Model Explanation Doc

This document explains the model structure, inputs, and details for the case study models of the Locks and Nisqually. It is currently structured for the Locks, so many of the details are tailored to that system at the moment. I will be trying to generalize for other systems as we go.

**Questions**

* How different is our response given different numbers of specialists in the system? What if there are no specialists and the seals exhibiting specialist foraging behaviors are just a carousel of different individuals with no elevated likelihood of targeting salmon?
  + How different is our response given different levels of social learning that govern the number of specialists in the system?
* How different is our response given different levels of connectivity (migration of specialist or non-specialist individuals, social learning) between systems?
* How do removals change the response in each of the above scenarios (varying numbers of specialists, systems with varying degrees of social learning of specialist behaviors, and different levels of connectivity between systems)?
* How does the expected degree of avoidance of removals change the response to each of the above scenarios?

**Model Structure**

*States*













N: Normal seals

S: Specialist seals

I: Inactive seals

Ops: general Puget Sound salmon

Ol: salmon that have arrived at the gauntlet and are navigating the ladder or locks

Osafe: salmon that have made it past the gauntlet

*Rates*

A note: some of these are rates conceptually but I seem to have written them as states at the moment…tbd how/if that changes





D: discovery, the number of seals that randomly discover a salmon buffet and start exhibiting specialist foraging behaviors and join group S

R: removal rate for each seal group, human caused either hunt or management

L: leave, the number of seals that stop exhibiting specialist foraging behaviors and join group I

Z: switch, the number of seals that start exhibiting specialist foraging behaviors and join group S

Mig: migration of salmon from the general Puget sound area into the Locks area/gauntlet

P: predation, the number of salmon eaten by pinnipeds

E: escape, the number of salmon that pass the gauntlet into the safe zone

*Scope*

Time step is 1 day.

Spatially the model represents one salmon system, with potential for connectivity to others through the N seal group and Ops salmon group.

**Details**

*N*

The N group consists of seals that exhibit a diet that is not specializing on salmon. For now, this is just a source population for seals to join the S or I groups. In future iterations it will also be interesting for exploring migration and connectivity between salmon systems. At the moment, it starts at 10,000 as a rough approximate for the total abundance of harbor seals in WA Inland Waters.

*S*

The S group consists of seals that are currently exhibiting a salmon specialist foraging strategy during the time step. For now, this group starts at 150, which is based on a rough anecdotal estimate by Ava and Eric on how many seals they think are hauled out at Elliott Bay marina when salmon are running up the locks.

*I*

The I group consists of seals that are specialists even when they are not actively eating salmon, as in they have a higher probability of switching to that foraging strategy than an N seal. The idea is that seals that have tried this strategy before are more likely to try it again and may be more sensitive to changes in salmon abundance.

*Ops*

The Ops group of salmon are the salmon that are migrating through Puget Sound or otherwise have not yet reached the gauntlet area.

*Ol*

The Ol group of salmon have reached the gauntlet area. They exit this area either by being eaten or by escaping past the gauntlet.

*Osafe*

The Osafe group of salmon have passed the gauntlet and are available to spawn or be caught by upriver fisheries, or otherwise die naturally in freshwater. This is our response for most questions we ask of this model.

*D*

The discovery rate is used to represent the possibility that N seals may randomly discover a salmon system and choose to exhibit specialist behaviors. Right now those seals cannot become naïve again, so they are then in the I or S groups forever. I’m not sure if this is right or if there should be some kind of decay back into the N group over time.

*R*

The removal rate is for harvest of seals. This is currently just a straight removal rate, but eventually I would like to incorporate the effect of harvest becoming more challenging as seals learn to avoid harvest activity.

*L*

The leave rate is the number of seals that choose to stop exhibiting specialist behaviors during the time step. For now this is a function of the number of salmon per seal available in the gauntlet. In future it would be cool to incorporate a disturbance term or avoidance of harvest activity aspect.

*Z*

The switch rate is the number of seals that choose to start exhibiting specialist behaviors during the time step. This is currently a function of the number of salmon in the Ol group. I don’t love that this isn’t based in any kind of mechanism, just a gut feeling for where that threshold might be.

*Mig*

The migration rate is the rate at which salmon arrive at the gauntlet. This is an arrival curve informed by Sockeye arrival data from the Locks collected by Muckleshoot technicians (data available in the folder Data>Ballard Locks Fish Counts. See “Sockeye arrival function creation.R”. This arrival curve may end up being characteristic of other runs, but also could be updated for different systems and species.

From Eric Warner: "There are actually two expansion terms combined into one. One extrapolates from the ten minute count to a full hour, and the other estimates the number of fish moving into the fish ladder during the rest of the day and night (it equates to counting for 13 hours and extrapolating to 16 hours -- for June and July anyway). As far as we can tell based on the old electronic counters and some other evidence, this is generally true for sockeye, but underestimates Chinook passage through the ladder. I'm not sure about coho. The combined estimates from the fish ladder and Locks are our best estimate of fish entering freshwater from Puget Sound. Yes there are a lot of other issues with these counts, but this is as good as it gets. If there are confounding issues that make an appreciable difference and we're off, at least we're off the same way every year."

*P*

The predation rate is the number of salmon that are consumed by pinnipeds during that time step. This is currently a total BS number informed by nothing. It will eventually be informed by diet studies and bioenergetics and be species specific.

*E*

The escape rate is the salmon that make it past the gauntlet and are no longer available to pinnipeds. This is based on residency information from Eric and Ava on how long fish stay at the Locks area (ladder or through the locks, back and forth) before making it all the way through. Can be updated for different residence times in different species and systems.

**Data Inputs**

Salmon arrival data from the Locks is available from 2012-2022 in the Data folder.