

Community-Integrated GIS in the Bay of Fundy Groundfishery

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Abstract

This paper is designed to examine the development of Community-Integrated Geographic Information Systems (CIGIS) in the marine environment. Through a review of a mapping project, whose information base is Traditional Ecological Knowledge (TEK) of spawning and nursery areas of the groundfishery in the Bay of Fundy, Canada, recommendations on data collection, database development, and data visualization are made for their incorporation into a GIS. This paper addresses how CIGIS may be useful not only for the constituents whose knowledge is the basis of the database, but for the fisheries managers who should consider this data in the overall framework of the decision-making process. Conclusions indicate that database development needs to start with the highest resolution possible. In dealing with local knowledge the dataset needs to be fully inclusive of all responses even when the information may not be validated by another source. A ranking system would separate unsubstantiated responses and validated responses. Visualization of local knowledge should also follow the same level of resolution as the database and, where possible, be confined to a single data point. More detailed information on the site should be incorporated as text into the metadata or as an actual record in the attribute table.

COMMUNITY-INTEGRATED GEOGRAPHIC INFORMATION SYSTEMS

Community-integrated geographic information systems (CIGIS) have developed to help democratize a process that had previously been solely in the domain of governmental management agencies, industry, and academia. GIS has the power to create maps that appear to be authoritative even when the process by which they were created might have been biased. Community-integration of GIS allows for community groups to have their points of view appear in the spatial domain. This works to help groups become technologically represented on the same level as managers. However, there are those (Harris & Weiner, 1998) that support the thought that GIS is, and will continue to be, both a democratizing and marginalizing force as different groups work to voice their opinion via GIS. They suggest that there is little evidence of genuinely “community-based” GIS, despite such stated intentions. Communities are becoming involved with GIS projects, but they are not in control of these projects and remain dependent on state agencies, NGOs, external funding, and technically oriented advocates. In the opinion of Harris and Weiner (1998), and this author as well, “community-integrated” GIS is a realistic objective for alternative systems and applications for geographic information systems. Traditional ecological knowledge (TEK) is only one type of data that a group

may pursue in the development of a CIGIS. Anybody can provide TEK for incorporation into a GIS but the process of doing it whereby the community is integrated into the development of the final product with facilitation by management is what makes CIGIS more meaningful to the community.

Both GIS for fisheries management and community-integrated GIS pose several challenges that the Bay of Fundy groundfish project will strive to address. Among these challenges are (previously postulated by Meaden 2000):

1. Data gathering and data standardization.
2. Fuzzy and indeterminate boundaries.
3. Visualization.
4. Organizational problems.
5. Socio-cultural challenges.

It will become clear that all of these challenges present themselves during the course of this project. By describing how these were dealt with in this project it is possible to give others working in this field the ability to better understand the issues as they arise. Data gathering, fuzzy boundaries, and visualization present the most difficult and immediate challenges so they will be dealt with in more detail.

GEOGRAPHIC INFORMATION SYSTEMS IN FISHERIES MANAGEMENT

This project is designed to explore the application of Community-Integrated Geographic Information Systems to the marine environment. The challenges in this effort are two-fold. First, GIS is still considered a new technique in mapping the marine environment. There are many problems that have to be solved relative to mapping dimensions of mapping depth and time. Second, community-integrated GIS, or public participation GIS as it is also known, is an effort to get more participation using a medium that previously operated in a sector that has been poorly represented by the constituents who are most directly affected by its use (Obermeyer 1998). Within CIGIS there are challenges pertaining to the spatial visualization of traditional ecological knowledge and in the development of the database itself.

A brief overview of the reasons GIS is important to the marine environment, and specifically to fisheries management, is necessary background for this study (adapted from Meaden (2000)):

- *The scale of the world's fisheries.* At the world scale, fisheries are the second largest employer after agriculture, with some 300 million persons world-wide employed directly or indirectly.
- *The spatial extent of activity.* With the oceans occupying 71% of the world's surface, and lakes and rivers providing additional water habitats, fisheries are the most spatially extensive economic activity.
- *The plight of the world's fisheries.* Probably 60% of fish stocks are exploited to their maximum sustainable extent, and many other stocks are exploited at a level that, given the present state of knowledge, catches should not be increased. The collapse of the Gulf of Maine/Bay of Fundy groundfishery is a well documented example of a species exploited beyond a sustainable level.
- *Problems are in the spatial domain.* Nearly all problems in fisheries are caused by the fact that the different factors affecting fish populations are in dis-equilibrium (Laevastu and Favorie, 1988; Cushing, 1995; Symes, 1996). Nearly all of this dis-equilibrium can be manifest as disparities in the spatial domain. Many examples exist to illustrate this problem but some notable factors include:
 - Ecosystems have been destroyed, e.g. areas are too heavily trawled, coral reefs are damaged, and mangroves have been removed.
 - Wide areas of the marine environment are suffering from pollution.
 - There is too much fishing effort in specific areas.
 - Many fisheries management systems are poor or ineffective.
 - Climate change is variably affecting marine community distributions.

All the problems listed above are spatially related, and it is just these types of problems that GIS was designed to address. It is also important to note that GIS also has the capability to view these problems in not just two dimensions but in four dimensions. The 3rd and 4th dimensions (depth and time) are extremely important in examining the problems encountered in fisheries management. Other maps and databases do not have the same potential for viewing and analyzing data in these four dimensions as does GIS.

To date, there have been few uses of GIS in fisheries management as compared to use in terrestrial applications. Areas where GIS has been used is in:

1. Site selection for aquaculture and marine protected areas

2. Matching fish distributions to environmental parameters.
3. Modeling fish activity and movement.
4. Analysis of catch and effort.
5. Establishing regional and national fisheries databases.
6. Mapping benthic habitat.

CLASSIFICATION OF BENTHIC MARINE HABITATS

In fisheries management fisheries *dependent* data and fisheries *independent* data are two important sources of information. Fisheries independent data in habitat mapping, such as with spawning and nursery grounds, may include geomorphological classifications and ecological classifications. Examples of geomorphic classes include “sand flats” and “boulder fields”. Geomorphology is often classified by both field work and imaging with remote sensors. In waters of low light attenuation (i.e. the tropics) remote sensors such as satellite and aerial imaging can be sufficient, with minimal groundtruthing, in order to classify geomorphology. In waters with high light attenuation, such as the well-mixed Bay of Fundy, shipboard imaging such as side-scan sonar and imaging from submersibles is required to get similar information. The cost of vessel time is far more expensive than obtaining satellite images. Ecological classifications of habitat can include assemblages of plant and animal species and functional descriptors. “Rockweed beds” and “spawning grounds” are examples of ecological classifications. Ecological information is collected in the same manner as geomorphology but requires far more field survey work and may require finer descriptive resolution in order to tease out zones of transition between classes (Mumby 1999).

Fisheries dependent data is primarily limited to economic information, type of species caught, gear type, and by-catch. Fisheries dependent data is rarely used for habitat classification. This study provides a way by which to include TEK (i.e. fishery dependent data) into the ecological classifications of groundfish nursery and spawning grounds. TEK can give detail on bottom habitat based upon bottom soundings from onboard computers, sediment type and plant and animal species pulled up by different gear types, condition of fish when pulled into the boat (i.e. egg filled, milt flowing), and spatial-temporal information (including perceptions of seasonal fish movement patterns).

Fisheries dependent data, however, cannot supplant independent data. It is unable to provide a complete, unbiased habitat characterization. Because of limitations in TEK it should be labeled, not as a direct ecological classification, but as a *human ecological* classification. A human ecological classification makes it clear that the classification scheme is based upon human interaction with the environment and not a structured scientific survey. Giving it a different name in no way diminishes the information. Instead, it adds an additional level of historical and cultural information to be integrated into a holistic habitat characterization. Because of the cost of field surveys, fisheries dependent data and TEK are often the only information available. If TEK is documented in a database it can prioritize sites in need of additional research. This paper will examine methods by which site information, based on TEK, can be classified by level of certainty.

A CHARACTERIZATION OF THE BAY OF FUNDY GROUND FISHERY

The Biophysical Environment

The Bay of Fundy is a long, narrow body of water bounded by three political jurisdictions: Nova Scotia, Canada to the north and southeast; New Brunswick, Canada to the north and west; and Maine, USA to the southwest. It is 250 km long and 40km across at its widest point. The Bay is considered the northern most extension of the Gulf of Maine. The New Brunswick and Nova Scotia together boasts a population of about a million and a half people most of which live along the provinces' coasts. The Bay of Fundy is characterized by an extremely complex geography including islands, peninsulas, convoluted bays and inlets, and extreme tides, known to be the highest in the world (nearly 16.5 meters at the head of the Bay). The complexity of the Bay lends itself to several commercial fisheries. The most important of these are the lobster fishery, scallop fishery, herring fishery, a number of inter-tidal fisheries, and the groundfishery. Lobster, harvested only by independent boats, makes up the most successful fishery in the region and is presently the backbone of local community economies. Scallops are pursued by a fleet of inshore independent boats on the New Brunswick side and a fleet of mostly company-owned boats based in Nova Scotia. The herring fishery is almost entirely

fished by one company's seiners with the exception of a small number of weirs operating primarily on the New Brunswick side. There are also a number of inter-tidal fisheries, notably for clams, that are especially important in the U.S. portion of the Bay (Brzeki 2001).

The Bay of Fundy groundfishery targets primarily cod, haddock, pollock, and hake. More recently the spiny dogfish has become associated with this fishery. Groundfish in the Maritimes Region of Canada are pursued by two separate fleets. The first is a fleet of inshore boats (under 45 feet in length (FG<45)), using gillnets, long-line, and hand-line fishing gear. These gear types are known as passive or fixed gear as they are fixed in one location. The fixed gear fleet fishes under local community-based management boards that manage and allocate quota within each fishing community. The other groundfish fleet is composed of larger vessels using mobile gear (i.e. otter trawl). These vessels are primarily company-owned and fish under an individual transferable quota (ITQ) system.

The Problems

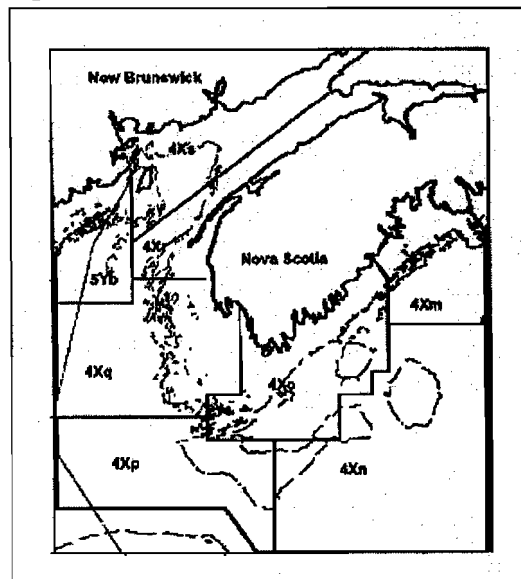
There is a strong feeling by the inshore fishermen that the will of the larger, corporate operated trawlers, or "draggers" as they are known, is directly reflected in the Department of Fisheries and Oceans (DFO) policy and management. With the development of community management boards the inshore, independent fishermen have been able to come together to increase their input to DFO. Most recently there has been a desire on the part of the fixed gear less than 45 feet group to gain more control over the management of their fishery by pushing for a shift in the management of groundfish from that of a level of a large single population to one on the level of localized fish stocks. Two main reasons behind this effort are that it is believed that since a decline in the Eastern Scotian shelf groundfish stocks that there has been a shift of effort by the mobile gear fleet to the mouth of the Bay of Fundy. This is believed to have severely affected fishermen based in the Bay as groundfish moving into the Bay to feed in the summer are being intercepted before they are able to arrive there. It is believed that these same fish are composed of a fall spawning stock that over-winter on the western side of the bay. The second reason for a shift in management strategy is that if spawning and nursery

grounds are identified then there might be a serious attempt to protect these areas under temporary seasonal closures to fishing. The incentive behind this is that it will improve the overall health of the groundfish stocks on which the inshore fishermen depend. As such a strategy would negatively affect the inshore fishermen in the short-run, it can be assumed that they would be in favor of just closing these areas to trawlers and limiting the closures to certain seasons. Many of the fishermen fish lobster in the fall and winter so they would be in favor of a closure during that time. The basic problem is the need for fishermen to have more income to maintain an acceptable standard of living. That need now manifests itself in an effort to establish a management regime based on a finer scale, one more suitable to the FG<45 group. This is most rapidly accomplished through system of management at the level of localized inshore stocks of fish. However, if management was aimed at sustaining livelihoods instead of optimizing fishery yields then there might not be a need on the part of the inshore independent fishermen to have more autonomy in their fishery.

The Scotia-Fundy Fisheries is defined geographically, for management purposes, as the area delineated by the Northwest Atlantic Fisheries Organization (NAFO) Statistical Areas, 4VWX and part of 5Ze and 5Y. This entire area is divided into three management areas. The Eastern Scotian Shelf Management Area (4VW), the Western Scotian Shelf Management Area (4X+5Y) (in the stock status reports this same zone is referred to as the Southern Scotian Shelf/ Bay of Fundy Area),

and the Georges Bank Management Area (5Z). Currently the FG<45 Community Groups fish in the Western Scotian Shelf Management Area (4X+5Y) (Refer to Figure 1). The total allowable catch (TAC) and the subsequent quota allocation that is determined by the TAC is based primarily on summer trawl surveys conducted in NAFO division 4X. This

Figure 1. NAFO Statistical Areas



sampling scheme assumes that there is one cod stock that spawns on Brown's Bank and then migrates into the Bay of Fundy after the spawning season. This system precludes the notion that there is a separate stock of cod that migrate up the U.S. (primarily Maine) coastline into the Bay of Fundy. A recent report by Ted Ames (Ames 1997) suggests that there are 140 relatively small, discrete spawning grounds and nursery areas from Monhegan, Maine to the Canadian border. If this report is accurate, it is logical to assume that locally spawning stocks continue into the Bay of Fundy and do not stop at the U.S.-Canadian border. This localized stock hypothesis is published in the Canadian literature as well (Hunt 1993). Preliminary analysis of the CIGIS in this project also points to the historical presence of groundfish closer to the shores. Through the years fishing has become concentrated in the center of the Bay as the inshore populations have declined. If there are locally spawning stocks then a question is raised as to if a different management regime could be applied to those stocks. A management shift to smaller scale, decentralized management, would likely result in fishermen who would want a reallocation of the quota based on revised stock structure. Currently there is an assumption of a large discrete stock in the Gulf of Maine based upon tagging studies and larval transport studies. However, some evidence suggests that cod may actually spawn separately, but experience significant mixing at the age they are being harvested (Hunt 1993). If the political will and popular support is present then it may be possible to limit a portion of the summer fishery to enhance small, traditional winter fisheries that once occurred on the western side of the Bay. While, there is no doubt that the stocks are intermixing, it is conceivable that low resolution management regimes (meaning only one stock) would give Brown's Bank cod a higher competitive advantage and would further mask evidence of the existence of local stocks. Furthermore, there may be less evidence of small discrete stocks because they have been severely depleted in relation to the Brown's Bank cod for which they were long considered a component. These are just a few of the issues currently in the debate over the implications of local stocks. Other issues include the decrease in genetic diversity and thus decrease the health and resiliency of the metapopulation. A precautionary approach, as currently being developed by the Department of Fisheries and Oceans (DFO) as a requirement of the Oceans Act, would try to manage a much smaller geographical scale and include as much knowledge as

possible including traditional ecological knowledge (TEK). A different management regime would require significant technological advances such as vessel monitoring systems (VMS) as currently in place in the U.S. Atlantic scallop fishery to allow for in-season management of groundfish populations (Fogarty 1998).

Unlike the United States, which allows each state to manage its fisheries inside state waters (up to three miles from shore), the Canadian system is regulated almost entirely by the Canadian Department of Fisheries and Oceans. This regulatory system is very important to keep in mind when considering the management of local stocks in entire Gulf of Maine. The State of Maine would be able to influence fisheries management if it is shown that the stocks are in fact separate and spawn in state waters. This system could prove to be more effective in the protection of these areas if it could take place on the State level without having to work through the entire U.S. Federal process. The U.S. system of governance is already set to deal with a decentralized system of management in comparison to that of Canada which relies entirely on the central government, in the form of DFO, to manage the fisheries of the entire country.

Governance

DFO is mandated to promote the understanding, conservation, and optimum use of marine resources and the aquatic environment for the benefit of present and future generations. It has responsibilities for navigational safety, environmental protection, and marine industry support. As required by legislation, they make the decisions on everything from local opening and closing dates to quota management systems and allocations. DFO establishes the rules and makes the final decision at virtually every level of the system (AFPR 2000). Although the rules may be developed by DFO, it is the Canadian Parliament that drafts the legislation. Parliament was given exclusive legislative authority over the "Sea Coast and Inland Fisheries" by the Constitution Act of 1867. Thus they pass the Acts, Orders, and Regulations that set the laws for fisheries management. Such Acts include the Fisheries and Oceans Act that created the DFO, the Fisheries Act, and the more recent Oceans Act. Although this system seems very top down Canada has been making an attempt to involve the stakeholders in the decision

making process. One way in which they are doing this is through the Fisheries Resource Conservation Council (FRCC). This council is made up of 15 members who are appointed by the Minister and represent an “appropriate balance between ‘science’ and ‘industry’” (FRCC 2001). The Council advises the Minister on research and assessment priorities, reviews DFO data and advises on methodologies, considers conservation measures that may be required to protect fish stocks, reviews stock assessment information and conservation proposals, and makes written public recommendations to the Minister on total allowable catch (TACs) and other conservation measures (FRCC 2001). This group solicits some of its information through the Regional Advisory Process (RAP). The RAP in the Maritimes consists of Regional Management Committees; a) Fixed Gear Advisory Committee, b) Scotia-Fundy ITQ Committee, and c) Fixed Gear ITQ and Generalist Groups representing the industry. Overall the RAP is a program in which scientists and stakeholders meet to discuss and peer-review scientific results and analyses on the status of fish stocks and their environment. They submit to the FRCC Stock Status Reports, Fisheries Status Reports, and Habitat Status Reports.

As previously mentioned the inshore groundfish fleet fishes under a quota administered by the Community Management Boards. These boards are a product of the Groundfish Integrated Fisheries Management Plan (IFMP) for the Maritimes Region. Integrated fisheries management plans build on the overall management plan and incorporate conservation, management, and scientific requirements for a fishery and also detail the process and implementation of resource management, conservation and protection measures. IFMPs also define processes for conferring with clients and stakeholders and define responsibilities and roles of all parties. The management boards thus provide input into in-season management and develop, implement and monitor community fishing plans through in-season meetings that examine their total landings to that point and decide how they will allocate their remaining quota. Each board develops harvesting plans for primarily three gear sector quotas (handline, longline, and gillnets). These Conservation Harvesting Plans (CHPs) are plans that describe the sets of conservation measures and requirements established for a fishing sector or group and approved by DFO before the fishing season begins.

Peripheral Government Agencies

Other than DFO there are two governmental agencies that have a significant impact on fisheries management in the Maritime Region. These are; 1) Human Resources Development Canada (HRDC), which is responsible for Employment Insurance (EI), and 2) Atlantic Canada Opportunities Agency and Canada Economic Development, which is responsible for community development and diversifying the economic base of fishery dependent communities. Of primary importance for the inshore fishermen is EI. The existence of this fund can indirectly determine a fishermen's catch because if a fisherman anticipates a poor year in fishing then the fisherman may actually limit his or her catch in order to not exceed a profit margin that would prevent him or her from receiving the EI. It is partly due to the great cost of maintaining EI in many fishing communities that the second agency mentioned, the opportunities agency, exists. In addition, the EI indirectly acts as a conservation measure as because it reduces the need for fishermen to continue to fish when it becomes less profitable than taking the EI.

Industry Associations

Fundy Fixed Gear Council (FFGC) is an alliance of inshore fishing groups from the Digby area of the Southwest Nova Scotia region. The alliance was originally formed by the Islands Inshore Fishermen's Association, the Digby County Inshore Fishermen's Association, and the Maritime Fishermen's Union Gillnet Society. This council is effectively the Community Management Board for Digby, N.S. and thus carries out the management functions of the board.

Other groups comprised of inshore fishermen are: the Bay of Fundy Inshore Fishermen's Association, the Fundy North Fishermen's Association, and the Grand Manan Fishermen's Association. Of these three the Grand Manan Fishermen's Association (GMFA) currently is the most active. These associations tend to be most active when there are perceived threats from regulations, "unfair" competition, and strong leadership in the organization.

The ITQ Fleet makes up the other part of the fishery. Their industry associations are well funded and, in general, are represented by the Fisheries Council of Canada (FCC). The FCC is a non-profit, private sector trade association representing companies engaged in the growing, harvesting, processing, and marketing of fish and seafood. The Council is a federation of like-minded fisheries and seafood associations and enterprises that support shared, fundamental principles. The Council acts to ensure that the conservation of the resource will be the basis of sustainable fisheries and seafood supply for consumers and works to strengthen members' capabilities to be economically viable. In a recent press release the FCC states that “individual transferable quotas or enterprise allocations have proven superior to common pool fisheries to assist in capacity matching the resource and the fishery delivering cost effective, high quality raw materials for processing and marketing... Some existing policies such as fleet separation which discriminates against vertical integration by some specific classes of industry participants must be ended to assist the economic viability of the industry. At the same time, the Department of Fisheries and Oceans cannot burden itself with social management objectives at the expense of the resource and industry.” (FCC)

The opposite view is one of “rational competition” that is generally favored by the small-scale fishermen. They argue that ITQs create monopolies or cartels. They believe that the overcapitalization of fishing vessels is the problem that needs to be addressed directly instead of indirectly through privatization schemes.

Non-Governmental Organizations

Although the fishing associations are technically non-governmental organizations this section is concerned primarily with organizations devoted to conservation and social equality. The main organizations involved in the Maritimes are the Conservation Council of New Brunswick, The Centre for Community-Based Management, Eastern Charlotte Waterways, and The Quebec-Labrador Foundation. Another organization, The Marine Resources Centre is composed primarily of members of the Fundy Fixed Gear Council and is thus somewhat biased toward the interests of that group. All of the above organizations have been involved with documenting spawning and nursery grounds for various commercial species in the Bay, including groundfish, through digital mapping

and development of geographical information system (GIS) databases. No formal arrangements exist between these organizations for the sharing of databases.

Recent Studies

A detailed study of groundfish spawning and nursery grounds was conducted in 1996-1998 by the Canadian Department of Fisheries and Oceans (DFO) Science through the Gulf of Maine Council. Interviews were conducted with local fishermen. Although some analysis of the data has been conducted, results are few and have never been published. With the current emphasis on integrated ecosystem management, such information is invaluable to fisheries managers, coastal communities, and interest groups. There is a great need to further our understanding of the locations and habitat requirements of spawning and nursery areas. This same study was financed on the U.S. portion of the Gulf of Maine and done through the Island Institute. Their report took the form of the 1997 "Cod and Haddock Spawning Grounds in the Gulf of Maine" by Ted Ames. (Ames 1997)

THE BAY OF FUNDY GROUND FISH HABITAT MAPPING PROJECT

Objectives

The Centre for Community-Based Management based out of St. Francis Xavier University in Antigonish, Nova Scotia partnered with the Canadian Department of Fisheries and Oceans to address under-represented fishermen's knowledge in regards to spawning and nursery grounds of cod, haddock, and pollock in the bay. Their objectives were:

1. To identify and evaluate existing studies of spawning and nursery grounds of Bay of Fundy commercial species.
2. To examine the original data from the DFO groundfish spawning and nursery study and conduct further analysis.
3. To identify the need for and to conduct follow up interviews
4. To produce GIS maps detailing results.
5. To develop a rating system to classify areas by level of certainty and importance.
6. To identify future research needs in this area.

This research project is designed to address challenges and successes involved in using GIS in a marine fishery using local knowledge. Specifically, the process to accomplish the fourth and fifth objectives listed above is presented, followed by suggestions on how a rating system might be developed. The use of GIS in these areas is recent and evolving. Documentation of both the process and output (results) is necessary for understanding the role GIS can play as a tool for community groups as well as resource management agencies. In this paper it is also hoped to address the following question raised by Craig and Elwood (1998) in regards to community groups and their use of GIS: What is the value of maps and geographic information to community groups? Does that value justify the effort it takes to produce a GIS?

Methodology

Interviews were conducted in both New Brunswick and Nova Scotia. The original DFO survey utilized a detailed ten-page, 177 question survey that was administered face-to-face by one individual between 1996 and 1998. In New Brunswick alone a total of 65 fishermen were interviewed in their homes. Seventeen individuals, out of a total 65 respondents, indicated the otter trawl as one of the gear types they used indicating that they were part of the mobile gear, ITQ fleet. Nineteen follow-up interviews were conducted in New Brunswick the summer of 2001 utilizing a much more informal semi-structured survey. These “kitchen table” interviews were conducted primarily at fishermen’s residences. Initially, well-known and respected individuals were sought for interviews after which a snowball sampling technique was used based on the advice of the former respondents. Most often two persons conducted the interview with one respondent in a time range of 1-2 hours. The respondents consisted primarily of both active and semi-retired individuals from the FG<45 group. A few mobile gear respondents were included.

The content of the interviews was transcribed through notes and information regarding locations of fishing activity was recorded through the use of CHS nautical charts as well as through direct heads-up (monitor interface as opposed to a digitizing table) digitizing on a laptop computer. ArcView 3.0 GIS software was used for the digitizing data to a

CHS base map. The base map was a digitized version of the same paper nautical chart that was simultaneously being used in the interview to locate areas of interest (CHS 14011 Approaches to the Bay of Fundy). The lines delineating the boundaries of the sites where juvenile fish and/or egg-filled or spawn-filled fish were located were made by: 1) direct marks by the respondent on the paper map, 2) marks by the interviewer on the maps indicating the location, usually a well marked shoal on either map and, 3) by the shoal name and depth constraints indicated by the respondent. As depth was always asked as a separate question some lines were redrawn at a later time to match the respondents indicated depth.

The attribute table consisted of separate response fields for the original survey and the follow-up survey. When determining the response rate for a particular attribute, such as the presence of a fish at a particular location, it should be noted that totaling the rows will result in the over-representation of some answers due to the fact that the same relatively small sampling universe was used for both surveys. Duplicated respondents between these two columns are assured. The attribute table itself was constructed around each species and its life history, i.e. juvenile cod, spawning haddock, ect.

Discussion

TRADITIONAL ECOLOGICAL KNOWLEDGE AND LOCALIZED FISH STOCKS

If the DFO is going to effectively move towards a precautionary approach (the proof demonstrating that an action will NOT have an adverse affect must be made by the resource user prior to the action) and ecosystem management, as called for in the Oceans Act, then there should be an increased role for participation by fishermen in the management of their resources. This participation could be in the form of restoration projects, monitoring, aiding scientific studies, and in making their present and historical knowledge regarding fish morphology, location at certain times of year, and age specific behavior. It is believed that with improved communication through increased

participation in scientific research and the development of management regimes there will be increased cooperation and reduced future risk of overfishing and mismanagement (Felt et al. 1997, Harvey and Coon 1997, Pinkerton, 1994). One of the ways by which DFO can incorporate TEK into a useable database is its incorporation into a GIS. This information could then be more accessible to be incorporated management as outlined by Neiss et al (1999):

- 1) *Helping to define management goals.* This is effectual in that the values of fishermen are embedded in their knowledge. By recognizing these values and incorporating them into the goal framework then there is an opportunity to reduce future conflict. Importantly, if there is a means by which to articulate these values then there might be a way by which to develop biological targets that take into account local variation in both fish and fishing activity in ways that do not result in a particular user group borrowing or intercepting the catch upon which another group has historically depended.
- 2) *Re-allocation of quota for the purposes of conservation.* Once a group has been allocated its quota it might decide to re-allocate some the quota towards conservation by holding back a certain amount for the purposes of letting stocks rebuild, by using time-area closures over spawning and nursery grounds, or implementing some other type area closure such as a marine protected area (MPA).
- 3) *TEK offers a way to gather large amounts of information, winnowed over several generations, to be used for developing testable hypotheses within the organizational framework of scientific knowledge.*
- 4) *Evaluation of changes in fishing behavior over time.* This can include charting the changes brought about by improved skill and technology.
- 5) *Determine factors that change the spatial extent over which fishers gather the data they use to make decisions about where and when to fish and the number of people they involve when forming fishing plans.*

Fishermen, through their activities, monitor seasonal movements (timing), habitat preferences (bottom type and depth), feeding behavior (gut contents), abundance dynamics, and the condition of the fish (morphology and marketability ie: worminess). This knowledge when assembled into a GIS database can begin to graphically portray a history of the fish and fishing behavior through time that fishermen have long been saying in narrative form.

CHALLENGES TO TEK IN THE MARINE ENVIRONMENT

Although there may be a desire to incorporate TEK into management through GIS there are still many hurdles to face in both traditional fishing knowledge applications of GIS, and gathering and validating TEK itself. One of the challenges to getting a good sampling of fish movement by using TEK is that fishermen do not fish year round for the same species. Most fishermen in this fishery turn their attention to lobster fishing in the fall. Fortunately, for this study, groundfish (in this case mostly cod, haddock, and dogfish) get caught in the lobster traps so that there is some, although spotty, data indicating the presence of a species during a time of year when it is not being pursued. Fish movement data is better on how fish have moved over several years. Specifically, fishermen often talked about how fish used to be caught much closer to shore, whereas now to have a good catch, one has to move to the center of the Bay and towards the mouth around Grand Manan. Although local knowledge might be weak on the level of annual variation it tends to be strong in the same season (summer) across many years (seasonal/interannual data). It is for this reason that many people are very reluctant to try and create a picture of an animal's life history using TEK.

TEK can be a challenge working in the dimension of depth as different gear types may span several depths. Nets have a large vertical surface area perhaps making it unclear as to where a fish was caught in the water column. Hook and line fishermen may be able to give an accurate account of the depth in which the fish was caught by noting which hooks are getting the most bites. The time dimension is often clear on the seasonal level but knowing the actual year may be difficult unless accurate logs were kept.

Collecting data is always a challenge in TEK. Data collection at the first level, through direct observation by the fishermen, may not be 100% reliable if the data is only recorded in the mind of the observer. It is still another challenge entirely to ask a question in a way that elicits the desired information. In this project the same question was asked several times, and in different ways, during the course of an interview in order to make sure that the respondent understood the question being asked.

VISUALIZING INDETERMINATE BOUNDARIES

In creating geographic objects it is essential to begin with the smallest resolution possible with the specific object. Small-scale resolution will allow for more detail and therefore less error to occur with the collected data set. This resolution is especially essential with mapping traditional ecological knowledge. Both scientists and managers often consider this type of information “anecdotal”. As a result it is important not to incorporate too many assumptions into the way that this knowledge is displayed on a map. In the case of the Bay of Fundy project, the smallest possible level of knowledge is an exact GPS or Loran coordinate obtained directly from a vessel’s computer or from a fishermen’s log book. Unfortunately, this level of detail was not always available due to the fact log books were not close at hand during the interview or, in the case of older fishermen, a watch, vessel speed, compass bearing and/or reference to a fixed landmark such as a point of land, or buoy were used to pinpoint their location on the sea. In the cases where specific information about a discrete place and time are used then the information is best portrayed as an instantaneous point feature on the digital map.

Many fishermen do not feel comfortable extrapolating information from fishing activities to form a concept of fish behavior. Constructing a geographic object around a concept or belief system has the potential to greatly increase fuzziness. For that reason, a link of some sort through the attribute table, to an actual quotation by the respondent in reference to a specific data point may be more appropriate to represent conceptual data. This type of information might also be included in the metadata that will follow the data wherever it goes. An example of this referencing is displayed in Figure 2.

A bottom-up approach toward capturing data related to spawning or nursery grounds could be accomplished by representing each record as a point feature. This type of information could then be overlaid on bathymetric data such as soundings, bottom type, and current that are known to be criteria for the concept being formulated.

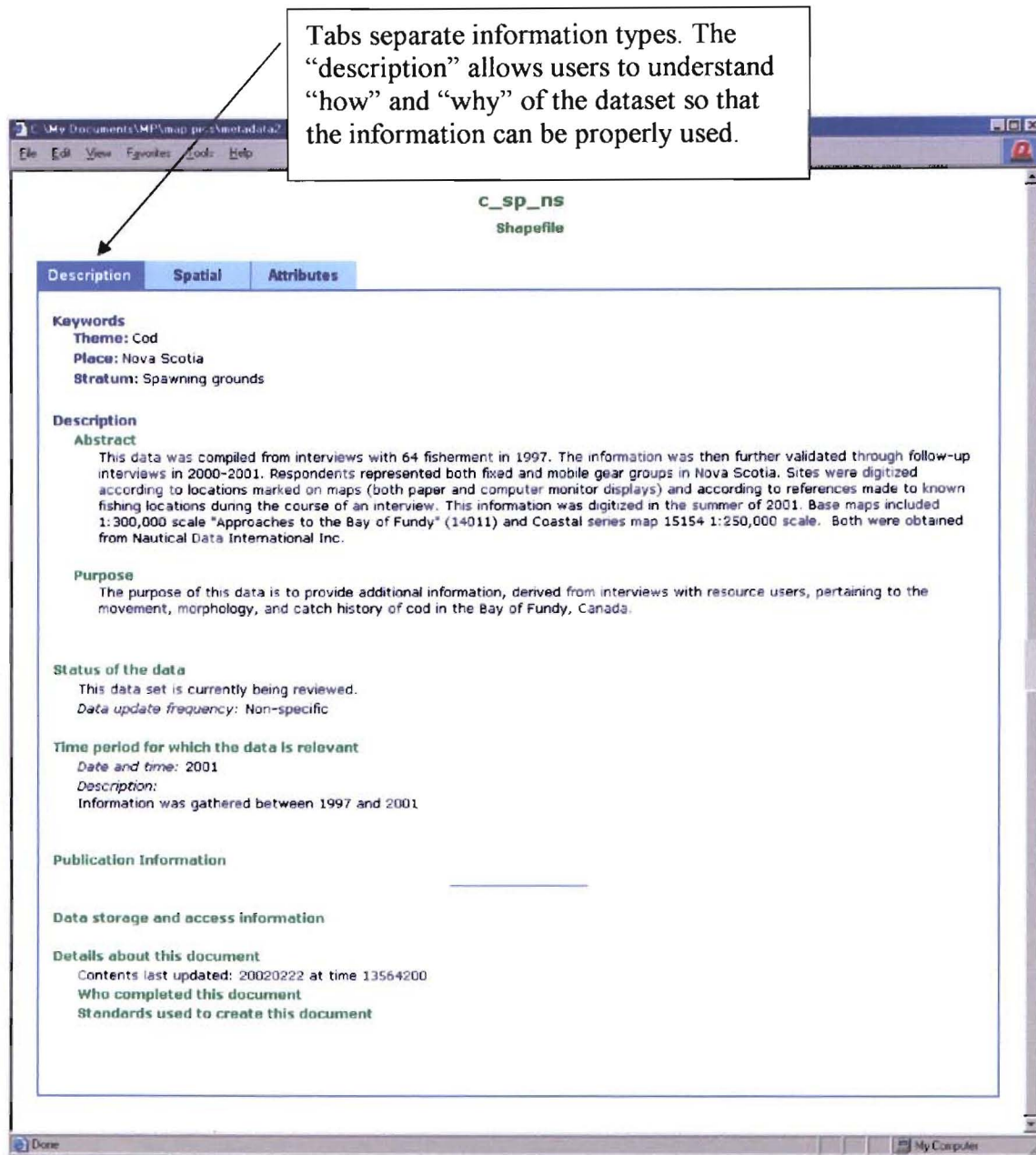
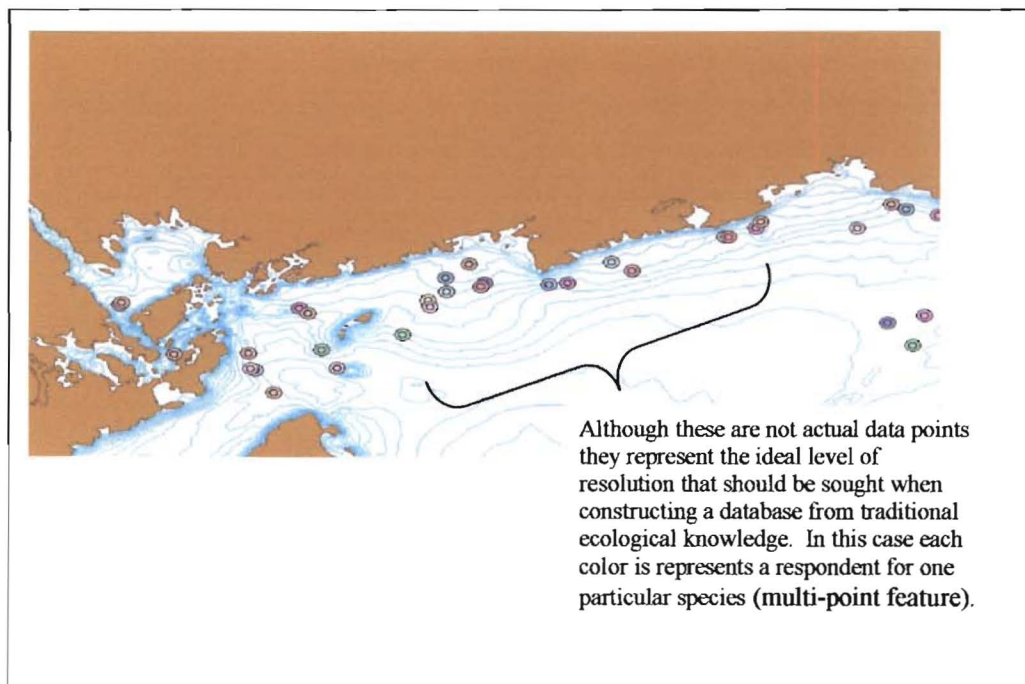


Figure 2. Example of ArcGIS 8.0 generated metadata.

Thus, a point feature indicating the species of fish, it's spawning condition (containing eggs, or having milt running from it), and the time of year in which it was caught, would appear with bathymetric data on currents, bottom type, and other seafloor features.

In Ames (1997) maps and in the formation of the atlas for this project (in press) the information about "habitat type" was incorporated into the TEK to form an undifferentiated polygon with finite boundaries (Figure 5). This technique might make the data difficult for scientists to use since assumptions were incorporated into its formation. Points do not confer the same ideas as polygons. Polygons by their nature, follow some kind of boundary criteria. Polygons infer, by their very existence, that the boundary is fixed (Burrough 1996). There are three kinds of uncertainty that are often related to classifying remotely sensed objects.

Figure 3. TEK represented by point features.



This uncertainty can also apply to information acquired through TEK: 1) we may not know the precise location of classified geographic entities and may thus be uncertain about their location, or 2) we know the precise location of the geographic entities including the transitions between them, but we are uncertain precisely how to classify

them, or 3) we know a precise location but are unsure of its extent, or 4) we have a combination of these possibilities (Freksa 1996). Uncertainty relates to a lack of knowledge about the position and shape of an object with a real border, or to the inability to measure such an object precisely. Fuzziness describes the vagueness of objects which certainly have an extent, but which inherently do not have a precisely definable border (Schneider 1996). For illustrative purposes a multi-point feature was created (Figure 3) in which the row attributes are the survey respondents. This technique allows one to examine the influence of one person's response on an entire area. However, this technique disallows the possibility of separating the responses temporally. A single point feature with a number identifying the respondent would be a better method of constructing the attribute table. This respondent based method is in contrast to the technique of forming the attribute table around the name of the location, which unless there was a field for every respondent, clumps all responses into a total without identifying the source (Figure 4). Other problems concern the different isobaths on different maps. Although the digitizing may have occurred on one base map, if the data is laid onto a different base map there may be completely different depth contour lines. This technique may have the effect of making the boundary delineation look arbitrary. For this reason it is important to avoid using isobaths as the boundary for an area.

Figure 4. ArcGIS 8.0 attribute tables.

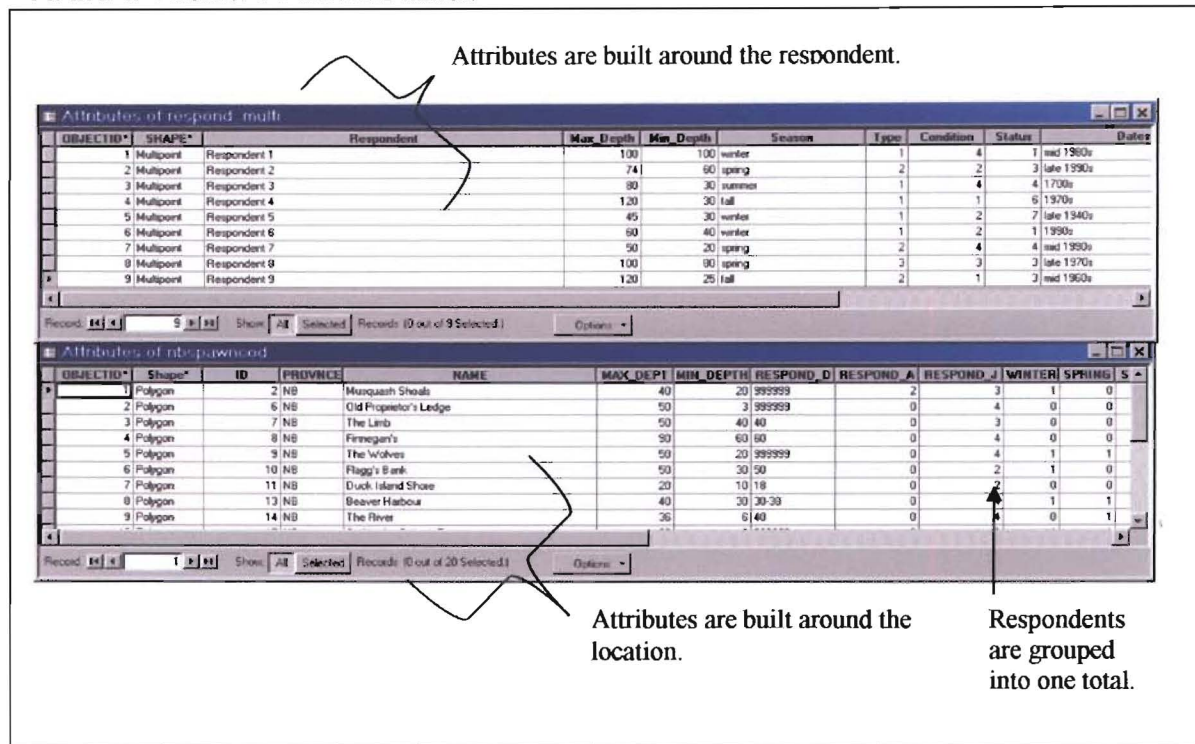
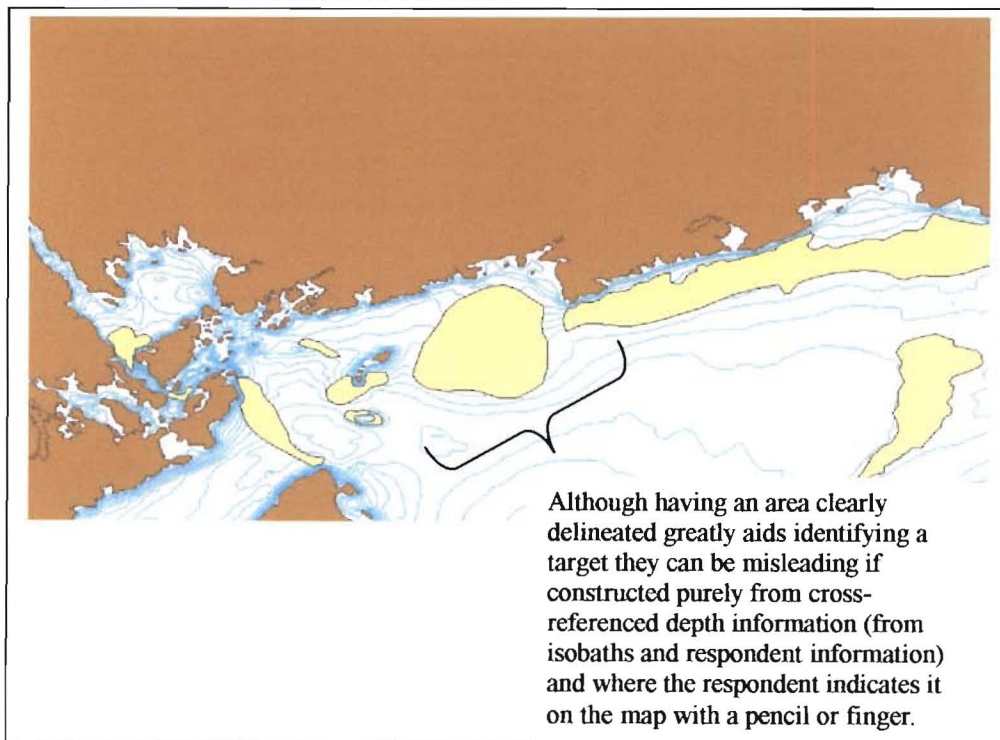


Figure 5. TEK represented by polygons.



VALIDATION TECHNIQUES:

There exists a need to use a method of validating spawning and nursery grounds as advocated by Ames (Ames 1997):

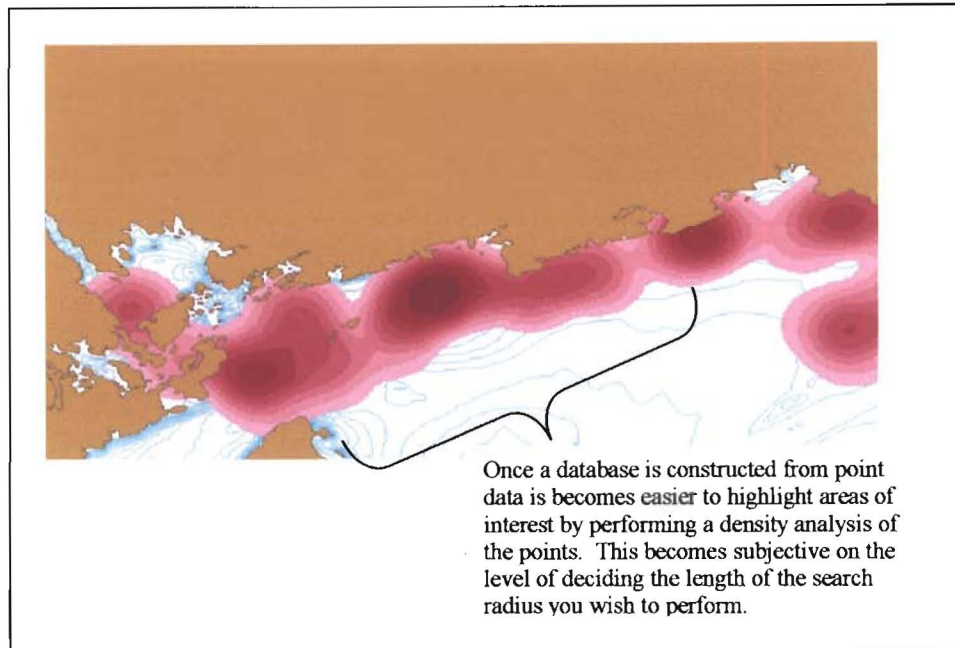
- a) Independently confirmed by two or more references or in the immediate vicinity of a confirmed area
- b) Have the appropriate bottom habitat (substrate) and water depth

However, if a site is NOT validated it should remain in the record but noted by a particular attribute as being uncorroborated by another source. This method of recording will allow records to be validated at a later date by another respondent or by further scientific investigation rather than being discarded. It is important to remember that there is a need to use scientific methodology. However, when dealing with a very small sample size and uncertain information I believe it would be wrong to eliminate data that is not immediately corroborated.

A rating system based on the validity of the site would aid in creating zones of fuzziness or transition around a site and not confer equality between sites. Examples of criteria for grading a site include proximity to a previously identified site and habitat matching to what is known about the species life history. Whether using point or polygon features, a standard maximum distance between sites needs to be established when exploring to see if site responses are corroborating each other. A method by which to ascribe certainty classes is by conducting a density analysis of the point data on the map (Figure 6). A search radius is assigned to the points in the analysis. Once the output raster is finished then one can assign the number of classes that would be preferred for certainty classification. This offers a way to show decreased certainty about a location by creating confidence classes around locations that have the most responses. According to the ArcGIS 8.0 Help Menu, density is calculated using simple or kernel calculations. In a simple density calculation points that are within the search are summed and then divided by the search area size to arrive at a density value for each cell in the output raster. Kernel density is conducted in the same fashion except that points lying in the center of a raster's search area are weighted more heavily than those near the edge. The result is a smoother distribution of values. Creating certainty classes around TEK data is one way

of validation. However, when information on benthic habitat type is available, it should be incorporated by creating an overlay coverage with the TEK data, thus creating an even higher level of certainty regarding a particular site.

Figure 6. Density analysis of point data.



COMMUNITY GROUPS AND GIS:

Currently, the value of the information collected in the Bay of Fundy project isn't clear, as the government, NGOs, and community group have yet to use the data. This is due to the fact that the most accessible medium for the data, a paper atlas, has yet to be published. It is also unclear as to who actually owns the information and thus how the information might be used. The NGO developed the GIS using DFO money, utilizing the knowledge of local fishermen. At this point, the time and funds put into the project do not justify their existence, however, if there is some management decision made that appears to threaten some aspect of the fishery then this database will certainly resurface, most likely on both sides of the issue illustrating opposing views. It is for this reason that the fishing community should have a relationship with DFO where their information can help direct scientific research (i.e. tagging studies based upon seasonal and spatial data provided, through the community-integrated GIS).

Conclusions

In order to accurately represent TEK I believe it is necessary for a survey to begin by obtaining point data from on-board computers and/or log books in order to get the finest level of detail. However, even if a specific point is not available one should construct a point, or several points on a paper map or a digital display, as indicated by the respondent. The method of using point data is preferred to that of drawing a polygon onto the map indicating a large approximate area of fishing activity. By using point data certainty classes based on the density of sites indicated by respondents can be constructed. The attribute table should be constructed around the respondent and not the location name. By constructing the attribute table around the respondent you will likely greatly increase the size of the table but will simplify analysis in the long run. Data should not be deleted from the database simply because it is not substantiated by another source. If the uncorroborated data point is an outlier it will appear that way in the analysis. When developing the habitat classifications using TEK it is important that it is clear from the beginning that it is a human ecological classification scheme that is being used. It is important to remember that the methods outlined here are the first steps to prioritizing and classifying areas of interest using ecological knowledge. In all cases it is wise to follow-up this approach with more extensive on-site scientific research and integration of other classification schemes. The TEK database will serve as a guide for where to begin. It is also important that in cases without the financial capacity to carry out follow-up work it becomes very important to use the existing data, but within its own constraints. Visualizations that reflect the data constraints are necessary. TEK should not be overlooked but instead more actively incorporated as an additional GIS tool by integrating the communities directly affected by the management decisions that come with the use of GIS.

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References

- Atlantic Fisheries Policy Review. 2000. The Management of Fisheries on Canada's Atlantic Coast. Ottawa, Ontario, CA.
- Ames, T. 1997. Cod and Haddock Spawning Grounds in the Gulf of Maine. Island Institute.
- Brehme, C. et al. 2001. Monitoring Coastal Fisheries in the Gulf of Maine with Fishermen, GIS and the Internet. CoastGIS '01, Halifax Nova Scotia, Canada. June 18-20, 2001.
- Brzeki, V, J. Graham, and G. Newkirk. 2001. Participatory Research and CBCRM: In Context. Coastal Resources Research Network, Dalhousie University, Halifax, Nova Scotia, Canada.
- Burrough, P.A. Practical Issues of Dealing with Objects with Indeterminate Boundaries. In Peter A. Burrough and Andrew U. Frank eds., *Geographic Objects with Indeterminate Boundaries*. Bristol, PA: Taylor & Francis Ltd. 1996.
- Craig W.J., and S.A. Elwood. 1998. How and Why Community Groups Use Maps and Geographic Information. *Cartography & Geographic Information Systems*. V25 i2 p95(1).
- Cushing, D. 1995. *Population Production and Regulation in the Sea: A Fisheries Perspective*. Cambridge University Press, Cambridge, U.K.
- Department of Fisheries and Oceans. 2000. Groundfish Integrated Fisheries Management Plan, Scotia-Fundy Fisheries Maritimes Region, April 1, 2000 – March 31, 2002. <http://www.mar.dfo-mpo.gc.ca/fisheries/res/imp/2000grndfish.htm>.
- DFO 2000. Cod on the Southern Scotian Shelf and in the Bay of Fundy (Div. 4X/5Y). DFO Sci. Stock Status Report A3-05(2000).
- Engle, S. 2001 Negotiating Technology – (Re)considering the Use of GIS by Indigenous Peoples. *New Zealand Geographer*. 57 (1): 27.
- Fisheries Council of Canada. <http://fisheriescouncil.ca/fcc.htm>
- Freksa, Christian and Thomas Barkowsky. 1996. On the Relations between Spatial Concepts and Geographic Objects. In Peter A. Burrough and Andrew U. Frank eds., *Geographic Objects with Indeterminate Boundaries*. Bristol, PA: Taylor & Francis Ltd. 1996.
- Gillespie R. et al. MGDI: An Information Infrastructure to Support Integrated Coastal Management in Canada. *GeoCoast*. V1 No. 1, 15-24.
- Harris T, and D. Weiner. 1998. Empowerment, Marginalization, and "Community-Integrated" GIS. *Cartography & Geographic Information Systems*. V25 i2 p67(1).
- Harris T, and D. Weiner. Community-Integrated GIS for Land Reform in Mpumalanga Province, South Africa.
- Hunt, J.J. and J.D. Neilson. 1993. Is There a Separate Stock of Atlantic Cod in the Western Side of the Bay of Fundy?. *North American Journal of Fisheries Management*. 13: 421-436.

- Laevastu, T. and Favorite, F., 1988. Fishing and Stock Fluctuations. Fishing News Books, Farnham, UK.
- Macnab, P. 2001. There Must Be a Catch: Participatory GIS in a Newfoundland Fishing Community. Community Participation and Geographic Information System
- Meaden, G. 2000. GIS in Fisheries Management. GeoCoast. V(1) No. (1), 82-101.
- Mumby, Peter J. 2000. "Methodologies for Defining Habitats" chapter 9 in Edmund Green, Peter Mumby, and Christopher Clark Remote Sensing Handbook for Tropical Coastal Management. UNESCO 2000.
- Neis, Barbara et. al. 1999. An Interdisciplinary Method for Collecting and Integrating Fishers' Ecological Knowledge into Resource Management. Chapter 11 in Dianne Newell & Rosemary E. Ommer eds., Fishing Places, Fishing People. Traditions and Issues in Canadian Small-Scale Fisheries. University of Toronto Press. 1999.
- Neis, Barbara, M. Morris. 2000. "Creative, Ecosystem, and Distributive Justice and Newfoundland's Capelin Fisheries" in Harold Coward, Rosemary Ommer, and Tony Pitcher, eds., Just Fish: Ethics and Canadian Marine Fisheries. Newfoundland: Institute of Social and Economic Research, 174-200.
- Obermeyer, N. J. 1998. The Evolution of Public Participation GIS. Cartography & Geographic Information Systems. V65 i2 p65(1).
- Payne, J. L. Advancing Coastal Resource Decision-Making with Information and Technology. GeoCoast. V1, No. 1, 1-14.
- Schneider, Markus. 1996. Modeling Spatial Objects with Undetermined Boundaries using the Realm/ROSE Approach. In Peter A. Burrough and Andrew U. Frank eds., Geographic Objects with Indeterminate Boundaries. Bristol, PA: Taylor & Francis Ltd. 1996.
- Schroeder, P. 1997. Personal e-mail communication to Obermeyer, N. J., Nov. 15.
- Sirait, M et al. 1994. Mapping Customary Land in East Kalimantan, Indonesia: A Tool for Forest Management. Ambio. V23, No 7, 411-417.
- Symes, D., 1996. Fishing in troubled waters, Fisheries Management in Crisis, (Eds. Crean, K. and Symes, D). Fishing News Books, Farnham, U.K. pp. 3-16.