**Visualization of Model Causality Evaluation Protocol**

**Abstract**

MS-PROD is an ecological fisheries model which models the biomass of fish over 30 years. In the model, the biomass of each fish species depends on effects from harvesting and interactions with the other fish species. Therefore, the visualization of this model requires representations for the biomass as well as the different inter-species relationships that impact the biomass. We represent the biomasses over time with time series and the relationships with links between the different time series charts. Users can interactively change the fishing levels to understand what fish species will be affected and why. The purpose of this study is to explore the extent to which different depictions of inter-species relationships help to explain the complex inter-species relationships in an understandable manner.

**Key**

Here is a key for the different types of text in the Script and Training Example sections:

* [*Italic text indicates an instruction to the evaluation proctor.*]
* [*Italic underlined text indicates an instruction to stop or start reading the instructions based on the experimental condition.*]
* Normal text indicates something the evaluation proctor should say out loud to the participant.

**Conditions**

There are four conditions in the experiment. The Kraken program features buttons on the top to toggle between the conditions.

* A: No between-species links
* B: Static between-species links
* C: Dynamic between-species links
* D: Dynamic, animated between-species links

**Script**

[*Run KRAKEN.exe and click the “RUN” button. Leave the program in Condition A.*]

Here we have a visualization for a model called Kraken, which predicts the effects of fishing on ten species, while also taking into account how the fish affect each other. The purpose of this visualization is to help people understand how fishing impacts the fish over a few decades.

Kraken is a mathematical model which makes 30-year biomass forecasts for ten species of fish. Here you can see there are ten charts, one for each fish species. [*Point to the ten charts*.]

We have time, measured in years, on the x-axis and biomass on the y-axis. [*Point to the x-axis of the bottom-most chart.*] Biomass is the amount of a species in an ecosystem at a time, measured in Megatons.

Since biomasses vary between species, each fish species has its own chart with its own y-axis scale. [*Motion to the different y-axes scales.*] Therefore, these gray circles show the absolute size of the biomass to allow for comparisons between species. [*Motion to the gray biomass indicators*.]

The biomass of an individual species is predicated by the Kraken model according to a few factors:

* growth of the species,
* losses due to harvesting by humans, and
* losses due to interactions with the other nine species

These ten species are divided into four functional groups. A functional group is a biological grouping of species that perform similar functions within their ecosystem. We have colored and positioned the ten species according to the functional groups [*point toward each functional group*]:

* Elasmobranchs
* Small pelagics
* Groundfish
* Flatfish

The fish are harvested according to functional group. The sliders on the left-hand side represent the harvest effort for each functional group. [*Point to the sliders.*] The harvest effort represents how hard the fishermen are trying to catch the fish in that group. Right now, all of the sliders are set to one.

Changing a slider causes the model to instantaneously recalculate the biomass forecasts. You can increase how hard the fishermen are trying by pulling the slider to the right and decrease by pulling to the left. [*Slowly pull the groundfish slider (green) down to 0.75 and up to 1.5. Leave it at 1.5.*]

We have drawn a shaded “ghost” to help you compare the current forecast with a “baseline” forecast. The “baseline” forecast is from when all of the harvest efforts were set to one. The “ghost” is drawn above or below the current forecast, extending toward the baseline forecast.

[*Motion to the large shaded area on the cod plot*.] This shaded area shows us that cod’s biomass has decreased from the baseline forecast.

[*Motion to the blue rectangle under the slider.*] This marker helps us keep track of where the effort was before we changed it. [*Click the “RESET” button next to the groundfish slider*.]

*[Condition A ends here; resume at Training Example]*

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| *[Condition B, C, and D continue]*  [*Change the program to Condition B with the button on the top of the screen.*]  Before we mentioned that species face losses due to either harvesting from humans or because of interactions with other fish. There are two types of interactions that occur between species:   * predation, which is when one species is consumed by another species, [*motion to the orange arrows going between some of the charts*] and * competition, which is when one species suffers due to its resources being consumed or utilized by another species [*motion to the blue arrows going between some of the charts*]   These semi-circle links going between the charts indicate the presence of one of these relationships between two species. The width of these links represents the strength of the relationship; wider links means the recipient species is impacted heavily by the source species.  The direction of the links is indicated by the triangle in the middle. For example, Spiny Dogfish eat cod. [*Hover over the Spiny Dogfish to Cod link, which is the largest orange one on the right*.] Additionally, the links are drawn clockwise, so the arrows on the right-hand side can be read top-to-bottom and the arrows on the left-hand side can be read bottom-to-top.  *[Condition B ends here; resume at Training Example]* |

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| *[Condition C and D continue]*  However, there are many links being drawn here. Instead, we can draw the links selectively.  [*Change the program to Condition C or D, depending on which condition this experiment is for.*]  [*Slowly pull the groundfish slider (green) again down to 0.75 and up to 1.5.*]  Now, the links are only being drawn to explain the differences between the baseline forecast and the current forecast. A link grows as that relationship becomes more relevant in explaining the differences when the two forecasts. If a link isn’t relevant at all, then the link isn’t shown.  A link disappearing does not mean the relationship isn’t part of the model anymore. It simply means that relationship does help to explain the changes from the baseline to the current forecast.  There are plus and minus signs drawn to indicate the nature of the relationship from the perspective of the recipient species.  For example, if a predator species is fished more, then this is good from the perspective of a prey species, because there are less of the predator eating the prey. In this situation, you would see a plus sign drawn on the arc from the predator to the prey.  A predator being fished less is bad from the perspective of the prey, because then the prey will be eat more. In this case, you would see a minus sign drawn on the arc from the predator to the prey.  Similarly, plus and minus signs are drawn on the links between the sliders and fish charts, to show the perspective of the fish on the change in effort.  [*Click the “RESET” button next to the groundfish slider*.]  *[Conditions C and D end here; resume at Training Example]* |

**Training Example**

*[ALL conditions resume here]*

In this evaluation, we will have you increase or decrease a specific harvest effort and then explain the changes you observe. We will go through a training example which is similar to the questions you’ll be asked.

[*Give the participant control of the mouse*.]

* Halve the harvest of groundfish.
* Notice that the redfish, haddock, and cod biomasses increased due to decreased harvesting.
* Notice that the biomass of other fish species changed as well, such as mackerel.

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| [*Conditions A only*]   * Interactions between the species must explain why mackerel decreased. * Perhaps one of the groundfish species eats or competes with mackerel. | [*Conditions B, C, and D only*]   * Notice the line going from redfish to mackerel. * This indicates redfish eat mackerel. * We halved the harvest of groundfish, so the biomass of redfish increased. * Since the redfish biomass increased, more mackerel were being consumed. * This could explain the decreased mackerel biomass. |

[*Allow the participant to play with the slider a bit to understand this, then BEGIN EVALUATION.*]

**Evaluation Questions**

1. Double the harvest effort on **small pelagics**.
   1. What is the effect on **herring**?

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* 1. Why?

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Reset the **small pelagics** harvest effort.

1. Halve the harvest effort on **flatfish**.
   1. What is the effect on **winter flounder**?

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* 1. Why?

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* 1. What is the effect on **yellowtail flounder**?

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* 1. Why?

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Reset the **flatfish** harvest effort.

1. Double the harvest effort on **elasmobranchs**.
   1. What is the effect on **skates**?

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* 1. Why?

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* 1. What is the effect on **cod**?

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* 1. Why?

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* 1. What is the effect on **haddock**?

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* 1. Why?

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* 1. What is the effect on **windowpane**?

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* 1. Why?

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**Evaluation Answers**

1. Double the harvest effort on **small pelagics**.
   1. What is the effect on **herring**?

BEST: Decreased a little

ACCEPTABLE: Decreased a lot, Stayed about the same

UNACCEPTABLE: Increased a lot, Increased a little

* 1. Why?

The fishing effort increased, so more herring are caught, resulting in a smaller biomass for herring over time.

Reset the **small pelagics** harvest effort.

1. Halve the harvest effort on **flatfish**.
   1. What is the effect on **winter flounder**?

BEST: Increased a lot

ACCEPTABLE: Increased a little

UNACCEPTABLE: Stayed about the same, Decreased a little, Decreased a lot

* 1. Why?

Winter flounder is a flatfish, so fishing less for flatfish results in an increased biomass for winter flounder.

* 1. What is the effect on **yellowtail flounder**?

BEST: Stayed about the same

ACCEPTABLE: Increased a little

UNACCEPTABLE: Decreased a little, Decreased a lot

* 1. Why?

One would expect the biomass of yellowtail flounder to increase due to halving the flatfish fishing effort. However, both windowpane and winter flounder, both flatfish, compete with yellowtail flounder. Their increased biomass seems to have prevented the yellowtail flounder biomass from increasing much.

Reset the **flatfish** harvest effort.

1. Double the harvest effort on **elasmobranchs**.
   1. What is the effect on **skates**?

BEST: Decreased a lot

ACCEPTABLE: Decreased a little

UNACCEPTABLE: Increased a little, Increased a lot, Stayed about the same

* 1. Why?

Skates are elasmobranchs, so fishing more for elasmobranchs resulted in a decrease in biomass.

* 1. What is the effect on **cod**?

BEST: Increased a lot

ACCEPTABLE: Increased a little

UNACCEPTABLE: Stayed about the same, Decreased a little, Decreased a lot

* 1. Why?

Spiny dogfish, which are elasmobranchs, predate on cod. Doubling the harvest on elasmobranchs caused the biomass of spiny dogfish to decrease. Since there were less spiny dogfish to predate on the cod, the cod biomass increased.

* 1. What is the effect on **haddock**?

BEST: Decreased a lot

ACCEPTABLE: Decreased a little

UNACCEPTABLE: Stayed about the same, Increased a little, Increased a lot

* 1. Why?

Spiny dogfish, which are elasmobranchs, predate on cod. The decrease in elasmobranchs caused an increase in cod. Cod compete with haddock, so the increase in cod led to a decrease in haddock.

* 1. What is the effect on **windowpane**?

BEST: Decreased a lot

ACCEPTABLE: Decreased a little

UNACCEPTABLE: Stayed about the same, Increased a little, Increased a lot

* 1. Why?

Spiny dogfish predate on cod, so the increased harvest on elasmobranchs led to the cod biomass increasing. Cod compete with windowpane, so the windowpane biomass suffers due to the increased cod biomass.

Reset the **elasmobranchs** harvest effort.