Age Composition, Growth, and Life History Characteristics of Juvenile *Oncorhynchus mykiss* in the Salinas River Basin

Insights from Scale Analyses

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Executive Summary

Juvenile outmigration monitoring for steelhead/rainbow trout (*Oncorhynchus mykiss*) has been conducted in the Salinas Basin since 2010 to quantify juvenile production and gather data on outmigration characteristics. Monitoring has revealed that the majority of *O. mykiss* outmigration from the Salinas River basin comes from the Arroyo Seco River, where, over the course of several years of monitoring, a total of about 500 scale samples of *O. mykiss* were collected and archived with FISHBIO. Similar to tree rings, scales of fish grow in proportion to their bodies and reflect differences in growth resulting from seasonal variation of the ambient environment, allowing researchers to determine the ages of sampled individuals. In order to better understand outmigration characteristics and the life history expressions of *O. mykiss* in the Salinas River Basin, these scale samples were recently analyzed.

Overall, 387 individual samples were successfully aged, while about 100 samples could not be aged due to scale regeneration or lack of clearly discernible annuli ("rings"). In addition, three samples were determined to be of Age 0, solely based on the individuals' fork length and collection date. The majority of fish migrated downstream at Age 1 (67%), followed by Age 2 individuals (30%) and Age 3 individuals (2%). The percentage of captured fish that were considered to be either silvery parr or smolts (meaning that they were physiologically prepared to outmigrate to the ocean) was 0 percent for age 0 fish, 60 percent for age 1 fish, and 100 percent for age 2 and 3 fish. These findings indicate that offspring produced during a single year can outmigrate during at least three subsequent years, increasing the opportunity of encountering favorable migration and survival conditions.

Sampled *O. mykiss* reached an average of approximately 80 mm (fork length) at the time of the first annulus deposition, determined to occur in late summer/early fall in the Arroyo Seco (the period of lowest streamflow and highest temperature). This size is within the range of 50-90 mm expected for *O. mykiss* by the end of their first summer in small California streams with low summer flows.

Of note, individuals captured during outmigration at age 1+ had a reached a larger size after their first summer in freshwater than those individuals that emigrated at age 2 and 3. Similarly, fish that migrated at age 2 were larger after their second summer than those that migrated at age 3, but smaller than those that migrated at age 1. These findings supports the notion that individuals that are larger than their conspecifics at certain points during their freshwater residence are more likely to smolt in a given year, but lacked statistical significance due to small sample size.

Lastly, this investigation provides evidence that juvenile production can occur even in years (winters) without connectivity to the marine environment (i.e., no breaching of the lagoon's sandbar). Three individuals collected in spring 2017 were aged successfully, and belonged to year classes 2015 (n=1) and 2016 (n=2). This is a clear indication that *O. mykiss* in the Salinas River basin exhibit a resident or partially migratory life history, permitting population persistence during extended periods (multi-year) of isolation from the marine environment.

Introduction and Background

Since 2010, various monitoring activities have been conducted in the Salinas River basin to provide insights on the status and trends of the steelhead/rainbow trout (*Oncorhynchus mykiss*) population. This includes outmigration monitoring during the spring in the Arroyo Seco, Nacimiento and Salinas rivers to quantify juvenile production and gather data on outmigration characteristics. Juvenile outmigration monitoring has been conducted using rotary screw traps (RSTs; E. G. Solutions, Eugene, Oregon), which are commonly used for sampling migrating salmonids. RSTs, consisting of a funnel-shaped cone suspended between two pontoons, are positioned in the current so that water enters the mouth of the funnel and strikes the internal "Archimedes" screw, causing the funnel to rotate. As the funnel rotates, fish are trapped in pockets of water and transported rearward into a livebox, where they remain until they are removed, identified, measured, and released in the river downstream of the trap (i.e., processed) by technicians.

On the Salinas River, a single 5-ft (cone diameter) RST has been operated approximately 0.5 river miles (RM) upstream of the confluence with the Nacimiento River. On the Nacimiento River, a single 8-ft RST has been operated at approximately RM 0.5, downstream of a Camp Roberts (United States National Guard Training Facility) river fording point. Similar to Palmer and Sonke (2010), flow deflection structures were constructed and strategically placed in the river during lower flow periods in order to divert more water toward the trap, increasing velocity into the funnel for optimal functioning of the trap. On the Arroyo Seco River, a single 8-ft RST was operated at RM 14, approximately four river miles upstream of the Elm Ave. Bridge (also referred to as the Green Bridge; Fig. 1).

Figure 1. Rotary screw trap operating on the Arroyo Seco River (April 5, 2010).

Juvenile outmigration monitoring has revealed very limited production of *O. mykiss* in the mainstem Salinas River and the Nacimiento River, where annual catches of *O. mykiss* ranged from 0 to 9 and 0 to 7 individuals per monitoring season, respectively. In contrast, *O. mykiss* production on the Arroyo Seco River is substantially higher, and in most years constitutes the majority of *O. mykiss* outmigration from the Salinas River basin (Table 1).

Table 1. Summary of RST monitoring on the Arroyo Seco River, 2010 – 2017. Catches are reported for *O. mykiss* only.

	Year					
	2010	***2011***	***2012***	***2013-2016***	***2017***	***2018***
Date[1]	3/19 – 5/31	3/13 - 5/30	3/15 – 5/14	NA[2]	3/17 – 5/31	NA[4]
Total catch	149	64	526	NA[2]	4	NA[4]
Est. abundance[3]	480	332	2,876	NA[2]	NA	NA[4]
Max. daily catch	10	10	99	NA[2]	1	NA[4]
Length Range[5]	46 - 275	40 - 228	67 - 300	NA[2]	162 - 284	NA[4]

[1] Date indicates the first and last day of trap operation; gaps in sampling coverage due to low flow may have occurred during this timespan. [2] Due to flows (no connectivity/dry river channel), no RST operation occurred from 2013 through 2016. [3] Estimated catches, based on trap efficiency, are only reported when sufficiently large catch numbers permit estimation. [4] No RST operation occurred in 2018 due to regulatory constraints. [5]Length range reported in mm measured as fork length.

O. mykiss have been captured in the Arroyo Seco at small sizes (40 mm fork length [FL]), though the majority of fishes captured in the RSTs range in length between 70 mm and 220 mm (FL). It remains unclear what proportion of fish sampled during their downstream migration enter the marine environment (becoming a steelhead), or how many are captured while distributing within the riverine corridor in search for rearing habitat (remaining a resident rainbow trout). However, the visual appearance of individuals, recorded as a smolt index (described in more detail below), suggests that the great majority of outmigrating individuals are indeed sampled during their journey to the estuarine or marine environment.

Over the course of several years of monitoring, a total of about 500 scale samples of *O. mykiss* were collected from fish captured in the RST on the Arroyo Seco River and archived with FISHBIO. In order to better understand outmigration characteristics and the life history expressions of *O. mykiss* in the Salinas River Basin, these scale samples were recently analyzed. Similar to tree rings, scales of fish grow in proportion to their bodies and reflect differences in growth resulting from seasonal variation of the ambient environment. During periods of rapid growth, spacing between circuli (or “rings”, growth increments on scales) is greater than during times of limited, or reduced, growth. Multiple narrowly spaced circuli form an annulus, the main feature of interest in age determination. Typically, in the northern hemisphere, annulus formation is associated with slow growth experienced during the winter months. However, on the Central Coast of California, the most unfavorable growth conditions for *O. mykiss* likely occur in late summer and early fall, when streamflow is low and water temperatures are high (discussed in more detail below).

This analysis allowed us to estimate life history expression (in terms of age at outmigration) and growth patterns of juvenile *O. mykiss* from the Salinas River Basin among different year classes.

To the extent possible, implications of connectivity and environmental conditions on rates of growth and apparent anadromy were also assessed, as well as the relationship between adult escapement and subsequent juvenile production. The results of this effort are presented herein.

Methods

Sample Collection

Scale samples were collected from juvenile *O. mykiss* during RST operations on the Arroyo Seco River. Several scales were removed from sampled *O. mykiss* using a collecting knife (Figure 2) and deposited onto sample cards, which were placed into envelopes labeled with collection information including species, fork length, total length, weight, and smolt index. The smolt index refers to the physical appearance of the fish, which is defined based upon early life history stage, and includes Sac Fry (visible yolk sac), Fry (yolk sac absorbed, pigmentation undeveloped), Parr (darkly pigmented with distinct parr marks, no silvery coloration), Silvery Parr (faded but visible parr marks, intermediate degree of silvering), and Smolt (highly faded or absent parr marks, bright silver or nearly white coloration).

Figure 2. Several scales are gently scraped from individual fish using a collecting knife.

Sample Preparation

To prepare samples for aging, scales were removed from sample cards and placed on a glass slide under a dissecting microscope. In order to determine suitability of a particular scale sample for aging, the focus, edge, and clarity of each sample were visually evaluated. Scales with foci that were large, misshapen, or malformed were labeled as regenerated scales and returned to their respective scale cards. Occasionally, scales had to be cleaned of debris such as sand, dirt, or dried-on dermal cells by briefly soaking the samples in water, then wiping them with Kimwipes®. For each sample, three to five scales determined suitable for ageing were mounted in line and centered on a microscope slide. A second slide was then placed over the top of the scales and taped on both ends to secure the samples in place. Prepared slides were labeled with identifying information (sample number and collection year). Fish size was deliberately omitted from the labels, as to avoid pre-conceived estimates of fish age by the scale readers.

Imaging

Mounted scales were again examined for the greatest focus, edge, and clarity under 4x or 10x magnification using a compound microscope. An image was taken of the single scale determined to be the most representative of all the scales mounted for the sample using a digital microscope camera. Images of scales were then catalogued based on the unique identifying information of each sample and saved for further evaluation.

Age Determination and Measurements

Digital images of scale samples were evaluated to determine the age of the fish at the time of capture. Each scale was examined for the presence of annuli, defined as a dark band of narrowly spaced circuli (Figure 3). Wider spacing between circuli indicates rapid growth whereas narrow spacing indicates slower growth. The distances from the focus of the scale to the outer margins of annuli and/or the outer margin of the scale were measured using calibrated digital imaging software. All distances were measured along the same line, 15 degrees to the right side of the scale's longitudinal axis (Figure 3). Each scale sample was aged independently by two readers. If discrepancies were noted between the two age estimates, the sample in question was examined by a third biologist and discussed. Generally, differences in initial age estimates could be resolved. If no consensus could be achieved, the sample was excluded from further analysis.

Back-Calculation of Lengths and Estimation of Growth Rates

The Fraser-Lee method was used for back-calculation of lengths from the body size:scale diameter relationship, wherein both measurements were log-transformed to improve linearity (Bartlett et al. 1984):

$$\widehat{\boldsymbol{ln\,L_\iota}} = \hat{\boldsymbol{\alpha}} + (\boldsymbol{lnL_c} - \hat{\boldsymbol{\alpha}}) * \frac{\boldsymbol{lnS_i}}{\boldsymbol{lnS_c}}$$

where $ln\,L_i$ is the estimated, back-calculated fork length at time i (corresponding to annulus i), $\hat{\alpha}$ is the estimated intercept of the (log-transformed) regression of scale radius to body length (FL), L_c is fish length (fork length, in mm) at capture, S_i is the distance from the scale focus to annulus i, in microns (μm), and S_c is the total scale radius in microns.

Each sample was assigned a cohort year (i.e. year class) by subtracting the age estimate (in years) from the collection year. As a result, the relative contribution of each reproductive year to downstream migrants could be calculated. A Julian date (a unique number assigned sequentially to days of the year, with January 1 being “1” and December 31 being “365”), and a corresponding “daily age” (defined as the sum of the Julian date and the number of years, in days,) was assigned to each sample. For example, a sample with a single, well-defined annulus, captured on January 2, would receive a daily age of 367. Of note, this number was used for analysis only and is not representative of the true daily age of the fish (as we do not know on which exact date the fish was born, only the day it was sampled, and the number of completed annuli).

Mean annual growth rates were estimated as the difference between mean estimates of $\widehat{L_i}$ (the average of lengths at age 1 or 2) and $\widehat{L_{i+1}}$ (the average of lengths at age 2 or 3). Analysis of variance (ANOVA) was used to compare the estimated lengths at age among different cohorts (year classes) of *O. mykiss*, and Tukey post-hoc analysis was used to determine significance values for pairwise comparisons.

To investigate the effects of environmental conditions on growth of juvenile *O. mykiss*, ANOVA was also used to compare the estimated lengths at age among cohorts based on water year type. Water year type was determined by obtaining annual mean streamflow for Arroyo Seco (based on approved USGS data for Arroyo Seco near Soledad) and classifying according to flow thresholds identified in Figure 2 of MCWRA (2018; Table 4). Annual mean streamflow was also used to test for a significant linear relationship between magnitude of discharge and estimated first-year growth.

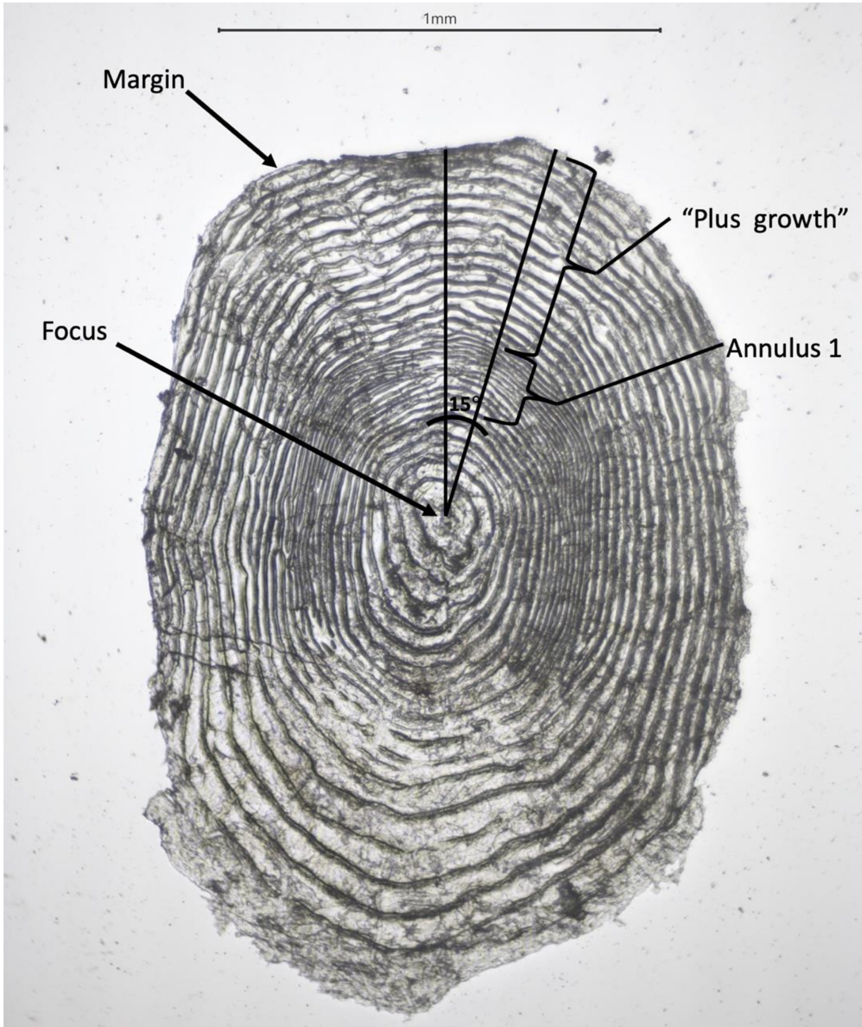

Figure 3. ***O. mykiss*** **scale sample collected on the Arroyo Seco River, illustrating relevant scale features (FL = 173 mm; sampled 04/20/2011; $\hat{L}_1$= 85.2 mm).**

Salinas Basin *O. mykiss* Growth Pattern Interpretation

In order to correctly interpret the results presented herein, it is important to first consider the environmental conditions and resulting physiological responses of *O. mykiss* in the Salinas River basin. The reproductive window of South-Central California Coast steelhead is thought to range over a period of five months, from December through April (Snider 1983). However, there is reason to believe that reproduction may occur more opportunistically (either sooner in the fall or much later in the spring) depending on environmental conditions and the status of the lagoon. Juveniles hatch three to four weeks after spawning (at 10°C - 15°C) and emerge from the gravel after an additional two to three weeks. In the Salinas River basin, the subsequent months (summer) are characterized by the lowest flows and highest water temperatures of the year, corresponding to high metabolic cost, physiological stress and, consequently - and of particular importance to this study - lowest growth and annulus formation, a pattern previously reported for other southern populations (Shapovalov and Taft 1954; Railsback and Rose 1999; Hayes et al.

2008). Conversely, more rapid growth is achieved from fall through spring. Accordingly, an individual sampled in mid-spring, determined to be of age 1 (i.e., one annulus), will display patterns of relatively rapid growth during the period immediately preceding sampling. Figure 3, featuring a scale sample collected in April, illustrates this growth pattern. The outer margin of the first annulus likely corresponds to the early fall period, but determining more definite date values proves difficult in absence of sample collection during all seasons. Therefore, throughout the remainder of this document, any reference to "Age" indicates the number of annuli (the number of completed summers), rather than the number of completed calendar years.

Results

Overall, 387 individual samples were successfully aged, while 76 samples could not be aged due to scale regeneration or lack of clearly discernible annuli. In addition, three samples were determined to be of Age 0, solely based on the individuals' fork length and collection date (FL 40 mm – 53 mm, collected between May 9 and June 1).

Age and Length at Migration

The majority of fish migrated downstream at Age 1 (67%), followed by Age 2 individuals (30%) and Age 3 individuals (2%; Table 2; Figure 4). The mean length of captured individuals in each year class was approximately 51 mm for age 0 fish, 120 mm for age 1 fish, 197 mm for age 2 fish, and 240 mm for age 3 fish. The cumulative distribution of sizes of fish determined to be of Age 1 is bi-modal, likely reflecting differences in reproductive timing, variation in peak outmigration (and therefore, sample collection), and differing first-year growth conditions among different year classes. The percentage of captured fish that were considered to be either silvery parr or smolts (indicating that they were physiologically prepared to outmigrate to the ocean) was 0 percent for age 0 fish, 60 percent for age 1 fish, and 100 percent for age 2 and 3 fish (Table 2).

All *O. mykiss* for which scales were analyzed that were larger than 64 mm and under 149 mm FL had spent one summer in freshwater. Most individuals larger than 180 mm had spent two summers in freshwater, although some younger fish (i.e. 1+) were larger than small two-year olds (Age 1+ ranged up to 219 mm, depending on the date and year of collection; Table 2; Figure 5). Fish that had spent three summers in freshwater before migrating downstream were rather rare, representing less than 3% of aged individuals.

Table 2. Summary of sample aging results for *O. mykiss* sampled in the Arroyo Seco River, including the age of the fish, the number of individuals belonging to each age class, the mean length of individuals in that age class (referring the fork length at collection, in mm), and the standard deviation. Smolt fraction refers to the percentage of individuals belonging to each age group that were classified as either "silvery parr" or smolt".

Age	n	$\bar{L}\ (SD)$	Min	Max	Smolt fraction
0	4	50.75 (10.31)	40	64	0
1	258	119.89 (35.30)	69	219	0.60
2	119	197.38 (19.68)	149	242	1
3	9	240.22 (38.30)	167	290	1

Growth

The mean back-calculated length at the first annulus was estimated as 80.09 mm (FL; Table 3), meaning that captured fish grew, on average, approximately 80 mm from hatching until the end of their first period of slow growth (late fall). Examination of individual year classes suggests differences in first-year growth among year classes. Estimated lengths at annulus 1 differed by up to 24.05 mm (between year classes 2008 and 2015; Table 4), but only few differences among year classes were statistically significant due to large variation in individual growth (Table 5).

No significant differences in first-year growth among fish born during different water year types (p=0.59). Similarly, no statistically significant linear relationship was found between first-year growth and mean annual discharge (p=0.71).

Table 3. Summary of estimated, back-calculated lengths ($\bar{\hat{L}}_i$) at annulus formation for *O. mykiss* sampled in the Arroyo Seco according to year class.

Growth	Year Class	$\bar{\hat{L}}_i(\pm 1SD)$	Number of Observations
At Annulus 1	2007	75.11 (9.40)	5
	2008	74.15 (15.79)	91
	2009	95.71 (17.91)	44
	2010	93.50 (19.44)	25
	2011	77.81 (14.62)	218
	2015	98.20	1
	2016	91.98 (8.83)	2
	Overall	80.09 (17.09)	386
At Annulus 2	2007	121.01 (6.16)	5
	2008	147.35 (23.29)	91
	2009	147.69 (17.60)	19
	2010	151.73 (20.48)	12
	2011	-	0
	2015	157.23	1
	2016	-	0
	Overall	146.86 (22.26)	128
At Annulus 3	2007	210.02 (16.85)	5
	2008	190.42 (33.78)	3
	2009	271.79	1
	2010	-	0
	2011	-	0
	2015	-	0
	2016	-	0
	Overall	210.35 (32.37)	9

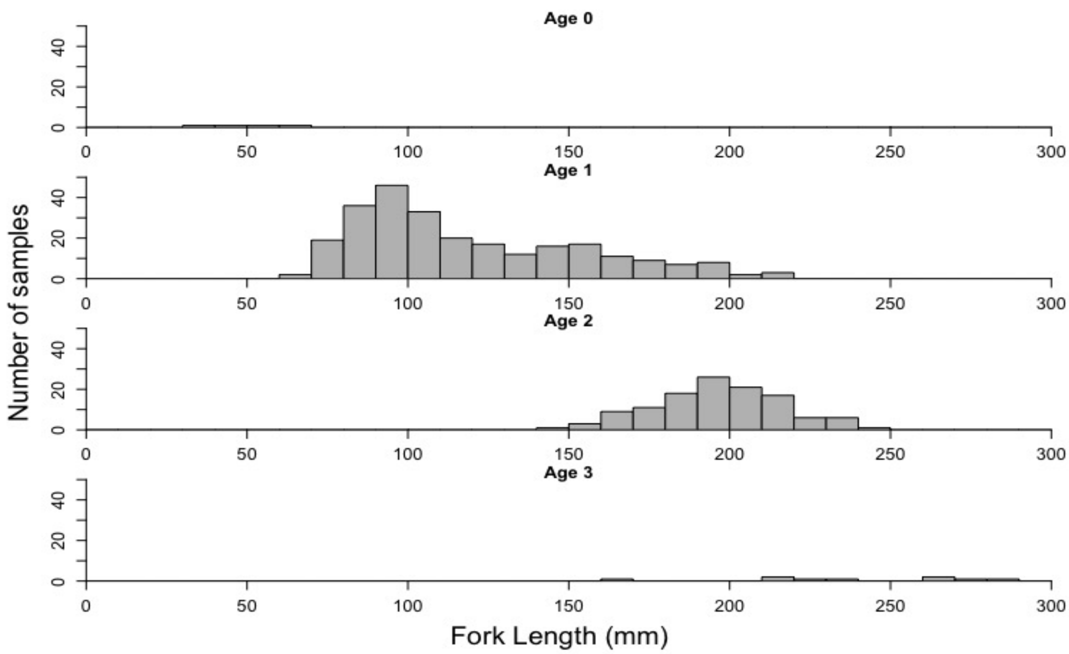

Figure 4. Length distribution of *O. mykiss* at different ages sampled at the rotary screw trap in the Arroyo Seco River.

Table 4. Summary of estimated annual growth ($\bar{\bar{L}}_{\iota}$) of *O. mykiss* sampled in the Arroyo Seco according to year class, including water year type and mean annual flow (MAF).

Growth	Year Class	$\bar{\bar{L}}_{\iota}(\pm 1SD)$	Water Year[1]	MAF (cfs)
By Age 1	2007	75.11 (9.40)	D	20.7
	2008	74.15 (15.79)	N	120.2
	2009	95.71 (17.91)	N	140.5
	2010	93.50 (19.44)	W	255.5
	2011	77.81 (14.62)	W	250.7
	2015	98.20	D	26.6
	2016	91.98 (8.83)	DN	298.3
Age 1 - 2	2007	45.90 (13.28)	N	120.2
	2008	73.20 (21.30)	N	140.5
	2009	61.76 (12.19)	W	255.5
	2010	69.45 (22.10)	W	250.7
	2011	-	D	26.6
	2015	59.04	DN	298.3
	2016	-	-	-
Age 2 - 3	2007	89.01 (21.77)	N	140.5
	2008	69.46 (25.57)	W	255.5
	2009	114.72	W	250.7
	2010	-	-	-
	2011	-	-	-
	2015	-	-	-
	2016	-	-	-

[1]Water year designation based on mean annual flow at for Arroyo Seco near Soledad; D=dry, DN=dry-normal, N=normal, W=wet).

Table 5. Pairwise comparison of mean size differences, in mm (FL), at Age 1 among different year classes of O. mykiss in the Arroyo Seco (e.g. the difference in fork length of age 1 fish born in 2007 and 2011 is 2.70 mm). Bold numbers indicate a statistically significant difference in size at age 1 among year classes.

Year Class	2008	2009	2010	2011	2015	2016
2007	0.96 (0.99)	20.60 (0.08)	18.39 (0.20)	2.70 (0.99)	23.09 (0.83)	16.87 (0.85)
2008	-	***21.56 (<0.01)***	***19.35 (<0.01)***	3.66 (0.49)	24.05 (0.72)	17.83 (0.68)
2009	-	-	2.21 (0.99)	***17.90 (<0.01)***	2.49 (0.99)	3.73 (0.99)
2010	-	-	-	***15.6 (<0.01)***	4.70 (0.99)	1.51 (0.99)
2011	-	-	-	-	20.39 (0.85)	14.18 (0.86)
2015	-	-	-	-	-	6.22 (0.99)

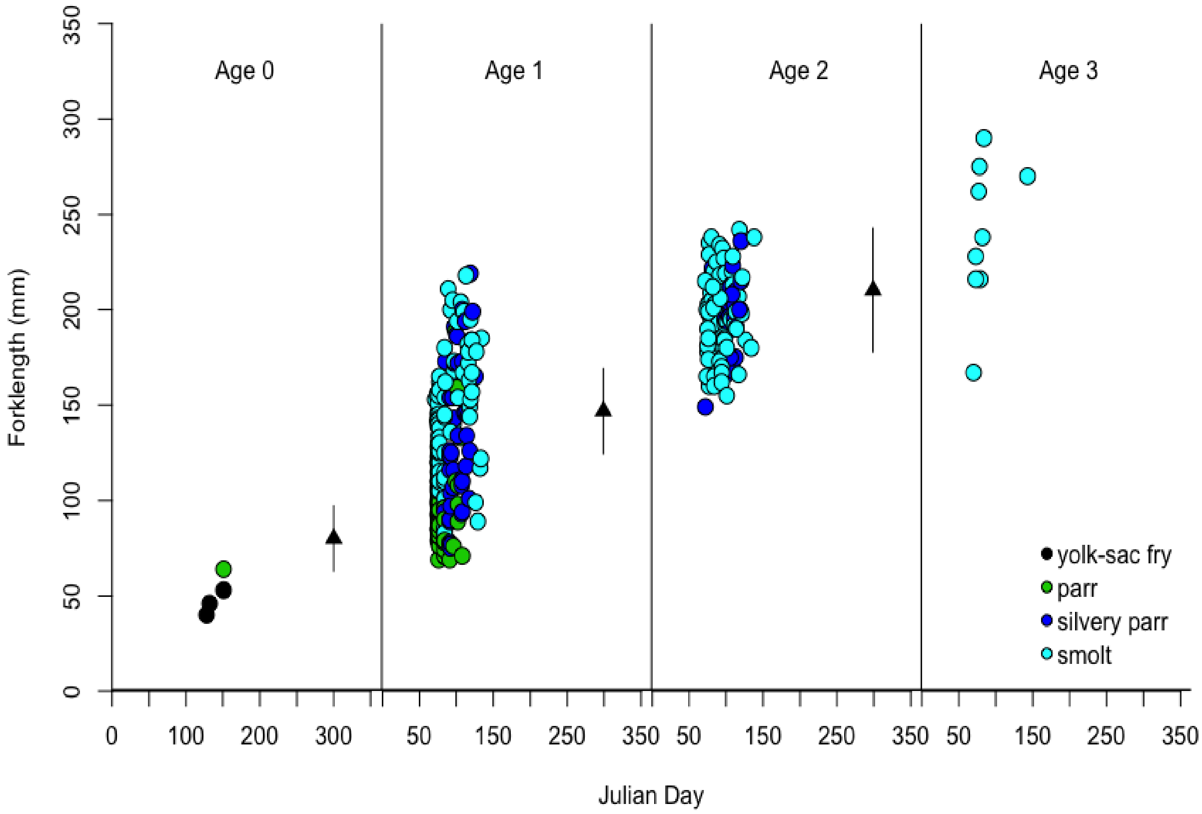

Figure 5. Growth of Arroyo Seco *O. mykiss* through time. Triangles with vertical bars represent estimated, back-calculated) length at annulus *i*, based on annulus formation around November 1 (±1SD). Julian day refers to the date of the year whereby January 1 is considered Julian Day 1; Jan. 2 is Julian Day 2; etc.

A comparison of estimated size at annulus *i* among different age classes captured in the rotary screw trap supports the notion that individuals that are larger than their conspecifics at certain points during their freshwater residence are more likely to smolt in a given year (Satterthwaite et al. 2009, 2010; also reviewed by Kendall et al. 2015). In other words, individuals captured during outmigration at age 1+ had a larger mean estimated size at annulus 1, ($\bar{\hat{L}}_1$), than individuals that emigrated at age 2 and 3 (Figure 6). Of note, only individuals classified as either "silvery parr" or "smolt" (i.e. those exhibiting external signs of smoltification) were included in this comparison (60% of age 1 fish; Table 2). Fish that migrated at age 2 were larger at $\bar{\hat{L}}_1$ than those that migrated at age 3, but smaller than those that migrated at age 1. Similarly, fish that emigrated at age 2 (all smolts; Table 2) were larger at $\bar{\hat{L}}_2$ than individuals that migrate at age 3. These differences at age *i*, however, were not statistically significant (p>0.05).

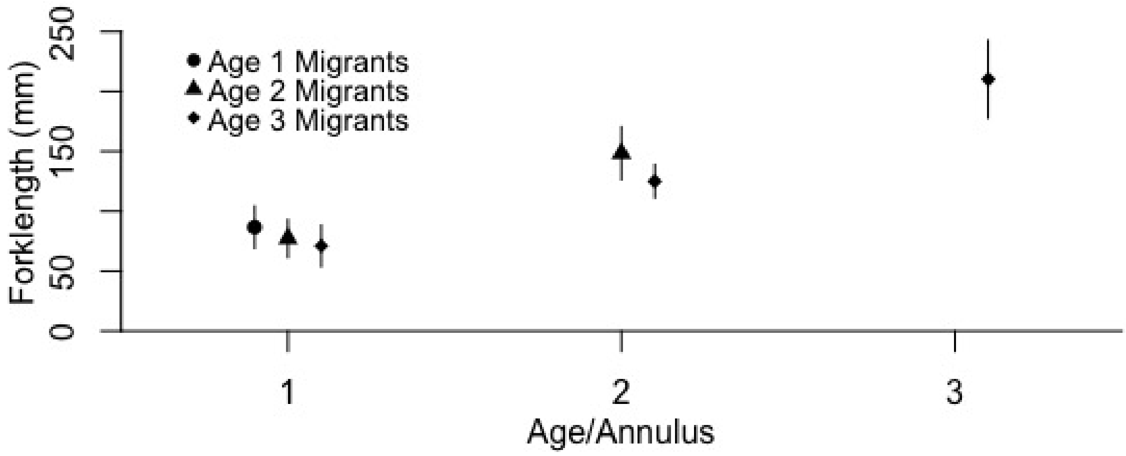

Figure 6. Comparison of estimated size at annulus formation for individuals captured in the Arroyo Seco River Rotary Screw Trap at different ages (± 1SD).

Adult Escapement and Juvenile Production

Unfortunately, there is little overlap in monitoring efforts for adult steelhead migration and corresponding juvenile abundance one to three years later. While adult monitoring has occurred annually since 2010/2011 (with the exception of 2014/2015, and 2017/2018), no juvenile monitoring occurred in the years 2013-2016 (Table 1). As a consequence, only juvenile abundance in spring 2012 (estimated at 2,876) could be partially related to adult escapement; namely, the 218 individuals determined to be of Age 1+ are offspring of the adult escapement during the 2010/2011 season, when 13 net upstream passages of steelhead were recorded at the Salinas River weir. Although it is hard to draw many conclusions about the effects of environmental conditions and connectivity on adult migration and spawning conditions during this year, it is worth noting that the lagoon was open for an extended period of time (12/25/2010-9/21/2011) during that year and peak flows were the highest observed throughout the entire monitoring period (~11,400 cfs at Spreckels on 3/26/2011).

Table 6. Summary of age composition of outmigrating *O. mykiss*, by collection year.

Collection Year	Age 0	Age 1	Age 2	Age 3
2010	3	25	88	5
2011	1	13	18	3
2012	0	218	12	1
2017	0	2	1	0

Discussion

Growth

The mean estimated growth of 80.09 mm by late summer/early fall (the time of annulus deposition) is within the range of 50-90 mm expected for *O. mykiss* by the end of their first summer in small California streams with low summer flows (Moyle 2002), although this estimate varies between 75.11 and 98.20 mm among year classes. The highly variable growth rates observed for *O. mykiss* in the Arroyo Seco indicate that individual growth is greatly influenced by local habitat conditions and seasonal climate patterns (which, in part, depend on the timing of reproduction by the parental generation), in addition to inherent individual variation in growth. Large variation in sizes, both within and among year classes, is expected for several reasons. First, inherent differences in individual growth result in various sizes of fish, even those belonging to the same brood (i.e. even related fish born at the same time reach different sizes at time *t*). Next, not all spawning within a given reproductive season occurs at the same time, and incubation duration can differ depending on local water temperature variation within the watershed, resulting in fish of the same nominal year class hatching at different times. Among year classes, variation in size at age can result from differences in timing of reproduction, especially for offspring of anadromous fishes, as migration opportunities into the Arroyo Seco depend on the timing of rainfall events. Lastly, environmental conditions influencing growth differ from year to year, so that individuals belonging to different year classes likely experience dissimilar growth conditions during their first year.

Age at Outmigration

Challenges exist in evaluating juvenile growth and outmigration characteristics in the Arroyo Seco in reference to other populations, as the timing of annulus formation differs compared to most other watersheds in California for which age and growth data is readily available. Perhaps the most applicable geographically proximate watershed for comparison is Scott Creek, where – like in the Arroyo Seco – most fish migrate after their first or second winter (Hayes et al. 2008).

From the available data, we cannot conclusively deduct that juvenile steelhead emigrate from the Arroyo Seco before spending at least one summer in the stream. In other words, although Age 0 individuals were captured in the rotary screw trap, it remains unclear whether these individuals were displaced or disbursing, rather than effectively migrating towards the marine or estuarine environment. However, in other watersheds on the central California coast, life history pathways wherein fry-sized individuals leave the upper watershed and move to a lagoon environment for rearing have been documented (Hayes et al. 2008). Regardless, insights from multiple years of rotary screw trap sampling in the basin strongly suggest that such behavior is comparatively rare in the Salinas Basin.

Life History Strategies

While the information presented herein provides previously unknown insights regarding the outmigration characteristics of *O. mykiss* in the Arroyo Seco, the role and effects of estuarine rearing - or even maturation - in this watershed remain unclear. It is possible that *O. mykiss* in the Salinas River basin, similar to Hayes et al. (2008), exhibit multiple life history pathways prior to ocean entry, which include prolonged rearing in freshwater and estuary/lagoon rearing. It remains to be determined whether the latter is facultative rearing (using the estuary due to beneficial growth conditions) or coincidental (lack of connection to the ocean by the time the fish arrives in the estuary). To date, very few individual *O. mykiss* have been observed in the Salinas River Lagoon, despite targeted monitoring efforts (i.e. seining). However, effectively capturing steelhead in a large, deep lagoon is inherently challenging.

Migratory Patterns and Connectivity among Habitats

This investigation provides further evidence that juvenile production can occur even in years without connectivity to the marine environment (i.e., no breaching of the lagoon's sandbar), in addition to the documentation of juvenile *O. mykiss* in the Arroyo Seco during visual (snorkel) surveys in 2014. Scale analysis of individuals collected in the rotary screw trap in 2017 (three individuals were aged successfully) indicate that these fish belong to year classes 2015 (n=1) and 2016 (n=2). This is a clear indication that *O. mykiss* in the Salinas River basin exhibit a resident or partially migratory life history, permitting population persistence during extended periods (multi-year) of isolation from the marine environment.

Management Recommendations

In order to gain a more refined understanding of the migration characteristics of juvenile *O. mykiss* (i.e. duration, speed, etc.), lagoon entry timing, lagoon residence and use of alternative migration pathways (e.g., via the Old Salinas River, in absence of lagoon breaching), individuals could be tagged with PIT tags, either opportunistically (during RST operation or index reach surveys) or during other targeted sampling efforts. Suitable locations for detection arrays include the Salinas River weir a short distance upstream from the lagoon and the tide gate to the Old Salinas River, which could be supplemented with streambed antennas in the lower Arroyo Seco, or a floating array in the lagoon. Lastly, as PIT tags are not limited by battery life, returning adults that were tagged as juveniles could be detected at the above-mentioned locations, furthering our understanding of the biology of the species in the watershed.

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