Exploitation of Salmon and its impact on biodiversity in Tongass National Forest, Alaska

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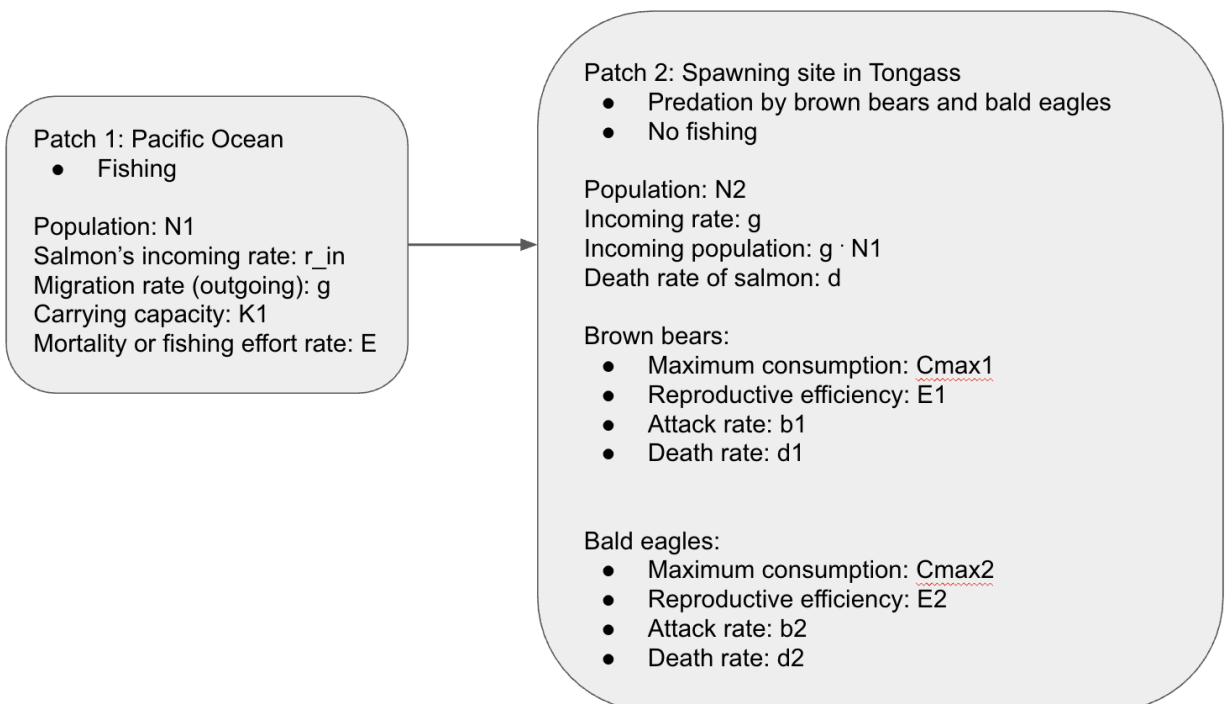
Background:

Tongass National Forest in Alaska is one of the last remaining intact temperate rainforests, where salmon is one of the keystone species impacting biodiversity levels by contributing to the changing population sizes of predators like brown bears and bald eagles. Overfishing in river estuaries of Tongass can lead to a huge change in the numbers of salmon that will successfully reach their spawning sites further inside the national park – a phenomenon that essential for the growth of many different species living there as they rely on salmon as a primary food resource during the spawning seasons. Our project aims to find out at what level of exploitation through fishing, can this yearly phenomenon come to a halt and thus cause the extinction of brown bears and bald eagles in Tongass National Forest?

Research Question:

What mortality rate level of salmon through their migratory routes across the Pacific Ocean results in the extinction of brown bears and bald eagles in the Tongass National Forest?

Model Sketch:

Patch 1: Pacific Ocean
- Fishing

Population: N1
Salmon's incoming rate: r_in
Migration rate (outgoing): g
Carrying capacity: K1
Mortality or fishing effort rate: E

Patch 2: Spawning site in Tongass
- Predation by brown bears and bald eagles
- No fishing

Population: N2
Incoming rate: g
Incoming population: $g \cdot N1$
Death rate of salmon: d

Brown bears:
- Maximum consumption: Cmax1
- Reproductive efficiency: E1
- Attack rate: b1
- Death rate: d1

Bald eagles:
- Maximum consumption: Cmax2
- Reproductive efficiency: E2
- Attack rate: b2
- Death rate: d2

Model Equations:

Patch 1:

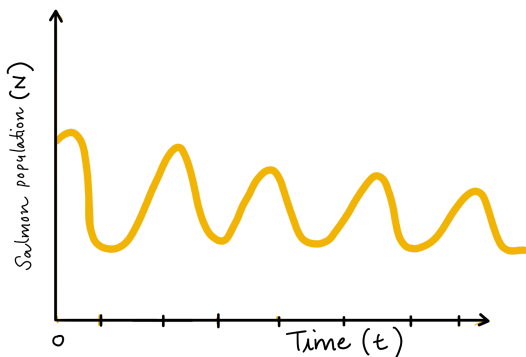$$\frac{dN_1}{dt} = r(K - N_2) - EN_1 - gN_1$$

Patch 2:

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

$$\frac{dC_1}{dt} = \left(\varepsilon_1 c_{1max} \cdot \frac{b_1 N_2}{b_1 N_2 + c_{1max}} - d_1 \right) \cdot C_1$$

$$\frac{dC_2}{dt} = \left(\varepsilon_2 c_{2max} \cdot \frac{b_2 N_2}{b_2 N_2 + c_{2max}} - d_2 \right) \cdot C_2$$

Model Graphs:

Patch 1 — Salmon population (N) vs Time (t)

Patch 2 — Population sizes vs Time (t)
Legend: Salmon, Brown bears, Bald eagles