Fisheries MPA visualization tool – an enhanced tool to define MPA

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Abstract

With fish stocks depleting world wide, the need for marine protected areas (MPAs) have been growing in the fisheries industry. To meet this need, we must implement better tools for constructing MPAs than what currently exists. This paper will introduce the current requirements for MPA construction tools, and present a new program built on top of existing MPA tools that tries to meet these requirements. This program's interface and visualization modifications, informed by rationale from the field of Information Visualization, will be discussed. This new tool utilizes well-tested theories from the field to provide MPA analysts with multiple layers of useful ecological information with minimal effort. We utilize color, textures, and glyphs in an effective manner as part of the interface's visualization.

CR Categories and Subject Descriptors: visual layering, MPA fisheries, colors, glyphs, pattern

Additional Keywords: visual salience, color theory, multiscale displays, ordered vs. categorical vs. quantitative data

1 Introduction

The majority of scientists in the fisheries community agree that the fisheries of the world have been experiencing depleting returns. It has been seen over and over again in under-managed fisheries that catches have gradually become smaller and smaller over time; as a result, lesser yields lead to overall diminishing profits. This in turn threatens aquatic habitats, as continued over-fishing to compensate for low yields is driving many species towards extinction. There is an urgent need for human intervention and control before it is too late.

Governing bodies and organizations have attempted to combat this problem by building Marine Protected Areas (MPAs). MPAs are defined as any coastal or open ocean area that is regulated to protect natural resources, biodiversity, or human livelihood. The level of protection between MPAs varies considerably; most allow some essential activities such as fishing for food, while prohibiting others such as drilling for oil or gas.
As the Canadian Parks and Wilderness Society states on their website, "MPAs are important tools for ensuring the protection of the marine environment."

With this increasing demand for MPAs, there is an increasing need to construct MPAs that are both effective in preservation while still being of a reasonable size. For example if an MPA is too small, the fishes will crowd the MPA region, which in turn leads to insufficient food for the population; thus making small MPAs ineffective. However, if an MPA is too big, fishers have nowhere to fish for food, or cannot fish their desired species. This would lead to fishers with no catches and a subsequent wave of job losses.

2 Problem Definition

To address the problem of managing MPAs effectively, ecosystem modeling tools have been developed to predict the trends of actual ecosystems. Ecopath with Ecosim (EwE) is one of the leading ecosystem modeling tools, and allows users to model MPAs within ecosystems. Students, researchers, government and non-governmental organizations use it all over the world to mimic ecosystems, which aids in the development of new fishing policies. EwE has a spatial aspect to its modeling, as it predicts movement and migration patterns of fishes and fishing fleets over a period of time. Along with this capability, EwE has a tool that allows the user to define MPAs in certain regions. Unfortunately, there is no set scheme or algorithm to determine the best way to set an MPA. The jobs of fisheries scientists would be made simple if one were able to simply set parameters for certain MPAs and allow an algorithm to compute a set of MPAs that would fit the ecosystems needs. These needs are specific to the region and is designed with an intention in mind. For example the modeler could be asked to build MPAs to optimise for maximum sustainability for the future, or maximum short term profits. As the situation stands, however, the complexity of variables involved in determining what makes a good MPA is too difficult to be determined automatically. This complexity cannot be solved with an automated search procedures.

Although the definitions of MPAs are too complex, generalizations could be made for establishing a starting point for an effective MPA. Some of these generalizations are listed as follows.

1. Define the species that are endangered / need to be sustained.
2. Set the MPA over the region that is optional for the targeted species. An optimal region could be defined by a combination of preferable habitat, bottom type and/or measures i.e. coral reef, sandy bottom, deep waters, high primary production (food for the ecosystem) and/or low temperatures.
3. Tweak the defined MPA region according to other important parameters such as size of MPA, ability to manage, closeness to shore and various other measures that cannot be calculated accurately.

This third generalization would require the fisheries modeler to make an accurate spatial judgement of the MPA in relation to the parameters mentioned above. However, the current interface as seen in Figure 1 does not give the fisheries modeler the ability to visualize these different layers of information. In this figure, the modeler can see the various different MPA's in color. The numbers on the top of each cell/location indicates the habitat type, i.e. coral reef, sandy bottom, plankton or various other habitats that described in the area.

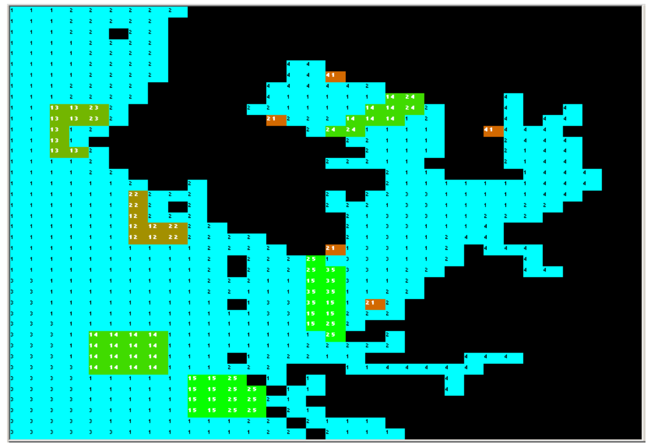

Figure 1 – EwE's version 5 method of displaying and drawing MPAs. Colors represent MPAs, and the first number represents habitat type, the second number represents a MPA .

Here is where the current visualization system in EwE falls short with regards to the task of defining an MPA. In order find a preferable habitat, the modeler would have to visually search the display in a sequential fashion, which is a slow process of varying effectiveness. Another limitation of this tool is its inability to visually present various parameters that would be pertinent to the definition of MPAs. Some of the key continuous data that is not shown above would be depth, primary production, temperature and various continuous data.

It is possible for EwE 5 to visualize three different types of data separately: habitat type, MPAs, and continuous data, using color as a medium. However, color is a difficult medium to display various layers of information. When layers overlap with one another, one can only see the top most color, and blending / using transparencies to visual multiple color layers is confusing and . This is not an effective way of visualizing the information required for the task of defining an MPA.

3 Problem Analysis

Due to the nature of the problem and the data set, various information visualization techniques can be applied. This data set can be categorized into 3 different categories: habitat, MPAs, and continuous data. Examples of *habitats* would be region modifiers such as *sandy bottom*, *coral reef*, or *sea shelf*. The number of different habitats defined in an average model can range from 3-10. Of course, it should be noted that EwE's design limits each cell on the display to containing a single habitat. Examples of *MPAs* would be policies placed on a certain region, such as a closure to the salmon fishery from June to August, or a no fish zone for all fisheries the entire season. There can be more than one MPA per cell/location and range between 0-6 MPAs for an average model. The last data category is *continuous* data, examples of which include temperature, depth and primary production. Most models will only have 2-3 different continuous data. Almost every location on the map has a specific temperature, depth and primary production. This means there will be a lot of visual overlap in attempting to represent these three attributes.

4 Background work

It is important to note how different approaches have attempted to address this visualization problem in the past. Healey[2] created a tool that utilizes textures and colors to effectively 'increase' the number of perceived dimensions. This tool uses the height of the image to effectively modify the density of the texture/pattern, and color was used as a redundant mechanism to increase visibility. These mechanisms are used to provide different layers of information.

Taylor[4] has explored using various techniques in conjunction with each other for visualization of multiple fields such as color, transparency, contour lines, surface albedo (reflectance function variations), and various texturing methods. He found that simultaneous perception of around 3-4 attributes was possible. Of these attributes, the most powerful ones in this regard were discovered were color, textures and glyphs.

Further ways of dealing with the specific issue of color overlapping has been addressed in 'color weaving' [5], in which Urness composites color by allowing multiple colors to be closely interwoven into individual streamlines rather than being blended together.

Linked highlighting is a classic technique that has been enhanced in various ways, such as in the work of Robinson [3], who has implemented linked highlighting methods including blurring/depth of field, or soft specular highlighting to further distinguish layers from one another.

5 Important visual attributes

The next version of the MPA visualization tool presented here attempts to represent different different categories in a visually effective manner. With 3 different data categories as mentioned earlier, the tool can utilize 3 different display techniques to display various layers of information with minimal interference between one another. These techniques are the usage of glyphs, patterns, and color. These techniques on their own are very tried-and-true techniques used in many information visualization applications. In fact, combinations of these visual techniques can be seen in common everyday items such as maps. Maps utilize color to represent different land masses, while at the same time using glyphs to represent capital cities. Glyphs and color are used in EwE5 in a limited fashion, with colors representing the different MPAs, and the numbers in each cell acting as glyphs to represent different habitats (although calling numbers "glyphs" is a bit of a stretch since they do not facilitate visual search as much as a dedicated iconic glyph would).

Each visual tool has its strengths and weaknesses, and each one was carefully chosen to fit the 3 different categories of data used in the definition of MPAs. When all other things are considered equal, visual overlap, salience, and distinguishability across layers are the main visual properties that we want to have for each of these data categories; here we evaluate how well our different visual tools fare in each aspect.

Visual overlap is the ability to for the user to understand what lies beneath each layer. Glyphs perform the best in this ability if they are accurately designed and placed. Patterns and textures, when overlapped, often become too dense to see what is beneath each layer, and lastly, colors will either fully cover the other color, or change hues when overlapped with another color, making it difficult to determine the value of either layer.

Salience is the ability for the eye to quickly find a target. In this aspect, color works the best because our eyes are developed though evolution to make quick decisions based on colored visual regions; the classic example being that of a person picking out red berries in a field of green bushes). Second to that comes glyphs which are effective in this regard, due to our ability to recognize individual shapes i.e. being able to see the circular shape of berries over the leaf shaped object in our example. Lastly, textures and patterns perform the worst in terms of salience since pattern receptors in human eyes are tuned to changes in certain patterns, but not so much to finding them as they do not stand out with the same kind of salience as the others do.

The last property we consider is *distinguishability in large quantities*, by which we mean the ability for a person to recognize differences from one another as the number of layers increase. When patterns are carefully designed, i.e. correct orientation, (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9509146), patterns work well because of our low level pattern receptors, which helps us distinguish them in large quantities. Colors have a limited ability to distinguish from one another because of our limited number of cone receptors; when the number of colors increases, these colors start appearing as the same color when they overlap. As glyphs start spanning a large area, glyphs tend to look like textures as the consistently repeat themselves. An overview is shown in table 1.

	Overlap-ability	**Salience**	**Distinguishability across layers**
Glyphs	best	average	worst
Patterns	average	worst	best
Colors	worst	best	average

Table 1 – Shows the strength and weaknesses of each technique.

6 Solution

We have assigned glyphs to MPAs, patterns to habitats, and colors to continuous data. Given each technique's strengths and weaknesses, it is important to carefully match each technique with the respective categories. From our data categories, we know MPAs and continuous data can overlap within each other, ruling out the use of patterns . We also know continuous data will span the largest area which could potentially turn glyphs to patterns. This leaves glyphs for MPAs and color for continuous data, and lastly, patterns for habitat.

Visual similarities also supports the solution above. For example, if one were to look at a habitat like a sandy bottom; it will have the look of a pattern. This is a very strong tie that would be very difficult to disjoint one from another. There is a high correlations between color and various data types. For example, continuous data can be intuitively represented by color; a hot temperature region could be represented by red, a high primary production region could be represented by green and so forth.
A tool was built as seen in Figure 2, on the basis of the problem and solution set described above. This tool utilizes color to represent continuous data, patterns to represent habitats, and glyphs to represent MPAs.

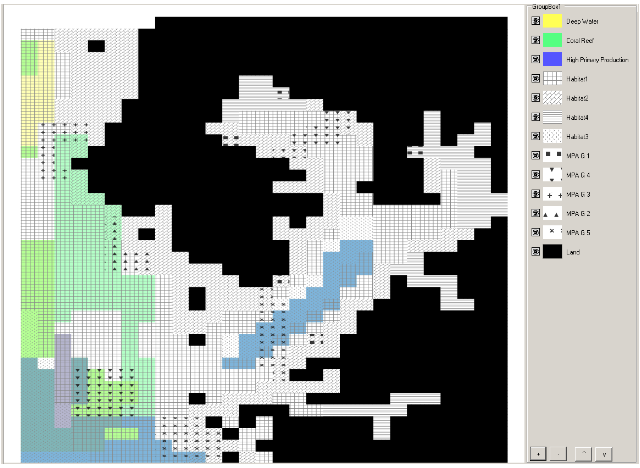

Figure 2 - Next version of MPA visualization tool. On the left is the map of the region, and the right is the legend. This visual tool currently displays 4 different habitats, 3 continuous data with range limits on them, 5 different MPAs and Land.

6.1 Habitat

When a user adds a habitat, this tool will automatically assign a pattern to the habitat layer. Patterns were carefully chosen to represent habitats on the display because of their easy distinguishability, and their minimal visual resemblance to any of the other data categories represented. Some of these patterns are patterns of squares, diagonal bricks, horizontal lines, diagonal lines, and arrows. As mentioned earlier, orientation plays the biggest role in distinguishing between patterns, which makes the distinction of these individual patterns relatively easy on the display. Since EwE does not allow for overlapping habitats, there are no problems in identifying and distinguishing these regions.

These patterns were drawn with gray with a slight transparency to further visually distinguish the habitats from the glyphs used elsewhere in EwE. Further, as seen in Figure 2, the distinction between these patterns is quite simple. The drawback of setting habitats as patterns is that nearly the entire map is strewn with patterns which increases the visual noise a great deal. As anticipated, visual search for a particular pattern is difficult.

6.2 MPAs

When a user adds an MPA to a region, a glyph representing that MPA will be automatically assigned as seen in figure 3. Glyphs were chosen to represent MPAs because of their ability to be perceived obviously when overlapping, which is one of the key requirements for EwE's model of MPAs. While visual performance on target/distractor tasks in the world of human perception is not fully understood; however, it is known that different orientation of glyphs and distinctive shapes makes them easily separable, which allows us to use similar shape for glyphs at different angles. In this way, these glyphs were carefully designed to be distinguishable. Glyphs are carefully placed so that the least amount of overlap is present, in order to further minimize the chance of one glyph being mistaken or completely covered by another. It is known that eyes are very good at completing certain shapes of glyphs when overlapping, but the tool added some benefits slight transparency. This would darken the overlapping region to aid the eye in recognizing the shape.

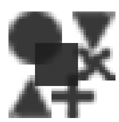

Figure 3 - All Glyphs at 200% designed to have minimal overlap with maximum distinguishability.

This tool is only currently limited to 6 different glyphs which is a slightly greater number of glyphs for an average model. This limitation was imposed by the number of available distinguishable glyphs, which is further limited by making sure the glyphs are of sufficient size and appropriate shape as to be not mistaken for a pattern. To guard against the case in which glyphs span a large area and mimic a pattern, the glyphs were designed to be much 'bolder' than the patterns to aid in distinguishing these categories.

These MPA regions are easier to visually search than the pattern areas. The glyphs seem to stand out above the patterns, creating a distinct categorical layer which further aids this tool. However, a disadvantage of this is when the cell sizes get smaller than the glyph template size (1/2 the size of Figure 3), (what happens?); however, this is unlikely since MPAs that are that small are generally are not effective enough to be considered by the modeler in the first place.

6.3 Continuous

Users are able to add certain continuous data, represented by color in this visual tool. These colors are automatically assigned to each type of continuous data, although users can individually modify the colors. Transparency was set to 50% to ensure underlying colors would be seen in the event of overlap. This also desaturates the individual colors which is beneficial to users since oversaturated colors can unnecessarily draw visual attention; as we know, color is the most salient of the 3 visual tools. The user is able to set the range of values to be displayed for each color. The color will be drawn only if the cell lies between the defined range. Users can set the colors and range though a dialog box.

It is important to note that colors are by far the weakest visual tool in terms of overlap. Colors can change dramatically when continuous data is overlapped. This not only confuses the users with identifying colors, but with a number of colors across different layers there is an increase in visual clutter. To address this, a linked highlighting mechanism was added to help deal with this problem.

6.4 Linked Highlighting

It is known that as the number of layers increases, visual understanding of the data diminishes. To alleviate this problem, this version of EwE has the ability to inform the user as to which layers are covering a given panel, by using the mouse to highlight the gray layers as shown in Figure 4. It is quite likely that users will be unsure of the data due to an increase in layers. An example of an unclear data set is the blue area on the bottom left of Figure 4. One cannot quickly tell which layer it belongs to, or what combination of colors definitively represents it.

However, using the linked highlighting tool, if the user wants to see what an area is comprised of in its individual parts, the user can hold down the Shift key and select multiple different layers making, them appear gray in the legend section. As soon as a user clicks on the any layer on the right, a bright red region is drawn on top of all images to tell the user the location of all the combination(s) of the selected regions. This will aid in helping the users pick the correct region for assigning MPAs.

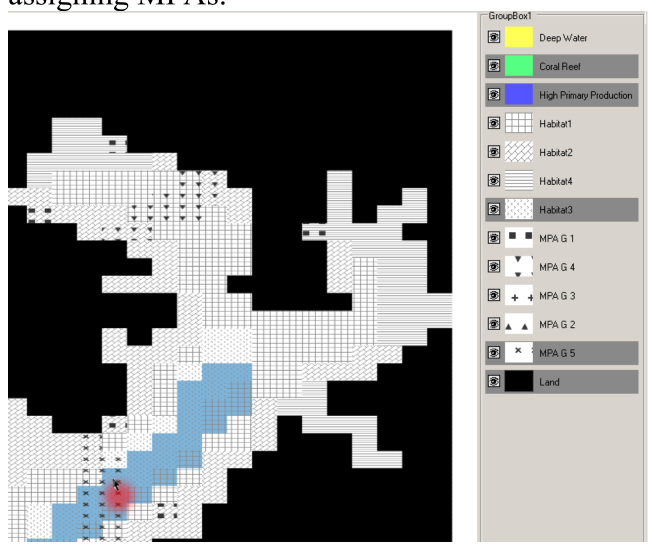

Figure 4 - Linked highlighting is shown here. When the user hovers his or her mouse over a cell as highlighted on the bottom left in red; all layers that exist in that cell location is highlighted in light gray. Here, Land, MPA G 5, Habitat 3, Coral Reef and High Primary Production.

6.5 Enforced ordering

The generally strict structure of representation used in this program requires a strict manner of enforcing order within layers. As such, there are a small number of layers between categories which does not require much ordering. On top of that, there is no significant need *across visual categories* (i.e. between glyphs and textures) to have strict ordering. In any case, the glyphs, patterns and colors were designed to have minimal interference with one another during overlapping. The tool has to strictly enforce grouping of the category because it reinforces the users perception of what an MPA should look like, or what to look for when searching for variance in habitats. The importance here lies in grouping each category together.

6.6 Show/Hide/Add/Remove/Edit Layers

As the techniques used above to aid in showing the maximum number of layers, there will still be diminishing returns as layers increase. The ability to show and hide layers aids in minimizing visual clutter. The user is able to only show pertinent layers that deals with the definition of MPAs. As the user clicks on the eye on the left side of the legend, the layer disappears, revealing only what the user wants/needs to see.

Similarly, the capability of adding, removing and editing layers is important. This functionality was built to cater to users who want an alternative manner for inputting values, changing colors, and selecting the range of the continuous data. One would do this by clicking the left image/glyph/pattern on the legend. This pops up a dialog box for users to tweak the layer accordingly.

6.7 Drawing MPA and Habitats

We include some HCI techniques here that are worth mentioning, as they make it easier for users to interact with this project's visualization. One has the option to draw on a region on the map that the user wants to paint. The user has to simply select the layer, and click and drag over regions he/she would like to modify. If the user starts by clicking down on an empty cell, the tool will add the selected region onto the map. If the user starts with a cell with a value, the tool will erase that cell and all other regions the mouse is dragged over.

7 Conclusion

This tool takes advantage of the data types required to find optimal locations for MPAs. Due to the nature of the EwE data categories, color, glyphs and patterns were used to represent this data in order to maximize visual overlap, salience and distinguishability across layers. In turn, this made it possible to increase the number of distinguishable layers of data in this visualization, relative to the old version EwE. The old EwE was able to easily distinguish between 5-7 separate layers; by contrast, this tool is able to increase the number of distinguishable layers to 10-12 as it effectively and successfully uses patterns, glyphs and color across multiple layers. Even there are certain issues that need to be addressed and functionality to be polished, on the whole this new system works significantly better than the old EwE.

8 Further work

Color seems to be the weakest link as it does not handle overlapping very well; this needs to be addressed in future work. Additionally, there are drawbacks to using habitats as textures because of visual similarity between textures; it seems that patterns, when all habitats are visible, create a uniform layer of visual noise over a the entire map region. Thus, when a user hides a layer, it seems arguably more salient than the other region. This phenomenon almost works against "showing" the preferred MPA region. The ratio of patterns to other elements of the visualization could perhaps be adjusted accordingly to reduce visual noise; this would require more research that is beyond the scope of this project. A proper HCI evaluation would be the next step to determine the success of this tool.

9 Implementation Details

I used Visual Studio to build this tool. A base mapping utility called SAUPUtil that was built mostly by Jeroen Steenbeek with myself prior to this class was used as well. This utility allowed me to draw layers of colors onto a map region. I extended the functionality of this utility to be able to draw patterns and glyphs on the region. This class was also extended by me to modify the map layers in a more efficient manner . Visual Studio brushes were used to draw the patterns. The glyphs, layer tool bar and all related interaction methods were implemented by me using Visual Studio.

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