8.0 part 2
Redfish Lake Sockeye Salmon

Barry Berejikian
(for Tom Flagg)

NOAA FISHERIES
Northwest Fisheries Science Center
Environmental and Fisheries Sciences

5 May 2015

Manchester Research Station
Captive Broodstock Facilities

Hatchery Reform Science Programs at the Manchester Research Station

Hatchery Reform

- **Operational guidelines**
- **Research to improve hatchery practices**

HSRG - Congressionally established (1999): Puget Sound & coastal Washington & all Columbia River (WA, OR, ID)

Gene Rescue for ESA stocks

Redfish Lake sockeye

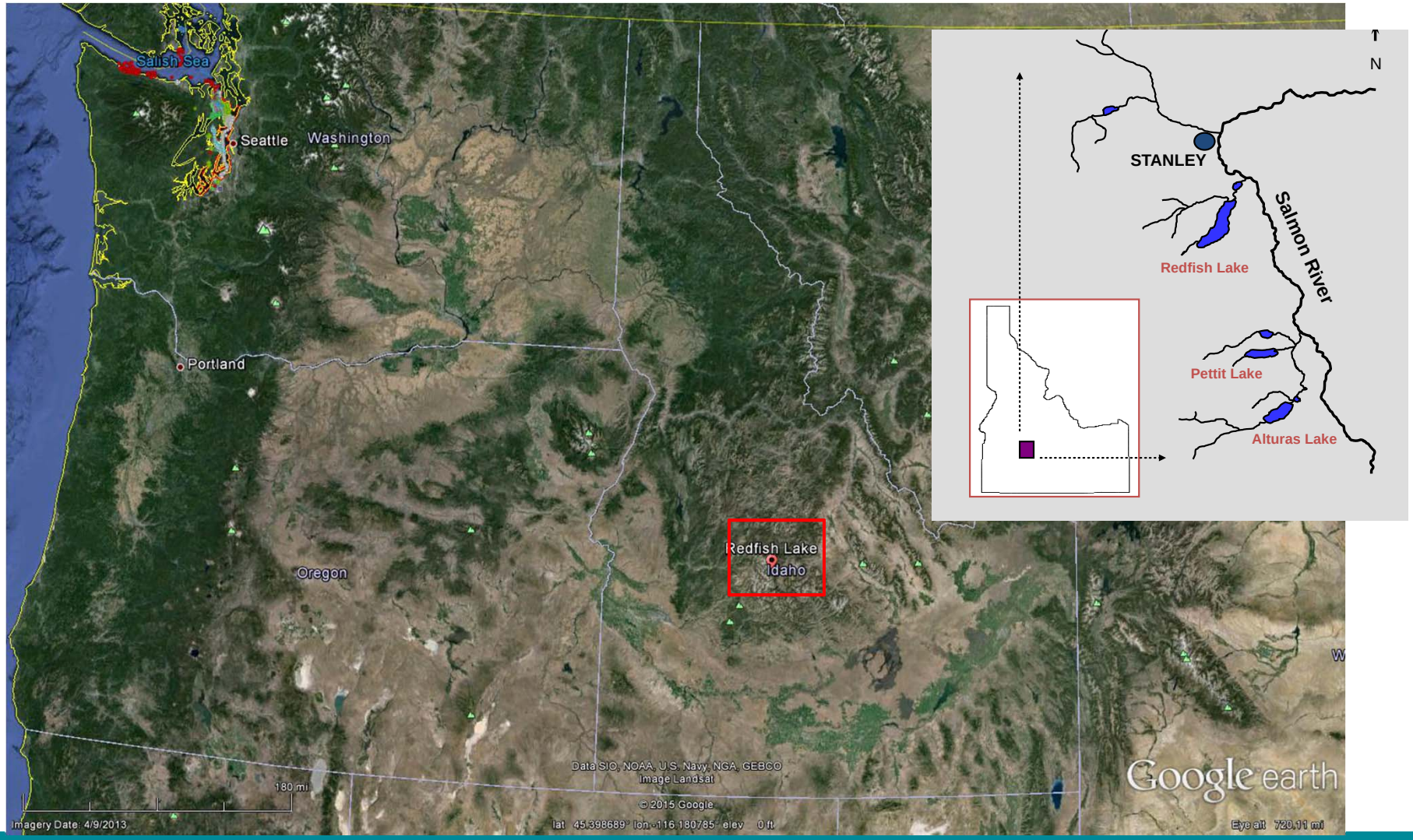
North Puget Sound spring Chinook

Elwha River Pink salmon

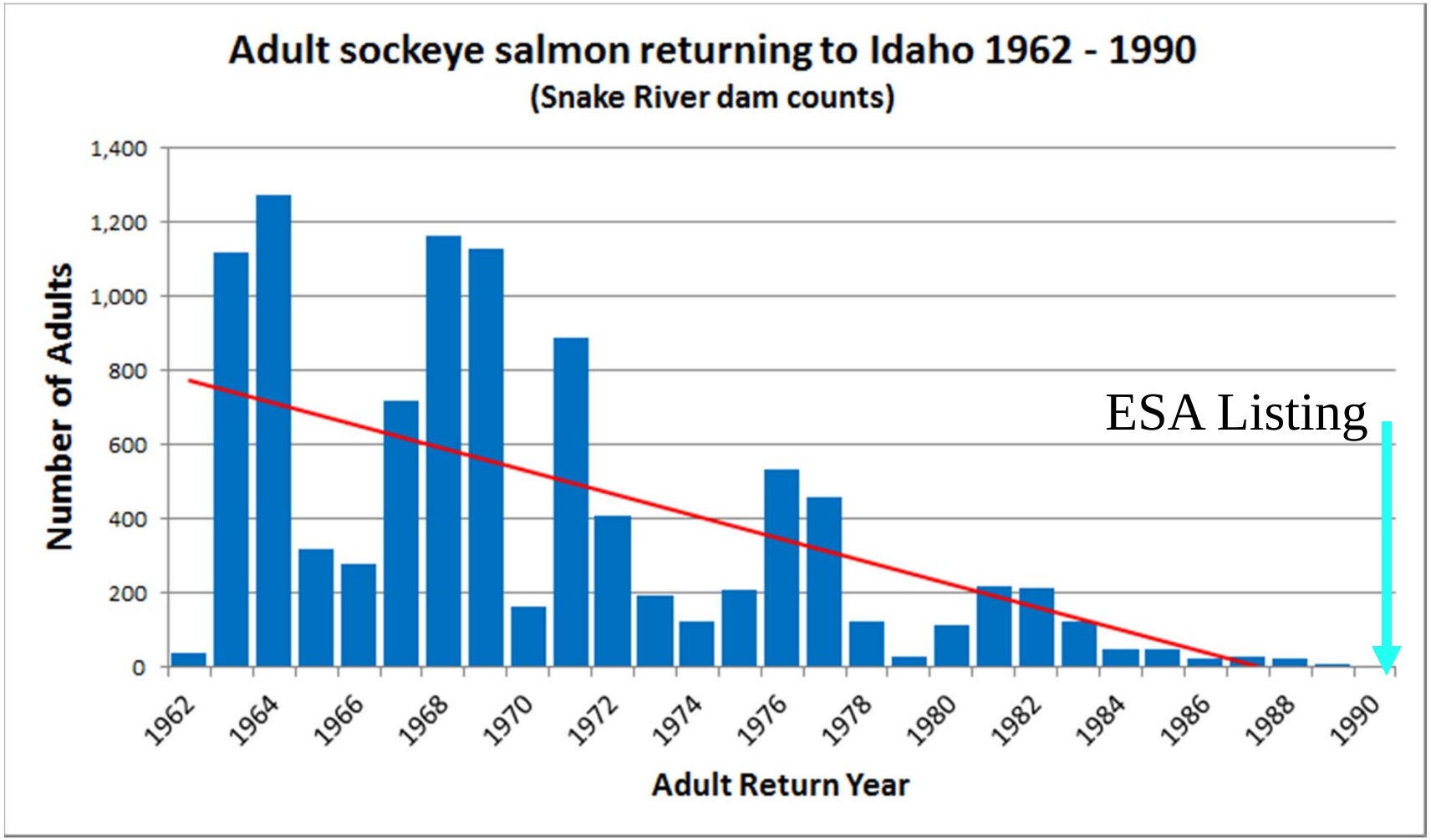
Hood Canal steelhead

Evaluate effects of hatchery programs

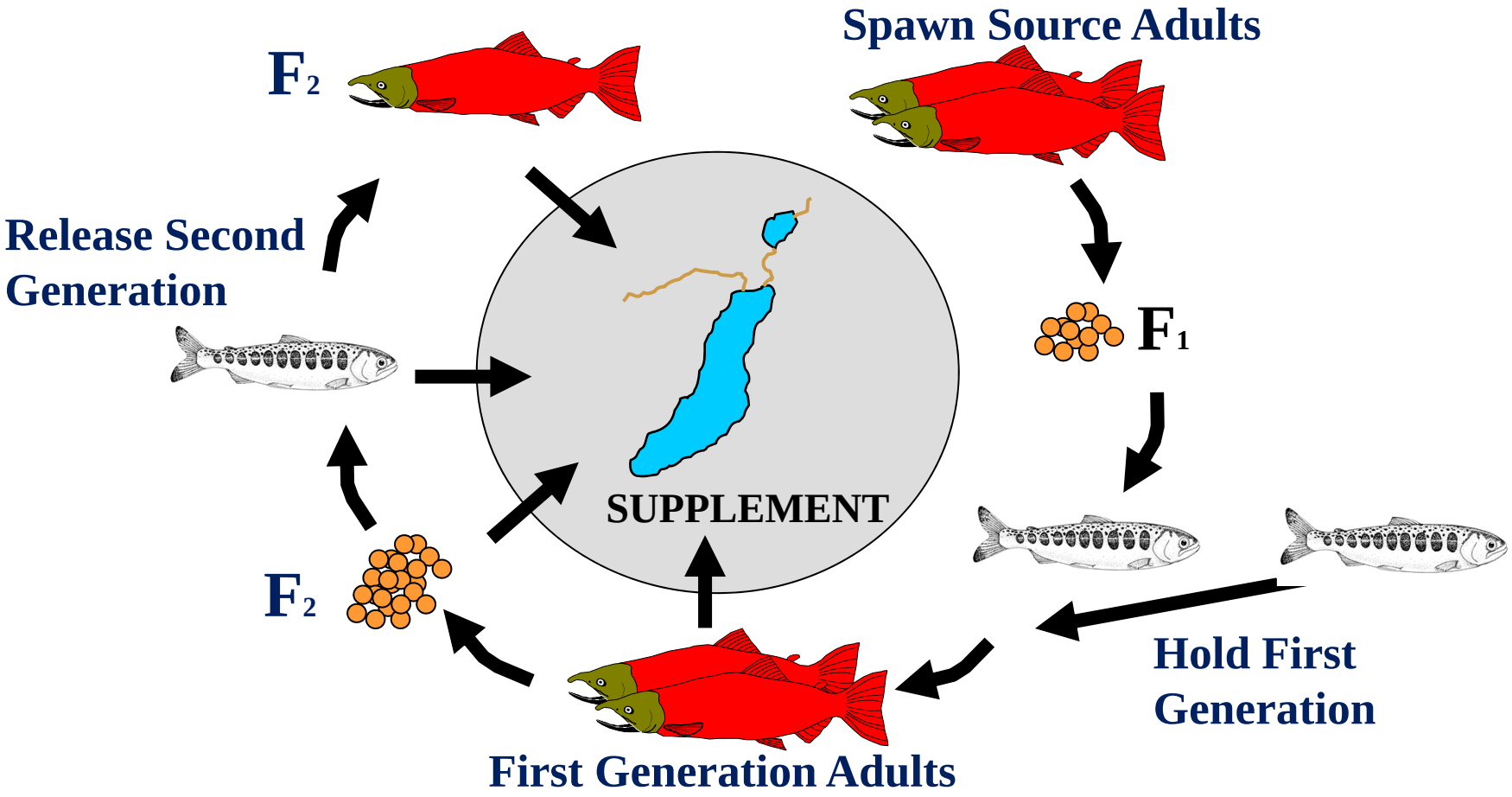
Stanley Basin Sockeye Salmon



Abundance


Adult sockeye salmon returning to Idaho 1962 - 1990
(Snake River dam counts)
Number of Adults
1,400
1,200
1,000
800
600
400
200
0
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Adult Return Year
ESA Listing

Captive Broodstock Cycle



Stanley Basin Sockeye Captive Broodstock Program

- **Captive broodstock program founded with:**
  - **16 wild adult sockeye returning in the 1990's**
  - **Several hundred out-migrating sockeye smolts (1991 – 1993)**
  - **26 "residual" Sockeye Salmon (1993 – 1995)**

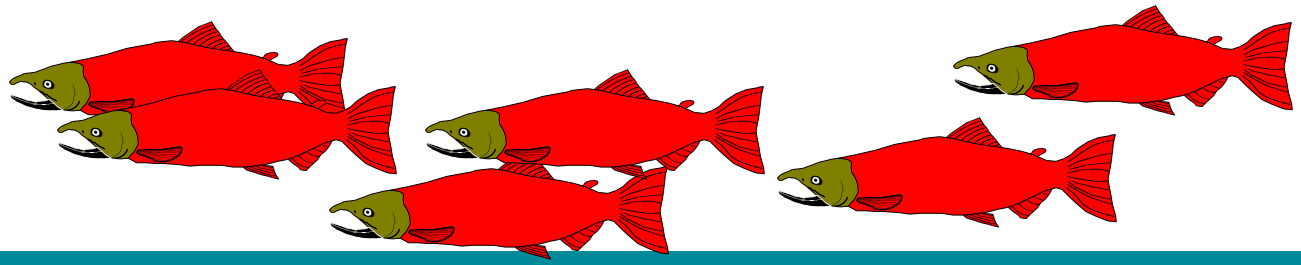
Program Goals

Tier 1

- Avoid population extinction using captive technology
- Conserve population genetic diversity
- Increase the number of individuals in the population

Tier 2

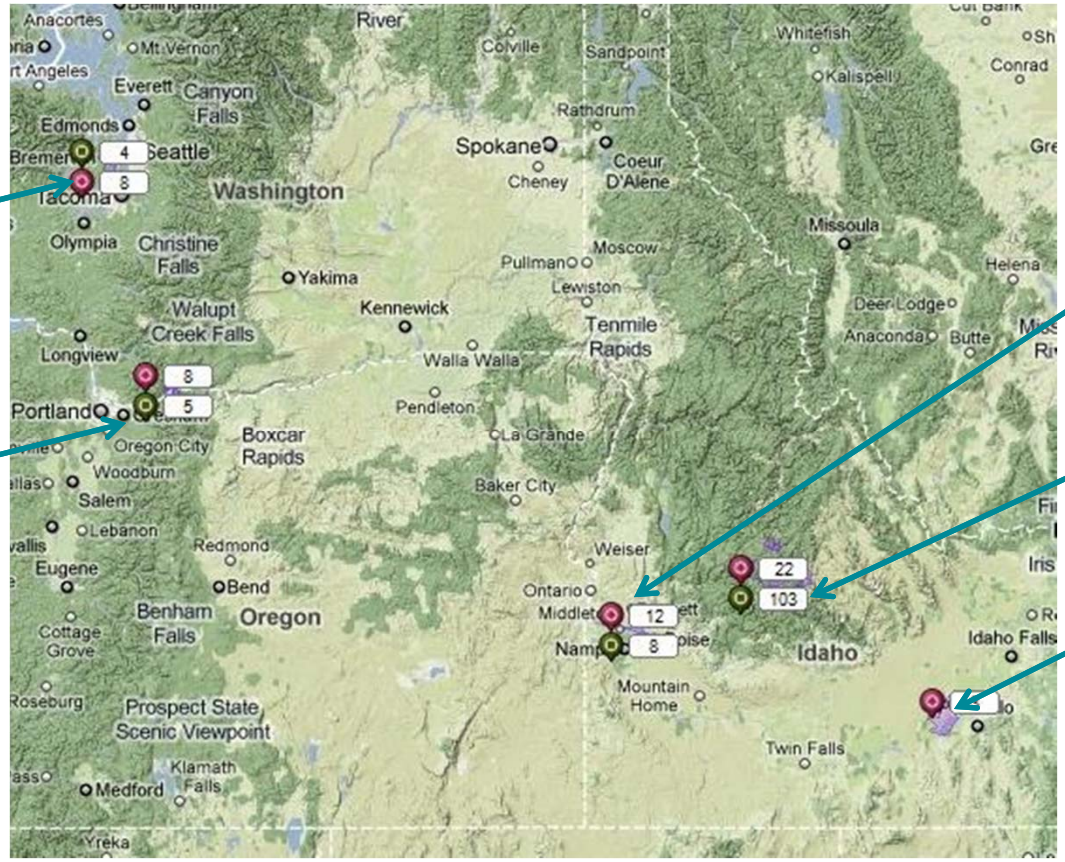
- De-list the population
- Provide sport and treaty harvest opportunity.



Rearing facility locations

NOAA Manchester Research Station

ODFW Oxbow Hatchery



IDFG Eagle Hatchery

IDFG Sawtooth Hatchery

IDFG Springfield Hatchery

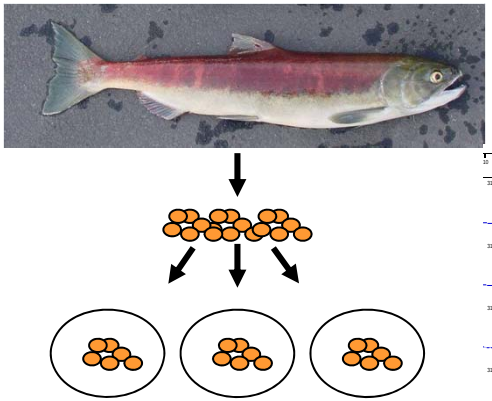
Spawning and Rearing

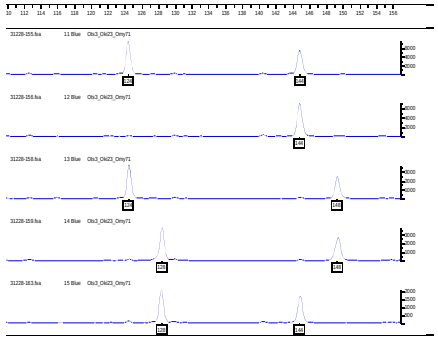
Mating Protocols

1991 – 2004: Family groups were kept separate using pedigrees

2005 - 2013: Microsatellite data, relatedness estimation, inbreeding avoidance matrices

Factorial Matings
(3 X 3 EFH, 2 X 2 BCFH)





3D9.1C2C8A4726	3D9.1C2C8A4726	0.35	3D9.1C2C8A4726	0.31
3D9.1C2CEF4DFB	3D9.1C2CEF4DFB	0.31	3D9.1C2CEF4DFB	0.23
3D9.1C2CFD894A	3D9.1C2CFD894A	0.35	3D9.1C2CFD894A	0.38
3D9.1C2CFE310E	3D9.1C2CFE310E	0.27	3D9.1C2CFE310E	0.35
3D9.1C2CFE6E2B	3D9.1C2CFE6E2B	0.35	3D9.1C2CFE6E2B	0.42
3D9.1C2D37BF8B	3D9.1C2D37BF8B	0.38	3D9.1C2D37BF8B	0.31
3D9.1C2D37DACE	3D9.1C2D37DACE	0.34	3D9.1C2D37DACE	0.44
3D9.1C2D37E207	3D9.1C2D37E207	0.28	3D9.1C2D37E207	0.22

Genetic Diversity

Kalinowski et al. 2012:

"….The redfish lake sockeye population has retained more genetic diversity (93%) than many other populations propagated in captivity to prevent extinction."

Conserv Genet (2012) 13:1183–1188
DOI 10.1007/s10592-012-0363-9

RESEARCH ARTICLE

Genetic diversity in the Snake River sockeye salmon captive broodstock program as estimated from broodstock records

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Abstract Snake River sockeye salmon spawning in Redfish Lake, Idaho are one of the most endangered taxa of Pacific salmon. The wild population nearly went extinct in the 1990s, and all surviving fish were incorporated into a captive broodstock program at that time. We used pedigree analysis to evaluate the effectiveness of the breeding pro- gram in retaining genetic variation from 1991 through 2008. Broodstock records document which males were crossed with which females, but fish from multiple crosses were frequently reared in the same tank so the exact ped- igree of the population is unknown. Therefore, a simula- tion-based approach was used to estimate how much genetic diversity was retained by the breeding program. Results indicate that in 2008, after 5.5 generations of breeding, the average inbreeding coefficient was probably about 0.056. We estimated the inbreeding effective popu- lation size to be 41 over the entire program and 115 for the most recent generation. This amount of inbreeding is substantially less than has occurred in many high-profile captive breeding programs. Our results depend on several assumptions regarding the relatedness of fish in the breeding program, but simulations suggest our main results are relatively insensitive to these assumptions.

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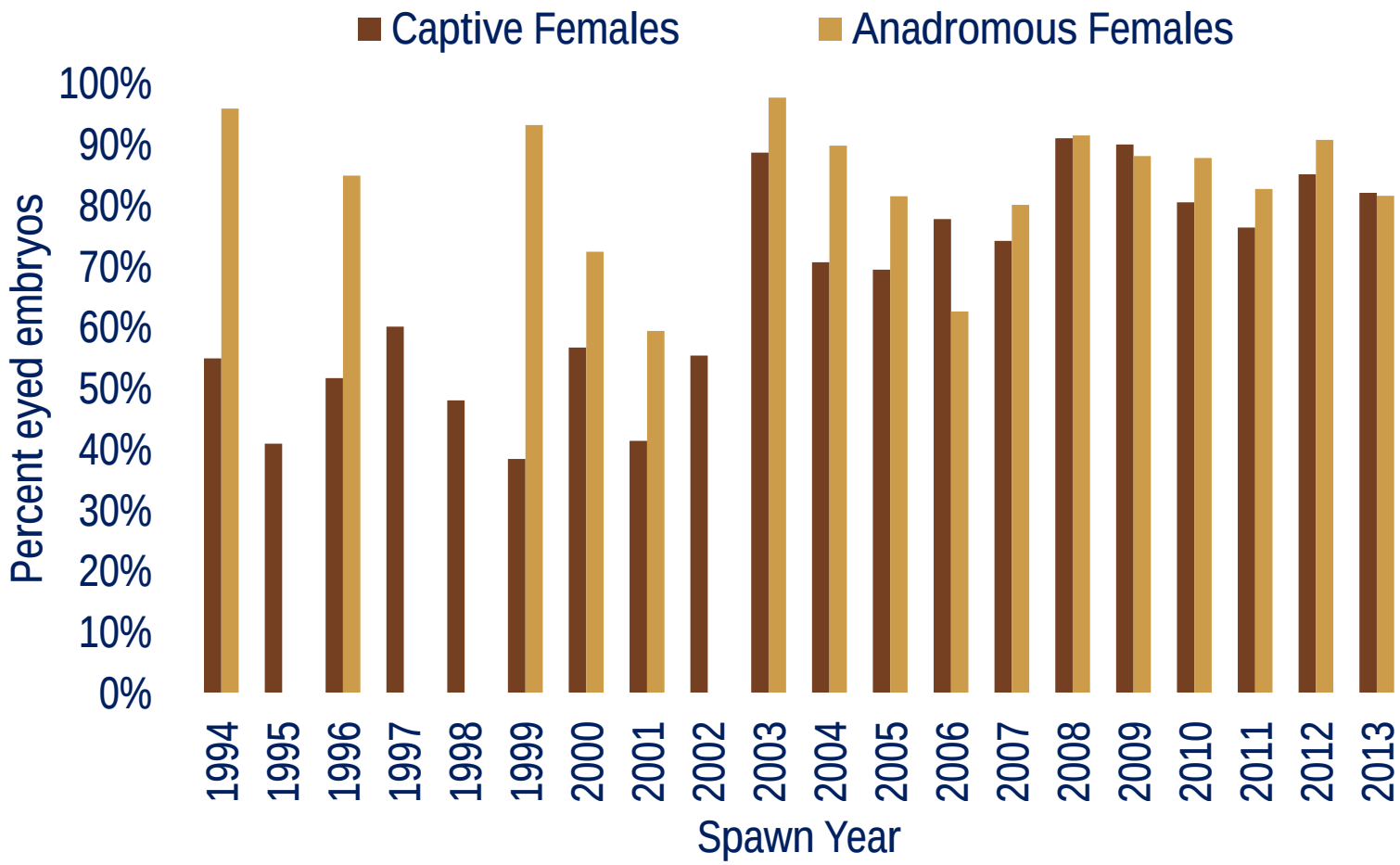
Keywords Captive · Broodstock · Breeding · Oncorhynchus nerka · Genetic diversity

Introductio
n

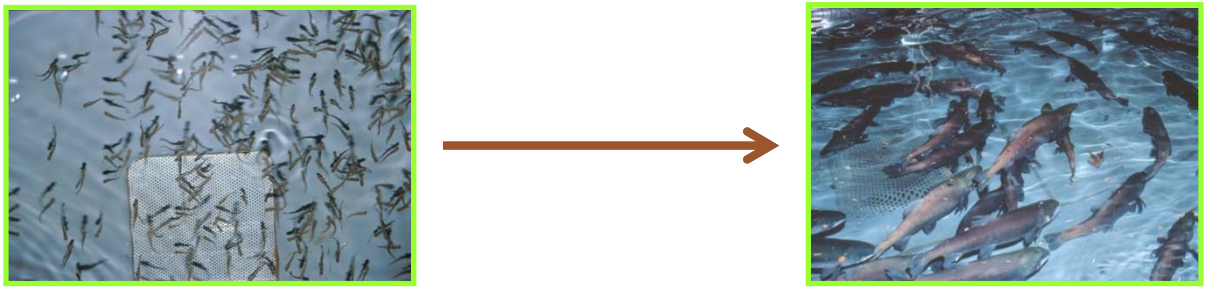
Captive propagation has been widely used to manage small populations (see Frasier 2008 for a review focusing on salmonid fishes). These propagation programs can take many forms, and can have different objectives. Common objectives for captive breeding programs include main- taining gene pools until factors limiting survival can be alleviated, speeding recovery in the wild, translocating individuals for genetic rescue, and reseeding vacant habitat (Waples and Drake 2004). One of the most high-profile applications of captive breeding has been with critically endangered species—those for which extinction in the near future is a realistic possibility. In these situations, the short- term goals of captive breeding are generally to (1) avoid complete extinction of the gene pool; (2) conserve as much genetic diversity as possible; and (3) accomplish objectives (1) and (2) without compromising prospects for long-term survival of the population/species. This is a tall order, and accomplishing all three goals requires carefully designed breeding/husbandry protocols, substantial financial and other resources, dedication and lots of hard work, and more than a little good luck.

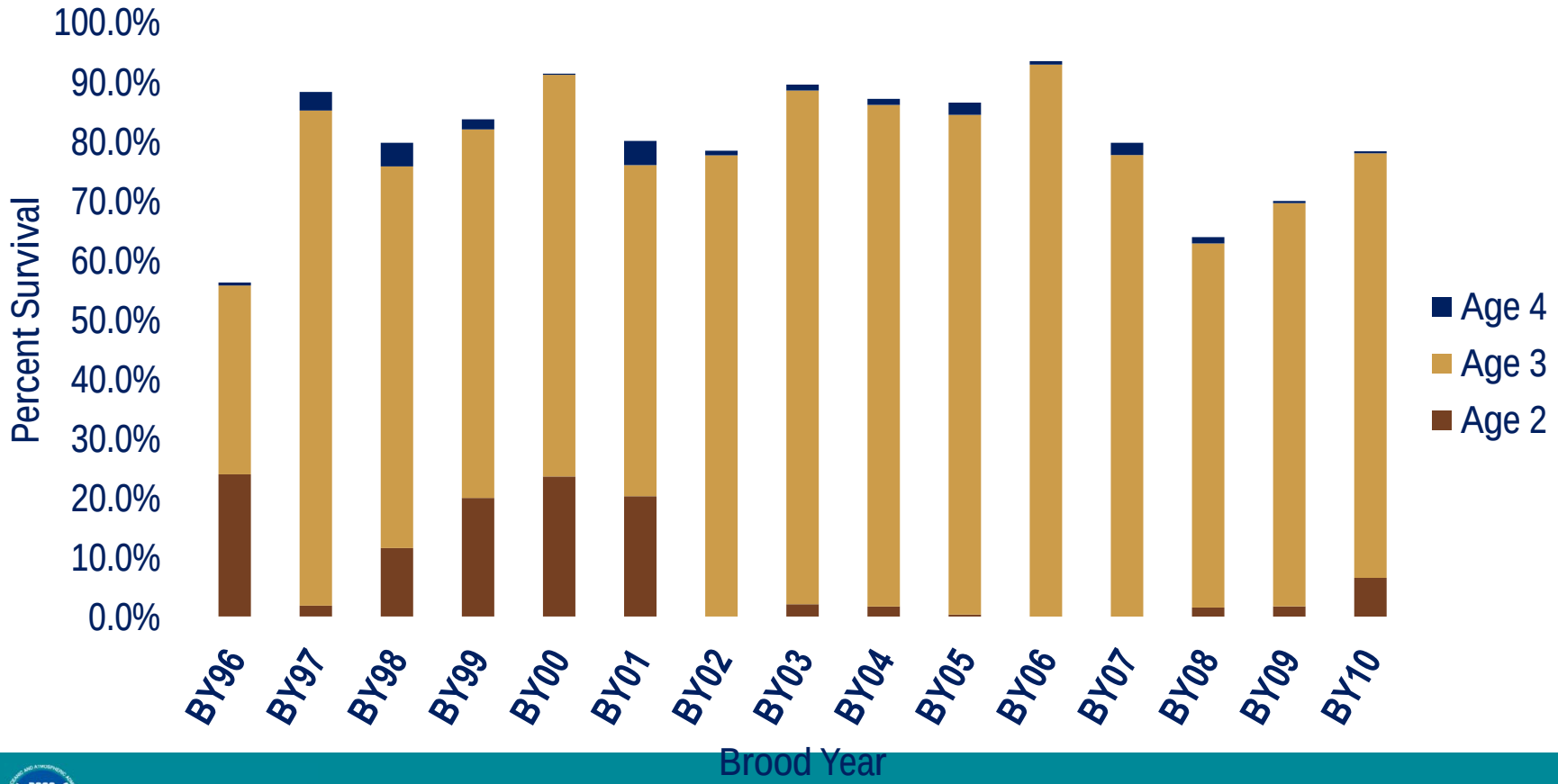
Sockeye salmon (Oncorhynchus nerka) from Redfish Lake in central Idaho are the only population of sockeye salmon in the Snake River. They live farther south, migrate farther in freshwater (1,500 km), and spawn at higher ele- vation (2,000 m) than any other population of sockeye in the world (Burke 2002; Waples et al. 1991). The population has also been critically endangered by any reasonable cri- terion (Waples et al. 1991): in 1990, no anadromous adults

Egg-to-eyed Embryo Survival

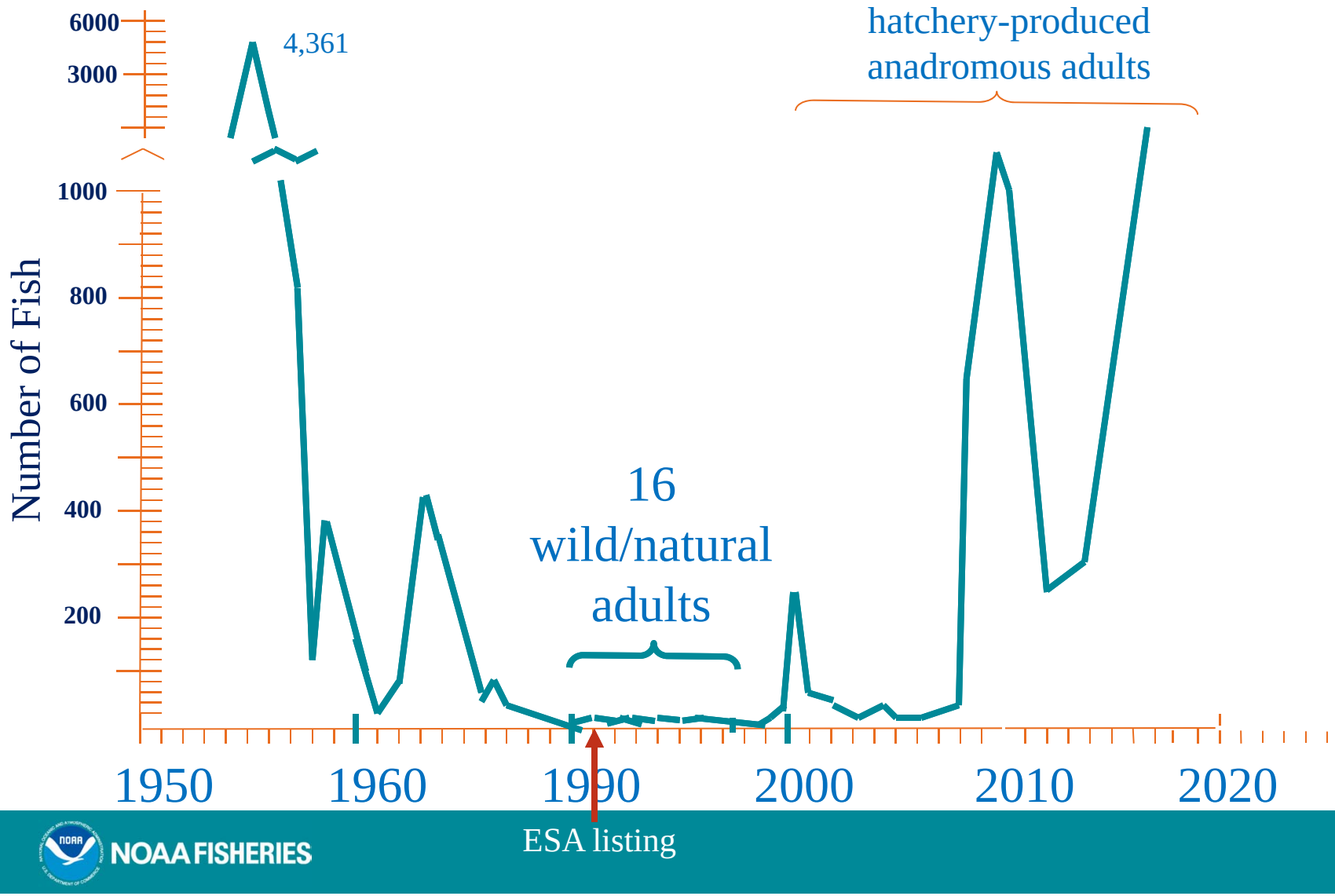


Fry-to-adult Survival and Age Structure





Adult sockeye salmon returns to Redfish Lake 1954 - 2014



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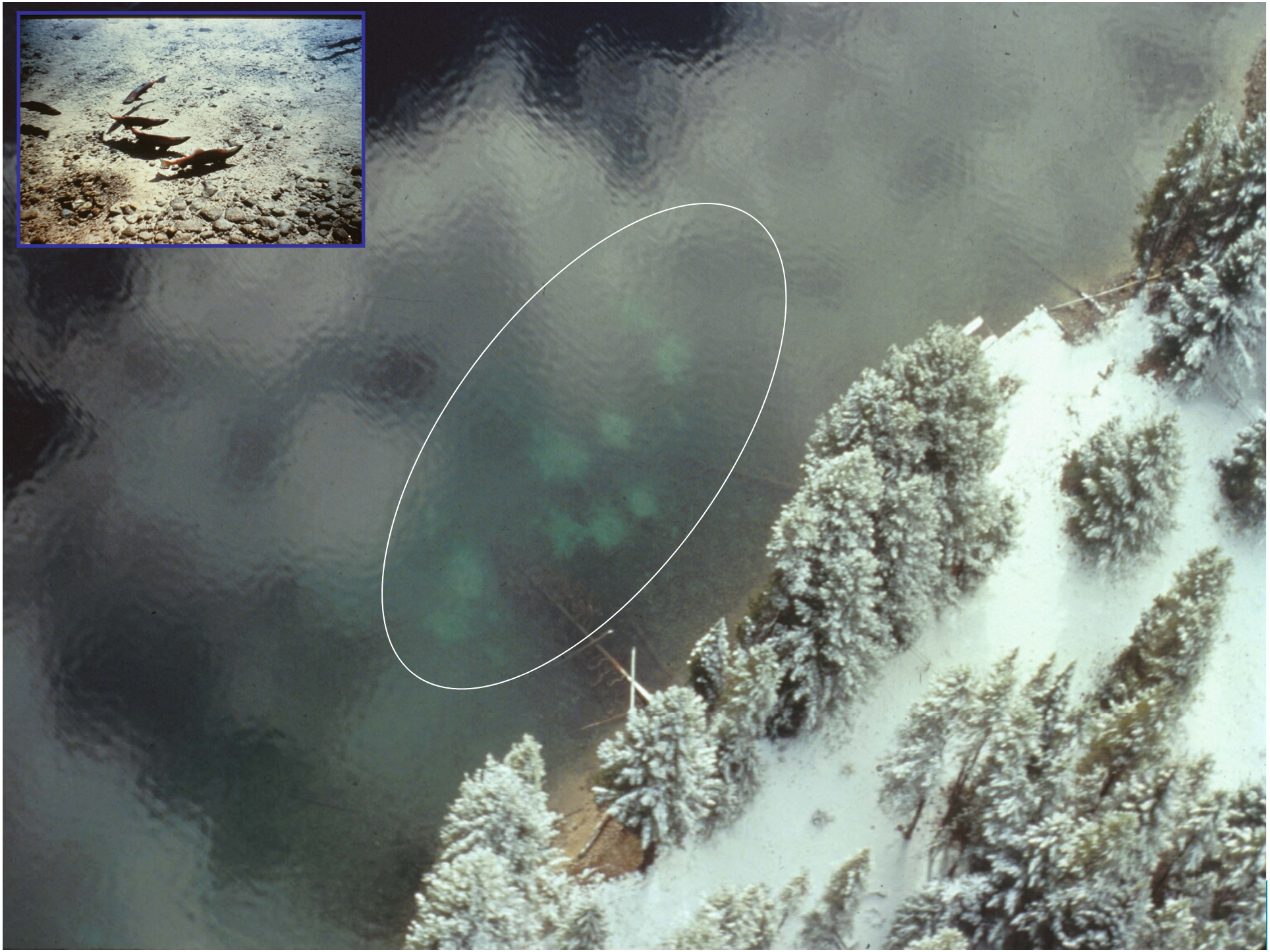
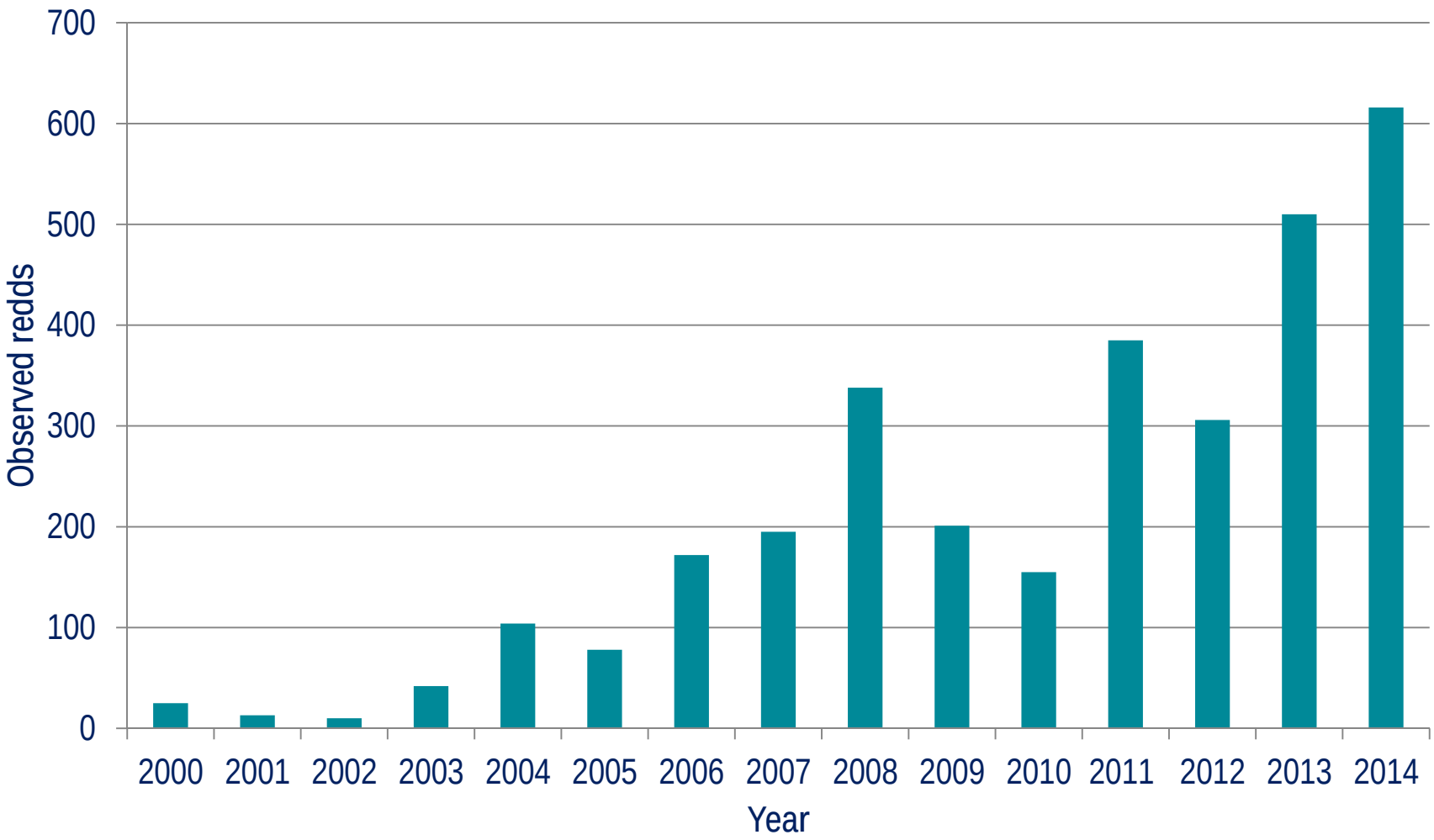
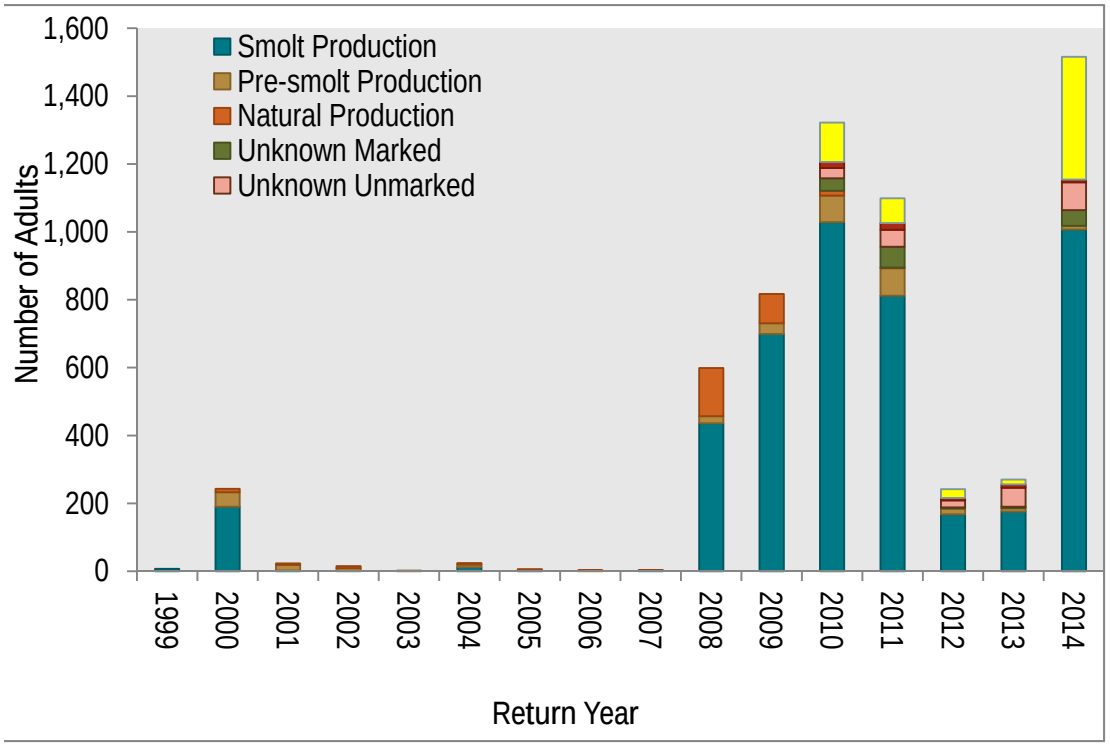


Sockeye salmon redds in Redfish Lake

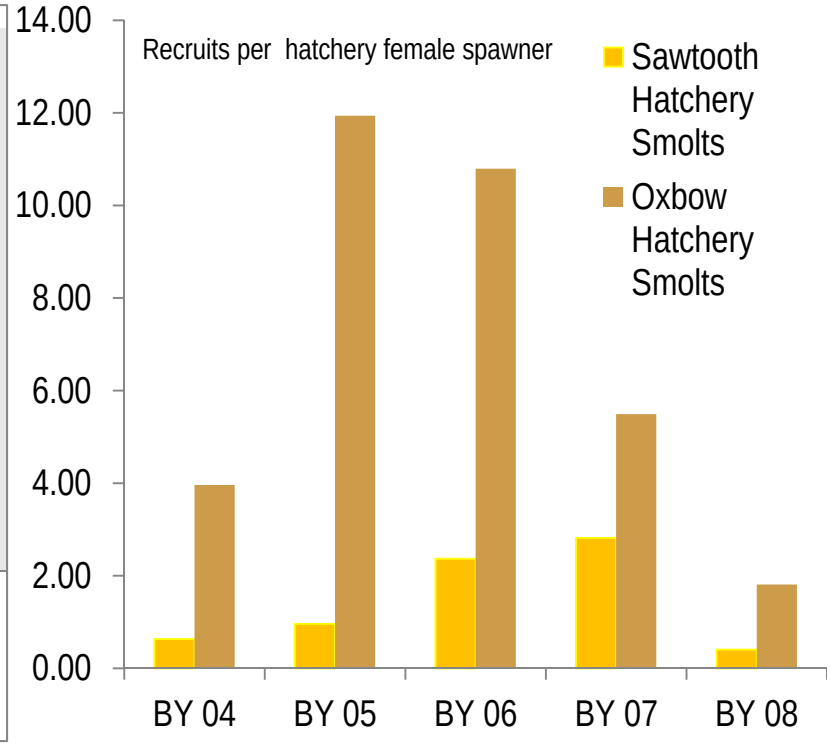


Release strategy effectiveness

Smolts > Presmolts > Egg Boxes



Oxbow > Sawtooth smolts



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Conservation program results

Redfish Lake information

	1996	2004	2005	2006
SAR for RFLpre-smolt release	0.06%	0.04%	0.13%	0.20%
SAR for RFL smolt release	0.35%	0.36%	0.78%	0.42%
SAR for RFL natural production	0.39%	0.84%	1.50%	1.92%

Example: 0.10% = 1 adult back for every thousand smolts out
1.00% = 10 adults back for every thousand smolts out

Putting the red back in Redfish Lake – twenty years of captive broodstock progress

- 1991: Snake River sockeye salmon listed as Endangered under the ESA
- Phase 1: Current captive broodstock program initiated in 1991
- Phase 2: Re-colonization phase
- Phase 3: Local Adaptation phase

NMFS Recovery Plan, FR notice June 2014

Kline, P. & T. Flagg 2014. Fisheries 39(11):488-500.

Stanley Basin Sockeye Captive Broodstock Summary

1. Developed conservation aquaculture techniques to raise sockeye full-term to maturation in the hatchery (with high survival)

2. Maintained population genetic diversity and conserved the adaptive potential of the population

3. Increased the number of adult sockeye spawning in Redfish Lake

4. Implemented a comprehensive m&e plan that

    - identified smolt releases as the most effective reintroduction strategy

    - Established achievable recovery planning phases and triggers