

Influence of Resident Rainbow Trout on Steelhead Populations in the Columbia Basin

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Resident rainbow trout produce anadromous offspring in a large interior watershed

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Abstract: Rainbow trout (*Oncorhynchus mykiss*) have diverse life histories, including both freshwater-resident and anadromous "steelhead" life-history forms. Here, we demonstrate that female resident rainbow trout produce anadromous offspring that survive and return to spawn as adult steelhead. This study represents the first successful attempt to quantify steelhead production rates from female resident rainbow trout across a large watershed. Otolith microchemistry ($^{87}\text{Sr}/^{86}\text{Sr}$) techniques were used to determine the maternal life history (resident or anadromous) of 498 emigrating steelhead kelts in the Yakima Basin, Washington. Five geochemically distinct freshwater rearing regions were identified within the basin. All five regions were predicted to produce steelhead with resident maternal life histories. Basin-wide, 20% and 7% of steelhead collected in 2010 and 2011, respectively, had resident maternal life histories. Cross-life-history form production may be critical to persistence of anadromous life histories within partially anadromous salmonid populations, particularly in areas where anadromous fish abundance is low due to natural or anthropogenic influences.

Résumé : Les truites arc-en-ciel (*Oncorhynchus mykiss*) présentent divers types de cycle biologique; elles comptent notamment une forme résidant en eau douce et une forme anadrome. Nous démontrons que des truites arc-en-ciel femelles résidentes peuvent produire des rejetons anadromes qui survivent en mer et retournent en eau douce pour frayer. L'étude constitue la première tentative fructueuse de quantifier les taux de production de truites arc-en-ciel anadromes issues de femelles résidentes à l'échelle d'un grand bassin versant. Des techniques de microchimie ($^{87}\text{Sr}/^{86}\text{Sr}$) des otolithes ont été utilisées pour déterminer le cycle biologique (résident ou anadrome) maternel de 498 bécards de cette espèce émigrant du bassin de la rivière Yakima, dans l'état de Washington. Cinq régions d'alevinage en eau douce distinctes sur le plan géochimique ont été cernées dans ce bassin. Il avait été prédit que ces cinq régions produiraient des individus anadromes associés à des cycles biologiques maternels résidents. À l'échelle du bassin, 20 % et 7 % des truites anadromes prélevés en 2010 et 2011, respectivement, étaient associés à des cycles biologiques maternels résidents. La production de formes caractérisées par des cycles biologiques distincts d'une génération à l'autre pourrait être essentielle à la persistance des cycles biologiques anadromes dans les populations de salmonidés partiellement anadromes, en particulier dans les régions où l'abondance de poissons anadromes est faible en raison d'influences naturelles ou anthropiques. [Traduit par la Rédaction]

Introduction

Partial migration, when one portion of an animal population migrates while the other portion remains sedentary (Lundberg 1988), has been well documented in a variety of fish species, including salmonids (Jonsson and Jonsson 1993; Table 1). A related term, "partial anadromy", refers more specifically to a behavioral strategy whereby fish of the same population adopt divergent anadromous and resident freshwater life-history strategies (Hendry et al. 2004). Evolutionarily stable migration plasticity is thought to be a response to environmental stochasticity and density-dependent survival (Lundberg 1987; Kaitala et al. 1993). Life-history diversity, represented by these mechanisms, is believed to buffer against extinction (Hilborn et al. 2003; Greene et al. 2010). Such diversity may be particularly important to the perpetuation of salmonids facing a variety of natural and anthropogenic causes of mortality.

The term "steelhead", which has been conventionally used to identify anadromous rainbow trout, represents one of several potential life-history forms within *Oncorhynchus mykiss* populations (Favlov et al. 2001). Stream residency is also common for this species, with resident individuals remaining in fresh water

throughout their life cycle, often moving between suitable habitats (Gowan et al. 1994), but never venturing to the ocean. In watersheds with ocean access, researchers have found that in addition to interbreeding (McMillan et al. 2007), resident rainbow trout and steelhead can produce progeny of the alternate life-history form (Pascual et al. 2001; Thrower and Joyce 2004; Korman et al. 2010). These findings indicate that life-history trajectories of partially anadromous salmonid populations are driven by a combination of genetic predispositions and environmental cues (Jonsson and Jonsson 1993; Hendry et al. 2004).

The extent to which resident and anadromous *O. mykiss* life-history forms are reproductively mixed remains somewhat equivocal. In some cases, researchers have found evidence for reproductive isolation between the two forms (e.g., Zimmerman and Reeves 2000), while others have found evidence for substantial reproductive exchange (e.g., Pascual et al. 2001). There is need for resolution concerning the question of whether resident rainbow trout and steelhead are reproductively isolated in the majority cases (Behnke 2002) to inform whether population assessments should be expected to quantify the impact of resident rainbow trout on the persistence of steelhead.

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Partial Anadromy



brown trout	(Jonsson 1985)
cutthroat trout	(Zimmerman et al. 1997)
rainbow trout	(Pavlov et al. 2008)
bull trout	(Brenkman and Corbett 2005)
Dolly Varden char	(Koizumi et al. 2006)
brook char	(Curry et al. 2010)
Arctic char	(Nordeng 1983)
Atlantic salmon	(Fleming 1998)
sockeye salmon	(Wood 1995)
masu salmon	(Arai and Tsukamoto 1998)

Evidence For and Against Reproductive Isolation between Resident and Anadromous *O. mykiss*

For

Zimmerman and Reeves 2000

Narum et al. 2004

Docker and Heath 2003

Against

McPhee et al. 2007

Olson et al. 2006

Pearsons et al. 2007

Berntson et al. 2011

Christie et al. 2011

Pascual et al. 2001

Pavlov et al. 2008

Zimmerman et al. 2008

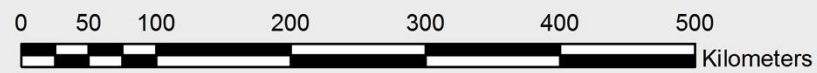
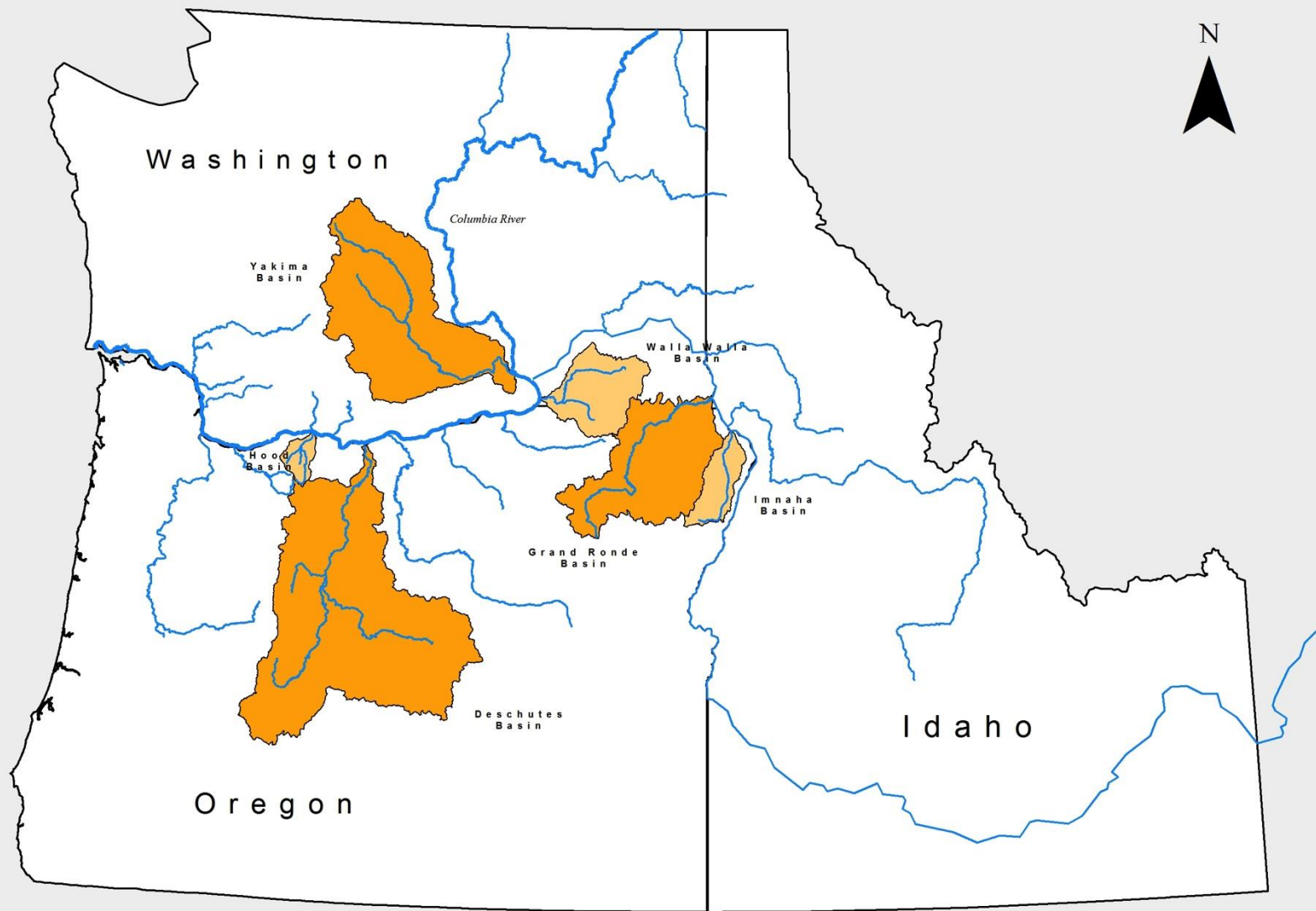
McMillan et al. 2007

Korman et al. 2010

ODFW unpublished data

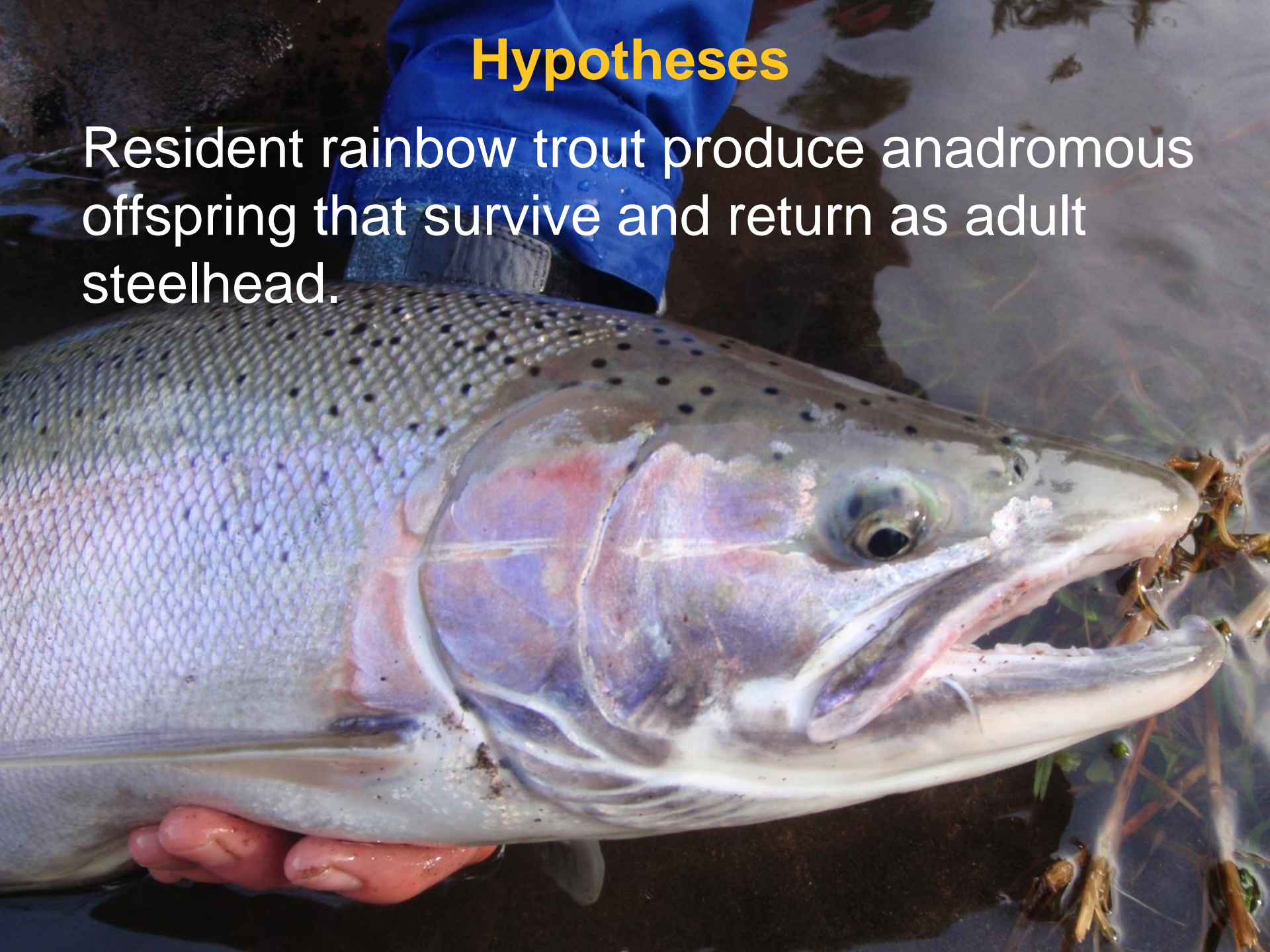
WDFW unpublished data

Pacific Ocean



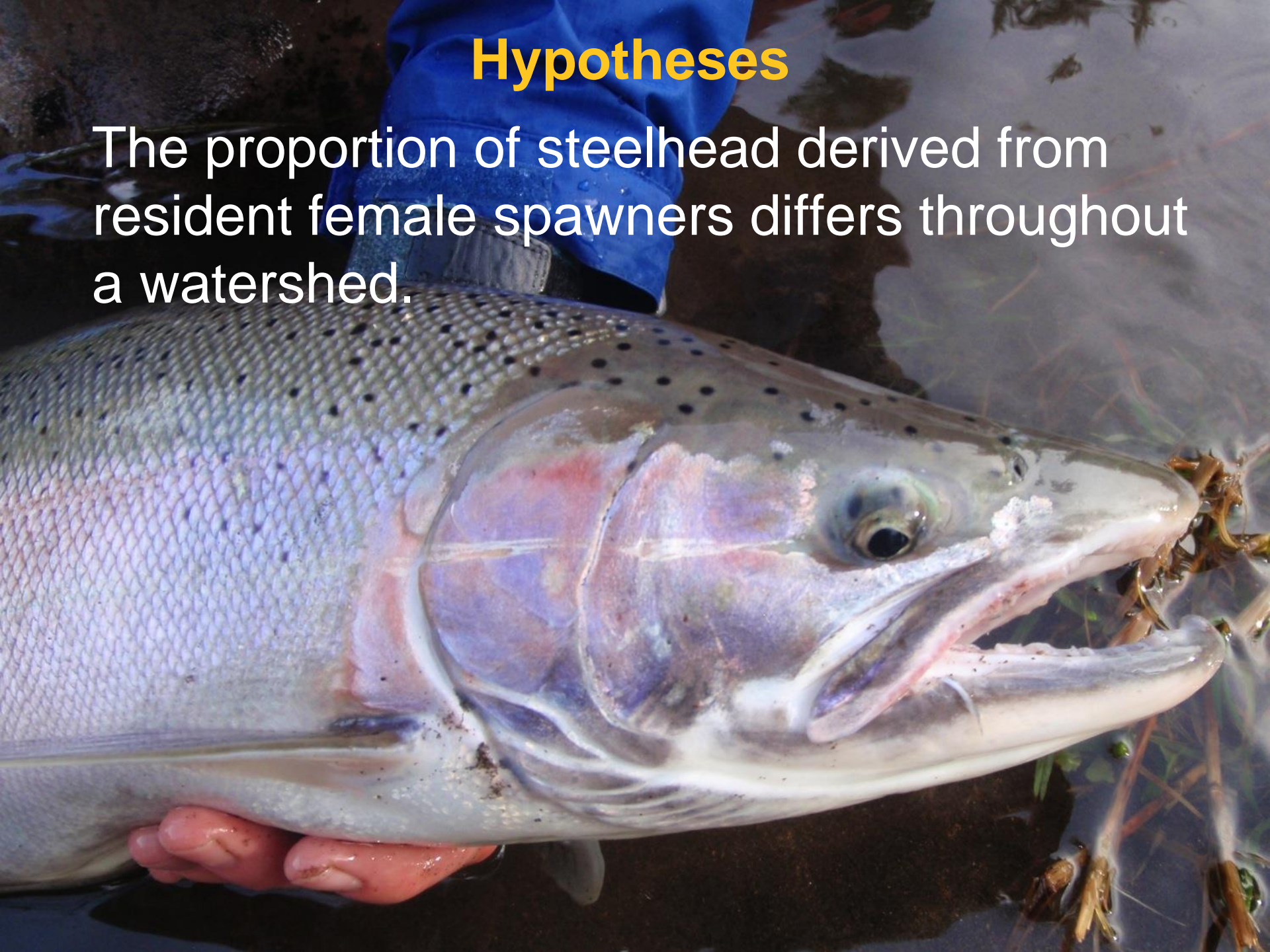
Hypotheses

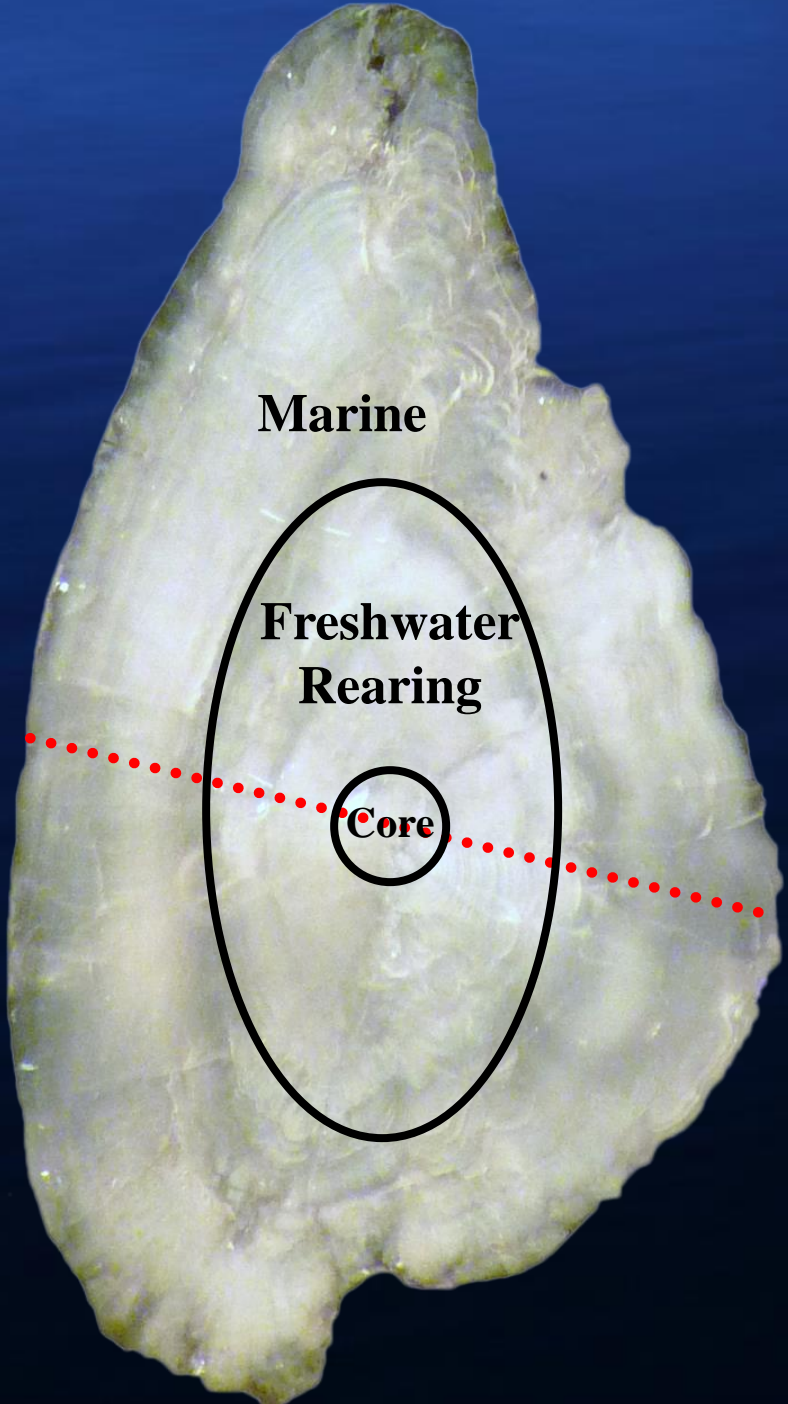
Resident rainbow trout produce anadromous offspring that survive and return as adult steelhead.



Hypotheses

The proportion of steelhead derived from resident female spawners differs throughout a watershed.

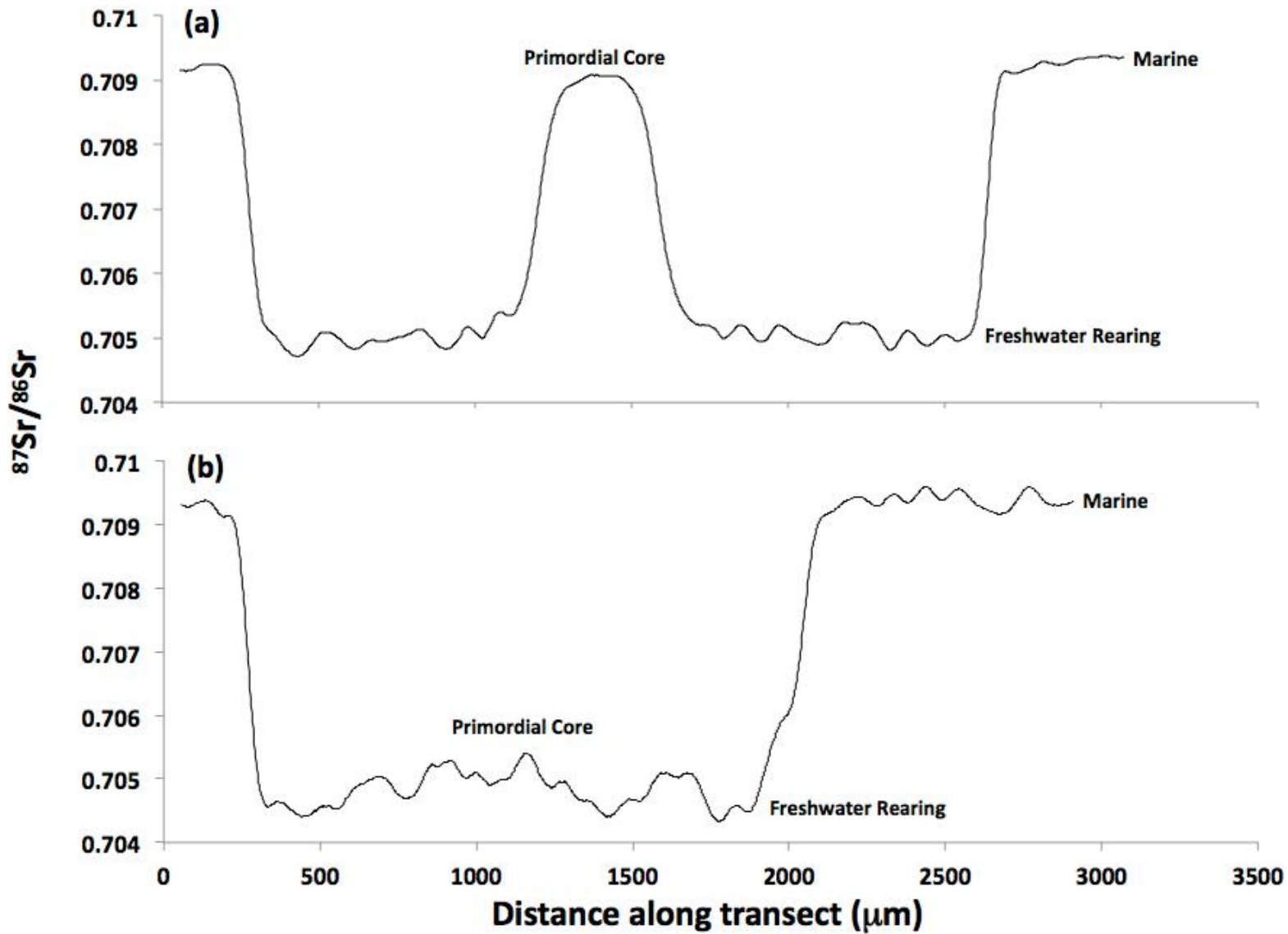




Marine

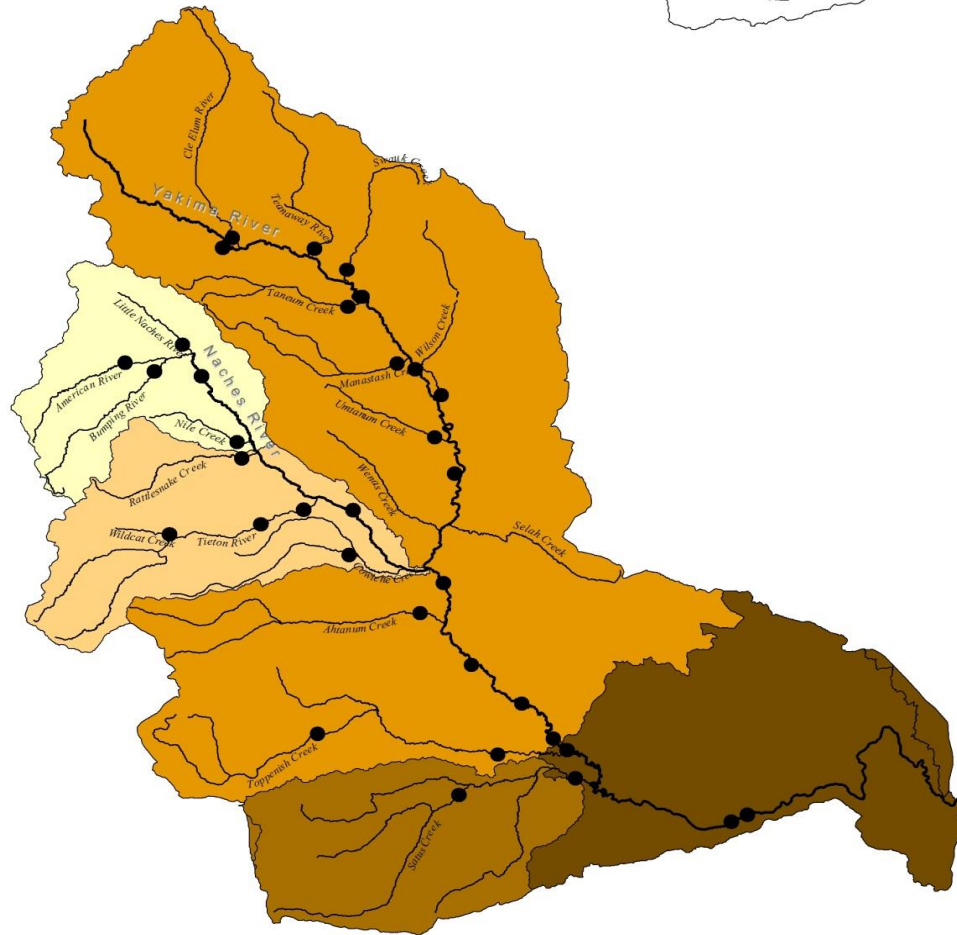
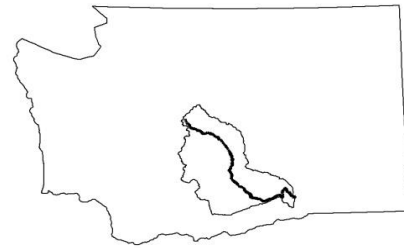
**Freshwater
Rearing**

Core

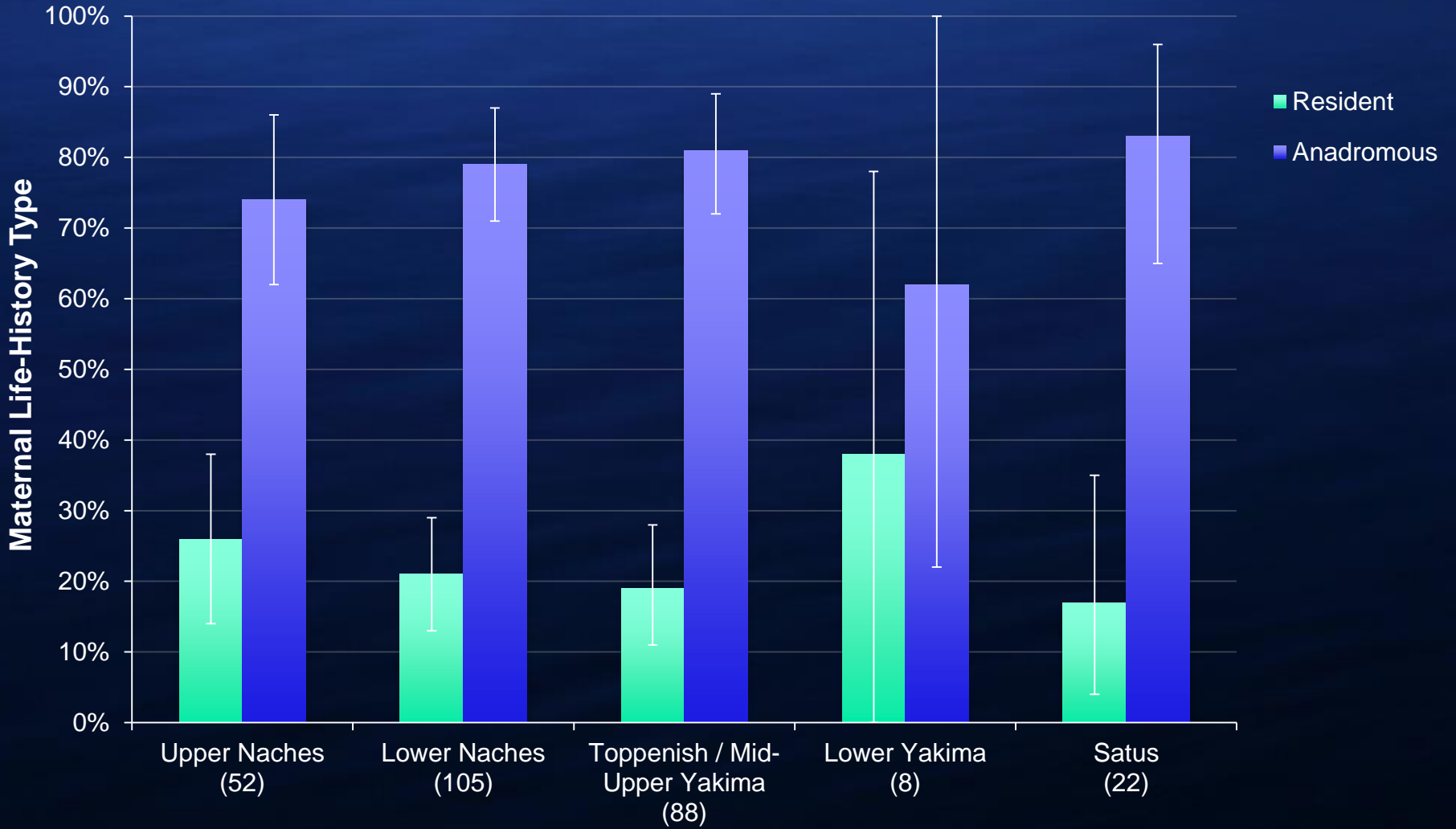


Water Regions

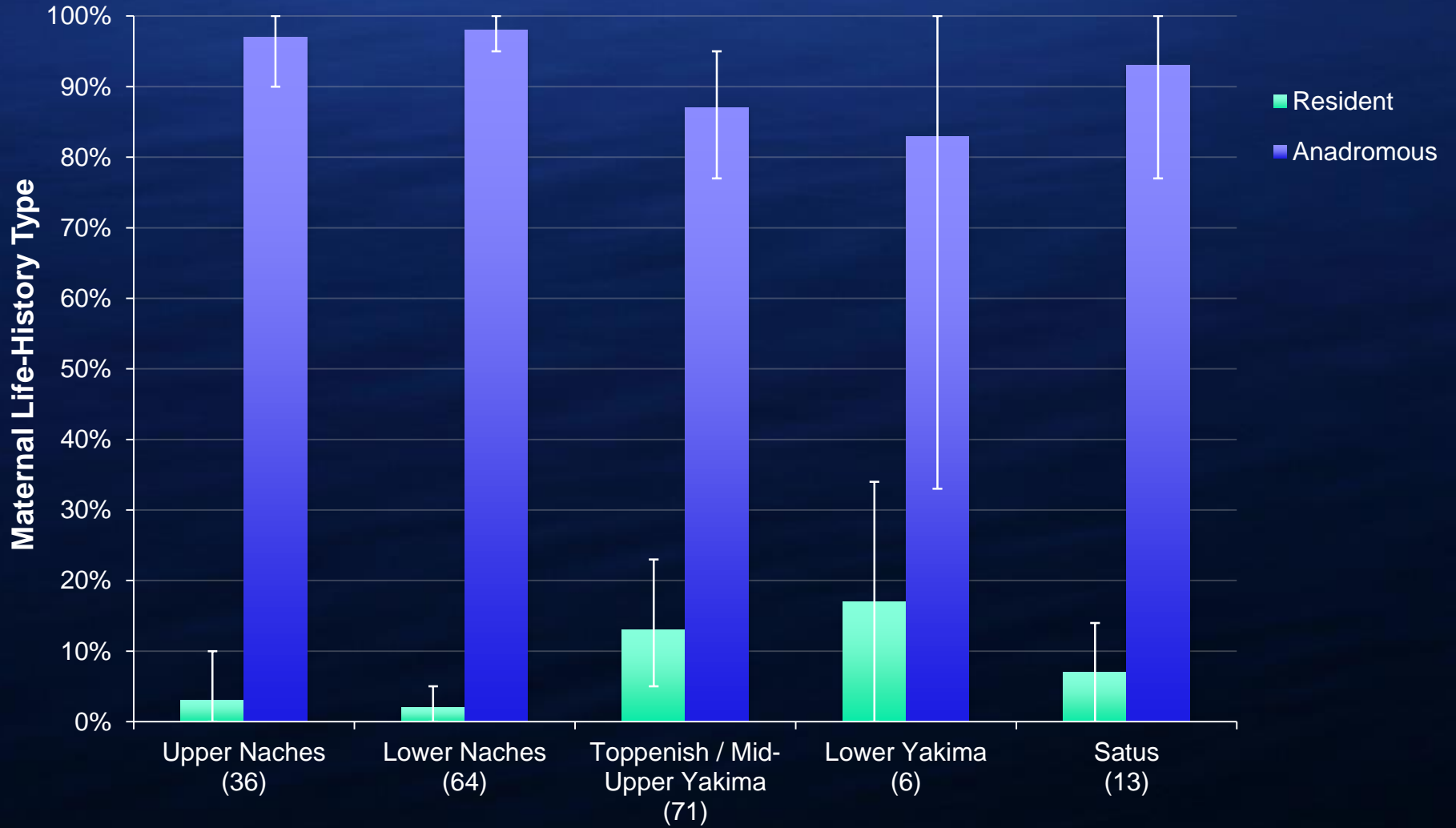
- Upper Naches
- Lower Naches
- Toppenish / Mid-Upper-Yakima
- Satus
- Lower Yakima



2010



2011



Conclusions

- Yakima Basin *O. mykiss* are partially anadromous
- Resident Maternal Origin
 - 20% in 2010
 - 7% in 2011
- A large sample is needed to detect cross life-history production.

Naturally reproducing populations of anadromous and resident rainbow trout are not reproductively isolated.



Future Plans

1. Expand this unique dataset
2. Examine effects of environmental conditions on cross life-history production

Are steelhead really threatened?

...there is another, less congratulatory way species have made it off the lists: new and better information becomes available showing a species is no longer or never was in danger of extinction.

Peter Moyle, December 2013

