Has salmon aquaculture harmed wild salmonid populations?

Admission to Candidacy Exam

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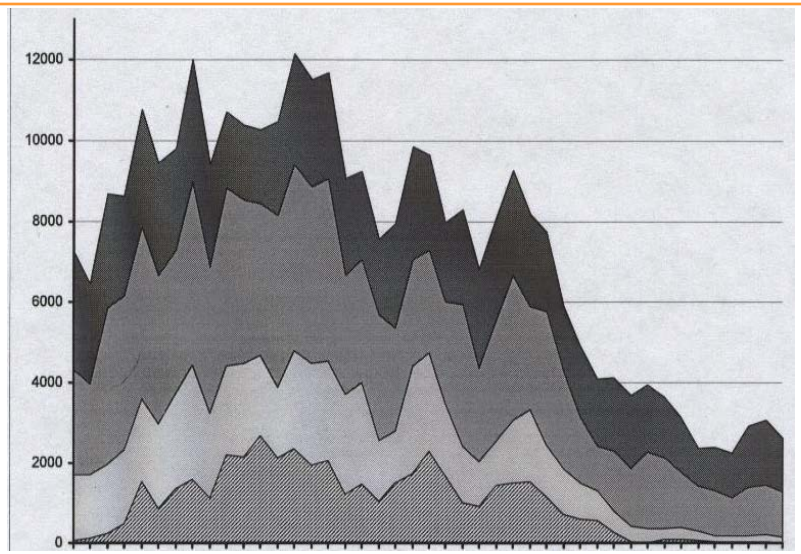
Outline

- Atlantic salmon and the project motivation
- Hypothesis for decline: salmon aquaculture
- Comparisons
- The data and a simple model
- Meta-analysis
- Advantages and disadvantages
- Contribution

Atlantic salmon declines



1960 2002

Total catch:

Northern Europe
Southern Europe
North America
Greenland

Source: ICES, 2003

Populations of Atlantic salmon have declined steeply over the past two decades, despite efforts to improve freshwater habitat and drastic reductions to fisheries.

Hypotheses for Atlantic salmon population declines

Freshwater

- Habitat destruction
- Water quality and quantity
- Hatcheries (competition, genetics)
- Fisheries
- Aquaculture (competition, genetics)

Marine

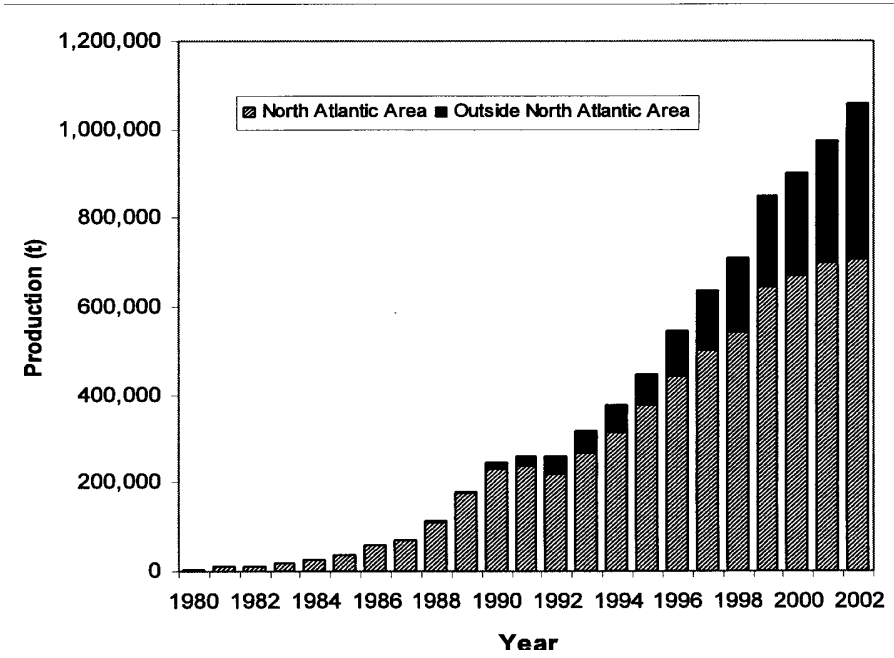
- Climate (winter habitat, smolt timing)
- Predation
- Fisheries (directed or as by-catch)
- Aquaculture (disease, competition)

The salmon aquaculture industry

- Definition
- How farms and wild salmonids interact

Source: CCNB

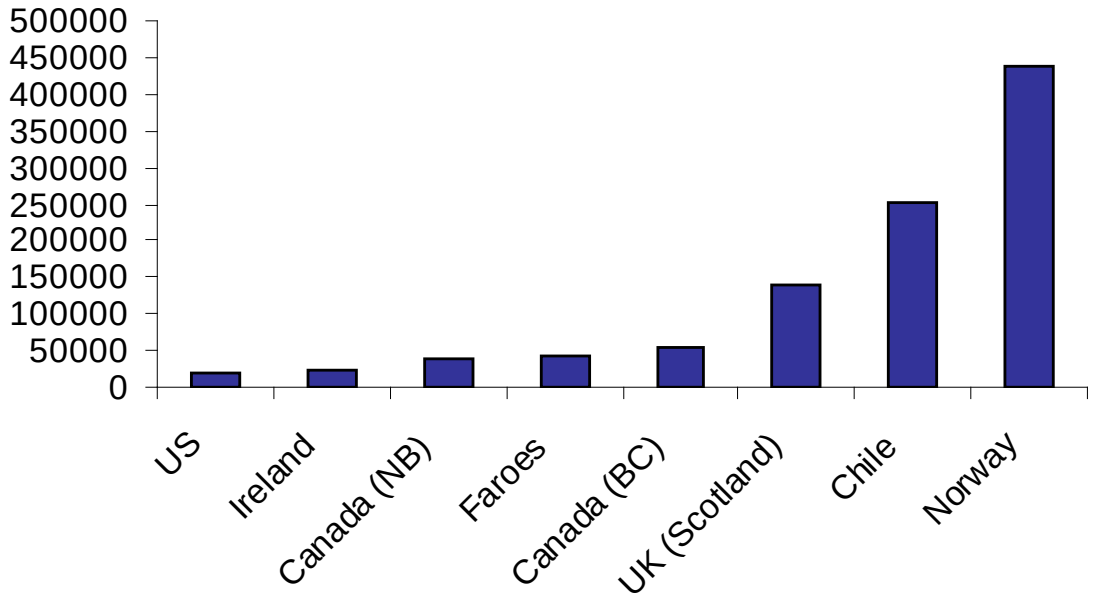
The salmon aquaculture industry



Source: ICES, 2003

- ~98% of the present biomass of Atlantic salmon is in the artificial culture of salmon as a food fish. (Parrish et al. 1998)

The salmon aquaculture industry



Source: FAO 2001 (Fishstat)

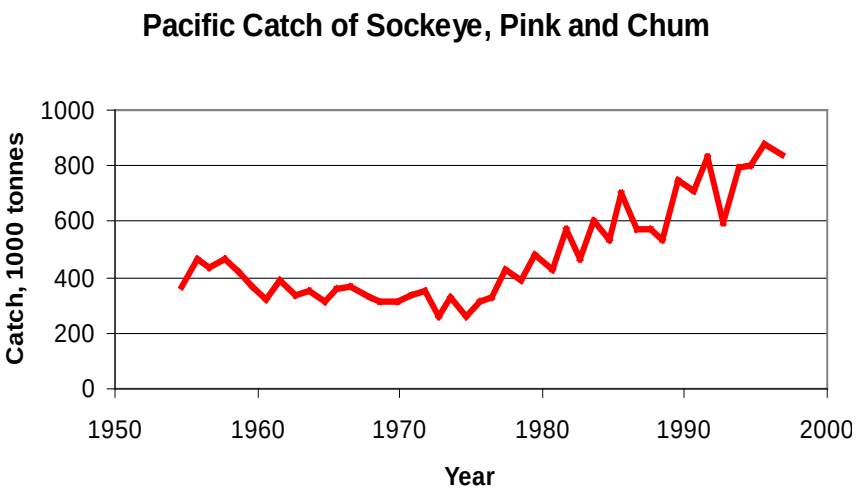
Potential effects of aquaculture

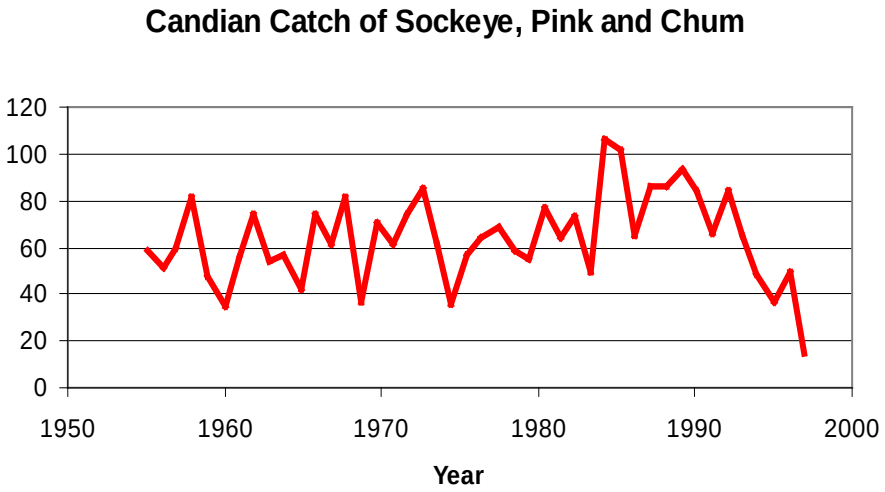
- Increased predation
- Genetic effects of escapees
- Competition from escapees
- Disease

Potential effects of aquaculture and spatial scale

- Increased predation - localized
- Genetic effects/ competition –proportional to escapees
- Disease
  - Lice seem limited in spatial scale: 20-30 k in Scotland/Ireland
  - Furunculosis spread along entire Norweigan coast (1985-1992)
  - Spread of disease on feeding grounds totally unknown

In the Pacific





Source: Noakes, Beamish, Kent 2000

- Climate factors appear to be dominant forces
- Interactions with aquaculture have been implicated in isolated declines of pink salmon in the Broughton Archipelago.

Comparisons

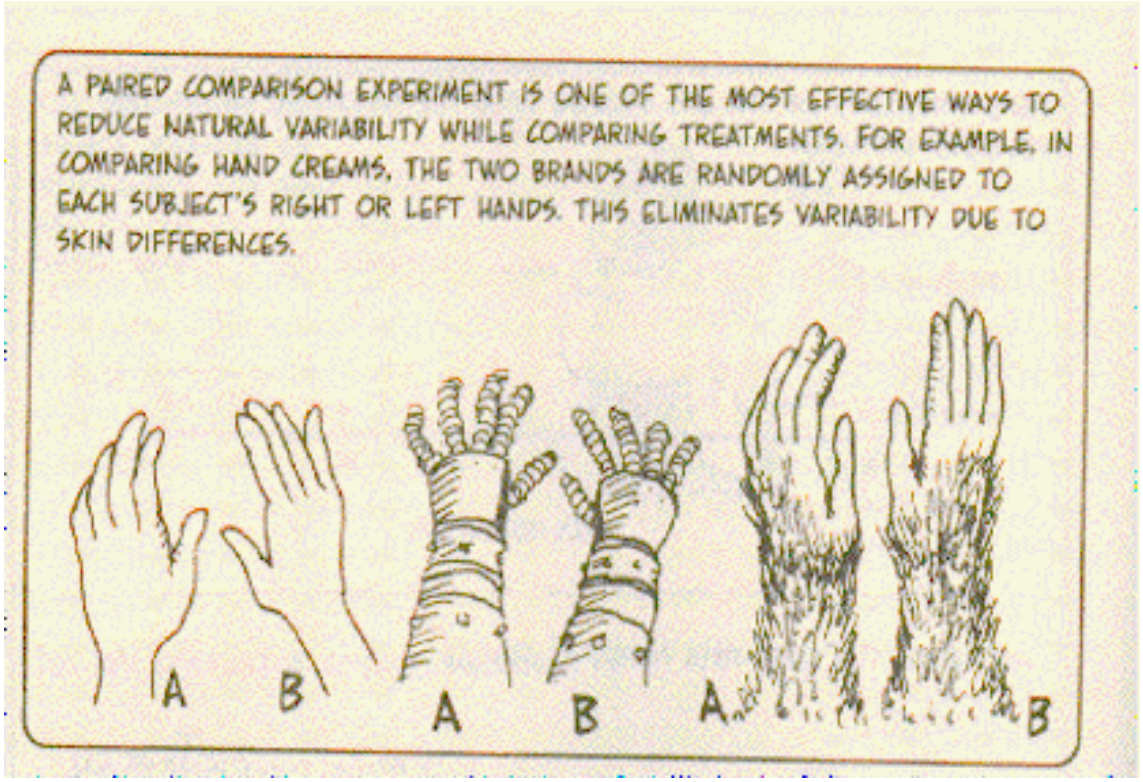
Atlantic salmon and trout:

- Newfoundland
- New Brunswick
- Ireland (also trout)
- Scotland (also trout)
- Norway / Russia
- Norway
- Baltic

Pacific salmon and trout:

- Puget sound (coho and cutthroat)
- BC: different sounds, various levels, species undecided (Pinks + ?)

Why use paired comparisons?



Source: Cartoon Guide to Statistics, Larry Gonick & Woolcott Smith

Variation in time spent near cages

- Disease outbreaks on farms and increased predation are more likely to effect populations that spend more time in coastal areas.
- Examples: Bay of Fundy Atlantic salmon, some Pacific salmon stocks, and trout in all regions (sea trout in the Atlantic, cutthroat and steelhead in the Pacific).

The data

- Marine survival estimates
- Juvenile abundance estimates and adult returns (indices of marine survival)
- catch-effort indices, especially rod catches
- smolt abundance estimates

- Potential gaps: information about trout, access to aquaculture information may be limited

A simple model

In a familiar form:

$$N_{t+1} = N_t e^{-z}$$

or

$$survival = N_{t+1}/N_t = e^{-z}$$

A simple model

$$S_{i,t} = G_{i,t}/R_{i,t} = exp\,(-(\mu_0 + \mu_i + \mu_t + F(\theta, P_{i,t}) + \varepsilon_{i,t}))$$

i – River
t – Smolt year
S – Survival
G – Grilse
R – Smolts

μ_0 – Mean mortality
μ_i – River mortality
μ_t – Year mortality
θ – Aquaculture effect
$P_{i,t}$ – Aquaculture production
$\varepsilon_{i,t}$ - error

An example - Newfoundland

- Used survival estimates from 5 rivers, 1986-2001
- Conne River salmon migrate past cages
- Assumed effect of aquaculture to be proportional to square root of production
- Estimated intercept (Western Arm Brook in 2000) at $e^{3.05}=0.047$
- Estimated effect of aquaculture: $e^{1.08}$, a decrease in survival of 66% at highest volumes

Meta-analysis

- Meta-analysis : weighted means
- Any one comparison is weak
- By combining multiple comparisons, a more accurate and reliable result can be obtained

Disadvantages of this approach

- Picking suitable comparisons is difficult
- Data may be limiting
- Statistically, this may be complicated, and meta-analytic step is largely undetermined
- Scale issues – will not detect effects on really large scales, or effects on only freshwater stages
- Mechanisms are not always clear

Advantage of this approach

Allows estimation of what the actual impact on mortality in the ocean has been, which is what we want to know.

Contribution to science and management

- The model could be applied to other questions where a comparative approach might be useful – such as hatchery effects or pollution for salmon
- Potential to increase understanding of which expected effects of aquaculture are occurring and important
- Potential to aid in management decisions regarding placement and regulation of Atlantic salmon farms