CHARACTERIZATION OF SCALE IN COMMERCIAL FISHERIES DATA

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Abstract

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As management of commercial fisheries becomes more spatially oriented, collection of commercial fisheries data must adapt to accurately reflect location. An important component of accurate spatial data is scale. In an attempt to characterize patterns of scale in fisheries data, I tested the National Marine Fisheries Service Northeast bottom trawl survey data for spatial dependency using semivariogram analysis. Specifically, and more importantly for management, I wanted to determine if the distance between sample locations is a good predictor variable for how much fish will be caught. Focusing on 1996-2002 catch data for Atlantic cod and witch flounder, I found that for current data collection techniques, the variance of catch weight is spatially independent from distance between observations. Thus, the scale and spatial pattern of the data can not be characterized based on distance for the range of space and time analyzed. This finding does not rule out the possibility that spatial dependence may be observed in these fisheries if we were to examine data sets with finer spatial distances and finer time intervals. Because ocean processes vary significantly across time, the effect of aggregating the spatial data across time may have acted to conceal some of the potential trends in the data set.

Determining the spatial patterns in the data is part of a sequential approach to understanding ecological processes. Alternative hypotheses that may possibly explain the spatial pattern of the data need to be tested and include spatial patterns being dependent upon bottom habitat complexity, water temperature, and/or prey availability. The goal is to find a variable that explains fish biomass patterns, allowing managers and scientists to begin to understand what proxy data they really need to collect and map, and at what scale, in order to predict patterns of fishes for effective and sustainable fisheries management.

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Introduction

Fisheries Management & Data Collection

Commercial fisheries have historically been managed for optimal resource exploitation, but as the fisheries crisis unfolded in the 1990's, fishery managers were challenged with the opposing goal of sustainably managing, even conserving, fish stocks. The Sustainable Fisheries Act of 1996 provides four goals for fisheries management:

1) Prevent overfishing, end overfishing of depleted stocks & rebuild depleted stocks.
2) Reduce by-catch wherever possible and minimize mortality of unavoidable by-catch.
3) Describe, identify, conserve & enhance essential fish habitat as part of Fisheries Management Plans.
4) Provide optimum yield from fish stocks (where optimum is MSY reduced by any relevant social, economic or ecological factor).

(NMFS, 2003(a)).

These goals indicate a need for new management frameworks, as noted by Caddy (1999): "projected increases in demand, future prices for fisheries products, and impacts of growing world populations on the ecosystem all require an urgent search for improved management frameworks." These new management frameworks must account for interactions within the entire ecosystem, which means a large amount of data will be required. If fisheries management is going to create sustainable commercial fisheries, data collected from the fisheries needs to be timely, accurate, and functional.

Data used in fisheries management is either fishery independent or fishery dependent. Independent data is collected by researchers and commonly includes habitat, species diversity, and oceanographic trends; it occurs separate from fishing activities. On the other hand, fishery dependent data is information collected from the fishery, through landing reports, observer coverage, and dealer reports. Dependent data often includes weight landed of each species, bycatch numbers, and economics of the industry.

Fisheries management and resource allocation are increasingly becoming more geographically orientated: allocating within certain spatial extents and closures of certain areas as a form of spatial harvesting (Bohnsack and Ault, 1996; Roberts, 1997). Meaden (1996) points out the importance of optimizing location in fisheries management: "allocation of activities to areas, in order to achieve some level of spatial optimization, will be increasingly necessary if conflicts are to be minimized and the maximum success is going to be achieved for most marine activities." In addition to spatial optimization, the traditional technique of stock assessments will continue to be incorporated into future management. However, the "scientific basis on which the stock assessments are made is liable to have a considerable margin of statistical error as the catch data used is generally recorded at a resolution that is too coarse to provide valid or reliable information" (Kemp and Meaden, 2002). With such changes in management focus, data collection also needs to become more geographically orientated and catch data needs to be recorded at a finer resolution.

The U.S. Ocean Commission (2004) and Pew Ocean Commission (2003) reports lend further support to the changes in fisheries management. There will be a new focus on how fishermen are reporting their catches and how that reported data will be used. Past policies on data/catch reporting have left managers with a lot of information that takes months, or even years, to process, and it is often spatially and/or temporally vague. As ecosystem management emerges, landing reports will not be adequate; spatial data revealing the actual location of the fishing will be needed to match effort with habitat type, closed areas, and use zones. Additionally, as current technologies are utilized (i.e. vessel monitoring systems, automatic data collection and processing) and reporting requirements change and evolve, there will need to be new policies in place to direct data collection. As noted in the Pew Oceans Commission *Report to the Nation*, "We need new research and monitoring programs to improve the timely collection, compilation, and analysis of data" (2003).

Spatial Scales, Variance, & Geographic Information Systems

The spatial scale of commercial fisheries data is the main problem I address in this study. Simon Levin elegantly summed up the importance of scale in his MacArthur Award Lecture:

> It is argued that the problem of pattern and scale is the central problem in ecology, unifying population biology and ecosystems science, and marrying basic and applied ecology. Applied challenges… require the interfacing of

> phenomena that occur on very different scales of space, time, and ecological organization. (1992)

Our ability to detect environmental heterogeneity depends on the scale of the measurements. Scale, or resolution, can be defined as the “degree of geographic detail in a description of the Earth’s surface” (Goodchild, 2001) and is dependent on data collection techniques. For example, in some mid-Atlantic fisheries, catch location is recorded using boxed areas on a map of 10 x 10 arc minutes in size(60 x 60 nautical miles), which is much too coarse to analyze against habitat when trying to determine marine protected area placement (Merriner, 2004) or to identify areas of essential fish habitat. For the New England Fishing Vessel Trip Reports, an area, often 1degree-by-1 degree boxes, is indicated as the “area fished” and a single set of degree and minute coordinates are recorded for where most of the fishing occurred (NMFS, 2003(b)). The geographical detail can refer to resolution, grain size, or extent. The extent is the overall area of a study, while the grain is the size of the individual units of observation (Wiens, 1989).

Scale is also used to define the spatial level of ecological processes (Platt and Sathyendranath, 1988; Wiens, 1989); characteristic scale of patterns can distinguish between basin wide larval transport and larval transport across two adjacent reefs. Scale can also be thought of in terms of statistical variance and the spatial pattern of the data. As the scale of measurement changes, the variance within and between samples also changes. As grain is increased, more of the spatial heterogeneity of the system is contained within a single observation and is thus averaged into more homogeneous data. When this happens, the between grain heterogeneity, or variance, also decreases. Understanding spatial patterns is directly linked to scale, since “spatial pattern detection is a function of the extent and the grain” (Wiens, 1989).

Current management decisions rely more on stock assessments and landing trends; in order to move towards ecosystem based management we will need the data to be more spatially orientated, identifying where the fish are caught with a greater geographic detail. Additionally, a useful scale needs to be determined in order to take advantage of observing environmental heterogeneity and performing spatial analyses.

If this more accurate data can be collected, geographic information systems (GIS) may provide a solution to processing and analyzing this data for fisheries management. GIS is currently used in many marine science applications: coastal zone management, nautical charts, aquaculture locations, and marine water quality (Meaden, 1996). Meaden further discusses some potential uses of GIS in marine fisheries science, including monitoring changes, comparative studies, modeling “what if” scenarios, mapping natural marine resources, and fisheries management and regulation. However, the coarse scale of the current data does not lend itself to GIS applications in management.

Geostatistics & the Semi-variogram

Geostatistics provides a framework for identifying spatial trends in the data that could help to determine optimal scale. As a methodology, it is used to “analyze, model, estimate, and map the spatial distribution of natural resources through an analysis of their spatial autocorrelation.” (Maynou, et al., 1996). Geostatistics began with meteorologists’ need to interpolate weather characteristics from minimal data and mining engineers desire to estimate mineral quantities from drill cores (Oliver, et al., 1989). Oliver, et al. also note that the theory of regionalized variables used in mining is “properly applicable in many other branches of earth, atmosphere, and marine science.” Petitgas (1996) goes further and discusses the use of geostatistics in analyzing fisheries survey data.

The dependence of marine organisms on their habitat, including oceanographic and benthic structure parameters, indicates that animals are not independent from their spatial location. Many fishes congregate when there is specific habitat, while others follow schooling behaviors, temperature, and other ecological and behavioral trends (Fogarty and Murawski, 1998). When we collect fisheries data for management purposes, the high level of spatial variation must be taken into account when analyzing the data.

Traditional parametric statistics, including t-tests, F-tests, X^2 tests, or ANOVAs, assume that one datum is independent of all other data and that the data are normally distributed. However, ecological phenomena involve recognition of correlation: dispersion and patterns in association between different species at different places and at different times, thus spatial dependence is a more practical and realistic assumption (Rossi, et al., 1992).

The semi-variogram (also referred to as a variogram) is considered the central tool of geostatistics; it "provides an unbiased description of the scale and pattern of spatial variation… by measuring the degree of spatial correlation or dependence between sampling points" (Oliver, 2001). Semi-variogram analysis characterizes the spatial patterns in the data; it also allows for the prediction or interpolation of unsampled locations. Rossi, et al. (1992) go on to describe variograms as models of the "average degree of similarity between the values as a function of their separation distance." Semi-variograms can have a scalar lag measure when computed in an average overall direction or have a vector lag measure when computed as specific to a particular direction. If spatial autocorrelation exists within a vector lag measure, the data is considered anisotropic.

Objective

The original conception for this project was to determine the optimal scale for fisheries data collection. This progressed into the more manageable task of determining what spatial patterns exist in the data and characterizing the scale of the fisheries data. Is there a relationship between the amount of fish caught and the distance between the trawls? More simply, and more importantly for management, is the distance between sample locations a good predictor variable for how much fish will be caught? As distance between samples increases, the variance in catch weight should also increase, out to a point, at which the data become spatially independent. The null hypothesis I was testing is: the catch weight of the fish at each sample is spatially independent from distance between samples. Determining spatial patterns in data is part of a sequential approach to understanding ecological processes. Once the pattern is found and the characteristic scale is determined, predictor variables that also occur at the characteristic scale may serve as explanatory variables (Urban, 2003). Finding these predictor variables would ideally provide an easily measured proxy value for predicting fish distributions (Warner, 1987).

Materials & Methods

Data

The Northeast Atlantic groundfishery represents a multispecies fishery that has had historic management problems and continues to face challenges in rebuilding stocks and creating effective management regulations. The data used in this analysis were provided by the National Oceanographic and Atmospheric Association (NOAA). The fishery independent data were the National Marine Fishery Service (NMFS) Bottom Trawl Survey data for the Northeast Atlantic groundfishery. This data ranged from the Gulf of Maine to Georges Bank. The trawl survey was completed every fall and spring for the last thirty years and includes data for many species, including Atlantic cod, pollock, yellowtail flounder, witch flounder, winter flounder, fluke, and fourspot flounder. Each Otter trawl was towed along the bottom (figure 1) for 30 minutes and start and stop latitude and longitude were recorded, along with catch weight (kg), numbers caught for each species, depth, and station identification.

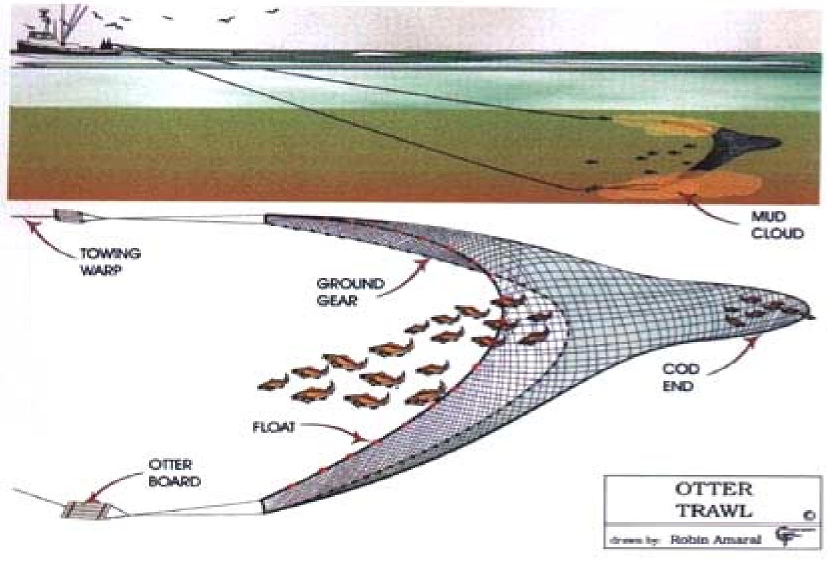


Figure 1: Diagram of an Otter trawl, illustrating how it is towed through the benthic habitat. (Smolowitz, 1998)

I analyzed the 1996 to 2002 data since this time range had relatively similar resolutions, ranging from one arc second to one arc minute (31 meters to 1,852 meters), becoming more accurate over time. The locations of the trawls were distributed in a stratified random fashion. In order to make the analysis more manageable, I looked at just the Atlantic cod, *Gadus morhua*, (figure 2) and the witch flounder/grey sole, *Glyptocephalus cynoglossus*, (figure 3) as representatives of nekton and demersal species. The map in figure 4 illustrates the extent of the study area and the locations of the 4,807 trawls.

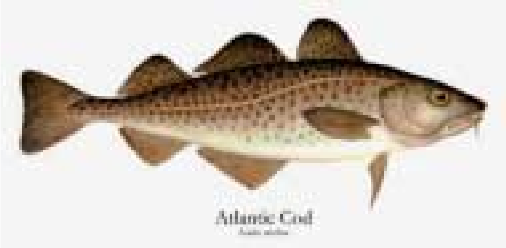


Figure 2: Atlantic Cod, *Gadus morhua* (Charting Nature, 2004(a))

Figure 3: Witch Flounder, *Glyptocephalus cynoglossus* (Charting Nature, 2004(b))

Semi-variogram Background

Geostatistical semivariograms were used by Jackson and Caldwell (1993) to determine soil properties around individual perennial plants at variable scales. Geostatistical techniques have also been successfully employed in a biological oceanographic context by Maynou, et al (1996); they analyzed the spatial structure and seasonality of crustaceans, beginning with a spatial variability assessment using an experimental semivariogram where the covariance functions were analogous to the spatial autocorrelation functions used in spatial ecology.

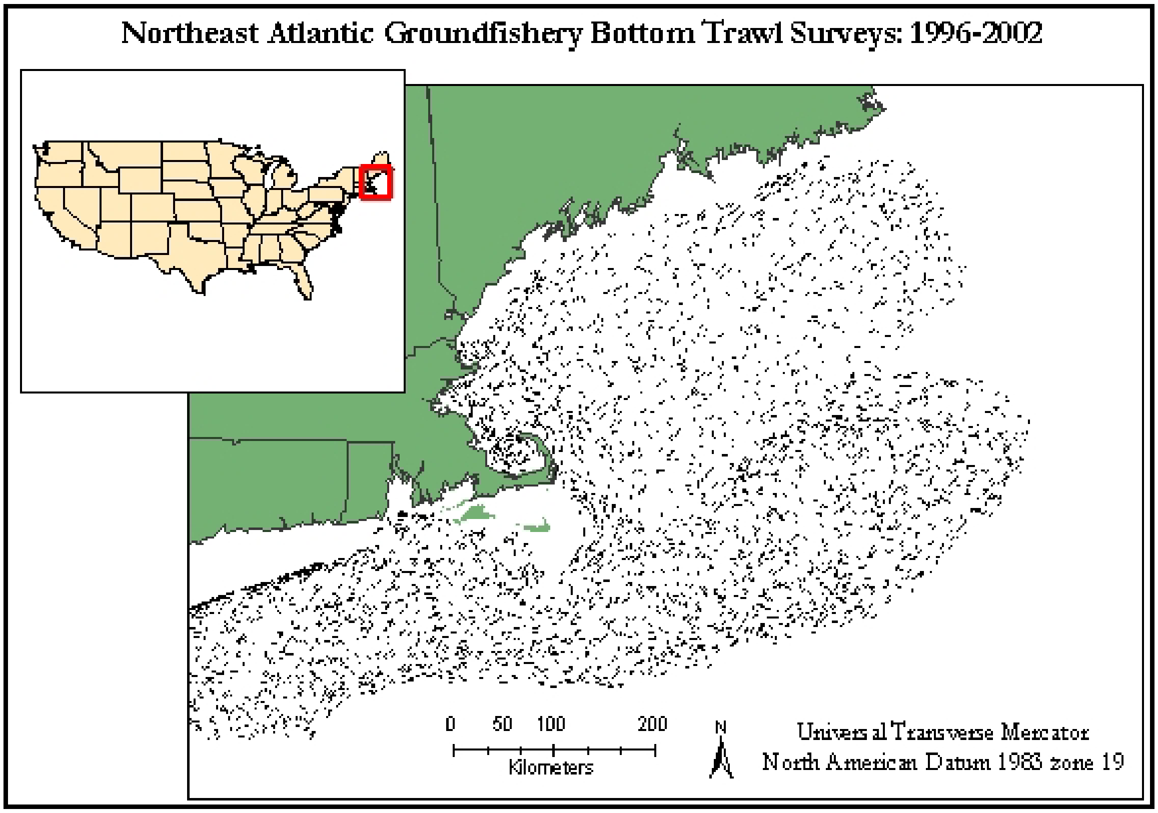


Figure 4: Map of study area; black lines represent locations of all spring and fall survey transects for the years 1996-2002.

The semivariogram is created by measuring the distance between two locations and plotting the lag distance on the x-axis. The difference squared of the values at the two locations is also calculated and is plotted on the y-axis. This is done for every possible pairing of locational observations. In the absence of spatial autocorrelation among samples, the spatial position of the samples are independent (Maynou, 1996).

Semivariance, γ, at a given separation is half the expected squared difference between two values at that separation, and is computed by the following formula (Oliver, 2001):

$$\gamma(h) = \frac{1}{2} M(h) \sum_{i=1}^{M(h)} \{z(x_i) - z(x_i + h)\}^2$$

Where $M(h)$ is the number of comparisons at a given lag, and $z(x_i)$ and $z(x_i + h)$ are the observed values of z at x_i and $x_i + h$, respectively. By changing the lag, h, an ordered set of values is obtained, which is the sample variogram.

A polynomial function is then fitted to the cloud of points representing the experimental values, yielding actual values that can be used for interpolation. The main values taken from the model are sill variance, range, and nugget, as illustrated in figure 5(b). The upper bound of the function, or asymptote, is known as the sill and designates that all of the variation at this level of resolution has been included. For this study, the sill represents the point at which increasing distance does not affect the biomass of the fish caught. The range, which is measured as the distance from zero to the point at which the sill begins, represents the distance at which the data is spatially dependent or autocorrelated. Beyond the range distance, the data become spatially independent. The nugget is the y-intercept of the function and represents apparent spatial independence, measurement error, or some combination of the two. It is unresolved variation in the sampling. Figure 5 additionally shows possible outcomes from a semi-variogram where the range is undeterminable. 5(a) is an unbounded function and indicates that there is additional variation that has not been encompassed by the scale of the observations. The extent of the study may need to be increased or the grain of observation may need to be adjusted. The result is “pure nugget” if the result is a straight horizontal line, as in 5(c). The nugget variation is considered uncorrelated noise. If there is spatially correlated variation present, it is taking place at a scale that is less than the sampling interval (Oliver, 2001).

The results of semi-variograms can be highly influenced by the input parameters of lag size and number. Lag size controls the size of the bin, while lag number specifies how many bins. Bins break up the data and are used to classify the lags so that each lag contains values that have similar distance and direction. Oliver, et al. (1989) recommend a "minimum of a hundred comparisons at the first lag, and following practices in the analysis of time series suggest that estimates should be made for lag distances no more than a fifth of the entire transect for one dimension." Furthermore, "the larger the sample and the shorter the lag, the better the semivariance is estimated." On the other hand, Rossi, et al. (1992) recommend that each lag class should have at least 30-50 pairs of comparison points.

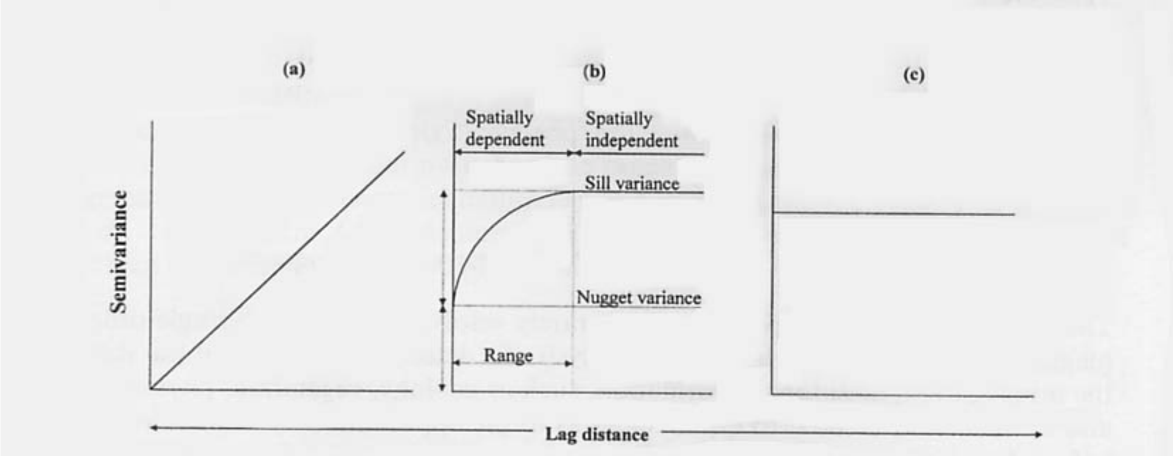


Figure 5: Three idealized forms of variograms: (a) unbounded, (b) bounded, and (c) pure nugget. (Oliver, 2001)

Methods

First the raw fisheries data, obtained in text format, were processed into a useable database and GIS coverages for use in the ArcGIS Geostatistical Analyst. Lines representing the trawls and points representing the midpoint of the trawl were created in ArcINFO and the trawl attributes were attached to the midpoints. The coverages were then projected according to table 1, in order to preserve distance between points and reduce distortions of area and shape.

	Geographic	**UTM zone 19**
Projection		
	Original Data	*Projected Data*
Datum	North American Datum 1983	North American Datum 1983
Units	Decimal degrees	Meters

Table 1. Projection details for GIS coverages.

The trawl midpoints were then subset by month and year. For each monthly subset file, I calculated the distance from each point in the coverage to every other point in the coverage. This allowed me to create plots of distance *vs*. day of the month in order to visualize both the temporal trends of the data and the minimum lag distances (figure 6). I then subset the data based on the temporal patterns of the trawls, creating subset files that had from 3 to 6 days worth of data in order to have a statistically valid number of observations, but also to have a short enough temporal frame that spatial location could be affected by oceanographic trends. Minimum lag distance was determined after sub-setting the data, by counting out the closest 30 points (representing a distance pair) and noting the largest distance as the minimum lag distance.

I then conducted a semivariogram analysis on each temporal subset for each species' catch weight, using the ArcGIS Geostatistical Analyst. Where there was zero catch weight for an entire subset, the analysis was omitted. Empirical models were fitted to each semivariogram when the cloud of points showed potential for fitting to a line. This was done at three different lag sizes: the minimum for 30 pairs as calculated by the distance *vs*. day plots, the auto-calculated default of the software, and the minimum distance between any two points in the subset greater than zero. The number of lags was then determined by dividing the subset extent distance by the lag distance. The maximum lag distance was limited to half the extent (Anselin, 2002).

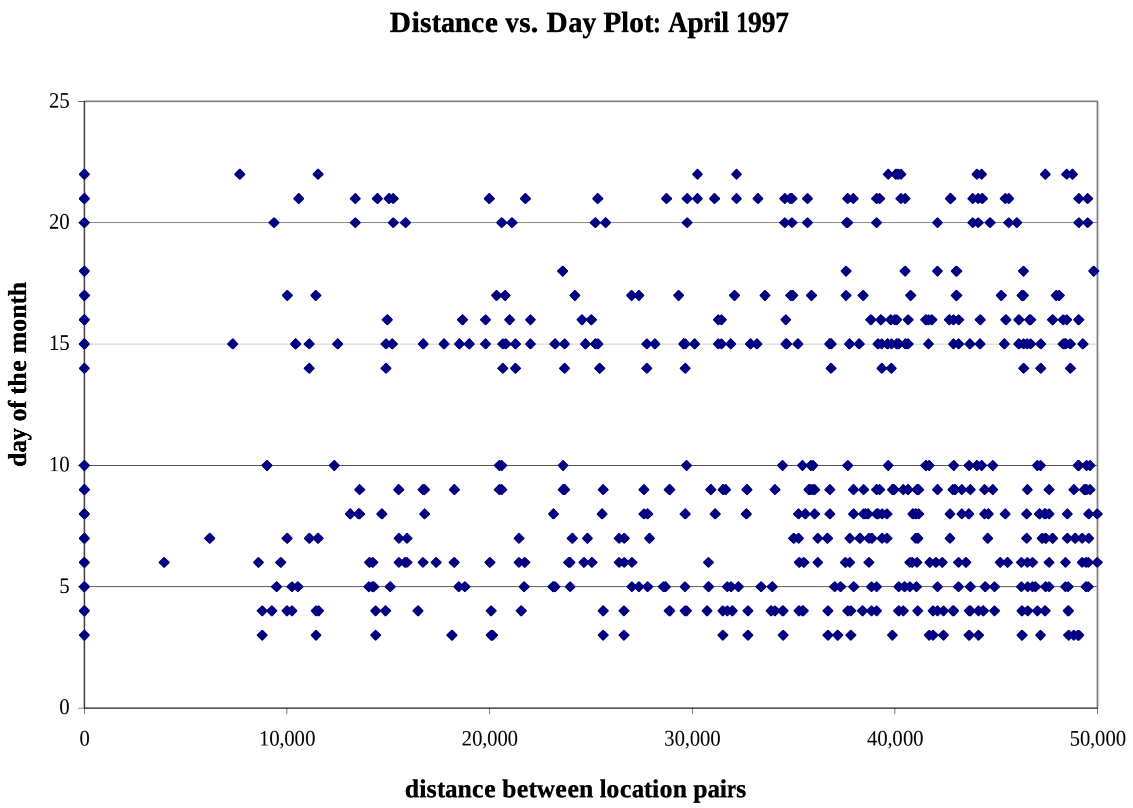
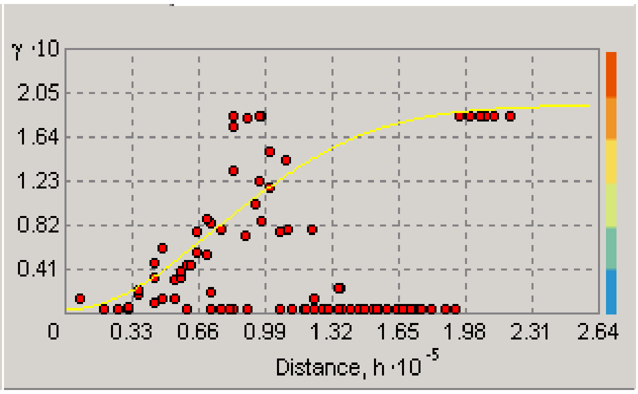


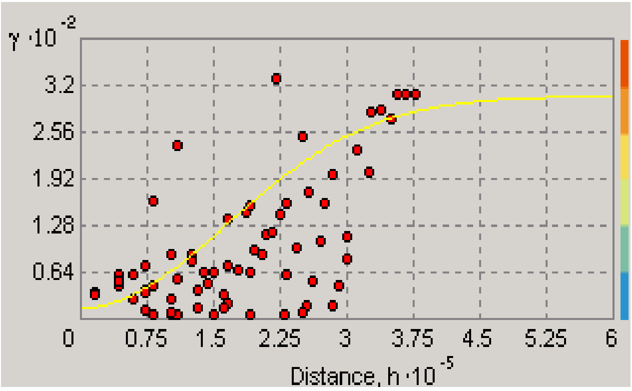
Figure 6: Distance *vs*. Day Plot for visualizing temporal trends in the data.

Results

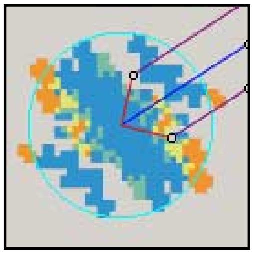
There are two general possibilities resulting from the analysis; (1) there is some spatial dependence exhibited in the data, or (2) there is no spatial dependence in the data. Of the 266 subsets that were analyzed, including the weekly and monthly subsets for each of the species, only 4 exhibited spatial dependence at shorter lag distances. Two witch flounder subsets were anisotropic. These 2 subsets, exhibiting the strongest spatial trends, only exhibited this trend when using directional variogram analysis. Figure 7 shows the semivariogram and related information for each of the 4 subsets.

The other 98.5% of the semi-variogram analyses can be represented by the plot in figure 8. Non-directional and directional variogram analyses of the monthly and 3-6 day subsets resulted in 262 noisy plots that exhibited no spatial trends. The overall results of the study are negative; there is no spatial dependence exhibited in the data.

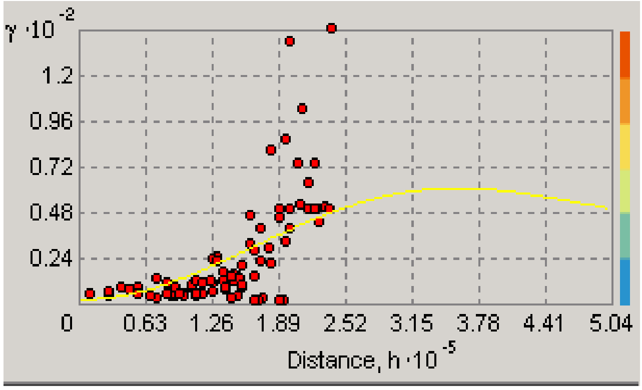


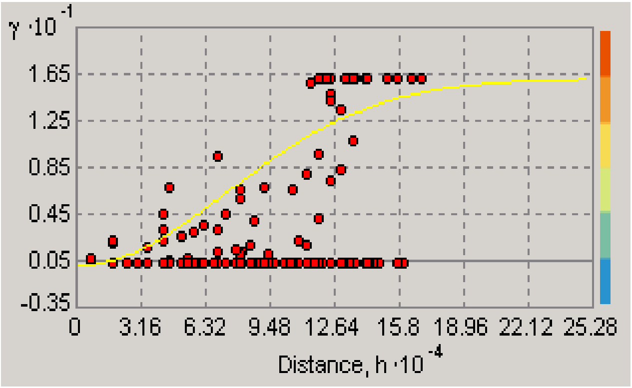


March 24-26 1998, witch flounder
Gaussian Model
Range: 183 km
Sill: 0.19
Angle Direction: 57.4
Angle Tolerance: 45.0
Bandwidth (lags): 5.8

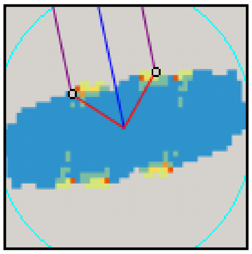


February 20-23, 1999 Atlantic cod
Gaussian Model
Range: 402 km
Sill: 290
Not anisotropic



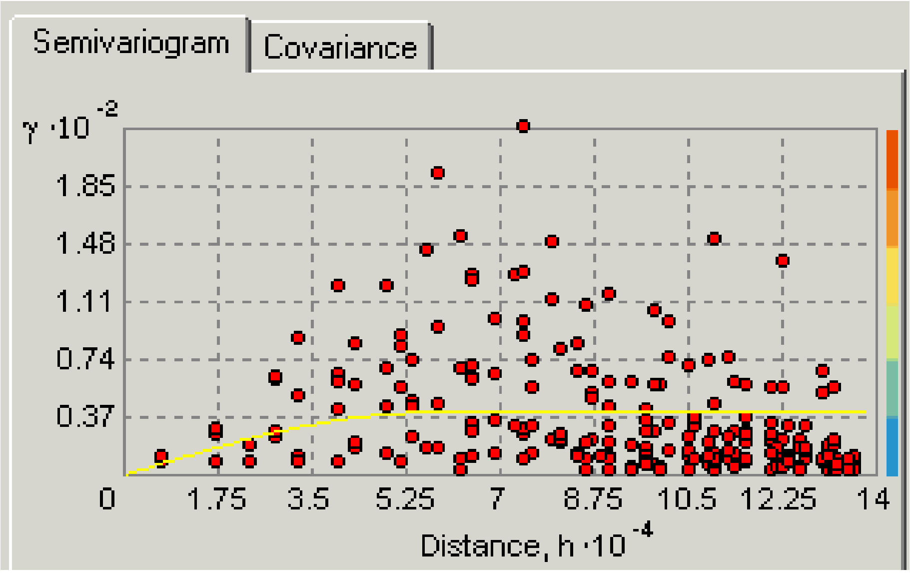


September 1996, witch flounder
Hole Effect Model
Range: 500 km
Sill: 48
Angle Direction: 347.1
Angle Tolerance: 45.0
Bandwidth (lags): 8.5



February 12-14, 2001 Atlantic cod
Gaussian Model
Range: 180 km
Sill: 16
Not anisotropic

Figure 7: Positive semivariogram plots of four subsets exhibiting spatial dependence. The two witch flounder subsets are anisotropic.



April 24-27, 2000 witch flounder

Figure 8: Representative semivariogram plot of negative results, exhibiting no spatial dependence. The yellow line indicates the software's attempt to fit a model line to the cloud of points.

Discussion

While there was some spatial dependence in the data, it represented a mere 1.5% of the subsets; not nearly enough to indicate a spatial relationship between catch variance and distance between observations. Also, the anisotropic nature of the strongest trends does not meet the presumption of isotropy while determining autocorrelation (Oliver, 2001). The data, on the whole showed no signs of spatial dependence.

If the 4 subsets exhibiting some spatial dependence were stronger trends with more tightly fitted lines, the scale and spatial patterns could be characterized. For illustrational purposes, if the March 1998 witch flounder subset (figure 7) was characterized, it would have a range of 232km. The data become spatially independent when the distance between observations is greater than 232km. Lag distances of less than 232km can be considered spatially dependent. The range value can also be considered the minimum spatial extent for a study area. If the extent sampled for the subset was smaller than the range, then the function would be unbounded and the range may not be determinable. Additionally, it can guide further sampling; a rule of thumb is to sample at an interval that is half of the range (Oliver, 2001).

For current data collection techniques, the variance of catch weight is spatially independent from distance between observations. Thus the scale and spatial pattern of the data can not be characterized based on distance for the range of space and time analyzed. The null hypothesis can not be rejected. Since the data are spatially independent, they can undergo parametric statistics by fishery managers and scientists, without breaking the assumption of independent data.

Unfortunately, another potential tool is lost to the managers. The interpolation techniques that allow for powerful predictions of fish distribution or catch success depend upon spatial dependence of the data to fit an accurate prediction model. The geostatistical method of kriging uses the output from the fitted semi-variogram's empirical model to create more accurate estimations of unobserved locations. It utilizes spatial covariance to make predictions, emphasizing the local spatial structure of the variable. The range of the variogram dictates the size of the window for used for kriging prediction, and the statistical estimated weights provide error estimates, allowing for the identification of areas that need more sampling (ESRI, 2001).

There are three data caveats that must be addressed and considered when interpreting the results.

1) The trawl survey was designed by NMFS to collect statistically robust data. The station locations were chosen through a stratified random process in order to ensure consistency of station locations over the years in order to compare the data temporally. This may have compromised the randomness of the observations and may have built spatial independence into the data collection method.
2) It is possible that the data have been collected below the spatial resolution of any potential autocorrelation. The trawls may be too far apart in space and/or time to observe any spatial trends. If there were data available at a finer spatial and temporal resolution, it could potentially provide more points in the lower left side of the semi-variogram plot, as illustrated in figure 9, and draw out some more defined spatial trends.
3) While the data was available to subset by hours, the finest subset I could feasibly use was 3-6 days due to sample size restrictions. The spatial patterns of mobile fish may be on

hourly scales instead of daily or weekly, thus requiring more intensive trawling efforts each day of the study.

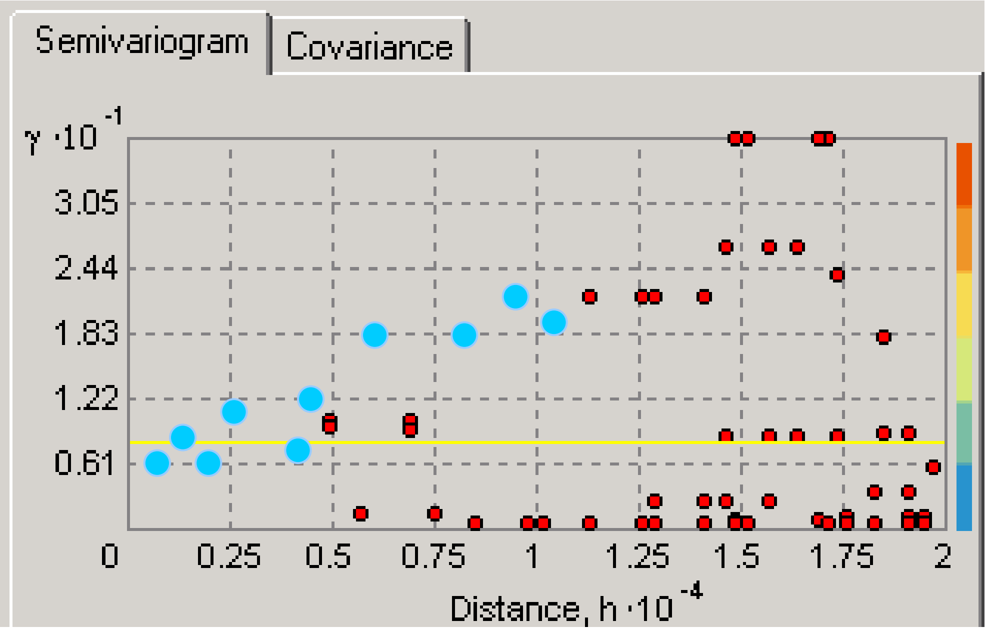


Figure 9: Potential effects on semivariogram analysis of finer resolution in data collection. The blue points indicate where finer scale data may add additional points to the semivariogram cloud.

Conclusions

What is the optimal spatial resolution for data collection? Unfortunately, there is no single scale at which to study ecological phenomena (Levin, 1992); however, the next step for this data is to determine which scale of data collection will serve fishery managers the best, allowing them to accurate predict fishery patterns. How useful is the current data collected at coarse resolutions? I was unable to reject the null hypotheses that the fisheries data are spatially independent across the spatial lag distances measured. The lack of exhibited spatial trend in the data did not allow for the scale to be characterized; thus, these questions still remained unanswered. This finding does not rule out the possibility that spatial dependence may be observed in these fisheries if we were to examine data sets with finer spatial distances and finer time intervals. Because ocean processes vary significantly across time, the effect of aggregating the spatial data across time may have acted to conceal some of the potential trends in the data set.

It would be useful to compare these results of the fishery independent data with fishery dependent data. NOAA has comparable observer coverage data available for the Northeast Atlantic Gillnet fishery. This dataset covers 2-5% of the total days fished in the gillnet fishery and represents year round coverage. While trawl data would be optimal, both the gillnet and otter trawl data sample the same fishery. Not only would this comparison provide some insight on how the stratified random NMFS stations affected the spatial trends, it could also compare the effectiveness of fishery independent versus fishery dependent data for interpolation of fisheries.

Since the null hypothesis was not rejected and spatial patterns, as measured in this study, may not be predictable by distance, I came up with three alternative hypotheses to test in future studies:

1) Spatial pattern is dependent on bottom complexity of habitat
2) Spatial pattern is dependent on water temperature
3) Spatial pattern is dependent on prey availability

If we can find a variable that explains the fish biomass pattern, we can begin to understand what proxy data we really need to collect and map, and at what scale, in order to predict patterns of fishes for effective and sustainable fisheries management.

Policy Implications

Data Reporting in Commercial Fisheries: Current Policies and Future Trends

Technological innovations are becoming the norm in all aspects of fisheries. From GPS and navigational instruments to fish finders and faxed sea surface temperature maps, the wheelhouses of commercial fishing vessels hold a bounty of electronics. It is no wonder that fishery managers are looking towards technology to help manage fisheries and enforce policies. The four goals of the Sustainable Fisheries Act, outlined in the introduction, when combined with current technology, create the need for timely, accurate, and functional data collection. Waiting for paper reports to be mailed in, added to a database, and checked is a slow process that does not allow for adaptive management. Time is particularly critical when managers are assessing how much of a total allowable catch (TAC) is remaining. The data collected needs to be accurate; typographical errors and misreporting may place some boats far from their actual locations. Additionally, much of the reporting is only spatially accurate within a mile (NMFS, 2003(b)).

Once the data become more timely and accurate, managers can effectively use the data to help manage the fish stocks. Better models can be made with the data, closures can be more precisely defined, and the data can be combined with other species and habitat research to look at ecosystem-level interactions. As an added benefit, the technology that can help improve the catch reporting can also help enforce the policies. This is particularly useful as the difficult to enforce time-area closures are becoming a common management tool (Jones, 2002; Allison, et al., 1998). But these changes in data reporting cost money and require a change in attitude, especially in New

England. In this case, changing the policies regulating data reporting is the only way to change the behavior of the fishermen.

The possibility of changing federally managed commercial fisheries data reporting policy exists due to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (16 U.S.C. §1801). This Act calls for a national fishery management program and designates the structure and function of the regional fishery management councils. These councils, using stakeholder involvement, are responsible for crafting fishery management plans. However, it is only the Secretary of Commerce that has authority to approve and implement a plan. The day-to-day implementation, monitoring, and enforcement are the responsibility of NMFS.

Within the MSFCMA, there are some specific regulations regarding data reporting. Section 303 (M-S Act §303 (b) Discretionary Provisions (4) & (7)) allows fishery management plans to regulate the use of equipment, including devices to facilitate enforcement, and to require fish processors to submit data. Title IV, Fishery Monitoring and Research, more specifically addresses the reporting done by the fishermen. Section §401 requires the collection of basic vessel information, including gear and geographic unit of operation. Section §402 allows the councils to request additional information as deemed necessary. The Sustainable Fisheries Act of 1996 (SFA) (16 U.S.C. §1801), which amended and reauthorized the MSFCMA, requires managers to establish a system to report the amount and type of bycatch.

The New England groundfishery provides an ideal example of a federally managed fishery that is desperately trying to recover its stocks and is undergoing significant change. Environmental groups, led by the Conservation Law Foundation, sued Secretary Evans and the National Marine

Fisheries Service (NMFS), alleging that the amended Northeast Multispecies Fishery Management Plan "violated the overfishing, rebuilding and bycatch provisions of the Magnuson-Stevens Act." (Federal Register, 2002). Consequently, the past two years have seen the New England Fisheries Management Council struggle with interim rules and devising a fisheries management plan that is acceptable to all parties. While data reporting plays a very minimal role in the overhaul of the management plan, the current controversy allows for technological data reporting recommendations that could help manage a broken system that is lagging behind the rest of the country in their catch reporting.

The fishery management plan specifically outlines the data reporting requirements for any given fishery. The Northeast Multispecies Fishery Management Plan (NEMSFMP), which is implemented through the Code of Federal Regulations for *Fisheries of the Northeastern United States* (50 CFR Part §648), regulates the New England groundfishery. The NEMSFMP applies to stocks of cod, haddock, yellowtail, winter flounder, witch flounder, plaice, white hake, and redfish. Currently, the fishermen are required to report each trip, using a Fishing Vessel Trip Report (FVTR). Prior to 1994, reporting catches was voluntary. According to 50 CFR §648.7 (b), every trip must have the following information submitted to NMFS by the 15th of the following month:

> Vessel name; USCG documentation number; permit number; date/time sailed; date/time landed; trip type; number of crew; gear fished; quantity and size of gear; mesh/ring size; chart area fished; average depth; latitude/longitude (or loran station and bearings); total hauls per area fished; average tow time duration; hail weight, in pounds, by species, of all species…; dealer permit number; dealer name; date sold,

port and state landed; and vessel operator's name, signature, and operator's permit number.

The latitude/longitude reported is only a single reading, presumably at the central point of the fishing activity. If the vessel moves into a different chart area to fish, an additional FVTR must be submitted. Additionally, the fishermen must keep copies of all submitted FVTRs for at least 3 years, and the most recent year must be onboard (NMFS, 2003(b)). While these reports give managers data as to how much is being caught and a general idea of where the fishing is occurring, the spatial resolution is very coarse. The chart areas, as shown in figure 11, average an area covering over 3600 sq. nautical miles. There is no electronic catch or trip reporting occurring in the groundfishery, despite the availability of the technology.

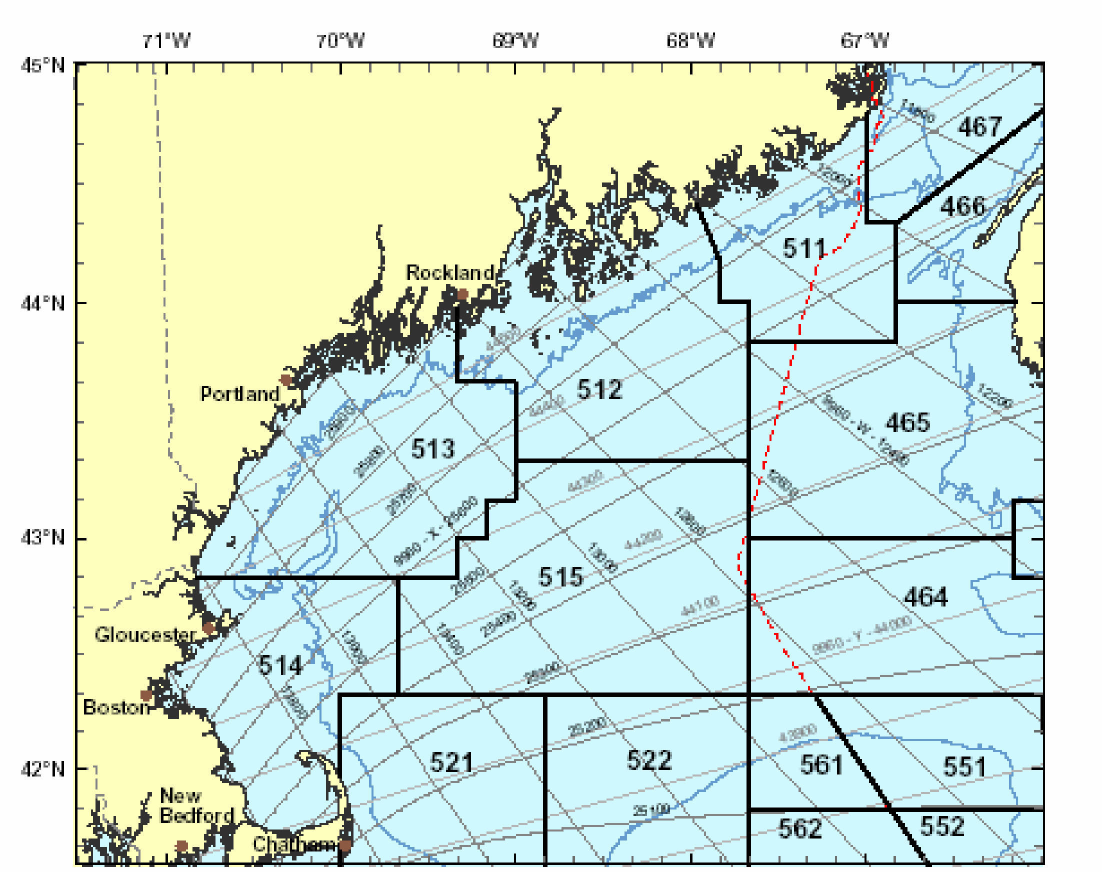


Figure 11: Chart used by fishermen to report areas fished on Fishing Vessel Trip Reports (NMFS, 2003(b)).

Portions of the NE multispecies fishery require the use of vessel monitoring systems (VMS) as a way to "report" vessel location. NMFS must annually approve the VMSs to meet the criteria requirements set forth by 50 CFR §648.9. The VMS helps enforce fishery policies by transmitting vessel location, identification, date, time, and any additional information directly to NMFS via satellite. This location is automatically reported every hour of every day at a positional accuracy of at least 400 meters, as well as real time polling of vessels. For the NE multispecies groundfishery, vessels may voluntarily have an approved, operational VMS onboard. However, if the vessel has special permitting to fish inside the various closed areas (limited access), a VMS is required. The only changes to NE multispecies VMS regulations under the Council approved Amendment 13 will be the allowance for vessels to "opt out" of the VMS program for at least a month when the vessel will not be engaged in fishing activity (Federal Register, 2004).

While barely in use in the NE multispecies fishery, VMS is widely used in other fisheries. In New England, the scallop fishing vessels are required to have VMS onboard, to monitor their position and enforce the scallop closed areas (50 CFR §648). The impact of the closed areas is already being felt, as the scallop fishery has rebounded and is now considered a healthy stock (NEFMC, 2004). The high seas drift net fishery was the first to implement VMS. It has since become a standard tool on the west coast. The new management plan for the over fished California rockfish used VMS to monitor vessels, ensuring the closed areas around the Channel Islands stay closed. In Alaska, the North Pacific Fisheries Management Council has embraced VMS as a monitoring and enforcement tool. (RFMC/NOAA, 2003). Electronic logbooks (ELB), like the one developed by OceanLogic, are in use in the North Pacific. These ELBs are a specially designed software package that links to the navigational equipment onboard and provides a tool for catch management. “It collects, stores, and archives a vessel’s fishing data for compliance and analysis whenever and however the user sees fit” (OceanLogic, 2003). NMFS accepts electronic logbook submissions instead of the time-consuming paper logbooks in the North Pacific catcher vessel trawl fishery, making it an efficient and accurate way of compiling management data for a fishery. The managers can monitoring the quotas and TACs from day to day, thus preventing over-fishing (Fuglvog, 2003).

The human ecology of policy formation is evident in all marine legislation, but perhaps it is felt most strongly in fisheries management. Since the plans are devised by the Council and its stakeholders, the human constituents play a huge role in how the groundfish are managed. The fishing industry comprises 80% of the NEFMC members, leading many to point at this “self-regulation” as a primary reason for the decimated state and slow recovery of the NE Multispecies fishery. (Okey, 2003; U.S. Newswire, 2003). Beyond the fishing industry, including commercial and recreational fishermen, dealers and processors, other interested parties include the fishing communities, fishing coalitions/associations, business operators, and many environmental groups, including the Conservation Law Foundation, the Ocean Conservancy, and Oceana.

The Pew Oceans Commission, in their report to the nation, identified the need for “new research and monitoring programs to improve the timely collection, compilation, and analysis of data” (Pew, 2003). Their *A Dialogue on America’s Fisheries* does report the fact that in fishing communities across the country, there are inadequate financial resources to support more sophisticated data collection (Pew, 2002). The many concerns about increasing management technology, as well as the benefits, seem to be the general consensus of the New England constituents, as determined through the following FMP comments, fishermen publications, and regional fishing associations (ASMFC, 2000; Crocker, 2003; NEFMC, 2003; Parker, 2003; Valleau, 2003; Zeman, 2003). As with all issues there are definitely pros and cons to each tool. The largest obstacle is the cost of implementing new, mandated technology and the fear of a vendor monopoly. To purchase a VMS is between $1800 and $5000, and there is a daily reporting fee of $5 and $1, respectively. Who pays for this cost? It would make sense to have the fishermen pay, adding it in as a cost of doing business; they are, after all, utilizing the public trust for their private gain. However, the West coast set a precedent, subsidizing the costs of the VMS units when they first mandated them. New England, of course, also wants theirs subsidized; particularly the traditional small vessels, where the cost of implementation could be a significant percentage of their revenues. These smaller vessels, while not in the majority, are definitely vocal participants in creating management plans. They also are concerned with the design of the units. Most VMSs must have a generator onboard and shore power when docked in order to operate. Many fishermen claim they would be in favor of the VMS if they were smaller and battery operated. There is also the general fear of more regulations and the 'big brother' aspect that makes their fishing secrets public. An effort is being made by NOAA's Northeast Science Center and some New England fishing alliances to develop a VMS that the fishermen would gladly use. They are redesigning it and testing various models in a study fleet program, to see which VMS model meshes best with New England fishing practices, focusing on physical design and ease of use. They are overcoming the confidentiality issue by protecting the real time reportings and only making data publicly available at 10 day/10 minute temporal and spatial resolutions (Meredith, 2003).

There are many recognized benefits to outweigh the above concerns. Not only do VMSs help enforce locational restrictions, but they offer an opportunity to electronically submit basic catch information, provide a greater safety at sea and an increase in operational efficiency. The use of electronic logbooks and real time data collection is supported by the majority of the constituents, particularly the environmental community, although the New England fishermen have instead focused their comments on changes that must be made to mandatory VMS requirements.

Attitudes of fishermen are changing, especially in areas where they have seen the success of management using VMS. In Alaska, fishermen have helped to create supplements to VMS technology. A group called OceanLogic, with the input of the fishermen, has created a vessel verification system (VVS) and an electronic logbook (ELB). While the VVS is not yet approved by NMFS to replace VMS, this technology is helping to remove the stigma of monitoring systems. VVS allows the fishermen to monitor themselves, keeping track of exactly where they are, and is more accurate and precise than the VMS systems. With this software, the fishermen can have a backup in case their VMS is faulty, can have their own copy of their locational data in case of disagreements with managers, and can visualize and record their fishing activity to help plan future fishing (Mikol, 2003).

The technology exists, the desire for easier reporting and enforcement exists, and fishermen around the country are successfully using this technology. However, there are roadblocks to seeing these management tools used in the New England groundfishery. Fishing is what built New England, particularly Massachusetts, where a wooden cod hangs in the capital building. It is the traditional occupation for many families and has created strong community fabrics (Kurlansky, 1997). Historically, the industry-driven Council's goal was to increase fishing capacity and maximize yields. They were allowed to catch more than the optimal yield if economic and social hardships would occur with less fishing. For twenty years the industry voices on the Council did their job, fishing as hard as they could. It wasn't until the SFA in 1996 that their responsibilities changed. New England has had a hard time coming to terms with the fact that the Council management plans, in order to effectively stop overfishing, will displace a lot of fishermen and create financial hardships. The political power of the industry is strong, which has allowed the industry to maintain its hold over Council membership. The strength of the fishermen's voices is evident in the recent Amendment 13 decision. Instead of adopting one of the five alternatives listed in the environmental impact statement for the multispecies fishery, the Council approved a sixth alternative that was submitted by Northeast Seafood Coalition and drafted by the fishing industry. While an average display of industry power, it was unusual in the fact that the normally fractured sectors of the fishery came together to present a united front, supporting this alternative. That display helped to sway the Council into accepting the plan (Plante, 2003).

As a proposed rule available for public comment, Amendment 13 appears to have few changes in terms of reporting technology (Federal Register, 2004). Thus, there is still plenty of room to suggest alternatives for how the fishery should embrace this new technology. While the stakeholders resist entire plans based on allocation and optimal yield assessments, data reporting does not draw as much resistance. Mandatory VMS and electronic reporting could be included in the plan by ensuring that the rest of the plan is well supported by the fishing industry. Of course, this will probably involve erring towards a higher yield, so the increased efficiency of the management tools will be necessary to balance the fishing effort and the stock rebuilding effort. The use of these electronics should help to manage the difficulty of multispecies stocks, adjusting for individual species TACs and allowing for increased complexity in time-area closures. Another option would be to increase the cooperative research efforts on designing VMSs and electronic logbooks that the industry will embrace as their own. Together they can come up with a product that the industry doesn't have as many objections to and also meets federal VMS criteria. The study fleet program mentioned above is an excellent example of this option already in the works. By having the buy-in of the fishermen, there may not have to be so many compromises in the restrictions on effort to have an acceptable management plan. Doing nothing is always an option; allowing the technology to slowly infiltrate into the fishing community. This is the least effective way of making data reporting more efficient and functional. An increase of observer coverage would be necessary if this was allowed to happen. The Secretary of Commerce always has the authority to disapprove the Council's management plan. Consequently, a plan could mandate the use of new enforcement technology, forcing the fishermen to use VMS and electronic catch reporting.

As ecosystem management emerges, landing reports will not be adequate; spatial data revealing the actual location of the fishing will be needed to match effort with habitat type and other species information in a technologically advanced GIS modeling program to manage for the future of the fishery. Additionally, as technologies advance and reporting requirements change and evolve, there will need to be new policies in place to direct data collection. In order to see mandatory data collection from the fisheries, behavior modification through policy must occur. Of all the recommendations, I see the most value and potential from having the groundfishermen cooperate with the managers and scientists to develop acceptable designs for the reporting technology. With the current political atmosphere of New England, the technology must be acceptable and it must become mandated policy.

Currently, I propose that the future management and recovery of the groundfishery will require more spatially detailed, mandatory reporting that will be implemented through policy changes. Possible alternative future policies will be devised, with the intent of increasing data reporting while simultaneously streamlining the process.

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