LOCATING HISTORICAL FISHING GROUNDS
AND
TRACKING THE MOVEMENTS OF COD IN THE GULF OF MAINE WITH GIS

ABSTRACT

The following report describes a procedure for locating and mapping historical Gulf of Maine fishing grounds on modern digitized charts, the methodology for determining seasonal distribution and relative abundance. These procedures were developed as part of a study to determine the population structure, range, and distribution of cod populations in the Gulf of Maine (GOM) by tracking historic seasonal distribution and abundance.

In the "Fishing Grounds of the Gulf of Maine", Rich identified 250 individual fishing grounds between Ipswich Bay and the Bay of Fundy. *(10)* Many of these grounds still have vestigial cod populations on them and 92 grounds have been actively fished for more than a century. He described the location of each fishing ground with compass courses and distances from known landmark(s). Rich also described the substrate and bottom characteristics for each fishing ground.

Rich's landmarks for each fishing ground were found by using the appropriate digitized NOAA charts and the ChartView Pro navigation program,. From the landmark, a range line was drawn along the bearing for the specified distance to the fishing ground, thus identifying the estimated location. His benthic description was then matched with the substrate and depth contours displayed on the chart in the vicinity of the fishing ground site. The estimated size, shape, and orientation of the fishing ground was then drawn to scale.

Once the sites were located on modern charts, descriptive information about substrate, benthic features, variations in the size of cod caught, and their relative seasonal abundance were used to analyze their movements. Data sets for different time periods revealed the persistence and stability of cod populations in various areas.

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By
Ted Ames

METHODS FOR USING HISTORICAL FISHERIES INFORMATION

INTRODUCTION

GIS is a particularly powerful tool for understanding ecological change and processes whenever the changes can be viewed over long periods of time for a selected area. Such a data profile gives unprecedented opportunity to study the relationship between ecological degradation and human activity. In some cases, it provides tools to cope with or reverse the process.

Fisheries problems in particular have lacked this tool. There has not been a practical way to convert historical coastal and near-coastal fishing ground information to GIS and modern nautical charts, or to use information about species movements associated with them. The reasons for this are clear. Historical nautical locations, described by magnetic compass bearings and landmarks or estimates of distance from a single point are not very compatible with GIS. Yet, if such information could be screened and used, a large, descriptive database of valuable historical ecological information about marine locations could be developed.

After the recent collapse of cod stocks throughout New England and Eastern Canada, it became obvious that relatively little was known about the behavior and critical habitats of cod and other commercial fish stocks found there. Even though cod had been fished in the area for more than 400 years, basic information was lacking about when and where reproduction occurred, what their distribution and migration patterns were, and what the population structure might be in the Gulf Of Maine. Worse, the cod stocks in the GOM had collapsed, leaving little chance that new studies would be able to gather the missing information.

Historical Fisheries Analyses: An Alternative Approach

In the absence of healthy cod stocks, an alternative approach has been developed that would evaluate such factors as cod distribution, behavior, critical habitat, and population structure, based on the analysis of historical fishery information. This approach would be applicable to the study of any fishery where historical landings information is available, and its methodology allows the mapping of a variety of marine habitats. The strategy involved mapping historical cod habitats and then tracking their movements during a period when the stocks were still abundant.

A brief overview showed that the marine habitat of a species such as spawning and feeding areas, can be located and mapped from historical reports, ships logs, and interviews with fishermen. Often, benthic characteristics of the grounds can be compiled from these sources at the same time. Once located on GIS, habitat sites can be used to show seasonal distribution and

relative abundance of stocks, based on information gathered from fisheries reports. This allows various stock characteristics to be analyzed. The approach used to characterize cod stocks follows.

Cod have recently been found to return to the same spawning area each year, much the same as do salmon (3). This provides a convenient "time zero" when all adult cod are in the vicinity of their spawning grounds. By using the spawning season and sites as the point of origin for subsequent movements and migrations during the year, it becomes possible to identify patterns of movement in local areas, rather than the whole GOM. So, the first step was to establish where GOM cod spawned each year and establish the points of origin for cod movements and migrations.

To find exactly where those historical cod spawning areas were located, though, was more of a challenge. Classical references suggested cod spawning grounds were limited to a few locations in western GOM. However, a number of fishermen between Ipswich Bay in Massachusetts and the Lurcher Shoal, Nova Scotia challenged this. A protocol was developed to interview numerous old fishermen who had participated in the coastal fishery. These fishermen identified many additional spawning areas. Ultimately, an area of more than 1,000 square miles of cod spawning grounds were identified just offshore from the coast and fringed the whole northern GOM coastline (15). The wide distribution of these areas during the 20's also reflect the distribution of cod in the Gulf and suggests that their movements originated from many different locations.

It was assumed that the distribution of cod in the GOM could be determined by finding out where fishermen were catching cod during each month or season. Once this information was placed in a GIS platform, seasonal patterns of distribution could be studied.

This required that all fishing grounds, along with the spawning grounds identified earlier, be plotted on digitized charts first. Plotting historical fishing and spawning grounds resulted in an unexpected benefit. During the 1920's, most fishermen used hook-and-line methods to catch cod. This site-specific technology allowed fishermen to record quite detailed descriptions of the benthic characteristics of their fishing grounds, even though they had no electronics. Once these locations were plotted on digitized charts in a GIS format, it became possible to link a wealth of historical ecological descriptions to more than 330 sites bordering the coasts of New England and Canada.

With fishing and spawning grounds loaded into GIS, the times of year that cod were found on each fishing ground had to be determined. This information was obtained from fisheries reports. (8,9,10,11) A table was prepared showing which grounds had cod present during each month/season of the year. Then, by displaying the months/seasons sequentially, patterns of movements and the distribution of cod in the GOM became visible.

Yet, to tell whether the fish found on a fishing ground were migrating through the area or had already been there, required a more sophisticated approach. Landings information for individual fishing grounds during the 1920's was not available. This final step required that a method be developed to track concentrations of fish moving from one fishing ground to another, without

having to use landing records.

The concept of relative abundance was developed to track concentrations of cod moving from one fishing ground to another. Relative abundance is based on historical fishermen's reports of how good fishing for cod was on a particular ground and at a certain time of year.

Cod often tend to move in schools. Being able to track their movements as they approach (or leave) spawning areas, by differentiating between the abundance of cod on each ground with respect to time, gave additional information about cod behavior.

MATERIALS

Fishing and spawning grounds were plotted on a 350 MHz Pentium II with 120MB RAM, using ChartView Pro 2.5 (Nautical Software, Inc.) and ArcView 3.2 gis (ESRI) with a National Oceanic and Atmospheric Administration (NOAA) extension to accommodate digitized NOAA charts in a KAP format (MapTec).

METHODS USED

1. Interview Methodology

A modified interview protocol based on a procedure developed by Ives (15) was used to collect historical fisheries information about cod spawning areas along the GOM coast. Most of the information collected used dead-reckoning methods based on course and distance, except where cross bearings from land marks were used. Historical GOM cod spawning areas in a GIS format was provided by Island Institute, Rockland, ME. This format proved to be incompatible with the digitized NOAA navigation charts being used in the project. this information was subsequently converted to GIS, using the same approach as that used for fishing grounds.

2. Identification of Fishing Ground Habitat

The study used the Bureau of Commercial Fisheries report "Fishing Grounds of the Gulf of Maine" (Rich, 1927) to establish the location of GOM cod-fishing grounds. This is perhaps the most comprehensive work available on historical GOM cod grounds. Therein can be found distances and bearings to each fishing ground, its approximate dimensions and orientation, with descriptions of bathymetry, substrate, and species.

Figure 1 Typical Source of Fishing Ground Information

Compass courses can be quickly converted to degrees by consulting the conversion tables in traditional navigation references. (17)

3. Location of Fishing Grounds: Finding Reference Points With ChartPro on NOAA Charts

The steering information to each fishing ground directed one to a specific part of the fishing ground, but considering the limitations of dead-reckoning navigation, the best a fisherman could hope for was to get his vessel in the vicinity of the ground. Finding the actual ground required the use of a sounding lead to sample and characterize the bottom. In the current study, the reference point for the fishing grounds were found by following Rich's navigation instructions while using the ChartPro navigation program.

A bearing line was drawn from the point of origin, using the steering information given, and extended for the recommended distance to the fishing ground. When additional information was given, multiple points were identified. Once this reference point was located, the immediate area was examined for a site fitting the dimensions, orientation, bathymetry and substrate characteristics described by Rich.

A graphic image of the site was then drawn and converted to a shapefile in ChartPro.

Figure 2 Bearing Line and Shapefile in ChartPro

4. Making Shapefiles for GOM Fishing Grounds in ArcView From ChartPro

ChartPro shapefiles are not compatible with ArcView, even though both use digitized NOAA charts in a KAP format (MapTec). However, by opening both programs, the shapefiles could be copied from one window to the other.

Charts used during the transfer were NOAA Chart 13260, Bay of Fundy to Cape Cod, 1:378,838 and Canadian Chart 401001, Approaches to the Bay of Fundy, 1:300,000.

Next, a graphic was carefully drawn to duplicate the ChartPro shapefile of each fishing ground in ArcView. The resulting ArcView graphics were converted into shapefiles.

Figure 3 Display Showing ChartView and ArcView

5. Converting Spawning Ground Data into Compatible ArcView Shapefiles

Historic cod spawning grounds of the GOM were taken from "Cod and Haddock Spawning Grounds of the GOM" (15). Island Institute, Rockland, ME, donated the GIS information. Because the spawning ground shapefiles were not compatible with the KAP format, they were transferred into ArcView using the same procedure as with fishing grounds.

Next, a graphic duplicating the shapefile of each spawning ground was carefully drawn in ArcView. The resulting ArcView graphics were converted into shapefiles.

6. Determining Seasonal Distribution of Cod

Seasonal distribution in the GOM during the 1920's was based on information reported by Rich. From this, separate data layers were prepared for each month and season, using digitized NOAA charts as the base layer in ArcView (Figure I). Each layer showed only the fishing grounds where cod were caught during that month or season. The layers were then displayed sequentially to track cod movements during the course of the year.

Figure 4 Seasonal Distribution of Cod

7. Determining the Relative Abundance of Cod

Relative abundance is an estimate based on estimates given by fishermen about how productive they found a fishing ground to be at different times of the year. Their reports were specific to each ground, and relative to the season being discussed. The term represents no actual quantity

of fish, but rather the time of year when most of the fish were being caught As such, the term describes only how abundant cod appeared to be on a specific fishing ground during specific seasons, and is relative only to itself.

By displaying the location of several fishing grounds at once and then applying relative abundance values to fishing grounds with cod on them, the grounds where cod were concentrated can be identified. If the seasons are changed sequentially, the display shows that the grounds with concentrations of cod change. When these changes occur as a series of concentrations moving in the same direction, they may indicate migrations, particularly if they can be linked to seasonal movements toward or away from a spawning area. Thus, migrations moving across an area containing resident cod would be revealed, even though other fish were present, and without having to quantify landings.

Fishermen-estimates of cod abundance for each of the fishing grounds described by Rich were placed on a scale of 0-4 for each season of the year. These values, standardized according to the protocol in table 2, were loaded into ArcView and joined to the appropriate fishing grounds to make a separate data layer.

Table 2 Standardization of Abundance Estimates
(Describes the relative quantity of cod caught each month/season)

Descriptive Comment	Relative Abundance
no mention/absent	0
scarce/poor	1
fair/present but no estimate	2
good, abundant	3
excellent, very abundant, etc.	4

Changes in abundance were displayed as different shades of the same color; the darker the color, the greater the abundance. When applied sequentially to seasonal distribution data layers, changes in abundance could be tracked with respect to time.

Figure 5 Display Showing Relative Abundance in Winter
Figure 6 Display Showing Relative Abundance in Spring
Figure 7 Display Showing Relative Abundance in Summer
Figure 8 Display Showing Relative Abundance in Fall

POTENTIAL SOURCES OF ERROR

1. Accuracy of Drawn Locations

Many of Rich's fishing grounds had distinct geological features that were easily located on digitized NOAA charts. Others were relatively close to the coast, allowing the use of detailed charts to identify the features described by Rich. Unfortunately, some of the data sets used by NOAA to make offshore charts in the GOM area are of questionable accuracy. A more accurate digitized Canadian chart (40110) was used as the reference chart for the eastern half of the GOM.

Further west, the depth contours on the 13260 chart (Bay of Fundy to Cape Cod) for the Cashes Ledge area allowed relatively effective identification of neighboring fishing grounds. A few of the sites farther offshore, however, were difficult to locate; particularly those found outside the Cashes Ledge area, where NOAA charts had too few data points to match with Rich's description of the bottom. Consequently, only the fishing ground reference point could be found. In these cases, the ground was drawn as close to the reference point as possible. All grounds were drawn to scale, using the dimensions and orientation given by Rich.

2. Accuracy of Charts and Navigation used by Rich

Rich positioned the grounds using the only navigational techniques available to fishermen of the period. During the 1920's, fishermen had only compass and sextant to navigate with. Using compass bearings and distances from known landmarks, or Lat/Lon, they could come close to the location of a given fishing ground. Fishermen then searched the immediate area by using a sounding lead to sample the bottom and substrate. When bottom characteristics matched those of the ground they were seeking, they knew they had arrived.

During this period, the most common method of catching cod was still by hook and line. This forced generations of fishermen to repeatedly sample the bottom characteristics of each fishing ground until its size, shape, substrate, and benthic characteristics became well-known. This allowed Rich to give such detailed bathymetric descriptions of the grounds, even though he could only approximate its location.

In sum, correlating bathymetric descriptions with navigation information allowed period fishermen to repeatedly return to the same fishing ground. The same strategy has allowed Rich's fishing grounds to be plotted on modern navigation charts, with the advantage that today's navigation devices are much more effective.

3. The Bias of Historical Fishery Information

Historical references using fishermen-based data collected prior to 1940, were relying on tub trawling and handlining, both hook-and-line methods of capture. The landings used during the period represented only cod that were actively feeding. If the fish weren't hungry, fishermen had no way to catch them, or even to tell if they were there. This introduced a bias that completely excluded non-feeding fish from the landings. However, it did identify how cod were using the habitat and explained one of the reasons why they were there.

By contrast, spawning ground information came from sources that did not rely so heavily on feeding behavior. Much of the spawning ground information came from early gillnetters and dragger fishermen who otter trawled during the 1930's and 1940's. The rapid collapse of the cod stocks found on these inner spawning grounds and the fishing grounds associated with them, demonstrates their sensitivity to fishing pressure and suggests that different management strategies would be needed if they were to be restored and made sustainable.

4. The Use of Relative Abundance

Detailed information about the monthly or seasonal landings from the 250-odd fishing grounds listed by Rich was not available, but he did record fishermen's estimates of seasonal abundance

for each ground. These were generalizations made by fishermen about how good fishing was on a particular fishing ground at different times of year. Fishermen were comparing their success on the ground at different times of year. As such, they described the abundance of cod on a given ground for each month/season of the year without measuring actual abundance or quantifying landings in any way.

Relative abundance measures seasonal variations in cod availability for only one ground. However, when several fishing grounds were plotted, cod concentrations appeared to shift location, moving with seasonal long-shore migrations of cod. More often, these shifts showed progressive movements inshore towards (or away from) spawning areas. This has allowed such movements to be followed through areas with other cod being present.

CONCLUSIONS

A method for using historical marine ecological information has been developed that can be used to study historic fisheries, to evaluate marine ecosystem characteristics prior to depletion, and to study long-term features, constants, and trends in current fisheries. The location, character, and seasonal nature of fishing grounds can be mapped and evaluated as fisheries habitat. Interactions occurring between and among species that have used these sites can be analyzed and compared to current behavior, to add to the process of building an information base that will allow fisheries to be managed in an ecologically sound way.

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