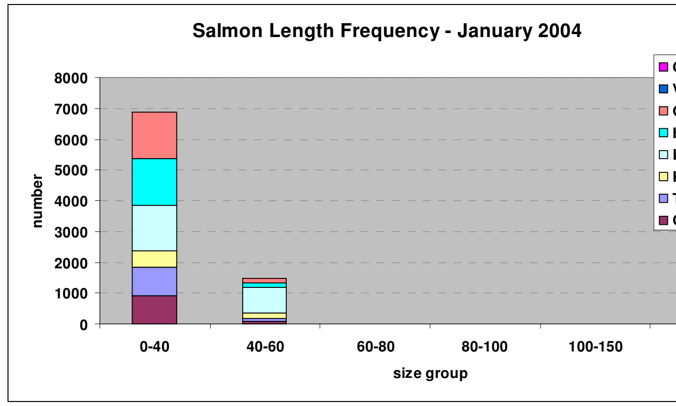

0 + Trout
Fast
Slow
Temp
Fish/100 m2
Temperature (C)
Week

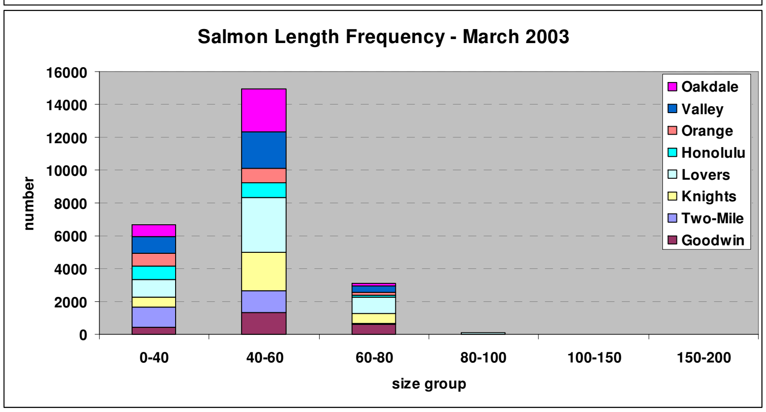

1 + Trout
Fast
Slow
Temp
Fish/100 m2
Temperature (C)
Week

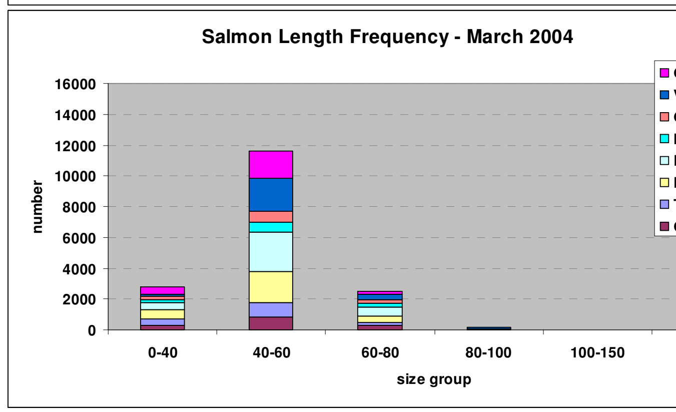
Appendix B Length Frequency

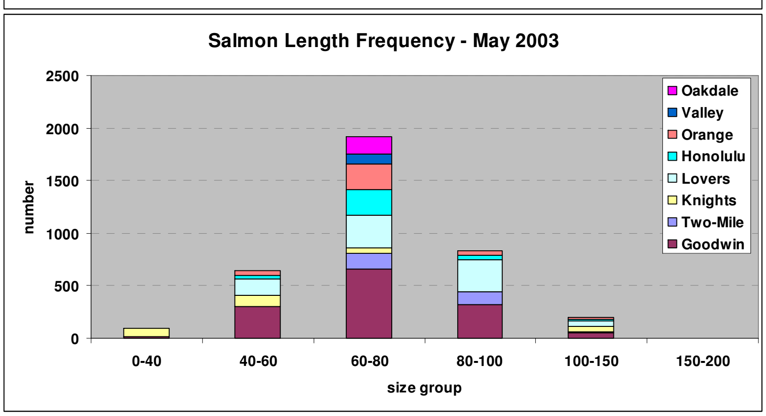
Salmon (Appendix B-1)

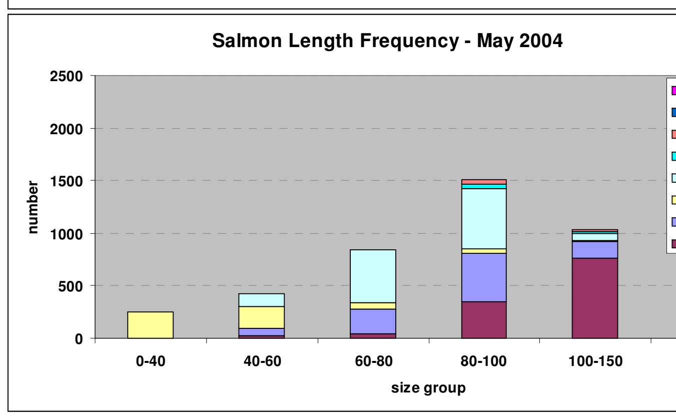


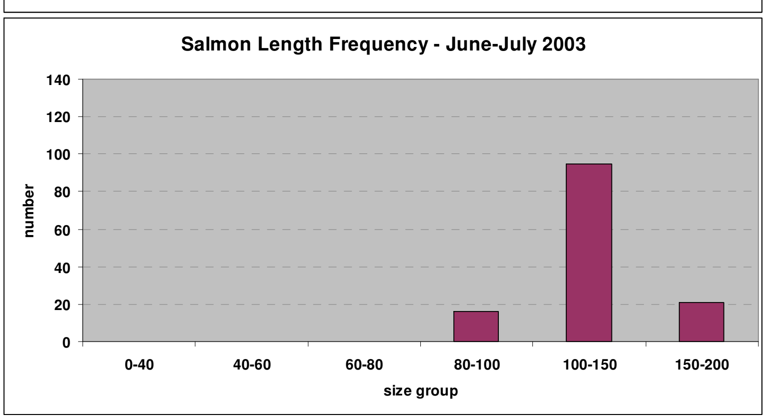


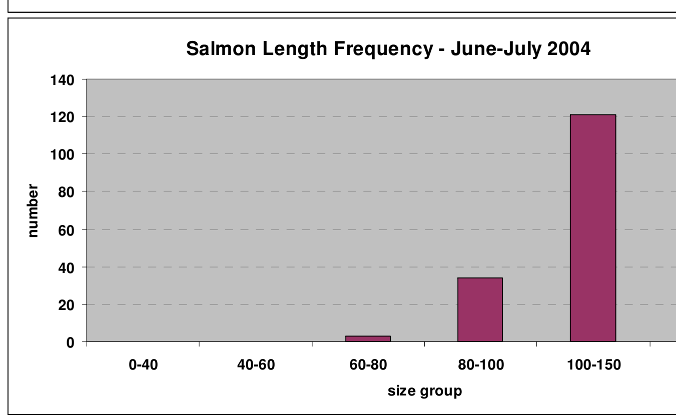




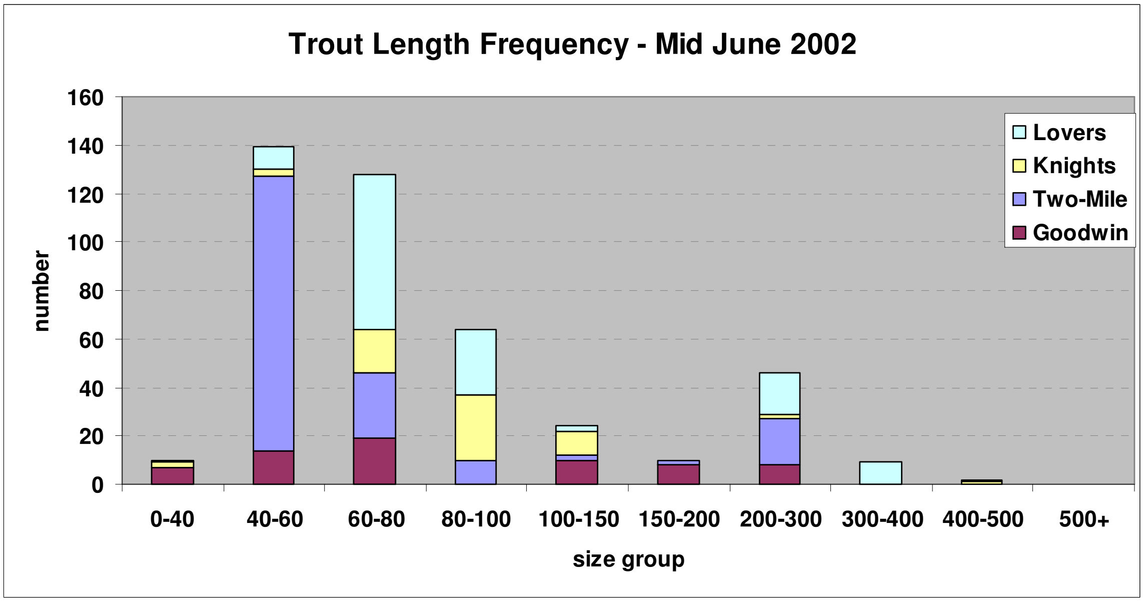


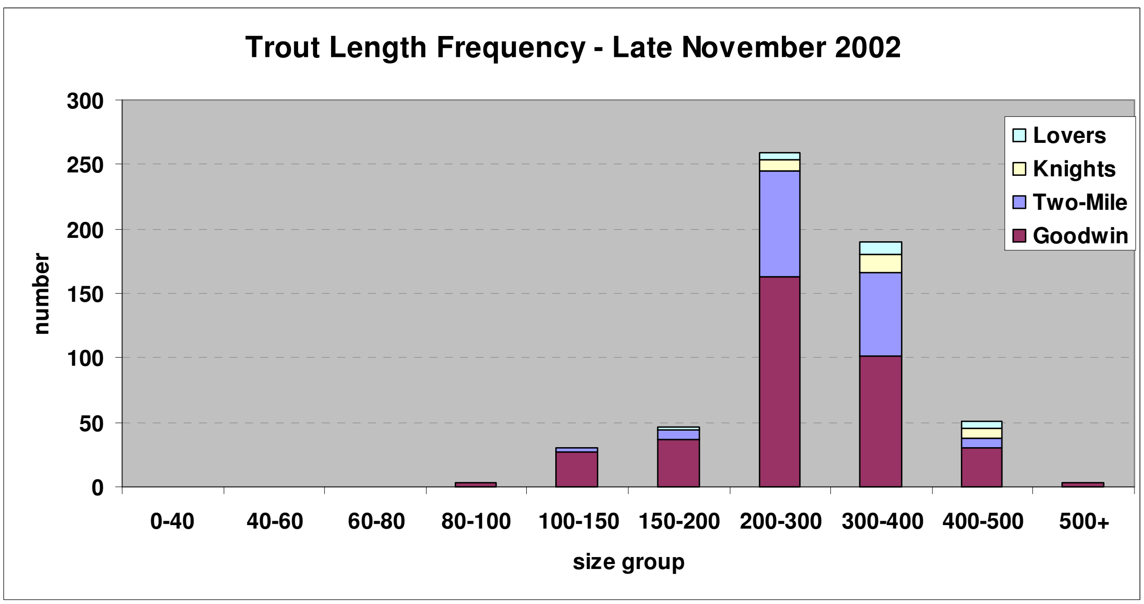


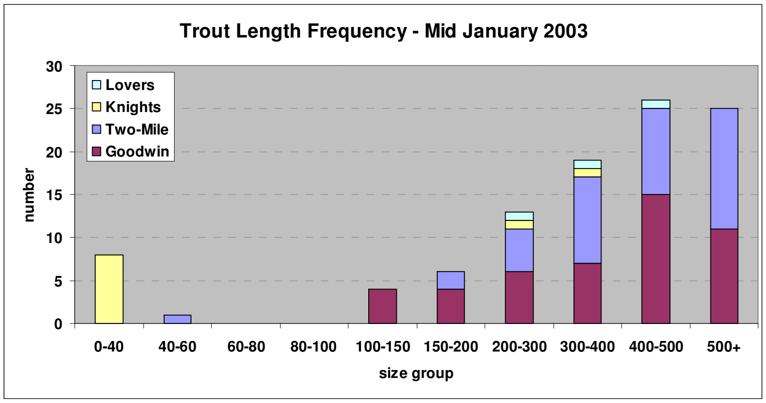


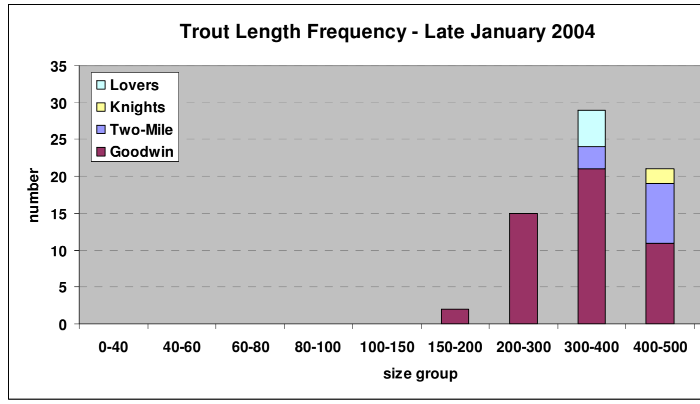


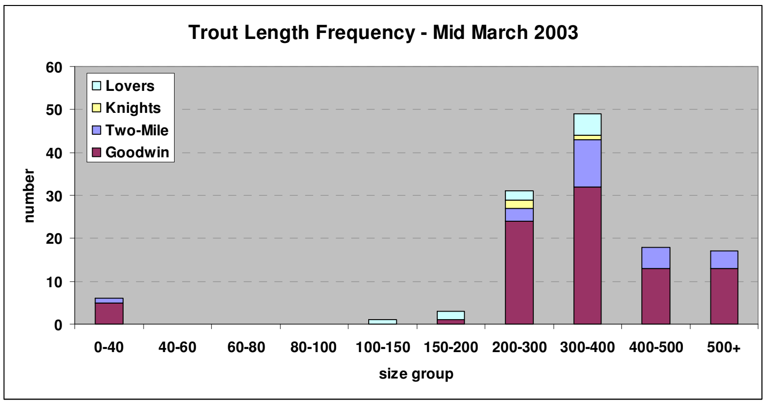
Trout (Appendix B-2)

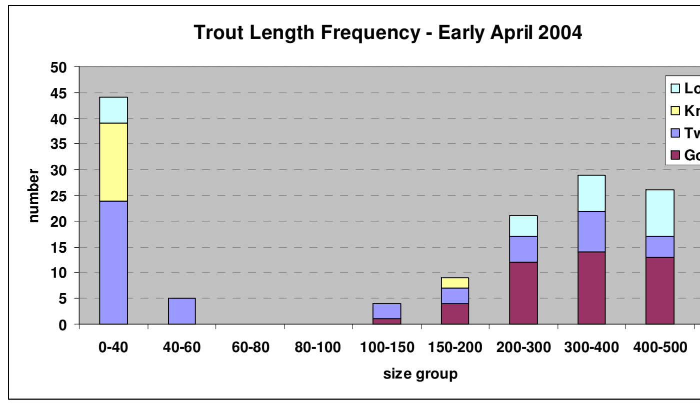


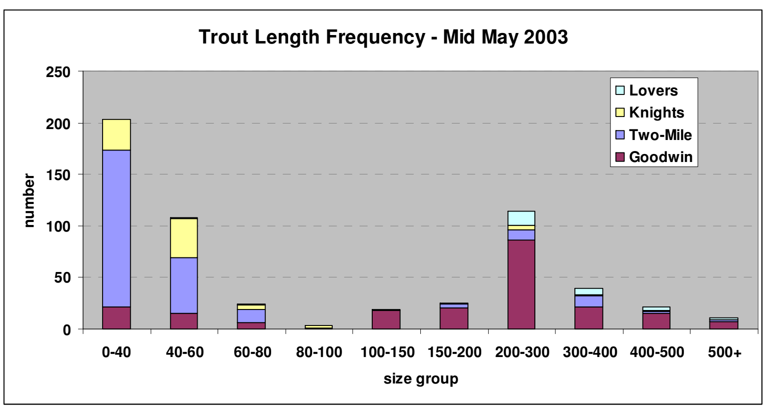


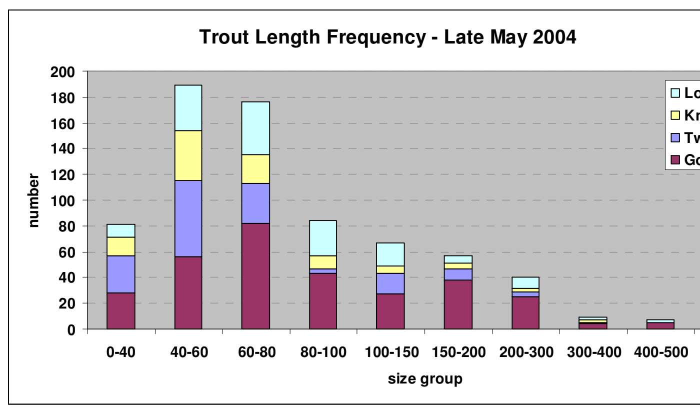

Trout Length Frequency - Mid January 2003
Lovers
Knights
Two-Mile
Goodwin
number
0 5 10 15 20 25 30
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500 500+
size group

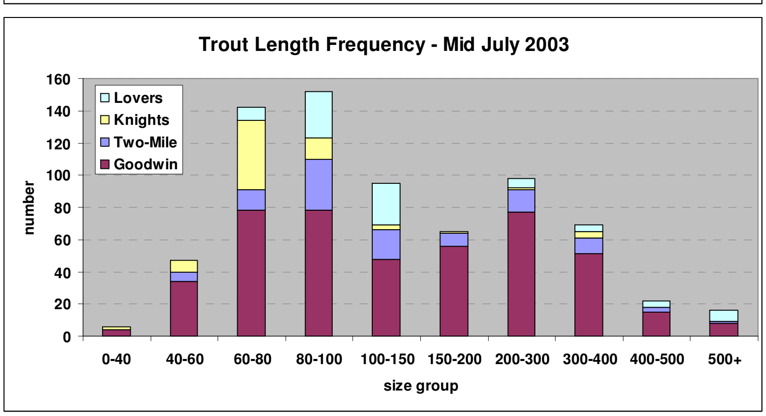

Trout Length Frequency - Late January 2004
Lovers
Knights
Two-Mile
Goodwin
number
0 5 10 15 20 25 30 35
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500
size group

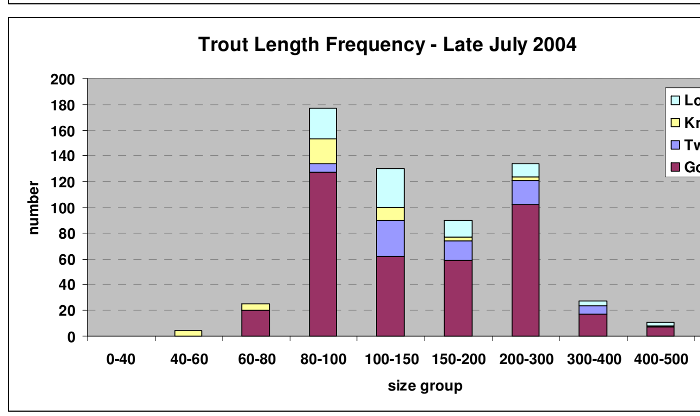

Trout Length Frequency - Mid March 2003
Lovers
Knights
Two-Mile
Goodwin
number
0 10 20 30 40 50 60
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500 500+
size group

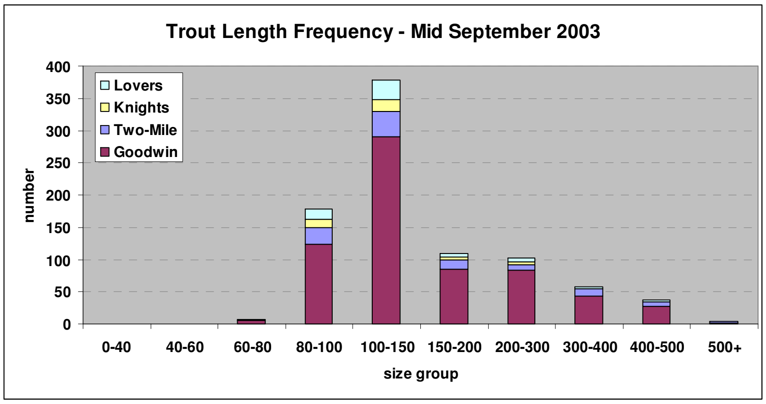

Trout Length Frequency - Early April 2004
number
0 5 10 15 20 25 30 35 40 45 50
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500
size group

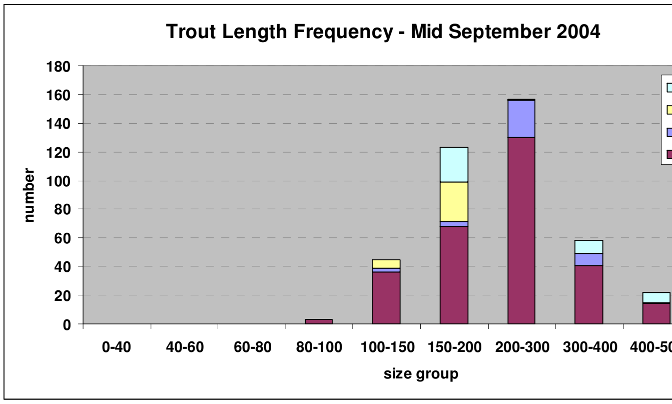

Trout Length Frequency - Mid May 2003
Lovers
Knights
Two-Mile
Goodwin
number
0 50 100 150 200 250
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500 500+
size group

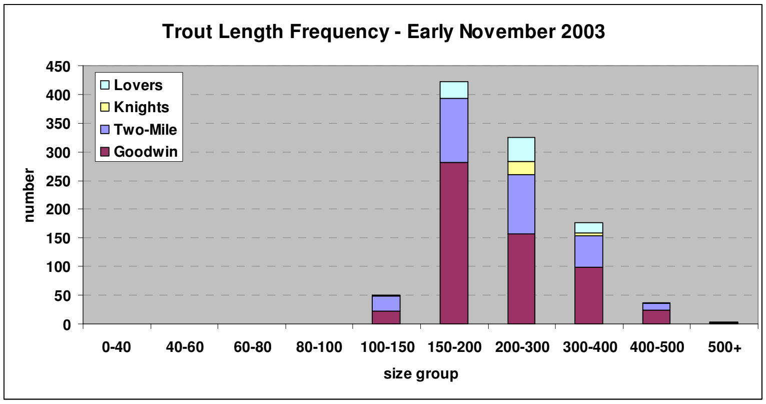

Trout Length Frequency - Late May 2004
number
0 20 40 60 80 100 120 140 160 180 200
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500
size group


Trout Length Frequency - Mid July 2003
Lovers
Knights
Two-Mile
Goodwin
number
0 20 40 60 80 100 120 140 160
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500 500+
size group

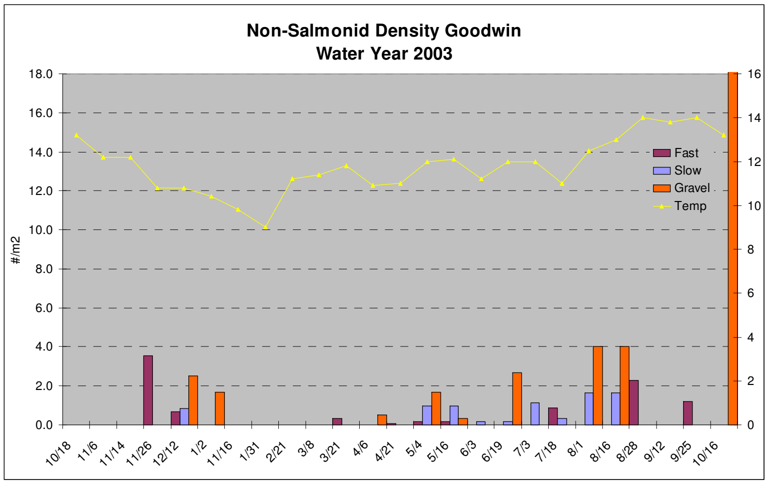

Trout Length Frequency - Late July 2004
number
0 20 40 60 80 100 120 140 160 180 200
0-40 40-60 60-80 80-100 100-150 150-200 200-300 300-400 400-500
size group

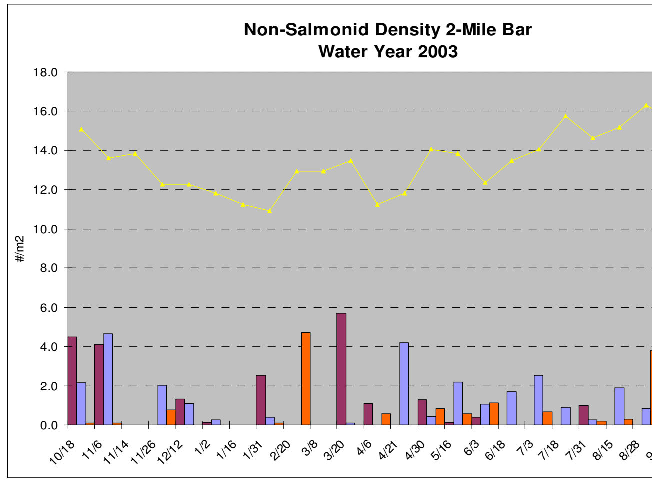

Trout Length Frequency - Mid September 2003
Lovers
Knights
Two-Mile
Goodwin
number
size group
0-40
40-60
60-80
80-100
100-150
150-200
200-300
300-400
400-500
500+

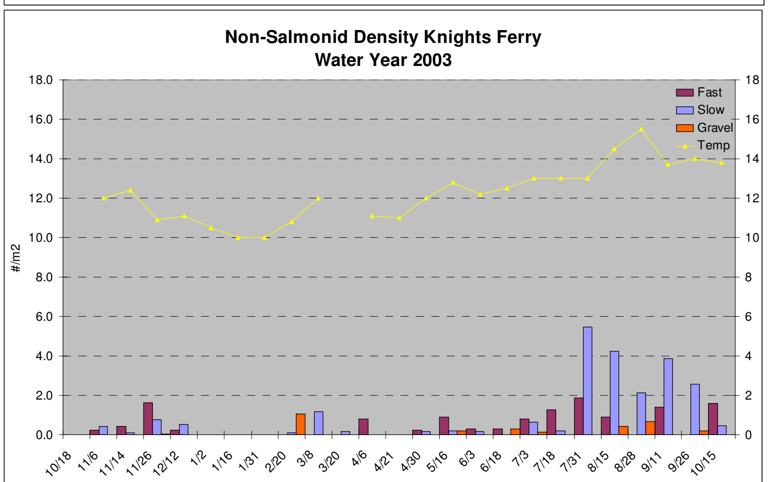

Trout Length Frequency - Mid September 2004
number
size group
0-40
40-60
60-80
80-100
100-150
150-200
200-300
300-400

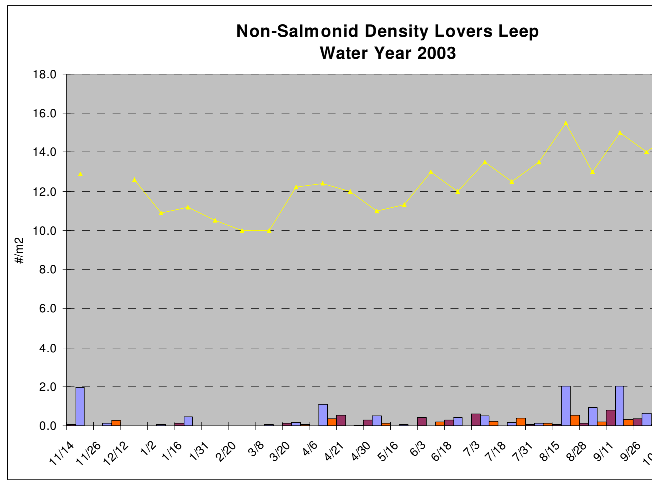

Trout Length Frequency - Early November 2003
Lovers
Knights
Two-Mile
Goodwin
number
size group
0-40
40-60
60-80
80-100
100-150
150-200
200-300
300-400
400-500
500+

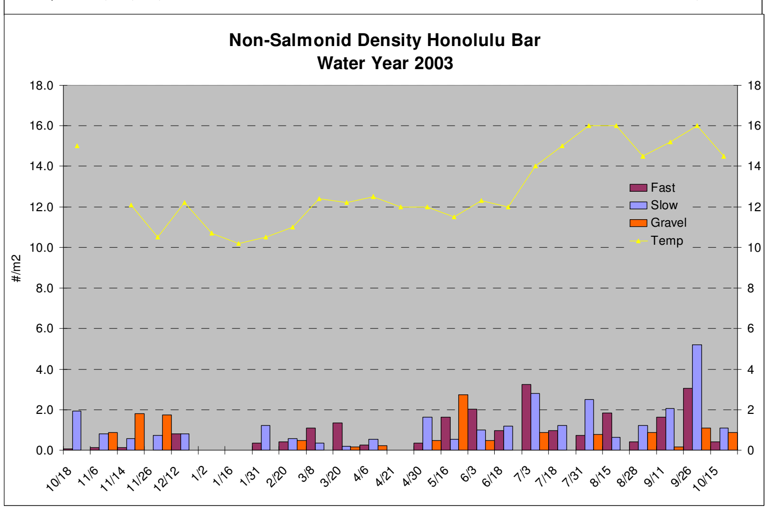
Appendix C. Non-Salmonid Distribution

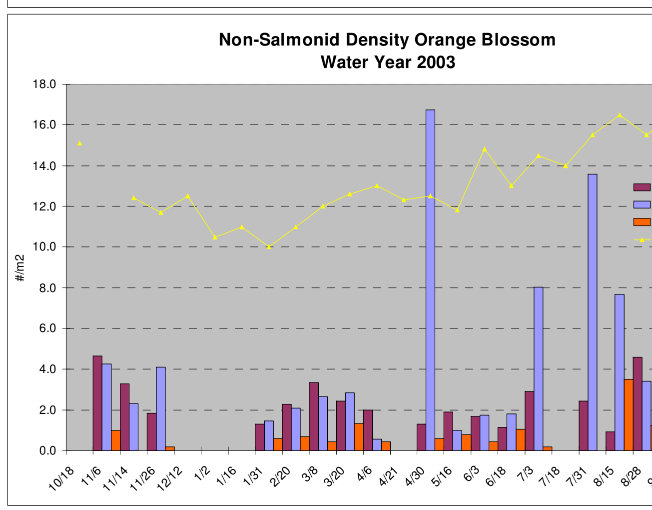


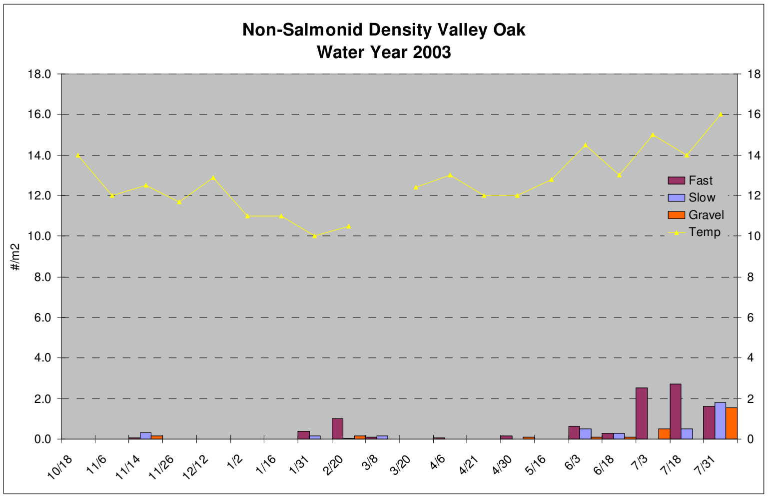






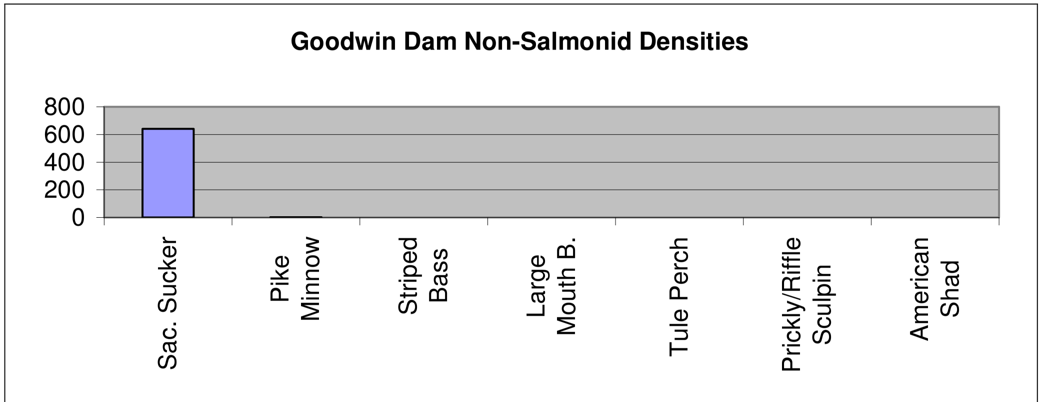


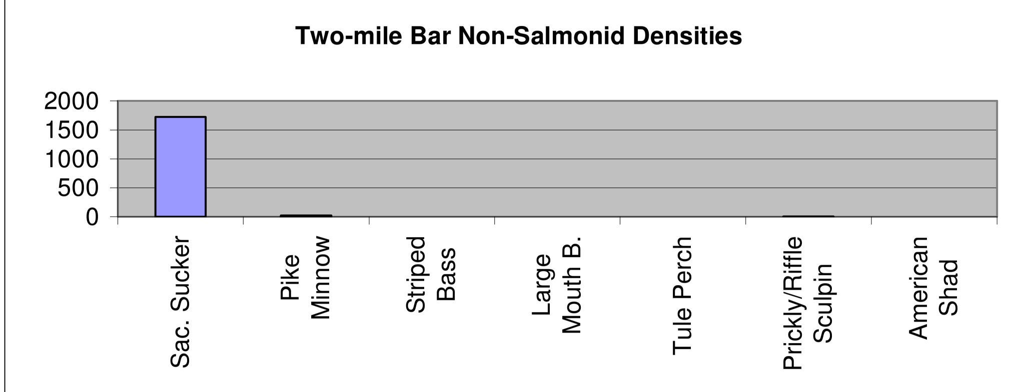


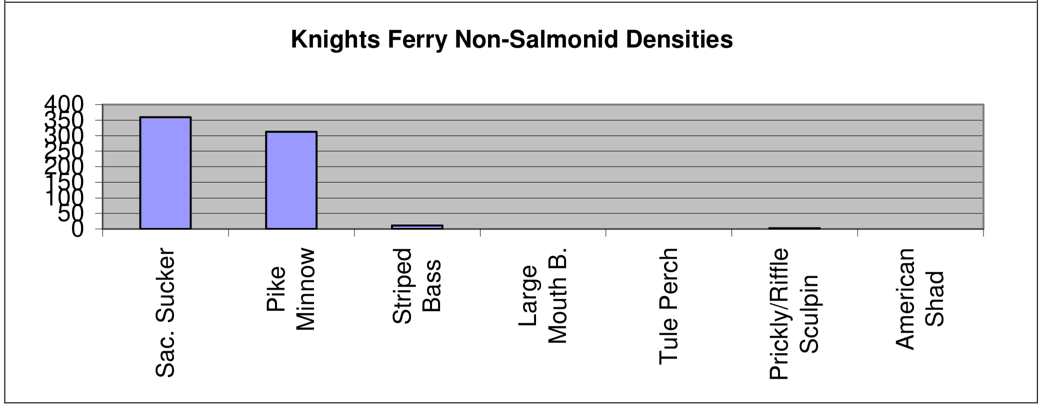


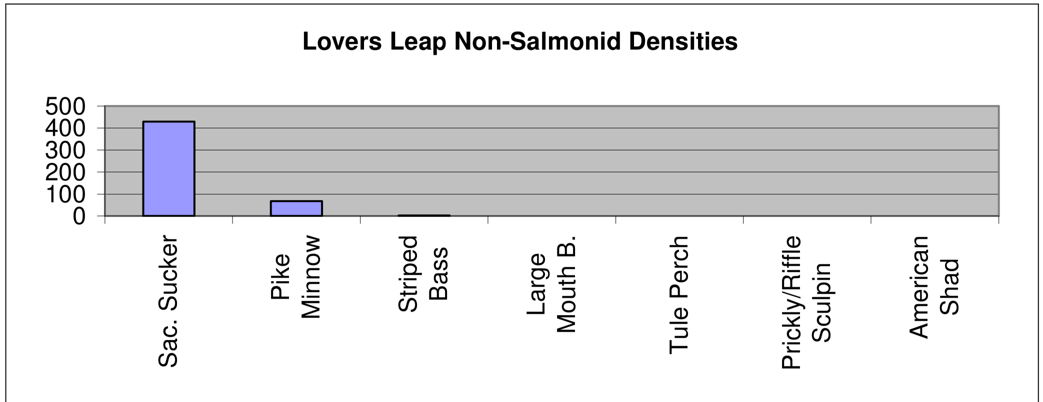
Non-Salmonid Density Valley Oak
Water Year 2003
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
#/m2
18
16
14
12
10
8
6
4
2
0
Fast
Slow
Gravel
Temp
10/18
11/6
11/14
11/26
12/12
1/2
1/16
1/31
2/20
3/8
3/20
4/6
4/21
4/30
5/16
6/3
6/18
7/3
7/18
7/31

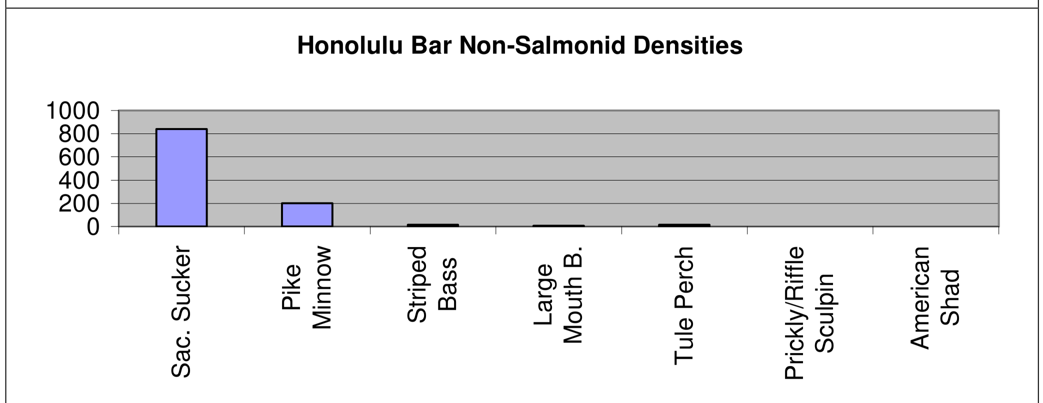
Appendix D. Non-Salmonid Densities by Reach

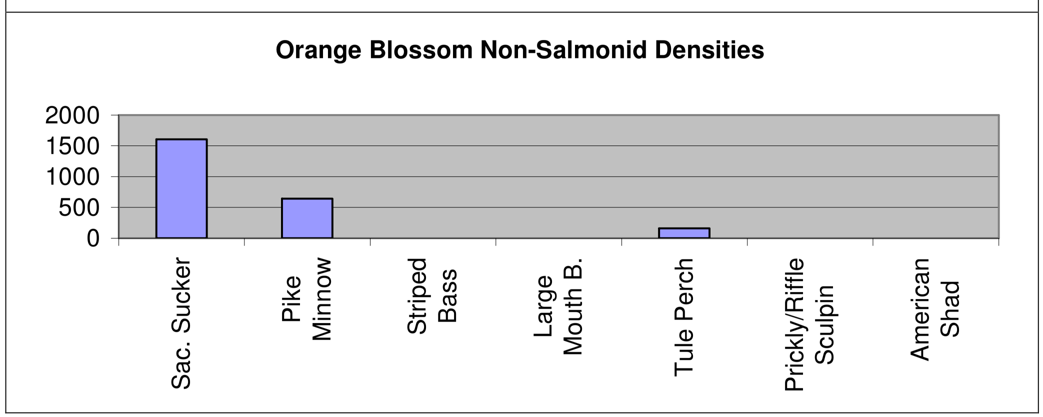


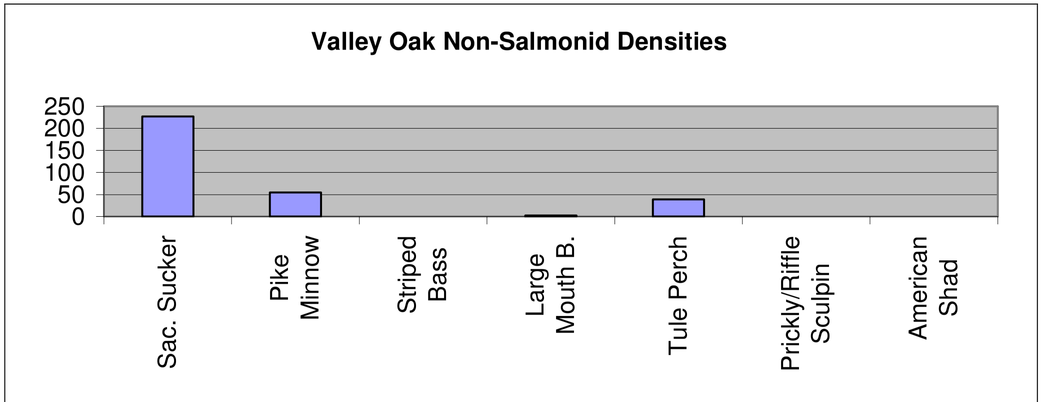


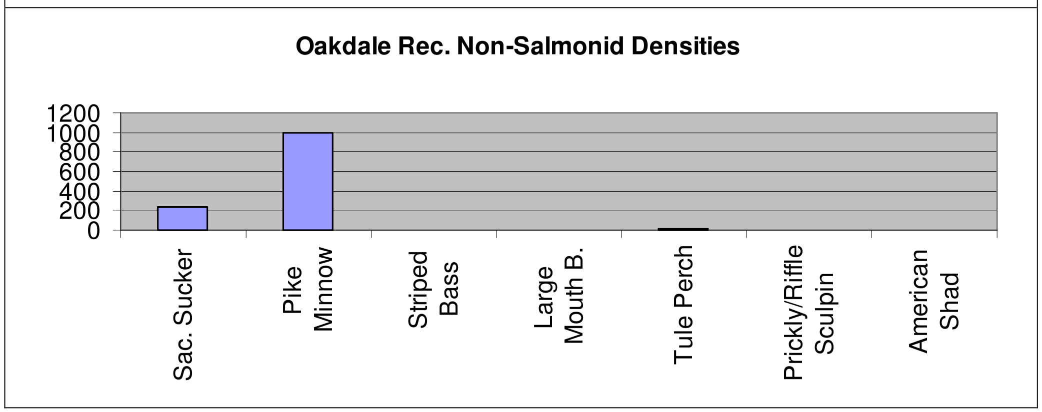



Lovers Leap Non-Salmonid Densities
500
400
300
200
100
0
Sac. Sucker
Pike Minnow
Striped Bass
Large Mouth B.
Tule Perch
Prickly/Riffle Sculpin
American Shad


Honolulu Bar Non-Salmonid Densities
1000
800
600
400
200
0
Sac. Sucker
Pike Minnow
Striped Bass
Large Mouth B.
Tule Perch
Prickly/Riffle Sculpin
American Shad


Orange Blossom Non-Salmonid Densities
2000
1500
1000
500
0
Sac. Sucker
Pike Minnow
Striped Bass
Large Mouth B.
Tule Perch
Prickly/Riffle Sculpin
American Shad


Valley Oak Non-Salmonid Densities
250
200
150
100
50
0
Sac. Sucker
Pike Minnow
Striped Bass
Large Mouth B.
Tule Perch
Prickly/Riffle Sculpin
American Shad


Oakdale Rec. Non-Salmonid Densities
1200
1000
800
600
400
200
0
Sac. Sucker
Pike Minnow
Striped Bass
Large Mouth B.
Tule Perch
Prickly/Riffle Sculpin
American Shad