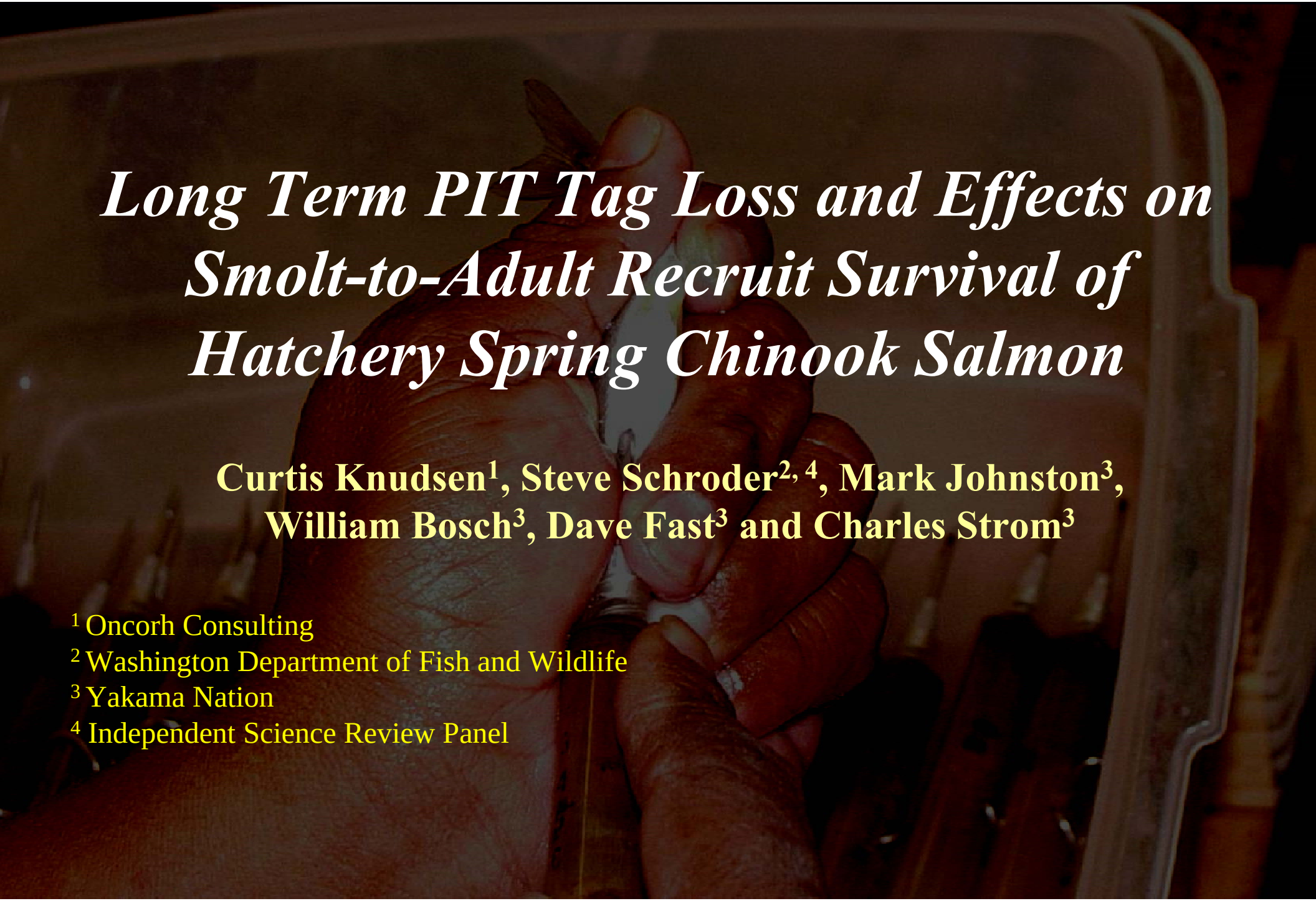


Long Term PIT Tag Loss and Effects on Smolt-to-Adult Recruit Survival of Hatchery Spring Chinook Salmon

Curtis Knudsen[1], Steve Schroder[2, 4], Mark Johnston[3], William Bosch[3], Dave Fast[3] and Charles Strom[3]

[1] Oncorh Consulting
[2] Washington Department of Fish and Wildlife
[3] Yakama Nation
[4] Independent Science Review Panel

From: *McDonald et al. 2003. Tag loss can bias Jolly-Seber capture–recapture estimates. Wildlife Society Bulletin 31(3):814–822.*

Assumptions

- **tagged animals and untagged animals survive equally well.**
- **all tagged animals retain their tags and are correctly identified.**
- **tagged animals are representative of untagged animals (size, growth and behavior).**

“An important practical consideration when designing a study is to use a … marking method such that it does not influence the animal’s survival, but at the same time mark loss should be negligible.”

“If mark loss cannot be avoided completely, it should be estimated through techniques such as double marking.”

Pollock et al. 1990. *Statistical Inference for Capture-Recapture Experiments*. Wildlife Monographs 107:1-97.

Citations Correcting Tag Loss

- Seber and Felton. 1981. Tag loss and the Petersen mark-recapture experiment. Biometrika 68(1):211-219.
- Arnason and Mills. 1981. Bias and loss of precision due to tag loss in Jolly-Seber estimates for mark-recapture experiments. CJFAS 38:1077-1095.
- Nichols and Hines. 1993. Survival rate estimation in presence of tag loss using joint analysis of capture-recapture and resighting data. in Marked Individuals in the Study of Bird Populations.
- McDonald et al. 2003. Tag loss can bias Jolly-Seber capture–recapture estimates. Wildlife Society Bulletin 31(3):814–822.
- Conn et al. 2004. A General Model for the Analysis of Mark-Resight, Mark-Recapture, and Band-Recovery Data under Tag Loss. Biometrics 60:900-909.
- Rotella and Hines. 2005. Effects of tag loss on direct estimates of population growth rate. Ecology 86(4):821–827.
- Cowen and Schwarz. 2006. The Jolly-Seber model with tag-loss. Biometrics 62:699-705.
- Gonzalez and Cowen. 2010. The Jolly-Seber-Tag-Loss Model with Group Heterogeneity. The Arbutus Review 1:30-44.
- Hyun et al. 2011. Accounting for Tag Loss and Its Uncertainty in a Mark-Recapture Study with a Mixture of Single and Double Tags. Transactions of the American Fisheries Society 141(1):11-25.

- The important information is on tag performance under real life study conditions, where fish of the appropriate
  - **species,**
  - **life history type,**
  - **size and state of maturation**

  and where they must

  - **compete for resources,**
  - **escape predators,**
  - **experience exposure to diseases and physiological stressors,**
  - **and make directed migrations.**
- **Tag performance under real life conditions is the only accurate way to asses whether model assumptions regarding long term tag loss, growth, survival and behavior are being violated.**

Objectives

- **Review how we estimated juvenile-to-adult PIT and CWT tag loss rates over 5 broodyears (1997-2001)**

Knudsen et al. 2009. E*ffects of Passive Integrated Transponder Tags on Smolt-to-Adult Recruit Survival, Growth, and Behavior of Hatchery Spring Chinook Salmon.* NAJFM 29:658–669.

Objectives

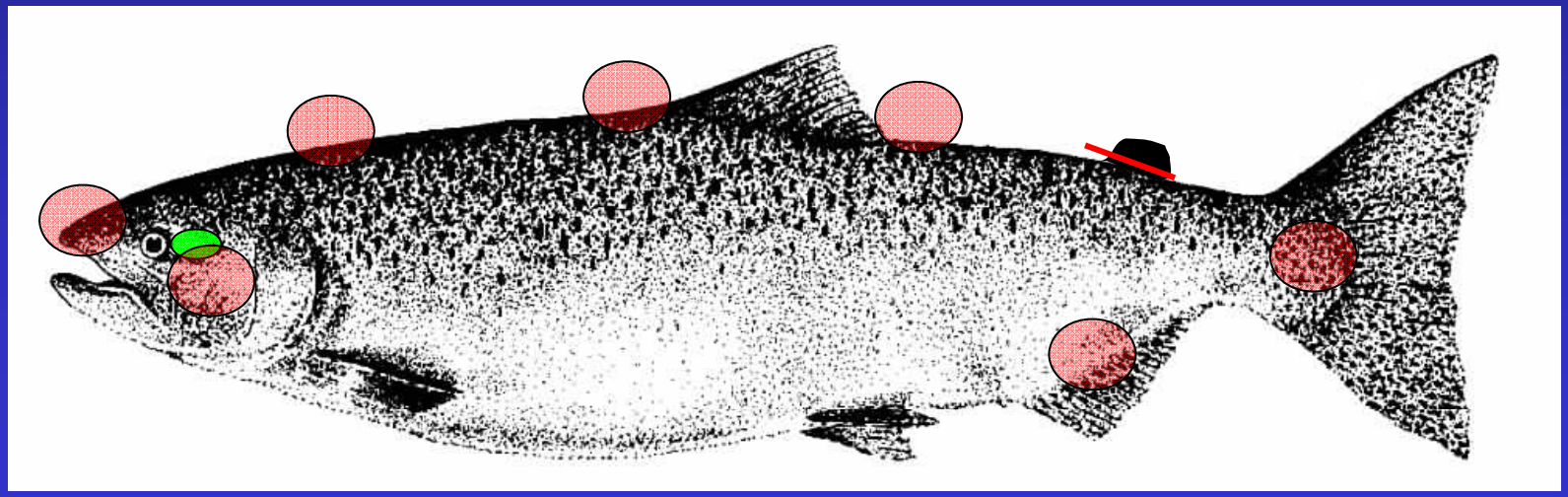
- **Review how we estimated juvenile-to-adult PIT and CWT tag loss rates over 5 broodyears (1997-2001)**
- **Compare Smolt-to-Adult Recruit Survival (SARS) for PIT tagged and non-PIT tagged fish**
  - **Apparent SARs (using only observed PIT tags)**
  - **SARs Corrected for PIT tag loss and Recapture Efficiency**
- **Include BYs 2002-2006 comparisons**

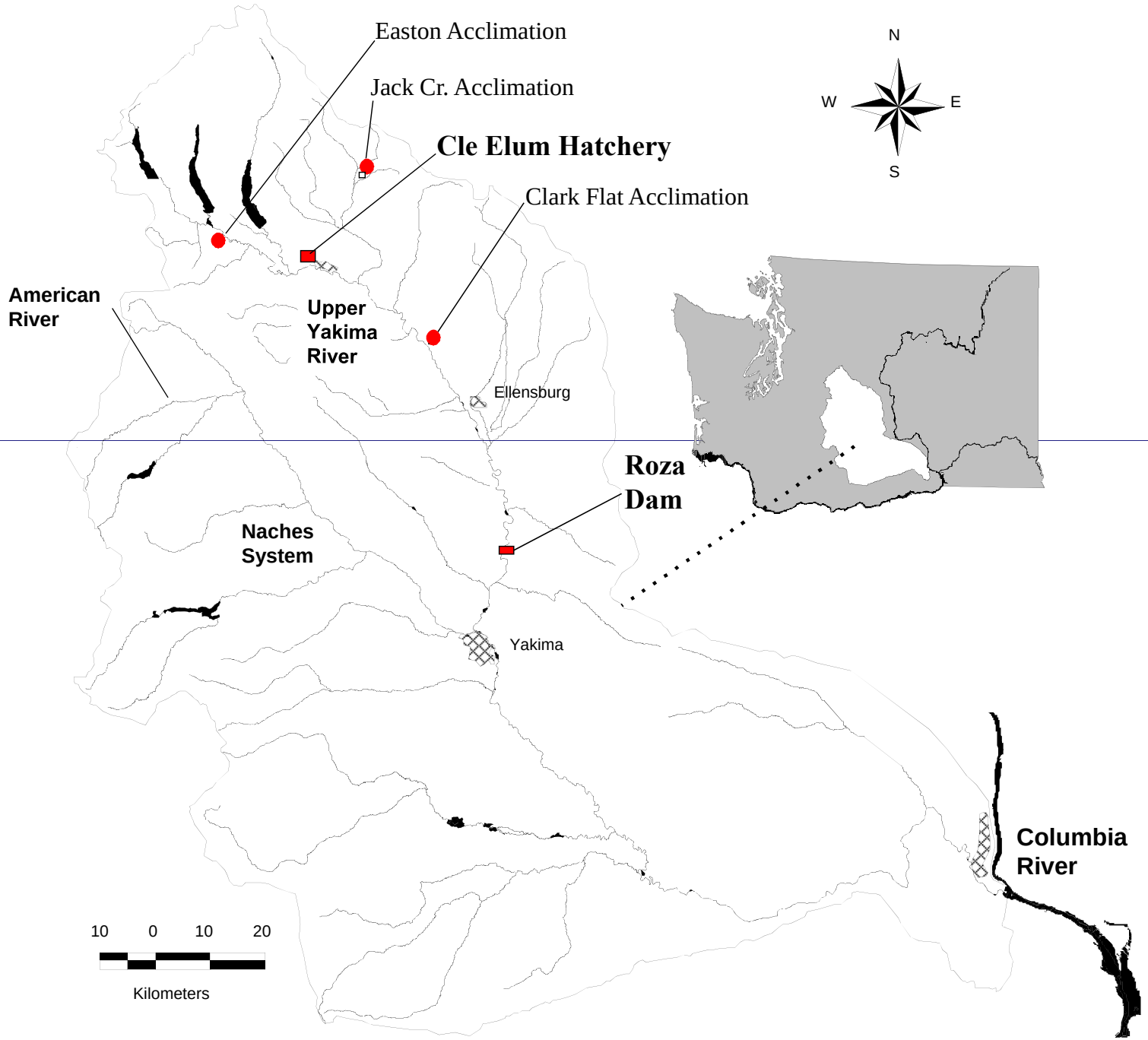
Study Design

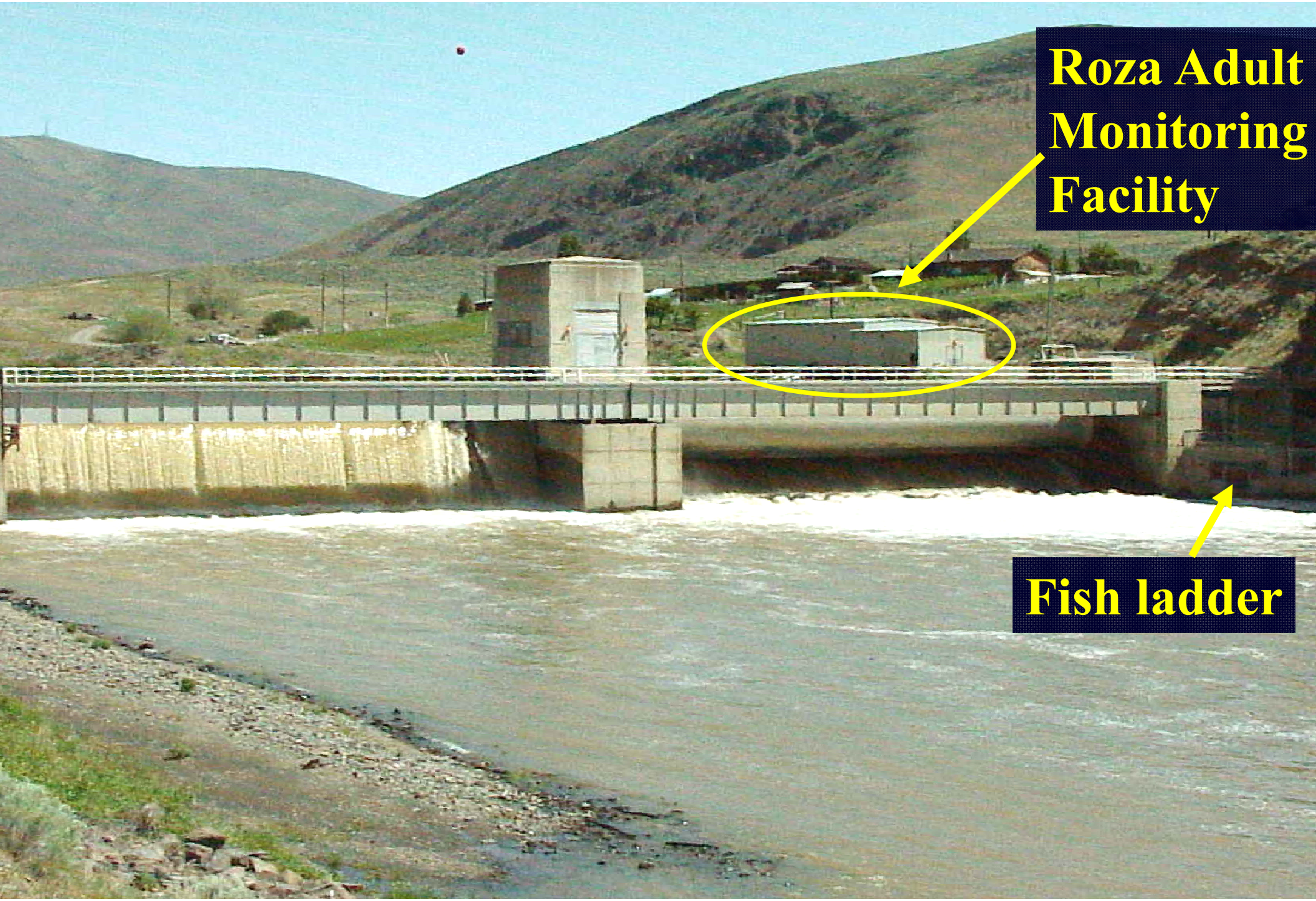
- **Double tag (PIT and snout CWT) approximately 40K juvenile spring chinook in October-December (5-11% of the fish released each year)**
- **Held for between 1.5 to 4 months post-tagging and volitionally released from March 15-May 30**
- **Replicated over 5 years (releases in 1999 to 2003)**
- **All hatchery origin adults (ages 3, 4 and 5) were interrogated for tags at Roza adult trap (April-Sept.) sampled for length, weight, and subsample age (scales)**
- **Smolt-to-Adult Recruit Survival (SARS) and tag loss by broodyear were estimated based on recapture data**

Tagged Releases

Juvenile Releases (x1000)	Broodyear 1997	1998	1999	2000	2001
PIT + Snout CWT	40	37	39	38	40
Elast + Body CWT	346	552	720	797	334
Total released	386	590	759	834	374




Easton Acclimation
Jack Cr. Acclimation
Cle Elum Hatchery
Clark Flat Acclimation
American River
Upper Yakima River
Ellensburg
Roza Dam
Naches System
Yakima
Columbia River
N
W
E
S
10 0 10 20
Kilometers


Roza Adult Monitoring Facility
Fish ladder

Roza Recapture Efficiency Estimates

- Andy Dittman, NOAA, conducted carcass surveys on the upper Yakima River from 2002 to 2010.
- Checked all carcasses for PIT tags.
- We could estimate annual Recapture Efficiency at Roza Trap from the carcass recapture data:

$$\textbf{RecapEff} = \frac{\textbf{(\# Roza recapture)}}{\textbf{(\# carcass recaptures)}}$$

RAMF PIT tag recovery efficiency estimates

Recovery Year	PIT tag carcass recoveries	# observed at RAMF	% observed at RAMF
2002	13	12	92.3
2003	9	9	100.0
2004	10	10	100.0
2005	2	2	100.0
2006	8	8	100.0
2007	12	11	91.7
2008	16	15	93.8
2009	59	59	100.0
2010	65	65	100.0
Totals	194	191	Bootstrap Med. 98.7

Data provided by Andy Dittman, NOAA

95% CI (98.1–100.0)

Potential Problem:
Out-of-Basin CWT'ed Fish Recaptured at the Roza Adult Monitoring Facility

- Leads to overestimates of PIT tag loss...
- ...but also results in overestimating PIT tag survival.
- These fish are misidentified as PIT tagged fish that lost their PIT tag.

The total number of coded-wire tags (CWT) recovered from carcasses recaptured within the upper Yakima River by year.

Provided by Andy Dittman, NOAA.

Year	Total CWT recoveries	Out-of-basin Recoveries	Percent in-basin Recoveries
2002	1327	1	99.9
2003	406	0	100.0
2004	786	0	100.0
2005	260	0	100.0
2006	422	0	100.0
2007	358	0	100.0
2008	817	0	100.0
2009	1199	0	100.0
2010	1638	0	100.0
Total	7213	1	100.0

Juvenile Pre-Release Tag Loss

- Each year 136 to 327 PIT tagged juveniles were sampled 1-2 months post-tagging to estimate tag loss prior to release.

$$\hat{\text{Pr}}_{pit} = [\text{Probability of losing a PIT tag}] = \frac{R_{cwt}}{(R_{cwt} + R_{pit,cwt})}$$

$$\hat{\text{Pr}}_{cwt} = [\text{Probability of losing a snout CW tag}] = \frac{R_{pit}}{(R_{pit} + R_{pit,cwt})}$$

From: *Seber. 1982. The estimation of animal abundance*

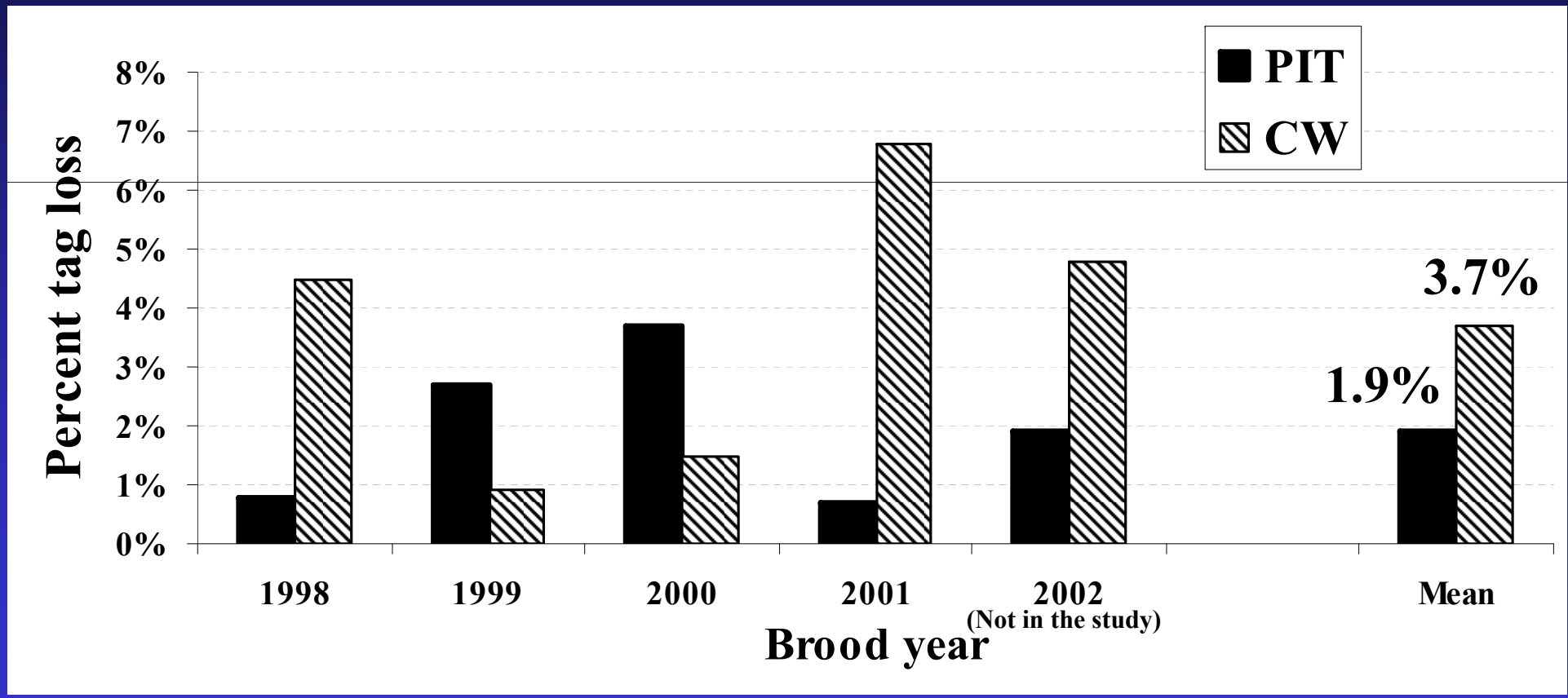
$\hat{R}$ is the number of recaptures corrected for tag loss and recapture efficiency

$$\hat{R} = c(R_{cwt} + R_{pit} + R_{pit,cwt}) * (RecapEff)^{-1}$$

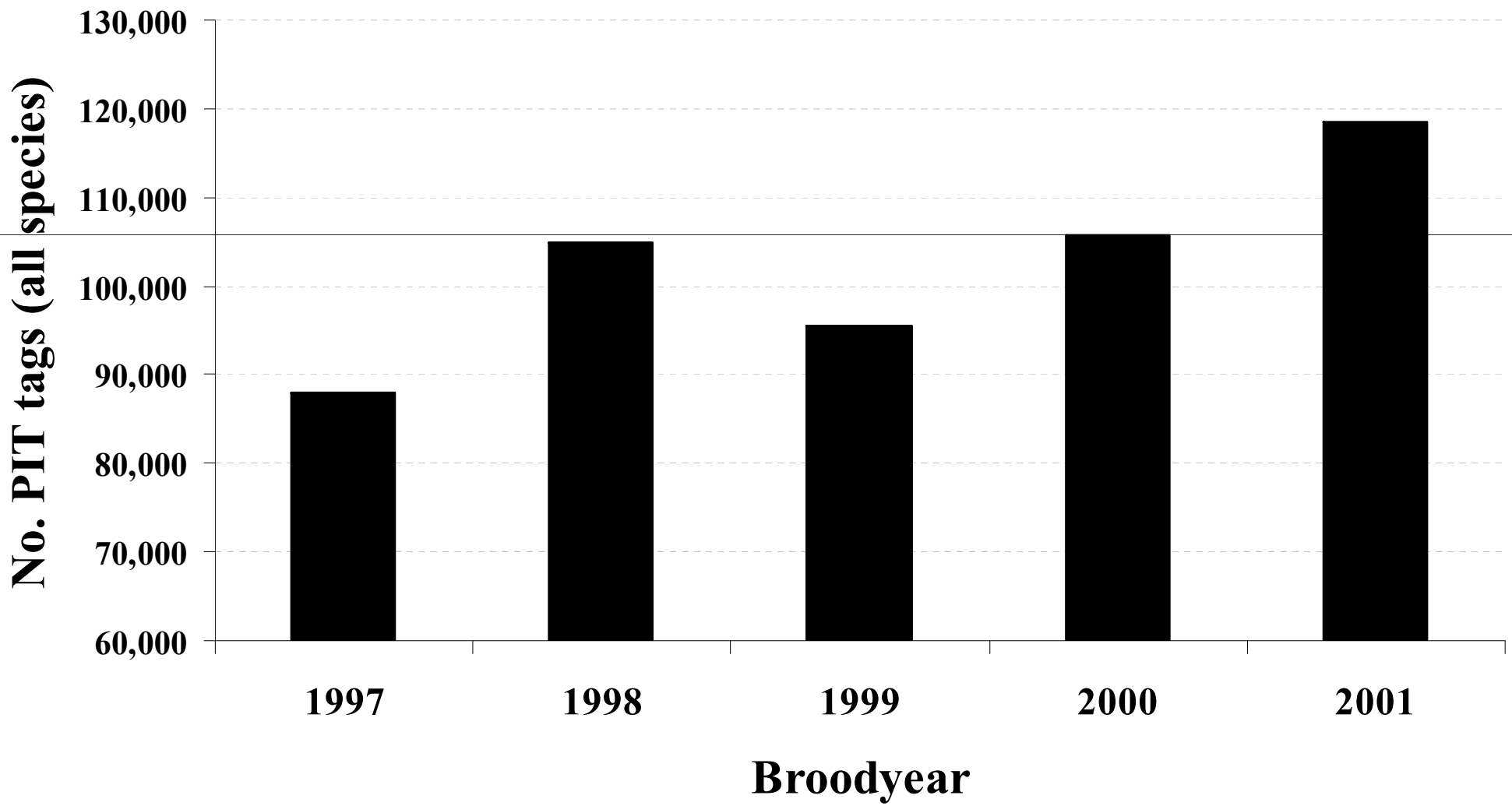
$$c = \left[1 - \frac{R_{cwt} * R_{pit}}{(R_{cwt} + R_{pit,cwt})(R_{pit} + R_{pit,cwt})}\right]^{-1}$$

(Joint probability of losing both PIT and CW tags)

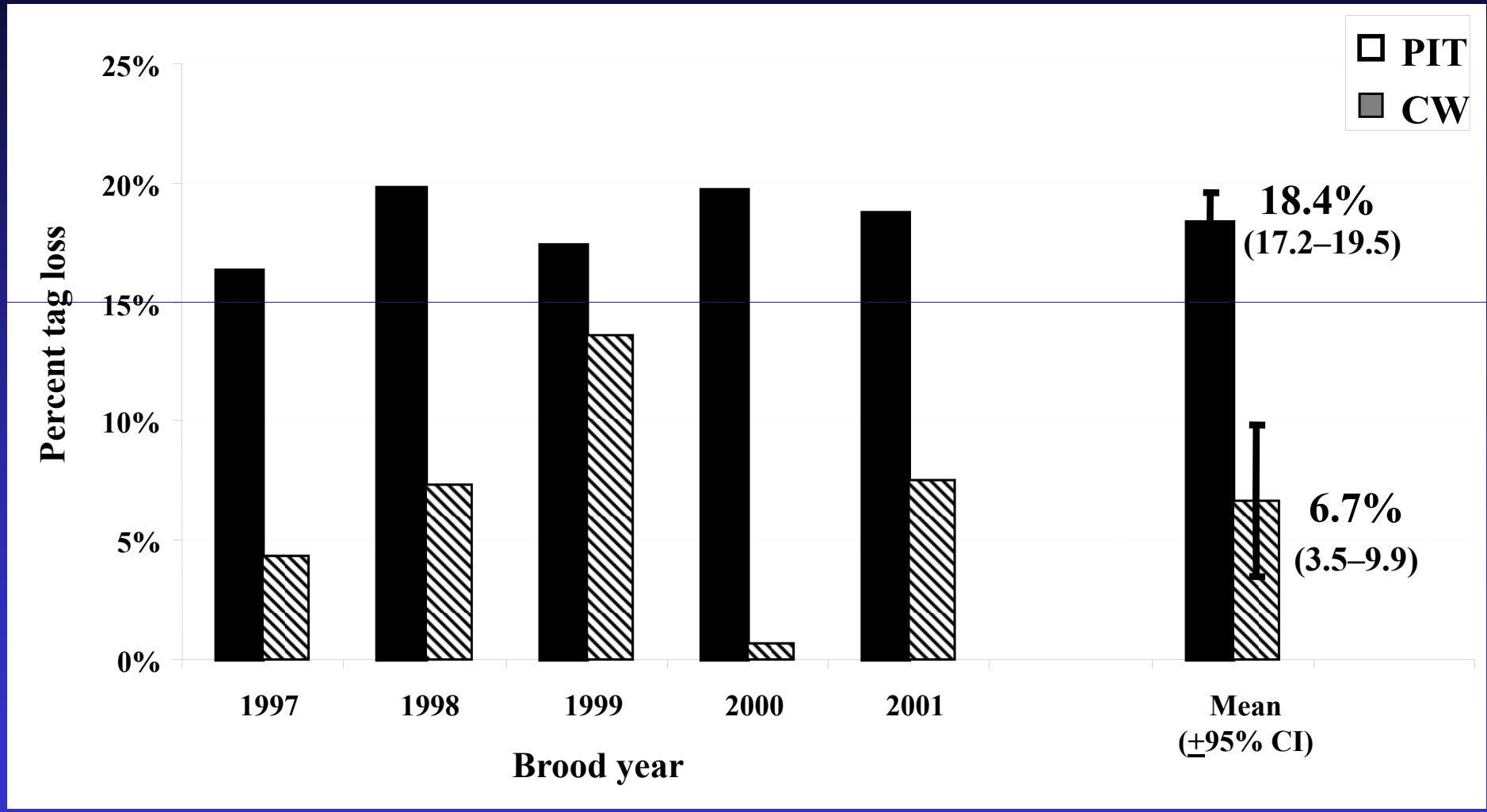
Juvenile tag loss 1-2 months after tagging and 1-2 months before release



Number PIT Tagged Annually By Yakama Nation

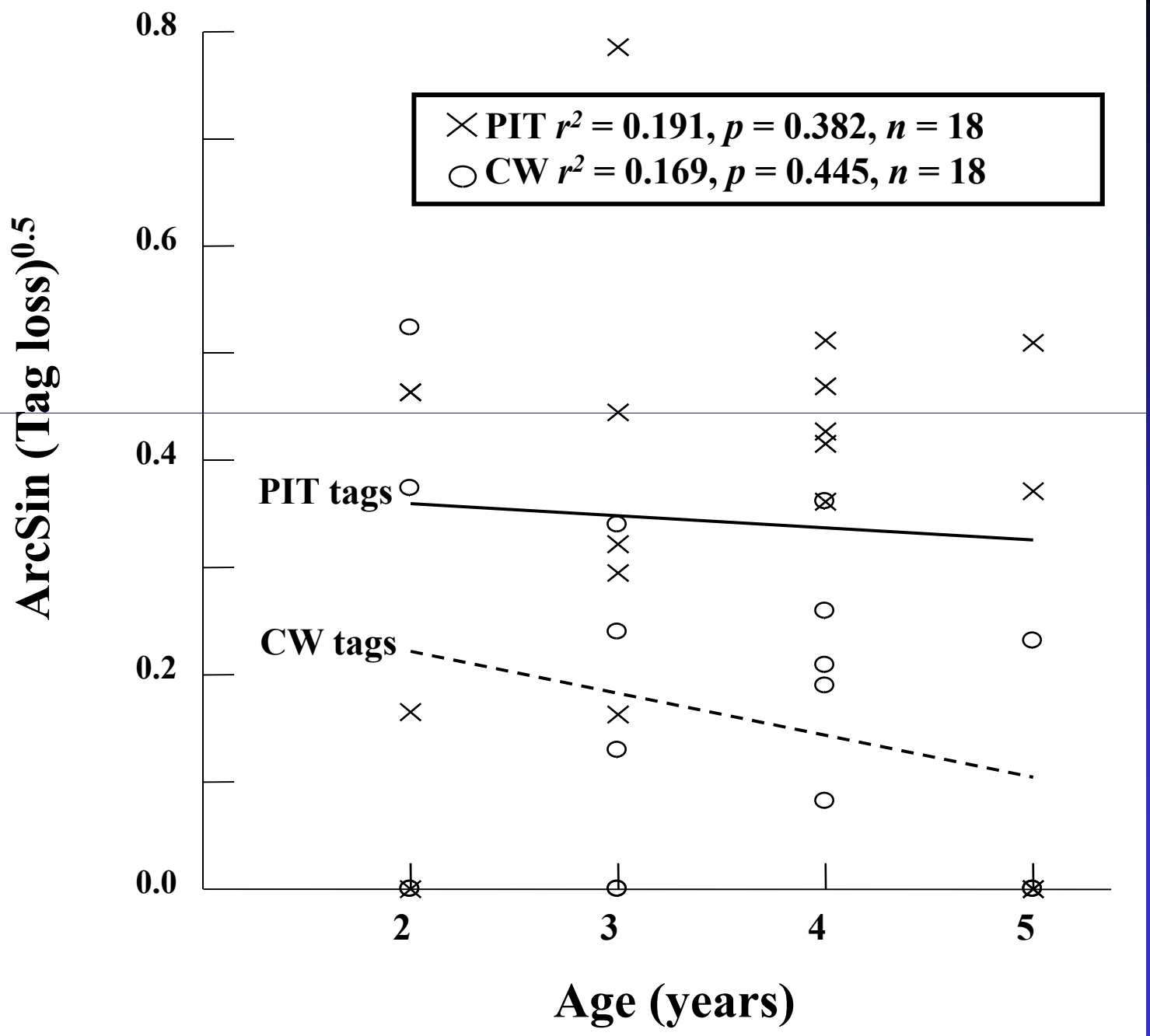


Adult PIT and CW tag loss rates



In Situ PIT Tag Loss

Species	Mean PIT loss	Citation
Artic grayling	17%	Buzby and Deegan 1999
Coho	59% ♀ 13% ♂	Prentice et al. 1994
Chinook	18%	Knudsen et al. 2009
Brown trout	20% 56%	Acolas et al. 2007 Dieterman and Hoxmeier 2009
Rainbow	20% 19%	Gastelecutto et al. 2008 Meyer et al. 2011
Cutthroat	26% 3% 24%	Bateman et al. 2009 Harding et al. 2009 Berger et al. 2009


0.8
0.6
0.4
0.2
0.0
ArcSin (Tag loss)^0.5
PIT r² = 0.191, p = 0.382, n = 18
CW r² = 0.169, p = 0.445, n = 18
PIT tags
CW tags
2
3
4
5
Age (years)

Correcting SARS for Lost and Missed PIT Tags

Apparent or Uncorrected PIT SARS = $\dfrac{R_{pit} + R_{cwt+pit}}{\#PIT_{\mathrm{Re}leased}}$

Corrected PIT SARS = $\hat{R}_{pit}/(\#PIT_{Released})$

Uncorrected Non-PIT SARS = (# Non-PIT recoveries) / (# Non-PIT released)

Corrected Non-PIT SARS = (# Non-PIT recaps - Est PIT lost or missed) / (# Non-PIT released)

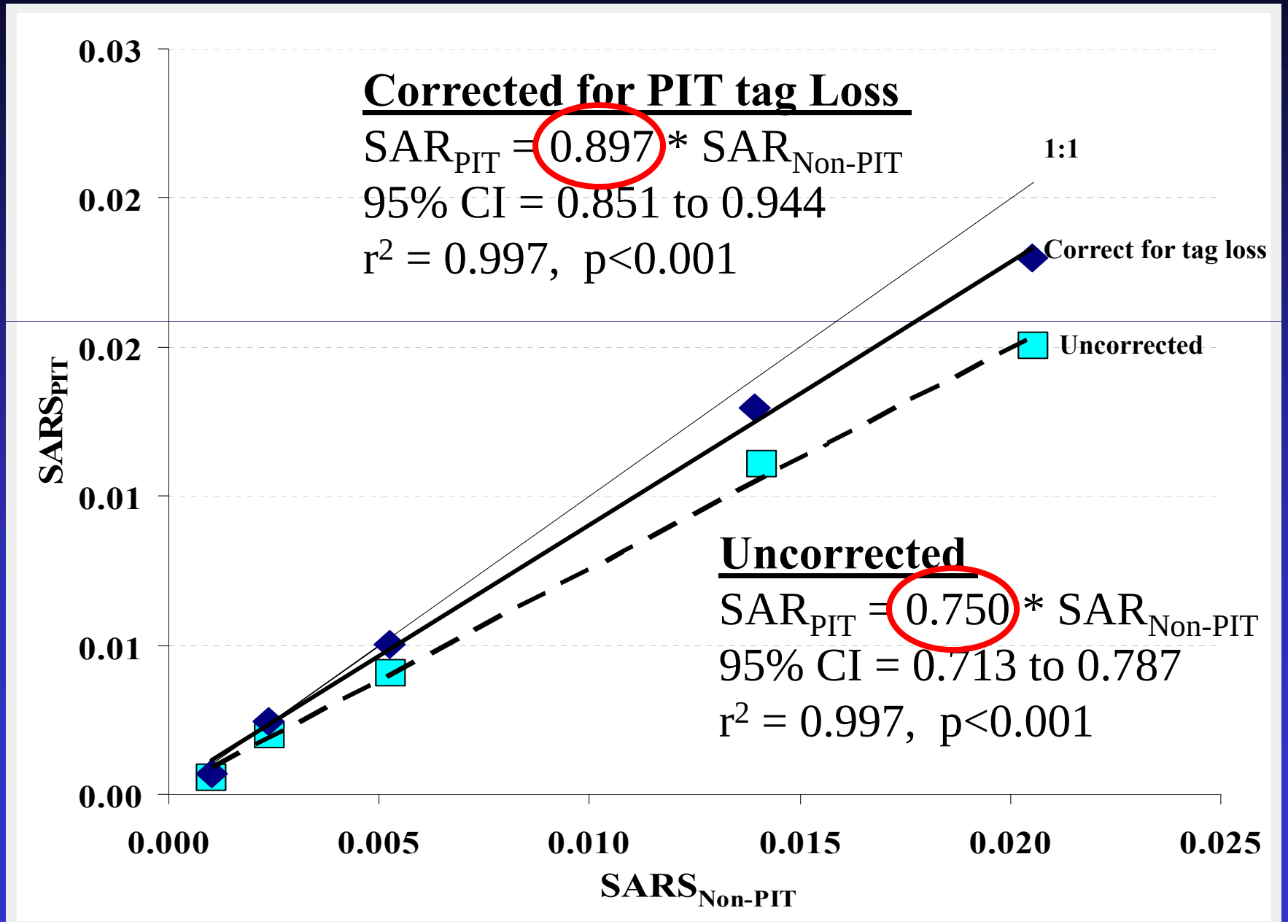
Linear model of PIT tag effect:

$$SARS_{PIT} = [(1-PIT_{effect})* SARS_{NonPIT}] + \varepsilon$$

Regress $SARS_{NonPIT}$ vs $SARS_{PIT}$

The slope is an estimate of $(1-PIT_{effect})$

PIT vs Non-PIT SARS



1997-2001 Results

Based on observed (apparent) recaptures:

- **PIT Tag Loss + Mortality ⟶ 25.0% mean (range 17.1 to 44.9%) reduction in adults PIT tagged SARS**

After correcting for Recap Efficiency and tag loss:

- **PIT tag mortality ⟶ 10.3% mean (range -4.4% to 33.3%) reduction in adults PIT tagged SARS**

Assumptions for BY2002-2006

- PIT tag recoveries are corrected for tag loss using the average PIT tag loss rate of 18.4% (17.2-19.5) from Knudsen et al. (2009).
- PIT tag recoveries are also corrected for years when Roza recapture efficiencies <100%.
- Non-PIT tag recoveries are corrected by removing the estimated number of fish that had lost their PIT tag and those not detected due to PIT tag recapture efficiencies less than 100%.

Brood Year	PIT SAR	Non-PIT SAR	Ratio uncorrected PIT/Non-PIT SAR
1997	1.50%	1.81%	0.829
1998	1.06%	1.31%	0.809
1999	0.06%	0.11%	0.545
2000	0.40%	0.48%	0.833
2001	0.22%	0.32%	0.688
2002	0.25%	0.28%	0.893
2003	0.09%	0.22%	0.409
2004	0.37%	0.61%	0.607
2005	0.37%	0.79%	0.468
2006	1.16%	1.42%	0.817
arithmetic mean		0.74%	0.690
geometric mean		0.53%	0.668

31-33%

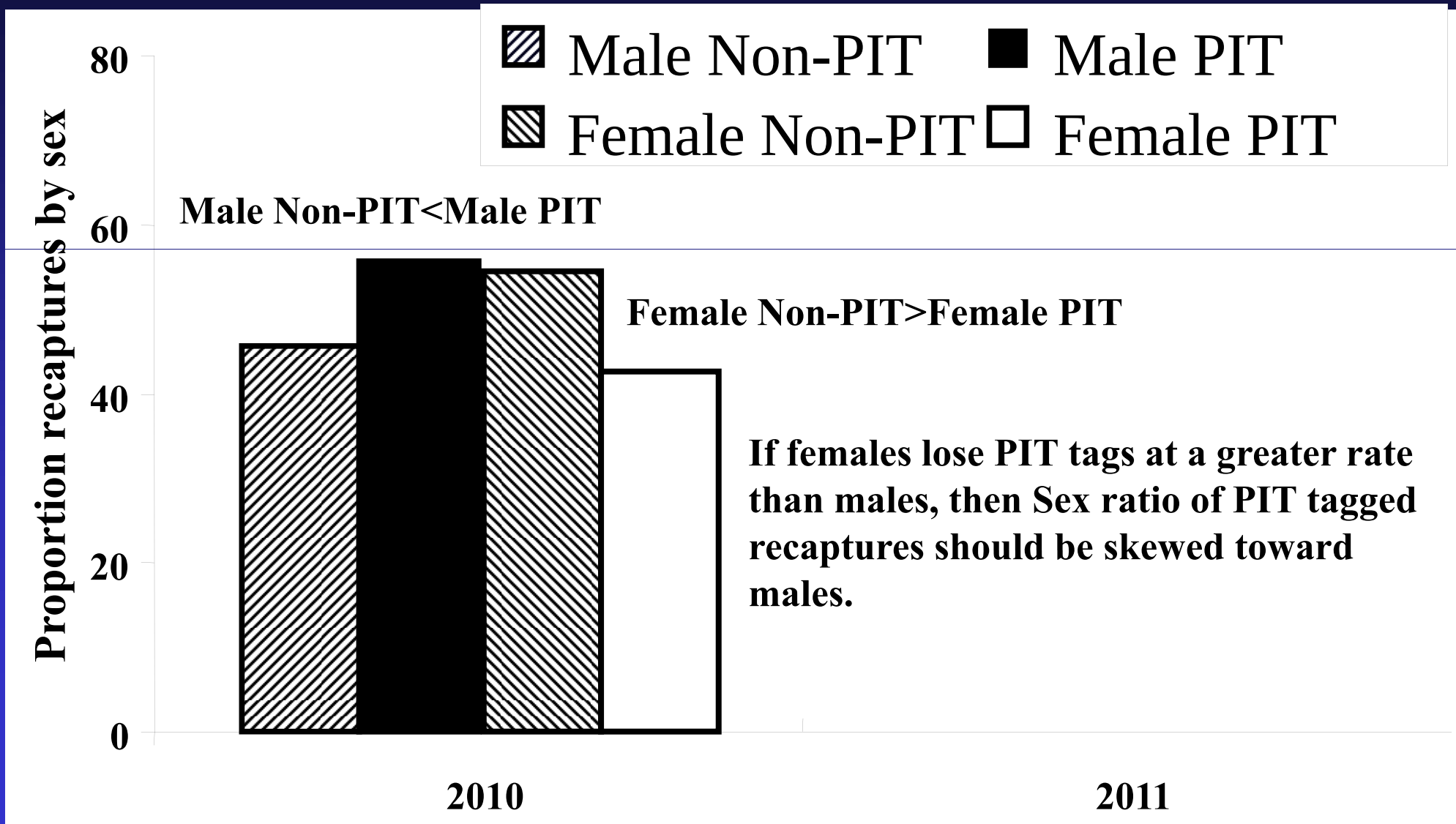
Brood Year	PIT SAR	Corrected PIT SAR	Non-PIT SAR	Ratio corrected PIT/Non-PIT SAR
1997	1.50%	1.83%	1.81%	1.013
1998	1.06%	1.30%	1.31%	0.997
1999	0.06%	0.07%	0.11%	0.685
2000	0.40%	0.49%	0.48%	1.023
2001	0.22%	0.27%	0.32%	0.835
2002	0.25%	0.30%	0.28%	1.098
2003	0.09%	0.11%	0.22%	0.490
2004	0.37%	0.45%	0.61%	0.741
2005	0.37%	0.45%	0.79%	0.575
2006	1.16%	1.42%	1.42%	1.000
arithmetic mean		0.67%	0.74%	0.846
geometric mean		0.43%	0.53%	0.819

15-18%

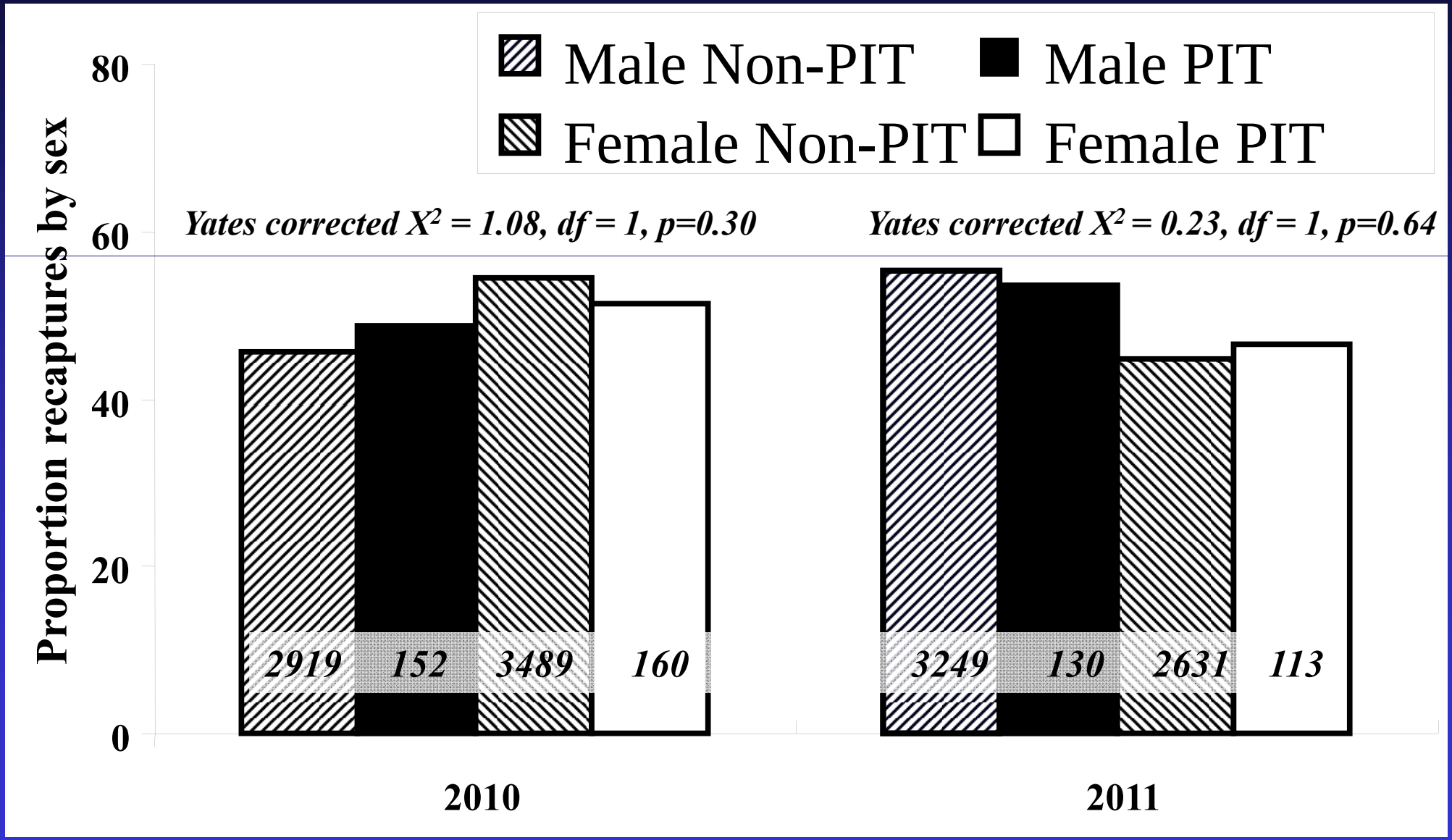
Differences by Sex

- Gender classifications using an ultrasound device were done in 2010 and 2011 on all fish passing Roza Dam.
- Accuracies were 99.5% (n=624) and 99.8% (n=433) in 2010 and 2011, respectively.

Differences by Sex



Differences by Sex



Conclusions

- **Cle Elum Hatchery Spring Chinook**
  - **Mean PIT tag loss was 18.4%; very stable over 5 years**
  - **PIT tag loss occurred within the first 6 months after release and did not increase with age**
  - **Brood year SARS were underestimated by up to 59% due to a combination of tag loss and induced mortality; averaging 33% less over all brood years**
  - **PIT tag induced mortality was as great 51% and averaged 18% over all brood years**

The Big Picture

- **Long term PIT tag loss and effects can be significant and short term tagging quality metrics will not necessarily indicate that**
- **You won't know what tag loss and tag effects are if you don't test under "real world" study conditions**

Taken from: *PIT Tag Steering Committee, and Columbia Basin Fish and Wildlife Authority*. 1999. PIT Tag Marking Procedures Manual: Version 2.0. Pages 8-9.

d. Fish Recovery and Release

Fish should be allowed to recover in a cool dark tank for at least a half-hour before release back into the stream.

e. Post-Tagging Mortality and Tag Retention

The PTSC recommends that a sub-sample of the marked population should be held and observed for up to 24 hours to obtain information on post-tagging mortality and tag loss.

The Big Picture

- **Long term PIT tag loss and effects can be significant and short term tagging quality metrics will not necessarily indicate that**
- **You won't know what tag loss and tag effects are if you don't test under "real world" study conditions**
- **Different species, life histories, time frames, basins and ecological circumstances will result in different effects – There is no *Universal Control***
- **Design studies to include double-tagged fish to assess tag loss and replicate over a number of years**
- **When possible, include non-PIT tagged 'Control' fish to assess PIT tag effects on survival and replicate**

Acknowledgments

- **PIT tagging of juveniles and recapture of adults was performed by Mark Johnston and Yakama Nation personnel**
- **Elastomer and CW body tagging was done jointly by WDFW/YN personnel, then by YN**
- **BPA provided funding through the Yakima/Klickitat Fishery Project's M&E Program**


QUESTIONS?