Outline

1. Risk-benefit considerations for AP
2. Empirical results from salmon supplementation
3. Meta-analysis of Columbia River Chinook supplementation
4. Reproductive success studies in upper Columbia River
5. Review key questions

Key questions regarding endangered species conservation

1. Pros and cons of AP?
2. When can AP be used effectively?
3. When should AP not be used?
4. What species are best suited to AP?
5. What are alternatives to AP?

Why is it important to conserve *wild* populations?

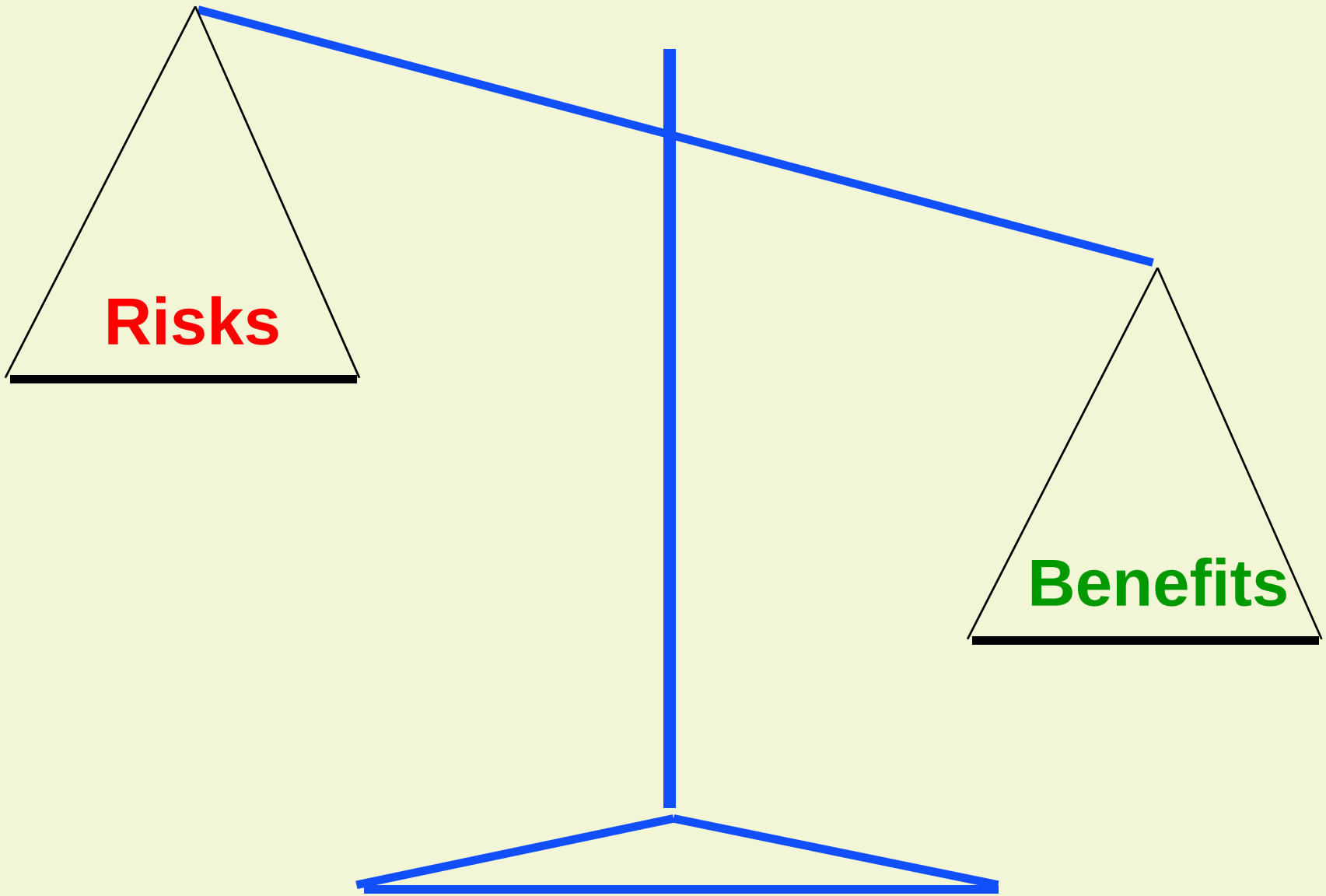
Long-term sustainability unproven

- Catastrophic failure
- Political and funding uncertainties
- Erosion of ecological/genetic/life history diversity
- Loss of fitness and productivity

Hatcheries don't promote functioning natural ecosystems

The following slides are based on:

Waples, R. S., and J. Drake. 2004. Risk-benefit considerations for marine stock enhancement: a Pacific salmon perspective. pp. 260-306 *in* K. M. Leber et al., eds. Stock Enhancement and Sea Ranching: Developments, Pitfalls and Opportunities. Second Edition, Blackwell, Oxford.


Risks
Benefits

Types of benefits to be considered

Conservation	General
• Natural populations	• Natural populations • Harvest • Mitigation • Treaty obligations • Public education

What are program objectives?

Harvest increase?

Legal mitigation?

Conservation?

All of the above?

Potential benefits of propagation for natural populations

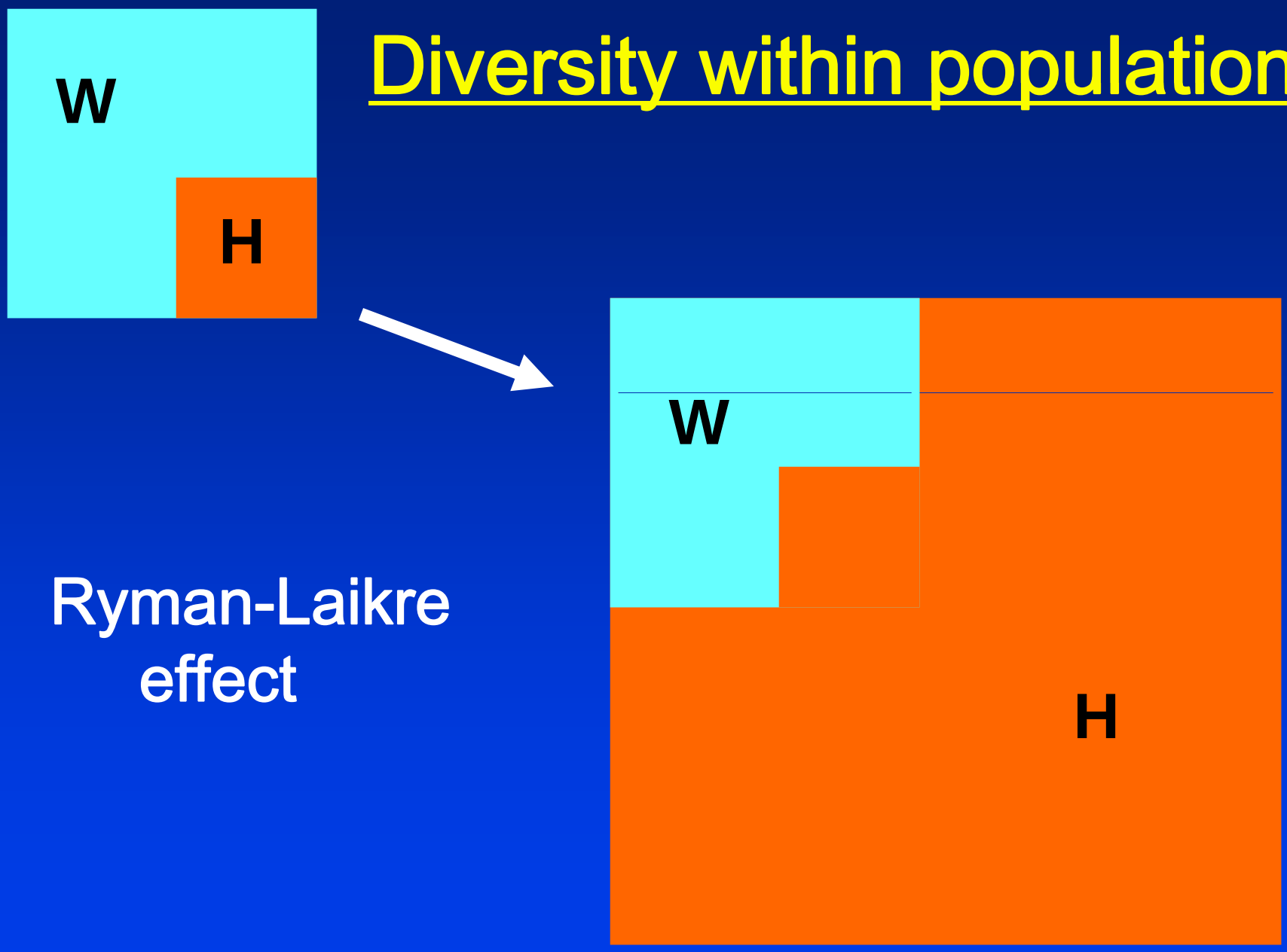
1. Reduce short-term extinction risk*
2. Reseed vacant habitat*
3. Speed recovery

* Empirical evidence exists

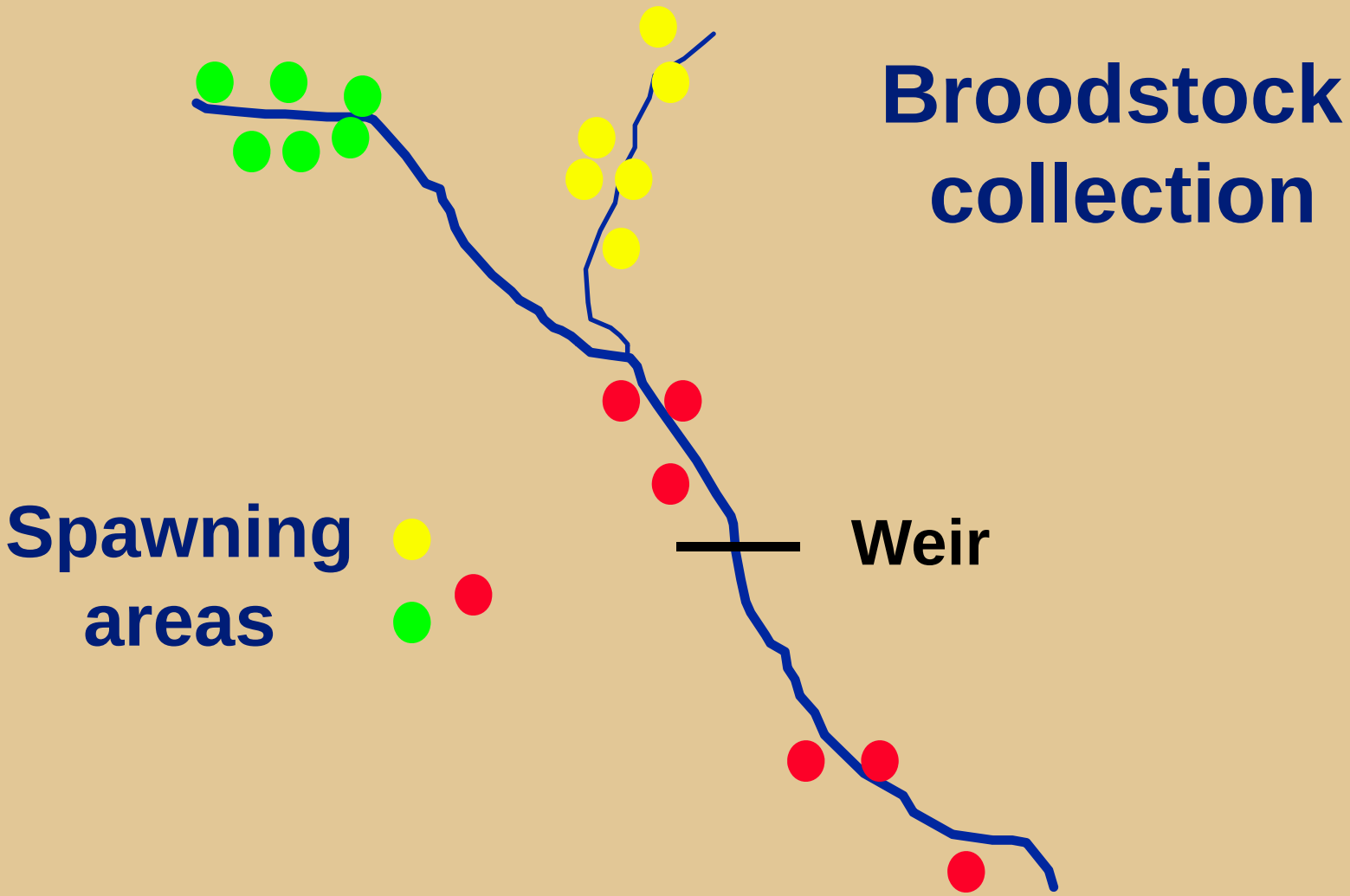
Risks of captive propagation for natural populations

1. Loss of diversity
   - Within population
   - Between populations
2. Loss of fitness
3. Ecological effects
4. Other considerations

Diversity within populations



Ryman-Laikre effect


Broodstock collection
Spawning areas
Weir

Fitness

Hatchery vs. wild environments

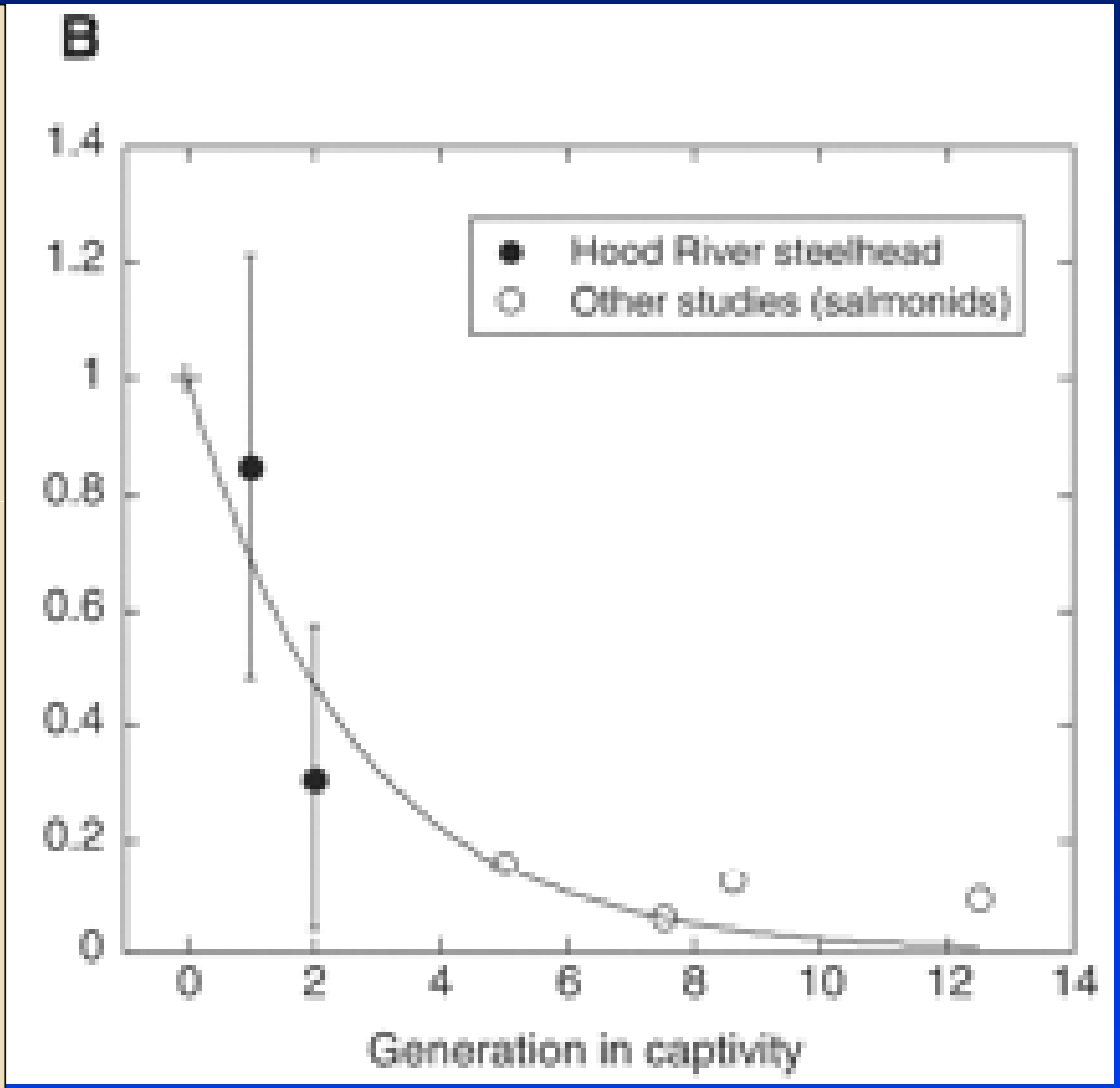
Similarities

Water

Differences

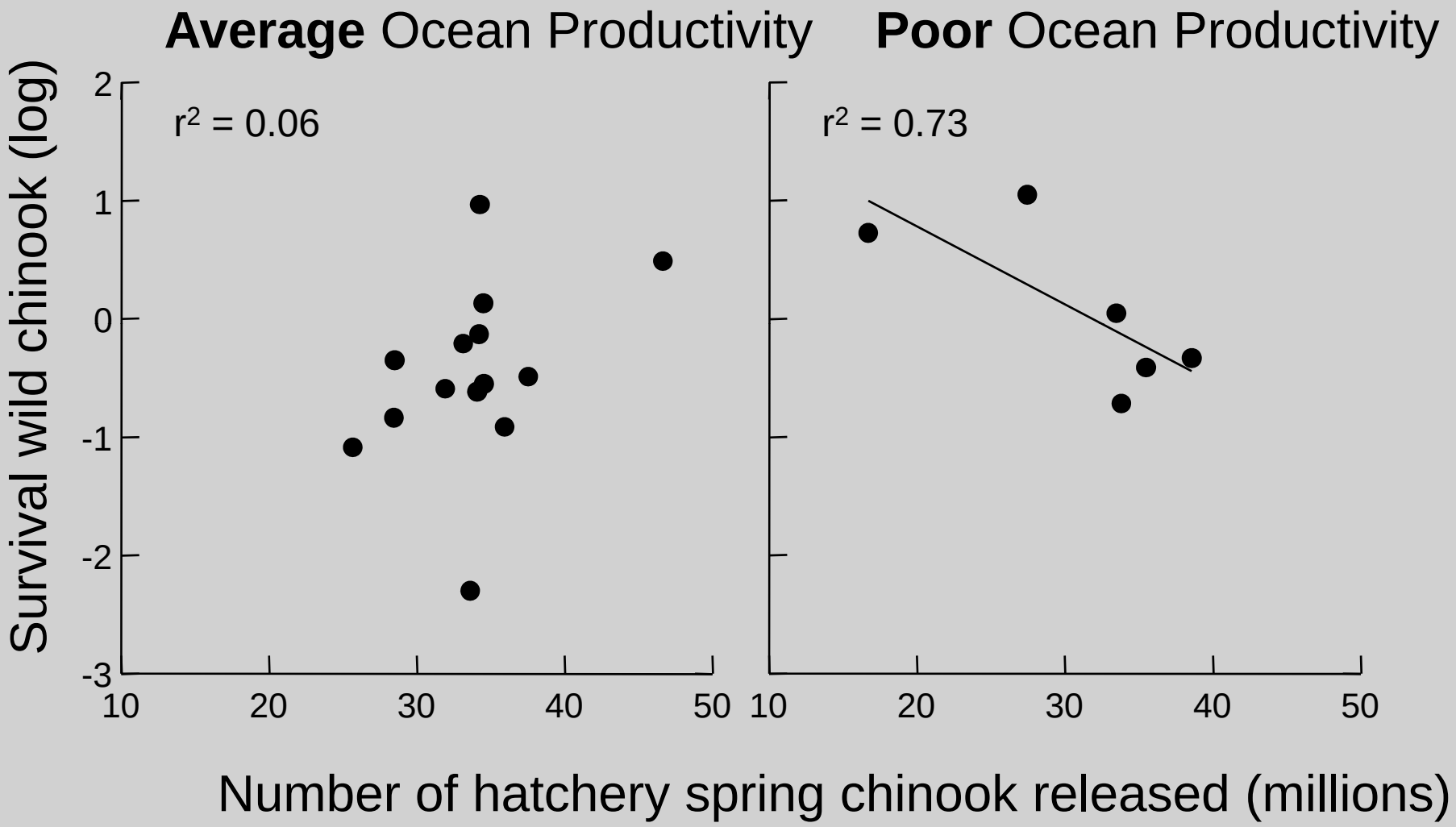
Food
Substrate
Density
Temperature
Flow regime
Competitors
Predators

Relative fitness



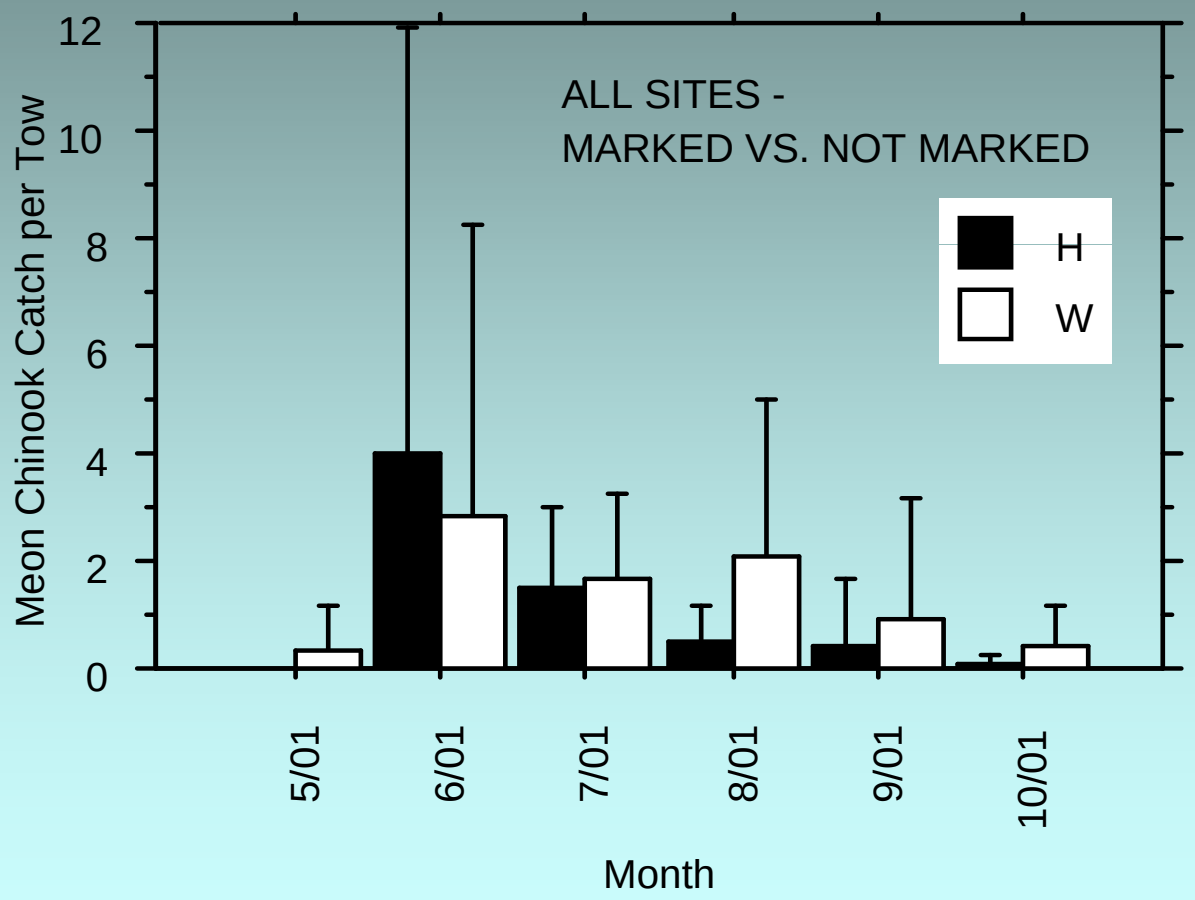
Araki et al. 2007

Ecological effects



Levin et al. 2001

Skagit River chinook Catch per tow



C. Rice et al, unpubl. data

Miscellaneous concerns

1. Risk tradeoffs
2. Marking
3. Statistical power
4. Unexpected developments
5. Termination of program

Tradeoffs in minimizing risks of supplementation

- Broodstock collection
- Release strategies
- Program scale
- Population mixing
- Marking

Sampling for broodstock: balancing opposing risks

1. Take small fraction of population
   - Inbreeding
   - Founder effect

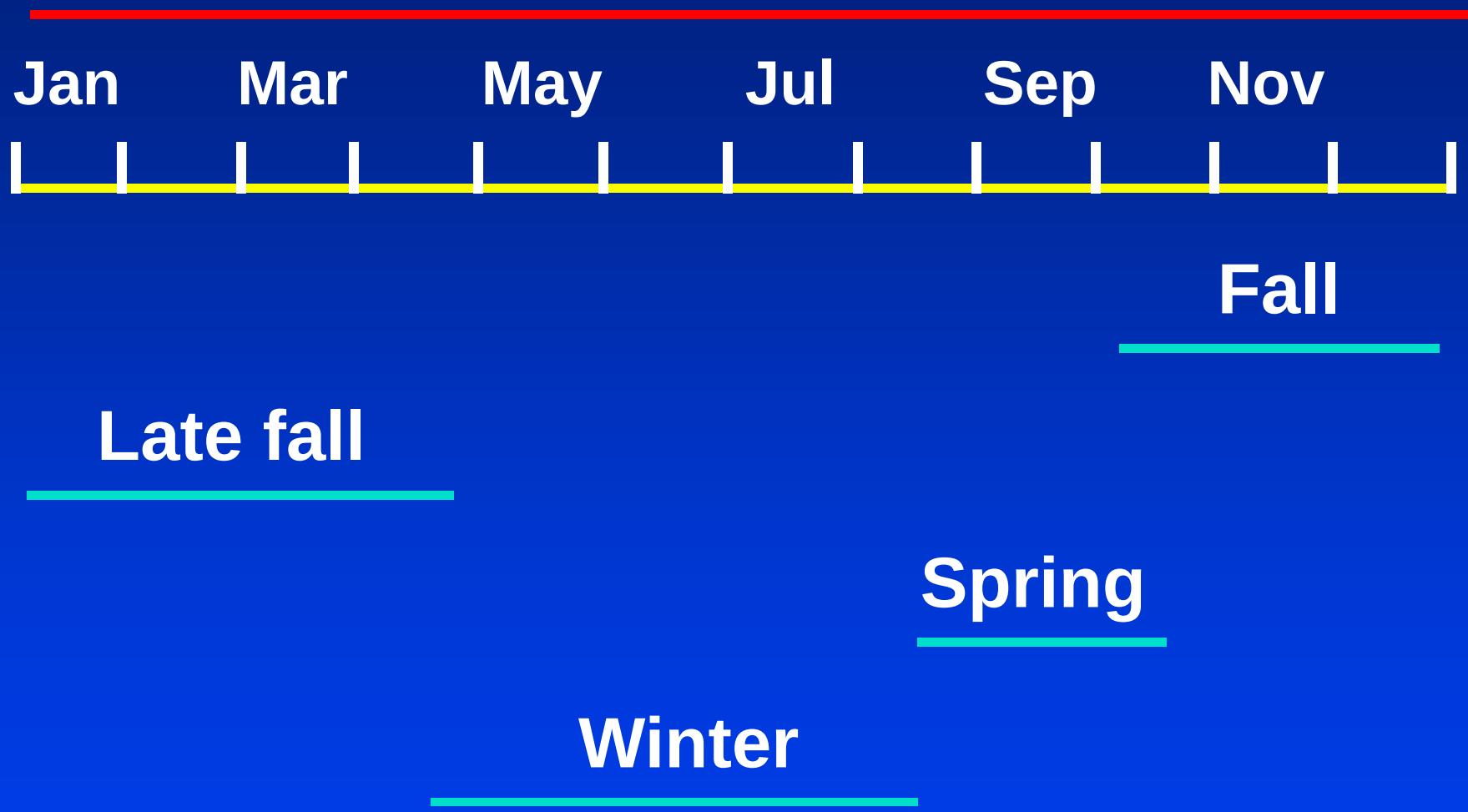
2. Take all or most of population
   - Catastrophic failure
   - Fish culture effects

Broodstock integrity: balancing opposing risks

1. Sample from entire spawning run
   - Maximize % of diversity sampled, but
   - Risk capturing non-target fish
2. Sample only part of run
   - Reduce risk of contamination, but
   - Reduce diversity of population

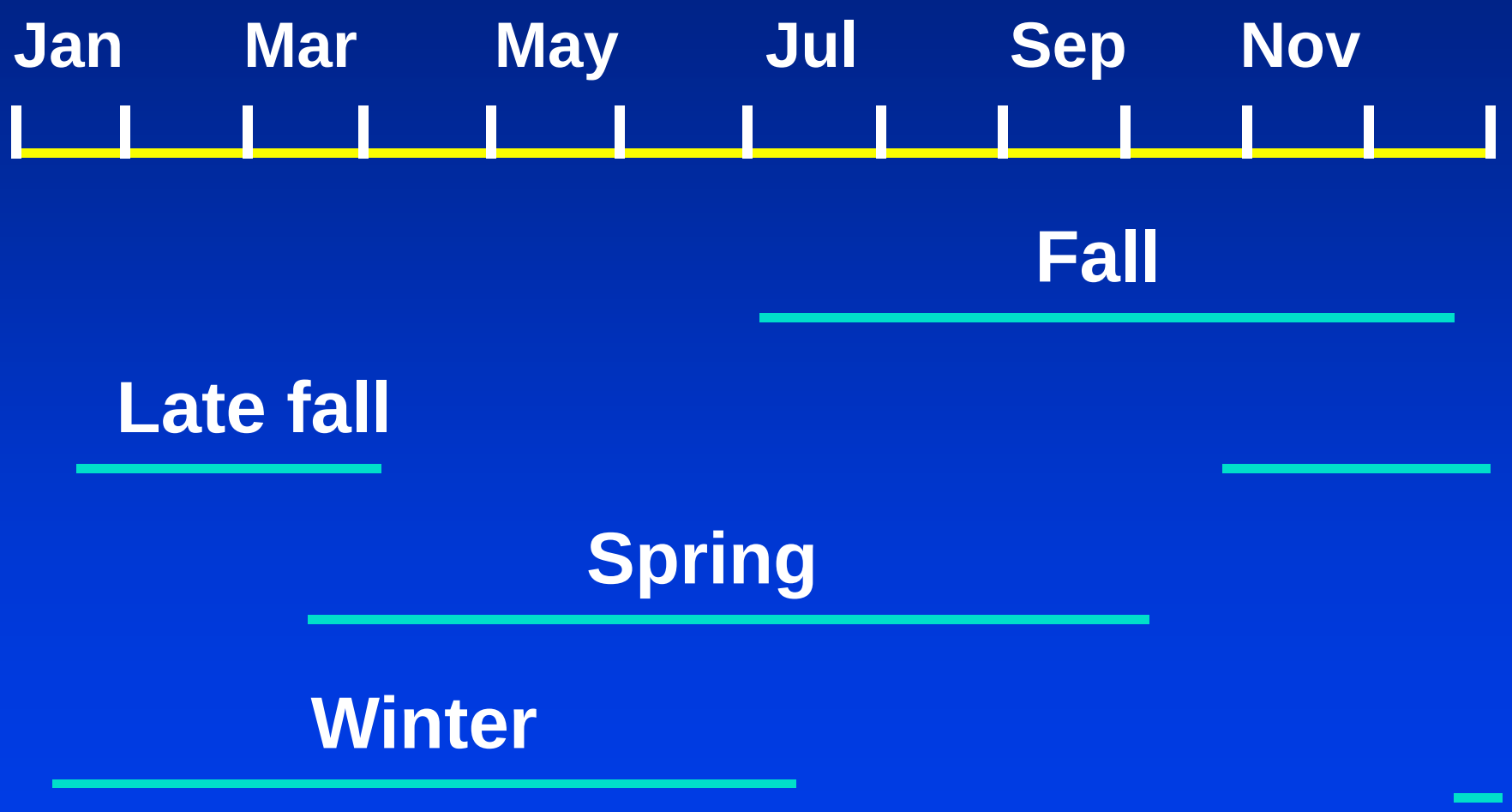
Sacramento River chinook salmon

Spawn timing



Sacramento River chinook salmon

Run timing



Key questions: Monitoring

1. What level of marking is necessary for program evaluation? For identifiability?
2. Are the costs (time, money, mortality) of necessary marking acceptable?
3. What is the power of monitoring program to detect undesirable effects?

Miscellaneous concerns

1. Risk tradeoffs
2. Marking
3. Statistical power
4. Unexpected developments
5. Termination of program

Risk-benefit considerations: Summary

- A risk/benefit analysis depends on the goals
- It is impossible to avoid all risks
- Uncertainty and its consequences must be acknowledged
- Recognize programmatic inertia
- Integrate with other recovery efforts
- Hope that demographic boost (if any) outweighs negative effects

AP programs can try to minimize (but cannot avoid):

- Inbreeding
- Ryman-Laikre effect
- Effects of broodstock selection
- Genetic drift
- Domestication

The following slides are based on:

Waples, R. S., M. J. Ford, and D. Schmitt. 2007. Empirical results of salmon supplementation in the Northeast Pacific: A preliminary assessment. pp. 383-403 *in* T. M. Bert, ed. Ecological and Genetic Implications of Aquaculture Activities. Springer, Dordrecht, the Netherlands.

Review of salmon supplementation
Miller et al. 1990

"Twenty-five of the 26 supplementation projects were considered successful *by the principal investigator* …"

"We found no evaluated projects that had rebuilt wild/natural runs to self-sustaining levels."

Definition of supplementation

Intentional integration of hatchery and wild production, with the goal of improving the status of the natural population.

Hierarchical goals

- Effective broodstock collection
  - Representativeness
  - Integrity
- High survival in culture
  - Prespawning
  - Egg-smolt
  - Adult-adult
- Population increase
- Natural spawning success
- Sustainable natural population

Programs evaluated

Species	CR	PS	OR/ WA	BC	Tot
Chinook	11	4	-	1	16
Chum	-	2	-	1	3
Sockeye	1	-	-	-	1
Pink	-	-	-	1	1
Steelhead	1	-	-	-	1

Program length

Duration	Number
8-12 yr	7
13-20 yr	11
21-30 yr	4

Supplementation review

Waples et al. 2007

Objective	Was it met? Y	N	?
Broodstock collection (representative)			
Age	11	3	8
Run timing	10	2	10
Integrity	17	5	-
Hatchery survival			
Prespawning (90%)	12	6	4
Egg-smolt (70%)	19	2	1
Adult-adult (2x)	12	4	6
Population increase (20%)	8	11	3
Natural spawning (comparable)	1	2	19
Sustainable	-	2	20

Population status

	Before	After
Healthy	1	-
Depressed	8	-
At risk	10	-
Critical	3	2
Still being supplemented	-	20

Population response

	Supplemented	Control
Increased	6	1
Stable	3	2
Declined	10	3
No data	-	13

Salmon supplementation: Conclusions

Production goals often met

Most programs not rigorously evaluated for effects on natural populations

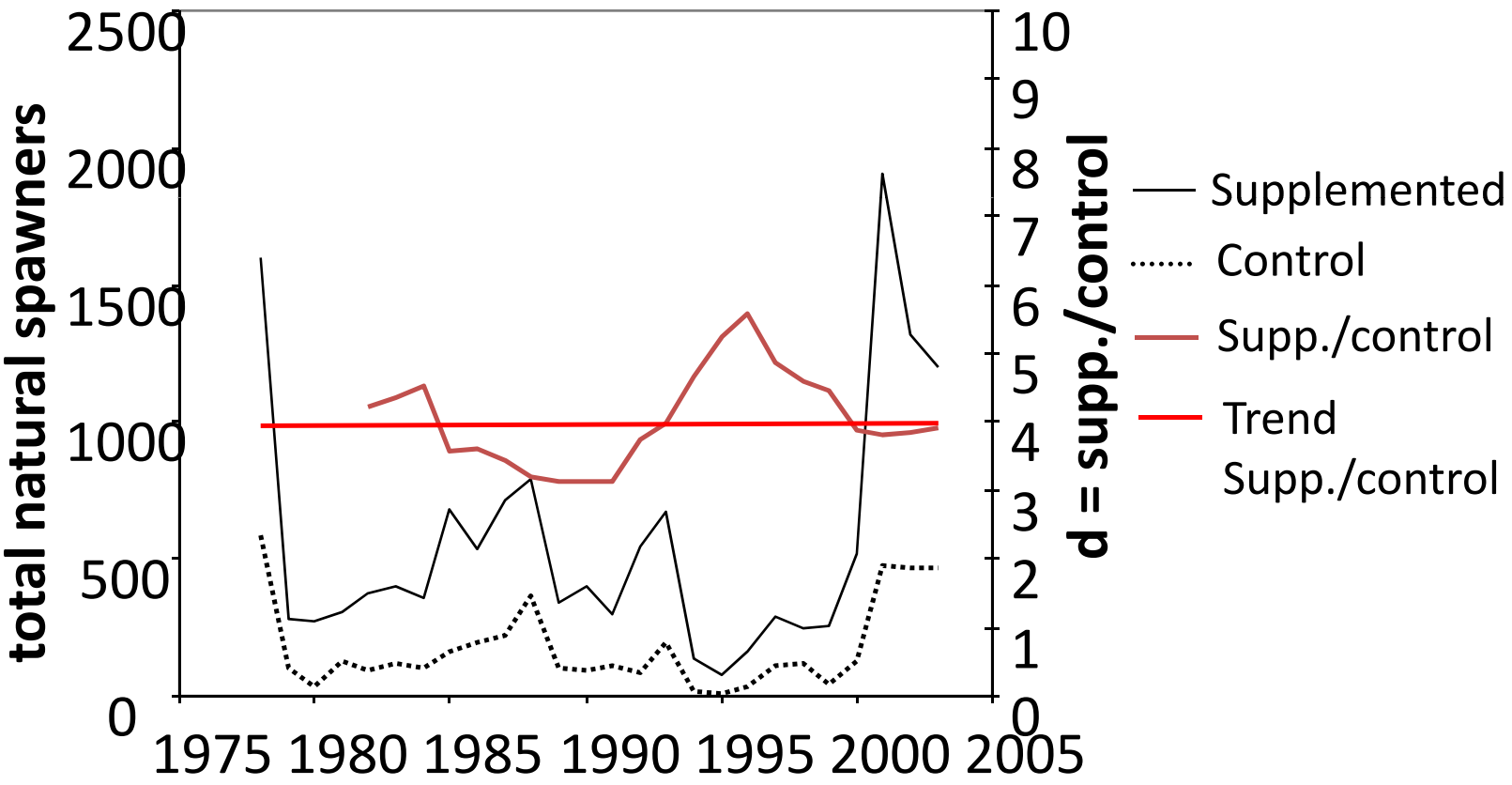
Long-term benefits remain to be demonstrated

The following slides are based on:

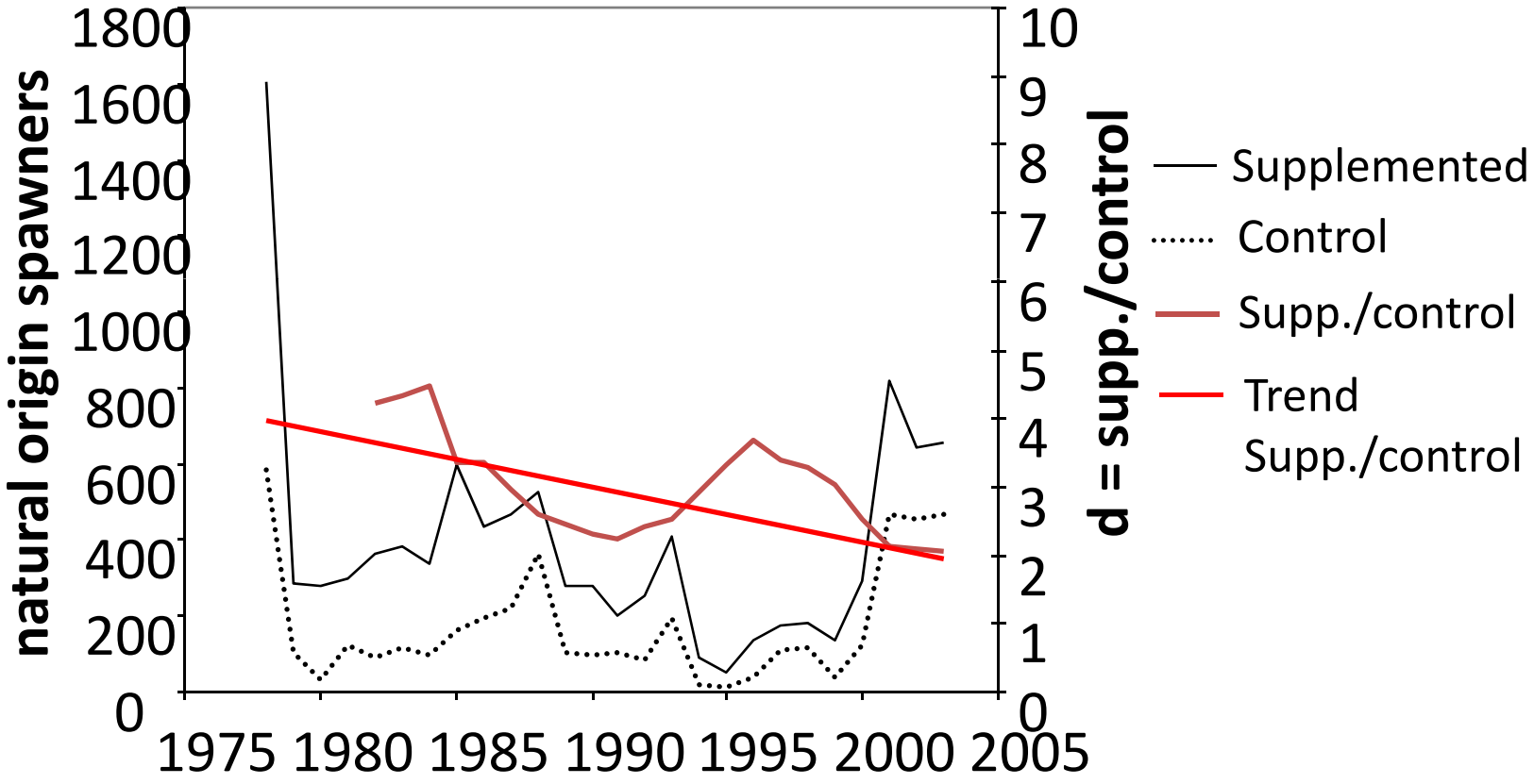
Mike Ford, NWFSC, unpublished data

A meta-analysis of supplementation of Columbia River basin spring-summer Chinook salmon

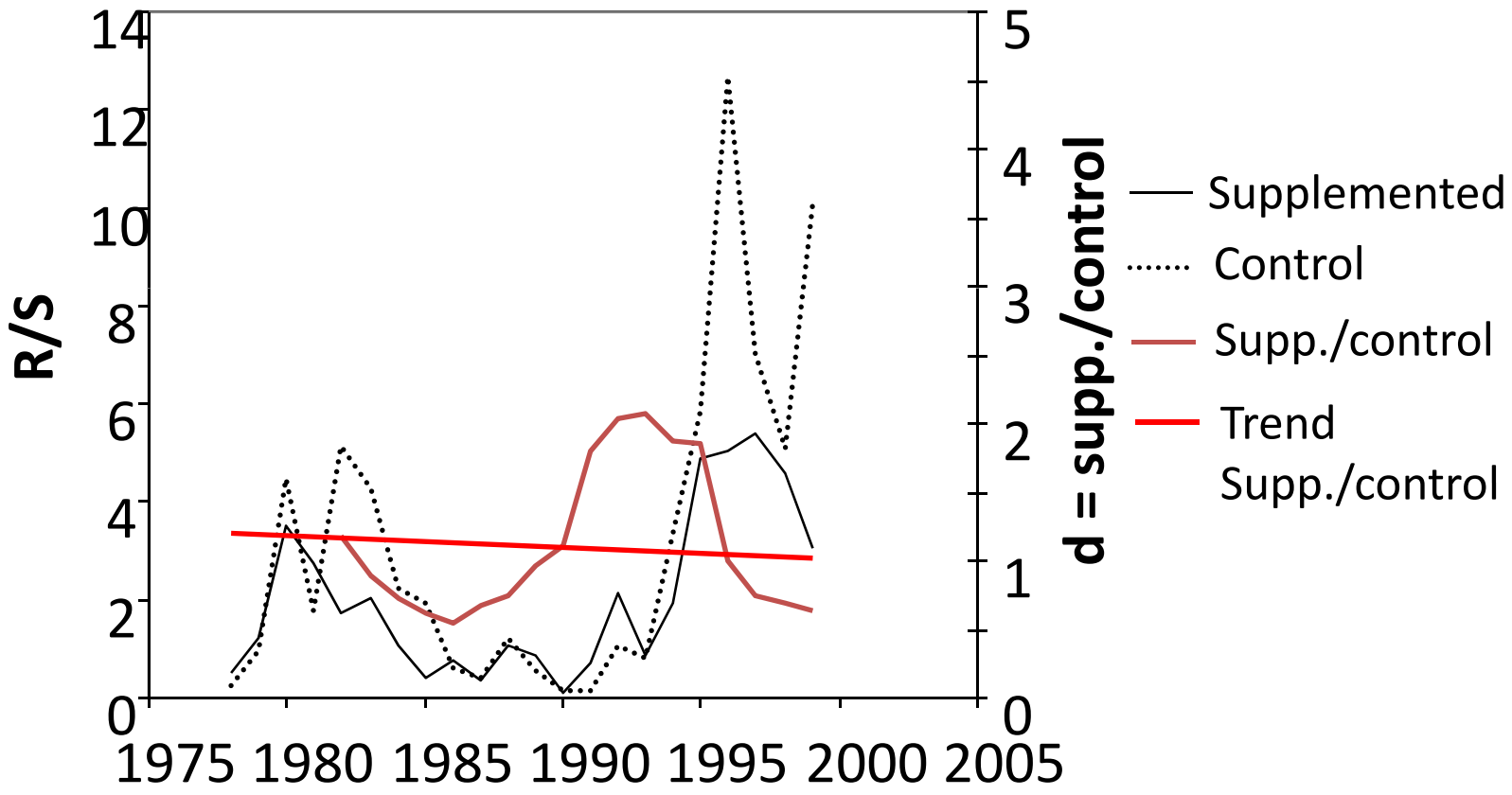
Total spawners (in river)



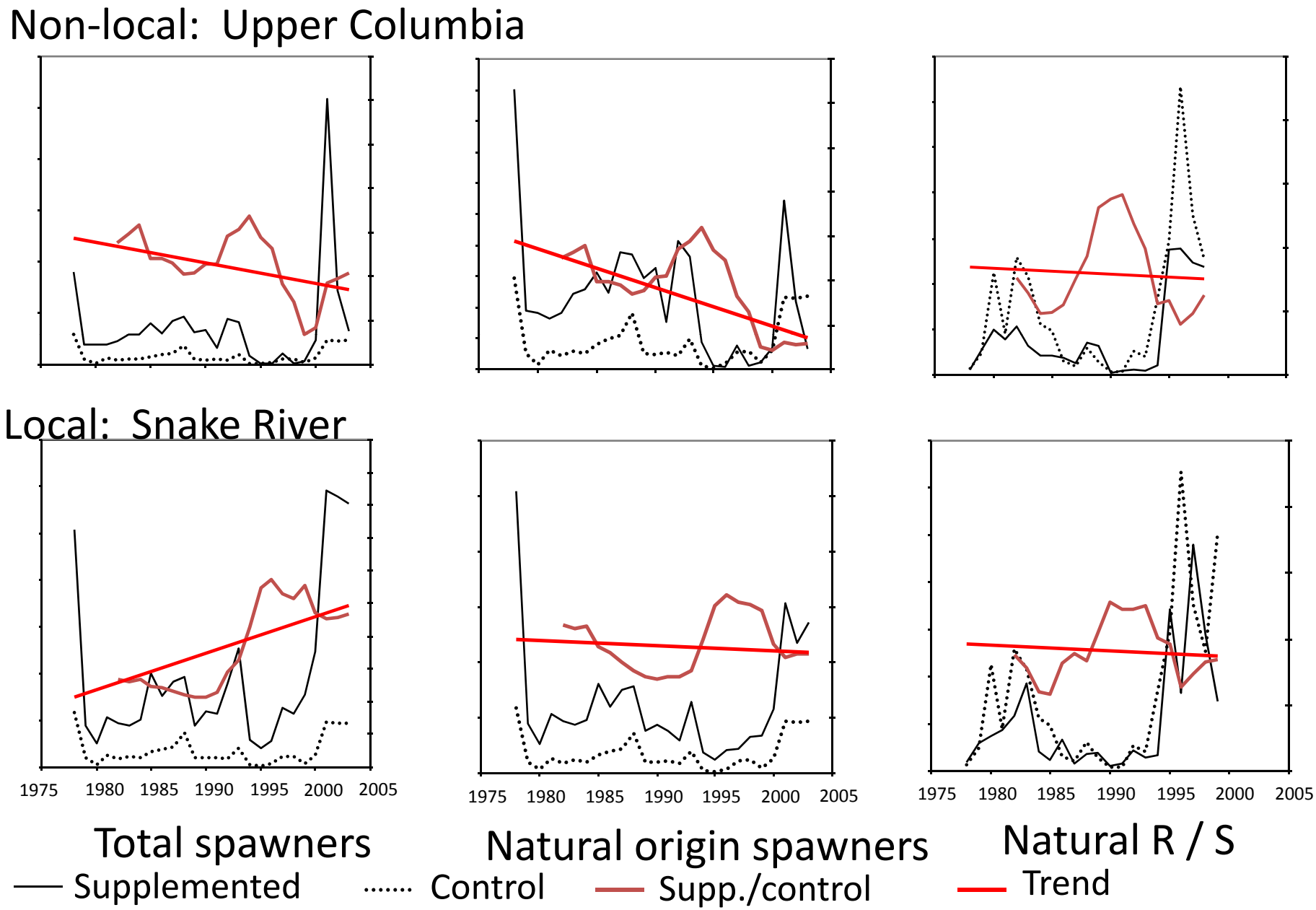
Natural-origin spawners



Natural-origin recruits/total spawners

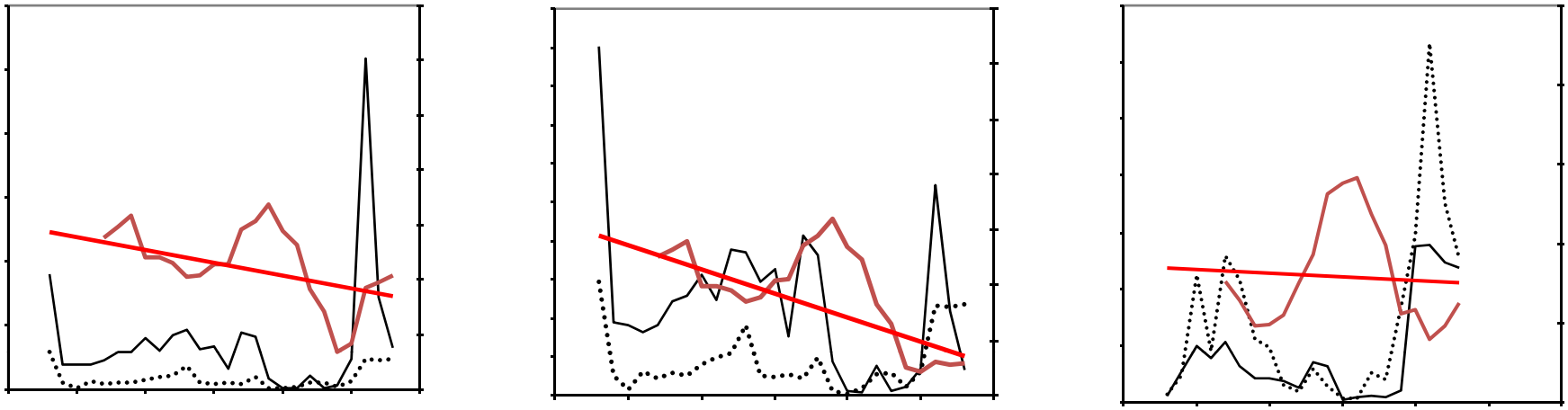


Local compared to non-local broodstock

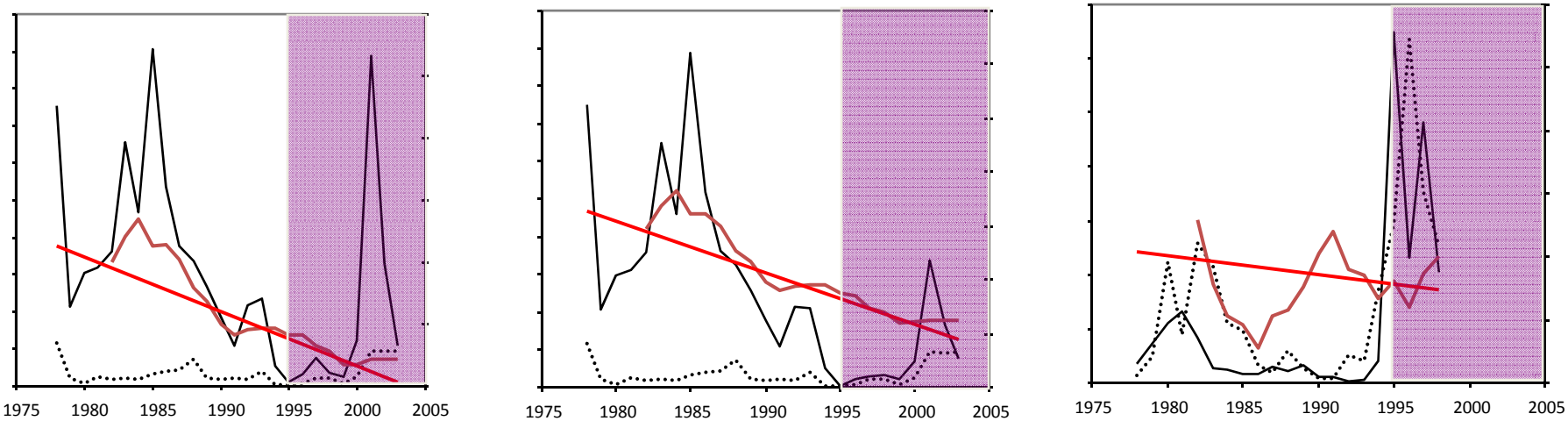


Local compared to non-local broodstock, 2

Non-local: Upper Columbia



Local: Wenatchee



Total spawners | Natural origin spawners | Natural R / S

Supplemented | Control | Supp./control | Trend

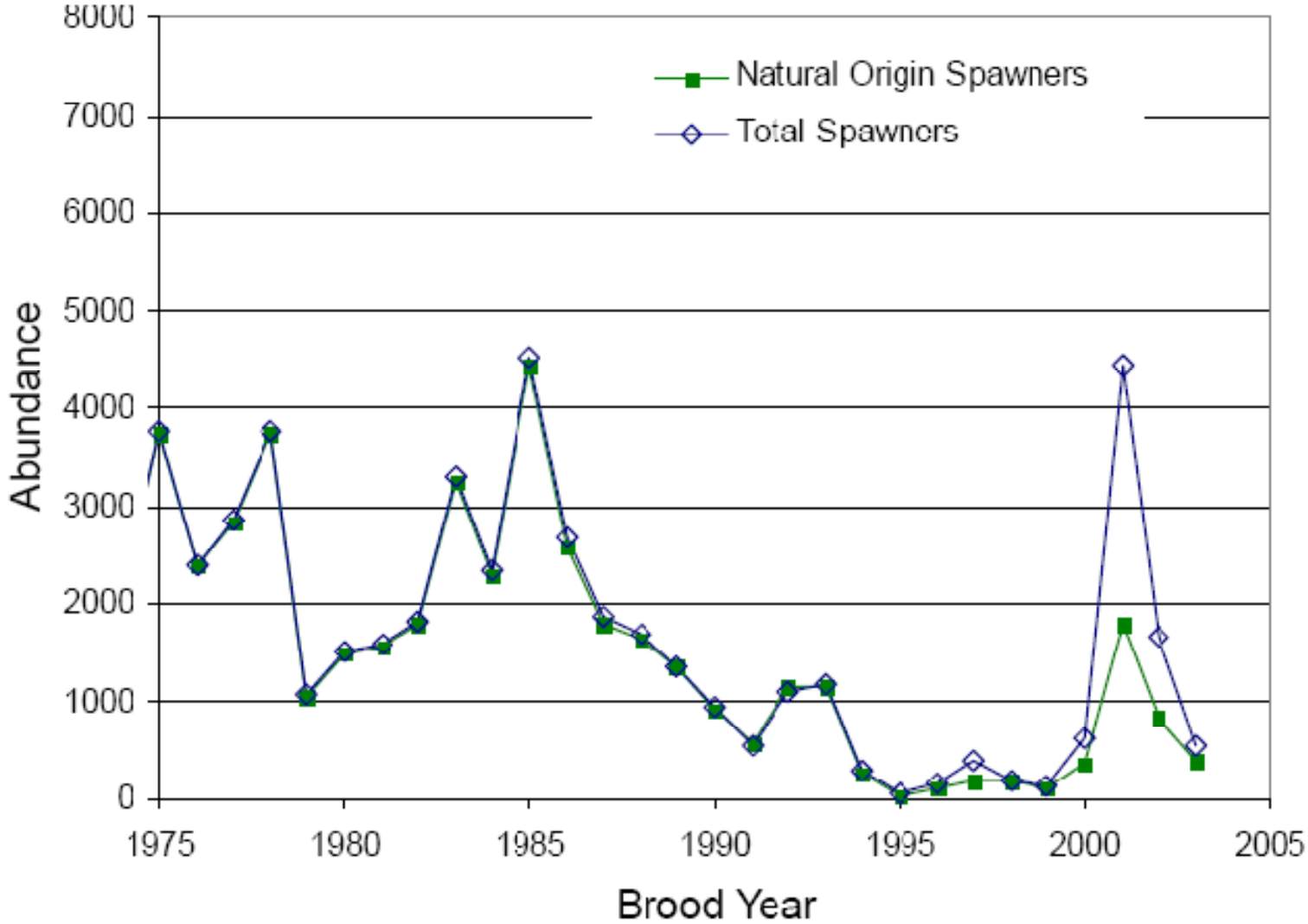
Col. R. supplementation -- summary

- Supplemented population are not increasing relative to unsupplemented populations
- Supplemented populations have lower productivity
- Populations supplemented with non-local broodstock had poor response to improved ocean conditions
- Supplementation appears to have helped buffer years of extremely low abundance
- Juvenile production data and long-term reproductive success data would help

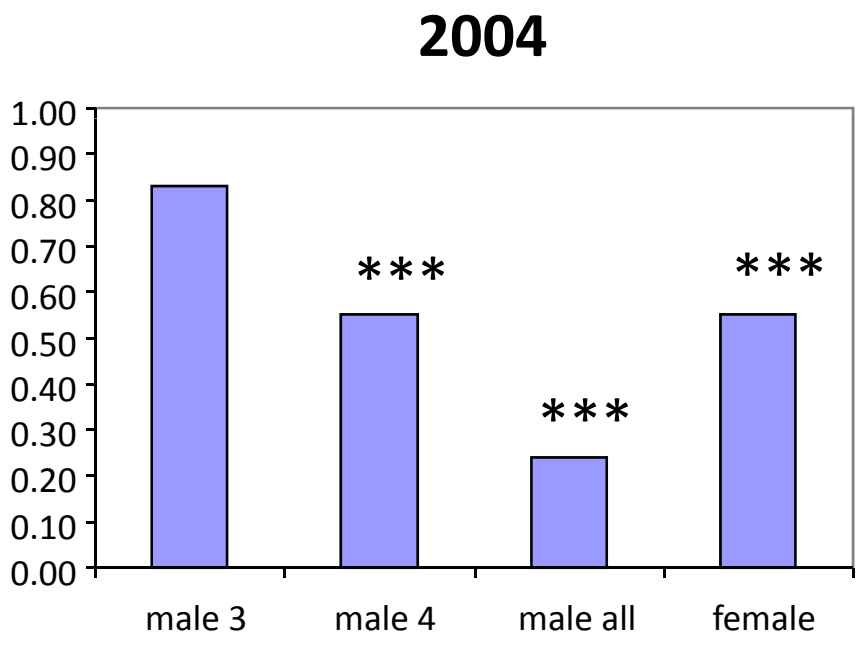
The following slides are based on:

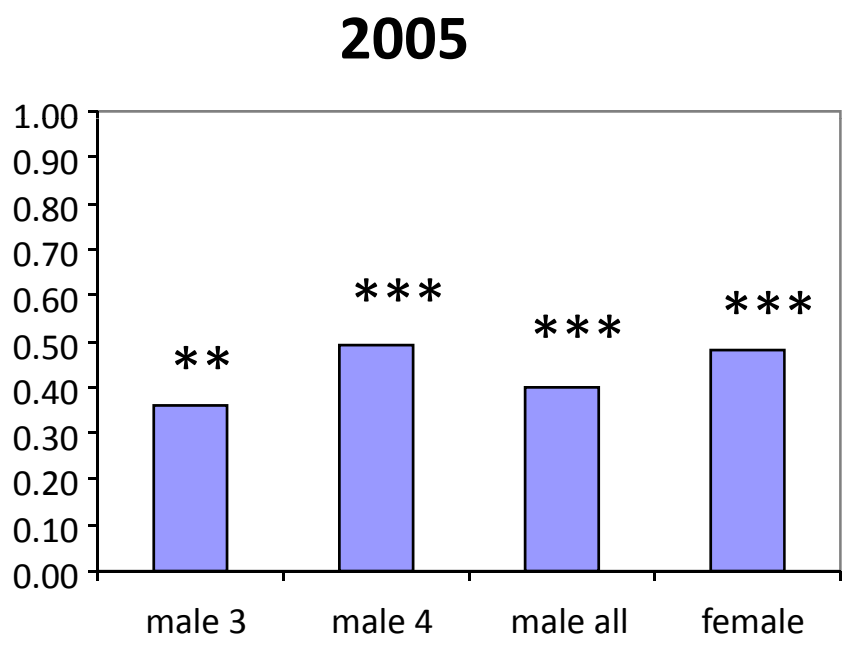
A. Murdoch et al. 2007. Monitoring the reproductive success of naturally spawning hatchery and natural spring Chinook salmon in the Wenatchee River. BPA Project No. 2003-039-00. Bonneville Power Administration, Portland, Oregon.

Wenatchee spring Chinook salmon

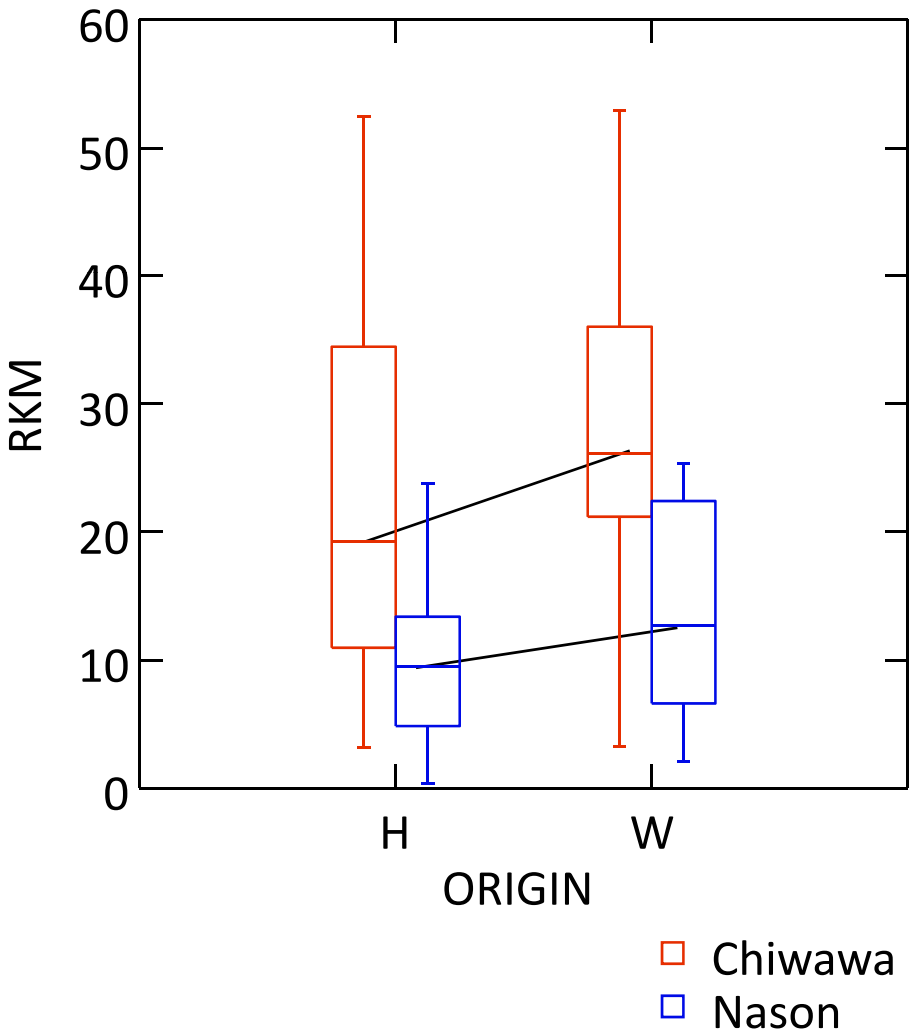


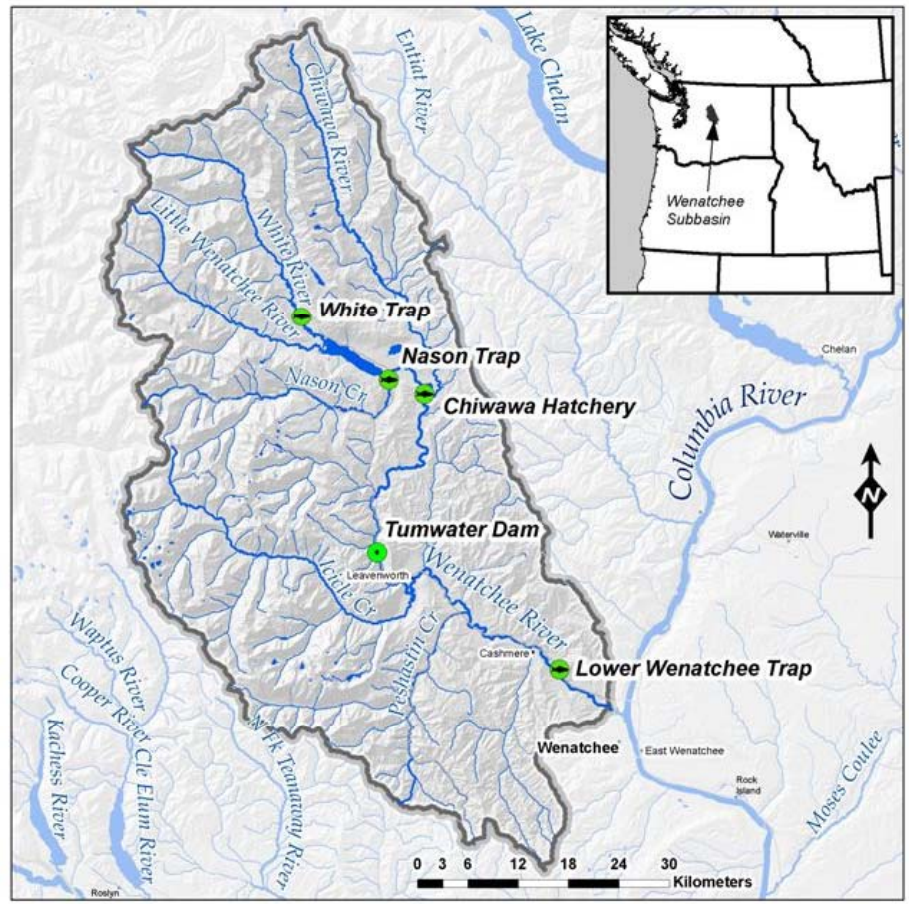
Relative fitness (smolts/spawner)





Traits – spawning location





Multiple effects, males

	2004		2005	
Effect	estimate	p-value	estimate	p-value
Constant	1.084		2.891	
Hatchery origin	-0.314	0.418	-1.245	0.033
Age 3	0.9	0.095	1.634	0.012
Origin X age 3	0.073	0.849	-1.092	0.059
Run timing	0.231	0.187	-0.002	0.991
Weight	1.479	<0.001	0.667	0.009
Location	0.519	0.005	0.48	0.007

Multiple effects, females

	2004		2005	
Effect	estimate	p-value	estimate	p-value
Constant	1.165		1.608	
Hatchery origin	-0.165	0.166	-0.023	0.893
Run timing	0.084	0.519	0.128	0.336
Weight	0.092	0.402	0.242	0.045
Location	0.651	<0.001	0.983	<0.001

Summary

- Large reduction in relative reproductive success of Wenatchee hatchery spring Chinook in spite of using local broodstock
- Size and spawning location appear to be important factors contributing to results

Pros and cons of AP?

Pro

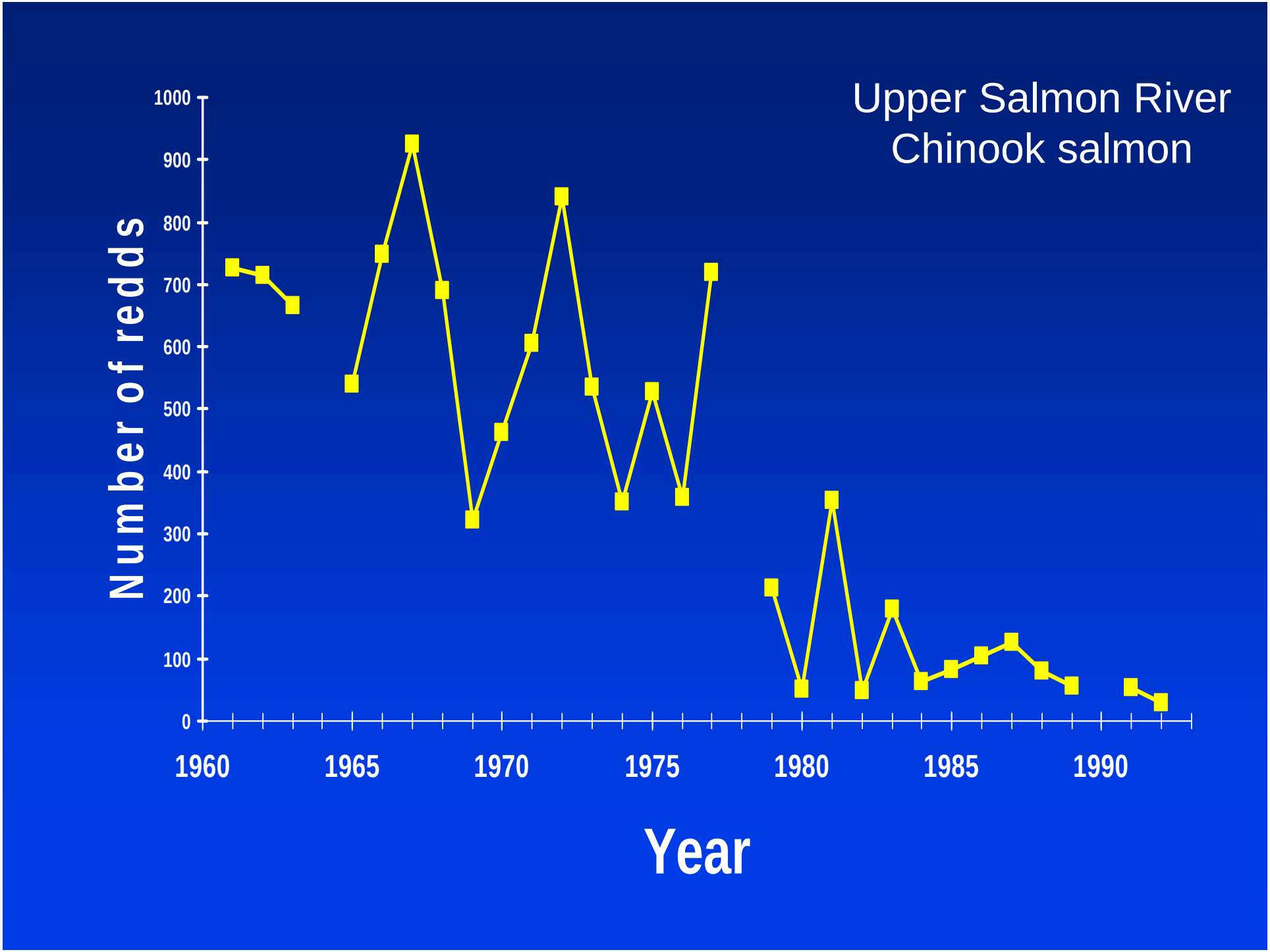
- Can help maintain gene pools
- Can help reseed vacant habitat
- Can help meet some societal goals

Con

- Long-term benefits not demonstrated
- Expect reductions in fitness
- Expect reductions in diversity
- Expect unanticipated complications

When might AP be used effectively?

- When target population faces high, short-term extinction risk
- When there are serious concerns for inbreeding depression
- When suitable and accessible habitat is unseeded
- When comprehensive risk-benefit analysis indicates net benefits are likely to outweigh adverse effects
- In conjunction with comprehensive recovery efforts


Upper Salmon River
Chinook salmon
Number of redds
1000
900
800
700
600
500
400
300
200
100
0
1960
1965
1970
1975
1980
1985
1990
Year

When should AP not be used?

- When there are not ‘enough’ fish but current risks to target population are not high
- When natural colonization can reseed vacant habitat
- When logistic challenges prevent risk-averse implementation
- When comprehensive risk-benefit analysis indicates net benefits are not likely to outweigh adverse effects

What species are best suited to AP?

- Freshwater species
- Anadromous species with brief freshwater life history
- Species with weak population genetic structure and few local adaptatations
- Species that can tolerate crowded rearing conditions

What alternatives to AP exist?

- Abundant good quality habitat
- Functioning natural ecosystems
- Fix the causes for decline