Fishing of Pacific Salmon and its Impact on Bears and Eagles in the Tongass National Forest

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Background:

The Tongass National Forest in Alaska stands as one of the few remaining pristine temperate rainforests, wherein the ecological significance of salmon as a keystone species manifests through its influence on biodiversity dynamics, particularly in relation to population fluctuations among apex predators such as brown bears and bald eagles. The potential repercussions of overfishing within the Pacific and river estuaries of the Tongass extend beyond the immediate impact on salmon populations, with far-reaching consequences on the successful migration of salmon to their spawning grounds within the national park. This phenomenon assumes paramount importance for numerous species within the ecosystem, as their sustenance is intricately tied to the availability of salmon as a primary food source during critical periods. Consequently, our research project seeks to elucidate the threshold of fishing exploitation that could disrupt this vital event, thereby posing a significant risk of extinction for brown bears and bald eagles in the Tongass National Forest.

Research Question: At what mortality rate of salmon along their migratory routes across the Pacific Ocean do brown bears and bald eagles face the risk of extinction in the Tongass National Forest?

Model Equation – Patch 1

$$\frac{dN_1}{dt} = r_{in}(K - N_2) - E \cdot N_1 - gN_1$$

Pacific Ocean

Salmons (N_1)

Subjected to fishing effort (E)

Model Equations – Patch 2

$$\frac{dN_2}{dt} = -\frac{c_{1max} b_1 N_2}{b_1 N_2 + c_{1max}} C_1 - \frac{c_{2max} b_2 N_2}{b_2 N_2 + c_{2max}} C_2 + gN_1 - dN_2$$

$$\frac{dC_1}{dt} = \epsilon_1 \left(\frac{c_{1max} b_1 N_2}{b_1 N_2 + c_{1max}} - R_1 \right) \cdot C_1 - d_1 C_1$$

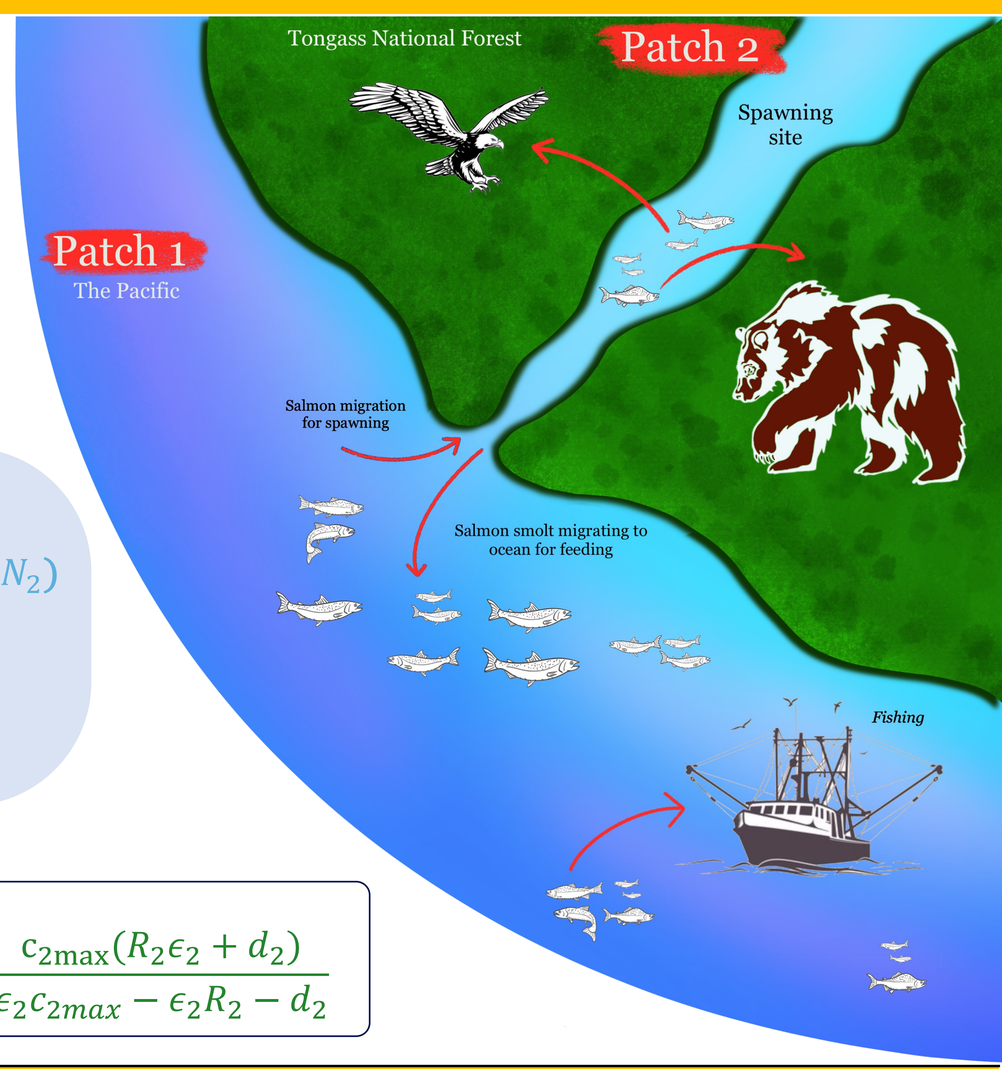
$$\frac{dC_2}{dt} = \epsilon_2 \left(\frac{c_{2max} b_2 N_2}{b_2 N_2 + c_{2max}} - R_2 \right) \cdot C_2 - d_2 C_2$$

Spawning site

Spawning salmons (N_2)

Predators:

- Brown Bears (C_1)
- Bald Eagles (C_2)



Critical resource concentration: $\mathbf{N}^*_{bears} = \frac{1}{b_1} \cdot \frac{c_{1max}(R_1\epsilon_1 + d_1)}{\epsilon_1 c_{1max} - \epsilon_1 R_1 - d_1}$ $\mathbf{N}^*_{eagles} = \frac{1}{b_2} \cdot \frac{c_{2max}(R_2\epsilon_2 + d_2)}{\epsilon_2 c_{2max} - \epsilon_2 R_2 - d_2}$

Parameters

Patch 1: Pacific Ocean

Salmons in ocean

Initial population	$N1_0 = 500$ salmons
Carrying capacity	$K = 500$ salmons
Salmon's incoming rate	$r_{in} = \frac{1}{30}\frac{1}{day}$
Outgoing migration rate	$g = \frac{1}{3}\frac{1}{day}$
Exploitation rate	$E = 0.3\ \frac{1}{day}$

Patch 2: Spawning Site in Tongass

Salmons in spawning site

Initial population	$N2_0 = 0$ salmons
Incoming rate	$g = \frac{1}{3}\frac{1}{day}$
Death rate of salmon	$d = \frac{1}{10}\frac{1}{day}$
Incoming salmons	$g \cdot N_1\ \frac{\text{salmons}}{day}$

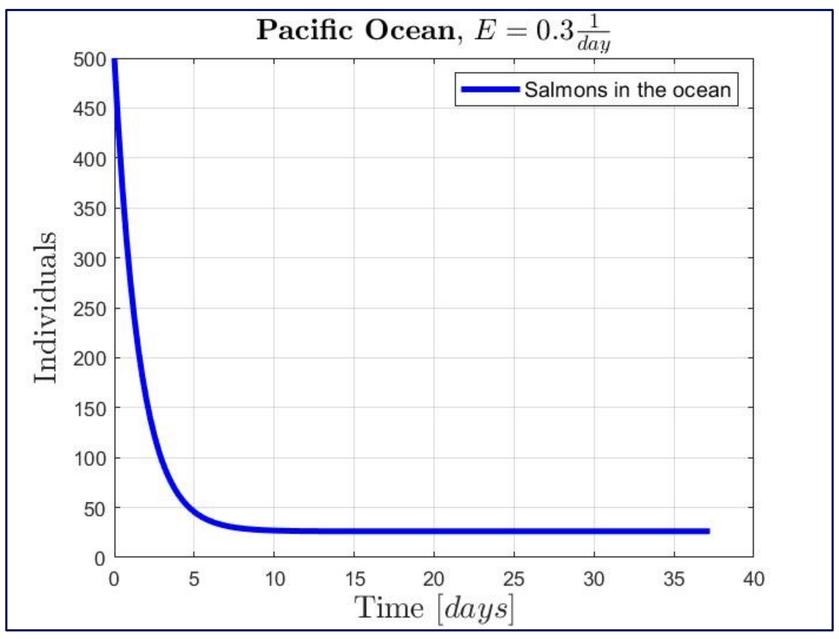
Brown bears

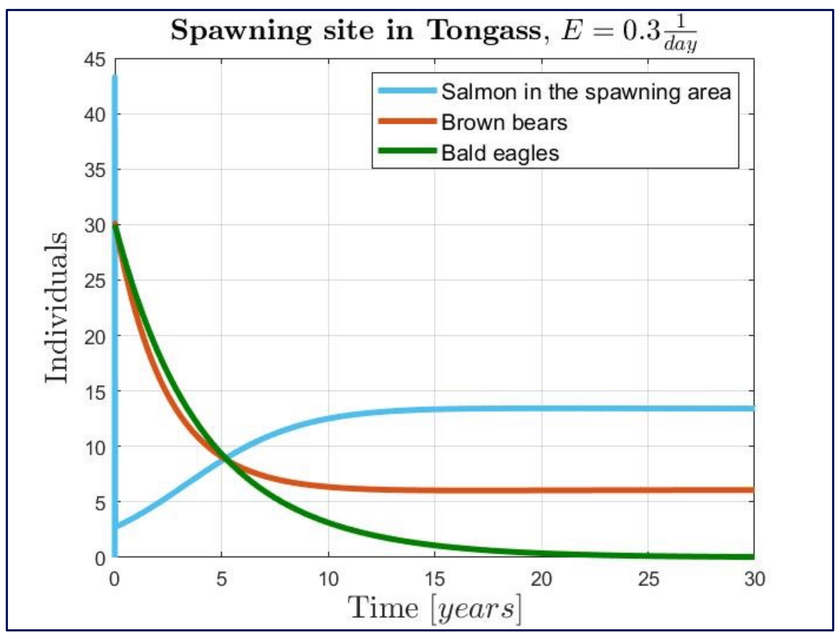
Initial population	$C1_0 = 30$ bears
Death rate	$d_1 = \frac{1}{15 \cdot 365}\frac{1}{day}$
Attack rate	$b_1 = 0.1\ \frac{1}{\text{bear} \cdot day}$
Efficiency	$\epsilon_1 = 4 \cdot 10^{-4}\ \frac{bear}{\text{salmon}}$
Max consumption	$c_{1max} = 10\ \frac{salmons}{\text{bear} \cdot day}$
Vital resources	$R_1 = 0.1 \cdot c_{1max}$

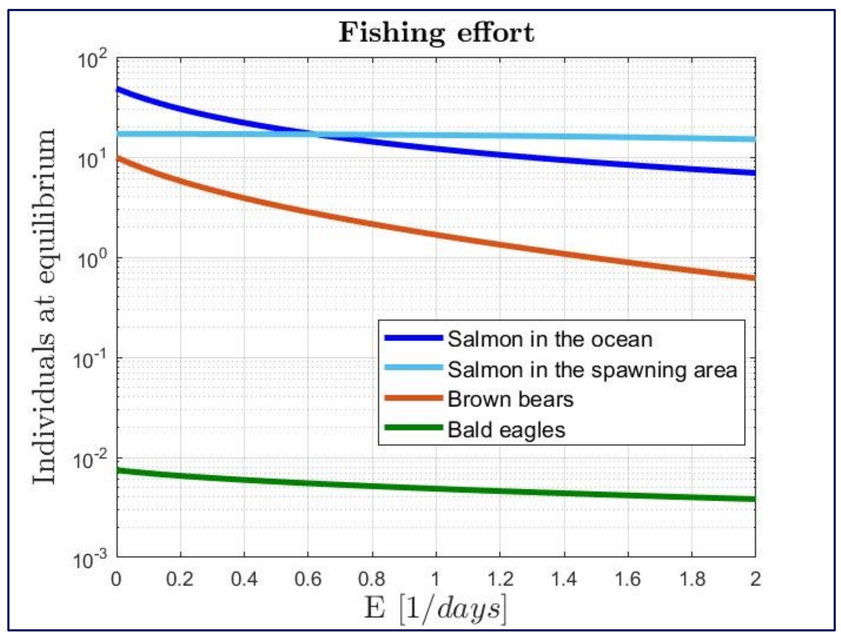
Bald eagles

Initial population	$C2_0 = 30$ eagles
Death rate	$d_2 = \frac{1}{10 \cdot 365}\frac{1}{day}$
Attack rate	$b_2 = 0.006\ \frac{1}{\text{eagle} \cdot day}$
Efficiency	$\epsilon_2 = 1.4 \cdot 10^{-3}\ \frac{eagle}{\text{salmon}}$
Max consumption	$c_{2max} = 3\ \frac{salmons}{\text{eagle} \cdot day}$
Vital resources	$R_2 = 0.1 \cdot c_{2max}$

Results







Salmon's population in the Pacific reaches a constant value in just a few days. The dynamic is much slower in the spawning site where the bears overcome the eagles. Bears' N* is lower than that of eagles this means that bear population can persist at a lower minimum resource concentration compared to the other species.

N* for brown bears ➔ 17.05 salmons

N* for bald eagles ➔ 100.00 salmons

Effort rates for fishing of salmon (E) [per day]	From 0 to 0.4	From 0.4 to 0.8	Greater than 0.8
Brown bears	Survive (more than 4 bears)	Endangered (less than 4 bears)	Extinct (less than 2 bears)
Bald eagles	Extinct	Extinct	Extinct

Conclusion

From the model, it is possible to conclude that the fishing of salmon that occurs in the ocean has a strong impact on the terrestrial organisms that rely on salmon as a primary food source. In particular, the bear population is strongly affected as its number depends directly on the salmon's number. Moreover, as shown in the table it is possible to conclude that for different fishing effort the bear population may get endangered or even extinct. The control of fishing quotas is therefore critical to preserve the whole rainforest ecosystem.

Information source: http://www.americansalmonforest.org/