Using Interactive Visualization to Enhance Understanding of a Fisheries Model

BY

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Chapter 1

Introduction

Fishery managers have only one “lever” to pull when it comes to fishery management: the ability to set harvest quotas. Fishermen work within these quotas by exerting various levels of fishing effort. Both managers and fisherman can better understand the ecosystem they work within and the implications of their decisions with the assistance of a production model. In this context, a production model is a mathematical model, based on data, that simulates interactions between species and predicts species biomass as a function of fishing effort, climate change, and other variables. MS-PROD is a multispecies production model developed by NOAA scientists Gamble and Link [8]. A visualization may enhance such a model by making its inner workings more explicit and may be useful for decision making. The goal of the proposed research is to explore design alternatives and evaluate the effectiveness of different modes of portrayal and interaction to make a visualization of the MS-PROD model that will be a valuable tool to the modelers and stakeholders alike.

Chapter 2

Background

2.1 Models

Both the short- and long-term effects of human exploitation on an ocean ecosystem, such as the species inhabiting the Gulf of Maine, are not easily understood since experiments which would allow ecosystem managers to investigate the impact of different levels of exploitation over many years are either impractical or impossible to conduct on a large scale. Fortunately, ecosystem models can be used instead to help gain a better understanding of an ecosystem.

2.1.1 Lotka-Volterra Equations

Ecosystem models are abstract representations of an ecological system, and can range from an individual species in its environment to an entire community of species. A classic example is the Lotka-Volterra model, which is a pair of differential equations for describing the non-linear interactions between a predator species and a prey species. [17, 24]:

$$\frac{dN_1}{dt} = N_1\left(\alpha - \beta N_2\right) \tag{2.1}$$
$$\frac{dN_2}{dt} = -N_2\left(\gamma - \delta N_1\right) \tag{2.2}$$

where N_1 is the number of prey, N_2 is the number of predator, t is time, α is the prey's growth rate, β is the rate at which the predator destroys the prey, γ is the death rate of the predator, and δ is the rate at which the predator increases from consuming the prey. The model can be generalized to discuss an arbitrary number of species rather than just a single pair.

The Lotka-Volterra model can be modified to take competition instead of predation into account, as in the Rosenzweig-MacArthur model [20] and the Leslie-Gower model [16]. These adaptations to the model also consider carrying capacity, which is the maximum number of a species that can be sustained indefinitely in a particular environment:

$$\frac{dN_1}{dt} = r_1 N_1 \left(1 - \left(\frac{N_1 + \alpha_{12} N_2}{K_1}\right)\right) \tag{2.3}$$

$$\frac{dN_2}{dt} = r_2 N_2 \left(1 - \left(\frac{N_2 + \alpha_{21} N_1}{K_2}\right)\right) \tag{2.4}$$

where r_i is the growth rate for species i, K_i is the carrying capacity for species i, and α_{ij} is the effect species j has on species i. As with Lotka-Volterra, this model concerns only two species, but it can be generalized to include more than two.

Both Lotka-Volterra and Leslie-Gower do not incorporate a factor which is critical when discussing fisheries management: the effect of harvest. The Schaefer model adds a term to account for the effect of harvest on an individual species [22]:

$$\frac{dN}{dt} = rN \left(1 - \left(\frac{N}{K}\right)\right) - qEN \tag{2.5}$$

where N is the number (or biomass) of the species, r is the growth rate, K is the carrying capacity, q is the catchability coefficient, and E is the fishing effort.

Simple models, when available and correct, are generally preferred; since fewer components are needed to describe their real-world counterparts, they are more easily understood and implemented. All three of these models are subjectively simple in that they only consider a few ecological factors each. However, in reality, ecosystems are complex systems which require management that recognizes them as such [3]. Thus, a more holistic approach called ecosystem-based fishery management (EBFM) has been advocated [18]. However, this approach has not often been implemented due to a lack of models which consider all necessary ecological factors. Gamble and Link developed a multispecies production model (MS-PROD) to fill this gap [8].

2.1.2 The MS-PROD Model

The MS-PROD model is built upon the Schaefer production model by also including Lotka-Volterra terms for predation, Leslie-Gower terms for competition, and carrying capacities for functional groups (K_G) as well as for the entire system (K_σ):

$$\frac{dN_i}{dt} = r_i N_i \left(1 - \frac{N_i}{K_G} - \frac{\sum_{j=1}^{g} \beta_{ij} N_j}{K_G} - \frac{\sum_{j=1}^{G} \beta_{ij} N_j}{K_\sigma - K_G} \right) - N_i \sum_{j=1}^{P} \alpha_{ij} N_j - H_i N_i \tag{2.6}$$

where N_i is the number (or biomass) of species i, t is a unit of time, r_i is growth rate for species i, β_{ij} is the interaction of species j on i, α_{ij} is the predation of species j on i, H_i is the harvest rate on species i, g is the number of species within species i's group, G is the number of groups, and P is the number of predators.

This model is distinguished from other multispecies production models by describing stocks with explicit ecological and harvest factors. Each species to be included in the simulation must be specified in the parameter file by listing growth rate, functional group membership, initial biomass, carrying capacity, and catchability. Additionally, matrices representing inter-species relationships must be provided to describe the relationship between every pair of species. Such matrices are required for *predation*, where one species consumes the other, and *interaction*, where one species affects the other in any manner besides predation.

The MS-PROD authors provided us with a parameter file which listed ten key species chosen from the Northeast United States Continental Shelf Large Marine Ecosystem (NEUS LME), listed here by functional group:

- **Elasmobranchs:** Skates, Spiny Dogfish
- **Flatfish:** Windowpane, Winter Flounder, Yellowfin Tuna
- **Groundfish:** Cod, Haddock, Redfish

- **Small Pelagics:** Herring, Mackerel

Given an input parameter set of initial biomass values, a predation matrix, an interaction matrix, catchability values, and harvest effort values, the MS-PROD model runs simulations for 30 years with an annual time step to predict individual biomasses. While this outputted information is potentially valuable to fishery managers, it was lacking an interactive graphical user interface.

2.2 Visualization Methods

When designing a visualization, there can be several techniques for visualizing a feature that are worth comparing. This section reviews existing research of visualization methods which have particular relevance to the problem of creating an effective inferface to a fisheries ecosystem model.

2.2.1 Time Series

Fisheries management is focused on the sustainability of choices concerning fish stocks. A main purpose of ecosystem management is to ensure that future generations can enjoy the same natural resources [3]. As such, the MS-PROD model provides biomass forecasts for 30 years. Therefore, time-oriented visualization techniques must be explored.

Frank categorized time-oriented data as follows [6]:

1. Linear vs. cyclic
2. Time points vs. time intervals
3. Ordered time vs. branching time vs. time with multiple perspectives

Aigner et al. point out that techniques for visualizing branching time and time with multiple perspectives are unfortunately uncommon [1], but a line chart—a technique frequently used for ordered time data—serves as a good starting point.

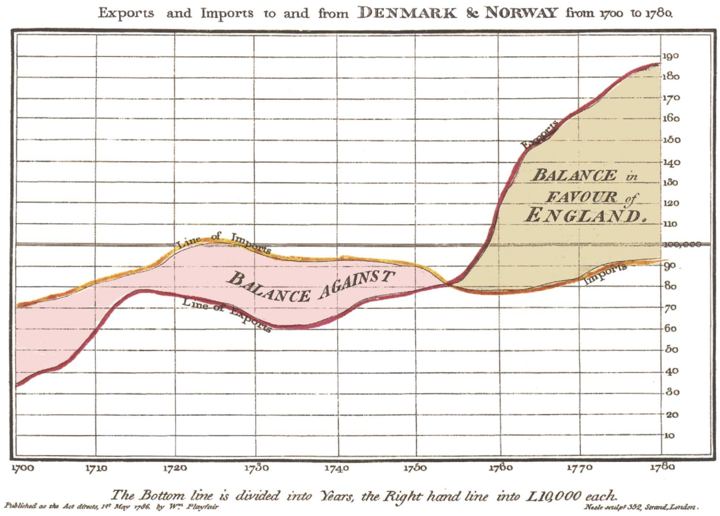
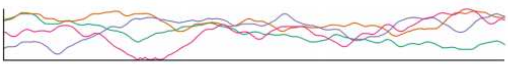
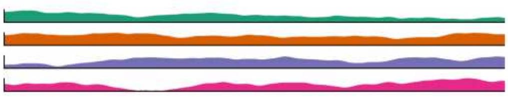


Figure 2-1: Playfair's original time series chart [19].

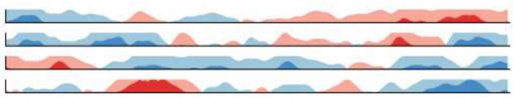


(a) A simple line graph.

(b) A braided graph.



(c) Small multiples.



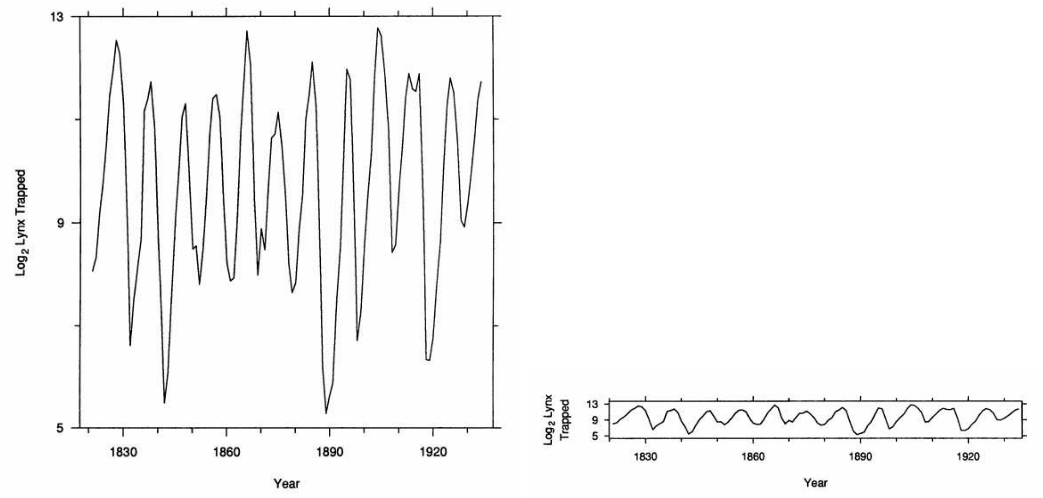
(d) Horizon graphs.

Figure 2-2: Four possible methods for visualizing multiple time series [14].

Line Charts

The line chart was first invented by William Playfair in 1786 to communicate time series data, seen in Figure 2-1 [19]. Today, it remains a common method for visualizing time-oriented data in many fields, including science, economics, planning, and engineering to name a few. Line charts typically encode time on the horizontal axis, progressing from left to right, and some time-varying value on the vertical axis. Points in the chart are connected by line segments such that the slope of the line indicates the rate of change between time steps.

Multiple time series can be part of a single line chart; each series needs only to be

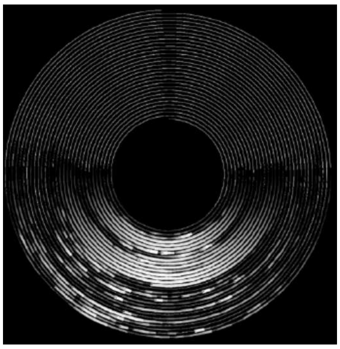


(a) Shape parameter of 1.0. (b) Shape parameter of 0.074.

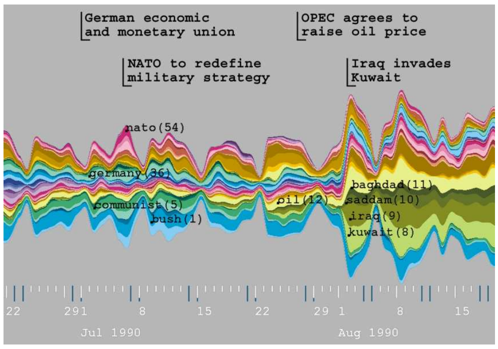
Figure 2-3: Two effect of chart shape on Canadian lynx data [4].

distinguished by a color and/or line style. However, as the number of time series on a single line chart increases, it becomes more difficult to identify an individual series. Javed et al. evaluated the four different plotting techniques for multiple time series, illustrated in Figure 2-2 [14]. The first of the techniques is the "simple line chart," which was Playfair's original line chart with all series plotted together. A slight variation on that is "small multiples," where each series had its own line chart though all charts share the same axis scales. Horizon graphs, originally developed by Saito et al., wrap around a baseline in two color tones to save space [21]. Lastly, braided graphs feature all series on one chart with the coloring under the curves alternating as series intersect each other. The user evaluation by Javed et al. revealed that a simple line graph with all time series on one plot or a single graph for each time series is better suited to a variety of tasks than a horizon graph or a braided graph. They also found that users complete tasks more correctly when there is more display space allocated to the graphs. They did not recommend using a higher number of simultaneous time series—their study used eight at the most—because it also leads to a decline in correctness of task completion.

Some line charts are more effective at conveying the nature of the data than others



(a) Spiral time series.



(b) ThemeRiver time series.

Figure 2-4: Two alternative time series visualizations.

because of the way different drawing techniques affect interpretability. Cleveland et al. found the shape of a line chart—defined as the height of the chart divided by the width of the chart—to be a critical factor [4]. Shape of the chart directly impacts the slopes of line segments, which viewers interpret in order to understand the dependence of the y variable on the x variable. Figure 2-3a, a time series of Canadian lynx trapping data, features a shape of 1.0 and seems to imply rapid increases and decreases in the population. On the other hand, Figure 2-3b has a shape of 0.074 and shows more clearly that the population rises somewhat steadily and declines somewhat rapidly, which Figure 2-3a failed to show. Their user evaluation found that judgment of two slopes is influenced by the orientation midangle, defined as the average of the minimum slope orientation and the maximum slope orientation. They proprosed line chart shape should be selected such that orientations are as close to $\pm 45°$ as is possible, like in Figure 2-3b.

Alternatives

There are many alternatives to and variations of Playfair's original time series. One example is Weber et al.'s spiral time series, seen in Figure 2-4a [26]. The spiral time series was designed for cyclic data. Cycles are emphasized in a properly-parameterized spiral visualization, however it may be difficult to describe periodic behavior in unknown datasets or determine if that behavior even exists. Another example is the ThemeRiver by Havre et al, seen in Figure 2-4b [11]. Each "current" in the ThemeRiver represents an entity or subject and must be of a distinctive color. Positioning along the y-axis is meaningless, instead the abundance of the entity or subject over time is indicated by the width of the current.

2.2.2 Networks

The input parameters to the MS-PROD model includes predation and interaction matrices. These are relationships which may be better understood if incorporated into the visualization. Relationships are often visualized through a node-link diagram, which typically represents entities as nodes and links as relationships between the nodes they connect. There are many types of node-link diagrams used for illustrating networks; those which are relevant to our research are discussed in the following sections.

Force-Directed Layouts

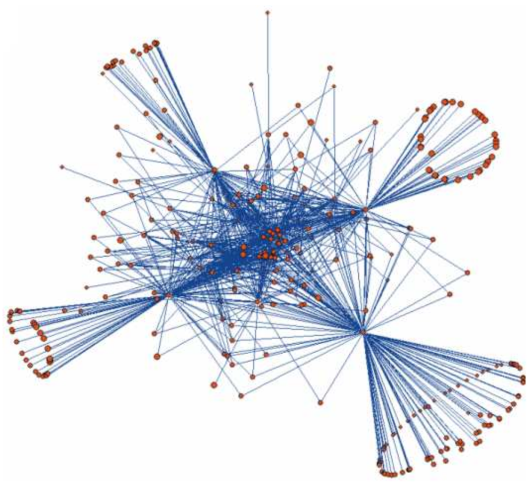


Figure 2-5: A force-directed visualization of a food web of Gulf of Alaska data [7].

One option for showing fish species interactions would be to use a force-directed layout as Gaichas and Francis did, seen in Figure 2-5 [7]. Here, the nodes represent an individual species in the Gulf of Alaska, while the links represent a predator-prey interaction. In a force-directed layout, nodes repel each other, while related nodes become pulled toward each other by links [12]. The result is an aesthetically pleasing layout where there are relatively few link crossings and links are of approximately similar length. The color of the node can be used to indicate group membership, while the size can represent the magnitude of some property of the node. Likewise, the drawing style of the link can be varied to encode different types of relationships.

Arc Diagrams

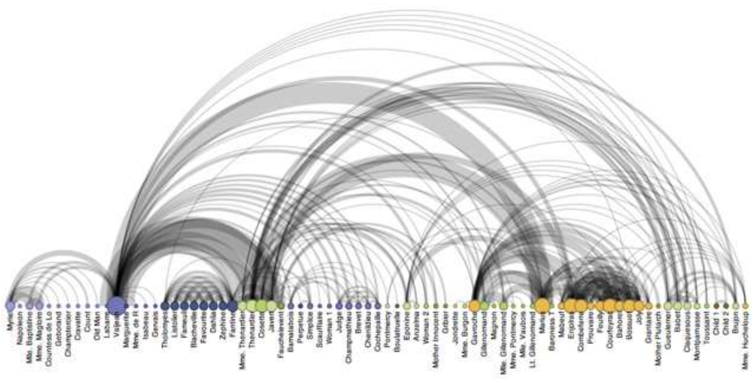


Figure 2-6: Knuth's arc diagram of *Les Misérables* characters [15].

An alternative for force-directed layout is an arc diagram. The name arc diagram was coined by Wattenberg [25], though they were invented earlier. Knuth used arc diagrams to illustrate interaction of characters in Victor Hugo's novel *Les Misérables*, seen in Figure 2-6 [15]. Each character is represented with a circular node, where size indicates the number of appearances. The nodes are arranged linearly, colored and ordered according to clusters of characters that appear together frequently. Semi-transparent arcs are drawn between the characters which appear in the same chapter, with the thickness of the arc representing the number of such appearances. While the arc diagram may fail to properly depict the structure of a network, Heer et al. point out it is advantageous because the one-dimensionality allows for other features to be easily displayed near the nodes [12], such as text labels.

Directed Edges

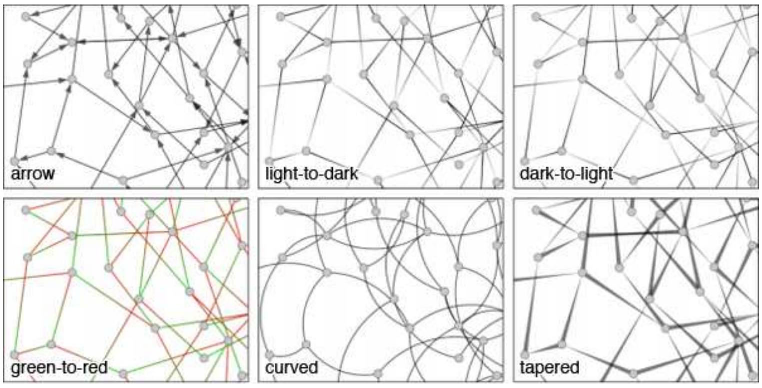


Figure 2-7: Different types of directed edges [13].

Relationships in a network may be directional, such as the predator-prey relationship. In a visualization of such a network, the direction of the edges must be encoded so these relationships can be understood. Holten and van Wijk studied the effectiveness of different techniques for indicating directionality of edges in a graph, seen in Figure 2-7 [13]. The traditional arrowhead was found to perform poorly, while a tapered edges performed best. As for an intensity-based direction cue, a dark-to-light representation was found to be clearer than light-to-dark.

Matrix Representations

Node-link diagrams can have occlusion problems when they are highly-connected, so a matrix-based representation of a network is a possible alternative [12]. In many cases, networks are stored as an adjacency matrix, so all that needs to be done is visualize that matrix as a grid, where the cell at the ith row and the jth column represents the relationship from entity i to entity j. Figure 2-8 shows Knuth's visualization of *Misérables* characters in matrix-form [15]. The color of the cell indicates the presence or type of a relationship, with some neutral color indicating the lack of a relationship. Ghoniem et al. showed that a matrix-based view is suitable for large or dense networks for tasks that involve finding or

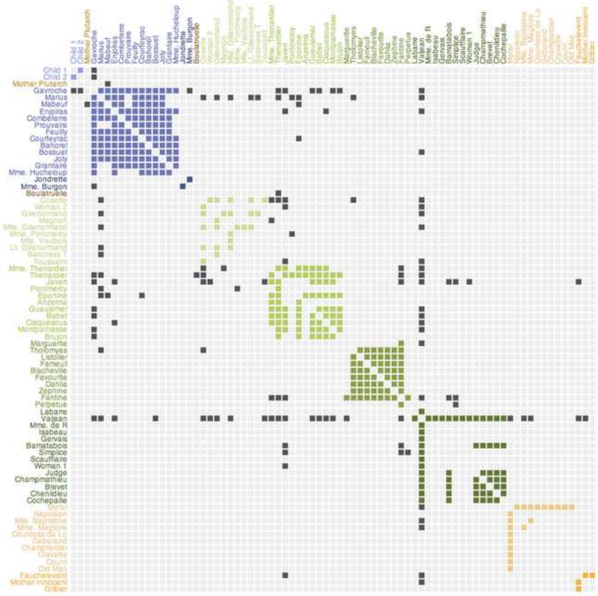


Figure 2-8: A matrix-based visualization of an adjacency matrix [15].

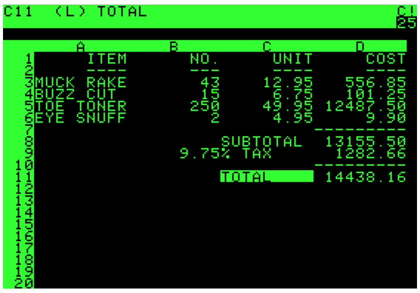
counting links or nodes [9]. With proper ordering of the rows and columns, the structure of the network can be effectively displayed, however path-finding tasks may be difficult.

2.3 Understanding Models

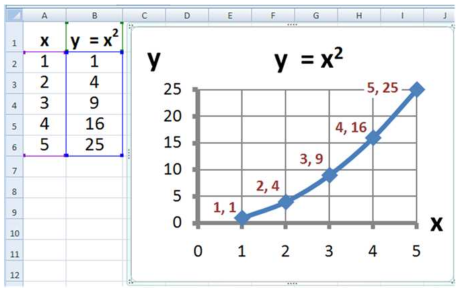
Users studying models can benefit from the aid of a visualization, because patterns and trends may be difficult—if not impossible—to discern from only a table of numerical values. The learning process can be even further enhanced through interaction with the model. If interactivity is supported by the visualization, then users can adjust parameter values, perceive a change (or perhaps no change) in the results, and begin to understand the degree of influence different parameters possess.

2.3.1 Spreadsheet Programs

VisiCalc was a very early example of software assisting the understanding of models [10]. As a business student, Bricklin wished there was a faster way to change the input or fix mistakes when working out financial models by hand [2]. To address this, he worked with Frankston



(a) A screenshot of VisiCalc (GNU General Public License).



(b) A chart made using Microsoft Excel (public domain).

Figure 2-9: Two examples of spreadsheet applications.

to develop VisiCalc, seen in Figure 2-9a. As the world's first electronic spreadsheet, VisiCalc consisted of rows and columns containing either text, numerical values, or formulas. Result cells were instantly updated according to changed inputs or adjusted formulas, allowing a user to work with models in a more efficient and dynamic manner. VisiCalc was superseded by Lotus 1-2-3, which was in turn supplanted by Microsoft Excel. Microsoft Excel remains popular and features graphing tools which can generate charts, such as in Figure 2-9b.

2.3.2 The Influence Explorer

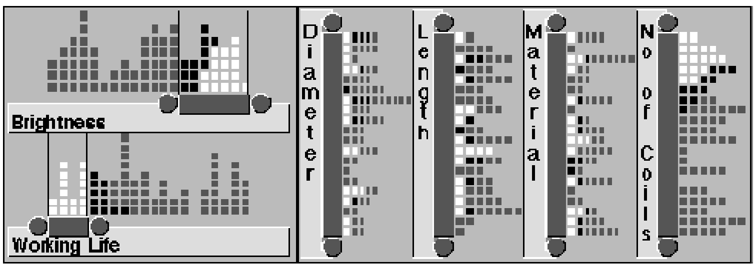


Figure 2-10: A screenshot of the Influence Explorer [23].

The Influence Explorer by Tweedie et al. is a good example of a more complex interactive visualization [23]. They developed an interface for understanding the relationships between different attributes in a design process. Parameter values of the Influence Explorer are initially randomly selected to represent different possible items. For each attribute, there is a histogram including each of the items. The attribute ranges are controlled by sliders. When the user adjusts the slider of a given attribute, all items that are within that range are highlighted on all of the histograms. Figure 2-10 is a screenshot of the Influence Explorer being used to test the performance of different light bulb designs; white indicates the design passed, black it failed one specification, and grey it failed two specifications. In a user evaluation, industrial designers found the ability to interactively explore the effects of different parameter ranges to be valuable.

2.3.3 Vensim

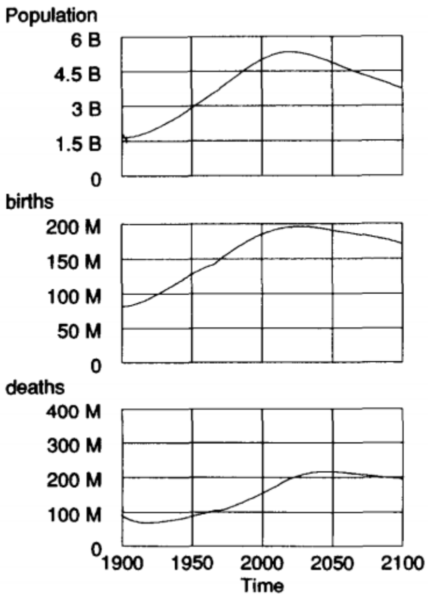


Figure 2-11: A screenshot of the strip graphs in Vensim [5].

Eberlein and Peterson recognized that both unskilled and skilled modelers have the same need: to quickly obtain a thorough understanding of a model and its implications [5]. This motivated their development of Vensim, which is a commercial tool for visualizing and analyzing simulation results. Vensim allows users to run a model under different conditions with a simple mouse click, enabling the user to learn the effects of different actions with ease. Various features enhance this learning process—e.g., "causal tracing" strip graphs, shown in Figure 2-11. Rather than simply seeing a chart of the projected population, a user exploring the causal tracing feature can begin to understand the various components that contributed to the population simulations—births and deaths—by seeing each component on its own chart. A major emphasis of Eberlein and Peterson is that the same visualization tool can and should be used for both the development and teaching phases of a model, especially since those phases may not be discrete.

Chapter 3

Proposed Work

The goal of this research is to provide an interactive interface to the NOAA MS-PROD model so as to help fishermen, fisheries managers, and other stakeholders understand the implications of decisions, such as changing catch quotas for particular kinds of fishing activity—e.g., bottom trawling versus mid-water trawling. From using our interactive interface, users should gain insights into:

- **Implications of the model:** E.g., how do two different sets of fishing effort values affect the biomass predictions of the ten species?
- **The model itself:** E.g., why does the abundance of one species increase when another species is caught?

Research for this thesis is being carried out in two phases, 1) a design and implementation phase and 2) an evaluation phase. In the first phase, various design alternatives have been implemented with some feedback from the originators of the fisheries model (Robert Gamble in particular). A substantial part of the research, particularly relating to design and implementation has already been completed; most of what remains is the evaluation component. The following section discusses completed work and the section following that discusses work that remains to be done.

Chapter 4

Work Completed

Time series line charts—of both the simple line chart and small multiples varieties—were chosen to display the biomass forecast data output by the model. A major reason line charts were chosen is that casual viewers can understand them without further instructions, as opposed to, say a horizon graph. Another advantage to line charts is that they tend to have a reasonable amount of whitespace where additional information can be displayed, such as uncertainty or alternate forecasts. A key design issue concerned the representation of change. A number of alternatives were implemented and are described below.

Interaction with the model parameters is done by means of a set of sliders with the goal of allowing the user to immediately see the impact of management decisions. The user can adjust sliders which represent harvest effort and watch the line charts change instantaneously as the model is re-run according to the new effort values. Like Eberlein and Peterson, we aimed to turn the "time consuming and tedious" task of working with a model into a "fast and fun" interactive experience [5]. Different views and features of the visualization are discussed in the sections below.

4.1 Visualization of Change

In order for users to understand and compare decisions, the ability to perceive changes in biomass resulting from changes in the fishing effort is necessary. Therefore, we have introduced two alternatives to displaying these changes. The first is a dotted line which shows the previously projected biomass compared with the currently projected biomass. The second is a blend of color originating from the current biomass projection that diminishes in opacity as it approaches the previously projected biomass.

4.2 Visualization of Inter-Species Relationships

Understanding of the model requires understanding of the underlying relationships between species—namely, predation and interaction. Thus, the interface must grant explain to users which species impact each other and the magnitude of those relationships. These are illustrated with arc diagram network visualizations between time series. Firstly, users have the ability to view either predation or interaction statically. Secondly, both predation and interaction can be viewed dynamically, which the arcs being drawn as effort values are adjusted and according to their impact at that moment.

4.3 Visualization of Uncertainty

Since models are merely simplications of reality, their is best understood as a range of expected values. Therefore, for the sake of more scientific users, it is better to include the ability to perceive these ranges in our visualization. Our interface can perform Monte Carlo simulations by randomly jittering the non-zero input parameter values $\pm 10\%$ for the MS-PROD model. The resulting uncertainty can be displayed in one of the following methods:

- Multi-line (one semi-transparent line per Monte Carlo simulation run)
- Error bars of standard deviations
- Error bands of standard deviations
- Error boxes of quartiles

4.4 Functional Group View

Early on in the design process, a design was made to organize the time series plots according to functional group. A functional group is a biological grouping of species which perform

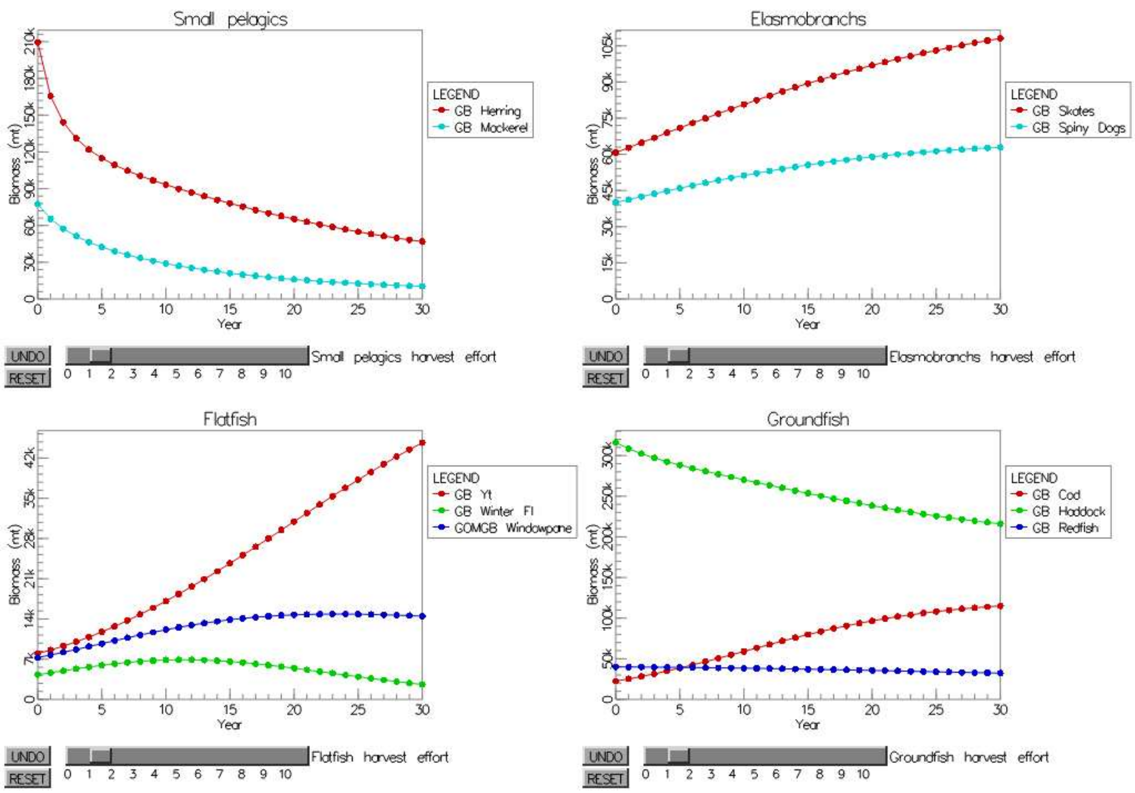


Figure 4-1: A "by group" view of our MS-PROD visualization.

similar functions within their ecosystem—e.g., mackerel and herring are both members of the "small pelagic" group since they live in the water column. There were three reasons for this design decision. First, it is difficult to select enough distinct colors to represent each species so that all species could be plotted on a single chart. Second, the biomass of some species was significantly larger than others, which was also problematic when all species were on one chart. By scaling the y-axis according to the largest biomass value in the entire 30-year timespan, the lines representing some species were crowded at the bottom of the chart and seemed to be flat even when they were not. It was then observed that species of similar functional groups tend to have biomass values in similar numeric ranges. Third, harvest effort is controlled by functional group, so it made sense to develop a line chart for each functional group. Figure 4-1 shows a screenshot of biomass predictions produced by the model and displayed by these four functional groups.

The major advantage of this "by group" view is that comparisons of species within a group are easy. For MS-PROD, there are only two or three species per functional group, so the line chart for each group tends to not suffer from occlusion problems, unlike with the initial single line chart approach. Direct and indirect effects of changes in harvest effort also become more clear with the "by group" approach—e.g., if the user adjusts the effort slider only for elasmobranchs, yet sees the biomasses change on the groundfish chart, then the user can begin to understand there is some kind of relationship between elasmobranchs and groundfish.

4.5 Species View

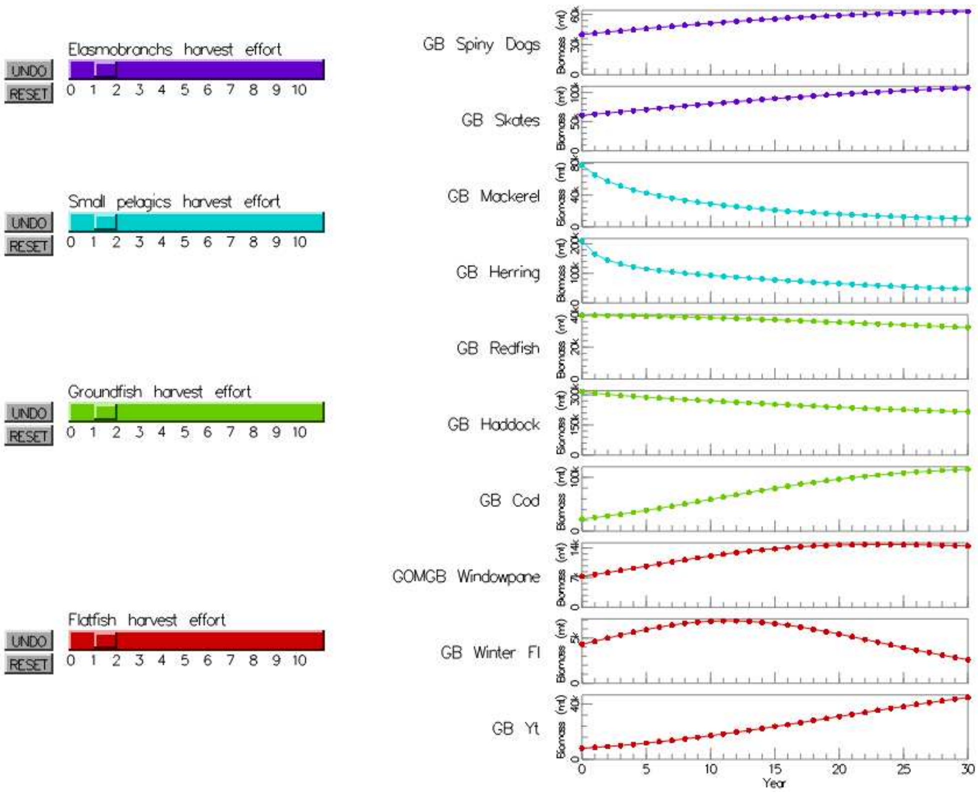


Figure 4-2: A "by species" view of our MS-PROD visualization.

The alternative to viewing "by group" is to view each species on its own plot, as in small multiples. In this style, each plot is sorted and colored according to functional group membership, as seen in Figure 4-2. The harvest effort sliders are also colored by functional group and positioned near the plots of the corresponding group. This allows for the ability to differentiate between direct and indirect effects of changes in harvest effort.

With each species on its own plot, it is much easier to interpet the biomass predictions of an individual species, since the y-dimension of a plot needs to be scaled to the data of one species only. It is easier to perceive increases or decreases in biomass because no species suffers from the flattening that can occur when a series is displayed on the same plot as a series that has significantly higher values. On the other hand, this makes comparison between species somewhat difficult because the user must either refer to the y-axis labels or hover over a specific point on a chart in order to determine the absolute value of the biomass at a point in time.

4.5.1 Absolute Size Indicators

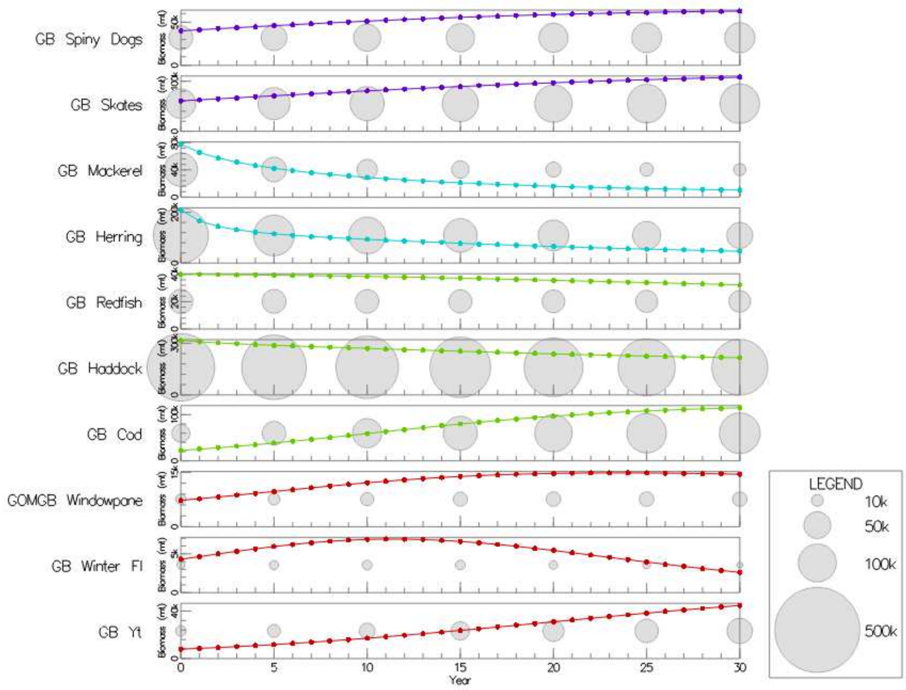
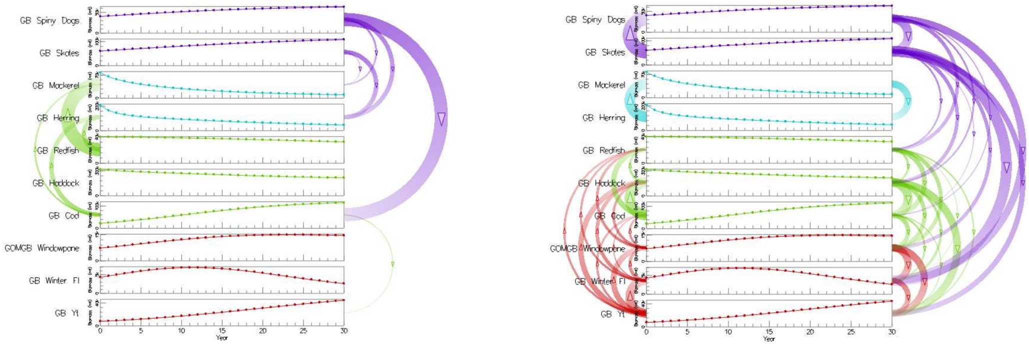


Figure 4-3: Absolute size indicators overlaying the “by species” view.



(a) Predation arcs. (b) Interaction arcs.

Figure 4-4: Arcs drawn between species charts to represent relationships.

In the "by species" view, the scaling of the y-dimension is adjusted to fit the data of each individual chart. Therefore, as mentioned, it is difficult to ascertain the absolute biomass sizes in order to compare between species. The introduction of absolute size indicators, seen in Figure 4-3, alleviates this problem by showing the absolute size of the population as the area of a circle. To avoid occlusion, these indicators are drawn every five years within the thirty-year timespan, but they still make for quick comparison between different species.

4.5.2 Between Species Arcs

The predictions for biomass in this model take inter-species relationships into account. These relationships are *predation*, where one species consumes another, and *interaction*, which accounts for the way any spcies might impact another that is not predation. Understanding these relationships may be critical to understanding why some a species fish is indirectly affected by fishing efforts of other types of fish. Therefore, we chose to include a network visualization of these relationships in our application, as seen in Figure 4-4.

The arc diagram was selected over other network visualizations because it is easily integrated into our time series visualizations. A separate node-link diagram, such as one with a force-directed layout, may have been confusing because it would require the user to mentally associate nodes in the network with line charts. As mentioned previously, Heer et al. described a major benefit of the arc diagram is that the one-dimensionality allows for other features to be easily displayed near the nodes [12]. In our case, the time series line charts are the nodes; the line charts are only enhanced, not occluded, by the arcs. Arc diagrams are also well suited to smaller datasets with clusters of nodes, which applies to our dataset since the fish are segmented into functional groups.

4.6 Displaying Change

The motivation of this visualization is to allow the modelers and other stakeholders to easily run the MS-PROD model in order to compare the effects of different choices of fishing effort. Thus, the visualization requires some method of comparing alternate biomass forecasts and granting users the ability to decide which fishing effort values seem most sustainable. Therefore, we have added a feature which allows the user to save a "base line" of fishing effort values, change the fishing effort values, and compare the new biomass predictions to those of the original base line.

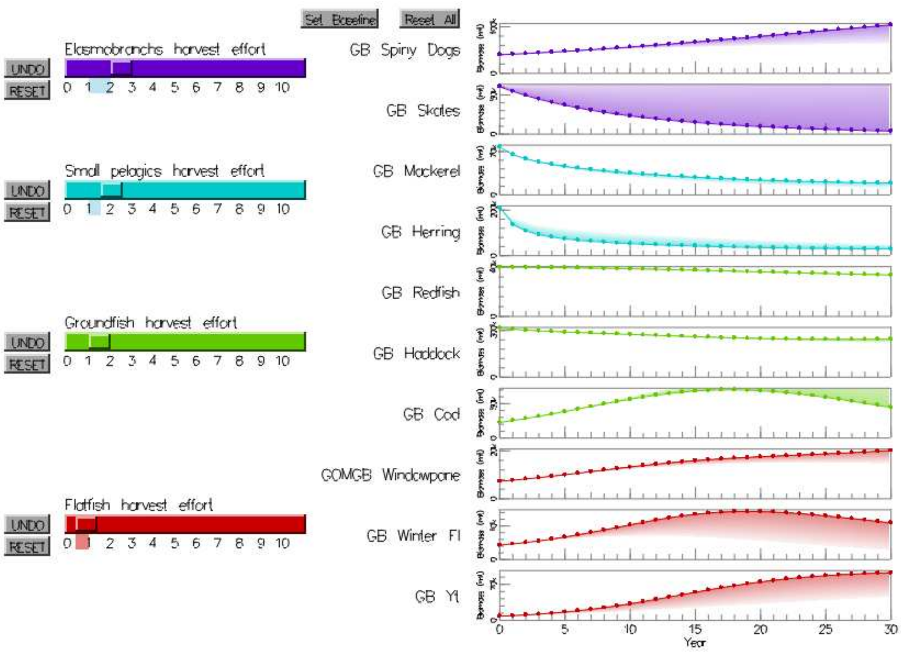


Figure 4-5: Showing change between different effort values.

Figure 4-5 shows this feature which displays change. The blended area in a line chart is colored from the current biomass line to the line as it was when the baseline was set; a colored area above the line indicates the biomass declined, while a colored area beneath represents the biomass increased—e.g., the "skate" population declined dramatically with the new effort values, the "winter flounder" population increased due to the changes, and "haddock" seemed to be unaffected.

Underneath the sliders, the colors—if present—indicate how the baseline effort values were set. Blue indicates the effort value has been increased since the baseline was set—e.g., again in Figure 4-5, the effort for "elasmobranchs" was originally set to 1.0 and now it is approximately 2.0. Red represents the effort value has been decreased since the baseline was set—e.g., the effort for "flatfish" was originally set to 1.0 and now it is approximately 0.5.

This feature is available in both the "by group" and "by species" views. The baseline can be saved at any time with a simple button at the top of the screen. Buttons are also available to undo or reset changes to the effort values.

Chapter 5

Work to be Completed

5.1 User Evaluation

The user evaluation will be conducted in the manner of a semi-structured interview. Users will be instructed on the various features of the MS-PROD visualization, then asked to either rate or rank the different features. Some questions which may be included are:

- Which visualization method did you like the best?
- How useful did you find this feature?
- How well do you think you have understood the model?

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