Retrospective Analysis of a Natural-Origin Steelhead Population's Response to Exclusion of Hatchery Fish

March 8, 2016

2:10 PM

PSMFC Steelhead Management Meeting

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North Coast Salmon & Steelhead Enhancement Fund

PGE

Hatchery Risks

Genetic
- -Diversity
- -Domestication
- -Inbreeding Depression

Ecological
- -Predation
- -Competition
- -Disease

Facility
- -Water Quality
- -Fish Passage
- -Intake Screening

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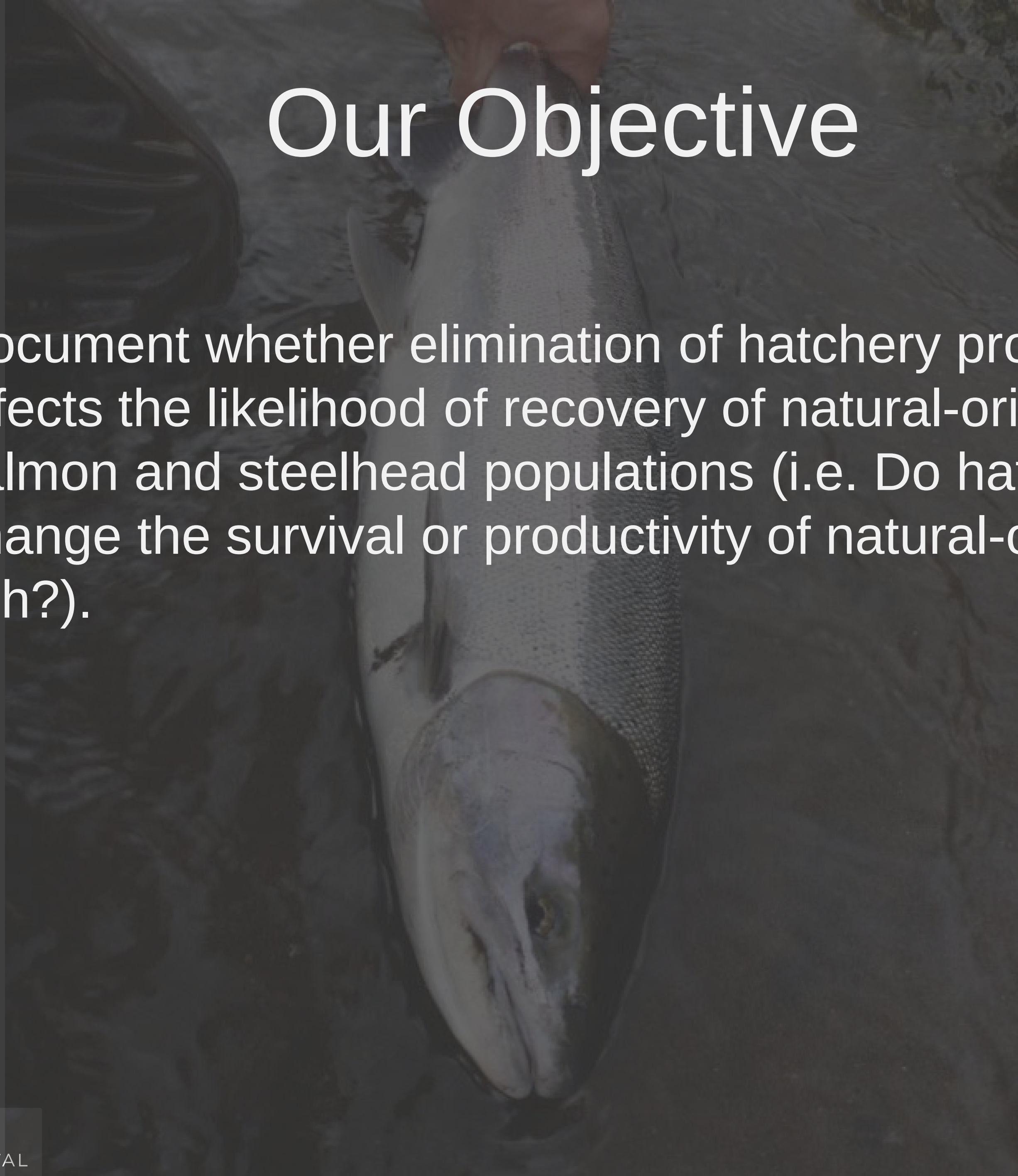
Our Objective

- Document whether elimination of hatchery programs effects the likelihood of recovery of natural-origin salmon and steelhead populations (i.e. Do hatcheries change the survival or productivity of natural-origin fish?).



Possible Effects Mechanisms

Negative	No Effect
Reisenbichler & McIntyre 1977	Collins *et al.* 2000
Chilcote *et al.* 1986	Hess *et al.* 2012
Nickelson *et al.* 1986	
Leider *et al*. 1990	
Johnsson & Abrahams 1991	
Fleming & Gross 1993	
Berejikian 1995	
Berejikian *et al.* 1996	
Berejikian *et al*. 1997	
Currens *et al.* 1997	
Reisenbichler & Rubin 1999	
Berejikian *et al*. 2001	
Lynch and O'Hely 2001	
Kostow *et al*. 2003	
Kostow 2004	
Goodman 2005	
Oosterhout *et al.* 2005	
Knudsen *et al*. 2006	
Araki *et al.* 2007	
Fritts et al. 2007	
Pearsons *et al.* 2007	
Araki *et al*. 2008	
Schroder *et al*. 2008	
Dittman *et al.* 2010	
Williamson *et al*. 2010	
Berntson *et al.* 2011	
Theriault *et al*. 2011	
Christie *et al.* 2012 a	
Christie *et al.* 2012 b	
Ford *et al.* 2012	
Satake and Araki 2012	
Milot *et al.* 2013	
Bingham *et al.* 2014	

Direct Tests for Effects

Negative	Positive	No Effect
Levin *et al.* 2001	Sharma *et al.* 2006	McClure *et al*. 2003
Levin & Williams 2002	Berejikian *et al.* 2008	Narum *et al*. 2006
Chilcote 2003	Winship *et al*. 2014	Van Doornik *et al.* 2010
Nickelson 2003	Scheuerell *et al.* 2015	Matala and Narum 2012
Kostow and Zhou 2006		Lister 2014
Buhle *et al.* 2009		Small *et al.* 2014
Chilcote *et al.* 2011		Smith *et al*. 2014
		Fast *et al.* 2015

"Although many ecological mechanisms of impact have been demonstrated (e.g. hatchery fish eating wild fish), few studies have been published that evaluate the impacts of a production scale hatchery in natural environments (e.g., percent of population consumed, or decrease in abundance)."

-Pearsons (2008)

Direct tests for hatchery effects

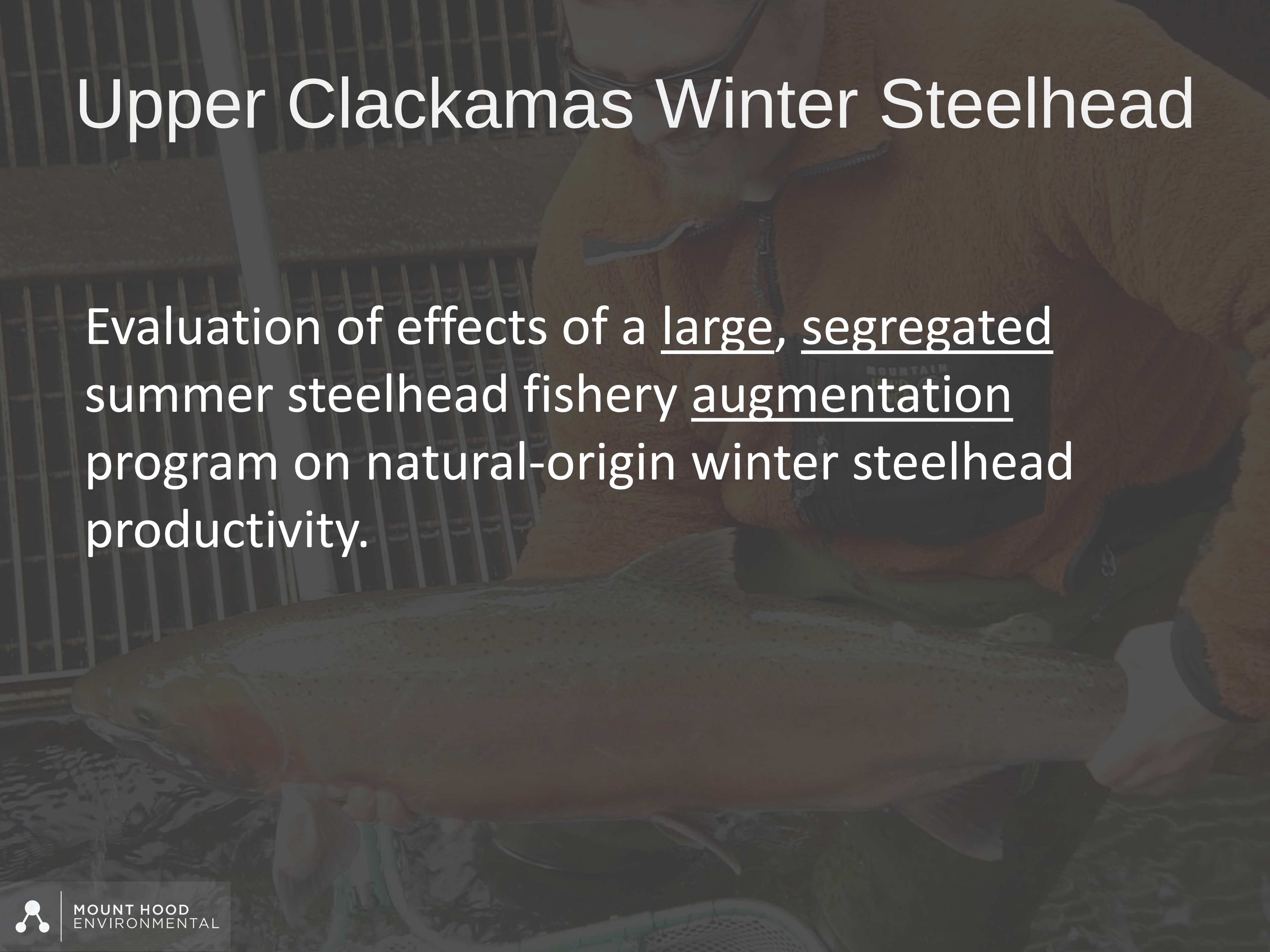
<u>Attributes of an ideal study of hatchery fish effects:</u>

-Complete fish census data

-Includes reference populations

-Minimal data manipulation

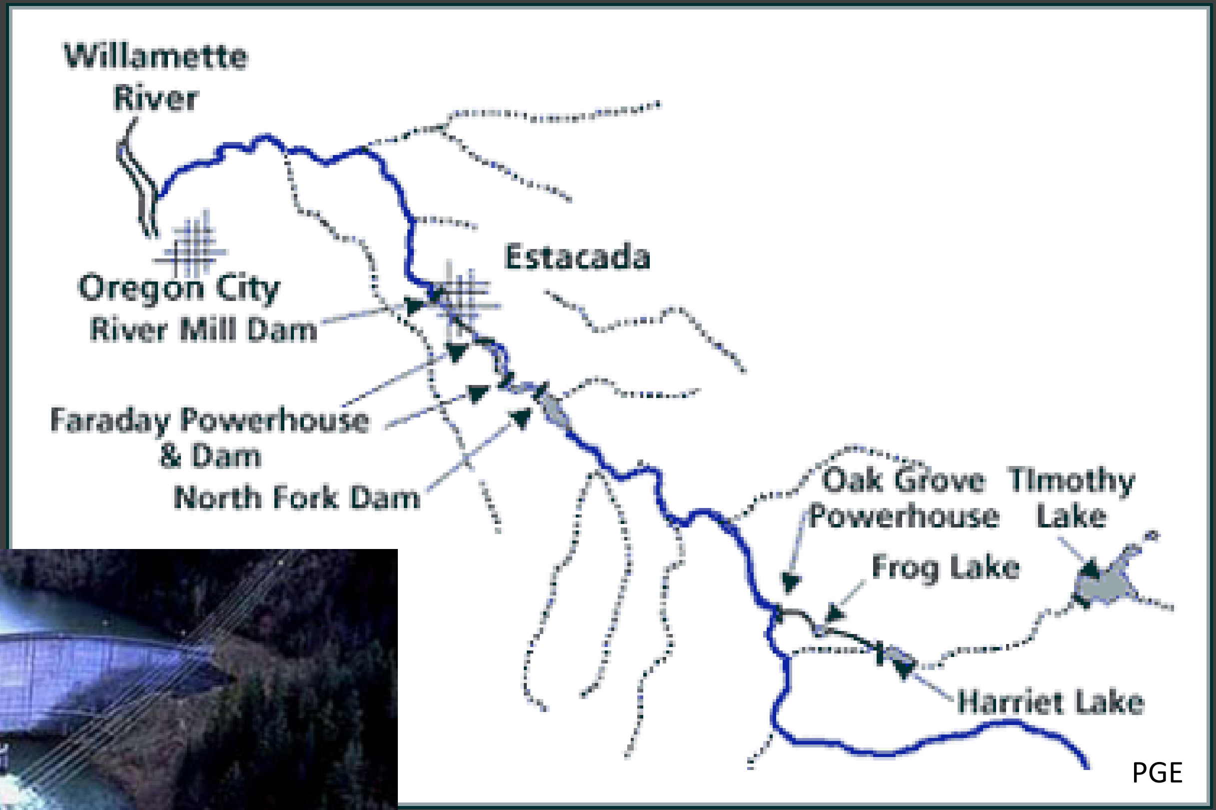
-Known influence of hatchery spawners on population productivity



Upper Clackamas Winter Steelhead

Evaluation of effects of a large, segregated summer steelhead fishery augmentation program on natural-origin winter steelhead productivity.

Why the Clackamas



Why the Clackamas

Transactions of the American Fisheries Society 135:825–841, 2006

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[Article]

The Effect of an Introduced Summer Steelhead Hatchery Stock on the Productivity of a Wild Winter Steelhead Population

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Abstract.—We investigated the effect of a hatchery program for summer steelhead *Oncorhynchus mykiss* on the productivity of a wild winter steelhead population in the Clackamas River, Oregon. We used a suite of Ricker and Beverton–Holt stock–recruitment models that incorporated species interaction variables to demonstrate that when high numbers of hatchery summer steelhead adults were present the production of wild winter steelhead smolts and adults was significantly decreased. We found that large releases of hatchery smolts also contributed to the decrease in wild adult productivity. Averaged over the results of our models, a 50% decline in the productivity parameter (the number of recruits per spawner at low densities) and a 22% decline in the maximum number of recruits produced in the basin were observed when high numbers of hatchery fish were present. We concluded that over the duration of the hatchery program, the number of hatchery steelhead in the upper Clackamas River basin regularly caused the total number of steelhead to exceed carrying capacity, triggering density-dependent mechanisms that impacted the wild population. The number of smolts and adults in the wild winter steelhead population declined until critically low levels were reached in the 1990s. Hatchery fish were removed from the system in 2000, and early results indicate that the declining trends have reversed.

Hatchery programs for Pacific salmon *Oncorhynchus* spp. may pose both genetic and ecological risks to wild fish populations (National Research Council 1996). Direct genetic risks resulting from interbreeding can affect conspecific hatchery and wild fish that share a high level of gene flow (Hindar et al. 1991; Waples 1991). Ecological risks occur in the absence of interbreeding; while these risks can affect conspecifics, impacts can extend to different life histories and to different species (Fausch 1988; Fresh 1997). Ecological impacts may include decreased productivity and altered evolutionary regimes that could contribute to wild population declines (Lichatowich and McIntyre 1987; Waples 1991).

Ecological risks are expected to occur when hatchery and wild fish share a limited natural environment for a prolonged period (Fresh 1997). In anadromous salmonids, this is most likely to occur in freshwater (Slaney et al. 1985), although some authors have speculated that such interactions extend into the ocean (Lichatowich and McIntyre 1987; Peterman 1991; Beamish et al. 1997; Heard 1998). Most previous studies of ecological risks have focused on interactions that occur immediately after the release of hatchery juveniles. For example, Nickelson et al. (1986), Nielsen (1994), and Nickelson (2003) demonstrated the impacts of fry and smolt releases of hatchery coho salmon *O. kisutch* on the juvenile growth and productivity of wild coho salmon in Oregon and California coastal streams. Levin and Williams (2002) demonstrated a relationship between large smolt releases of hatchery steelhead *O. mykiss* into the Snake River (Columbia River basin) and decreased smolt-to-adult survival rates in wild Chinook salmon *O. tshawytscha*. McMichael et al. (1997, 1999) explored the impacts of residual hatchery steelhead on wild steelhead, rainbow trout (resident steelhead), and Chinook salmon in an eastern Washington river. Although impacts to both species were demonstrated, McMichael et al. (2000) argued that competitive juvenile interactions would be maximized when the hatchery and wild fish are conspecifics, since juvenile life histories and habitat requirements are most similar in those cases. Slaney et al. (1985) noted that intraspecific interactions between hatchery and wild steelhead juveniles may be particularly high because the species is aggressive and territorial.

Adult hatchery fish that stray into wild populations may also cause ecological impacts, especially when they are abundant. The adults may compete for spawning habitats, and their naturally produced off-

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Previous Study Conclusions

"Our analysis demonstrated that the productivity of the wild winter steelhead population in the upper Clackamas River basin was depressed when large numbers of hatchery summer steelhead were present above North Fork Dam."

"We found that when large numbers of hatchery summer steelhead were present, winter steelhead production measured as recruits per spawner was reduced by 50%, while the maximum number of wild recruits produced was reduced by 22%, averaged across our various models."

"The hatchery program was meant to provide a sport fishery, and the production of adult offspring was not intended. If successful hatchery reproduction had occurred, at least the offspring could have contributed to fisheries. Instead, the hatchery fish wasted basin capacity by occupying habitat and depressing wild production while producing nothing useful themselves."

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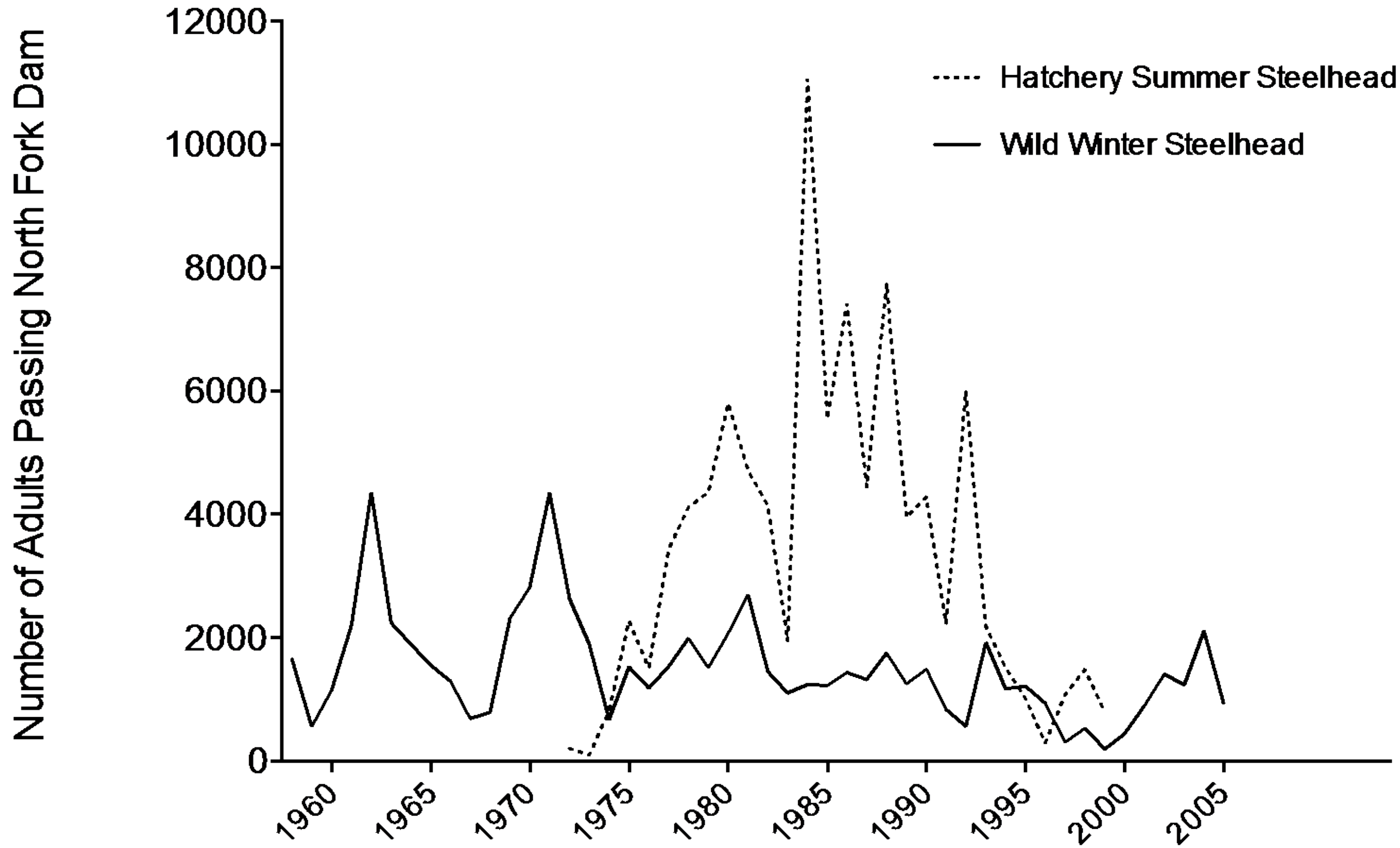
Kostow and Zhou (2006)



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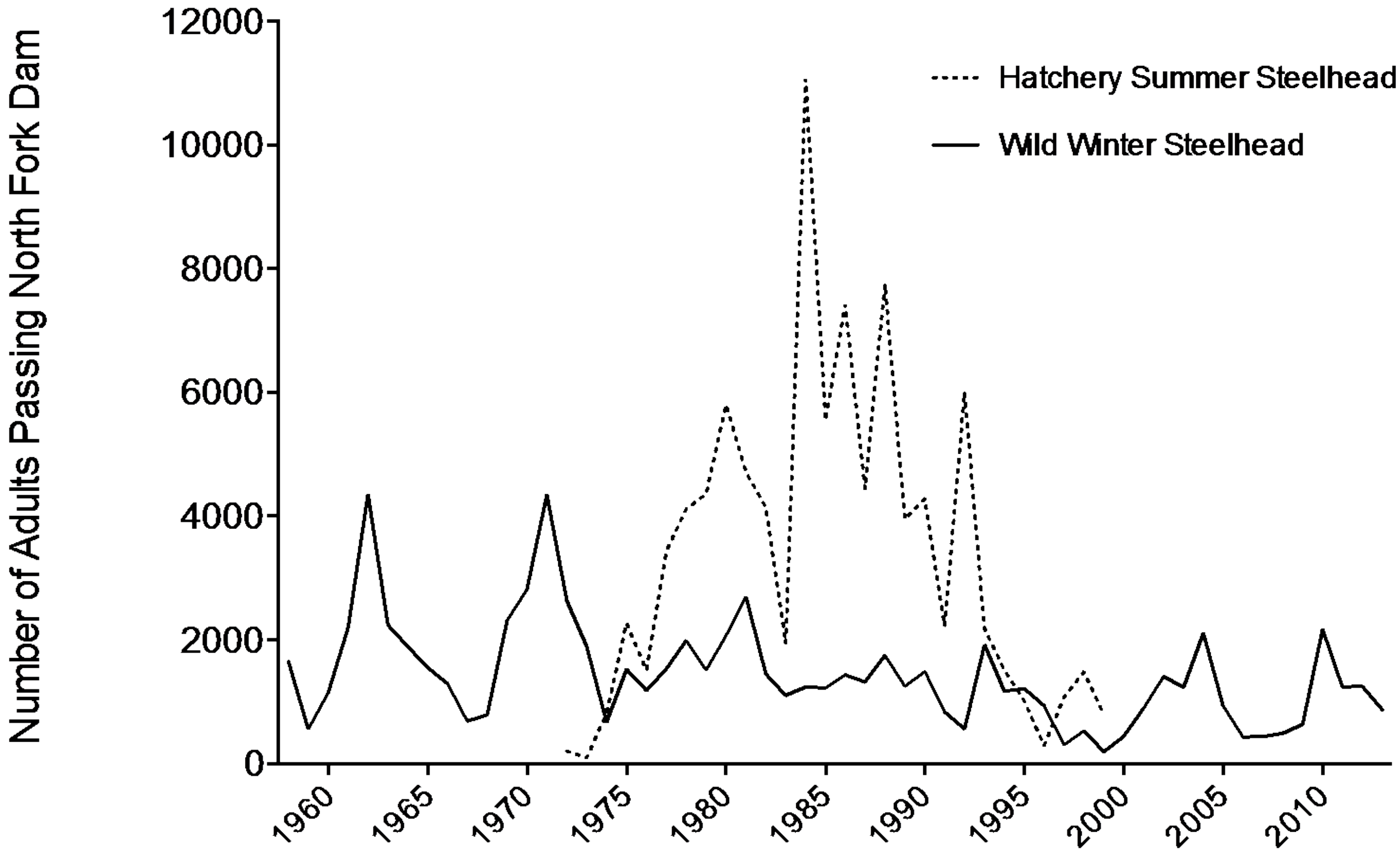

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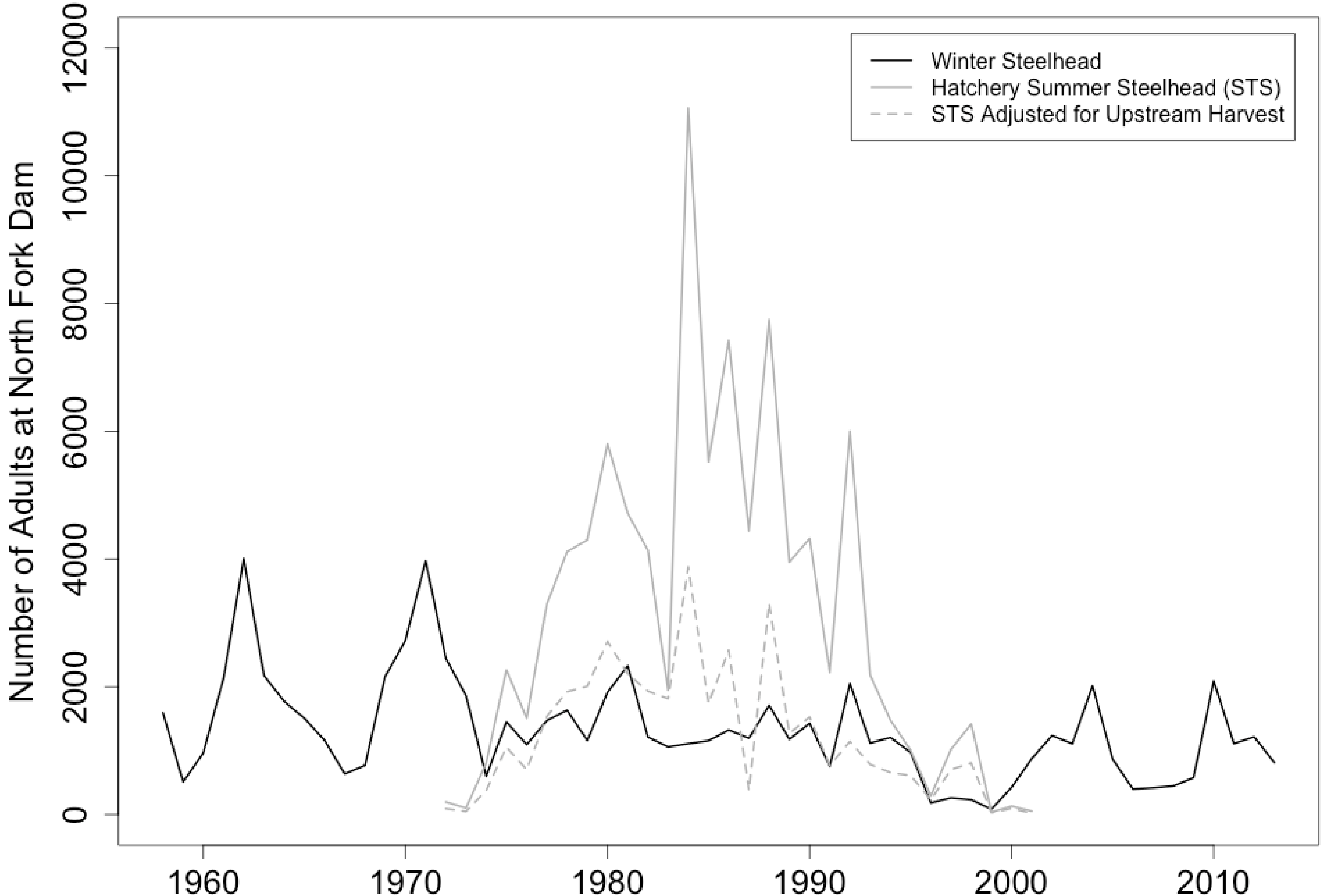
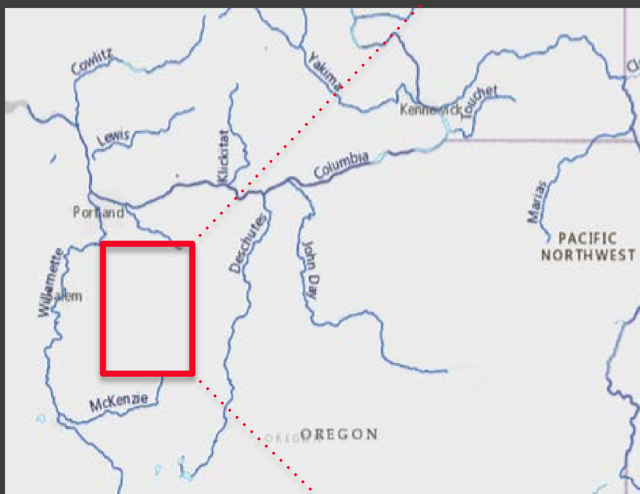
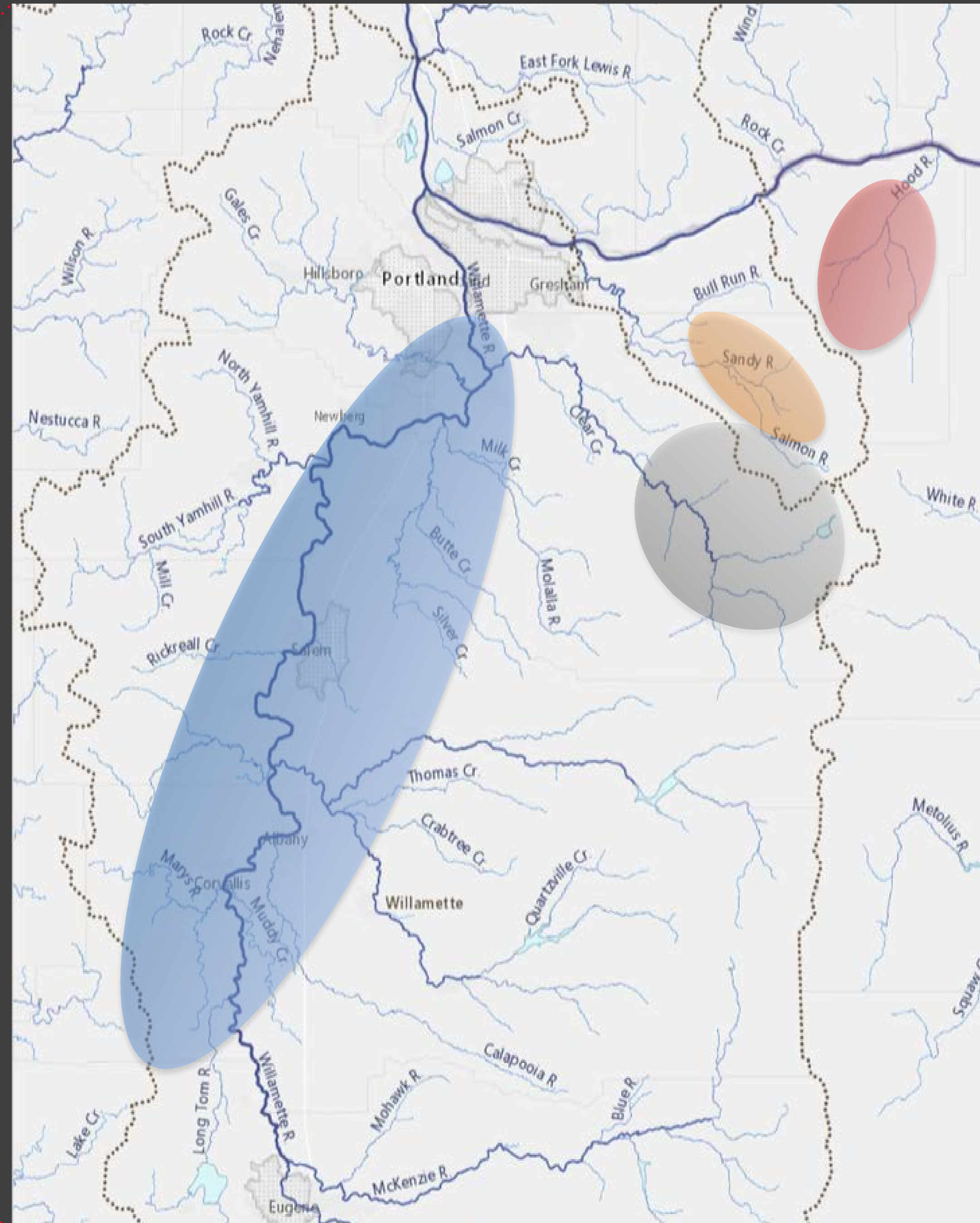


Winter Steelhead
Hatchery Summer Steelhead (STS)
STS Adjusted for Upstream Harvest
Number of Adults at North Fork Dam
0
2000
4000
6000
8000
10000
12000
1960
1970
1980
1990
2000
2010





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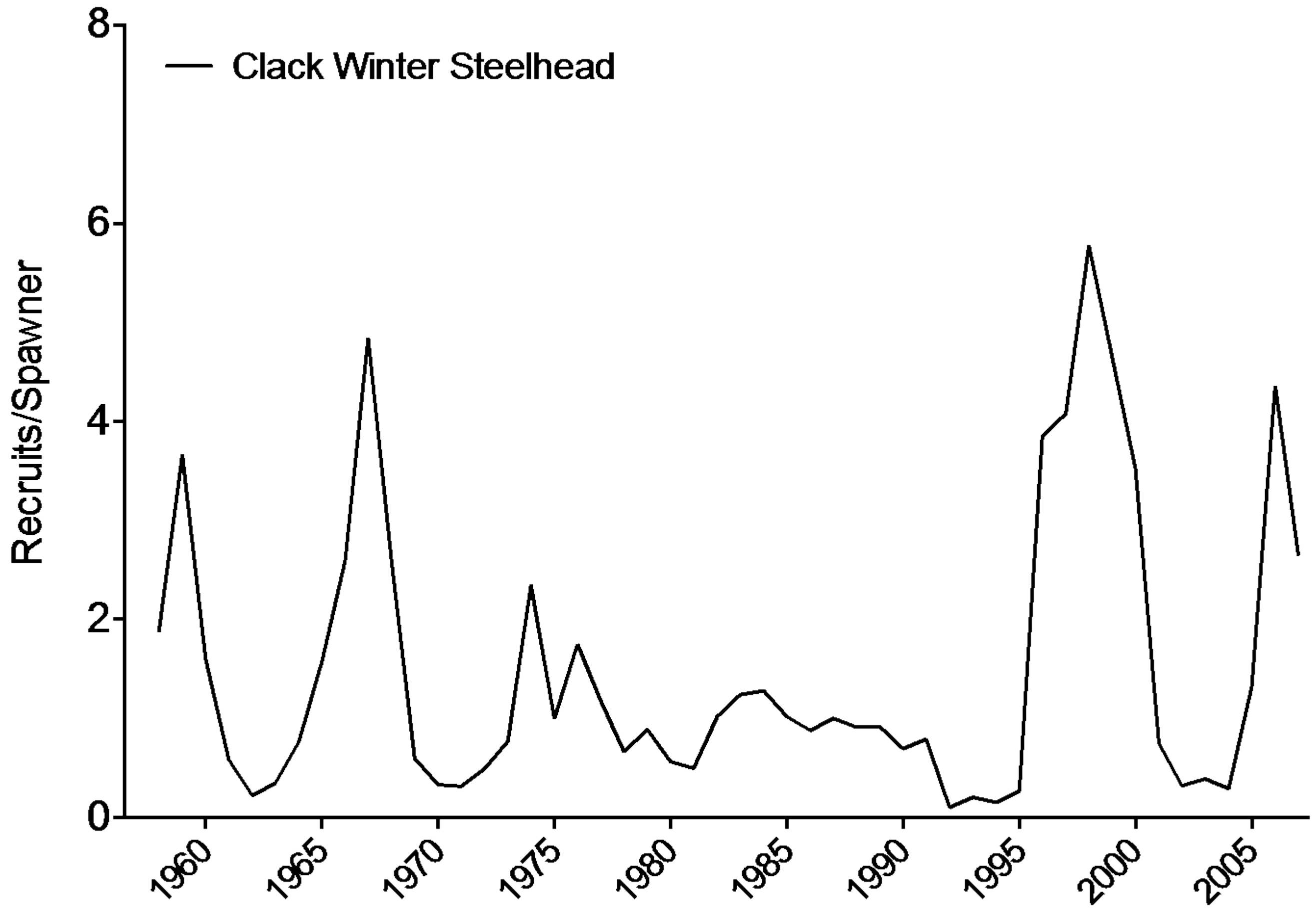
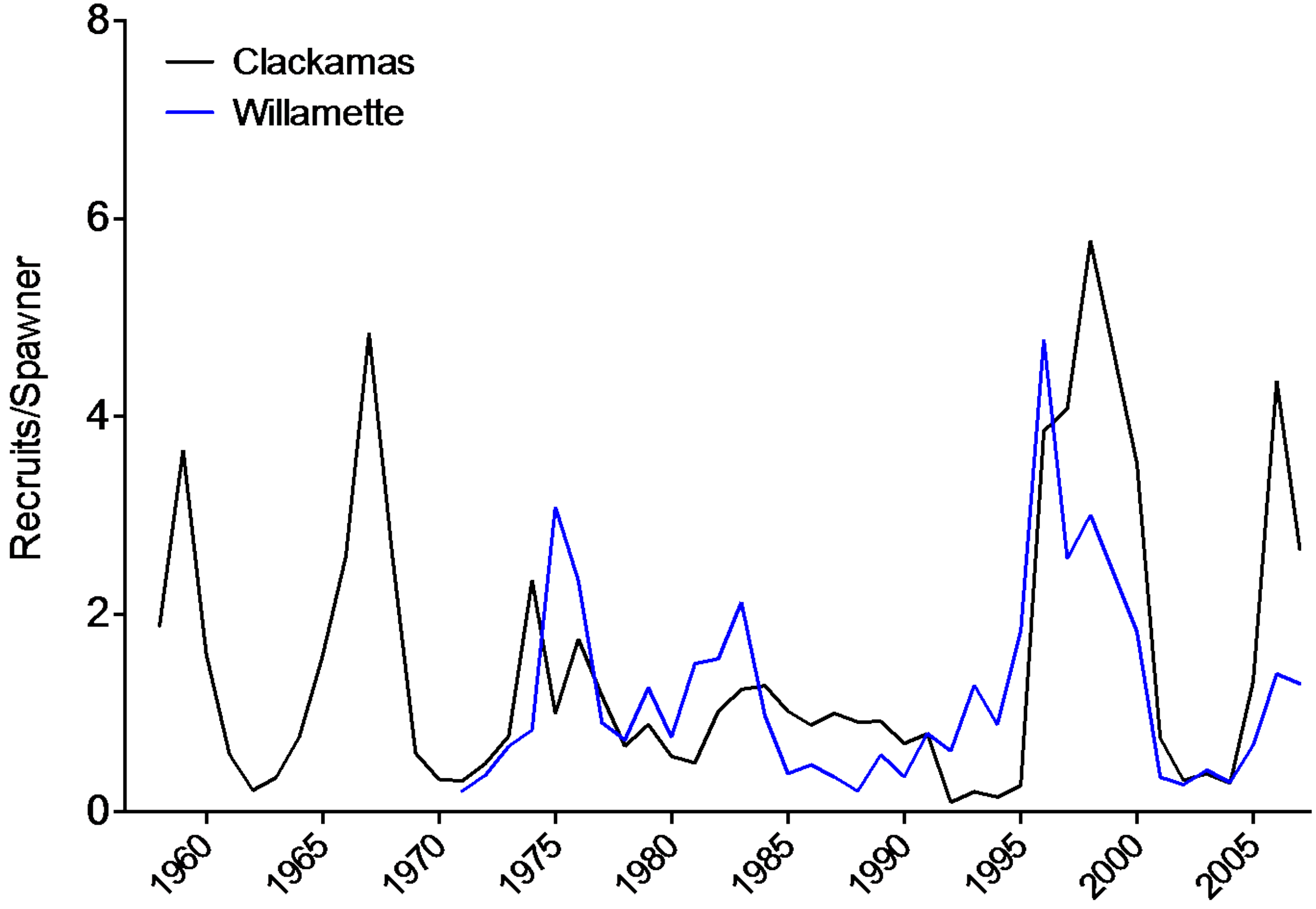


Clack Winter Steelhead
Recruits/Spawner
0
2
4
6
8
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005



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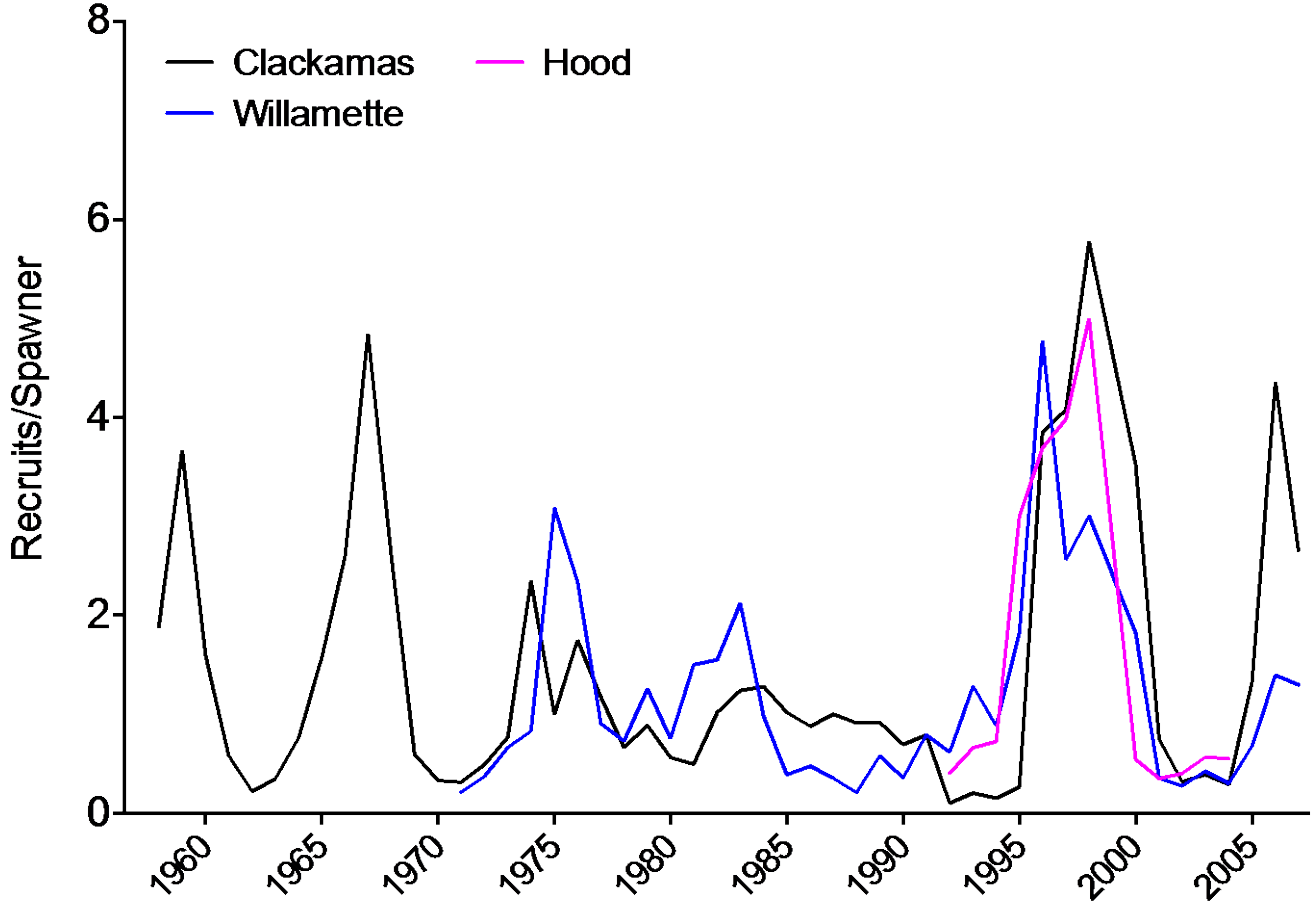
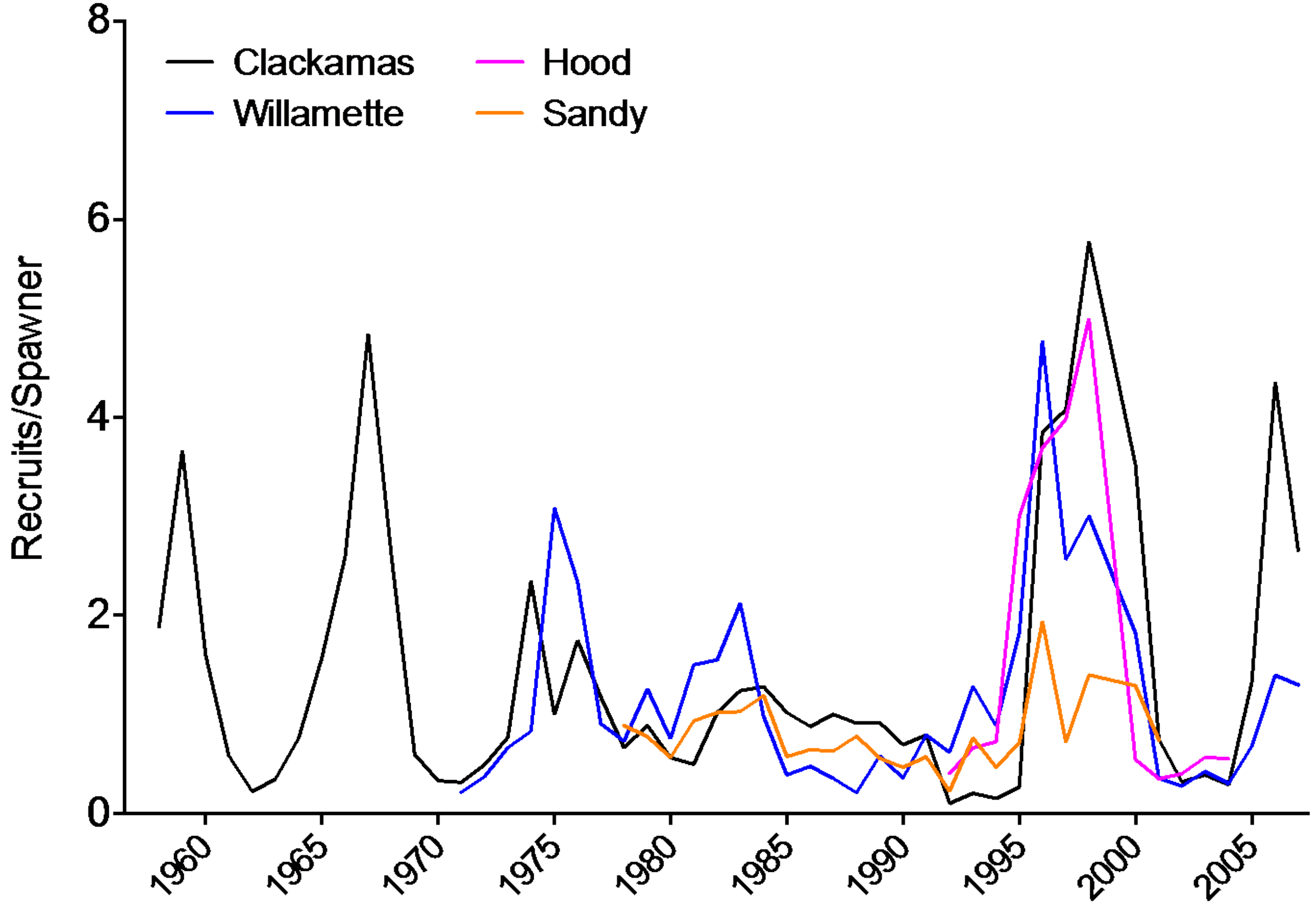
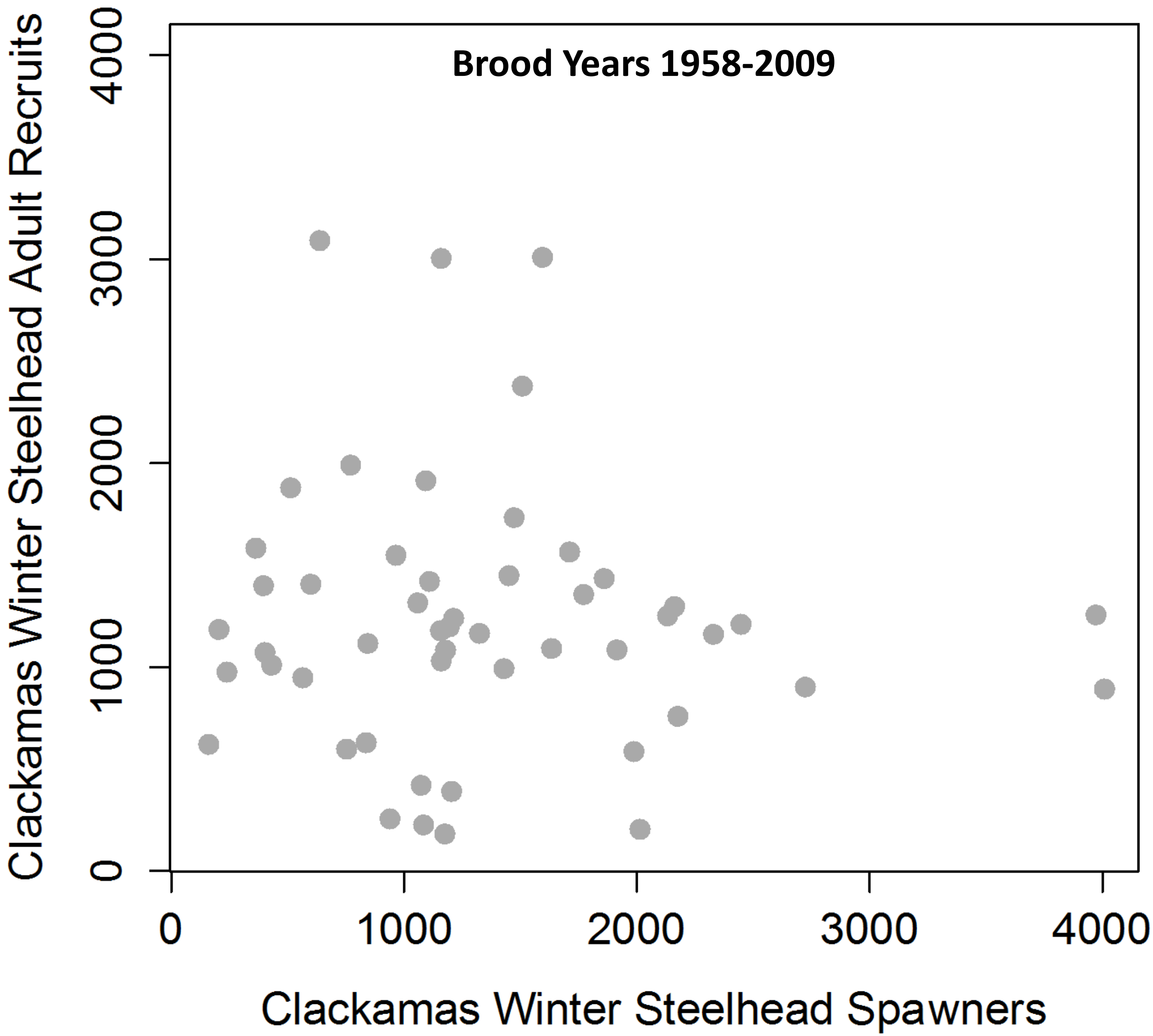
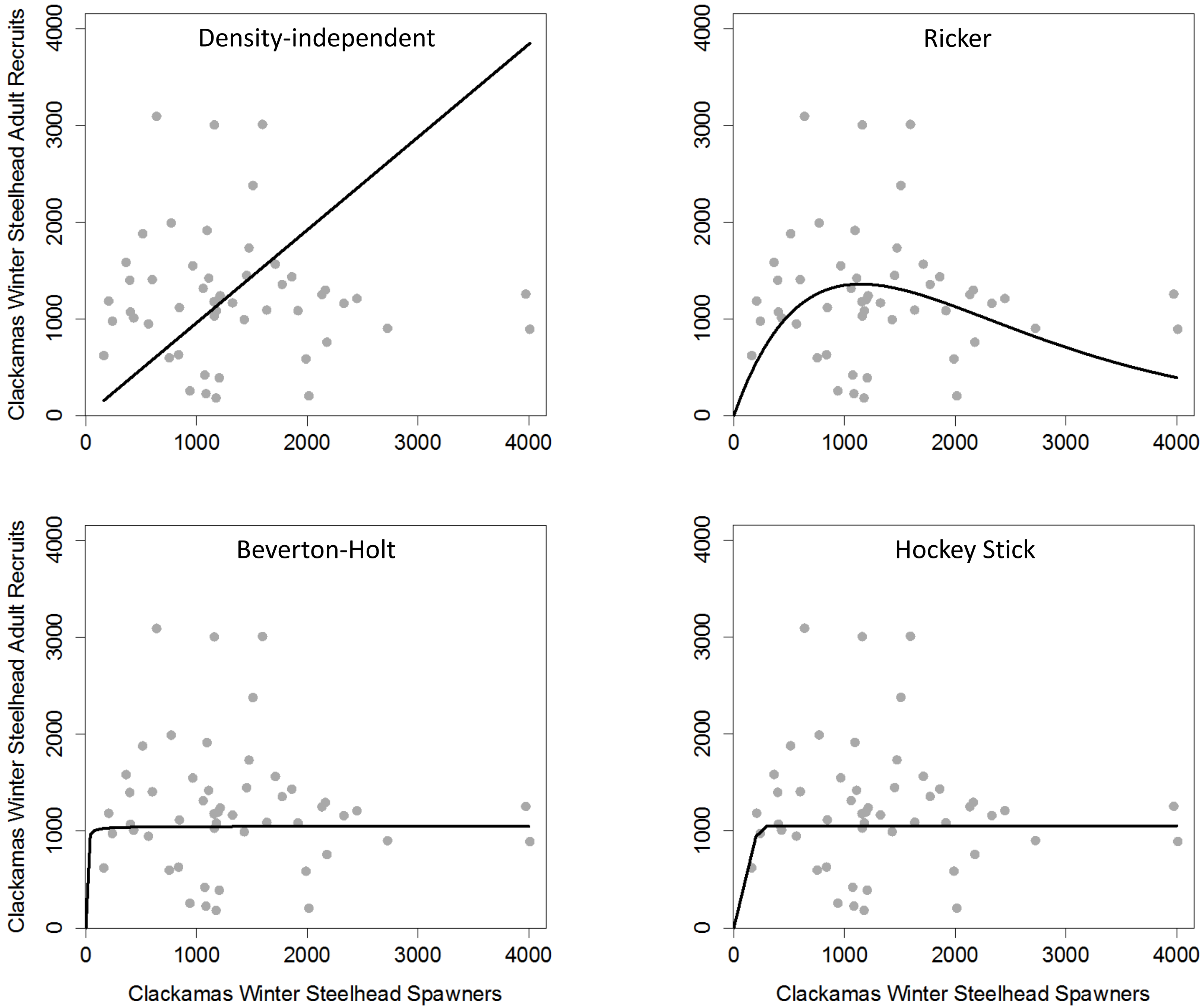


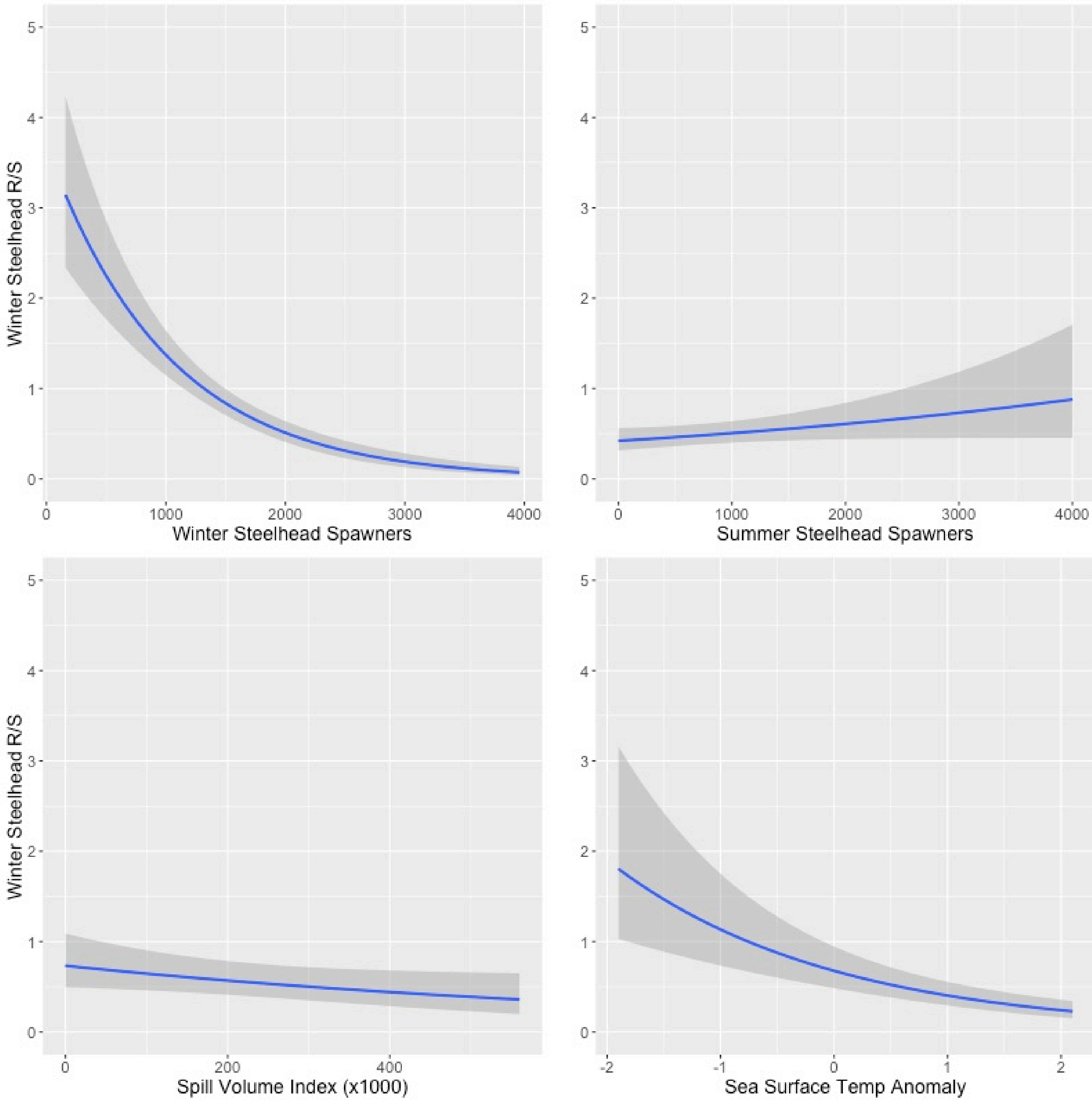
Recruits/Spawner
0
2
4
6
8
Clackamas
Willamette
Hood
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005



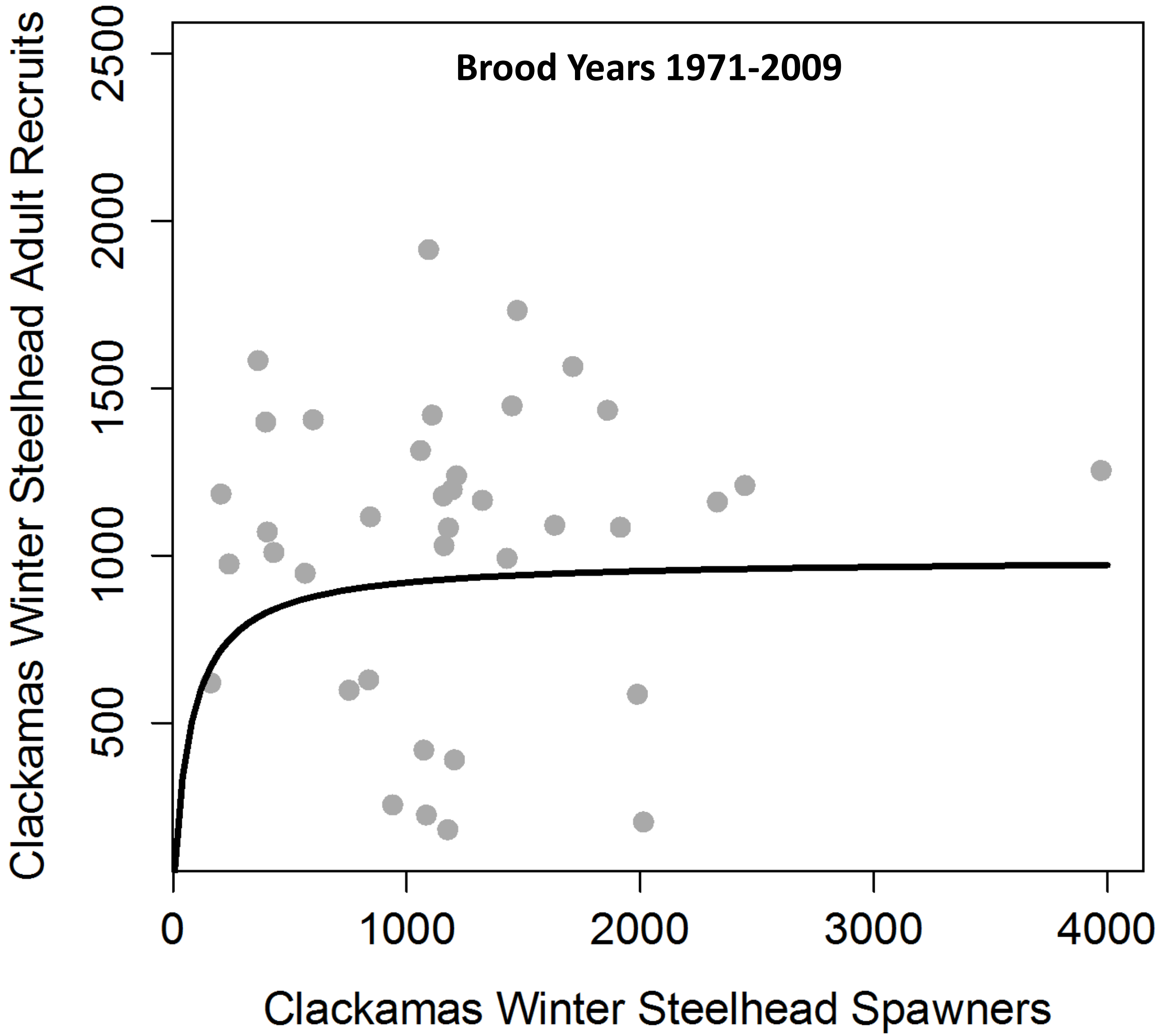
Recruits/Spawner
8
6
4
2
0
Clackamas
Willamette
Hood
Sandy
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


Brood Years 1958-2009
Clackamas Winter Steelhead Adult Recruits
0
1000
2000
3000
4000
Clackamas Winter Steelhead Spawners
0
1000
2000
3000
4000


Density-independent
Ricker
Beverton-Holt
Hockey Stick
Clackamas Winter Steelhead Adult Recruits
Clackamas Winter Steelhead Spawners
0
1000
2000
3000
4000


Winter Steelhead R/S
Winter Steelhead Spawners
Summer Steelhead Spawners
Spill Volume Index (x1000)
Sea Surface Temp Anomaly
0
1
2
3
4
5
0
1000
2000
3000
4000
200
400
-2
-1

$$R = \frac{a \cdot S}{1 + b \cdot S} \cdot \exp\left(cSST + dWFR + eSVI + fHSS\right)$$



Preliminary Conclusions

- Abundance of hatchery-origin summer steelhead spawners was positively correlated with natural-origin winter steelhead productivity.
- There is strong covariation between productivity of spatially contiguous populations of steelhead. The decline in abundance of natural-origin winter steelhead (1972-1998) appears to have been driven by variation in survival rates common to winter steelhead populations throughout the region.
- There was not a winter steelhead abundance increase following exclusion of hatchery fish in the Upper Clackamas Basin.

Kostow and Zhou (2006)

1. Data: 1958-2005
2. >3000 spawners in 2004
3. Est. Col. River harvest
4. No harvest in Upper Clack River
5. Eval. smolt and adult prod.
6. S-R models: Ricker & BH
7. Use of env. covariates
8. No Use of reference populations
9. Partition data into “periods”
10. No ocean effects
11. Large effect of hatchery fish

Courter and Wyatt

1. Data: 1958-2015
2. 2014 spawners in 2004
3. No Col. River harvest adjust.
4. Harvest in Upper Clack River
5. Eval. adult prod.
6. S-R models: BH & Hockey Stick
7. Use of env. covariates
8. Use of reference populations
9. Evaluate entire dataset
10. Ocean effects quantified
11. No detectable effect of hatchery fish

Questions