Shared displays to support collaborative exploration of *Ocean Summits*

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Abstract

In group decision support systems, understanding the roles, dynamics and relationships between participants is imperative to streamlining the decision-making process. This is especially true when decision makers have varying interests. Research has shown that decision-making processes amongst groups with varying interests will often reach bottlenecks with issues, such as unwillingness to share information, or a limited ability of the participants to share ideas at the same time. We explored this research territory of group decision-making by implementing collaboration software to support *Ocean Summits*, a new approach that uses real-time simulations as part of the decision-making process for stakeholders to explore fisheries management policies. The research reported in this thesis has three goals: (1) to better understand the decision-making process in fisheries management, (2) to build a prototype system to tackle the major issues in the decision-making process and (3) to determine the best way to share and display information critical to the stakeholders' decision-making process by exploring the use of shared screens and information in comparison to private displays. We discovered that the use of shared screens with shared information yielded the best results, as opposed to private screens with shared information or private screens with private information. It was observed that sharing information allowed participants to explore more alternative solutions.

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Chapter 1

Introduction

There is strong scientific evidence indicating that global fish stocks are decreasing [43], and a public awareness that something needs to be done to address the problem [42]. There are too many stakeholders in the industry acting with conflicting self-interest for fisheries to become a sustainable resource. Stakeholders in the fishing industries are often interested in short-term gains. Coupled with advances in fishing technologies, such as better nets, bigger and more powerful boats, a public policy of unmanaged fishing could lead to the demise of entire ecosystems.

One possible solution would be for stakeholders and decision makers representing different parties with interests in the fishing industry to come to a consensus on how to better manage the fisheries for the benefit of all. This could be done in a collaborative process by examining different fishing policies and evaluating the benefits and tradeoffs for each stakeholder.

By using modeling software to explore the effects of proposed policies, it would be possible to provide nearly instantaneous results for policy makers to analyze and weigh when they consider policy choices we here referred to as Environmental Group Decision Support System (GDSS) [12] [48]. This would be much faster than traditional methods such as analysts' reports. There are many systems in existence that facilitate the goal of assisting stakeholders in making more informed decisions in groups. Fisheries science groups have relied on many different modeling software programs that utilize varying techniques to present data to the experts that use them. However, these systems often lack the capacity for collaborative input, or do not provide feedback quickly enough to support policy discussions.

As a step toward reaching a consensus among stakeholders with conflicting interests, different investments and diverging goals, we have at the UBC Fisheries Centre built a system where stakeholders can put forth their issues and explore different scenarios while having access to a real-time computer simulator. This approach is called *Ocean Summit*. It marries a scientifically validated fisheries simulation software package (Ecopath with Ecosim) with an easy-to-use custom-designed interface to enable fisheries stakeholders to collaborate and explore scenarios that best fit all their individual needs.

This thesis evaluates the utility of the custom-designed interface to support *Ocean Summits*. We employ a lightweight methodology to evaluate various aspects of this interface and its effectiveness in facilitating fishing policy decisions with the participation of collaborating stakeholders. Our evaluation focuses on two aspects: (i) displaying of the results of real-time simulations on private and public screens, and (ii) sharing of information among the stakeholders directly affected, or among all stakeholders. We conducted a controlled experiment to test our hypothesis that *sharing* the results of simulations among all stakeholders on a *public* screen would improve the decision-making process.

The remainder of this thesis is organized in 5 Chapters. Chapter 2 presents relevant background information on fisheries, fishing policy models and group decision-making. Chapter 3 introduces the approach of *Ocean Summits* and how these summits are proposed to be developed. Chapter 4 presents a software system called *EcoManager* that couples existing technologies described in the previous Chapter to build a lightweight prototyping system that enables scholars to conduct and formally evaluate an *Ocean Summit*. Chapter 5 is a formal evaluation of the use of shared displays during a summit. We conclude the thesis in Chapter 6 and discuss areas of future work.

Chapter 2

Background research

This chapter outlines the fields of study on which the thesis focuses. It summarizes the current state of fisheries research, then moves on to Decision Support Systems, more specifically Group Decision Support Systems, and related issues, technologies and implications. After that, we describe Environmental Decision Support Systems (EDSS). We then propose the notion of an Environmental Group Decision Support System (EGDSS), which is an EDSS that facilitates groups interactions, as seen in Figure 2.1.

2.1 Fisheries

This section summarizes the current state of the art in fisheries management, followed by identification of several issues with traditional and modern management tools. We explore some examples of how these tools are used in collaborative management environments.

2.1.1 Current state of fisheries

Yields for worldwide marine fisheries peaked in the 1980s [45]. Since then, many studies have illustrated the effects of overfishing on marine biodiversity [20] [66] [43] [44] [45] [42] [46]. There is now a broad consensus that fisheries must be better managed.

Fishing down marine food webs

The concept *fishing down marine food webs* was popularized by Pauly et al. in *Science* [43]. The study shows that in the last half-century, global fisheries landings (fish caught and brought to land to be sold) have shifted from large piscivorous (predatory, high on the food chain) fishes toward planktivorous fishes (plankton feeding, lower on the food chain) and invertebrates (shrimps, jellyfishes, etc.).

A good example of this phenomenon is demonstrated by the decline of North Atlantic cod stocks on the east coast of Canada in the 1990s. Up until

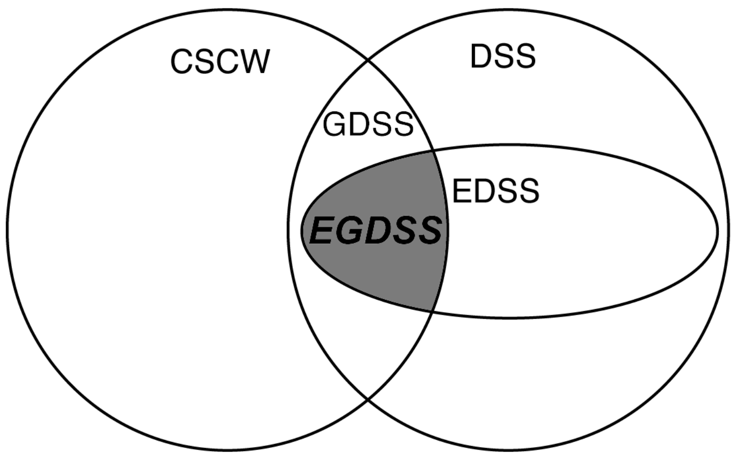

Figure 2.1: Proposed focus of our research study under Environmental Group Decision Support System (EGDSS), which is an Environmental Decision Support System (EDSS) that facilitates group interactions. It is the intersection of the two larger fields Computer Supported Collaborative Work (CSCW) and Decision Support Systems (DSS).

that time, cod stocks were abundant and the fishing industry was thriving. However, due to overfishing, cod stocks today are commercially extinct and shrimp have become the focus of the fishing in that area [38].

From a commercial perspective, *fishing down marine food webs* may be desirable to some extent. The fishing down of slower-reproducing, longer-lived species such as cod, will result in the survival of its prey such as shrimp, which has a significantly faster reproduction rate. The higher reproduction rate means the species can grow faster, resulting in more fish to catch, and ultimately in having more food on the table. In some cases, the faster reproducing, lower trophic-level species are more valuable than the species on which fisheries previously relied [28]. On the other hand, it may be undesirable to completely eliminate the higher trophic-level stocks such as cod.

Single-species fisheries management

The shift from the cod industry to the shrimp industry occurred under a single-species management vision, which focused on the trends of specific, targeted species while ignoring broader ecosystem effects [63]. Traditional single species management looks chiefly at the health of the species overall, mean productivity, and the abundance of a *single species* [63], ignoring interactions with other species in the ecosystem.

In the case of cod in the Canadian North Atlantic, mistaken over-optimistic catch quotas (a result of the parameters set in single-species models that only considered cod), coupled with over exploitation due to political pressure, led to a disastrous collapse in cod stocks [62]. Even the greatest efforts to replenish cod stocks in the North Atlantic have since failed [28]. The indirect costs of such failed management can be substantial. For example, 90% of all white marlins (a very desirable recreational game fish) in the region die as by-catches in the swordfish and tuna industry. Such side effects threaten the future viability of what is currently a $2 billion dollar recreational fishing industry[16].

2.1.2 Ecosystem-based fishery management (EBFM)

Ecosystem-based fishery management (EBFM) is an evolving new direction in fishery management that assesses multi-species in an ecosystem to evaluate management policies. Traditional single-species fisheries management does not take into account the complexities of the population dynamics in an ecosystem. The widespread application of single-species policies may therefore be at risk of causing a deterioration of ecosystem structure [61]. Many advisory panels such as the *Pacific Fisheries Resource Conservation Council* suggest a more holistic multi-species management approach using ecosystem-based fishery management (EBFM) [47].

As the future of fisheries management moves towards ecosystem-based management, it is important to develop appropriate ecosystem modeling tools for evaluating scenarios and trade-offs as part of management decisions [5]. These tools can be used in conjunction with traditional single-species fisheries management strategies [63].

Ecopath with Ecosim

One of the pioneering papers on ecosystem modeling was published in *Science* by Odum in 1969 [37]. Today, one of the most widely used modeling tools is *Ecopath with Ecosim* (EwE). More than half of all publications on fisheries related to ecosystem modeling are based on Ecopath [6]. A major reason for the success of EwE is its simple graphical user interface. The software is, however, developed for use by scientists. It has a steep learning curve, making it inaccessible to the public or other stakeholders.

2.1.3 EBFM in fisheries involving stakeholders

EBFM may be the best tool to assist in the management of fisheries but, unfortunately, most EBFM tools are used for research, rather than assisting the actual stakeholders that make decisions in the fishing industry. There have been various attempts to demonstrate EBFM's potential to stakeholders, but without much success or impact on overall outcomes as EBFM falls short in addressing the needs of stakeholders with different interest. Below describes theories addressing this issue.

Using an EBFM tool along with traditional single species assessments, stakeholders can establish a more holistic approach in the decision-making process. These efforts attempt to tie stakeholders and science together, unfortunately, none of the efforts utilizes an EBFM approach. Without the use of an EBFM tool with multi-species analysis, stakeholders may find their efforts will not amount to sustainable fishing policies, as seen for cod in the Canadian North Atlantic. The major hurdle with implementing EBFM in conjunction with ecosystem management is that it requires yet another dimension to the analysis of decision-making. Instead of stakeholders evaluating a single species and deciding how to best fish the stock, they must consider the dynamics of multiple species. This causes a dramatic increase in complexity, to say nothing of the fact that each stakeholder has different levels of knowledge with regards to each species.

2.1.4 Involving stakeholders

In all areas of decision making, the *analytic hierarchy process* (AHP) can assist stakeholders in identifying their priorities to relevant objectives, criteria and management options in hope of reaching more sustainable and responsible fisheries policies [58]. This process identifies the various priorities of stakeholders and how decision-making elements are interrelated. The first step is to produce a decision tree describing the interrelated decision elements, e.g. conserving biodiversity and ecosystem, and emphasizing food security (maximizing the amount of food). The second step is to rank these decisions using pair-wise comparisons done by each stakeholder, e.g. each stakeholder will have to determine if conservation of shrimp is more important that employment. The third step is to compute relative weights for the decisions made at the second step for each stakeholder to determine the most crucial objectives, criteria and management options.

Examples of EBFM implementations

Mikalsen [34] has done a thorough analysis of the differences between major classes of stakeholders in the fishing industry. Based on this, he classified fisheries stakeholders based on three attributes: *legitimacy*, *power* and *urgency*. *Definitive* stakeholders are groups/individuals whose demands and needs managers must consider, in order for the stakeholder to survive. This group possesses all three of the above attributes. These would be people with direct reliance on the fishery such as fishers, fish-processors, etc. *Expectant* stakeholders are those who possess two of the three attributes. This group will expect some form of representation or participation in the decision-making process, or possibly have high urgency and legitimacy, but does not have the power to enforce their stake in the group decision-making process. An example of this would be local communities with high legitimacy in the decision process because the decisions have direct impacts on the communities, but low power because communities lack the ability to address the issue and they have medium urgency because the decision may not have a large effect. The last category, *latent* stakeholders, are those who have only one of the attributes. These may be groups with power but no urgency or legitimacy to enforce their power in the decision-making process, e.g. future generations with high legitimacy but low power and urgency. An illustration

Stakeholders	Urgency	Power	Legitimacy
Definitive			
Fishers	High	High	High
Fish-processors	High	High	High
Bureaucrats	High	High	High
Enforcement agencies	High	High	High
Scientist	High	High	High
Fish workers	High	Medium	High
Expectant			
Indigenous peoples	High	Increasing	High
Environmental groups	Increasing	Increasing	Increasing
Local communities	Medium	Low	High
Latent			
Citizens	Increasing	Low	Increasing
The media	Increasing	Increasing	Low
Municipal authorities	Increasing	Medium	Increasing
Future generations	Low	Low	High
Banks	Low	High	Low
Consumers	Low	Low	Increasing
Equipment suppliers	Low	High	Medium
Tourist industries	Low	Medium	Low
Sports fishers	Low	Low	Increasing

Table 2.1: Fisheries management stakeholders in Norway as described by Mikalsen using a three-attribute taxonomy [34].

of this concept for Norway can be seen in Table 2.1. The specifics of this table could differ greatly between regions and countries.

Cooke applied simple survey techniques to decision makers, and synthesized a high-level overview of stakeholders and their interests in different regions of the Fijian fishing grounds [9]. Cooke showed that simple and rapid survey techniques could provide a rough guideline to stakeholder interests for future projects regarding management, policies and strategies.

Walters et al. [60] conducted workshops in 1985 on behalf of the Canadian government to expose commercial fishermen to some of the management principles and difficulties faced by government biologists. They implemented a simple simulation computer game where fishermen managed a salmon population. Several dozen fishermen played the simulator, Walters never saw a single instance where a player deliberately chose to take a quick killing and get out. The fishermen all adopted what was described as a sustainable approach ([60] pp. 15-17 and pp. 52-59).

Despite the effectiveness of the aforementioned approaches, none of them adequately implement EBFM by involving stakeholders to the degree described by Mikalsen. Furthermore, none of the approaches address the social implications on the dynamics of these stakeholders as a groups, especially those social phenomena that hinder the potential of utilizing EBFM in group activities.

2.2 Group Decision Support System (GDSS)

This section describes the two major research fields of Group Decision Support Systems (GDSS) and Computer Supported Collaborative Work (CSCW), and then provides greater detail on the components, issues and theories of GDSS.

2.2.1 Computer Supported Collaborative Work (CSCW)

Existing EBFM methods are inadequate to support fisheries management, as they lack stakeholder involvement and the high dimensionality of parameters required by modern fisheries management policies. However, there are other techniques in the area of *Computer Supported Collaborative Work* (CSCW) worth exploring. CSCW is a 'catch all' concept that is primarily concerned with the dynamics and interactions of people, computers, and their cooperative usage [32]. McGrath has described the major tasks of CSCW as shown in Figure 2.2. This depicts the different types of CSCW systems as they vary across different levels of cooperation and conceptualization. This thesis is interested in the *Group Decision Support System* (GDSS) aspects of CSCW.

A typical example where CSCW can be applied is in the generation of ideas via *MSN messenger* [33] where a computer system facilitates the remote collaboration of two or more individuals.

2.2.2 Group Decision Support System (GDSS)

Group Decision Support System (GDSS) is a major aspect of CSCW, but it is important to note that most GDSS work does not share all of the concerns evident in the CSCW community. A typical example of *brainstorming* [40],

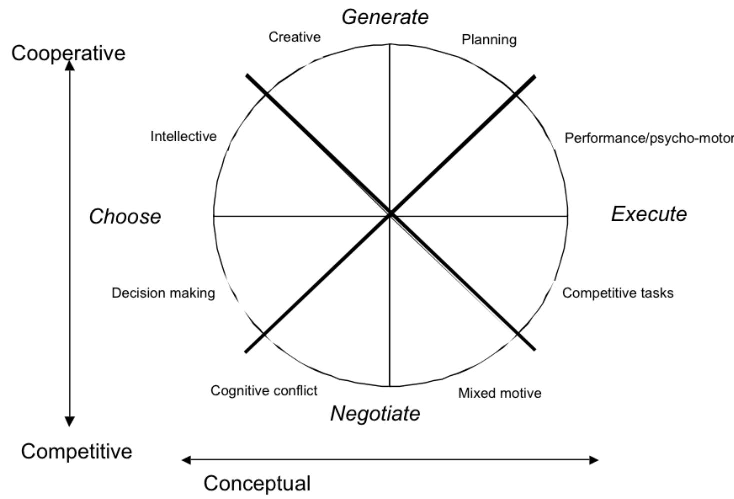

Figure 2.2: Taxonomy of a group interactions by McGrath 1984 [32]. McGrath classified group interactions to fall between the two extremes of cooperation and conceptualization. EGDSS falls on the very left-most quadrant of the circle.

where groups verbally express ideas to a 'note taker' and the note taker writes these ideas down on individual note cards. This process is linear where the note taker has to write an idea down one after another. A GDSS could increase the flow of ideas by supplying all group members a note card so all members of the group can write down their ideas in parallel.

GDSS is interested in interactive computer-based systems that facilitate the solution of unstructured problems by having a set of decision makers work together as a group [12]. GDSS research tends to be extensions of ideas presented in Decision Support Systems (DSS), which focuses chiefly on organizational practices [64]. There are various types of GDSS systems that vary on member proximity and group size as seen in Figure 2.3, as described by DeSanctis [13].

2.2.3 Design and implementation issues of GDSS

There are three implications from group dynamics as listed by DeSanctis [12]:

1. Encouraging active participation of all group members is critical in GDSS.

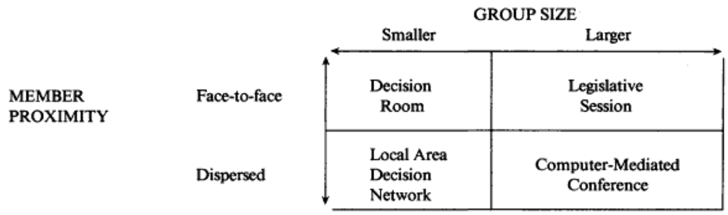

Figure 2.3: Taxonomy of GDSS, following DeSanctis [13].

2. Special accommodations are needed for groups who have no prior experience working together; newly formed groups lack the social dynamics because they are uncertain about their social and group expectations.

3. Selection of group members for specific group decisions will be important to reach harmonious group dynamics.

Without addressing all three issues, the group dynamics will be hindered, putting further strain on GDSS system.

2.2.4 Components of GDSS

DeSanctis [13] highlights four components of GDSS, *hardware*, *software*, *procedure/process* and *people*.

Hardware

For the *hardware* component, each participant in group has to have access to an input device, and a display for viewing information either as a group member or as an individual. Nunamaker [36] observed that the ability to display individual screens on a shared screen is important. The use of multiple shared screens will increase productivity by enhancing communication and the sharing of information. Nunamaker further states that to better utilize shared screens, they should be used to follow the activities of issue consolidation, rank ordering, etc.

Software

The *software* component includes a database, as well as a specialized application program and a flexible user interface. The database stores information in a centralized manner to facilitate coordination of inputs from individuals [36]. The interface then synchronize the user inputs/outputs with the database.

Procedure/process

The *procedure*, often known as *process*, is the methodology that the people are using in order to define how they are going to do things. The process may apply only to operating the hardware and software, or it may be used as the rules for discussion and flow of events during the session.

People

The last component is the *people*, the group members and the ‘group facilitator’ who is responsible for the operation of the GDSS. When a GDSS is first used, the group may be quite reliant on the facilitator who may take an active role in coordinating the group’s activities. Later in a session, the facilitator may take a ‘chauffeur’ role as the facilitator’s responsibilities diminish, and the group gets more familiar with the system.

2.2.5 Social theories of GDSS

In any form of group activity, computer-supported or not, there will be social and psychological theories that apply.

Production losses

The three key rationales described by Kraut [26] that cause productivity losses are *social loafing*, *production blocking* and *social pressure*. *Social loafing* is the phenomenon whereby individuals typically work less hard when they are part of a group than when they work on their own; this occurs when participants believe the outcomes of their efforts are being pooled with the efforts of other group members. It is a well-studied phenomenon and varies depending on the task and the nature of the group [8] [18] [24]. We all see these phenomenon in larger group meetings where some individuals participate less than to their fullest potential. *Production blocking* is the phenomenon whereby two people cannot talk simultaneously without drowning out or interrupting each other, thus leading to productivity losses. *Social pressure* is a phenomenon whereby participants might limit their willingness to contribute ideas because of evaluation apprehension - an individual fears others might think badly of him or her. This is especially true for people who offer minority points of view or controversial ideas [2].

Level of information: mixed-scanning

Ecosystem modeling might be perceived as overwhelming due to the vast number of input and output parameters. Presenting decision makers with all the information about the model would give them the highest degree of control, but absorbing this information might overload the decision maker, or might take too much time, as noted by Etzioni [15]. Thus, Etzioni suggests *mixed-scanning* which is a hybrid of the two levels of information, combining the *rationalistic approach* and the *incrementalist approach*.

The *Rationalistic approach* is where decision makers are presented with *all* the alternatives and consequences. The limitation of this approach is that it is infeasible to present all alternatives of a complex decision. Decision makers tend to "face [an] open system of variables in a world in which all consequences cannot be surveyed" [29]. This means that not all consequences have been predetermined, but are incorporated into the process as they are conceptualized. The vast number of variables to formalize in the system increases frustration, and exhaustion will likely overwhelm the group before a decision has been made, making rationalistic approaches infeasible.

Lindblom found the *Incrementalist approach* tends to narrow decision-making strategies to the limited cognitive capacities of decision makers [30]. The incrementalist approach focuses on a continually redefined set of policies that differ incrementally from existing policies, with a relatively small number of alternatives, each having their own limited number of 'important' consequences, and no one 'right' decision.

The incrementalist approach has its limitations. It tends to be skewed towards the interest of the most powerful participant, because needs of the underprivileged are underrepresented [15]. Incrementalism tends to focus on short term goals with minimal change, potentially leading towards circular policies that maintain the status quo.

Etzioni's proposal of *mixed-scanning* includes elements of both approaches, presenting all of the information and alternatives but in a high-level summarized format. For example, in a weather observation system, a rationalistic approach would present all the weather cameras to the user. The incrementalist approach on the other hand, would simply focus on areas with similar weather patterns in the past, and from this predicts the weather for the entire region. Mixed-scanning would provide a combination, both approaches, showing a summary using the incrementalist approval at the same time be-

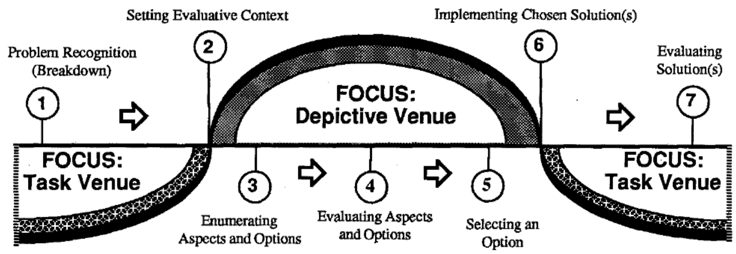

Figure 2.4: The decision-making/Problem Solving Cycle as described by Whitaker [65].

ing able to query detailed rationalistic approaches. While mixed-scanning may miss some areas that only views that all of the detailed weather cameras may catch, it is less likely to miss the more obvious spots.

Decision-making cycle

Whitaker argues that most decisions made by humans involve a decision-making/ problem-solving cycle as shown in Figure 2.4 [65]. A decision is usually defined as a selection from a finite set of alternatives. This is different from problem-solving where the group discovers, formulates or generates means to rectify a given problem. The first phase (steps 1 and 2) is recognizing the problem. The first goal (1) is breaking down the problem and finding the problem space. The second phase (steps 3 to 5) involves extracting a set of options, elaborating on them and finally selecting one. The resulting action leads to the third phase where attention is drawn to a new problem arising from the implementation and evaluation of phase two decisions, closing the cycle in Figure 2.4.

Conflict management

With people working in groups, there will almost always be conflicts. Conflict management is therefore necessary but very complex and multidimensional. Productive conflicts are conflicts where all groups are satisfied with the resolution. The most productive conflicts are ones that probably have optimal results. Productivity in conflict management can be measured by the amount of change in position during discussion. Conflict management is based on several behaviors: *distributive*, *avoidance*, and *integrative*, as noted by Sillars [57]. *Distributive* behaviors are when parties pursue their own best interest regardless of other's needs or interests. *Avoidance* behavior is when parties seek to flee or dampen the conflict. *Integrative* behavior promotes constructive resolutions.

The classic paper that sums GDSS conflict management is by Poole [49]. This paper highlights seven different aspects of GDSS Conflict Management:

1. Computer interaction facilitates communication more so than face to face.

2. GDSS promotes written media over spoken communication as it is less likely that people will change their position if it is written down, possibly leading to a less integrative and more distributive behavior.

3. Systems may de-emphasize personal relations; systems that are less intimate and immediate than face to face, leading to desensitizing of personal relations, which could lead to a higher degree of change. GDSS is a highly salient communication channel which may distract members away from interpersonal conflicts and focus them on the task at hand.

4. GDSS equalizes member participation; if the group can work out an agreement, there is likely to be higher consensus and greater feeling of ownership.

5. GDSS makes processes and roles more transparent by preempting the key source of conflict: tension created by social uncertainty and disorganization. This leads to higher levels of consensus, more change and more interactive behavior.

6. Incorporating decision rules such as voting is known to serve as a disincentive to conflict management, lowering consensus and reducing change leading to higher levels of distributive behavior and even avoidance.

7. GDSS promotes brainstorming or defining solutions which gives participants a wider set of alternatives to consider for the group. The results are likely to be more creative than with traditional approaches, and more likely to satisfy the group's overall interests.

Facilitator

As DeSanctis describes, there is a need for a facilitator in the people component to aid and smooth the decision-making procedure. There are three major support modes in GDSS. The first is *user-driven,* where group members, after some training, can fully use the system as they wish (seen in Gallupe et al. [17] and Zigurs et al. [67]). The second would be *facilitator-driven*, where a non-group member directs the members as to what GDSS features to use and when to use them (shown in Dennis et al. 1988 and McCartt [31]). The least common of the three is the *chauffeur-driven* system where an individual who, at the direction of the group members, implements features of the GDSS system, but, Jarvenpaa et al. believes, does not assist the group with the process [21].

The intuition that *facilitator-driven* GDSS support is superior has been proven incorrect by Dickson et al. [14]. They evaluated the use of the three modes and found that chauffeur-driven support encourages the highest levels of participation and performance, perhaps because facilitated groups are uncomfortable with the imposition of too much structure in the decision process. During the user-driven model, participants continually stumbled over learning the system even after significant training.

Means of successful collaboration

Kanter has characterized the critical means of successful collaboration within groups by the theory of "8 I's to form We" [23].

- *Importance* - partners need to realize the significance of the possible impacts of the matter.
- *Individual excellence* - all partners are strong to ensure they equally contribute.
- *Interdependence* - Partners need each other as they complement each other's skills and assets.
- *Investment* - partners need to invest in each other to help their interdependence.
- *Information* - communication needs to be reasonably open as they share the objectives, goals, technical data, etc.
- *Integration* - partners develop links where they work together smoothly.
- *Institutionalization* - giving clear responsibilities and decisions processes will help insure task are done.
- *Integrity* - partners have to behave toward each other in honorable ways to gain trust.

Successful implementation

One example of a highly successful process that acknowledges the above mentioned social theories is the Aspen Institute Congressional Program. It is a process that arranges to have high-level decision makers, i.e. congressmen, meet in a non-partican open environment to discuss ideas on specific topics there. Herein referred to as *summits*. Aspen Institute Congressional Program constructed a list of strict rules that is enforced throughout the summits [41].

- **Policy neutral** - A non-partisan approach is essential to minimize the social pressure bias towards any group or legislation. Summits are designed as a bonding experience to break down partisan barriers and to harvest unconstrained discussion that does not lead to predetermined outcomes. The summit developers go to great lengths to ensure this rule is enforced.

- **"What happens in the room stays in the room"** - Due to its neutrality and promotion of discussions, participants are not restricted by worrying what the media or other parties might say. This is known as *Chatham House Rules*. A safe heaven for intellectual discussion is enforced by limiting what is discussed to stay within the room. This is enforced throughout the summit and participants may have to sign a non-disclosure agreement because some information may be confidential.

- **Detach participants from representation** - No participant is identified with a political party, viewpoint or endorsement of specific legislation. This is required in order to ensure un-biased discussions because no single participant will be linked with any pre-conceived views. This has to be made clear from the very start of the summit, and enforced throughout.

- **Participation limited to representatives** - Enforcement of participation is critical, yet challenging. The summits do not allow lobbyists, biased viewpoints, or outside observers as they may skew discussions. On the other hand, with this regulation, not all viewpoints may be heard. It can be beneficial to select a set of participants with equal power to minimize the risk of one overwhelming another.

- **Do "homework" ahead of time** - Strict rules require all participants to do their preparation before attending the summits ensuring no single participant will slow the group down. The homework will be as straight forward as possible doing away with long tedious reports. Punishment can be enforced for not doing so such as sole sessions to catch up, or even revoked invitation.

- **Knowledgeable facilitator** - A facilitator that guides the flow of discussion and allows for carefully choreographed discussion is key to a successful summit. This facilitator will be required to understand all aspects of the summits and facilitate the dynamics of the groups. The facilitator will play a 'chauffeur' role to allow participants to experience the decision-making cycle, at the same time reducing conflicts by enforcing a set structured medium used to expressing ideas.
- **Free time and group activities** - Promote group dynamics by scheduling free time enables a more relaxed atmosphere for group discussions. Activities include team building exercises and time to chat with other participants. Experts are on standby during these times to facilitate any questions that may arise.
- **Bringing spouses** - the 'secrete weapon' of the Aspen Institute Congressional Program, where the program arranges for spouses (significant others) to come along to promote attendance and allow a more relaxed atmosphere. They join the activities during free time.

2.2.6 GDSS implementations

Another component of a GDSS is the hardware. The ability to show the content of individual workstations screens on a shared large screen projector is important for group work in CSCW [36]. Large shared displays have the ability to increase collaboration by increasing the amount of information displayed without introducing unwanted interactions, as compared to regular desktop monitors [3]. Large shared displays also increase mutual awareness of group activity [19].

Collaborative team rooms

It is critical to carefully design rooms that reflect these findings in the architecture of collaborative team rooms. Nunamaker summarizes different GDSS below [36].

- *Minnesota GDSS (SAMM)* described mixes private and public screens, and has the private screen powered by individual computers facing the public screen.

- *Claremont system* provides capabilities for information sharing, creating ideas and making choices, and uses a touch screen that requires almost no learning time from users.
- *COLAB* used two tools, the first of which was Cognoter, which supported brainstorming, organizing and evaluation, enabling group members to outline the task confronting them. COLAB's second system, Argnoter, is a spreadsheet augmentation tool that displays actions from group members and permits them to be evaluated amongst those of, other participants. Both use individual computers with group consensus displayed on a shared liveboard.
- *Microelectronics and Computer Technology Corporation (MCC)* did theoretical work analyzing computers such as personal computers, private displays group work surfaces, software for communication, communication sub-channels, and obtaining meeting statistics. An iterative method of feedback modification was used to refine the development of the technology.
- *Electronic Data System Corporation* created the *Capture Lab* which was an oval conference table with 10 desktop computers and electronic blackboard. These systems were designed to study the various psychological effects of different seating arrangements and personal management styles of executives.
- *PLEXSYS* created by the *University of Arizona*, which operated large groups of 90 or more. PLEXSYS consists of individual stations with personal computers and complement of audio visual and telecommunications equipment that allows group members to contribute ideas, set priorities, resolve differences and reach conclusions.

2.3 Environmental Decision Support System (EDSS)

In the previous section, we talked about a group of decision support systems and the theory behind them. In this section, we present decision support systems which focus specifically on the environment, called Environmental Decision Support Systems (EDSS). Poch et al. defined EDSS as any decision support system that advances the awareness of sustainability issues [48].

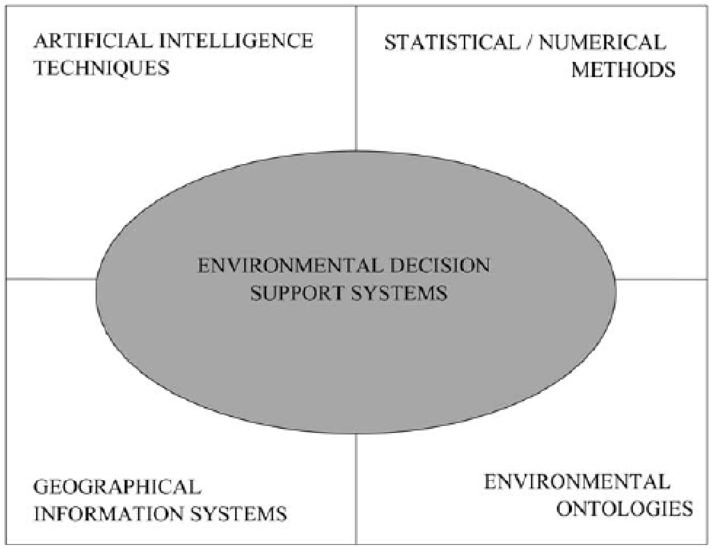

Figure 2.5: EDSS conceptual components - several methodologies from Poch [48].

EGDSS differs from GDSS that discussions take place within the system, whereas many GDSS simply support discussions as intermediaries to the humans. Poch states that EDSS are among the best approaches to tackling the complexities of environmental problems. It is a growing field with numerous publications relating to building better systems [1] [10] [11] [50] [52].

Many tools arguably fall into the category of EDSS. Poch et al. classify the different types of EDSS as artificial intelligence programs, statistical/numerical methods, geographical information systems, and environmental ontologies as shown in Figure 2.5. Popular EDSS systems are *ArcGIS*, a 'power tool' that has capabilities for geo-statisitical/spatial analysis [22]. This flexible system enables users to explore seemingly infinite possibilities if used in a correct manner. *CommunityViz* [27] is a land-use planning tool that calculates economic, environmental, social and visual impacts and indicators, as users explore alternatives. *Environment Explorer* [56] is another specialized tool that evaluates the effects on social, economical and ecological indicators in the Netherlands. *Ecopath with Ecosim* (EwE) [5] is a fishery-based ecosystem modeling tool that evaluates economic, environmental and social impacts of policies.

Unfortunately all of these systems cater only to single users in front of a computer display. This limitation allows for a limited audience even when a shared display is used, which hinders the goal of advancing awareness of sustainability issues to a broader audience.

2.4 Environmental Group Decision Support System (EGDSS)

The obvious next step to maximizing awareness of sustainability issues is to facilitate groups using EDSS. We propose the term Environmental Group Decision Support System (EGDSS), which is to be any system that aids advancing the awareness of sustainability issues for two or more individuals. EGDSS systems can range from simple sharing of an EDSS, where the group sits around a screen while one user drives the software, to more complex systems where the system facilitates the social dynamics in the groups (Section 2.2.2) while advancing the awareness of sustainability issues. Many authors, notably Kinzig [25] and Poch [48], note that EDSS in general have not been considered group interactions; the majority of them are designed for individuals in front of a computers.

2.4.1 Examples of EGDSS

Listed below are brief descriptions of known implementations that converge with the group aspect of EGDSS.

Water balance model

Cliburn [7] describes an EGDSS that allow decision-makers and their staff to explore the findings of water balance models, along with uncertainties in the model, to understand the potential impacts of public policy. The hardware for the room is a 25x6 foot curved wall that accommodates ten or more people looking in the direction of the wall as shown in Figure 2.6. The software uses three dimensional graphs that have cell locations on the x and y axis, with magnitude on the z axis. How interactions between people and the procedures used were, for the most part, unexplained in the description [7] in Figure 2.6.

Landscape Immersion Laboratory

There have been notable developments in the recent years such as in the Landscape Immersion Laboratory at the University of British Columbia,

Figure 2.6: An EDSS on a large shared display that aids policy makers in exploring a water balance model, at the University of Kansas [7].

which uses virtual representations of landscapes to allow users to 'visualize' potential impacts of decisions about forest management policies before they are implemented. These virtual landscapes are projected on three wall-size screens stitched together. This system aims to aid participants using 3D graphical representations of landscapes to advance people's awareness of sustainability issues, such as climate change, and their affects on the landscape with the expectation that this may alter behavior and policy in (Figure 2.7 [53]). Under controlled lab-testing, Sheppard from the Landscape Immersion Laboratory found that perceptions of alternative sustainable futures represented by landscape visualization triggers cognitive/attitudinal/behavioral change on sustainability policy and lifestyle choice for representative stakeholders [54] [55].

CIRS Decision theatre

A second generation of the Landscape Immersion Laboratory, is in the planning process and will be part of the Center for Environmental Research and Sustainability (CIRS). The new facility will accomodate up to 100 people, each with access to a touch screen/sensitive LCD panel. A shared large theater style screen with 3D simulation environment will be available to all participants. Figure 2.8 shows a conceptualization of the Decision Theatre. Using this, 'what if' scenarios can be played and visualized in this system, such as being able to see ones neighborhood in the year 2050, or see what

Figure 2.7: Landscape Immersion Laboratory at the University of British Columbia that provides virtual representations of landscapes.

ones grandchild might see in the same place in 2100. This visualizations is initiated to let participants 'see' implications of policy decisions similar to how the Landscape Immersion Lab does, but to larger audiences and with more engagement.

Arizona State University*: *Decision Theater

Arizona State University (ASU) has created a facility that aims to bring policy makers and decision makers together to address challenging problems in a unique visualization environment. Based on the theory that visualiza-

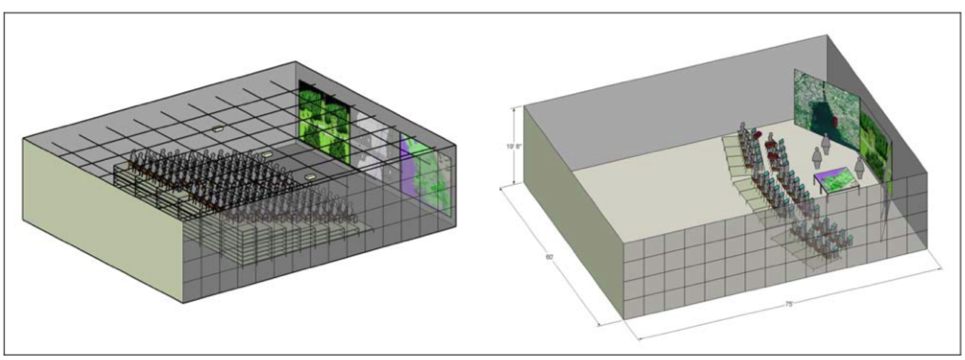

Figure 2.8: CIRS decision theater.

Figure 2.9: ASU's decision theater.

tions triggers changes on ideas about policy, as described in Section 2.4.1, ASU built the decision theater shown in Figure 2.9. This theater has been used to target issues such as the West Nile Virus propagation, unified school districts, chemical measurements, weather simulations, Afghanistan aerials, housing prices, and imagery of the planet Mars.

The Decision Theater caters to group interaction dynamics by having seats that rotate and move within the room. Breakout rooms have been installed to promote more interaction. To date, the group dynamics of the system is still largely unassessed.

QUEST: Interactive science in the Georgia basin

QUEST is a computer-based system for scenario generation and evaluation that is designed for public participation considering sustainability [51]. For larger groups, users sits with a voting controller in a movie theater-style environment. The system addresses various aspects of group dynamics, e.g. allowing anonymous decisions to be made, thus minimizing social pressure seen in Section 2.2.5.

2.5 Wrapping up

The emergence of EGDSS is harnessing the benefits of GDSS with an environmental twist often coupled with visualization components and the simulation power of an EDSS. This thesis will focus on providing a richer GDSS component of existing EDSS. The growth of environmental sustainability awareness will promote EGDSS applications that play a bigger role in decision-making; multiple parties with different stakes will be involved in the decision-making process. With luck, the EGDSS will bring a new set of tools that will aid decision makers to visualize the future.

Chapter 3

Ocean Summits: the future of fisheries management

Ocean Summits is an EGDSS approach that facilitates stakeholders with conflicting interests, different investments and diverging goals, to put forth their issues and explore different scenarios with the aid of a real-time simulator. It is a type of decision room that has a small group size with face-to-face member proximity (see Figure 2.3). In this chapter, we introduce the approach and goals of *Ocean Summits*, then we describe the system by its GDSS components, *hardware*, *software*, *procedure/process* and *people* . Then, in the next chapter, we describe flexible prototyping software used to evaluate certain aspects of *Ocean Summit* approach.

3.1 Introduction

The initial proposition of *Ocean Summits*, made by Villy Christensen and Daniel Pauly, is to hold workshops for high-level decision makers (i.e., CEOs of a fishing companies, governmental ministers and representation of Non-Governmental Organizations (NGO)) for a targeted fishing region. This activity is sponsored by the Lenfest Ocean Futures Project (LOFP). The objective is to develop a simple, integrated, non-computer-like environment, similar to a game interface, to cater to non-expert users. A 3D fish visualization is planned to add an emotional connection between participants and the problem domain. The concept will be under development from 2008 and 2009, with the first actual summit in 2010.

3.2 Goals

The high-level goal of *Ocean Summits* as developed by the *Lenfest Ocean Futures Project* is to construct an approach to evaluating scenarios for sustainable management of fisheries and ecosystems. To influence the fisheries management process, particularly where it involves high-level decision makers. This is done by supplying rich relevant information such as social, economic and ecological consequences for a range of scenarios. The specific goals for *Ocean Summits* are:

1. *Form a cooperative effort* - Alliances between companies are a fact of life in today's business world and are a key corporate asset, called *collaborative advantage* [23]. This same idea can be extended to stakeholders in *Ocean Summits*; there will be a bigger net gain if all parties collaborate.

2. *Educate the participants* - The ability to understand the benefits and tradeoffs of various policies will be invaluable to decision-making processes during the summits, and in the long run. Participants will better understand the repercussions of their decisions. This relates to the parable of teaching someone how to fish instead of doing the fishing for them.

3. *Place all issues and concerns on the table* - In order to have a successful cooperation, all stakeholders have to drop their barriers and expose their issues and concerns. This will lead to better-informed decisions without leaving out any participants who have not shared their concerns.

4. *Attain a consensus on future plans of fisheries* - A plan in which all participants agree on how the fisheries are to be managed is the ultimate goal of *Ocean Summits*. Although it may be an ambitious goal, because stakeholders may not always reach a decision, a summit will strive for, but not enforce that stakeholders reach a mutually agreeable conclusion.

In order to attain these goals, *Ocean Summits* will closely follow the rules of the Aspen Institute Congressional Program (as outlined in Section 2.2.5) by providing a non-partisan safe and open haven for decision makers to discuss ideas without outside pressure or pretense.

Ocean Summit approach utilizes the components described below to provide feedback mechanisms for the stakeholders to evaluate different scenarios.

3.3 The participants

The aim of this program is to allow successful collaboration between all stakeholders in a given fishery. With hopes, this program will recruit the top decision makers in the focused area. Examples of these may be chief executive officers of fisheries companies, fisheries ministers or non-lobbying NGO's.

To maximize participation from these groups, *Ocean Summits* will use a similar process to the Aspen Institute Congressional Program, providing participants and their significant others with all expenses and organized events throughout the summit.

The representatives should be very carefully selected, as it is imperative to not allow partisan groups that might advocate only certain policies. A participant who is biased could potentially cause biases in the discussion. Further, the phenomena of social pressure (see Section 2.2.5) could cause an unbalanced discussion. Participants will be urged to attend with an open mind and be detached from representing any specific view. However, complete detachment is unlikely to be achieved as relationships are embedded into participant's subconsciousness.

There are numerous different types of stakeholders with different roles as seen in Table 2.1. Unfortunately, it is still too early in the project to know the specific stakeholders in *Ocean Summits*, but we will consider a few examples to exhibit the issues and interactions.

3.3.1 Commercial fisher

A commercial fisher is a stakeholder that has one or more fishing fleets who directly catch biomass (living organisms such as fish, clams, etc.) from the sea for profitable purposes. In general, commercial fishers are interested in profits, both in the short and long run. Fishers can range from single boat owners, to CEO's of large fishing fleets. They have direct impact on the ecosystem and have the capability for over harvesting and eradicating entire species in a region. Because commercial fishers often hold a number of jobs and funds in the industry, they can be very influential over other stakeholders.

3.3.2 Minister

A minister is an elected or appointed government official who is the governing body of the fisheries. This stakeholder is in charge of the well being of all stakeholders. Ministers have the ability to impose regulations such as catch quotas on fishers or taxes and subsidies for various stakeholders in the region. Ministers have a very powerful yet delicate role. If they allow fishers to operate as they please, they may deplete the fisheries resource too quickly, leaving nothing for other fishers or other stakeholders such as recreational fishers.

3.3.3 Non-Governmental Organization

A Non-Governmental Organization (NGO) is an organization that has no participation or representation in any government, but is interested in the design and implementation of fisheries related development-related projects, i.e. sustainable fishing methods, conservation endangered species or animal humanity. NGOs use methods such as sophisticated public relations to influence social and political outcomes, enabling them to be quite important in the system.

3.3.4 Recreational fishers

Recreational fishers are ones who catch fish for non-commercial purposes, i.e. for the challenge of finding and catching (keeping or releasing) fish rather than for the financial value of the fish. These stakeholders can greatly impact an ecosystem by removing a large portion of biomass from the sea. This industry associated with recreational fishers has potential for major financial opportunity, i.e. fishing tourist pay guides, rent boats, stay in hotels, etc. as discussed in Section 2.1.1. Recreational fishers are highly reliant on the abundance of certain game fishes in the region.

3.3.5 Ecotourist

Ecotourists are similar to recreational fishers in that they are highly reliant on the abundance of certain species, mainly marine mammals (orca whales, dolphins, stellar sealions). They are relatively passive on the environment as they only observe the environment and its wildlife.

3.3.6 First nations

First nations are groups that are native to the land with long-standing fishing traditions. A large part of their diet is made up of species harvested using traditional fishing techniques. If species valued by the this group have been eradicated by technologically advanced commercial fishers, these first nations will have little to sustain their diet.

3.3.7 Problematic dynamics of stakeholders

There are dynamic relations between the various stakeholders. If the fishers were to fish as profitably as possible, taking as much from the sea as possible, this could potentially have a variety of repercussions such as: 1) drive the price of the fish down, 2) leaves not many fishes left for the other commercial fishers, 3) endanger other species, distress NGOs, 4) leave not many fish left for recreational fishers on ecotourists, 5) with this many stakeholders unhappy, the minister too is unsatisfied because he/she may not get reelected.

Suppose a policy is adopted to stop all commercial fishing, the following consequences will happen: 1) the ecosystem biomass will regain itself in time, 2) NGOs is successful from a healthy stock, 3) recreational fishers and ecotourist have a booming industry, 4) fishers will be out of business losing a lot of jobs for the economy, 5) ministers run risk of not being reelected because of losses in jobs, low revenue from commercial taxes and loss of support from powerful fishing industries.

Arguably these relationships are quite obvious, but the precise impacts from one decision to another are largely unknown. We need a system that will allow participants to explore the tradeoffs.

3.4 Procedure

The procedure for *Ocean Summits* not yet completely determined. We present a high level overview of how summits may take place.

Three guests, Frank (Fisher), Mike (Minister) and Nancy (NGO) are stakeholders in a fisheries in potential risk of collapsing and causing detrimental effects to the industry. They are selected by the LOFP to ensure the fishery is overall well represented, of equal stature and a non-lobbying group. The three guests send representatives to verify the simulator and the output data to ensure scientific integrity. They are then sent a reading package, which contains pertinent information about the summit and the system. Included are rules mentioned in the Aspen Institute Congressional Program (see Section 2.2.5). At the same time, two flight tickets are sent to each participant and their spouse.

On the day of the summit, media will be buzzing as they enter the summit location. As soon as they enter the summit room location, they are separated from the outside world as the rules specifically, detachment from representation, separation from the outside world and policy neutral. A knowledgeable facilitator will introduce the summit goals and explain details.

The first task is to allow all participants to lay their issues out in the open. Nancy starts by expressing her concerns over the cruelty of seal hunting and proposes to minimize it. Frank expresses his concerns on depleted cod stocks. Mike is concerned with job losses associated with low cod catches. The facilitator directs them to run the simulator to see what has happened historically. The participants start modifying parameters such as increasing subsidies, or cutting back on seal hunting, then visualizing the impact of their decisions. They will see their profits decreasing, at the same time as the lack of 3D cod swimming around. This likely, has the potential to be a very powerful mean of communication.

This schedule of short intensive sessions is continued for some days as they work to reach a consensus on the state of the ecosystem. If a plan is not reached, they will hopefully at least have a very good idea for the benefits and trade-offs of the ecosystem by the direct feed back to the participants from the scientific visualization of the simulations.

3.5 Hardware

Coupled with the convergence of stakeholders, and the best available science and visualization to discuss any topic at hand, *Ocean Summit* requires infrastructure, called the *Immersion Lab*. The *Immersion Lab* was designed to accommodate up to ten stakeholders by Patkau Architects, MC^3 and the UBC Fisheries Centre, including the author. The design focuses on a collaboration of stakeholders with supplemental of technology, not on the technology itself. The hardware design of the room was built prior to the present study, and therefore this thesis is shaped by the hardware setup. Although the idea of *Ocean Summits* are developed with the UBC lab in mind, this approach is designed to be portable to allow summits to be held in different places around the world.

The *Immersion Lab* contains displays, computers, interaction devices, lights and seats.

3.6 Immersion lab

The location is a rectangular closed-off room with multiple monitor displays. Each participant has a seat, with an individual computer terminal. Each participant's terminal is blocked from the view of other participants, so they cannot see any other group member's monitor. The participants will be in

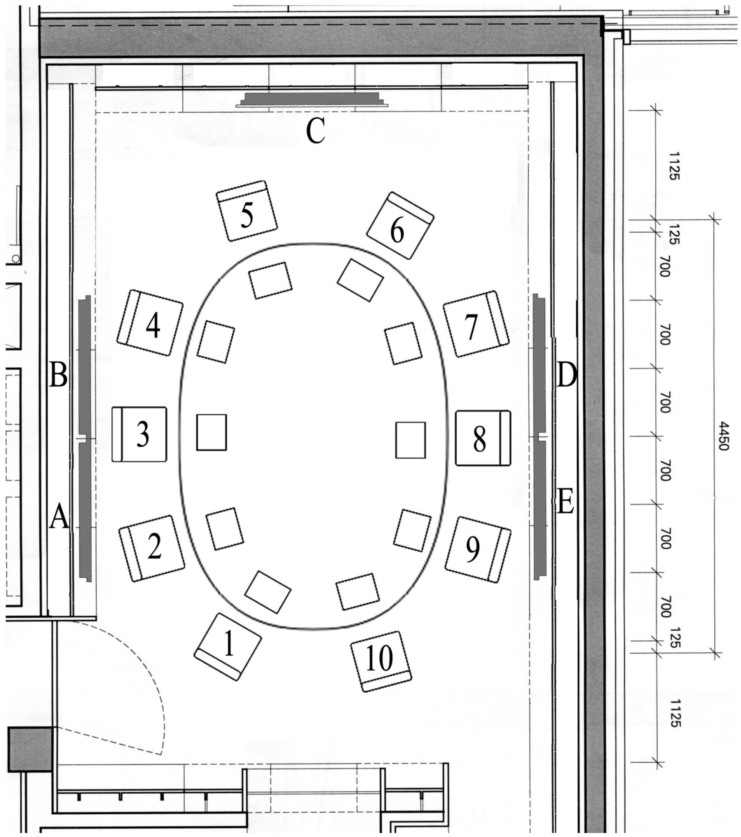

Figure 3.1: Floor diagram showing seating for ten participants with five monitors A-D along the left, top and right side of the diagram.

view of 5 large plasma screens located on three different walls in the room as seen on monitors A-E in Figure 3.1.

3.6.1 Displays

There are a total of 15 displays in the room. All of these connect back to a Cestron controller that enables any input to be displayed on any combination of monitors.

Large shared screens

There are 5 large plasma screens located throughout the room, each 60" with a native resolution of 1024x768. Plasma display (C) is used as a main

Figure 3.2: Wide angle (100 degrees) view from position 1 (see Figure 3.1). Notice the blockers set up to discourage glances of other's monitors. Only monitors C,D and E are visible in this photos, with A and B off to the left.

screen (see Section 2.2.4). It is located on the presenter's end and is lower than the others; lower edge is approximately four feet from the floor. The other four plasma displays are located on the side walls at four and a half feet from the floor. The largest viewing angle from one screen to the next is 180 degrees at seat locations three and eight as seen in Figure 3.1.

Private desktop monitors

There are ten evenly spaced monitors set into the super ellipse table as seen in Figure 3.2. Each monitor is 17", with 1024x768 resolution. Each monitor has a limited view of other monitors. For the research reported here, blockers were put up as a reminder not to peak at other's monitors.

3.6.2 Interaction devices

All 10 stations have a mouse and keyboard. These are located in keyboard trays that pull out from under the desk and control one of the 10 computers. The Cestron controller is able to switch all inputs from one computer to another. During the research reported here, only a mouse button was required for the participants. Three mice were set in front of each participant with tape on the movement sensor to disable movement. The facilitator has a

Computer type	*Num. of comps.*	*Description*
Participant	11	Two quad core 2.33 GHz, 4 Gb ram with 512 Mb video cards, 1Tb of HD raid 0
Graphics	1	Same as participants with two 765 Mb video cards, 1Tb of HD raid 1
Server	1	Two quad core 2.66 GHz, 8 Gb of ram, 1Tb of HD raid 1
Database	1	Single quad core 2.66 GHZ, 8 Gb of ram, 756 Gb of HD raid 1

Table 3.1: List of computers available in the Immersion lab.

mouse and a keyboard.

3.6.3 Computers

The immersion lab has a cluster of computers available as seen in Table 3.1. For the research study, only one of the were outfitted with three video cards, each with two VGA outputs. They are used to drive five inputs to be displayed on five different monitors. The computer used ran windows XP and was able to run the simulation software in a fraction of a second.

3.6.4 Lighting

Lighting in the room can be controlled in four different zones. The first zone is the *center zone* which illuminates the center of the table, the *perimeter zone* illuminates the parameter where participants sit, *presenter zone* will illuminate the presenter, and *track lights* illuminates the fish sculptures on the wall. In this thesis, all lights were set on full power to ensure full visibility between participants. This did not adversely affect the displays.

3.6.5 Seat arrangement

There are a total of 10 seating locations equally spaced relative to each other. Participants in all positions have unobstructed views to one another due to the super ellipse shape of the table. Note that positions on the longer end of the table will have a significantly more difficult viewing angle to of the shared displays because they are over 180 degrees apart.

For this research, participants were seated at one end of the table; the minister on seat 1, the fisher on seat 2, the NGO on seat 10 and the facilitator on seat 9. Since participants require a view of all monitors, this seating arrangement gave all participants the best overall view of all the monitors without sitting too far from each other.

3.7 Software

Software for *Ocean Summits* will utilize two main components to aid the collaboration of the summit, scientific simulation software and visualization. The visualization provides an emotional connection for the participants and scientific tool provides the trade-offs and benefits of each decisions. The distinguishing difference between *Ocean Summits* and other similar GDSS is that, unlike any EGDSS, the discussion is based around the software described below, not to aid the discussion.

3.7.1 Simulator: Ecopath with Ecosim

The tools that provide the necessary scientific feedback are a modified version of *Ecopath with Ecosim* (EwE) which models an ecosystem, and provides near instantaneous feed back for policy decision instead of traditional reports [5]. EwE is the leading ecosystem modeling tool, and allows users to model various parameters such as Marine Protected Ares, Gear types, Climate/Nutrient changes and changes in fishing effort to name a few, 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 can predict within minutes, movement and migration patterns of fishes and fishing fleets over a period of time. The software has been under development for 18 years.

The software also has the ability to evaluate benefits and tradeoffs for specific stakeholders. EwE could output estimates of profit, cost, number of job, biomass, and various other indicators that will interest these stakeholders directly. Further indicators such as ecotourist benefits, value of recreational fisheries, etc. can easily be implemented in EwE.

The current interface of EwE6 is called a 'Scientific Interface' where expert users of the software have to sort though various screens to find each indicator. The current scientific interface (as seen in Figure 3.3) is too detailed and will likely overload non-expert users making it unusable for *Ocean Summits*.

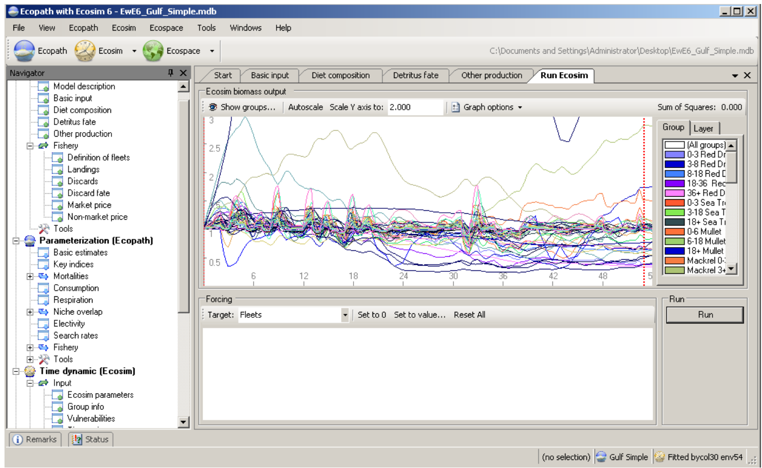

Figure 3.3: The current state-of-the art is the, Ecopath with Ecosim 6 scientific interface showing biomass estimates for a certain ecosystem. The software can easily overwhelm a non-expert user.

The summit software, called *Multi-player Interface* (the development name), will provide simple overview information plus some level of detail, and at the same time be visually enticing by animating fish in a virtual sea. The look and feel of the software must have a theme and seamless interface to immerse the participants, much like a modern video game. The software will use information visualization techniques, i.e. detail on demand, although the amount of detail could possibly undermine the success of the summits by allowing participants to focus too much on details. The detailed data will be presented in a simple straight-forward manner such as a message box with a single value in order to minimize the potential of participants focusing their attention on details. Data will be categorized into at most four to seven categories to not overload cognitive memory capacity. Examples of data a participant may want to explore are biomass, profit and jobs.

3.7.2 Visualization

Another aspect of the EwE software is the visualization of underwater scenes. In essence, this visualization will be a 3D representation of fish in the ocean (Figure 3.4). The number of fish will be driven by EwE for the participants to visually see the impact of their decisions. The benefit of the visualization is to trigger cognitive/attitudinal/behavioral changes about sustainability policies [54].

Figure 3.4: Current screenshot of the visualization aspect of *Ocean Summits* developed by the Masters of Digital Media (MDM) program.

3.7.3 The custom-designed interface

An easy-to-use custom-designed interface software is the mechanism through which stakeholders to interact with the simulation software, Ecopath with Ecosim. Through this interface, participants will be able to enter their policy questions, run the simulator, and see their results (general results, or results directly related to their interests). Because stakeholders may not be expert users of the system, the custom-designed interface has to be easy to use, consistent to maintain the software's integrity, and most importantly, designed to facilitate the varying needs of different stakeholders.

This thesis is helping to answer some design questions in this custom-designed interface.

3.8 Issues

Ocean Summit approach that has been presented is a very optimistic view with a lot of gaps to be filled in. In this thesis, we focus on the gaps between the four components, people, participants, hardware and software, and how would we share simulation results among all stakeholders on various screens to improve the decision making process. For example, we ask "will sharing of information on all large shared displays be more beneficial than if no results are shared?" In the next chapter, we built a custom-designed software system that enables researchers to address these questions.

Chapter 4

EcoManager: software for prototyping *Ocean Summits*

As described in the previous chapter, we found it is very difficult to explore how simulator results should be shared amongst stakeholders in *Ocean Summits*. In this chapter, we describe a software called *EcoManager*, which is a prototype for the custom-designed interface for *Ocean Summits*. This software has the flexibility to support evaluations of different aspects of the summits, more specifically, to evaluate different ways to share information amongst the various stakeholders.

We are in early stages of developing a prototype, therefore involvement of actual participants in summits was not an option. Instead, we recruited subjects and had them act as surrogates. We trained these subjects to obtain a basic skill for ecosystem modeling. This enable the subjects to use EcoManger in which we carried out our research.

4.1 *EcoManager*

This section gives a brief overview of the *EcoManager* software, then some of the technical details of the ecosystem model, the implementation framework, the computational representations of each stakeholder's interest, what is displayed with the software, and the interactions of the software.

4.1.1 Overview

The *EcoManager* software works in conjunction with the rest of the EGDSS, the hardware, people, and process, to make ecosystem modeling more accessible to the various stakeholders. The software accepts an ecosystem model, uses EwE6 core computations to get simulation results, summarizes the results and presents them to the users in an EGDSS setting. More specifically, *EcoManager* takes a modified version of an ecosystem model focusing on the Canadian North Atlantic coast, runs it through a temporal model called Ecosim, then takes the resulting biomasses and catches and summarizes these for individual stakeholder, i.e., with emphasis on jobs for ministers, biomass for NGOs, and profit for fishers. Appendix A.10 has a more complete description of the model.

4.1.2 Ecosystem model

Throughout this chapter, we will illustrate *EcoManager* with an example based on an instructional lab exercise in an ecosystem modeling course that was taught at UBC during the Fall of 2006 by Christensen. This ecosystem model was based on the state of cod stocks on the Atlantic coast of Canada back in the 1990s, when the cod stock were rapidly being depleted and drastic changes in effort needed to happen.

The model captures the ecosystem dynamics between six species: plankton at the bottom of the food web, benthic fish, shrimp, and capelin that feed on the plankton, and cod and seals at the top of the food web with cod feeding on the benthic fish, shrimp, and capelin, and the seals feeding on the cod, benthic fish and the capelin, but not the shrimp. Figure 4.1 shows these relationships in diagrammatic form.

In the 1990s, a major concern was that cod stocks may not recover in the foreseeable future [38]. Decreasing stocks would lead to losses in cod profits and jobs. During this time, stakeholders moved towards increasing the seal cull, provoked by the assumption that seals predate on cod. The increase in seal cull efforts still depleted the cod stocks taking it unsustainably low levels, where to recover the stocks will jeopardize the cod fishery. Therefore historically, the industry turned to shrimp, the demand for seal culling dropped, possibly due to activist organizations [39].

As Walters [60] said, the ecosystem model is not a one size fits all, but it has to be designed to address a specific question. The initial ecosystem model was made by Christensen, and showed that increasing seal effort would drastically decrease seal populations, with a minimal increase in cod populations. The ecosystem model was made to be very basic and transparent as can be seen in the food web diagram in Figure 4.1. There are no unpredictable variables that would lead the model to behave outside of what is explained in the pre-summit document (see Section 5.3.3). The simulation model ran for 20 years. The ecosystem model consist of six species and four fishing fleets, here known as fleets, which only target their respective species. The details of this model are described in Appendix A.12.

The optimum solution when seeking to optimize a combination of jobs, effort and ecosystem structure for this model is to stop the seal cull, increase the cod trawl effort to 2.5, increase shrimp trawling effort to 4, and stop

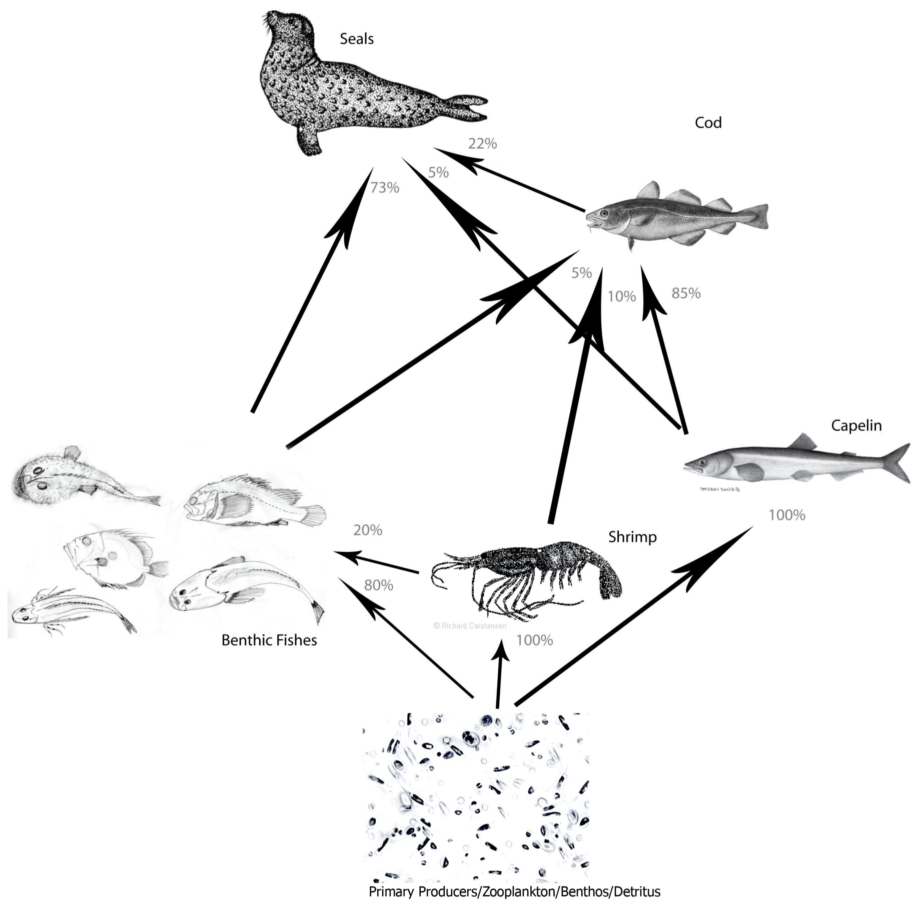

Figure 4.1: Flow diagram that describes the ecosystem model. This model is used in *EcoManager*.

Target species	*Jobs Per Catch Value*
Seal	10
Cod	20
Shrimp	10
Capelin	10

Table 4.1: *Jobs per Catch Value* is the number of jobs given a certain amount of effort for each type of fish. As seen, cod fishers have the highest relative value.

capelin fishing all together. By cutting the seal and capelin harvest, the NGOs gain from the resulting increase in seal biomass due to the availability of more food for seals by cutting the capelin fishery. Cod provided some jobs and profits to an already depleted system. Shrimp being a very resilient (able to sustain high fishing pressure), withstands heavy fishing, benefiting fishers and hence ministers.

4.1.3 Computational representation of stakeholder

EcoManager is developed as an extended plugin to the EwE6 software. It is designed to compute three realistic indicators for three of the stakeholders: it computes an ecosystem indicator for NGOs, profit for fishers, and jobs for ministers. The actual equations used in the computations are described below, for the three stakeholders.

Minister (jobs)

The number of jobs associated with a given level of catch is used as an goal for a minister because it is a straightforward measure similar to the ecosystem structure and profit. To compute this indicator, we estimate the *TotalValue* of the catch (how much of each species caught times its relative price). This is done for 20 years and for all the fleets, as shown in Equation 4.1. *TotalValue* is then multiplied by a constant for a given fleet representing *jobs per catch value* (Table 4.1) computed in Equation 4.2. *Fgear* is the amount of fish caught by the fishing gear, where F is a function of fishing effort. The parameters t and f denote the time in years and fleet respectively.

$$TotalValue(f,t) = \sum_{f=1}^{4}\sum_{t=0}^{20}((Biomass_{f,t}Fgear_{f,t})Price_f) \tag{4.1}$$

$$Jobs(f,t) = \sum_{f=1}^{4}\sum_{t=0}^{20}(TotalValue_{f,t})(JobsPerCatchValue_f) \tag{4.2}$$

Fisher (profit)

A single *profit* value is used to represent the fisher's level of satisfaction. To compute this indicator, we simplified the computation to the *TotalValue* (Equation 4.1) minus *Q*, where *Q* is the cost of fishing per fleet reported in Equation 4.4. In this equation, all other variables were equal, therefore, the *price* per kilogram of fish in the market, was the deciding factor on which to harvest (Table 4.2). Here, seals are intentionally valued at twice the value of shrimp to impose a conflict between fishers and NGOs. The other two prices are assumed to be almost negligible. *CPUECost* is the cost of employees per unit of fishing effort and *SailCost* is the cost of sending the boat to sea per unit of fishing effort.

$$Q(f) = \sum_{f=1}^{4}\sum_{t=0}^{20}((Effort_{ft})(TotalValue_{f0})(\frac{CPUECost_f + SailCost_f}{100})) \tag{4.3}$$

$$Profit(f)(t) = \sum_{f=1}^{4}\sum_{t=0}^{20}((TotalValue_{ft} - Q_{ft}) \tag{4.4}$$

Non-Governmental Organization (Ecosystem structure)

The *Ecosystem structure* is used to represent the NGOs level of interest. A single value is used to compute an indicator for the abundance of each species, the biomass amount of a species times *Longevity* as reported in Table 4.3. The interest of the NGO is the average life span of a species, which is the inverse of the production divided by the biomass as defined by Odum [37]. Longevity is described as the sum of biomass of key groups times the *longevity*. Longevity of cod and seals are given in Table 4.3. As can be seen, seals have a longevity of more than six times that of cod.

Species	*Price*
Seal	4
Cod	0.6
Shrimp	2
Capelin	0.1

Table 4.2: *Price* in dollars for each species. As seen, seals are the valuable species then comes shrimp.

Species	*Longevity*
Seal	6.66
Cod	0.95

Table 4.3: *Longevity* in years for each species for the NGO. As seen, seals are six times more long-lived than cod, and we neglect the other species as they are very short-lived.

$$EcoIndicator(b)(t) = \sum_{b=1}^{2}\sum_{t=0}^{20}(Biomass_{b,t})(Longevity_b) \tag{4.5}$$

Overall/average indicator

Trade offs are inherently built-in to this structure. NGOs are interested in stopping the fishing of seals, fishers want more seal effort, but will compromise for shrimp, and Ministers want more cod. Simulations show that with three parameters, the optimum policy is to stop the seal culling and increase cod and shrimp trawling, and stopping the capelin fishery. The NGOs will have to sacrifice the cod in the ecosystem, and the Fishers will have to sacrifice the profits from the seals and gain from cod and mostly shrimp.

4.1.4 Data displayed

This section outlines what the users can visualize in the software component of *EcoManager*. There are five major screens, three of which are indicators for each stakeholder. They are (1) fishing effort, (2) biomass, (3) profit, (4) jobs and (5) ecosystem structure.

Fishing effort

The primary purpose of this screen is to input all the parameters for the model, namely fishing effort for all four fishing fleets. This screen also provides secondary information such as the records of previous runs, a timer and a run button on the bottom right as seen in Figure 4.2. Fishing effort is defined as any measure of input extended by people to catch fish. This includes the days at sea by boats of a certain type, number of hooks set per day, fuel consumed, etc.. A fleet is defined by a set of boats that targets certain types of species. In the model, it is a value relative to the very first baseline year. The fishing effort is represented by a two dimensional graph with a relative value on the Y axis varying from zero to infinity, and time on the X-axis. Users can use a mouse to sketch on the graph, choosing various levels of fishing effort through time. Aside from giving users the flexibility to sketch the fishing rates, this plot is used to reinforce the understanding that fishing rate can be changed the period of 20 years. An up-down numeric control is placed above the graph to allow users to set a constant value through time. Colors are used throughout the software to indicate species, e.g., all plots and data-grids indicate shrimp with a pink color.

On the right sits a spreadsheet-like control that displays records of previous runs the participants have selected, ordered by the latest run on top. So if users entered 0.0, 3.6, 2.0 and 0.0 as fishing effort values for seals, shrimp, cod and capelin respectively, the numbers will be displayed along the right hand datagrid linked with the run number. The color-coded representation for species allows users to quickly identify the species. This spreadsheet-like display is only helpful for single value representation of each fishing effort.

The timer to indicate the remaining time in for participants to come to a conclusion has been placed on the bottom of this fishing effort screen where it is accessible to all participants. A run button is used to provide context when the button is clicked to run the simulator.

Biomass, profit, jobs and ecosystem structure

All biomass, profit, jobs and ecosystem structure graphs show a value vs. time graph for each species. Secondary feedback is accessed through buttons on the top indicating what graph is displayed, and a spreadsheet-like control that displays the score of each indicator on the right hand side seen in Figure 4.3. Note, the biomass graph is the only graph without the scores since it is not an index for any stakeholder. All graphs lines are color-coded and correspond to the species expressed in the fishing effort graph seen in

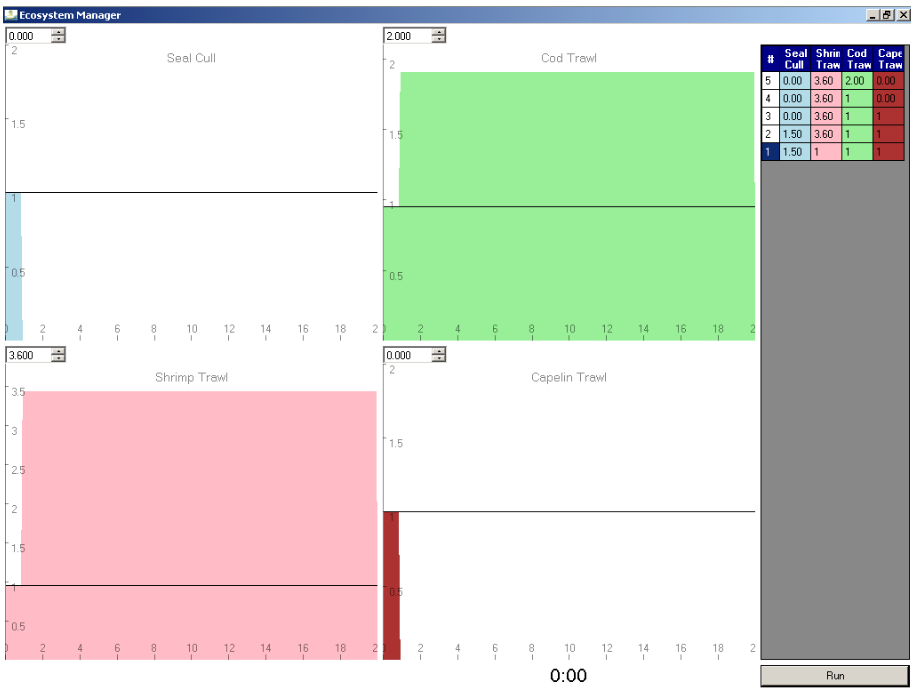

Figure 4.2: Screenshot of fishing effort screen showing fishing effort of individual fisheries on the left, records of previous runs sits on the right in a data grid format, a timer on the bottom and a run button on the bottom right.

Color	*Species/Fishery*
Seal	Blue
Cod	Green
Shrimp	Pink
Capelin	Brown

Table 4.4: Color codes that represent each fishery. These colors are used throughout the simulator to link the fishery to the corresponding species.

Table 4.4. The value on the graph is the score for a specific species at a specific time step. The indicator on the right shows the score and run number; score is simply the sum of areas under the graphs. The buttons on top are an indicator of which graph is currently displayed, when in the *toggle graph mode* described in Section 4.1.5. Biomasses can be seen in Figure 4.4; profit, jobs and ecosystem structure all have the same layout as seen in the profit screen on in Figure 4.3 with the exception that ecosystem structure only has one black line for a sum instead of multiple.

These graphs have the ability to display any number of previous simulation results as seen in Figure 4.5. The latest simulation will be drawn thicker than others. With this ability, the participants can easily see the changes between simulation runs. The downside to this is that the multiple lines cause clutter, making the graph harder to read. History lines were therefore not introduced during the actual studies for this thesis.

4.1.5 Software interactions

Participants have very limited hands-on interaction with the software. Their main method of interaction with the software is a visual feed back mechanism displayed on their respective monitors, which is described in 4.1.4, and interactions through the facilitator. All input interactions are controlled via the facilitator except when the system is set to *toggle graph mode* described in Section 4.1.5. All other times, participants have to verbally communicate to the facilitator to modify inputs. In this study, the facilitator plays the role of a chauffeur as described in Section 2.2.5. Participants are allowed to tell the facilitator that they want to do one of four main tasks. They can change the fishing effort, run a simulation, revert back to old runs, or end the simulation early because they have come to a decision.

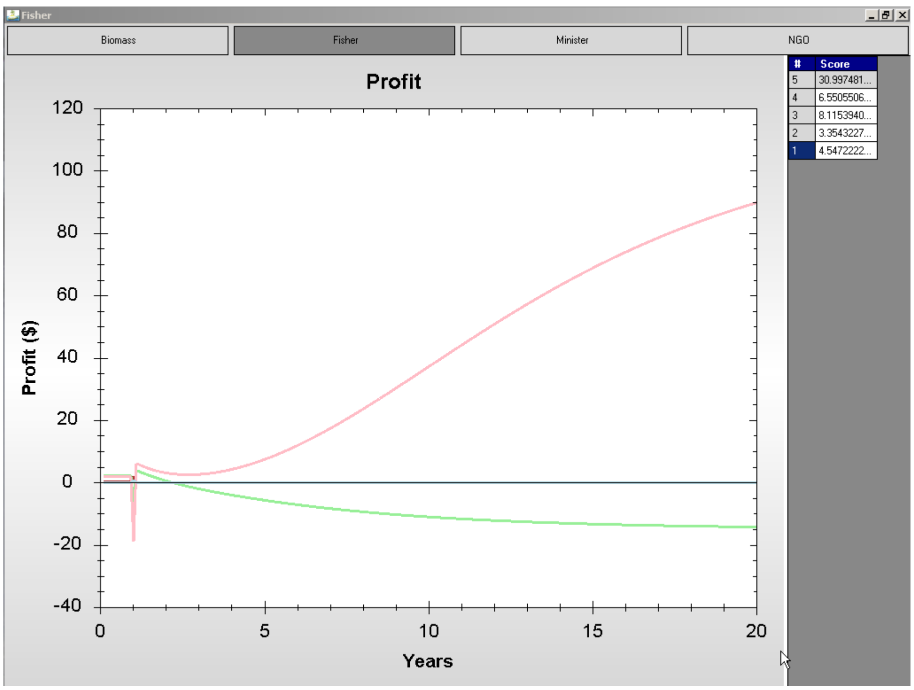

Figure 4.3: Screenshot of Profit. The same layout is used for the jobs and ecosystem structure.

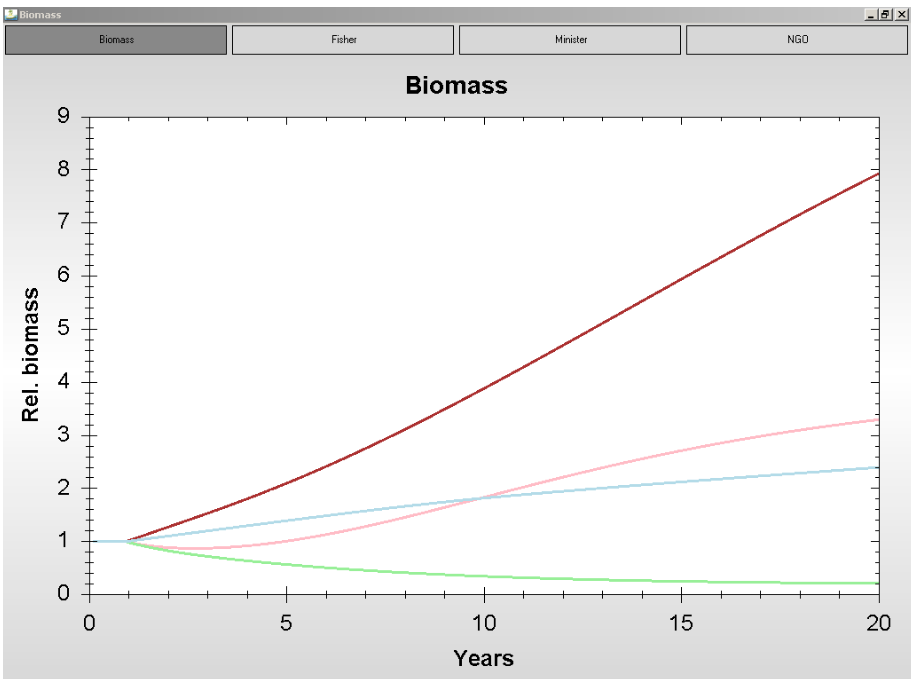

Figure 4.4: Screenshot of Biomass. Note biomass of each species is color-coded to consistently represent each species.

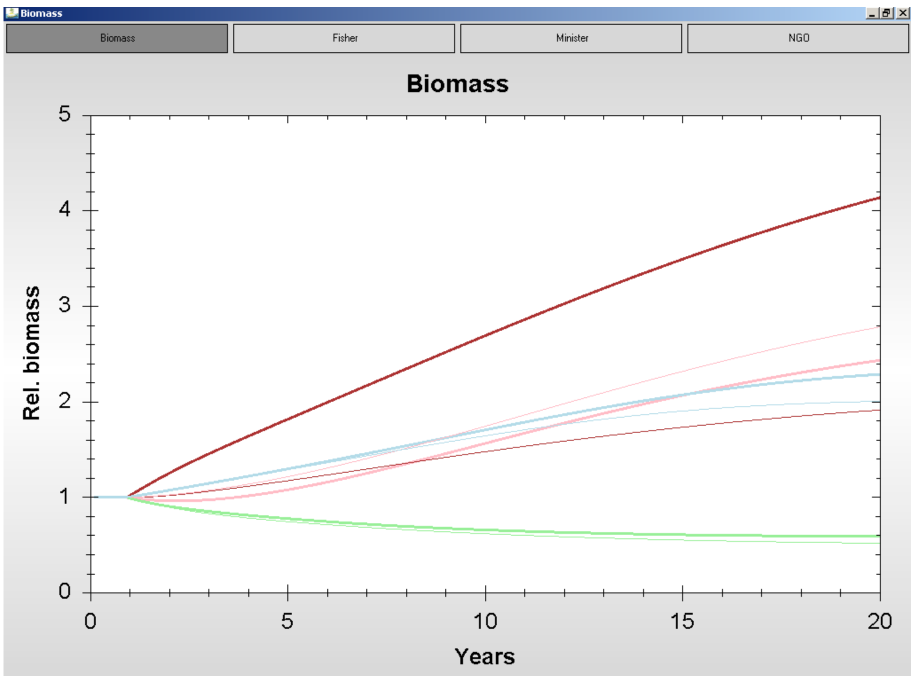

Figure 4.5: Screenshot of Biomass screen showing the simulators predicted amount of biomass in the water with records of previous runs.

Change fishing effort

Fishing effort is the only parameter that changes the simulation results thereby allowing the successfulness of a policy to be determined. Fishing effort has been simplified to a single real number for each fleet throughout the entire simulation time period. Since this model has four fleets, the participants will have to verbally give a real number and the corresponding fleet in order for the facilitator to change fishing effort e.g. "Shrimp trawl to 3.4 and cod trawl to 2.1." The facilitator will then modify fishing effort as any participant chooses, unless resistance from another participant is noted. When that is the case, the facilitator allows the participants to discuss and agree on a common setting for fishing effort. They are then able to change fishing effort however they choose and as many times as they feel necessary within the time constraint.

Run simulation

A facilitator will have to hit the "Run" button on the bottom right of the fishing screen described earlier in Section 4.1.4 and shown in Figure 4.2. When this button is invoked, the simulator reads the fishing effort inputs, computes the appropriate values, then updates the fishing effort datagrid, biomass graph, and all the indicator's graph and datagrids accordingly. In order to invoke the button a facilitator has click on the run button or hit enter on the keyboard. The facilitator was will be instructed to verify consensus with a nod from all participants and hit the enter key loud enough for an audio feed back that the simulator has been invoked. The graph animates throughout time within half a seconds and run number as it increases.

Revert to older runs

Participants are always able to see the effort value for each of the four fisheries in a datagrid on the right. If a new run is added, the values are added to the grid on the Fishing Effort screen, see Figure 4.2. Users are able to click on the desired run number on the data grid and this will populate the fishing efforts accordingly, but does not add a new run, nor change the graph. In order for participants to see the results, it is necessary to run the simulator again with same settings.

End simulation early

In the case where the participants reach a common solution for which there is consensus that it is the best achievable, they have an option to finish the simulation early. When the facilitator has been told by the participants that the group has reached a consensus, the facilitator will ask, "do all of you agree that this is the best policy and that each of you are individually happy with it?" When all participants agree, the time is noted for statistical purposes proceed to the next phase of the user evaluation.

Toggle graph mode

In this mode, each participant has a mouse and a view of one of the graphs (either biomass, profit, jobs or ecosystem structure). When the user left-clicks, the graph and the button on top cycle though each of the indicators. This gives the user the ability to toggle through each indicator to explore the different spaces of information similar to having it on different screens. This change is instantaneous and simple to learn and understand. Participants mouse movements have been disabled though the software and a piece of tape under the mouse.

4.1.6 Implementation framework

EcoManager has been implemented in VB.Net 2005 which means it runs on any computer that has the .Net 2 framework installed. It uses the .Net open-source graphing utility *ZedGraph* for all graphs, Calgary's open-source input utility *SDGToolkit* for multiple mouse inputs, EwE6 proprietary fishing effort sketch pad and finally the EwE6 core and plugin framework.

The EwE6 core and plugin framework enables the parallel development of EwE6 and *EcoManager*. This plugin framework allows monitored control over the EwE6 core computations. A plugin in EwE6 can change variables, run computations, extend/modify computations. Traditionally, plugins required the EwE6 Scientific Interface to run, which was bulky software that scientists used to create models. As an alternative we developed the EwEPluginLoader, as an invisible stand-alone application that initializes the EwE6 core and creates the *EcoManager*. This makes the loading of the EwE6 Scientific Interface unnecessary.

On the small model described in Section 4.1.2, a single processor 2.33 GHz computer with 1 Gb of RAM can run a 20 year simulation on the simulator in a fraction of a second for a 20 year simulation.

4.2 Summary

This chapter describes a prototyping software, called *EcoManager*, that is coupled with EwE6 for use in *Ocean Summits* approach, and which has the capability to be tweaked for rapid user evaluations in the actual *Ocean Summit*. This software is designed to be used by undergraduates as players, and imposes a role, indicates and teaches them to play their role. The software is built in a controlled framework to explore various aspects of the *Ocean Summit*, e.g., where and how much information should be displayed, and how many levels of interactions participants should have.

Chapter 5

The Experiment

The previous chapter described a lightweight, flexible EGDSS system for collaborative fishing policy management. The system was designed to be simple enough that lay persons could assume the roles of high-level stakeholders in making policy decisions based on using the software. This chapter will explain how this system was used to evaluate different methods for sharing information on various displays in the Immersion Lab, through a controlled user study.

5.1 Goals

The goal of the study was to evaluate the use of shared vs. private screens and shared vs. private information during *Ocean Summits*. At this point, it is very unclear where and how the simulation results should be offered to participants. We address two main questions: Is shared information better than private information? If so, where should the shared information be displayed?

5.2 Hypotheses

We conducted a controlled experiment where we explored the use of shared and private screens vs. public and private information. We wanted to examine: (1) if public screens and public information allowed participants to perform better at EGDSS decision-making tasks; and (2) if there is a learning effect before and after each condition.

This study tested four hypotheses: (i) shared information amongst participants using a EGDSS will enable participants to perform and collaborate better; (ii) shared screens provide better informational contexted thus allow users to perform and collaborate better; (iii) an EGDSS system will allow users to make better decisions than they would without a system; (iv) an EGDSS is an effective tool for educating users in the process of ecosystem modeling.

5.2.1 Hypothesis (i): Shared information is better than private information

From Section 4.1.3, we know that each participant has an individual indicator; NGO's care about ecosystem structure, fishers are concerned with profit, and ministers are interested in jobs. We hypothesize that sharing this information would help provide the group with a greater informational context allowing groups to perform better as a group when arriving at their task and allow for more collaboration that moves the group forward to attaining their goal. If information is shared, stakeholders can easily see how well one does and focus their attention on the group decision-making task, instead of having to decipher how well one did from a relative scale such as, "I like it better," or "This is not as good." Private information potentially creates barriers of communication which could slow down the decision-making process. Shared information should be better than private information.

5.2.2 Hypothesis (ii): Shared screens are better than private screens

There are two types of screens built into the immersion lab, private in-desk monitors and large shared displays. We hypothesize that shared screens will provide more context to the group allowing them to perform better as a group at their task and allow for more collaboration that moves the group forward to attaining their goal. Large shared displays allow users to monitor all systems states in a glance [59]. The ability to gain an overview of the system provides a more efficient manner to absorb information to make quick decisions, therefore allowing participants to further explore the decision space. Shared screens should perform better than private screens.

5.2.3 Hypothesis (iii): EGDSS is better than the limited system

It is difficult to compare this EGDSS system to existing systems, when the closest alternative is expert user software, Ecopath, or traditional single-species stock assessment software. We then evaluated the use of the limited software vs. the full software, that provided all the relevant indices. The full system should be better than EwE on no system at all.

Conditions	*Shared info.*	*Private info.*
Public screen	A	N/A
Private screen	B	C

Table 5.1: Breakdown of field of study for all participants.

5.2.4 Hypothesis (iv): EGDSS will facilitate learning

The educational goals of *Ocean Summits* are described in Section 3.2. An EGDSS may not always come to a final decision that all parties agree upon, but it could be just as important to make sure all members learn how the ecosystem works when using an EGDSS. An EGDSS system should give participants a better understanding of ecosystem modeling.

5.3 Methodology

We evaluated the functionality of one system in a controlled experiment by testing it in three different experimental conditions. We had groups of users perform collaborative tasks in each of these three conditions. The major independent variables were (a) the choice of system display screens and (b) the actual information displayed. The system can be used with either personal or public 'shared' screens as discussed in Section 3.6.1. In the study, the variable governing how information was displayed determined whether or not users were given the ability to share the information indicators (computed by the simulation), as described in Section 4.1.3. We can see the tree conditions summarized in Table 5.1. It is not possible to have private information on a shared screen, so there are three experimental conditions of the four combinations of screen and information choices.

5.3.1 Participants

A total of 27 participants were enrolled for the experiment. They were divided into nine groups of three participants; three groups were assigned to each experimental condition. All participants had a firm grasp of both written and spoken English, and had a limited understanding of ecosystem modeling. Groups where assigned to conditions by order of participation to normalize for the changes in recruitment techniques due to the subject pool.

Field of study	*Number of participants*
Biology	9
Computer Science	8
Business	4
Engineering	2
Education	1
Arts	1
Geography	1
English	1
Total	**27**

Table 5.2: Breakdown of field of study for all participants.

Subject pool

Initially, recruitment emails were only sent to university departments whose fields of study fell in line with the roles of the main stakeholders in our EDGSS. Ministers were recruited from political science students, NGO's were recruited from biology students, and fishers were recruited from business students. Later, the study was opened up to all undergraduates regardless of field of study. This was necessary in order to recruit enough participants because initial enrollment was sparse due to conflicts with upcoming examinations. The breakdown of participants by field of study can be found in Table 5.2.

Participants from each field were selected on a first-come first-serve basis then assigned to groups in the order of availability to fill the earliest timeslot. Roles were originally imposed by field of study, then issued sequentially in order of fisher, minister and NGO. 27 participants were sent an email (Appendix A.2) describing the study, along with a copy of the User Study Prep Document (Appendix A.10). Participants were assigned to groups in the order they were recruited, one per group in a round robin fashion and asked via email (see Appendix A.3) to show up with the other members of their group at a selected time for the experiment.

Incentive structure

The incentive structure for the study was that of tiered monetary rewards based on performance. An initial sum of $20 was given for participation. Additional money could potentially be earned based on task performance;

participants that performed the best in their group, or in their particular role across groups, were rewarded accordingly. The following list describes the breakdown of prize money. The total possible sum of money that could be awarded to a single participant was $150. The incentive structure were told to each participant.

- Win $20 extra for the least number of incorrect answers for each of the pre- and post-quizzes.
- Win $20 extra if you attain the highest individual score between all the other participating groups of your same role for both the stripped down and full simulators.
- Win $25 extra if your group gets the highest overall score for both stripped down and full simulators.

5.3.2 Task

Participants engaged in a group activity where they were asked to come to a consensus on the fishing policy they wished to pursue. This involves modifying fishing effort parameters in the EDGSS software (Section 4.1.4) and exploring the potential results of these modifications. Simulation results were displayed on different screens with different indicators as discussed in Section 4.1.4. The objective was for groups to maximize the individual utilities shown on the different screens.

The ecosystem model was based on a modified Northern Seal Cod Ecopath model used for a lab from a graduate level university course on ecosystem modeling. Users started with a baseline fishery model where all fishing efforts for the various species were set to a default of 1. All groups used the same software. The conditions under which the software was used varied by viewing condition and the relative privacy of each user's information. In Condition A all the information was displayed on shared screens as discussed in Section 3.6.1. Condition B had the users view everyone's information on their private monitors as discussed in Section 3.6.1; they are provided with a mouse to toggle though the information as discussed in Section 4.1.5. In Condition C, users could only see their own private information on their own private monitors.

5.3.3 Procedure

Three participants from various backgrounds were assigned different roles, NGO, minister and fisher, their roles were described to them ahead of time in a *pre-summit document*. The document also described the fundamentals of ecosystem modeling to ensure a common baseline of knowledge.

Upon entering the room, participants were asked to take a *pre-quiz* on the fundamentals of ecosystem modeling and some to answer some questions on their indicators to gauge their understanding of the model. They were then asked to use a *limited version of the software* that showed only biomass and fishing effort. In 15 minutes, participants had to come to a common solution in which they mentally inferred an agreed-upon solution without simulation feedback, and decide which fishing policies best fit their desired measures and verbally telling the facilitator (see Section 2.2.5) to set these policies accordingly. They were asked not to share how their values individual indicators were computed.

After using the stripped down version of the software, participants then had thirty minutes to use a *fully functional* version of the software, where they could see simulation results according to the viewing of the conditions. Again, they were asked to come to a consensus on a fishing policy that best fit their desired measures without sharing how the indicator values were computed, and with the same monetary incentives to maximize their score. To wrap up, they were then asked to take a *post-quiz* with questions similar to the pre-quiz, as well as additional qualitative questions to gauge their opinions of the system.

The remainder of this subsection will to describe the procedure in greater detail, and provide additional rationale for the experimental design.

Pre-summit document

The role-specific pre-summit document (Appendix A.10) was given to participants ahead of time. This document explains the basics of ecosystem modeling, how the system works, and how the indicator of interest for the participant's given role was computed. These documents were designed to educate participants on their respective roles, and to ensure that there was a common baseline understanding of the ecosystem model and the software.

Pre-quiz

During the pre-quiz session, users were asked to answer a web-based multiple choice questionnaire in the Immersion Room. There are five role-specific main quiz questions, each with two to five sub-questions. The participants were to answer all sub-questions correctly before advancing to the next question. If a wrong answer was selected, appropriate feedback was given as illustrated in Figure A.3. The score was based on the number of tries it took to finish the quiz. A monetary prize of $20 was given to the participant with the lowest number of tries for each given role.

The pre-quiz serves two purposes: to reaffirm that the actors have a baseline understanding of the model and as a measure of learning effects. The important that participants select the correct answer before moving ahead is to ensure a common understanding of the ecosystem model, and the roles and their incentives for each role. This is the second way in which participants learn about ecosystem modeling. The pre-quiz was intentionally designed to have five questions with two to three sub-questions each to minimize participant's ability to memorize the answers; in general the cognitive short-term memory capacity of most humans is limited to approximately seven units [35], but this quiz is five questions with additional sub-questions, thus adding another level which largely negates the possibility of strictly memorizing answers.

5.3.4 Limited software

At this point in the experiment, participants in a group would all have answered the pre-quiz questions. Participants were then reminded of some ecosystem modeling examples described in the pre-study document. The script in Appendix A.8 was read verbatim to the participants, illustrating effects of changes in fishing effort. This is the third way in which participants learned about ecosystem modeling.

Participants were then given 15 minutes to experiment with modifying fishing policy together, using a functionally reduced version of the software that exposes only fishing effort and biomass values. The participants were asked to come to a consensus on the best fishing policy that benefits them individually and as a group. The rules of the simulation, along with a food web document (Figure A.10) and the pre-summit document (Appendix A.10) were made available to them as references. The facilitator informed participants at the 10-minute, 5-minutes, 1-minute, and 30-second marks as to how much time remained. If a solution was not reached by the allotted time, they could either pick one previous run, do one last simulation run, or have the last solution on the screen be their final set of parameters as an answer. At the end of the 15 minutes, participants were asked if the model behaves according to their understanding of the model.

Whenever a group wished to explore a scenario, they informed the facilitator of such, as noted in the procedure. Once the facilitator saw that all participants agreed, he/she clicked on the 'run' button available on the fishing effort display. Was key that the facilitator to ensure that all the participants would like to explore a run simulation, but was also important not to promote extra interactions any further than asking for acknowledgments. Running additional simulations will have no direct effect on scoring; participants could run a simulation as many times as they agreed upon.

The importance of this phase of the experiment is two-fold. The first is to obtain a measure of how well the group performs before and after using the system. This is within Hypothesis (iii). Unfortunately, there is no similar system to compare; it will also be unreasonable to have participants learn the full expert system EwE. Secondly, with only fishing effort and biomass displayed, the implications of their fishing decisions on the ecosystem will be salient, thus reinforcing the learning of the ecosystem model. The monetary incentive structure is used to ensure they have a stake in this system by assuming that it is representative of real life.

Full software

After reaching a consensus with the limited software, participants were given the full simulator with access to their private role-specific information; this information was distributed to participants depending on the values of the independent variables that are described in 5.3. Participants were asked to not disclose any form of private role-specific information such as the computed indicators. Only phrases such as, "This scenario is better", or "I like this case because" were allowed.

Participants were read the script in Appendix A.9, then instructed to perform the same task as with the limited software, but with all their indicator data visible. A time limit of 30 minutes was given to complete this task. Participants wee reminded that they would be evaluated on the best scoring situation in which all parties see the largest measure within all the groups. They were told that the stakeholder or group with the most relative points between all the tested groups would win the prize.

Post Quiz

After the participants had come to a final outcome, they were asked to answer a quiz in a format identical to the earlier pre-quiz. The post-quiz consisted of eleven questions, and was the final part of the study. The first five questions were identical to the pre-quiz in order to gauge whether a single participant had learned anything after running the simulations. The remaining six questions were detailed questions on ecosystem modeling, the simulator, the software, their understanding of all the player's roles, as well as a quick survey to gauge their perception of satisfaction and performance with the system.

5.3.5 Design

The experiment used a between-subject factorial design split into three conditions as seen in Table 5.1. Conditions were assigned to the different groups in the order their experiment session took place within the entire experiment.

5.3.6 Design quality

In the context of our experiment, the term 'better' has a multi-faceted definition. Better means: (1) reach an overall weighted high score by all participants; (2) allow users to explore more scenarios so they explore the solution space better; (3) provide a better understanding of the ecosystem dynamics to participants.

5.3.7 Measures

There were several measures observed in the study: (a) **knowledge** the number of tries and the scores for the pre- and post-quizzes; (b) **decision quality** the values, scores and timing for each trial including the final trial; (c) **collaboration** user discourse and participation with the limited and full software recorded by the facilitator. Measures (a) and (b) were straightforward as they are direct outputs of the systems.

Measure (a) **knowledge** logs the quiz scores. The lower the value, the less mistakes were made, meaning the better the score. This was used to evaluate Hypothesis (iv).

Measure (b) **decision quality**, the group score, is computed by dividing each stakeholder score by the highest score in that group, then summing an stakeholders scores in a group to get the score for the group. The timing and scores are used to determine patterns in the different conditions. The net group score is also determined here.

Measure (c) **collaboration** was measured by counting the number of comments in two systematic categories refined in pilot studies similar to Blatchford [4], *constructive comments* and *suggestive comments*. A constructive comment is where a participant gives a statement that is directly related to the system whether positive or negative. For example, "cods increase because of ...", "I like this run" or "I don't like this." A suggestive comment is where a participant gives a proactive statement that recommends others to participate; for example, "We should increase cod to 2.3" or "Lets stop seal cull." Constructive comments counted as one point, whereas suggestive comments counted as two because they engaged with the ecosystem task.

5.4 Results

We collected both quantitative and qualitative results during the entire user study. We performed two repeated measures test for significance and report partial eta-squared η^2, mean μ, standard deviation *sd*, and the significance p.

5.4.1 Quantitative results

We first look at the quantitative data within our measures.

(a) Knowledge

In knowledge, we looked at the quiz scores for both pre and post quiz scores for all Conditions A-C. We found that participants were able to answer the quiz better after using the system (μ=10.33, *sd*=4.77), and had significantly better post-test scores (μ=21.56, *sd*=8.96) with $p \leq 0.016$ with $F(1,9)=9.447$ and $\eta^2=0.612$. No interactions between conditions were observed (Figure 5.2), using the Scheffe test for contrast.

Here seen, only Hypothesis (iv): EGDSS will facilitate learning, was supported.

(b) Decision quality

For decision quality, we looked at the simulation results using the full software and the limited software for all Conditions A-C. We found that using the full software (μ=2.317, *sd*=0.355) is significantly better than the limited software (μ=1.24, *sd*=0.190) with $p \leq 0.000$ with $F(1,9)=16.57$ and $\eta^2=0.911$. No interactions between conditions were observed using the Scheffe test for contrast although the average scores were 7.15, 7.10 and 6.60 for Conditions A, B and C respectively. The differences were not statistically significant, with p= 0.5880 seen in Figure 5.2.

Here seen, only Hypothesis (iii) EGDSS is better than the limited system, was supported.

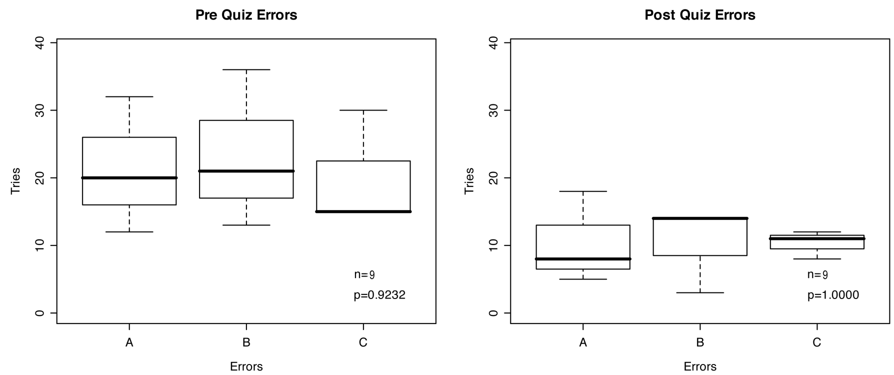

Figure 5.1: Quiz error plots of limited and full software for each condition (n=9). Lower value means better scores. Horizontal line is the mean, the box shows the first and third quartile, and bars show the range in values. Condition A is shared screens with shared information, Condition B is private screen with shared information, and Condition C is private screen with private information.

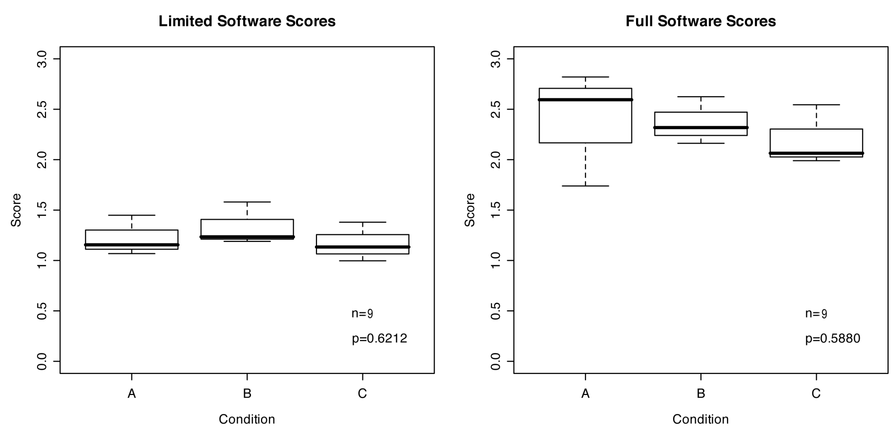

Figure 5.2: Simulation score plots of limited and full software for each condition (n=9). Horizontal line is the mean, the box shows the first and third quartile, and bars show the range in values. Condition A is shared screens with shared information, Condition B is private screen with shared information, and Condition C is private screen with private information.

(c) Collaboration

For collaboration, we looked at the amount of participation during the full software and the limited software for all Conditions A-C. It is not scientifically sound to compare full software vs. limited software as it was a different task and durations. We found no significant difference between conditions (p=0.2336) as seen in Figure 5.3. For discussion purposes, the means for Conditions A, B and C were 533, 335 and 452 respectively.

For Condition A, shared information with shared screens, it was observed that mostly quick acknowledgment statements such as "I like this," "this is better," "this is worst.", mixed with slightly charged statements that reached out to other participants, such as "You did better here", "You hated this one". In Condition B, shared information with private screen, we mostly observed limited, vaguely suggestive comments such "How about we try this," very limited acknowledgment comments and a few comments that reached out to other participants, such as "The NGO is a lot happier now". Condition C, private information with private screen, were mostly quick acknowledgment statements similar to Condition A but without as many suggestive statements.

Qualitative answers in the post-quiz were unfortunately not recorded due to an unforeseen error in the database recording process. Post-trial interviews indicated general satisfaction with the software among users, and that the overall system and study was easy to understand. In general, participants stated that they believed they all did pretty well. Overall qualitative verbal results showed no significant differences from group to group.

5.4.2 Qualitative findings

The following were noted during the study and were not anticipated prior to the experiments.

Start low, end high

The first observation is that when a group's initial score starts off high in a set of trial runs, they tend to finish with a lower score than participants who started low. This phenomenon was purely observed. We attribute the latter to the facilitator's observation that participants in the study with initially high scores seemed to lack the motivation noted in other groups. This could also be seen in Figure 5.4; the purple group in Condition B and the red group in Condition C are good examples. There were no advantages noted in the limited software scores that may affect the initial scores.

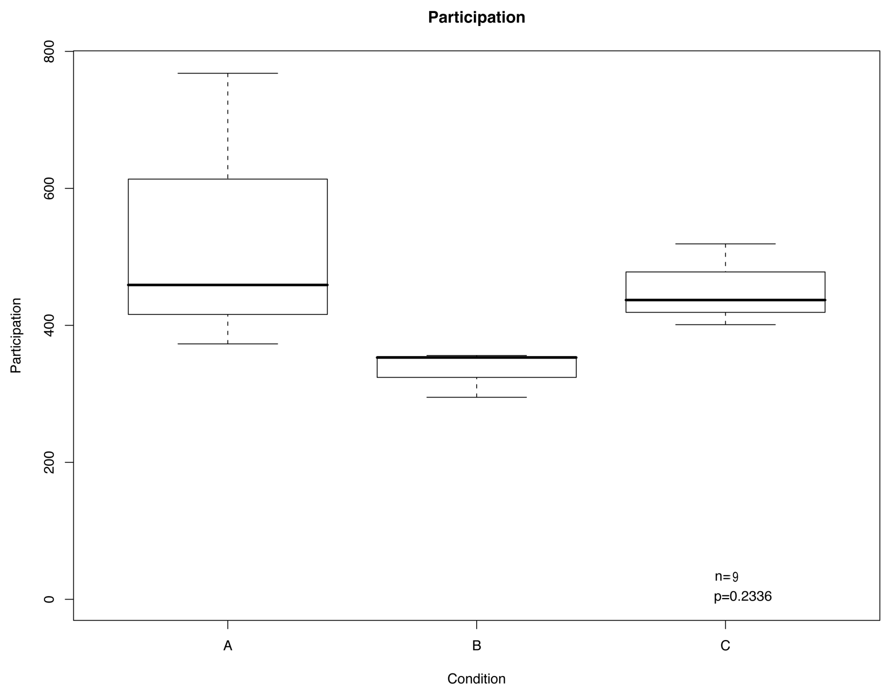

Figure 5.3: Amount of participation per condition. Without significance, Condition B is noticeably lower than other conditions. Condition A is shared screens with shared information, Condition B is private screen with shared information and Condition C is private screen with private information.

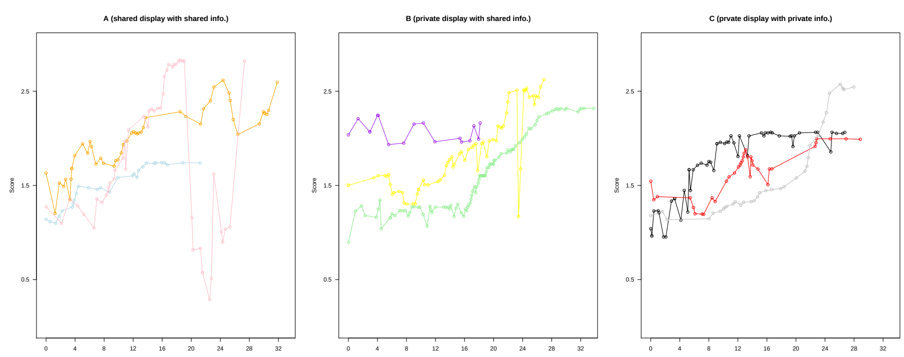

Figure 5.4: Score vs. Time plot of each simulation run the participants used. The colors simply distinguish the groups within each condition, and not conditions.

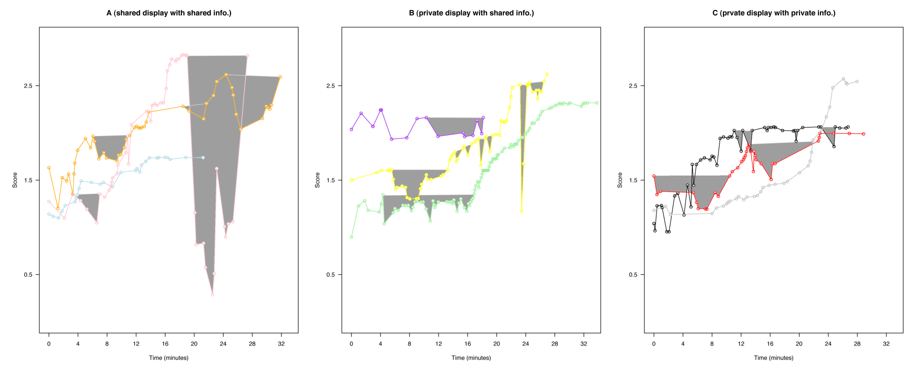

Figure 5.5: Score vs. Time plot each trial the participants used with highlights in gray where participants explore.

Willingness for exploration/alternatives

Another observation that is not supported by any statistical evidence, is that participants were more willing to explore or choose alternative solutions aggressively in shared information Conditions A and B than they were in private information Condition C. The red group in Condition C seems to be an anomaly, possibly related to the first observation. This can be noted in Figure 5.5 with large gray areas. An exploration of different parameters can be characterized by a dip in their scores and returns to their previous score at the same level as they choose negative alternatives. Positive exploration/alternatives are not highlighted here.

It is also important to note that intervals between each scenario run and changes in scores are larger during these exploration/alternative solutions than when a group chose to incrementally optimize their score.

Gaze patterns

It was observed that most participants in Condition A, shared information with shared screens, had gaze patterns moving consistently throughout the room from the index summary screen, to the fishing effort screen, and back.

For Condition B, shared information with private screen, participants stared the majority of the time at their personal screens. Active participants who made the most proactive comments looked up once in a while to look at the fishing effort. Participants very seldom looked at each other during the summit even when asking suggestive questions.

Condition C, private information with private screen, participants stared at their personal screens the majority of the time. Proactive participants also looked up once in a while to view fishing effort and sometimes biomass. Participants sometimes looked at one another to confirm if they were satisfied with specific runs.

It was observed that since participants were exploring the data in various screens, numerous facial expressions were missed; that is to say they were not observed by other users. For example, if a participant did not like the outcome of a simulation, they would twitch their face but not say anything. This reaction was missed more in private screen Conditions B and C.

Other-group specific observations

In one group under Condition B, shared information with private screen, the group reached a satisfactorily high score and did not want to budge their position downward much more than that. However, this turned out to be a suboptimal solution for the NGO for whom the individual maximum was not attained; the NGO was satisfied with whatever score s/he got. This was reflected in telling quotes such as "38 is my goal and I'm not moving below that." But, when profits increased, the same participant then changed her stance and said, "54 is my goal." When questioned by other participants, the participant said, "that was then!"

One group in Condition A, shared information with shared screens, had participants with bad eyesight; thus two of them had to get out of their seats to see the screens clearly. However, no quantitative artifacts were observed, and in the end they acted and performed similar to the two other groups in the same condition.

One group in Condition C, private information with private screen, and two others in B, shared information with private screen, chose to continually explore paths outside of what was asked, such as to attempt to restore cod as much as possible without looking at scores, or to attempt to increase seal biomass while fishing seals as hard as possible at the expense of their score. One group attempted to have cod move in an upward trend past their 20 year simulation even when they were explicitly directed by the facilitator that their only concern was their score at the end of the simulation.

General reactions

All groups were asked informally, "How hard was it to use the system?" The replies ranged from, "I'm just interested in how other people did." to, "It was easy!" or "No issues at all." Some further elaborated how nice it was to use the system, with its very minimal learning curve. Many said it was "very cool" and said "it is interesting to see how the groups work." They mentioned they had no problems with other people, but one group stated "the guy was really slow trying to tell the best score in range."

5.5 Discussion

In the following section we conclude the results and discuss the implications of our findings.

5.5.1 Summary of results

The following are results related to the four hypotheses:

Hypothesis (i): Shared information is better than private information: The hypothesis was not statistically conclusive. Private information, Condition C showed a noticeably lower mean score than the two shared information condition.

Hypothesis (ii): Shared screens are better than private screens: The hypothesis was not statistically conclusive. Shared screens, Condition A showed the highest mean of the three although very small (1% difference).

Hypothesis (iii): EGDSS better than limited system: The hypothesis was statistically conclusive. We find that participants performed better with the full simulator than the limited simulator results.

Hypothesis (iv): EGDSS will facilitate learning: The hypothesis was statistically conclusive. We find that participants were more knowledgeable after the summit than prior.

The following are additional results that have no statistical relevance, but are purely observations.

Start low, end high: We find that in most cases, if the participants starting score is high, they end up lower than groups that start lower.

Participation: We find that groups in Condition B participated less than the other two conditions.

Willingness for exploration/alternatives: We find that groups in Condition A and B were more willing to explore more aggressive alternatives than in Condition C.

Gaze patterns: We find that Condition A allows for more human interaction that the other two, where Condition B showed the least.

5.5.2 Detailed discussion

We can now explore how some of our results contributes to the field of EGDSS.

(i) Shared screens and shared information yields the most optimal results: The results demonstrated that in all measures, groups in condition A yielded the most optimal results. This could provide the rational towards many EGDSS systems in existence operates where all participants focused on a shared screen(s) with shared information, mentioned in Section 2.4. With a single large display, the participant's focus will be targeted towards the display and information. The goal of this summit is to form a cooperation and lay issues and concerns on the table. Thus there are benefits in the current setup with multiple monitors that allow people to focus their attention on each other. This problem is taken full circle as we address the issue of practicality to display all indicators on a limited array of public screens. The field of Information Visualization has solutions to these problems by detail on demand, layering or lensing. One should consider if these solution will fit for a collaborative decision-making environment.

(iii) *EcoManager* is better than any EGDSS: Convincing statistical analysis demonstrates *EcoManager* can attain better conclusive answers than traditional systems and provides a medium for participants to learn. Along with a positive significance, informal responses were positive and found the system "easy to use". As mentioned in previous chapters, there are no similar systems that allows non-experts to explore scenarios with near instantaneous feedback. Therefore we can say this thesis contribution is by providing targeted summarized results can gives more optimal results, for different interest groups in fisheries, than simply providing biomass.

(a) Start low, end high: Although no statistical significance was found, we observed the implication of starting low and ending high is that the incremental gains from run to run are higher leading to sustained interest in the activity. This would be similar to classic reward systems described in the field of computer game design theory, as it would sustain participant interest. The implications of one starting high, with little incremental gains, would be that participants may lose interest and drive to find the maximum score as discussed in Section 5.4.2. This could potentially lead to detrimental results as the maximum potential score could not be attained. We recommend that during *Ocean Summits*, users should start the optimization at the worst fisheries state.

(b) Willingness for exploration/alternatives: Although no statistical significance was found, it is observed that the use of shared information enables participants to explore more alternatives. One potential rationale for this observation is that participants are more confident in other's response to satisfaction, thus are more willing to move on to other alternatives. The ramifications of exploring alternatives is that they could find more optimal solutions outside their current search space; for example if they shift gears to try save cod in a system, they may somehow find a solution to save the cod and become more productive. On the other hand it is very possible that they may head down a suboptimal path, although this could also benefit participants by understanding the problem space such as benefits and tradeoffs of their decision; which is a step toward the second goal of the *Ocean Summit*.

(c) Participation: Although no statistical significance was found, we observed the highest participation on Conditions A and C, shared information with shared screens and private information with private screens respectively. Conditions C may yield a high participation score due to the fact that all participants has to continually confirm their level of satisfaction which verifies the theory of *technology blocking* (see Section 2.2.5). In Condition B, shared information with private screens, participants continually glared at the screens querying the required information which potentially hinders communication. This leaves the shared screens with shared information, Condition A, where this EGDSS system could be used to promote useful participation.

(d) Gaze patterns: The observations found in the gaze patterns show that participants in Condition A and C, shared information with shared screens and private information with private screen respectively, lead to more gazes towards other participants than in Condition B, shared information with private screen. More gaze movement allows users to capture non verbal communications which could potentially be missed when the sole focus is on their personal monitor. Facial gestures could help others more accurately determine the varying levels of satisfaction other participants feel which could lead to more confident evaluation of satisfactions and tradeoffs. Most importantly, facial gestures promote human connection with one another which is a strong step toward the first goal of the *Ocean Summits*.

Chapter 6

Conclusion and further work

We have evaluated the utility of the custom-designed interface to support *Ocean Summits*, a EGDSS that enables fisheries stakeholders to collaboratively explore policy scenarios aiming at solutions that optimally balance their individual interests. The evaluation focused on four aspects, (i) the use of shared information vs. private information, (ii) the use of shared screens vs. private screens, (iii) outputs of supported vs. non-supported task performance, (iv) learning effects (before and after).

The study yielded the following findings: (i) There is some evidence for the hypothesis that shared information is better than private information, however not significant. (ii) There is some evidence for the hypothesis that shared screens yielded the best solution for the given task, however not significant. (iii) Using a EGDSS results in better outcomes than without. (iv) Using a EGDSS facilitates learning; participants are more knowledgeable after using the system than prior.

The theoretical implications of this thesis are twofold. First, the basic assumption of superiority of shared information vs. private information has to be reconsidered. Second, the superiority of shared screens vs. private screens needs to be reconsidered.

The practical implications are that *Ocean Summits*, in particular, and EGDSS in general, should be designed in accordance with ‘best practice’, that means, they should apply the identified optimal setup of shared information on a shared screen. Moreover, considering the scoring dynamic, *Ocean Summits* and EGDSS in general should ideally start from the lowest possible collaborative performance.

The findings support the general insight that collaboration among fisheries stakeholder should be supported by a EGDSS, as the study indicates that, using a EGDSS results in better outcomes than task performance without, and facilitates learning.

However, even the best EGDSS supporting a sustainable fisheries management is not the management itself. There are significant changes to be induced in order to pave the path towards sustainable fisheries.

6.1 Limitations of study

One of the first weaknesses of this method is the low sample size where (n=9). Unfortunately it is hard to get statistical significance or even trends with such low sample sizes and large variance.

The second weakness is the inability to verify how closely the system represents the actual *Ocean Summits*. *EcoManager* uses a simplification of systems and indicators to simplify the learning curve for non-expert users. For example, we cannot tell if a fisher is really interested in only profit. Without a manner to judge how well *EcoManager* represents actual conditions, *Ocean Summits* has the potential of skewed results.

Another weakness in our methods is that we made a lot of assumptions that the role we imposed on participants is representative of actual stakeholders. It is unsure that actual stakeholders would only want to see the single output indicator, or would believe the complexities of such a simulator.

The intensive structure was not as strong as it could have been. We noticed when participants realized they are not going to win the highest prize, they gave up trying to achieve their best attainable score. A solution can be incremental prize money where the participant awards are based on a percentage of the best achievable score. This would allow them to compete individually as opposed to competing with other groups.

Unfortunately, not all participants read the documents which handicaps their ability to maximize their performance. A solution to this is to ensure each participant comes in ahead of time to be quizzed on the results.

6.2 Strengths of study

One strength of this thesis is the detailed learning process participants have to endure so that they maximize performance during the full software. Participants have to read a document, take a pre-quiz, play a limited version of the software and finally perform the actual study. This is done in stages which doesn't overwhelm the participants.

The design was a strong aspect of this thesis as it allows us to tease apart the before and after results, and the two aspects of information and location of screens. Although this is a standard two by two, design, we added the ability to test before and after using the tool. It is considered a strength because of its ability to depict some strong results.

6.3 Further work

EGDSS is still a budding field of research leaving a lot of future work to be done.

Level of detail for simulation output: We found that participants required relevant information in order to make better decisions. Our simulator told participants their performance indication during the simulations. It is possible that stakeholders may not want their level of satisfaction to be imposed on them by a simulator, but instead, use their judgement on different combinations of indicators to make a decision. Unfortunately, this judgement may utilize cognitive resources which in turn may hinder the collaboration process. Further research will be required to explore how the additional workload can be streamlined.

Willingness to share information: We found that shared information is beneficial to making better decisions. We made the assumption that stakeholders were very willing to share personal information relating to their satisfaction. Yet we are still largely uncertain that the actual stakeholders participating in *Ocean Summits* will be as willing. The ability to thoroughly evaluate the willingness and the amount of information actual stakeholders share will be an invaluable tool to creating a more usable *Ocean Summits*.

Lower starting score, higher end score: We found evidence of participants who initially started with a low score, usually end up with a higher score than participants that started high. This in turn means that participants who initially score high, may not reach their highest potential. More research is needed to evaluate and recreate this phenomenon to maximize stakeholder scores during the actual summits.

Improving quality of communication: We found both conditions that had most verbal participation was: (1) shared information with shared screens and (2) private information with private screens. We speculated that participation in the later condition, private information with private screens, was hindering communication where participants had to verbally communicate their satisfaction. On the other hand, the earlier condition, shared screens with shared information, promoted constructive communication where comments were based on ideas. An in-depth study in improving the quality of communication will be highly beneficial to *Ocean Summits*.

Understanding the dynamics: For the prototype, we have used three different stakeholders, representing fishers, ministers and NGOs. It is predominately unknown how the dynamics will change when other stakeholders were to join. For example, how will the dynamics differ if apprehensive indigenous people are invited, or even a dominating lobbyist. Further research is needed to understand the dynamics of including various stakeholders. Development of techniques to mitigate the social pressure involved will be invaluable for developing the approach.

Benefits of visualization: *Ocean Summits*' plan is to develop 3D fish visualization as part of the simulator output as described in Section 3.7.2. Further work is needed to verify the truth to Sheppard's claim of visualization triggering cognitive/attitudinal/behavioral changes [55]. During this prototype, we used simplified graphs and values to display results. It will be very helpful to evaluate how much benefit 3D visualizations will improve *Ocean Summits*.

Trackable vs. non-trackable: In the prototype summits we developed, we simply allowed participants to explore any combination of inputs they wished, known as a non-trackable task. A trackable task is where participants have a finite solution space they can explore. This has the potential to find better results [13]. Unfortunately, due to the complexities of ecosystem modeling, it is difficult to build one model that fits all solution [6]. Research is needed to explore whether the trackable solution of EBFM hinder the potential of participants attaining a 'better' solution during *Ocean Summits*. A method of testing the benefits of trackable vs non-trackable solution space will offer great benefit to further design of *Ocean Summits*.

6.4 Wrapping up

We explored the use of EGDSS (environmental group decision support system) in fisheries management. The term EGDSS has not appeared in the literature, but there have been systems described, in our review, that fall within the definition of EGDSS that we introduced. One contribution of this thesis is to raise awareness of the importance of explicitly recognizing the need for collaboration and designing an integrated EGDSS tool rather than using a GDSS (group decision support system) collaborative tool coupled with an non-collaborative EDSS (environmental decision support system) tool. We explored this design space, focusing on the role of public and private displays and the information appropriate for each. We discovered, at least in the setting we examined, that there is a choice to be made about where and how information is displayed. We believe that this choice can be exploited to better support public policy decisions if we understand the social and political aspects of the decision-making process. The evidence we have for particular case of fisheries management is promising, although clearly there is a need for further exploration of the design space and better assessment of the recommendations made this thesis.

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Appendix A

Study specific documents

A.1 Email to recruit participants

Subject: Fisheries Management User Study

Message follows below:

We are looking for participants for a study that involves some light reading, answering some questions, and participating in some collaborative group activities.

This study will take at most 2 hours and will likely take place the third or fourth week of December. This study involves basic marine ecosystem modeling (the process of managing populations of multiple species of marine life). You will be working in a group of 3 to come up with a fishing policy for your marine ecosystem.

The only requirement is that you are an undergraduate and have little to no understanding of Ecosystem Modeling (mathematical representation of ecosystems).

You will be paid an honorarium of $20 for your participation. For this study, we are interested in task performance by participants. To this end we offer additional monetary premiums beyond the basic sum of $20 for superior performance on certain tasks, as an added incentive for participants to perform well on the tasks they are given.

If interested please reply with your:

- Name: - Contact phone number: - Email: - Academic field of study:

Early replies are encouraged because of the limited number of slots available. Thank you very much for your time. If you have any questions, please contact me at s.lai@fisheries.ubc.ca.

Sincerely,
Sherman Lai
Primary Investigator
UBC MSc candidate Computer Science
(s.lai@fisheries.ubc.ca, tel: 604-889-4852)
Kellogg Booth
UBC Professor Computer Science

(ksbooth@cs.ubc.ca, tel: 604-822-8193)
Villy Christensen
UBC Associate Professor Fisheries Centre
(v.christensen@fisheries.ubc.ca, tel: 604-822-5751)

A.2 Acceptation of participation

Subject: Fisheries/Comp. Sci. User Study: Acceptation of Participation

Dear,

Thank you for choosing to participate in this user study. You are reminded that you must be an undergraduate have little to no understanding of Ecosystem Modeling (mathematical representation of ecosystems). If you do not fall in the above category, please notify me (s.lai@fisheries.ubc.ca) as soon as possible.

This study will take less than 2 hours of your time. You will be asked to work with 2 other students to make decisions to come up with fishing policies. The location of the study will be on the UBC main campus, at 2202 Main Mall. More information will be available through the URL below.

The following steps will be required:

1) Read and understand the ethics documented provided at the end of the link and attached to this email.

2) Select the time you are available using your user ID: 100 as your name at (http://www.doodle.ch/).

3) Read the URL (http://someurl.com). Do not share this document with any potential participants. Take the sample test at the end of this URL. When you are finished with the sample test, you will be able to select your available times. If you cannot make any of the following times, please contact me.

You will have 48 hours to answer this email. If you do not get a response 24 hours after you have submitted your test via the website, please let me know ASAP. Thank you very much for this, your time is well appreciated.

Sincerely, Sherman Lai

A.3 Email to confirm study

Subject: Fisheries/Comp. Sci. User Study: Confirmation of Study

Dear,

Thank you for taking the time for participating in this study. By this time you should have successfully read the ethics and preparatory document.

You are now confirmed to take part in the main study. Please meet me at the following time and location.

Location: 2202 Main Mall (AERL) 3rd floor Immersion lab. Proceed to the 3rd floor via the elevator. Turn right and right into loft area 311. Proceed through printers area and turn left. Immersion lab will be straight ahead.

Time: Your allotted time is tomorrow, Tuesday at 4pm to 6pm. If you cannot make this time, please let me know ASAP. Please show up 5 minutes early.

If any plans changes, please let me know ASAP.

Sincerely, Sherman Lai

A.4 Email reject participation

Subject: Fisheries/Comp. Sci. User Study: Study Full

Dear,

Thank you for your interest in our Fisheries/Computer Science user study. I regret to inform you that our study is now full and will not require your participation. Thank you for your time.

Sincerely, Sherman Lai

A.5 Ethics consent form

Ethics consent forms in two pages, of Figure A.1 and A.2.

THE UNIVERSITY OF BRITISH COLUMBIA

November 19, 2007

Department of Computer Science
201-2366 Main Mall
Vancouver, B.C., Canada V6T 1Z4
Tel: (604) 822-9289 Fax: (604) 822-5485
www.cs.ubc.ca

Video Consent Form for Fisheries Management Study

Principal Investigator:

Dr. Kellogg S. Booth, Professor, Department of Computer Science
Email: ksbooth@cs.ubc.ca Tel: (604) 822-8193

Co-Investigators:

Dr. Villy Christensen, Associate Professor, Fisheries Centre
Email: v.christensen@fisheries.ubc.ca Tel: (604) 822-5751

Sherman Lai,, M.Sc. Student, Department of Computer Science
Email: s.lai@fisheries.ubc.ca Tel: (604) 822-0293

Study Purpose and Procedures

This study is designed to investigate how people interact through decision making tasks in the field of fisheries management. The purpose of the study is to gather information that can aid in the design and improvement of existing collaborative decision making software. You will be asked to do some preparatory reading, as well as answer a few questions related to fisheries management, and then work in a group of 3 people to come up with a fishing policy for a simulated management scenario. We will record and analyze your performance of the tasks. You will be asked to complete a questionnaire at the end of the study, and we may ask you questions on your impressions of certain features of the software. The study session will last no more than 2 hours. This session may be videotaped; videotapes will be used for analysis purposes only. You may choose to not be videotaped.

We are happy to answer any questions or concerns you may have regarding the study's purpose or procedures.

This research is funded by NSERC and the Network for Effective Collaboration Technology through Advanced Research (NECTAR). Portions of this research will go towards a graduate thesis.

Confidentiality

Your identity will remain anonymous and will be kept confidential. Data and tapes will be kept in a locked filing cabinet in the offices of the principal and/or co-investigators. All data from individual participants will be coded so that your anonymity will be protected in any reports, papers, and presentations that result from this work.

Figure A.1: Ethics consent form with video.

THE UNIVERSITY OF BRITISH COLUMBIA

Remuneration/Compensation

You will receive an honorarium of $20 for your participation. You may refuse to participate or withdraw from the study at any time. You will receive your honorarium even if you withdraw from the study. You will be offered a full study debriefing at the end of your session and we will be happy to brief you with the results of this study upon its completion.

Contact information about the Study

If you have any questions or require further information about the study you may contact Dr. Kellogg Booth at (604) 822-8193.

Contact for information about the rights of research subjects

If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at 604-822-8598.

Consent

We intend for your experience in this study to be pleasant and stress-free. Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time. You may refuse to be videotaped at any time during the study.

Your signature below indicates that you have received a copy of this consent form for your own records.

Your signature indicates that you consent to be videotaped during this study. You do not waive any legal rights by signing this consent form.

I, ______________________________, agree to be videotaped during the study as outlined above. This agreement is voluntary and I understand that I am free to refuse at any time to be videotaped.

____

Participant's Signature Date

____

Researcher's Signature Date

Version 1.0 / Nov. 19, 2007
Page 2 of 2

Figure A.2: Ethics consent form with video.

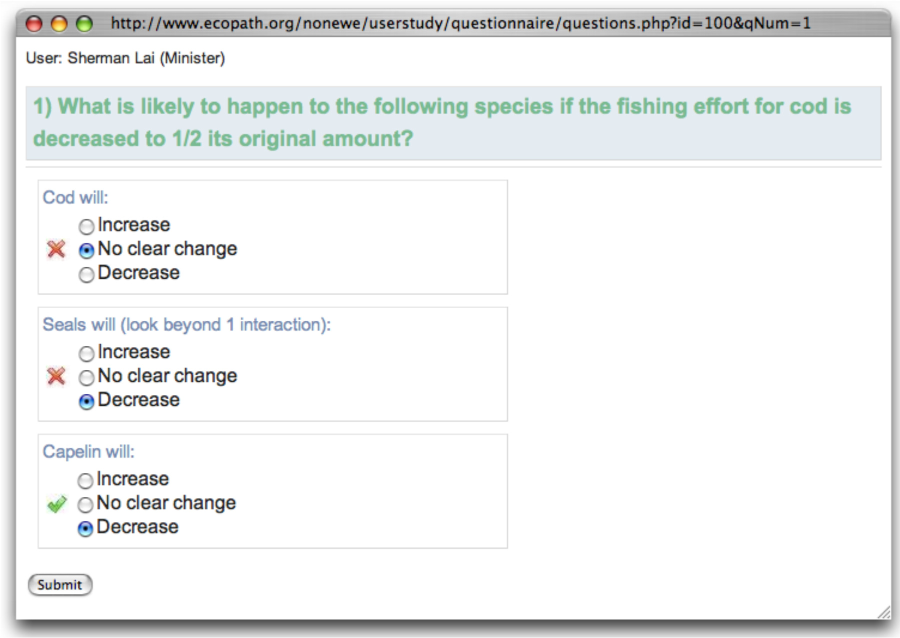


Figure A.3: Sample quiz question as taken by participants. Here shown, the user has made two mistakes and has to try hit "submit" button again. The "submit" button will only change to "Next" when the participants have gotten all the sub answers correct.

A.6 Pre-quiz

Quizzes are in a url format as seen in Figure A.3. The quizzes are multiple choice in the format of one main question that pertains to multiple sub questions. Listed below are all the questions with sub questions and choices. The sub question and answer choices are in separate lines. The main questions are numbered and corresponds to the green words in the figure. The sub questions which are highlighted in italics corresponds to the blue text. The choices are delimitated by " : " and corresponds to the black text.
1) What is likely to happen to the following species if the fishing effort for cod is decreased to 1/2 its original amount?

Cod will: Increase : No clear change : Decrease

Seals will (look beyond 1 interaction): Increase : No clear change : Decrease

Capelin will: Increase : No clear change : Decrease

2) What is likely to happen to the following species if the fishing effort for capelin is increased to 1.5 times its original amount?

Cod will: Increase : No clear change : Decrease

Seals will: Increase : No clear change : Decrease

Benthic Fish will: Increase : No clear change : Decrease

3) What is your role in this summit?

Personally interested in: Fishing profits : Jobs : Biomass of certain species : Biomass

As a group you can only directly modify: Biomass : Fishing Effort : Catches : Jobs : Group interactions

4a) Choose the appropriate outcome for the following situations, over a period of 20 years.

If cod fishing effort were doubled from the original and catches increased accordingly, there would be: 20 times as many cod jobs : 10 as many cod jobs : No change in cod jobs : 5 times as many cod jobs

If shrimp fishing effort were decreased to half the original and catches increased accordingly, there would be: 20 times as many shrimp jobs : 10 as many shrimp jobs : No change in shrimp jobs : 5 times as many shrimp jobs

4b) Choose the appropriate outcome for the following situations, over a period of 20 years.

If effort increases and catch decreases for seals, your profit from seal fishing will: Increase : No change : Decrease : No clear change

If catches increases for shrimp with no change in effort, your profit from shrimp fishing will: Increase : No change : Decrease : No clear change

4c) Choose the appropriate outcome for the following situations, over a period of 20 years.

If the biomass of seals were to increase to twice the original amount, the contribution of seals to the Ecosystem structure *would be*: increased with 13.3 times more seal structure : decrease by 3.33 more seal structure : No change in seals structure : No overall change

If the biomass of cod were to decrease to 1/2 the original amount, the contribution of cod to the Ecosystem structure would be: increase with 1.84 times more cod structure : decrease 0.47 times less cod structure : No change in cod structure : No overall change

5) What were to happen to the Cod in the ecosystem if, over a period of 20 years :

Shrimp effort were to decrease to 0: Drastic increase : Minimal increase : No change : Minimal decrease : Drastic decrease

Capelin effort were to increase to 10: Drastic increase : Minimal increase : No change : Minimal decrease : Drastic decrease

A.7 Post-quiz

This post-quiz has the exact same format as the pre-quiz as seen in A.6.
6) What is likely to happen to the following species if the fishing effort for cod is decreased to 1/2 its original amount?

Cod will: Increase : No clear change : Decrease

Seals will (look beyond 1 interaction): Increase : No clear change : Decrease

Capelin will: Increase : No clear change : Decrease

7) What is likely to happen to the following species if the fishing effort for capelin is increased to 1.5 times its original amount?

Cod will: Increase : No clear change : Decrease

Seals will: Increase : No clear change : Decrease

Benthic Fish will: Increase : No clear change : Decrease

8) What is your role in this summit?

Personally interested in: Fishing profits : Jobs : Biomass of certain species : Biomass

As a group you can only directly modify: Biomass : Fishing Effort : Catches : Jobs : Group interactions

9a) Choose the appropriate outcome for the following situations, over a period of 20 years.

> *If cod fishing effort were doubled from the original and catches increased accordingly, there would be*: 20 times as many cod jobs : 10 as many cod jobs : No change in cod jobs : 5 times as many cod jobs
>
> *If shrimp fishing effort were decreased to half the original and catches increased accordingly, there would be*: 20 times as many shrimp jobs : 10 as many shrimp jobs : No change in shrimp jobs : 5 times as many shrimp jobs

9b) Choose the appropriate outcome for the following situations, over a period of 20 years.

> *If effort increases and catch decreases for seals, your profit from seal fishing will*: Increase : No change : Decrease : No clear change
>
> *If catches increases for shrimp with no change in effort, your profit from shrimp fishing will*: Increase : No change : Decrease : No clear change

9c) Choose the appropriate outcome for the following situations, over a period of 20 years.

> *If the biomass of seals were to increase to twice the original amount, the contribution of seals to the Ecosystem structure would be*: increased with 13.3 times more seal structure : decrease by 3.33 more seal structure : No change in seals structure : No overall change
>
> *If the biomass of cod were to decrease to 1/2 the original amount, the contribution of cod to the Ecosystem structure would be*: increase with 1.84 times more cod structure : decrease 0.47 times less cod structure : No change in cod structure : No overall change

10) What were to happen to the Cod in the ecosystem if, over a period of 20 years :

> *Shrimp effort were to decrease to 0*: Drastic increase : Minimal increase : No change : Minimal decrease : Drastic decrease
>
> *Capelin effort were to increase to 10*: Drastic increase : Minimal increase : No change : Minimal decrease : Drastic decrease

11) What is the primary interest for each participant during the summit?

    The Fisher was interested in: Catches : Effort : Jobs : Profit : Overall outcome : Biomass

    The NGO was interested in: Catches : Effort : Jobs : Profit : Overall outcome : Biomass

    The Minister was interested in: Catches : Effort : Jobs : Profit : Overall outcome : Biomass

12) How successful in terms of primary interest do you think each role did?

    The Fisher: Very successful : Slightly successful : Average : Below average : Not successful

    NGO: Very successful : Slightly successful : Average : Below average : Not successful

    Minister: Very successful : Slightly successful : Average : Below average : Not successful

13) Rate the level of satisfaction for each of the following.

    The Fisher: Very happy : Slightly happy : Average : Below average : Not happy

    NGO: Very happy : Slightly happy : Average : Below average : Not happy

    Minister: Very happy : Slightly happy : Average : Below average : Not happy

14) Rate the following, 1 being the hardest, 5 being the easiest.

    Ease of sharing results between one another: 1 : 2 : 3 : 4 : 5

    Ease of communicating ideas between one another based on results: 1 : 2 : 3 : 4 : 5

    Usability of the software: 1 : 2 : 3 : 4 : 5

15) How do you think everyone did as a group?

    The group success in terms of primary interest was: Very successful : Slightly successful : Average : Below average : Not successful

    The group happiness was: Very happy : Slightly happy : Average : Below average : Not happy

16) Overall questions?

> *To come to a consensus, we needed*: A lot more time : A few more minutes : We finished in time : We finished early : We finished very early
>
> *The software was*: Very easy to use : Easy to use : Average : Hard : Very hard
>
> *My understanding of Ecosystem modeling is now*: Very good : Above average : Average : Below average : Very bad

A.8 Facilitator script describing example

Below is the script for facilitator to read verbatim before the stripped down software.

> On this screen you can see fishing effort as described in the document. There are four fishing effort graphs for Seals, Cod, Shrimp and Capelin. You can individually increase or decrease any combination of fishing effort in this simulator [as the facilitator modifies the graphs as an example, then sets them all back to 1]. Here you have the relative biomass over time produced from the simulator.
>
> As a group, you have to agree on a fishing policy or fishing effort. When all of you agree as a group, I will run he simulator and you will all see on this screen biomass [as the facilitator points to the biomass screen]. The rules are infront of you. Do you have any question?
>
> Let's quickly go over the examples described in the document. Let's say you were to agree on increase in Cod's fishing effort, and run the simulator, you'll see cod's biomass go down (Increase Cod's effort to 1.5 and point to biomass screen). Since less cod eat less shrimp and capelin, their biomass increase.
>
> Can someone explain why the biomass of Shrimp increases more than capelin? [Wait for an answer]. Yes, this is because there is less food for Benthic Fish thus decline in biomass and thus less predation in on Shrimp. Any questions? [Wait for any questions and proceed when participants are ready.]
>
> Let's take another scenario. When you increase fishing effort for the seals to 1.5. (Set all biomass to 1 except 1.5 for seals and run

> he simulator). You'll see that the biomass of seals decline. This leads to more cod. With more cod, will lead to less of it's pray, capelin and shrimp as you can see pink and brown going down. Does this make sense? [facilitator will answer any questions?]
>
> For now you are asked to modify the fishing effort as a group, and come to a fishing policy decision using what you see, fishing effort and biomass, based purely on your estimated scores, or what you think your scores will likely be. Your scores will not be shown to you in this round. The results will be recorded and your results will be used for a the first set of prize money. You have 15 minutes to come to this conclusion. You will be given $20 for your best individual score vs other groups, and $25 if you have the highest group score vs. all the other group. If you don't have any other questions, you may start.

A.9 Facilitator script describing full software

Below is the script for facilitator to read verbatim before the full software.

> In this phase of the project, you are now given your indicators that are described in the document in-front of you. These are your personal indicators and you are reminded not to share how these values are computed. Saying weather you like it or not is a fair game. Your task is the same where you have to come to one single fishing policy you all agree on based on your individual indicators. You have 30 minutes to come to this conclusion. Again, you will be given $20 for your best individual score against other groups, and $25 if you have the highest group score against all the other group. If you don't have any other questions, you may start.

A.10 User study prep-document

Sample of document given to surrogate participant before the summit see in Figures A.4 A.5 A.6 A.7 A.8 A.9. The document provided to the other participants were identical except for the description of stakeholder interest.

http://www.ecopath.org/nonewe/userstudy/index.php?id=2 04/12/07 12:04 PM

User Study Prep-Document

This document will walk you through what to expect during the user study. It will give you a general idea of how ecosystem modeling works, as well as a brief understanding of the ecosystem you will be exploring. For this study to be successful, you should understand the material in this document so you do not get "left behind" during the user study.

Objective

Your role is a Fisher. Your only objective is to maximize fishing profit by ensuring fishing for sustainable fishes. You will be working with two other participants whom have roles of Non-Governmental Organization (objective = Ecosystem structure), and Fishing Minister (objective = jobs). The three of you will work as a group to set fishing policies which will impact each person's objective.

Ecosystem Modeling Basics

An *ecosystem* is defined as a combined community of organisms and the environment in which they live, and through which they interact. *Ecosystem modeling* is the process of describing an ecosystem in terms of the interactions within an ecosystem, using a formal model that tries to emulate reality as closely as possible. In this study, we will be analyzing a hypothetical scenario using an ecosystem modeling tool (an actual computer program) to explore and forecast ecosystem trends. The reason for exploring scenarios is to assist in setting fishing policy in a particular region for the next 20 years.

More specifically, you will be looking at an ecosystem which is modeled based on the North Atlantic, an area where fishery on the northern cod stocks have thrived for centuries. This ecosystem is of particular interest to us because cod stocks in the region were severely depleted in in the 1990's, which led to growing concerns that cod would never replenish and eventually may be going extinct. The stop to cod fisheries that the region has witnessed for more than a decade has led to severe hardship for many people traditionally involved in cod fisheries in the area. You will be working with other stakeholders in this scenario to come up with a set of fishing policies that best fits the different stakeholder objectives. You will be in charge of maximizing your objectives as specified later in this document.

The software you will be using will have the appropriate data on groups/organisms/fishing in this ecosystem, as well as a semi-realistic model that describe their interactions. With this information, the software model can figure out who eats what and how much as described schematically below in the food web diagram (Figure 1). Knowing the food web and how much fishing is done over time, (here known as 'fishing effort'), the software predicts the population size (called 'biomass') of each species that will exist in the future, and returns results to the user.

http://www.ecopath.org/nonewe/userstudy/index.php?id=2 Page 1 of 6

Figure A.4: User preparation document give to participants that have Fishers as roles.

A.11 Rules and food web diagram

Food web diagram see in Figure A.10.

http://www.ecopath.org/nonewe/userstudy/index.php?id=2 04/12/07 12:04 PM

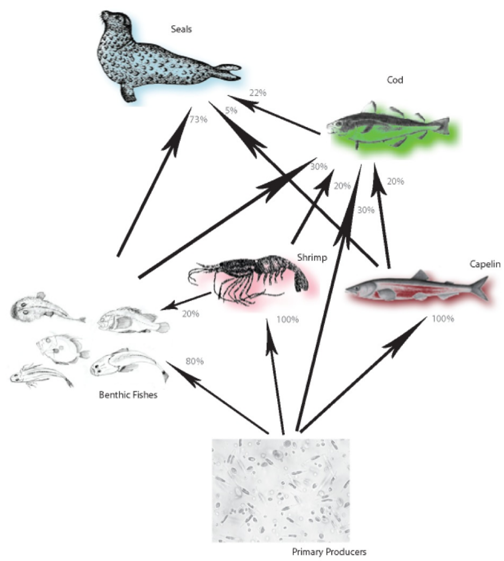


Figure 1 - Food web diagram showing the interactions among organisms (not drawn to size) in the model you will be evaluating. Here seen, the diet of seals are 73% benthic fish, 5% Capelin and 22% Cod. Cod in turn eats 30% benthic fish, 20% Shrimp, 30% Primary Producers and 20% Capelin (a small forage fish).

Participant instructions

As a participant in this user study, you will be asked to work with 2 other people in specific roles to come up with a fishing policy solution that all parties will be content with. You do however need to keep in mind that you (in principle) will have to answer to your constituency for your fishing policy, e.g., that the minister will have to consider what impact the outcome will have come election day. During this study you will be asked as a group to discuss the data presented in this scenario, and modify the fishing effort parameters with the help of a facilitator to come to a working solution. Using the software provided, the facilitator will enter and modify parameters based on your group's cumulative suggestions, and the results will be made visible on a display. The facilitator will take on a passive role, and be specifically instructed to only modify fishing efforts and invoke the simulation through the software. The facilitator will not answer any questions related to the study and will only perform modelling functions on the software.

The scenarios you will be working with will present data and models that are simplified to facilitate your understanding. A description of basic food web chains and other aspects of ecosystem modelling are described in the following section. (More complex ecology such as carrying capacity, by-catches, and foraging arena theory have been built into the software but are not relevant for developing this exercise).

http://www.ecopath.org/nonewe/userstudy/index.php?id=2 Page 2 of 6

Figure A.5: User preparation document give to participants that have Fishers as roles.

http://www.ecopath.org/nonewe/userstudy/index.php?id=2 04/12/07 12:04 PM

Important Concepts

To demonstrate how basic ecological models work, we will present some simple examples. The first example is related to the the northern seal/cod issue that will be used in the study. We describe in the food web diagram above (Figure 1) a food web involving seals, cod, capelin, and shrimp. We describe some of the basic interactions between the four organisms in this food web.

A simple situation to describe is when the fishing effort for cod increases as more fishers will seek to catch more cod. The result of this will likely be a decrease in the biomass of cod. The typical seal diet includes approximately 22% cod; as a result of a decrease in cod, the seals will have also less food and thus would experience a decrease in population size (and therefore, biomass). Capelin would likely increases because cod and seal both consume capelin. Also, since shrimp and capelin is eaten by cod, the result of the decline in cod should also lead to an increase in shrimp and capelin. Further, Benthic fish have less to eat thus decreasing which leads to less predation on shrimp. This behavior can be observed on inspection of (Figure 2) below. On the left, fishing effort is slowly increased over time by one and half times (as seen in the light green graph on the left), compared to the baseline amount prior to the 1980s. On the right, we can see the relative changes in biomass for each group.

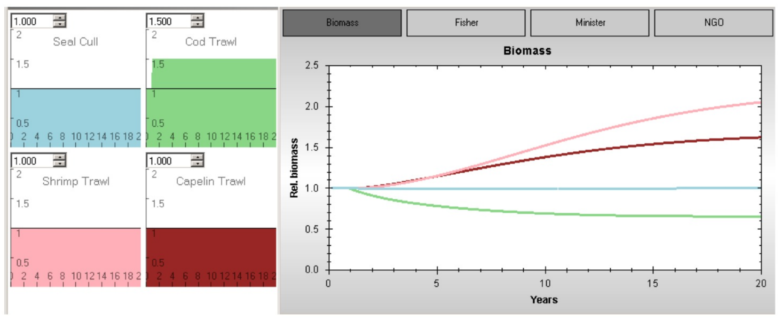


Figure 2 - Interface you will be using during the study. Here shows an increase in Cod fishing effort (green) to 1.5. One can see the cod biomass on the right-side plot decrease while the shrimp (pink) and capelin (brown) biomassincreases.

> We will provide another example of how the ecosystem is affected by changes in fishing effort, from a real world example. Some years ago, while the cod fisheries were stopped, the honourable Mr. Brian Tobin (at the time Canada's Minister of Fisheries and Ocean) stated that it was "...intellectually dishonest to claim that seals have not had a significant impact on recovering fish stocks... There is only one major player fishing that stock," he said, "and his first name is Harp and his second name is Seal". "The seals" , Mr. Tobin concluded, "must ...be harvested...in the context of building the groundfish [Benthic and cod] stocks".

Mr. Tobin believed that culling the seals would increase the cod, as predicted in the first scenario in (Figure 3) below, which can be expressed as a decrease in seal biomass, and an increase in cod biomass. Under the assumption that culling seals would lead to more cod being available to harvest, fishers started to target both cod and seal more aggressively (e.g., for every twofold increase in seal culling, fishers would fish twice as many cod) as seen in the lower (Figure 4) below. Unfortunately, this had the unexpected effect of causing both the cod and seal populations to crash.

This was partially due to the fact (as assumed in the model at least) that the typical seal diet was only 25% cod, which meant that culling seals would not lead to a large enough increase in cod stocks to justify what fishers believed to be a proportional increase in cod fishing. Due to the lack of knowledge and mismanagement surrounding the fisheries at this time, this situation was not accurately foreseen.

http://www.ecopath.org/nonewe/userstudy/index.php?id=2 Page 3 of 6

Figure A.6: User preparation document give to participants that have Fishers as roles.

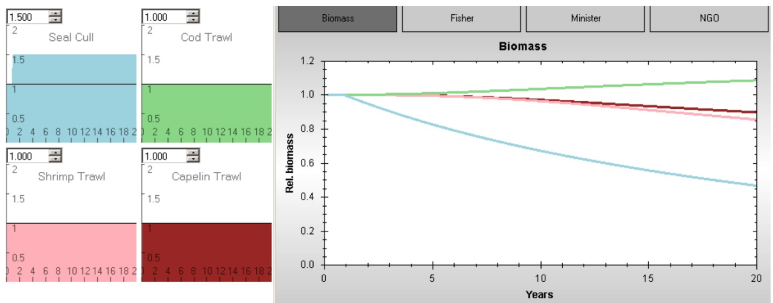


Figure 3 - Here shows an increase in Seal Cull (blue) to 1.5.
One can see the seal biomass on the right decrease while the cod (green) increases minimally.

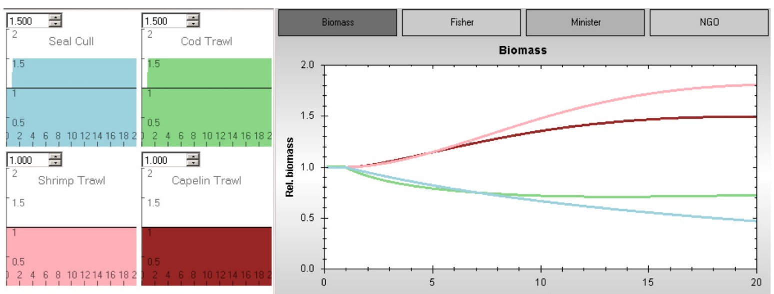


Figure 4 - Here shows an increase in Seal Cull (blue) and Cod Trawl (green) to 1.5.
One can see the biomass on the right decrease while the Capelin (brown) increases.

Here are some relevant ecosystem modeling terms:

- *Species/Group - A distinct class of living creature with features that distinguish it from others. In this model, it could be cod, seals and various other*
- *Fishing Effort – The total fishing gear in use for a specified period of time (http://www.streamnet.org/pub-ed/ff/Glossary/glossaryfish.html). For this study, we are only interested in the relative fishing effort compared to the baseline level. This could be any unit because it is a relative value. Note it always starts with 1 because fishing effort at year1/year1 = 1. This data is visualized by the top left in figure 4 The Y-axis is Year, and the X-axis is relative amount. (in*
- *Biomass – the amount (in weight units) of each species. For this study, we are only interested in the relative biomass, meaning the percentage change from the starting amount. This figure is visualized in this study by figure 4 right of fishing effort.*

Commercial Fisher

Figure A.7: User preparation document give to participants that have Fishers as roles.

In this study, you will be asked to take on the role of a commercial fisher. You will be primarily interested in personal profit over the entire fishing period of 20 years. Your profits are calculated by the equation below. In plain English, the equation says that the profit in the fishing industry is the proportion of catches in the industry minus the effort of fishing. Ignore the formula below if it is too complicated.

$$Profit(f)(t) = \sum_{f=0}^{4} \sum_{t=0}^{20} (Catch_{f,t})(Price_f) - Q_f(Effort_{f,t})$$

Where *f* is the 4 targeted species cod and seals, and *t is time from 0 to 20 years. Catch* is the amount of biomass that is put onto the boat and sold. *Q is a constant that is constant for every fleet, you can treat this as 1 for simplistic purposes. Effort* is fishing effort, the amount of work that the fleet puts into fishing, i.e. number of days at sea. *Price* is the market value of a given species which is described in the table below and does not change over time.

Group name	Price
Harp Seal	4
Cod	0.6
Shrimp	2
Capelin	0.1

Ultimately, you are interested in the highest *fishing effort* without crashing the stock (biomass gets too low that makes it harder to catch). Crashing stocks with high effort would lead to low profit. Harp Seals and Shrimp are by far more profitable than Cod and Capelin.

Sample Quiz

T1) What is likely to happen to the following species if the biomass for shrimp increases to 3 times the original amount?

- Cod will:
  - Increase
  - No change
  - Decrease
  - No computable change
- Benthic Fish will:
  - Increase
  - No change
  - Decrease
  - No computable change
- Capelin will
  - Increase
  - No change
  - Decrease
  - No computable change

T2) What is likely to happen to the following species when the biomass for benthic fish decreases to 1/2 its original amount?

- Shrimp will:
  - Increase
  - No Change
  - Decrease
  - No computable change
- Cod will

Figure A.8: User preparation document give to participants that have Fishers as roles.

- Increase
- No change
- Decrease
- No computable change

- Seals will:
  - Increase
  - No change
  - Decrease
  - No computable change

Prizes

Again, you will be given $20 for your participation. There will be two quizzes, one before the study about this document and one after the study. You will also have a chance to win extra money in the following manners:

- Win $20 extra dollars for the **least incorrect answers** for each of the two quizzes.
- Win $20 extra if you attain the highest individual score between all the other participating groups of your same role for both the pre test and post test simulators.
- Win $25 extra if your group gets the highest overall score.

Overall, you will have the chance to attain as much as $145 dollars if you win all prizes. On average, you are likely to win $30. You will have this print-out available during the user study.

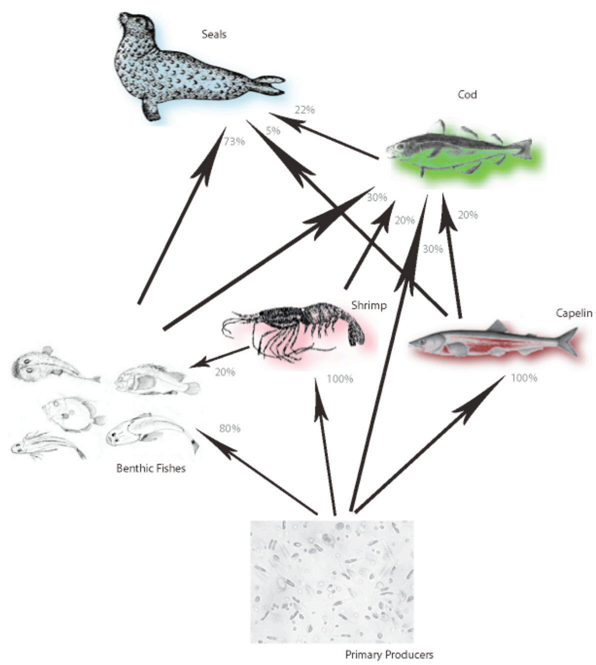
Confirmation of time

If you haven't already done so, please go to the following link: http://www.doodle.ch/qqv2vpvk6vebf86v to select the times you are available. You must use your USER ID: **2** as your name.

- [ ] I certify that I am Test User.
- [ ] I have read and understood the ethics document attached in the email or linked here.

Submit

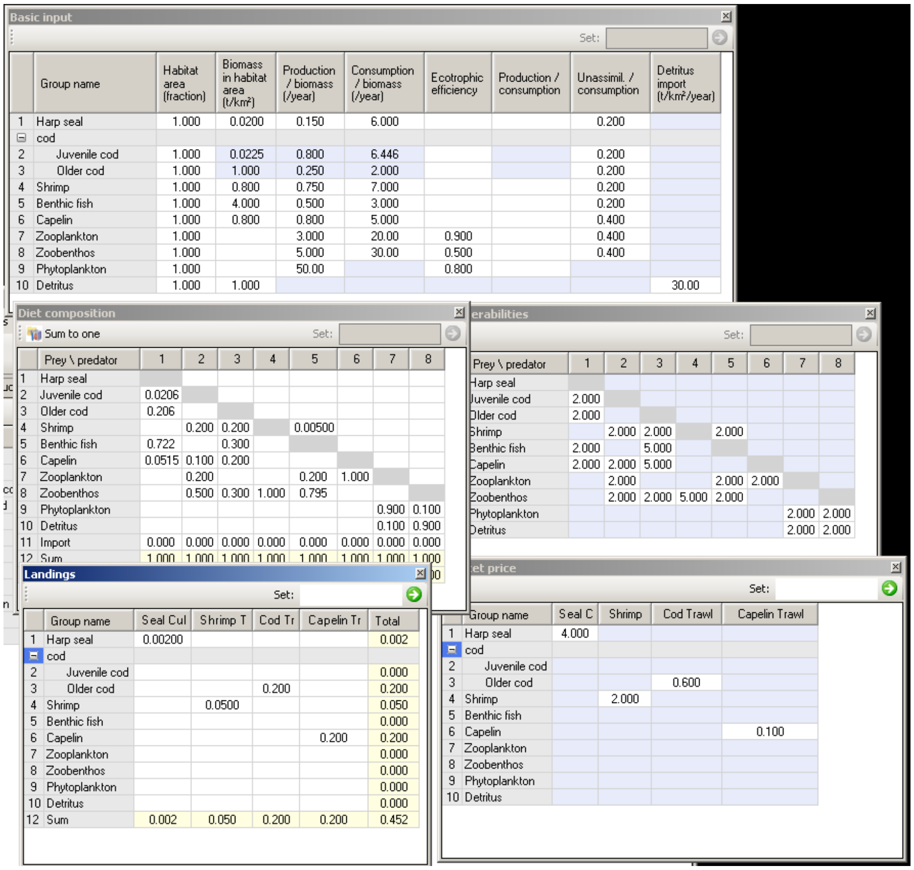
Figure A.9: User preparation document give to participants that have Fishers as roles.



Rules:

- You are asked not to peak at other's screen (if applicable)
- You are asked not to share your results or how your results are derived. Saying I like this results better is fair game, but saying your exact number is disallowed.
- One can run the simulation only when all parties agree;
- You can have as many runs as you'd like, but only the last scenario will count.
- If time runs out, the last scenario on the screen will be your final answer.
- I will let you know how much time you have left or at 10 minutes, 5 minutes, 2 minutes, 1 minute and 10 seconds.

Figure A.10: Rules and the food web diagram. This document is placed in front of each participant for quick reference.



Basic input

	Group name	Habitat area (fraction)	Biomass in habitat area (t/km²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Production / consumption	Unassimil. / consumption	Detritus import (t/km²/year)
1	Harp seal	1.000	0.0200	0.150	6.000			0.200	
	cod								
2	Juvenile cod	1.000	0.0225	0.800	6.446			0.200	
3	Older cod	1.000	1.000	0.250	2.000			0.200	
4	Shrimp	1.000	0.800	0.750	7.000			0.200	
5	Benthic fish	1.000	4.000	0.500	3.000			0.200	
6	Capelin	1.000	0.800	0.800	5.000			0.400	
7	Zooplankton	1.000		3.000	20.00	0.900		0.400	
8	Zoobenthos	1.000		5.000	30.00	0.500		0.400	
9	Phytoplankton	1.000		50.00		0.800			
10	Detritus	1.000	1.000						30.00

Diet composition

Sum to one

	Prey \ predator	1	2	3	4	5	6	7	8
1	Harp seal								
2	Juvenile cod	0.0206							
3	Older cod	0.206							
4	Shrimp		0.200	0.200		0.00500			
5	Benthic fish	0.722		0.300					
6	Capelin	0.0515	0.100	0.200					
7	Zooplankton		0.200			0.200	1.000		
8	Zoobenthos		0.500	0.300	1.000	0.795			
9	Phytoplankton							0.900	0.100
10	Detritus							0.100	0.900
11	Import	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

erabilities

Prey \ predator	1	2	3	4	5	6	7	8
Harp seal								
Juvenile cod	2.000							
Older cod	2.000							
Shrimp		2.000	2.000		2.000			
Benthic fish	2.000		5.000					
Capelin	2.000	2.000	5.000					
Zooplankton		2.000			2.000	2.000		
Zoobenthos		2.000	2.000	5.000	2.000			
Phytoplankton							2.000	2.000
Detritus							2.000	2.000

Landings

	Group name	Seal Cul	Shrimp T	Cod Tr	Capelin Tr	Total
1	Harp seal	0.00200				0.002
	cod					
2	Juvenile cod					0.000
3	Older cod			0.200		0.200
4	Shrimp		0.0500			0.050
5	Benthic fish					0.000
6	Capelin				0.200	0.200
7	Zooplankton					0.000
8	Zoobenthos					0.000
9	Phytoplankton					0.000
10	Detritus					0.000
12	Sum	0.002	0.050	0.200	0.200	0.452

et price

	Group name	Seal C	Shrimp	Cod Trawl	Capelin Trawl
1	Harp seal	4.000			
	cod				
2	Juvenile cod				
3	Older cod			0.600	
4	Shrimp		2.000		
5	Benthic fish				
6	Capelin				0.100
7	Zooplankton				
8	Zoobenthos				
9	Phytoplankton				
10	Detritus				

Figure A.11: Required parameters from EwE6 to replicate the Seal Cod model used in the user study.

A.12 Seal Cod Model

Figure A.11 shows the seal cod model used for the user study.

A.13 Ethics certification

Ethics approval seen in Figure A.12.

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL - FULL BOARD

PRINCIPAL INVESTIGATOR:	INSTITUTION / DEPARTMENT:	UBC BREB NUMBER:
Kellogg S. Booth	UBC/Science/Computer Science	H07-02147

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
N/A

CO-INVESTIGATOR(S):
Villy Christensen
Sherman Lai

SPONSORING AGENCIES:
Natural Sciences and Engineering Research Council of Canada (NSERC)

PROJECT TITLE:
Shared vs Private Displays for Collaborative Policy Discussions About Fisheries

REB MEETING DATE:	CERTIFICATE EXPIRY DATE:
November 8, 2007	**November 8, 2008**

DOCUMENTS INCLUDED IN THIS APPROVAL:	DATE APPROVED: November 27, 2007

Document Name	Version	Date
Consent Forms:		
Video Consent Form	Version 1.0	November 19, 2007
Participation Consent Form	Verson 2.0	November 19, 2007
Advertisements:		
Advertisement to Recruit Subjects	Verson 2.0	November 19, 2007
Questionnaire, Questionnaire Cover Letter, Tests:		
Questionnaire (All pre and post test)	1.01	October 11, 2007
Letter of Initial Contact:		
Letter of rejection	1.01	October 8, 2007
Letter of Initial Contact	Verson 2.0	November 19, 2007
Letter of Confirmation	1.01	October 8, 2007
Other Documents:		
User Study Prep-Document - NGO	1.01	October 8, 2007
User Study Prep-Document - Fisher	1.01	October 8, 2007
Sample URL Based Questionnaire	1.01	October 11, 2007
User Study Prep-Document - Minister	1.01	October 8, 2007

Other:
http://www.ecopath.org/nonewe/userstudy/index.php?id=12345 - the id will determine which of the three attached UserStudyPrepDocument (Minister, NGO, Fisher).
http://www.ecopath.org/nonewe/userstudy/questionnaire/questions.php?id=12345&qNum=1 - the ID will determine the user, qNum will determine the question number. All the questions are listed in the Questionnaire document. They will be in the above format.

The application for ethical review and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board and signed electronically by one of the following:

Dr. M. Judith Lynam, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair

Figure A.12: Ethics approval.