

Redwood Creek Juvenile Salmonid (Smolt) Abundance Project YRS 2000-07

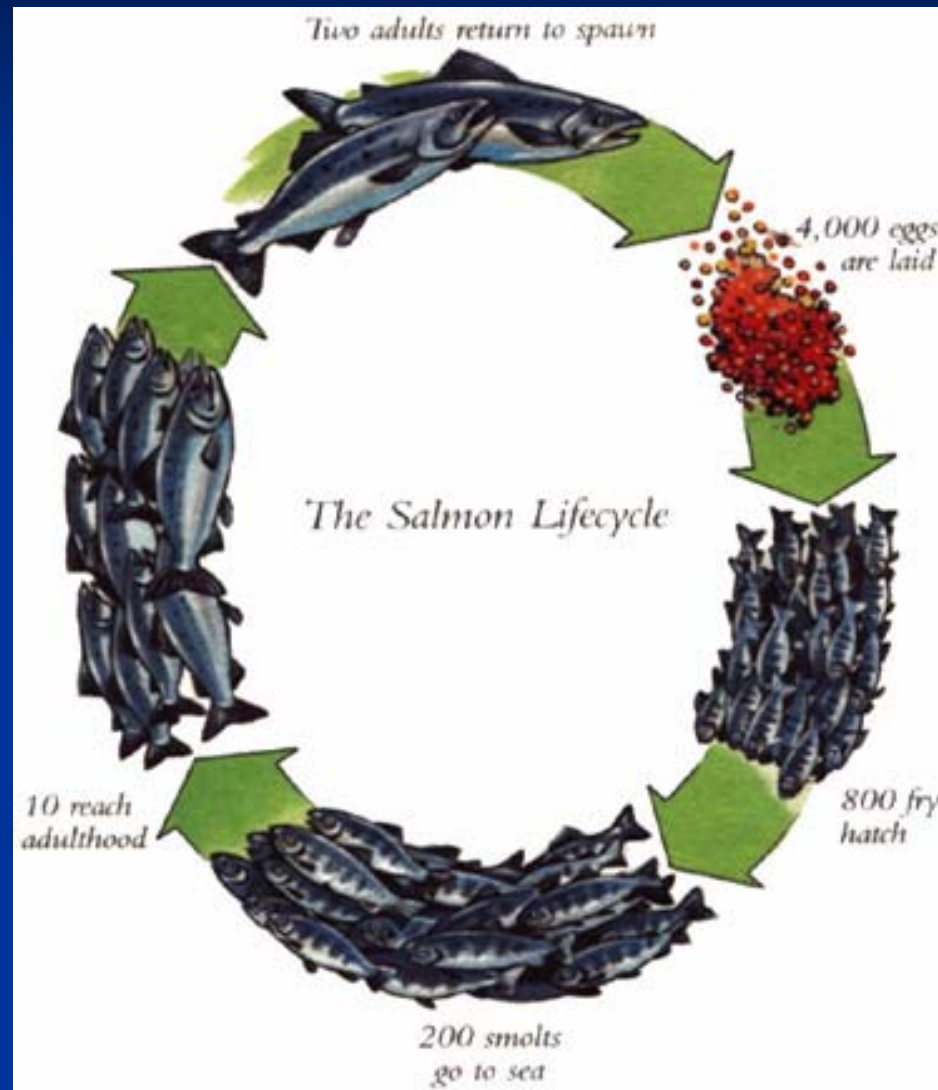
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 - Save the Redwoods League (YR 2008)

Salmon and Steelhead Trout Life Cycle



- The number of smolts migrating to the ocean relates to the number of adults, and the condition of the stream and watershed.
- As the juvenile fish migrate to the ocean (as smolts) we trap them with a downstream migrant trap (Rotary Screw Trap or RST).

Rotary Screw Trap



Study Objectives

- Determine the presence of juvenile anadromous salmonids in Redwood Creek.
- Document life history types (age class of migrants for a given species).
- Determine population size of smolts (Chinook salmon, Steelhead Trout, Coho Salmon, Cutthroat Trout).
 - Status and trends: Are the populations decreasing, increasing, remaining stable or unstable?

- What factors are influencing the populations, or specific parts of their life cycle in Redwood Creek?
- Are restoration activities benefiting salmon and steelhead populations in Redwood Cr?
- Provide data and information that fisheries and habitat managers can use.

Jargon

- Juvenile fish ages
- Definition of 'smolt'

Ages of juvenile fish

- 0+ (zero plus) = young of year fish that is less than 1 years old.
- 1+ (1 plus) = age of fish that is ≥ 1 years old and less than 2 years old.
- 2+ (2 plus) = age of fish that is ≥ 2 years old and less than 3 years old.

What is a smolt?

- Smolts are juvenile salmon and steelhead that are undergoing smoltification, and migrating downstream to the estuary and ocean.
- Smoltification:
 - Can occur at different juvenile ages.
 - Considered to have a genetic component.
 - Influenced by environmental conditions: photoperiod (often a trigger), water temperature, and even the act of migrating downstream (behavioral cue).
- Smoltification can begin in stream locations that are far from the estuary and ocean. The finishing touches to smoltification occur in the estuary.
- Visible morphological changes:
 - Silvery in coloration
 - Darkening of the caudal (tail) fin edges or most of the caudal fin.
 - Some may appear 'skinny'.

Steelhead Smolt (2+)





Smolts continued

- Steelhead trout juveniles normally smolt at ages of 1 – 3, with 2 being most common in many streams.
- Chinook salmon juveniles are tricky (3 life histories):
 - ***Ocean Type***: some fry can immediately go to the estuary and ocean without showing full smolt characteristics, and others will stay in the stream to rear for additional months, and show full smolt characteristics as they move downstream.
 - ***Stream Type***: reside in the stream 1 full year prior to smolting and ocean entry.
- Coho salmon juveniles normally smolt at age 1, although smolting at age 2 is also possible.
- Not all downstream migrants are in a smolt stage (parr, pre-smolt, smolt).

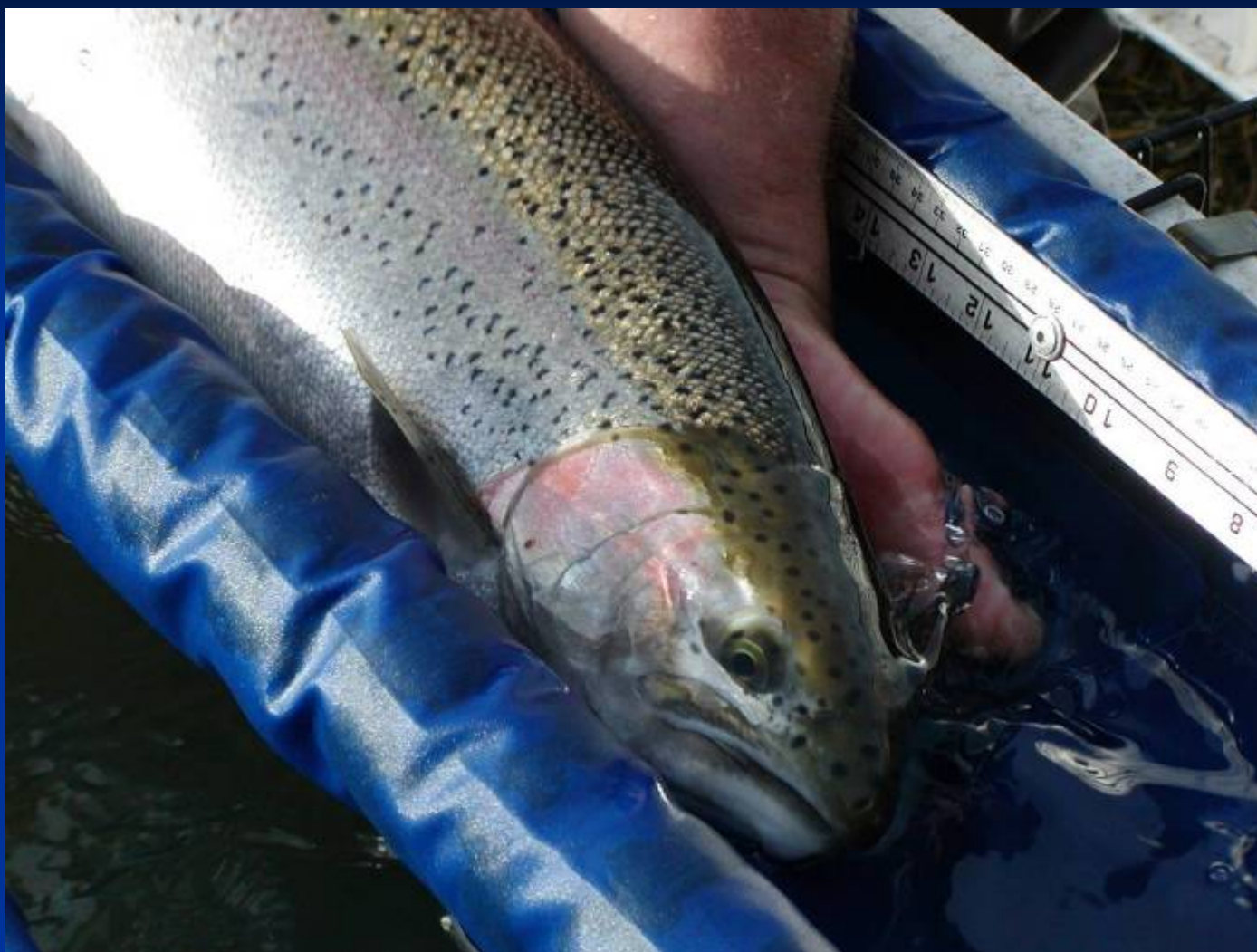
Fish that we expected to
be present before
studying Redwood Creek

Adult Chinook Salmon



Adult Steelhead Trout





Adult Coho Salmon



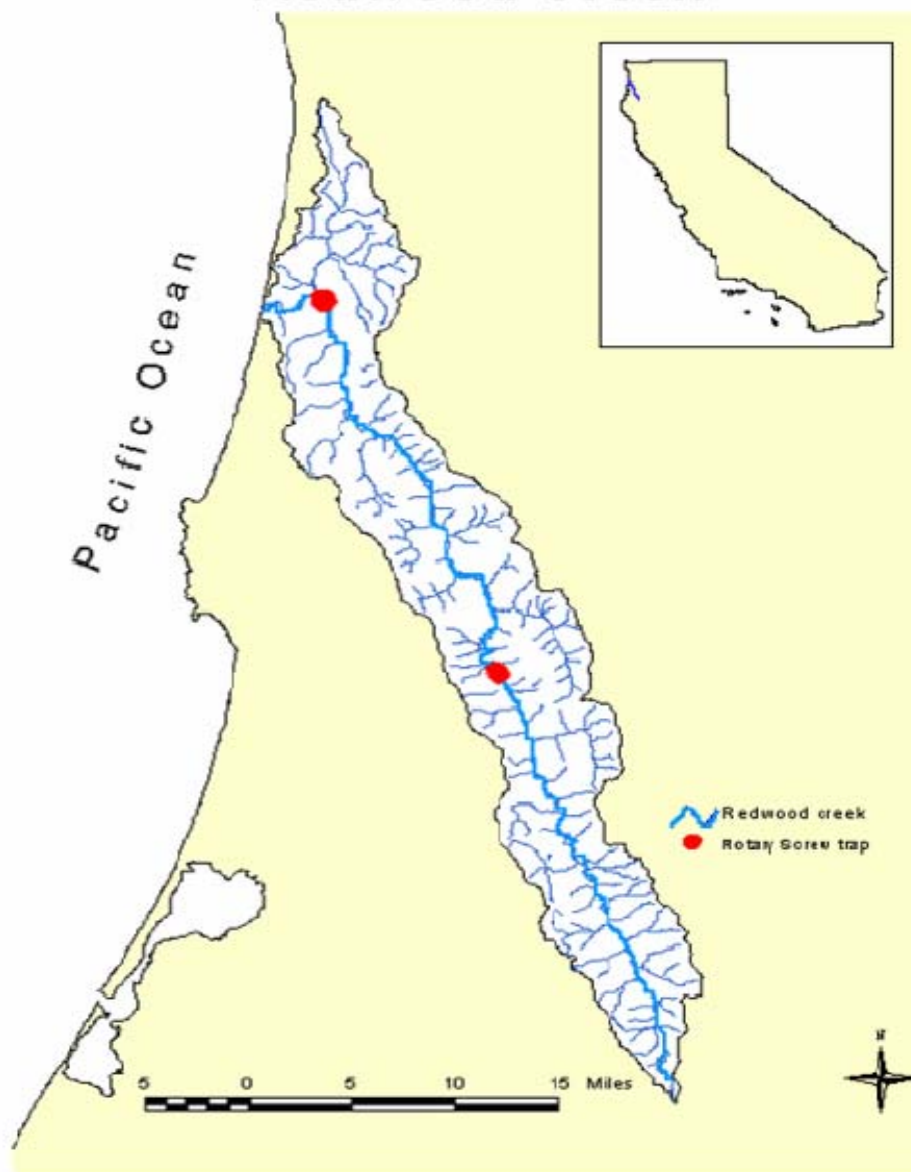
Adult Cutthroat Trout



Redwood Creek

- About 67 miles long.
- Extensive clear cut logging (81% of original forest) and road network.
- Major flood events in 1955, 1964, 1972, 1975, 1995.
- Listed as Sediment and Temperature impaired by US EPA (like most streams in North. CA.)
- Data 'rich' with respect to physical measurements (geology, geomorphology, hydrology).
- Data 'poor' with respect to fish abundance, trends, etc.
- All salmonids except Cutthroat Trout are federally listed as threatened.

Redwood Creek



Upper Redwood Cr RST (RM 33)





(very low flow)



Pipe Trap to finish season (prior to sedimentation at trap site)



Fyke Net (to finish season)



Lower Redwood Cr RST



High Flow Event





New Trap Site (75 m below)









End of season



Methods*

Trap operations

- Traps run 24 hrs/day, 7 days a week from late March to early to late August.
 - Except for some high flow events.
- Operated to maximize catches and trapping efficiency.
 - Our modified trap in upper Redwood Cr can handle flows from 8 – 1,200 cfs; even higher (2,000⁺ cfs) in lower Redwood Cr.
- Checked 1-2 times a day (morning and evening).
- Evening check to remove debris/release efficiency trial fish.

Heaviest debris load in livebox



Trapping in High Flow Event



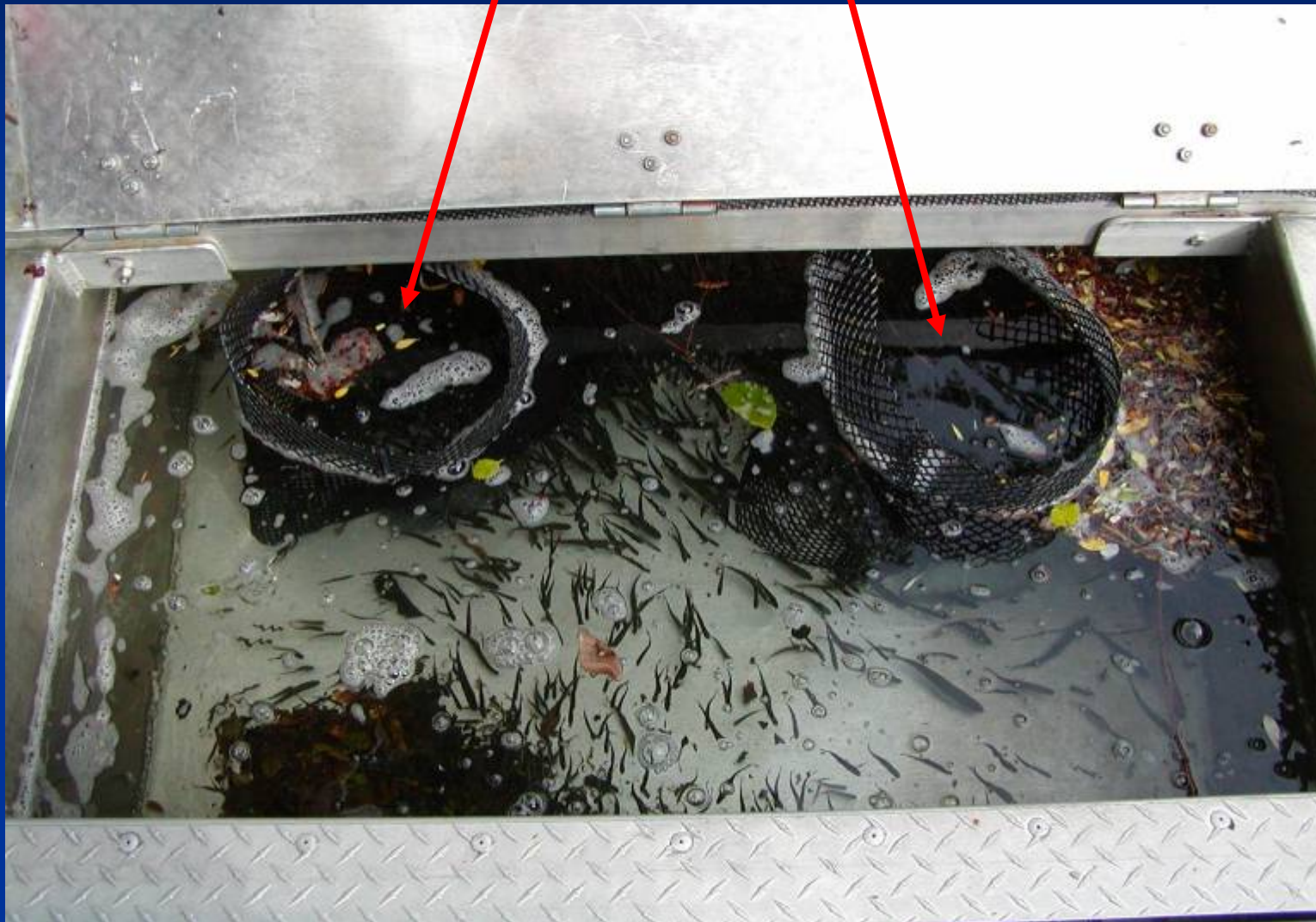
Day to Day Activities

- 0+ fish first then older age classes.
- Each fish is identified to species at age, observed for trap efficiency trial marks, and enumerated.
- Fork Lengths and Weights
- Scale Samples
- Genetic samples*
- Pit Tagging
- Record number of fish with parasites (eg 'fungus', black spot disease, leeches, etc).
- Additional experiments (gravel seep and fish use, diet analysis, etc).

Peak Catch of 0+ Chinook salmon



Safety Cages



Processing Station (upper Redwood Cr)



Upper Redwood Cr



Processing Station (lower RC)





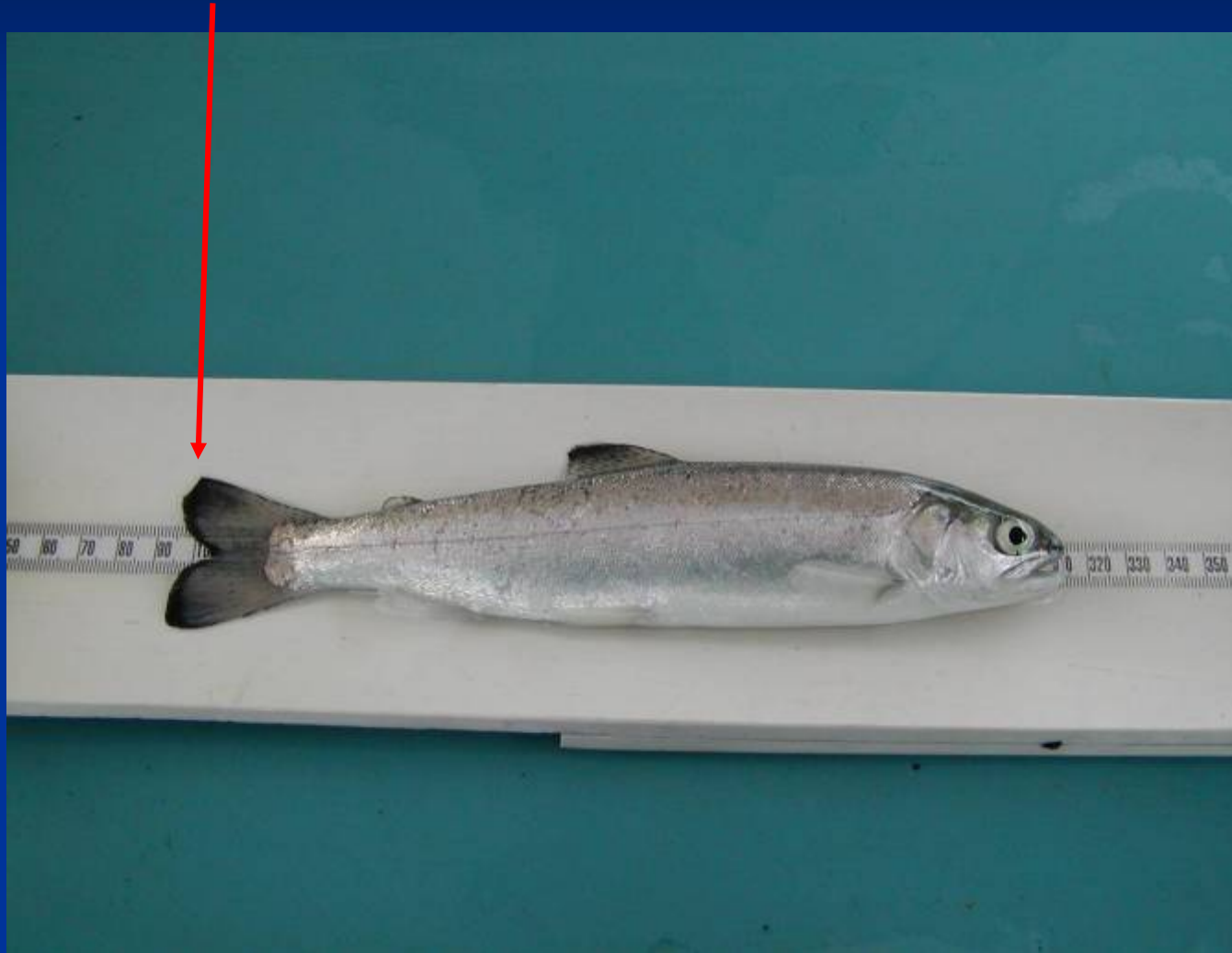
Ice chest to count and measure fish from



Mark-Recapture Experiments

- We use partial fin clips for the mark:
 - Stratified by species/age and trap.
 - Fast and easy to apply.
 - Do not harm fish.
 - Relatively long lasting.

Partial caudal fin clip on 2+ Steelhead



Mark-Recapture

- We mark and release smolts 3-5 times each week upstream of the trap.
 - Data is pooled for each week.
 - Multiple trials within the week account for changes in flow.
- Sample sizes vary from 3 – 100 fish each trial, depending upon trap catches.

Population estimates for:

- 0+ Chinook Salmon
- 1+ Steelhead Trout
- 2+ Steelhead Trout (includes 3+ SH)
- 0+ Coho Salmon
- 1+ Coho Salmon
- Cutthroat Trout

Population Model

- Carlson et al. (1998) is the model we favor.
 - Stan R. Carlson is a bio-metrician for Alaska Dept. of Fish and Game.
 - Improved version of a Peterson: they found errors in the Peterson and corrected for it.
 - Tested in the field for accuracy with a smolt trap and downstream counting fence (weir)*.
 - Favorable peer review by CDFG Bio-metrician Phil Law.
- We have compared and used three models in the past:
 - Peterson
 - DARR
 - Carlson

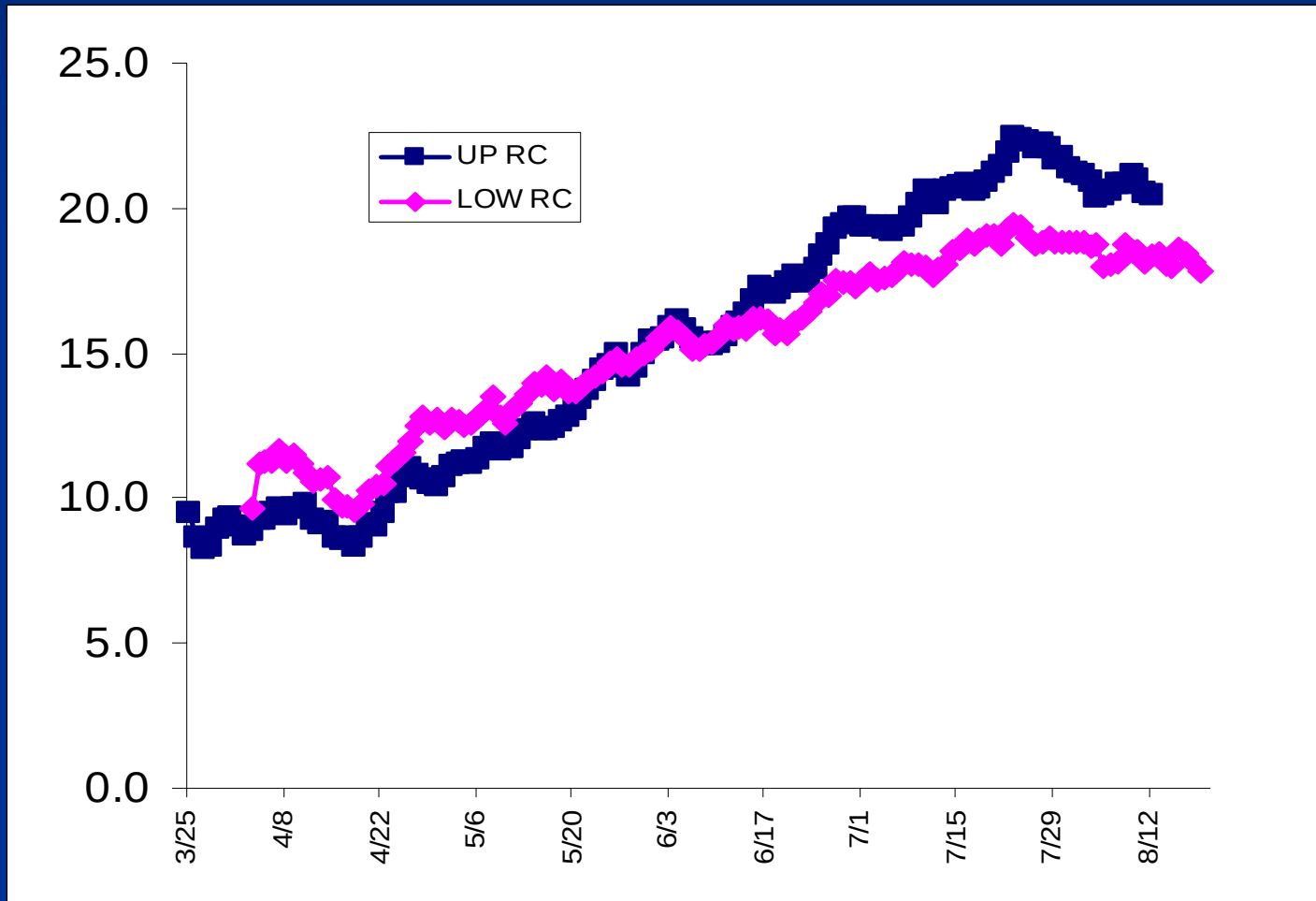
Delayed Mortality Experiments



Delayed Mort. Experiments Cont'd.

- To test for mortality due to:
 - anesthetization and counting
 - partial fin clipping
 - measuring FL and WT
 - pit tagging
 - elevated water temperatures

Stream Temperatures (°C)



Results

Trapping Rate

- Upper Trap: 122 - 145 days, Avg. = 135 d.
Avg. # of miss. days = 4 or 3%.
In YR 2007 we missed 2 days.
- Lower Trap: 117 - 139 days, Avg. = 130 d.
Avg. number of missed days = 5, or 4% of total.
In YR 2007 we missed one day.

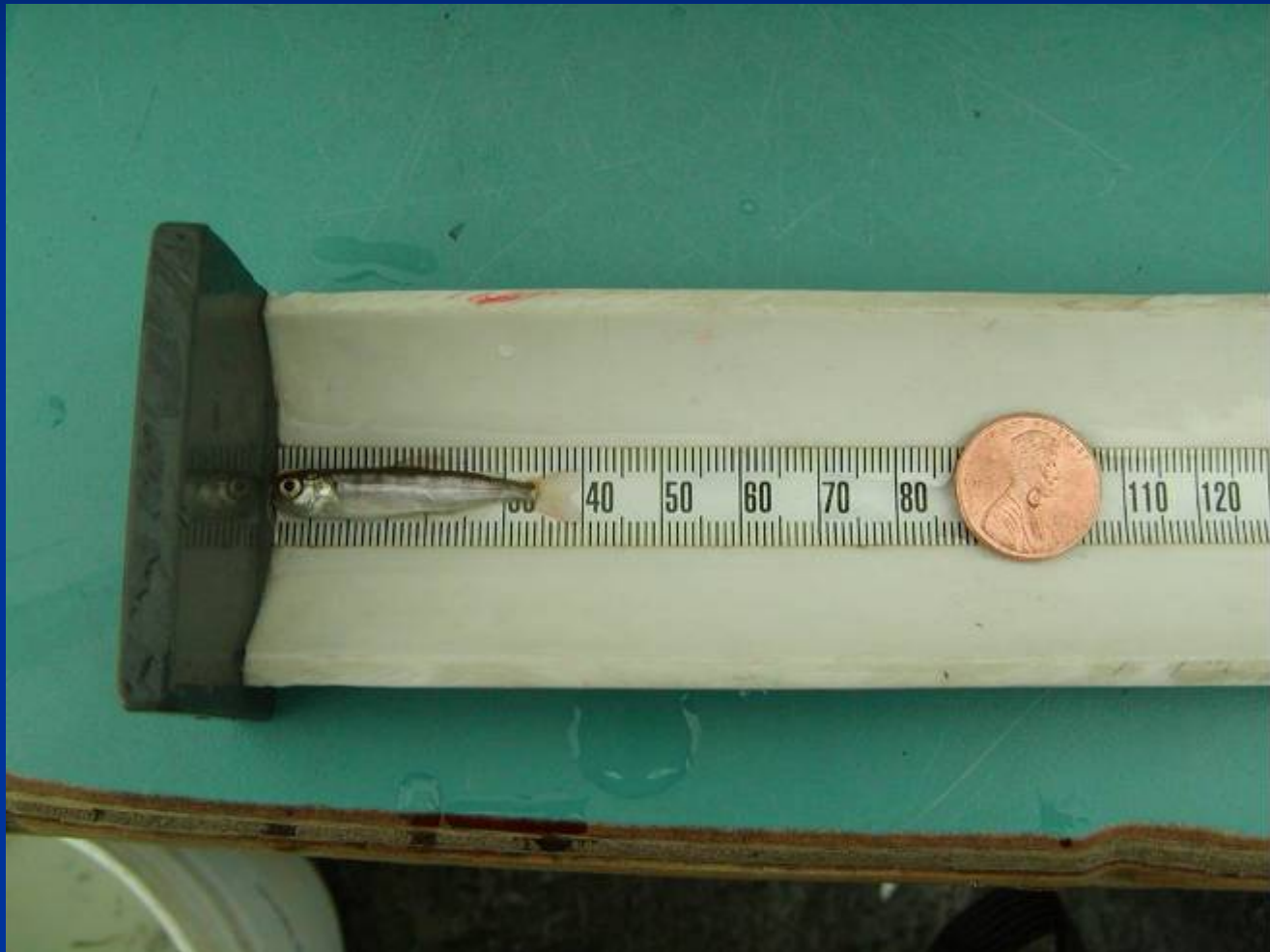
Fish Present in Redwood Creek

- Chinook Salmon
- Steelhead Trout
- Coho Salmon
- Cutthroat Trout
- Pink Salmon*
- Sucker
- Sculpin (2 kinds)
- 3 Spined Stickleback
- Brown Bullhead

Miscellaneous Species

- Pacific Lamprey (adult and juveniles)
- Pacific Giant Salamander
- Painted Salamander
- Rough Skinned Newt
- Red Legged Frog
- Yellow Legged Frog
- Tailed Frog
- Toads
- American Bullfrog
- Countless invertebrates (stoneflies, etc).

Juvenile Chinook Salmon (Fry)







1+ Chinook Salmon (Stream Type)



Juvenile Pink Salmon



Pink Salmon and Chinook Salmon



Juvenile Steelhead Trout (4 ages, 3 shown)



2+ Steelhead Trout (watershed indicator)



0+ Coho Salmon



1+ Coho Salmon Smolt



1+ Coho Pre-Smolt



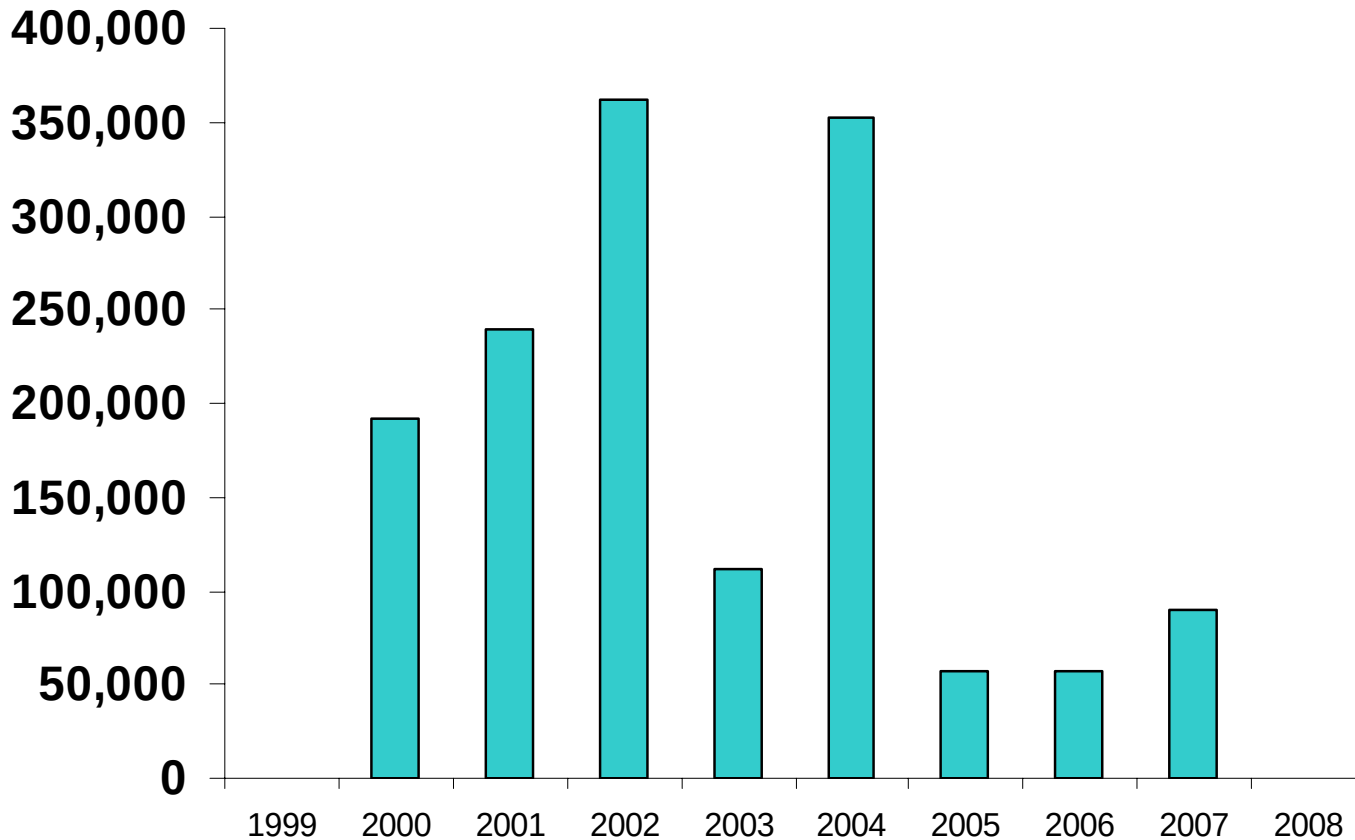
Cutthroat Trout



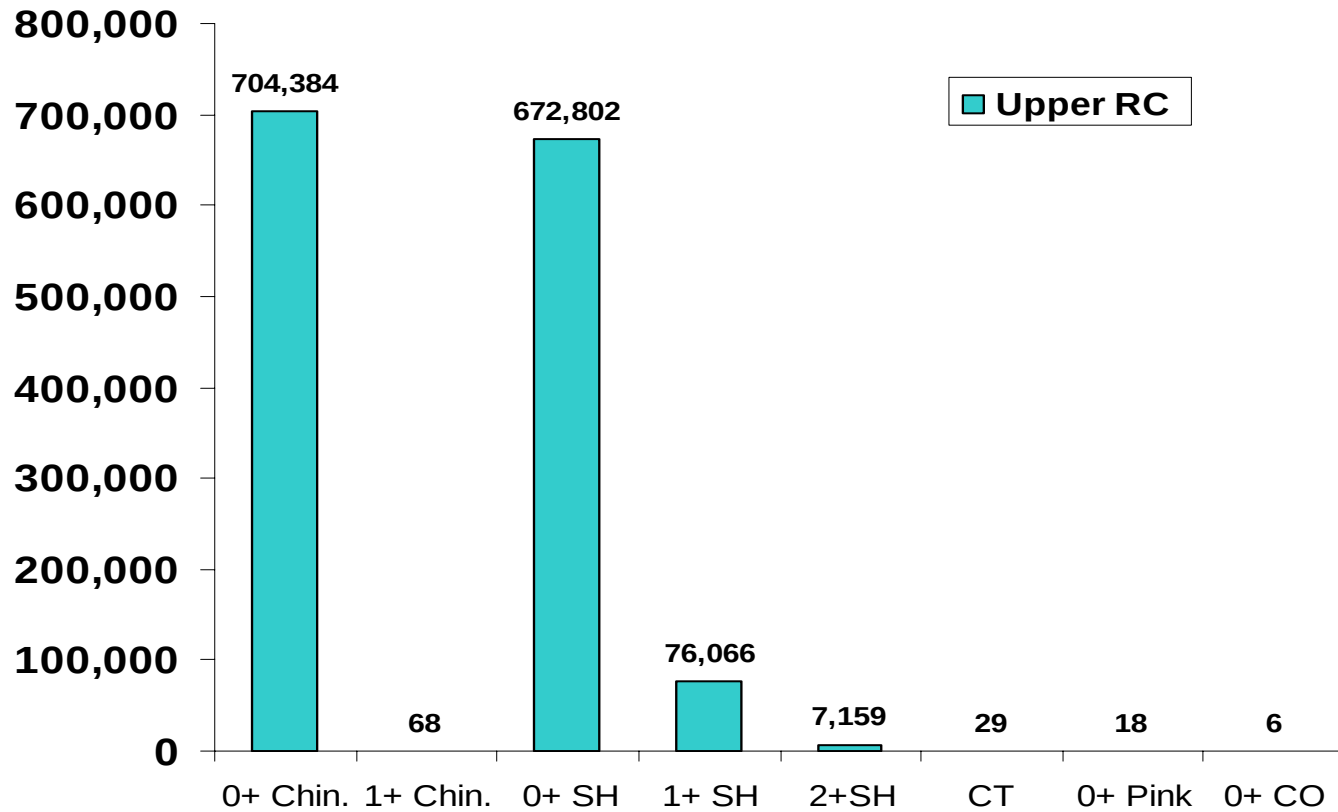


Trap Catches (upper Redwood Cr)

8 YR Total = 1.46 million, Avg = 182,567 per year

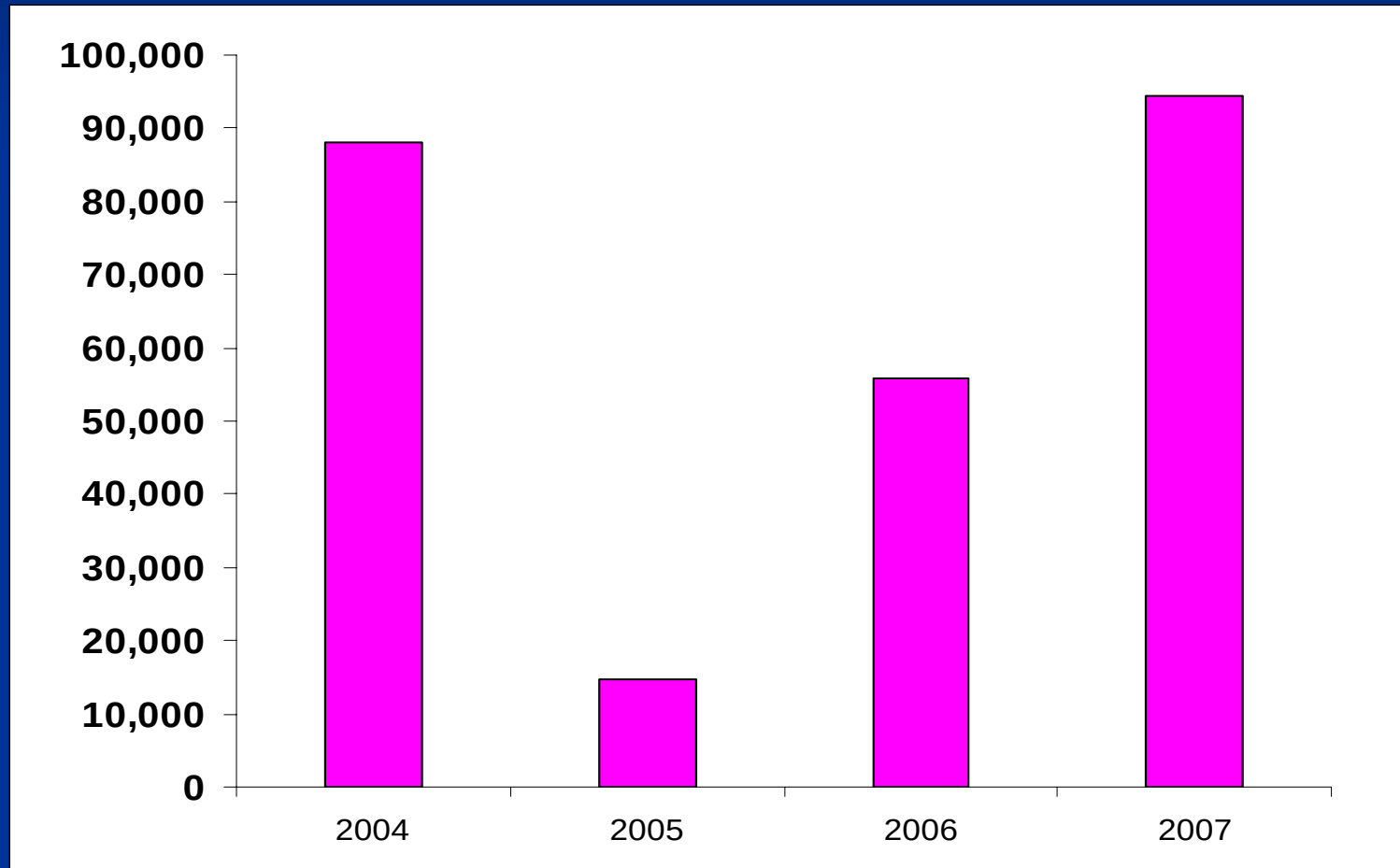


Total Trap Catches (8yrs)

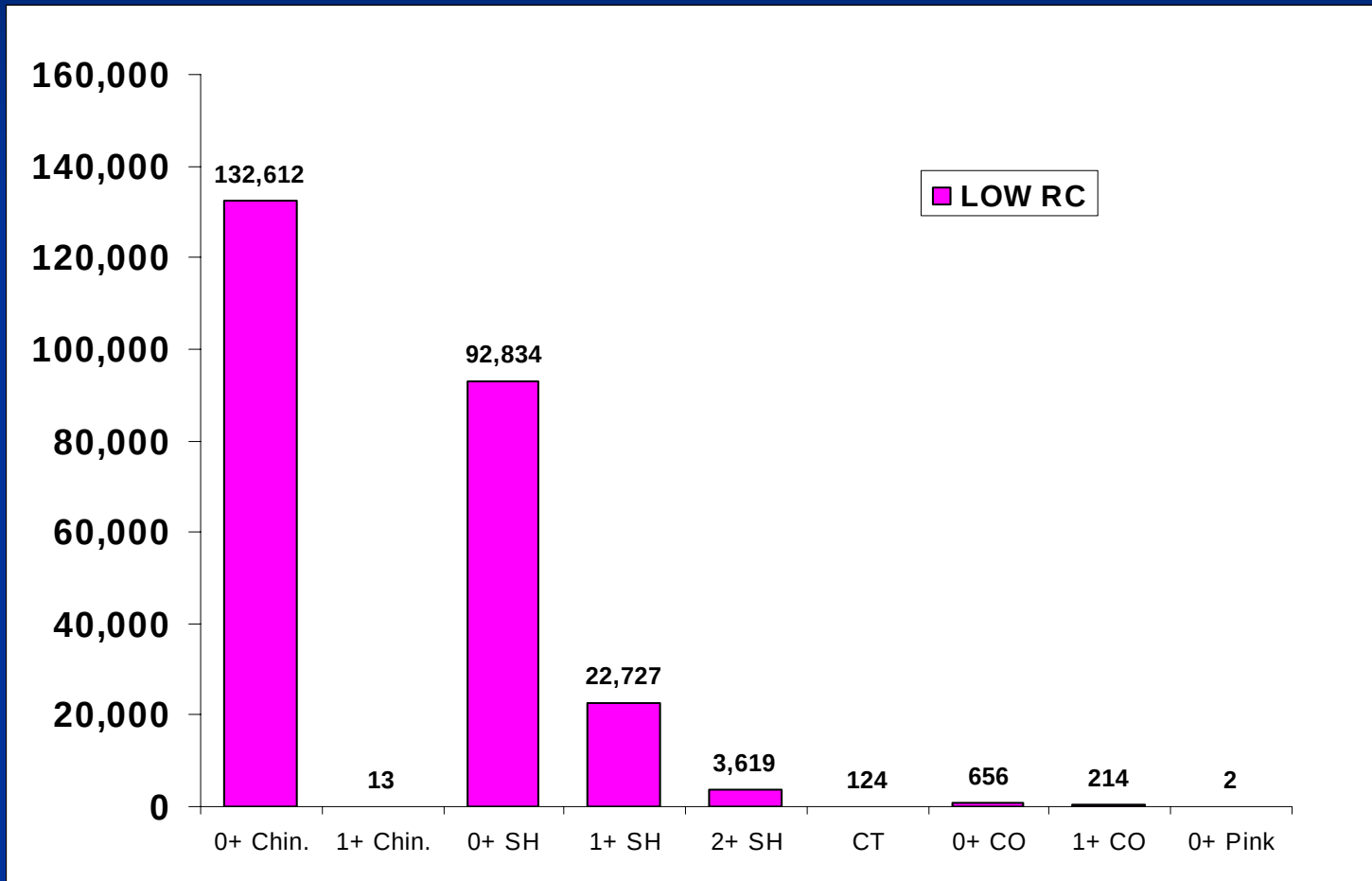


Trap Catches (lower Redwood Cr)

4 YR Total = 252,801 Avg. = 63,200



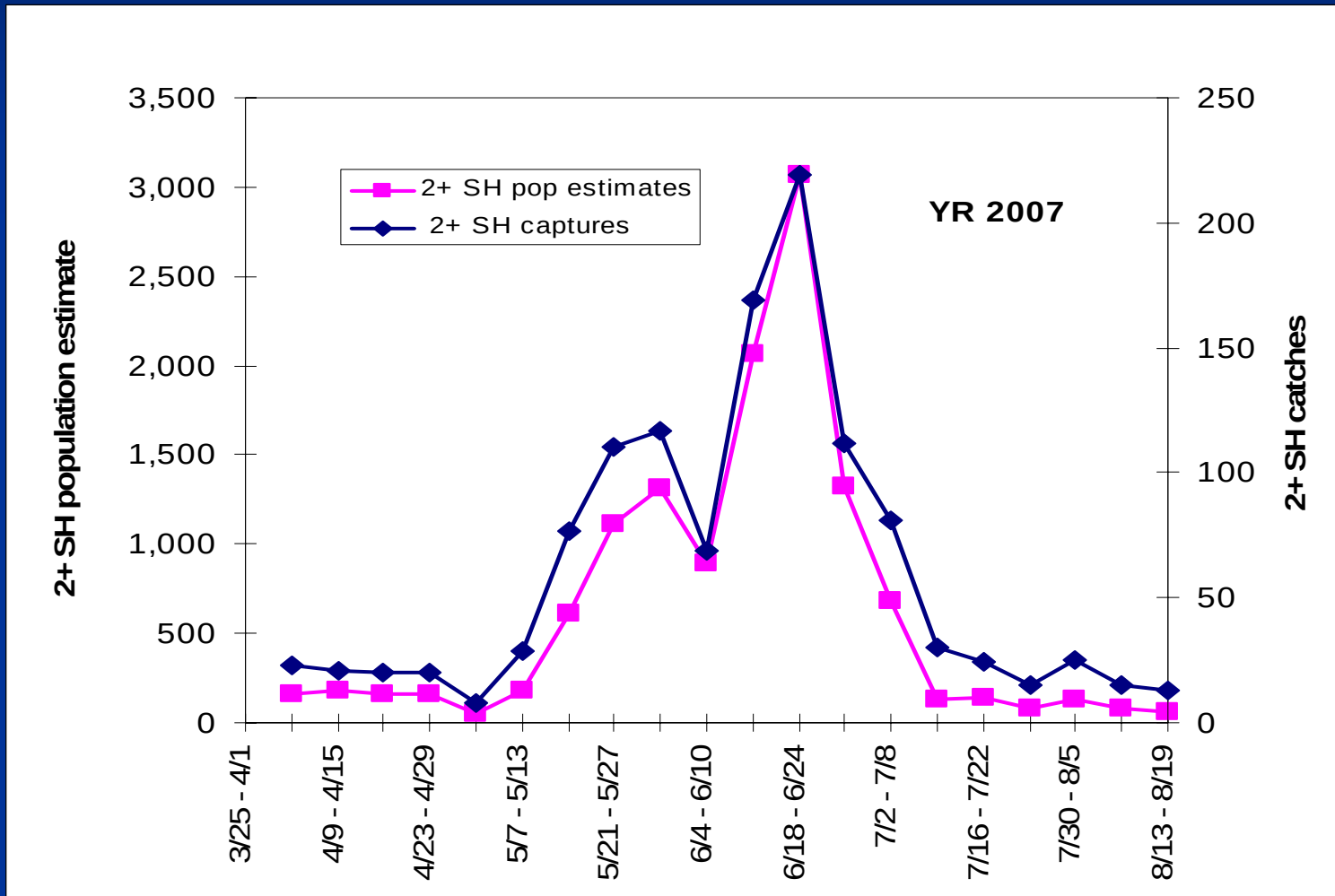
Total Trap Catches (4 yrs)



Trapping Mortality (%)

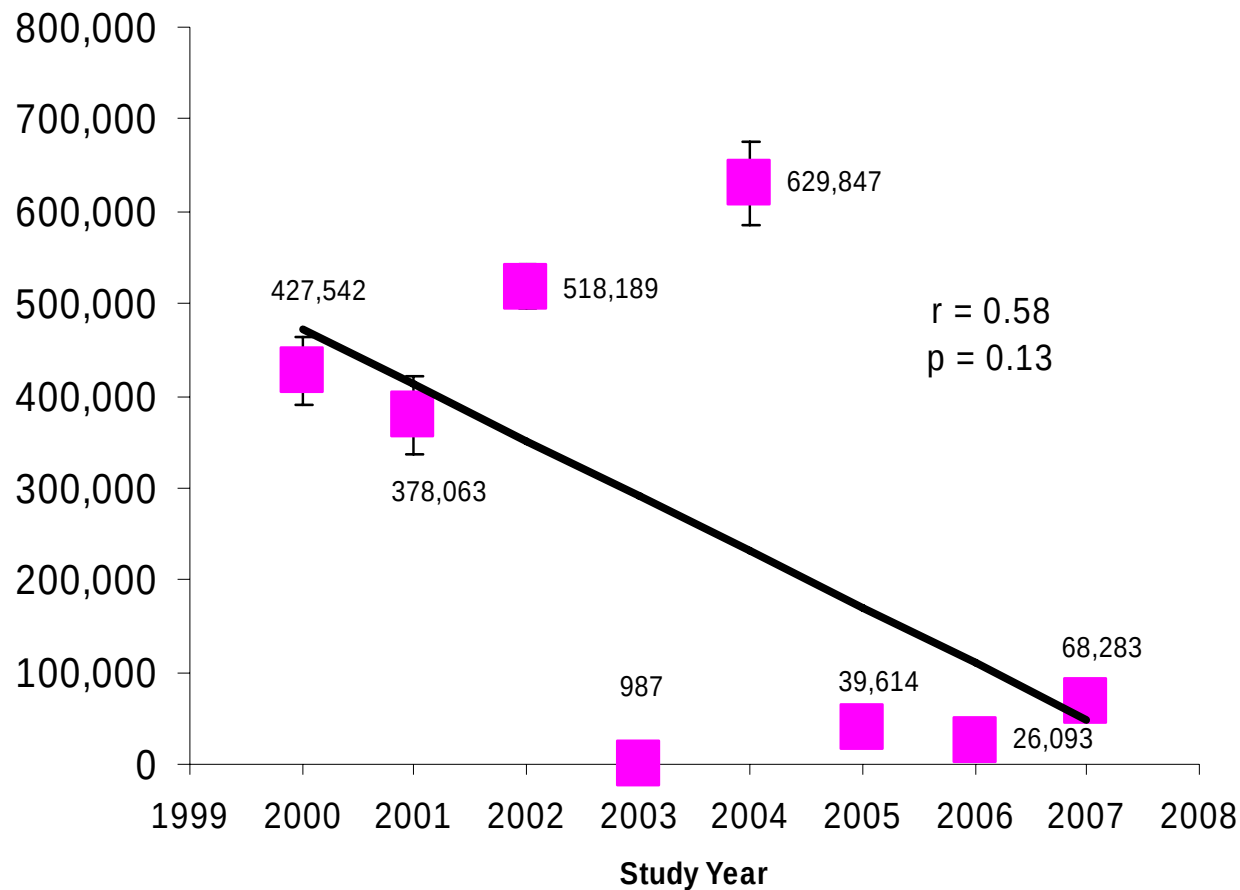
	Upper Trap	Lower Trap
2000	0.49	-
2001	0.68	-
2002	0.41	-
2003	0.32	-
2004	0.34	0.19
2005	0.65	1.00
2006	0.23	0.17
2007	0.22	0.06
Avg.	0.42%	0.36%

2+ Steelhead Trout (Low. RC)

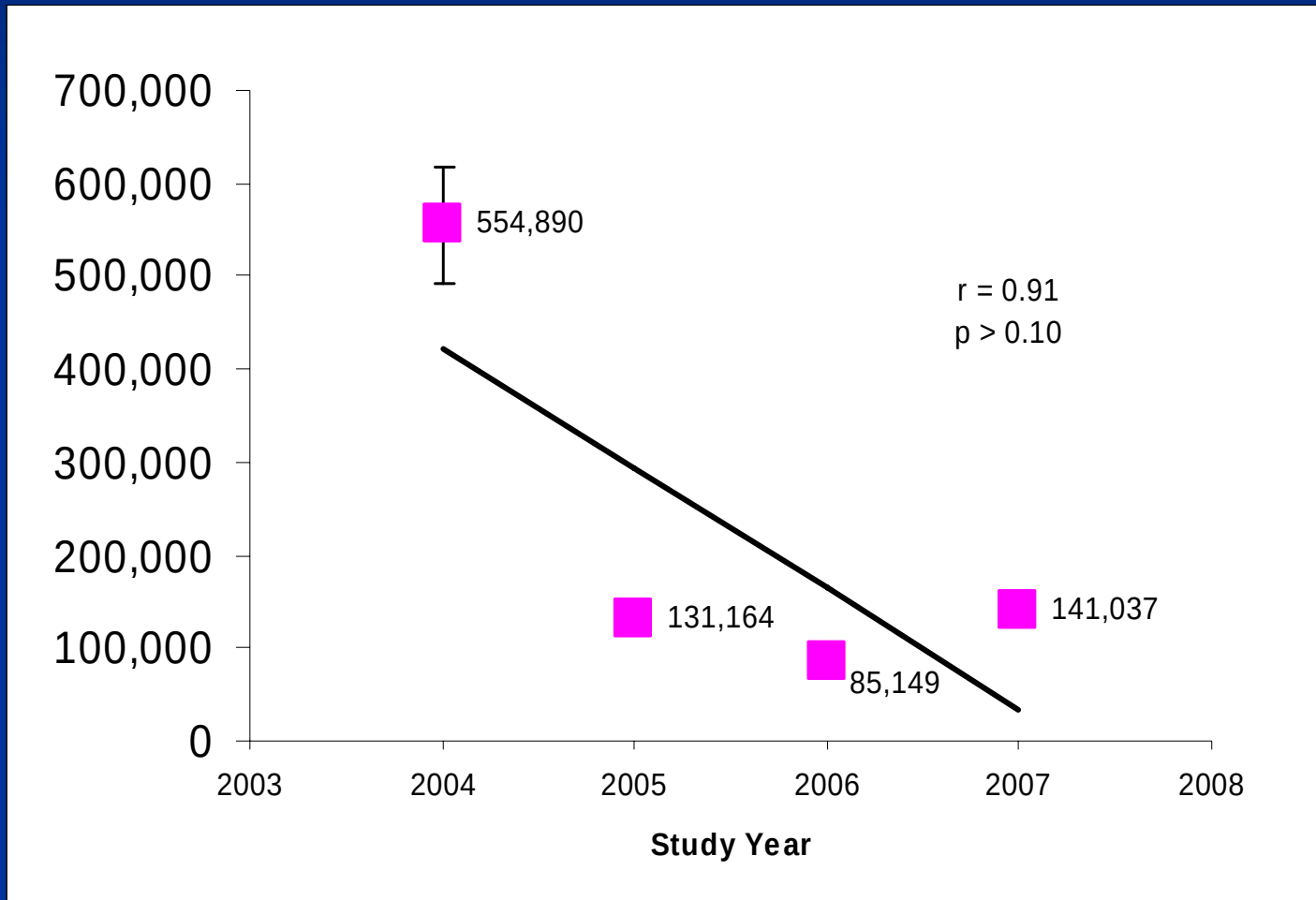


Chinook Salmon

Population of Juvenile Chinook Salmon (upper RC)



Population of Juvenile Chinook Salmon (Lower RC)



Temporal Component (0+KS)

- Upper RC: **April** is the most important month, followed by May and June. Emigration is basically over by end of June.
- Lower RC: **June** is the most important month, followed by May and July. Emigration is over during August.

Why are Chinook declining in upper Redwood Cr?

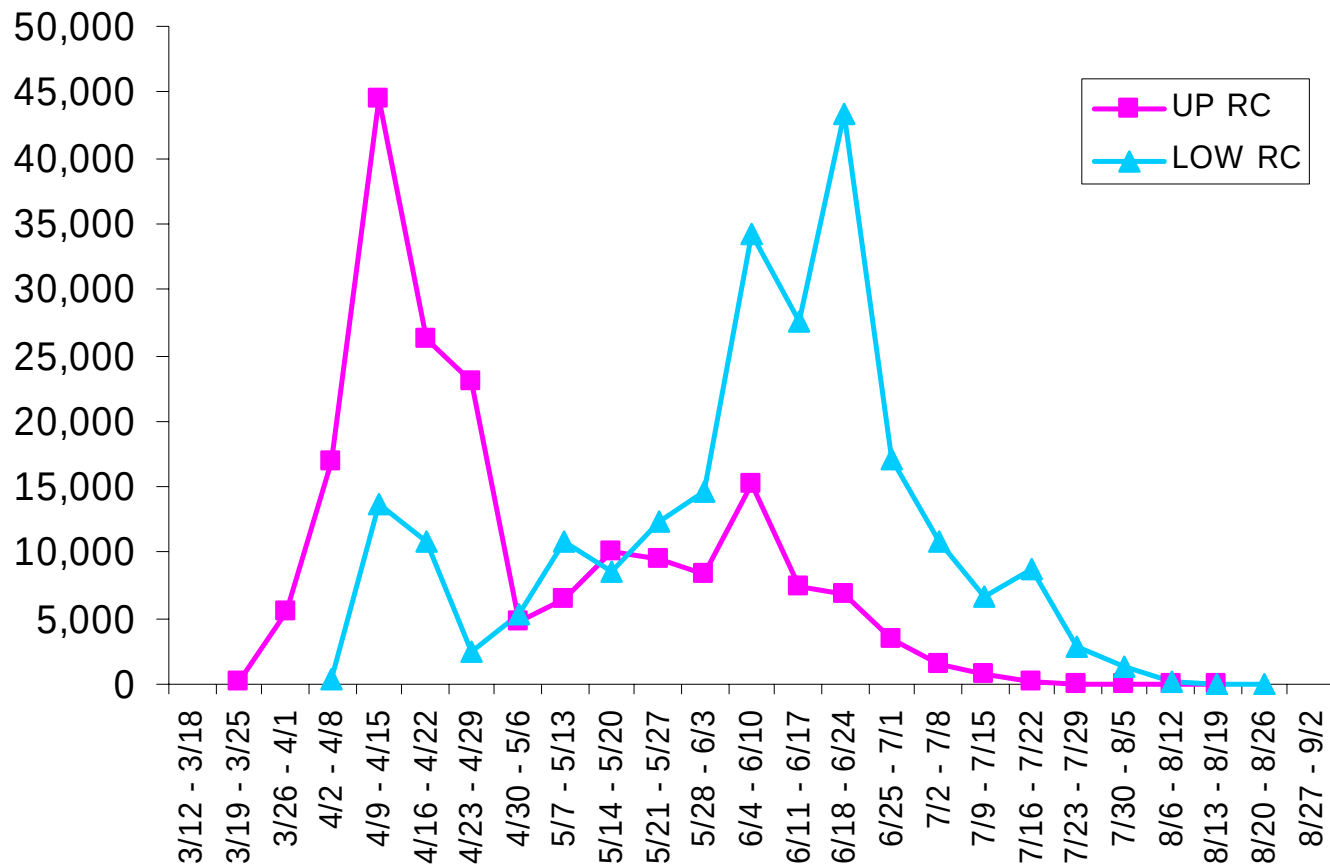
- High, flood type flows ($> 5,000$ cfs) in December – February can destroy the redds (nests) of adult Chinook Salmon in upper Redwood Creek (YRS 2003, 2005, 2006).
 - R^2 of linear regression for # smolts on flood or non flood flows = 0.52, was 0.92 prior to year 2007.
- Some years there are just less adults, so there will be less smolts (YR 2007).

Why the decline in Lower RC?

- Flood type flows ($\text{cfs} > 15,000$) in YR 2005 and YR 2006 scoured Chinook salmon redds.
- Some years there will be less returning adults, and therefore, less production of 0+ Chinook (YR 2007).
- Populations in lower Redwood Cr appear to be strongly influenced by population decrease in upper basin.

Pattern of Emigration

(Avg. wkly pop. size, YRS 2004-07)



Percentage of Fry in Populations

	Upper	Lower
2004	69.0	14.9
2005	58.0	1.6
2006	39.8	0.1
2007	46.3	2.7
Avg.	53.3	4.8

- High percentage of fry emigration from upper basin indicates stream habitat is important for adult spawning.
- Possible genetic component as to whether 0+ Chinook emigrate as fry or larger fingerlings.

- Average FL in upper Redwood Cr is not related to the percentage of fry (or fingerlings) in the population (regression, $p > 0.05$).
- Average FL is negatively related to population size in upper Redwood Cr.
 - Restoration activities / improved habitat may change this relationship such that we have relatively larger smolts even at higher population abundances.
- No statistical relations for lower Redwood Cr.

Steelhead Trout

The background of the slide is a solid dark blue. In the lower right quadrant, there are several light blue, wavy, horizontal lines that suggest the movement of water or the shape of a river. These lines are layered and have a soft, ethereal quality.

0+ Steelhead Trout (catch data)

■ Upper Trap:

- Large numbers emigrate each year (catch data: range from 41,671 – 128,885, Avg = 84,100).
- Make up 89% of total steelhead trout catches at upper trap.
- **Ratio of 0+ to older steelhead age classes averages 2:1**
- 0+ steelhead trout marked and released at upper trap were recaptured at lower trap* (29 mi distance) in YRS 2006 and 2007 (up to 12% recapture per group).

0+ Steelhead Trout (catch data)

■ Lower Trap:

- Far less emigrate through lower Redwood Cr compared to upper Redwood Cr.
- Emigration in lower Redwood Cr ranged from 1,345 – 42,890; Avg. = 23,209.
- Make up 78% of total steelhead trout catches.
- **Ratio of 0+ to older steelhead age classes averaged 1:3**

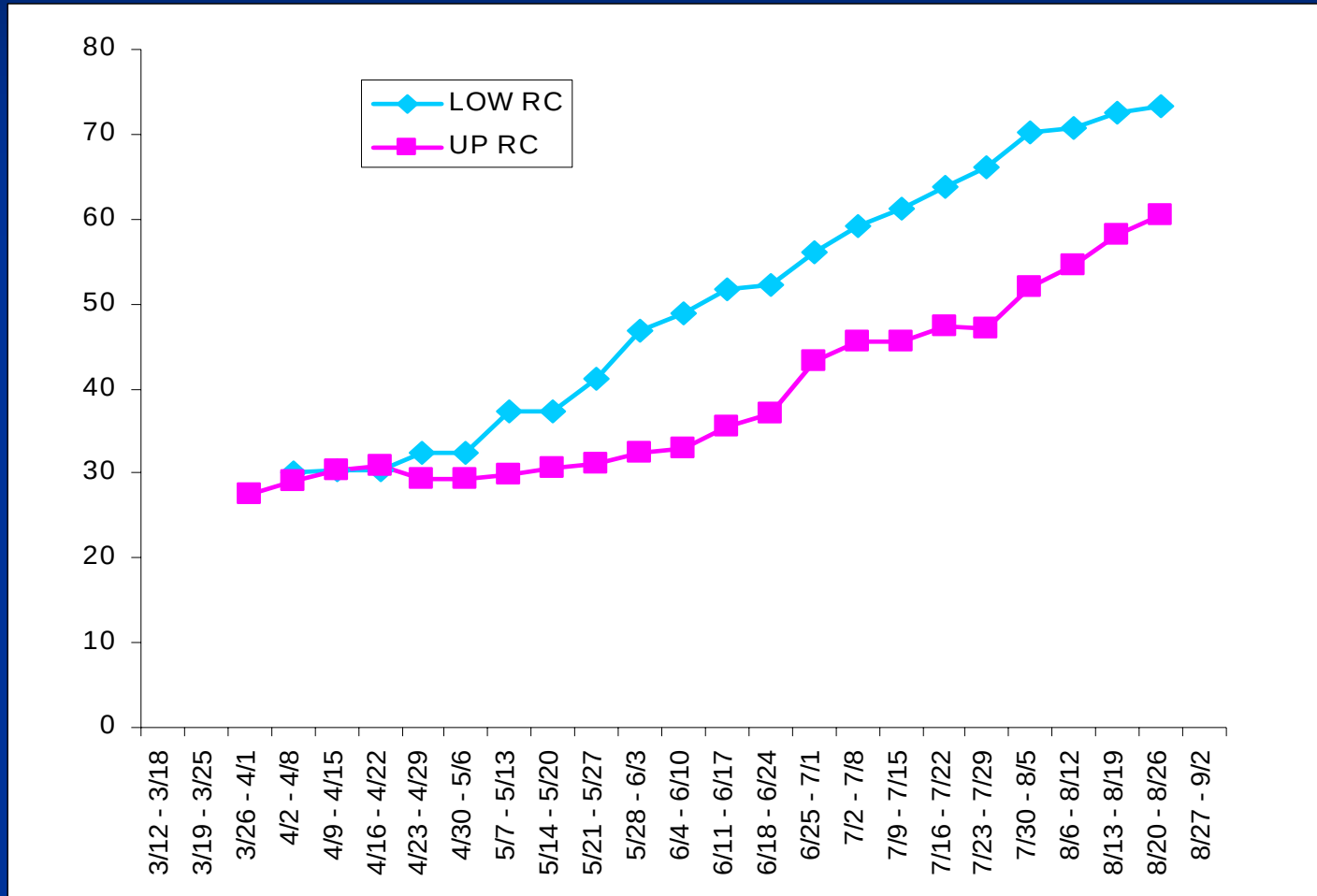
What does this indicate?

- Upper Redwood Cr is very important for adult steelhead trout spawning.
- Dispersal may indicate rearing habitat is marginal or carrying capacity has been met.
 - However, we see emigration even with low total catches, and when the stream has ample space for rearing (May).
 - Streams with much better habitat (ie Prairie Cr) have 0+ emigration, but not to this degree.

- High dispersal in upper Redwood Cr may limit the production of older age classes (1+, 2+).
 - If habitat conditions improve, these young of year fish may stick around to rear, which would increase the numbers of older juvenile steelhead trout in the following years.
- Dispersal is an often overlooked life history variation for 0+SH.
 - Normal to some degree.
 - Could have a genetic component.
 - Adaptation to environment.
- Mark/release experiments showed 0+ steelhead may travel considerable distances in search of rearing areas, and those that leave do not necessarily die.

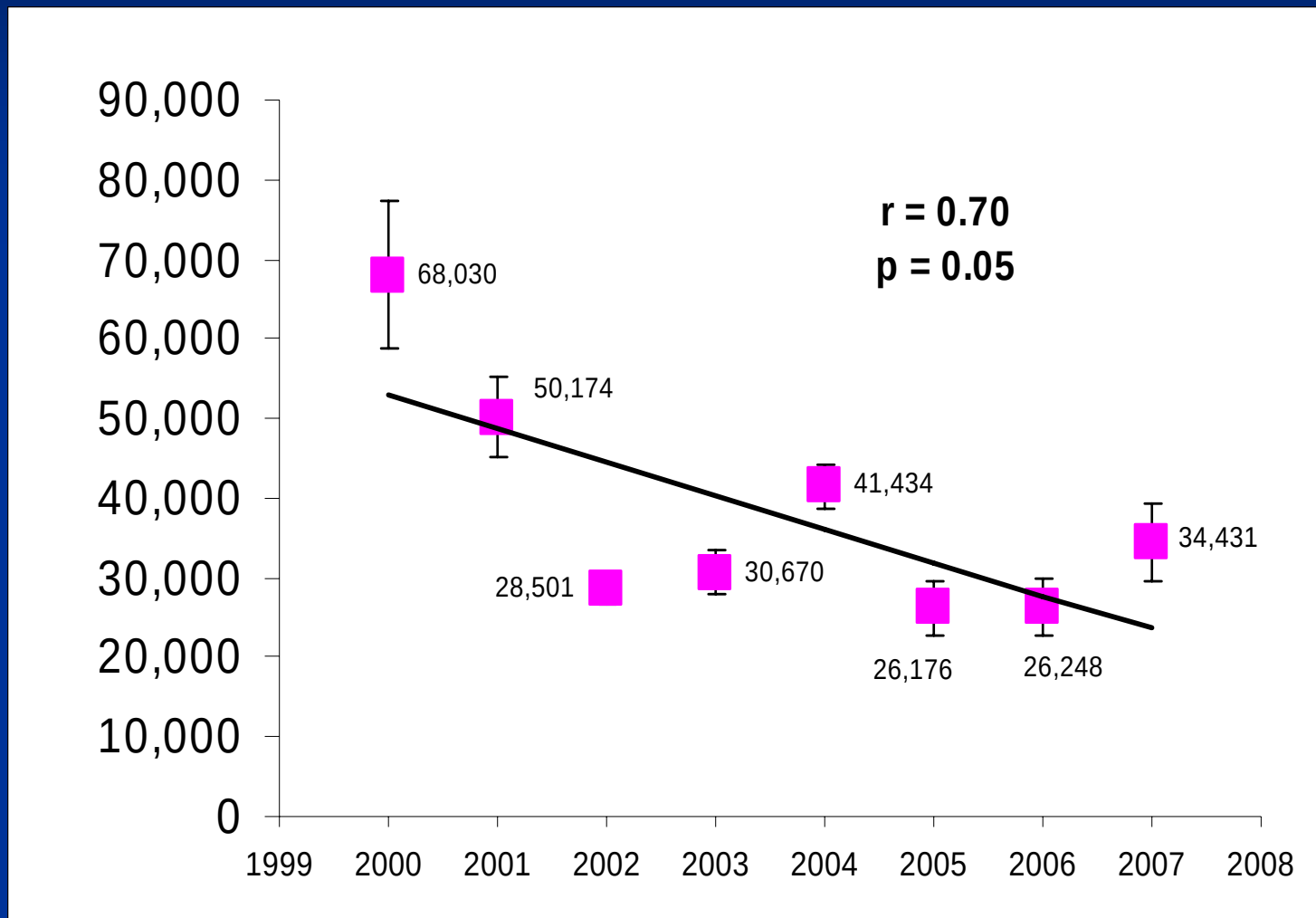
- Lower Redwood Cr and the estuary are important areas for 0+ steelhead to rear.
- By the time juvenile steelhead reach lower Redwood Cr, most juvenile steelhead are older than 0+.
 - > survival with size and age

0+ Steelhead Avg. FL (mm)

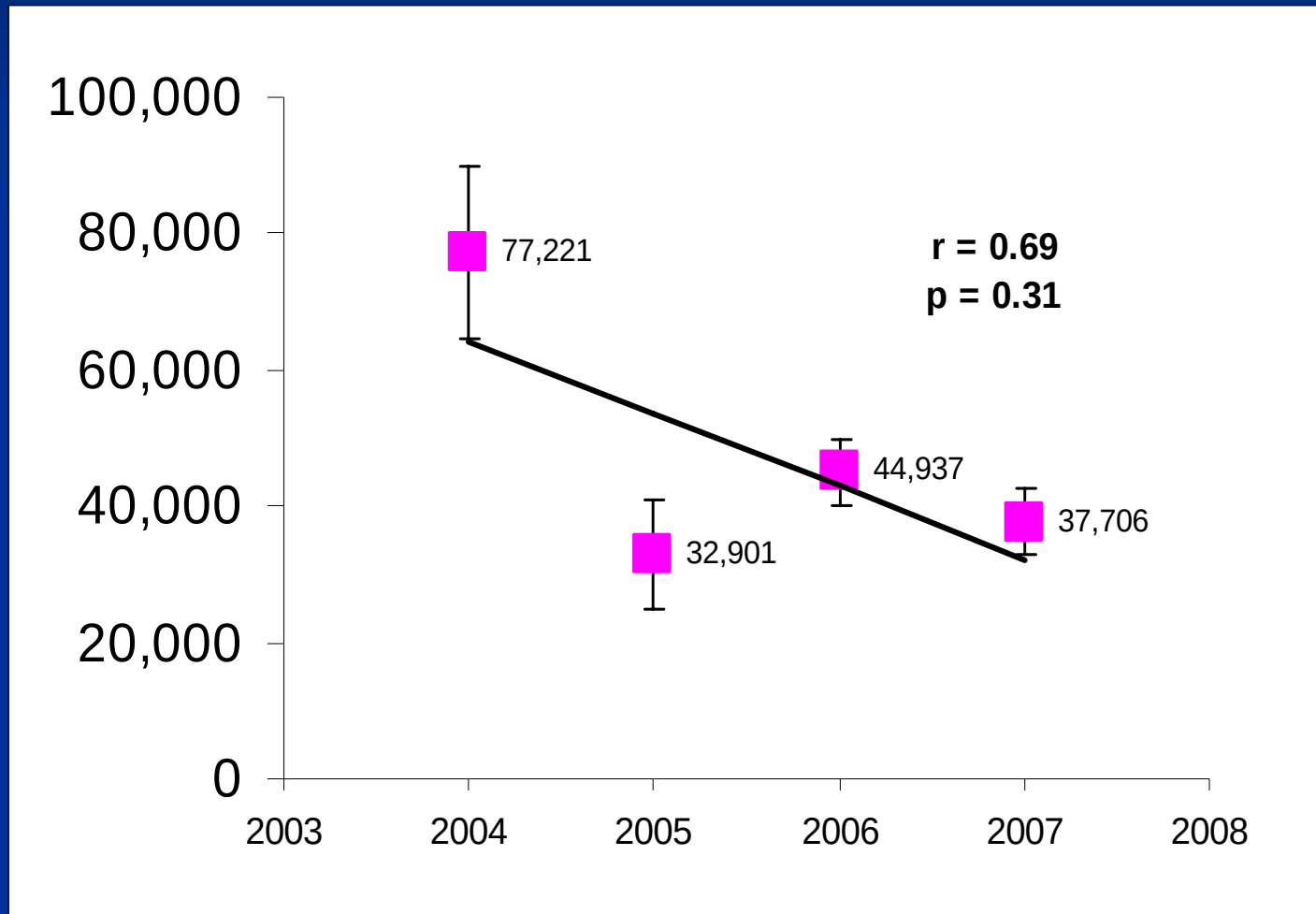


1+ Steelhead Trout

1+ Steelhead Pop. Abund. (Up. RC)



1+ Steelhead Pop. Abund. (Low. RC)



Temporal Component (1+SH)

- Upper RC: **May** is most important month, followed by April and June.
- Lower RC: **June** is most important month, followed by May and July.

Why are 1+ Steelhead Declining?

■ Upper RC

- Large emigration of 0+ steelhead can limit the production of older age classes.
- Habitat impairment (Cumulative effects) and decrease in quality of rearing habitat.
 - Loss of old growth riparian.
 - High summer stream temperatures (max. of 80+ ° F ea. yr).
 - Sedimentation of stream (decreases in pool depths, > temperatures).
 - Lack of large woody debris.
 - Lack of alcoves and backwaters (during winter).

Why 1+ SH are declining, cont'd.

■ Lower Redwood Cr:

- Habitat impairment.
- Populations appear to be strongly influenced by population decrease in upper basin.

- If restoration efforts improve stream habitat, less 0+ SH should emigrate downstream, which should increase production of 1+SH.
- Improved stream conditions will lead to better summer rearing habitat, which should increase survival from 0+ SH to 1+ SH.
- Improved stream conditions may improve over-winter habitat, which would increase over-winter survival.

Ratio of 1+SH to 2+SH

- Upper RC (8 yr avg.): 1+ to 2+ ratio equaled 10:1
- Lower RC (4 yr avg.): ratio averaged 4:1, and was 4:1 each study year.
- Unfortunately, most (70%) of the returning adult steelhead spent 2 yrs in freshwater.

Reasons for 1+ SH smolt emigration

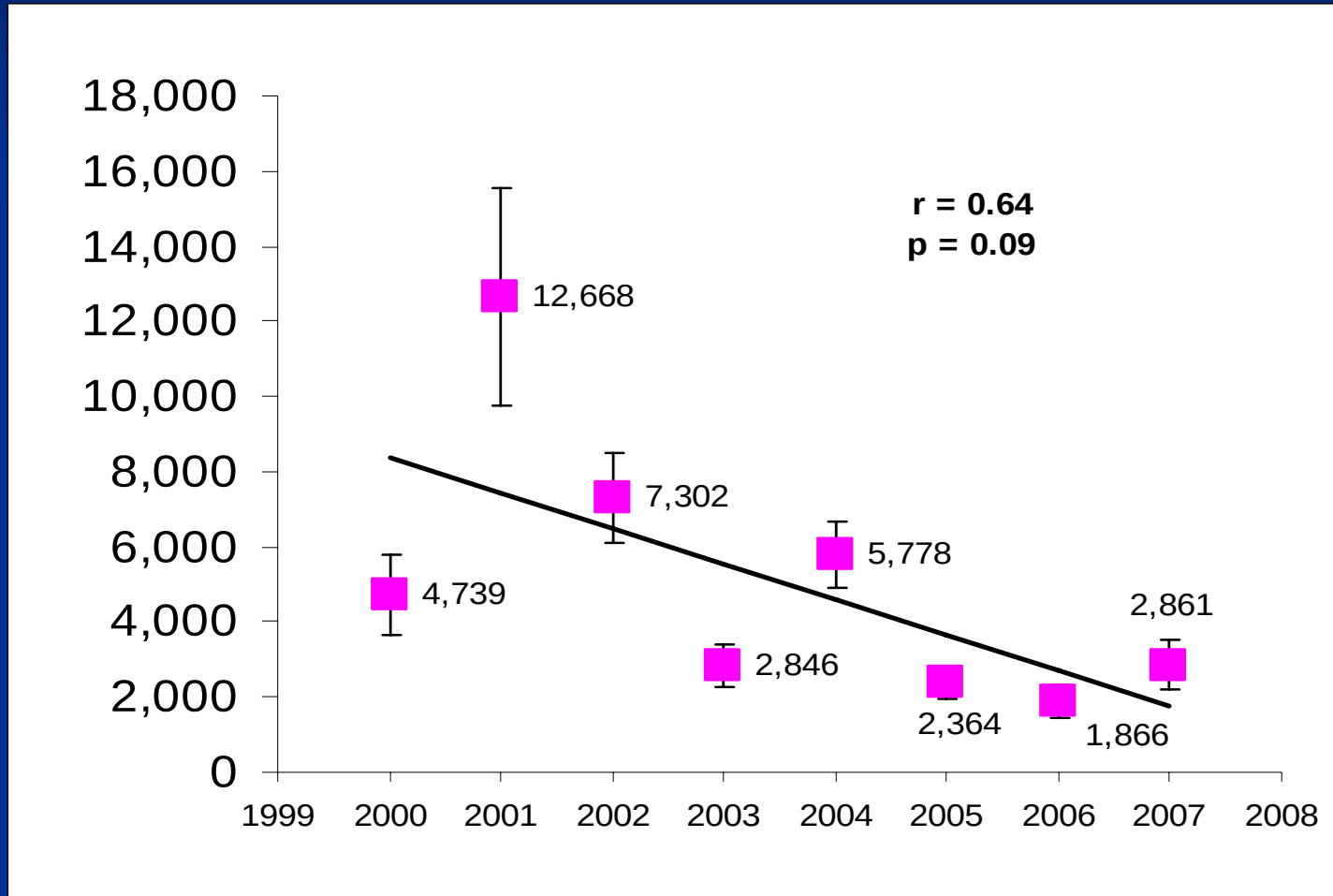
- Normal life history variation: Many streams have 1+ SH emigrate downstream (Mad R, Prairie Cr, etc) but not to the degree we see in Redwood Cr.
- Could be due to marginal stream habitat for rearing*.
- Could be a genetic difference between 1+ and 2+ steelhead trout smolts.
- The estuary is an important place for 1+ SH to finish rearing prior to ocean entry.

2+ Steelhead Trout

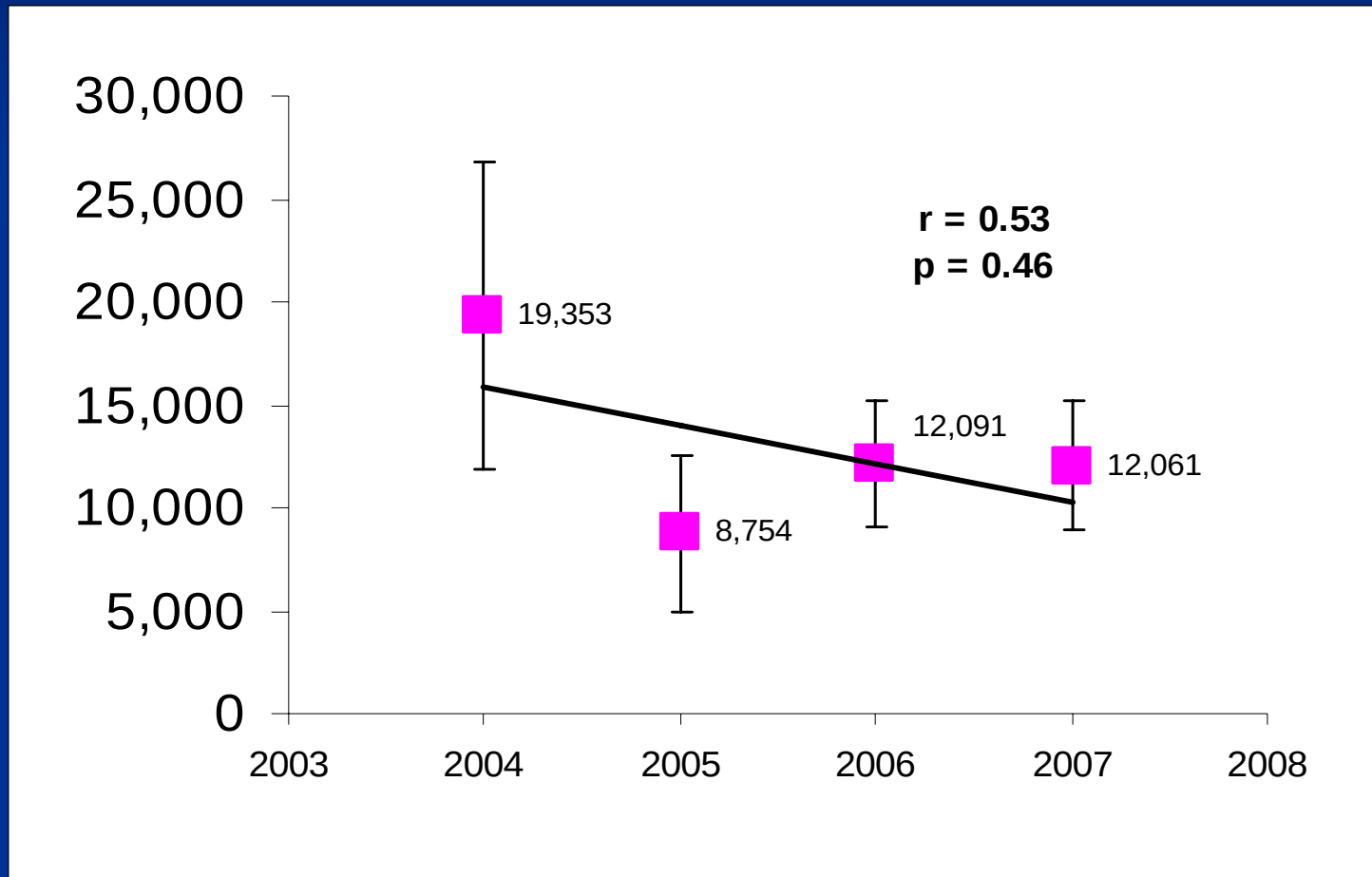
Watershed Indicator

- 2+ SH have successfully over-summered twice, and over-wintered twice prior to ocean entry; they spend more time in freshwater habitat than other juvenile salmonids (except for some Cutthroat Trout).
- Better at testing restoration actions because numbers are less variable than younger age classes (Keogh River, BC; 20+ YR long Steelhead Trout study).
- Most direct recruit to adult steelhead trout, yet they are the least numerous juvenile steelhead in Redwood Cr.
- Have higher smolt to adult survival than younger age classes.

2+ Steelhead Pop. Abund. (Up. RC)



2+ Steelhead Pop. Abund. (Low. RC)



Temporal Component (2+SH)

- Upper RC: **April** is usually the most important month, followed by May and June.
- Lower RC: **May** is the most important month, followed by June and April.

Why are 2+ Steelhead Declining?

■ Upper RC:

- Similar to 1+SH (large emigration of 0+SH).
- Large emigration of 1+ steelhead the previous year can limit the production of 2+ steelhead the following year.
- Habitat impairment (Cumulative effects).
 - Loss of old growth riparian.
 - High summer stream temperatures (max. of 80+ F° ea. yr).
 - Sedimentation of stream (decreases in pool depths, > temperatures).
 - Lack of large woody debris.
 - Lack of alcoves and backwaters (during winter) that serve as refugia.

Why 2+ SH are declining, cont'd.

■ Lower Redwood Cr:

- Large emigration of 1+ steelhead the previous year can limit the production of 2+ steelhead the following year.
- Habitat/watershed impairment.
 - Sedimentation of stream.
 - Decreases in pool depths.
 - Stream temperature
- Populations appear to be influenced by population decrease in upper basin.

- If restoration efforts improve stream habitat, less 1+ SH should emigrate downstream, which should increase production of 2+SH; assumes that 1+SH emigration is not genetically determined.
- Improved stream conditions will lead to better summer rearing habitat, which should increase survival from 1+ SH to 2+ SH.
- Improved stream conditions may improve over-winter habitat (> in refugia), which would increase over-winter survival.

Cutthroat Trout

The background of the slide is a solid dark blue. In the lower right quadrant, there are several light blue, wavy, horizontal lines that suggest the movement of water or a river current. These lines are layered and have a soft, ethereal quality.

Cutthroat Trout Trap Catches

- Upper RC:
 - Very few emigrate from upper Redwood Cr based on catches (Avg. 4/yr; ranged from 1 – 9 per/yr).
 - All were in a 'smolt' stage.
 - Too few to determine population estimates.

Cutthroat Trout

■ Lower RC

- Higher abundance than upper RC, but still low.
- Can emigrate during any month of trap operation.
- (Avg. 31 per yr; ranged from 9 - 42).
- All were in a 'smolt' stage.
- Larger in size than CT's in upper Redwood Cr.
- Beginning in YR 2006, we conducted Mark/recapture trials to investigate population size.

CT Pop. Abund. Low RC

- Avg. weekly efficiency for CT's in YR 2006 was 27%.
- Population estimate in YR 2006 equaled 97 individuals.
- YR 2007: slightly higher abundance, data needs to be entered into model.

Coho Salmon

Coho: Upper Redwood Cr

- Historically were present in upper Redwood Cr according to long-time residents in Redwood Valley (Bill Chezum, Marlin Stover).
- 1 adult was seen during a spawning survey in YR 2001.
- Juveniles were seen at mouth of Minor Cr during summer steelhead dives in 1997.

Coho: Up RC cont'd.

- In YR 2007, we captured six 0+ Coho for the first time in eight consecutive years.
 - May, June, and July.
 - We captured two 0+ Coho on April 6, 2008, and one on April 13, 2008.
- The big question is whether we will find 1+ coho salmon smolts in YR 2008.

Coho: Lower Redwood Cr

- 0+ and 1+ coho salmon pass through lower Redwood Cr each year.
- Low numbers are captured.
- We started mark/recapture on 0+ Coho beginning in YR 2006.
- We have determined population estimates for 1+ coho salmon each study year (2004 - 07).

0+ CO Lower RC

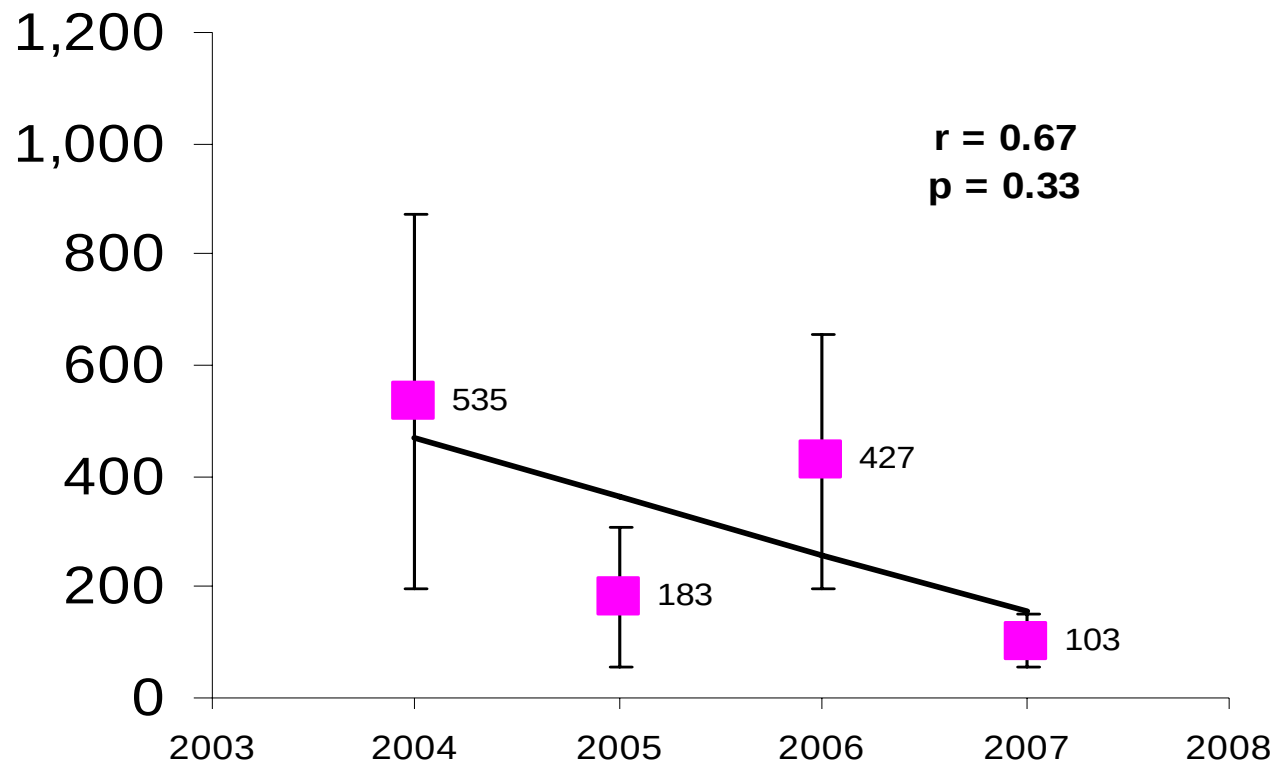
YR	Catch	Population
2004	202	
2005	53	
2006	108	508
2007	293	1,057

Inference on 0+ Coho

- Although not many 0+ coho salmon are passing through lower Redwood Cr (upstream of confluence with Prairie Cr), the fact that some are indicates that lower Redwood Cr and the estuary are important areas for rearing.

1+ Coho Salmon

1+ Coho Pop. Lower RC



Why the decline?

- 1+ Coho population estimates are limited by small sample sizes for marking, and should be viewed as being less than the 95% UCL (upper confidence level).
- Each year the population was less than 1,000 individuals, which is very low.
- April and May are when they migrate downstream.
- Will take more years to better understand population abundance.

Travel Time / Growth

Travel Time / Growth

- Experiments began in YR 2005.
- 11.5 mm pit tags are used.
- 0+ Chinook salmon, 1+ steelhead trout, and 2+ steelhead trout are marked and released in upper Redwood Cr and recaptured in lower Redwood Cr (distance of 29 mi), or estuary by David Anderson et al. (RNP Fish Biologist and crew).
 - We use surgical scalpel to make incision, and then apply pit tag by hand.
 - Fish must have FL > 65 mm to minimize tag effect on growth.
 - Fish are given a partial fin clip as a secondary mark.
 - Fish are held from 34 – 48 hrs prior to release to assess delayed mortality and tag loss.

0+ Chinook w/ pit tag



Travel Time / Growth

- No Tag loss.
- No delayed mortality over 3 years, but an infrequent immediate mortality in YR 2007.
 - For example, in YR 2007 immediate mortality was 5 out of 696 tagged, or 0.7%
 - Obvious when this happens.

0+ Chinook Salmon

Year	n =	Travel Time Range (d)	Averages			
			Travel Time (days)	Travel Rate (mi/d)	Δ FL (mm)	Abs. Growth Rate (mm/d)
2005	27	1.5 – 19.5	7.5	8.2	2.81	0.223
2006	28	2.5 – 20.5	8.0	5.5	2.79	0.242
2007	245	2.5 – 29.5	10.7	4.0	3.86	0.293
Avg.			8.7	5.9	3.04	0.253

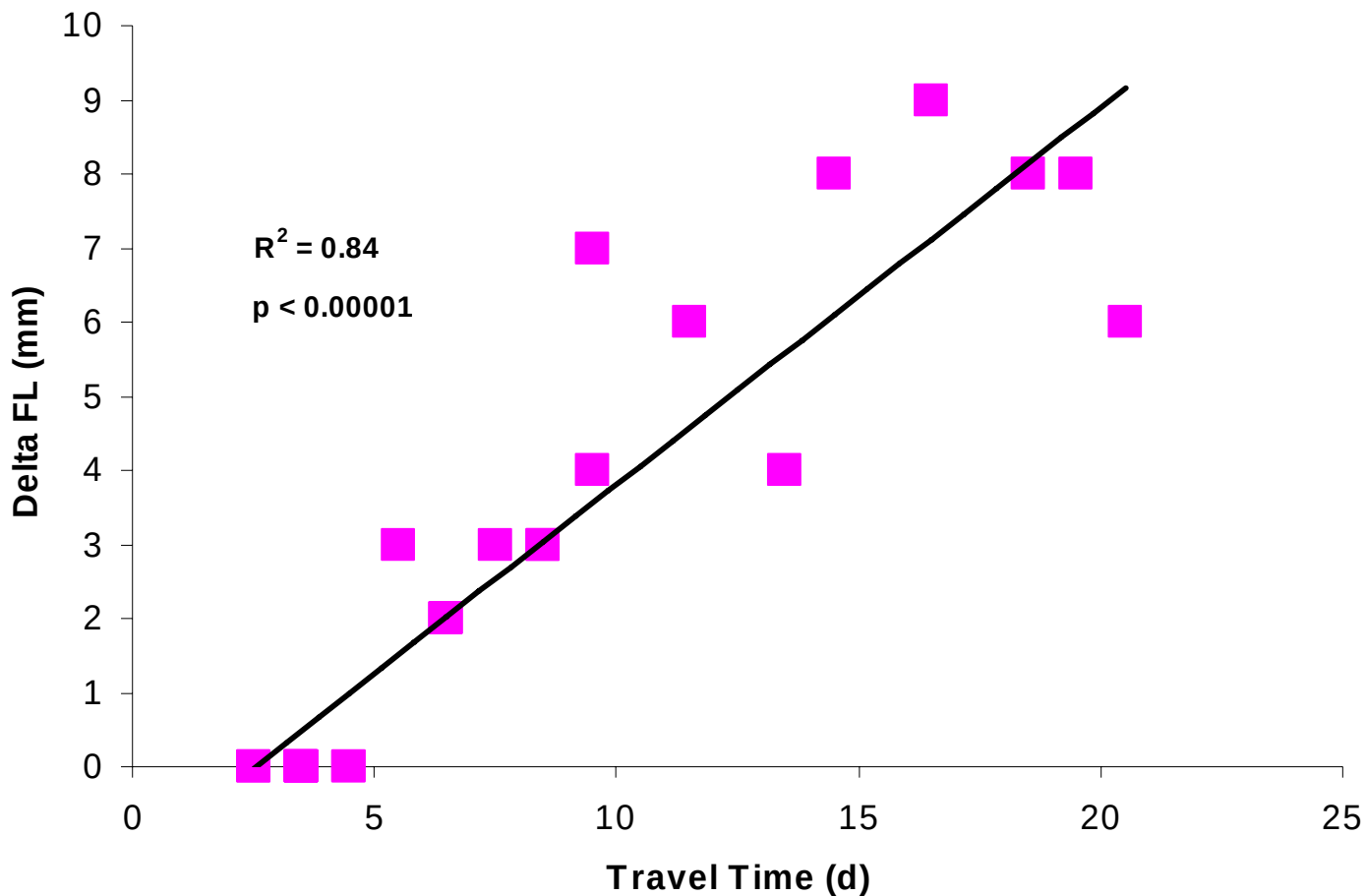
0+ Chinook

- Travel time: no statistical relationships with physical variables, or size of smolt (2005, 2006).
- Travel rate:
 - Positively related to FL at time 1.
 - Inversely related to average lunar phase.

0+ Chinook Growth

- Best explained by travel time (positive relation).
- Positively related to lunar phase.

0+ Chinook Growth



Working Hypotheses

- The slower Chinook move downstream, the more time spent feeding, and more time for growth.
 - Fish with zero growth usually get to the trap in 2.5 days.
- Travel time increases and travel rate decreases under higher moon illuminations.
 - Fish are spending more time feeding than migrating.
 - Therefore they also grow more.

1+ Steelhead Trout

- Take longer to travel downstream (avg. 20.9 d, YRS 2005 - 07) than 0+ Chinook (avg. 8.7 d).
- Travel rate averaged 3.78 mi/d.
 - Depending upon study year, travel rate is:
 - Positively related to FL at time 1 (release).
 - Positively related to average water temperature*.
 - Negatively related to lunar phase.

1+SH Growth

- Absolute Growth Rate (mm/d) averaged 0.33 mm/d for YRS 2005 - 07.
- Growth rate:
 - Best explained by travel time (positive relationship, $R^2 = 0.97$ in YR 2007).
 - Positively related to lunar phase.
 - Negatively related to stream temperature*.

Genetic Sampling (purpose)

- Build a genetic database for future comparisons.
- Chinook:
 - Fry vs. fingerling migrants.
 - Ocean type (common) vs. Stream Type (uncommon)
- Steelhead:
 - 1+ smolt vs. 2+ smolt.
 - Hatchery introgression into wild Redwood Cr populations.

Conclusions

- Our data supports the US EPA listing of Redwood Cr as temperature impaired.
- Although our data indicates stream habitat is still impaired, there is no doubt that the habitat is much better than what existed immediately after the 1964 flood event.
 - However, the rearing environment is most likely limiting older age class survival (Steelhead Trout).
 - The bottleneck to adult steelhead populations is most likely the low number of 2+ steelhead trout smolts.

Conclusions cont'd.

- Our data also supports the federal listing of Chinook Salmon, Coho Salmon, and Steelhead Trout as 'threatened' under the Endangered Species Act.
- Given the concern and efforts to rehabilitate Redwood Cr, we need to keep this monitoring project intact and funded, to show if populations:
 - Will reverse the negative trends we are seeing.
 - Respond favorably to habitat improvements via watershed restoration.

Two trap design

- Allows for a more detailed study of Redwood Cr and juvenile salmonid life histories.
- Can allow for partitioning populations within the basin (upper vs. lower).
- Allows for using pit tag data to study smolt growth and migration within Redwood Cr.*
- Better for detecting watershed restoration efforts (upper basin restoration vs. middle or lower basin restoration).

Future

Information on Adults

- Adult counts could be made using DIDSON (ultra sound video camera).
 - Would allow for smolt to adult information.
 - Would increase our understanding of population dynamics.
- Next fall/winter, we are going to survey 'high use' adult spawning areas in Redwood Valley, which may index adult populations.

