Stocking of captive-bred fish can cause long-term population decline and gene pool replacement: A model prediction



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Cumulative Effect of Captive Breeding

A) Hood River steelhead

B) General trend (y = $e^{-0.375x}$, R = 0.963)



(Araki, Cooper & Blouin 2007. Science)

Domestication Selection as a Primary Cause?

YES, IF:

- 1) Selection is very strong both in captivity <u>AND</u> in the wild ($T \ge 0.9$, $\omega^2 < =5.0$)
- 2) Heritability of the trait under selection is high ($h^2 >= 0.5$)



(Araki et al. 2008. Evolutionary Applications)

Loss of ~ 8% population fitness due to the carry-over effect



(Araki, Cooper & Blouin 2009, Biology Letters)

QUESTION

Long-term consequences of recurrent stocking?

Compromising point between demographic boost and genetic conservation?

Two-stage Population Dynamics Model of Stocking



Two-stage Population Dynamics Model of Stocking

DRAFT



y_W: Number of wild-type adults
y_H: Number of hybrid-type adults
y_C: Number of captive-bred-type adults

 $s_{\rm W}$: Fitness of wild-type $s_{\rm H}$: Fitness of hybrid-type $s_{\rm C}$: Fitness of captive-bred-typ

Model assumptions: Random mating

Fitness disadvantage in individuals carrying "hatchery gene" Density dependent mortality at the recruitment Ricker-type recruitment function

Long-term Consequences of Recurrent Stocking

Demographic effect

Genetic effect



Gene pool replacement before the positive demographic effect

Negative demographic effect at the intermediate stocking level

Cause I: Natural Selection against "Hatchery Gene"



Cause II: Strong Density-dependent Competition

e.g. *r* = 7



SUMMARY

The population dynamics model predicts:

1) Below the threshold stocking amount,
→ Stocking has no or little demographic effect in the long term

2) Above the threshold,

- \rightarrow Positive demographic contribution
- → Gene pool replacement by 'hatchery gene'

3) Around or at the threshold,

- → Negative demographic effect
- → Gene pool replacement by 'hatchery gene'

DISCUSSION



No 'compromising point' for demographic boost and gene pool conservation by fish stocking

Mitigating the hatchery rearing effect is a solution using local wild stock, improving hatchery environment, minimizing the time kept in captivity etc.



Mechanistic Understanding of Rapid Fitness Decline

Theoretical framework development

Detecting fitness difference among groups

Modeling the fitness effects to understand the mechanism

Empirical application



Stocking programs of brown trout (Salmo trutta) in Switzerland

Where Have All the FISH Gone?



FIGURE 1

Trout catches in Switzerland

Catches have steadily declined since the 1980s, according to anglers' personal data records.



Burkhardt-Holm et al. (2005)



Benjamin Adjei



Corinne Schmid





Empirical Evidence for long-term stock enhancement?

species	fitness effects	stock enhancement	reference
Atlantic salmon (Salmo salar)	lower survival	possibly negative impact on wild stock	McGinnity et al. (2003)
ayu (Plecoglossus altivelis)	n.a.	small proportional contribution	Pastene et al. (1991)
barfin flounder (<i>Verasper moseri</i>)	not found	n.a.	Ortega-Villaizan Romo et al. (2005)
black sea bream (<i>Acanthopagrus schlegelii</i>)	n.a.	Indicative of positive contribution	Jeong et al. (2007), Blanco Gonzalez et al. (2008a)
brown trout (<i>Salmo trutta</i>)	lower reproductive fitness/not found	little contribution	Moran et al. (1991), Hansen (2002), Dannewitz et al. (2004)
chum salmon (<i>Oncorhynchus keta</i>)	Indicative of low reproductive fitness	n.a.	Berejikian et al. (2009)
coho salmon (Oncorhynchus kisutch)	not found	n.a.	Ford et al. (2006)
Japanese flounder (Paralichthys olivaceus)	not found	n.a.	Sekino et al. (2005)
rainbow trout (Oncorhynchus mykiss)	lower survival	n.a.	Miller et al. (2004)
steelhead trout (Oncorhynchus mykiss)	lower reproductive success	possibly negative impact on wild stock	Reisenbichler & McIntyre (1977), Chilcote et al. (1986), Leider et al. (1990), McLean et al. (2003, 2004), Araki et al. (2007a, b, 2009)

(Araki & Schmid, Aquaculture, in press)

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Thank you!

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Hood River Steelhead at Powerdale Dam trap, 2 days ago