APPENDIX G.

Spatial Distribution of Fishing Effort for Sea Scallops: 1998-2000

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Effects of Fishing Gear on Fish Habitat in the Northeastern U.S.
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Introduction

Precise information on the spatial pattern of fishing by commercial vessels is available for few fisheries. Such information is critical for assessment of potential impacts of fishing gear on target and non-target species. The short report summarizes recent information on the spatial distribution of the US sea scallop fishery and estimates the area-specific landings and revenue. Additional information related to this report may be found in Rago et al. (2000).

Methods

Each vessel that participates in the limited access fishery for Atlantic sea scallops is required to use a vessel monitoring device. This device identifies the position of each vessel at intervals of one hour or less. Positions are tracked by a geosynchronous satellite and the information is relayed to ground-based stations. Vessel speed can be computed as the distance between successive position divided by the duration between position reports. The combination of vessel tracking devices, satellite and ground-based monitoring, and associated databases and software define the vessel monitoring system (VMS) for sea scallops. The VMS database was originally designed as an enforcement tool to track time at sea accurately, and to identify possible violations of closed areas. The potential uses of such data for assessment and management, however, are far-reaching. We present a few examples related to development of a synoptic map of fishing activity.

Estimates of area-specific fishing activity by calendar year were derived by overlaying a grid of 1 nm^2 squares over a region extending from Georges Bank to Virginia. Total fishing time in each cell was estimated as the sum of vessel-hours where speed is less than 5 knots (scallop vessel typically fish at 4-5 knots). Speed is estimated as the Euclidian distance between successive position reports divided by the time between observations. This estimate of fishing activity includes haul back time as well as any other time spent processing catch or cessation of fishing during bad weather or mechanical breakdowns. Fishing activity is assigned to the 1 nm^2 cell in which the report is received. In theory however, the fishing activity could have occurred within a five nautical mile radius of the recorded position. In practice, vessels tend to concentrate fishing activity around locations were capture rates are high. The effects of uncertainty in specification of fishing activity time could be examined via various smoothing procedures and through more detailed analysis of individual vessel tracks. For the purposes of this summary, we felt that the overall pattern of vessel activity was sufficiently characterized.

Total fishing activity hours by cell were estimated by quartiles (Table 1) and coded by color (red >75%-ile, 50%-ile<yellow <75%-ile, 25%-ile < green < 50%-ile, blue < 25%-ile. An upper bound on area swept can be obtained as the product of fishing time (hr), an estimated average speed of 4.5 knots while towing, and an industry norm of two 15 ft wide dredges. This product provides a measure of potential bottom contact area, but the actual area covered is determined by the number of times that the bottom is repeatedly towed. The VMS data alone are insufficient to estimate this quantity.

The spatial distribution of landings and revenue was approximated by linking vessel monitoring data with dealer records of landings and total value. Landings associated with each trip were distributed in proportion to time fished over set of 1 nm^2 cells that comprise the area fished. The sum over all trips provides an estimate of the landings per unit area. An equivalent procedure was used to estimate the revenue per unit area. This procedure does not account for the non-uniform distribution of fishing success over the course of a trip. Since most landings are likely to come from the areas fished the most intensively, it is likely that the application of the average success rate (i.e., lbs/hr) to all cells in a trip will overestimate the landings and revenue from marginal areas. Although the VMS reports record all trips, not all VMS trips can be matched with dealer records. The degree of matching exceeded 90% in all years. Unmatched records arise from a variety of sources and can generally be resolved by investigation of individual trips. In some instances it is necessary to combine several “trips” that give rise to a single landing event. Multiple VMS “trips” can arise when a vessel moves back and forth across inshore demarcation lines during a single trip.

Results

The scallop fishery is highly concentrated and the degree of concentration is consistent across years. The spatial distribution of fishing effort in 1998 and 1999 is depicted in Fig. 1. Fishing effort quartiles were estimated for the set of all cells (1 nm^2) in which fishing occurred in 1998 and 1999. Cells below the median hours of fishing activity experienced less than 9 hours of fishing activity per year. The upper quartile of fishing effort was highly concentrated in a zone of about 3000 square miles in all three years (Table 1). Estimated mean fishing activity in these areas was about 110 hr in 1998 and 1999. The fishing activity in cells below the median level is largely incidental and constitutes only about 4% of the total landings per year. It is hypothesized that such fishing activity is exploratory to recheck old fishing sites or to identify overlooked scallop concentrations. The most heavily fished areas produced the 77 to 88% of the total landings. Hence, the VMS data provides a heretofore unknown quantification of the concentration of fishing activity. The implications of this concentration may be important for bycatch and habitat issues (e.g., the environmental “footprint” of fishing effort).

Discussion

Monitoring of fleet behavior during the reopening of area II also revealed the importance localized concentrations of scallops on the distribution and intensity of fishing effort. The observed pattern of effort was consistent with the predicted "limiting distribution of fishing effort" described by Beverton and Holt (1957, p. 162). The concentration of effort on high abundance patches also suggests a reason why predicted yields based on *average* densities may not be realized. The ability to locate and exploit scallop beds will tend to maintain high average catch rates, while at the same time, reduce the true average density faster than would be predicted.

The long term value of the Vessel Monitoring System has been only partially exploited. At a minimum, it provides a common language for fishermen and scientists to gain insights into fishing behavior and resource distribution. Fishermen cannot argue that scientists don't know where the fleet actually fishes and what the catch is. Moreover, scientists cannot dismiss fishermen's observations as anecdotal fragments of the whole. In such circumstance the strengths and weaknesses of each others tenets can be evaluated. Cursory examination of the areal distribution of effort suggests coherence with substrate types. Such coherence may ultimately allow prediction of habitat impacts and bycatch considerations. Managers will find it easier to evaluate the effects of management measures in real time and make short-term corrections when appropriate.

References

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Appendix

Background on Sea Scallop Biology and Fishery

Sea scallops, *Placopecten magellanicus*, are found in western North Atlantic continental shelf waters from Newfoundland to North Carolina. Principal USA commercial fisheries in the EEZ are conducted primarily on Georges Bank, and in the Mid-Atlantic offshore region at depths between 40 and 100 m where water temperatures are less than 20º C. In terms of total revenue, the sea scallop fishery is the second most valuable fishery in the Northeast USA with annual values in excess of $100 million USD. Average price per kg of adductor muscle (meat) increases with average size with small scallops (~10 g) fetching approximately $8.80/kg and large scallops (>45g) valued at about $15.40/kg.

Scallops grow rapidly during the first several years of life. Between ages 3 and 5, scallops commonly increase 50 to 80% in shell height and quadruple their meat weight. During this time span, the number of meats per kg is reduced from greater than 220 to about 50. Maximum size is about 23 cm shell height, but scallops larger than 17 cm are rare. Sexual maturity commences at age 2, but scallops younger than age 4 probably contribute little to total egg production. Spawning occurs in late summer and early autumn; spring spawning may also occur in the Mid-Atlantic region. Eggs are buoyant, and larvae remain in the water column for four to six weeks before settling to the bottom.

Approximately 250 vessels participate in the year round commercial fishery for scallops. Nearly all landings are taken with dredges (89%) and otter trawls (10%). The USA fishery is managed under the New England Fishery Management Council's Fishery Management Plan for Atlantic Sea Scallops (*Placopecten magellanicus*). Current management measures include a moratorium on permits, days-at-sea limits, and restrictions on gear and crew size. Since the 1998 fishing year, vessels have been restricted to a maximum of 120 days at sea. Days at sea are monitored via a satellite tracking system that logs the position of all full-time scallop vessels on an hourly basis. Scallop dredges must use 3.5 inch (89mm) diameter steel rings to reduce capture of smaller scallops. Crew size is limited to seven individuals. As scallops are shucked by hand at sea, the crew size limitation constrains the daily landings rate during periods of high abundance. The minimum ring size was intended to reduce the catch of undersized scallops to improve yield per recruit, but the efficacy of this measure in the fishery was difficult to isolate in stock assessments (e.g., NEFSC 1997). In addition to these effort reduction measures, closed areas have excluded scallops from traditional harvest areas. Three large areas of Georges Bank were closed to scallop fishing in December 1994 to protect groundfish resources (Murawski et al. 2000). Later, in April 1998, two areas in the Mid-Atlantic were closed to protect undersized scallops present in these areas.

The National Marine Fisheries Service has conducted a stratified random survey of the scallop resource from Virginia to Georges Bank since 1975. In general, the relative biomass indices from scallop survey closely track the landings from the fishery. This is due largely to the intensity of the fishery which rapidly harvests recruiting size classes. The growth potential of sea scallops and the implications of reduced fishing mortality for management have been demonstrated in the closed areas of the Mid-Atlantic and Georges Bank regions (Murawski et al. 2000). Between 1994 and 1998, relative biomass indices from research vessel surveys increased between 5-15 fold in the Georges Bank areas closed to fishing compared to those areas open to fishing. Comparisons of the size structure between 1994 and 1998 for population inside and outside of the closed areas revealed the virtual absence of scallops greater than 110 mm shell height except in the closed area. By 1998 nearly 80% of the total scallop biomass resided in the closed areas. On Georges Bank the closed areas, which historically held about 50% of the total biomass, now had almost 90% of the total. Average densities in August 2000 in Georges Bank closed areas were approximately 4.5 times greater than densities in open areas. Similarly, relative densities of scallops in the Mid-Atlantic were about four times higher than in areas open to fishing (preliminary data from 2000 R/V survey) after only 27 months of closure.

Limited Reopening of Closed Areas in 1999

Partly as a result of information from cooperative studies, standard R/V surveys, and observer sea sampling, the New England Fishery Management Council voted to reopen a portion of Closed Area II south of 41° 30' N to limited scallop fishing. The reopening was subject to strict controls that included a total allowable catch of scallops (4,257 mt), a total allowable bycatch of yellowtail flounder (387 mt), individual vessel trip limits (4.54 mt/trip) , a restriction on the total number of trips per vessel (3 before Oct. 1; 3 after Oct, 1, 1999) , an intermediate decision date for authorization of additional trips (Oct. 1), a requirement for 8 inch (20.3 cm) mesh in the top panel of dredges to reduce yellowtail flounder bycatch, and a requirement that each trip, regardless of its duration, would use 10 of the 120 days-at-sea allotted to the vessel. Moreover, total scallop landings and yellowtail flounder bycatch were to be monitored on a daily basis. Under the plan, the area would be closed whenever the scallop landings or yellowtail flounder bycatch limits were attained. A 10 nm-wide “buffer” area around Area II was closed to improve enforcement of closed areas. The Council also specified a target level of 25% observer coverage for trips to the closed area.

The real-time monitoring requirements for this management action were much greater than normal and would have been impossible to achieve without a vessel monitoring system (VMS). Beginning in May 1998, all full and part-time scallop vessels were required to have a VMS to track of days at sea usage. The VMS also allows the vessel to communicate via e-mail to a central site. Messages received at this site can then be routed to appropriate destinations. The vessel location is embedded in each transmission so it is possible to develop a general map of catch rates by location. Data forms were developed at the central site and distributed to all vessels; hence, the basic components of a real-time monitoring system were already in place. VMS position reports are logged and regularly loaded into a database— generating about 200,000 reports per month.

The limited fishery was closely monitored by observers and via electronic reporting of daily catches. Approximately 2,700 mt (meats) of scallops were landed from this area before closure based on attainment of the yellowtail bycatch limit. Approximately 23% of the vessel-days were covered by at-sea observers.

Table 1. Summary of hours of fishing activity and catches from Vessel Monitoring System data. Quartiles of fishing activity are based on distribution of total number of hours per 1 nm^3 grid for the 1998 and 1999 calendar years.

Year	Quartiles of Fishing Activity (hr) (Range) [mean]	Number of 1-nm sqr sub-areas in which fishing activity occurred	Total Effort—fishing activity (hr)	Total Catch (lb)**	Percent of Total Catch	Value of Catch ** (million $)
1998	(0.1-1.9) [1.0]	2,604	2,521	59,149	1	0.36
	(2-9.2) [4.4]	2,992	13,039	245,087	3	1.65
	(9.3 - 44) [23.9]	3,808	91,181	1,613,070	20	10.04
	(44.1-591) [103.3]	2,796	289,792	6,283,570	77	37.58
	Total	12,200	395,532	8,200,870	100	49.51
1999	(0.1-1.9) [1.0]	3,181	3,127	141,163	1	0.90
	(2-9.2) [4.1]	3,023	12,287	468,550	2	2.83
	(9.3 - 44) [22.5]	2,026	45,677	1,855,170	10	10.43
	(44.1-857.7) [119.4]	2,999	357,934	16,854,300	87	98.63
	Total	11,608	407,787	19,319,200	100	105.48
2000	(0.1-1.9) [0.9]	4,403	3,930	225,839	1	1.14
	(2-9.2) [4.2]	2,953	12,495	760,983	3	3.90
	(9.3 - 44) [23.6]	2,500	59,096	3,883,500	15	20.0
	(44.1-1,543) [104.9]	2,946	309,045	20,620,200	81	102.39
	Total	12,802	384,565	25,490,500	100	127.45

**total catch based on match of VMS data with landings records from commercial dealers. In 1999 the landings were about 91%. In 1998 the match was only 68% in part due to lack of VMS requirement until May 1998

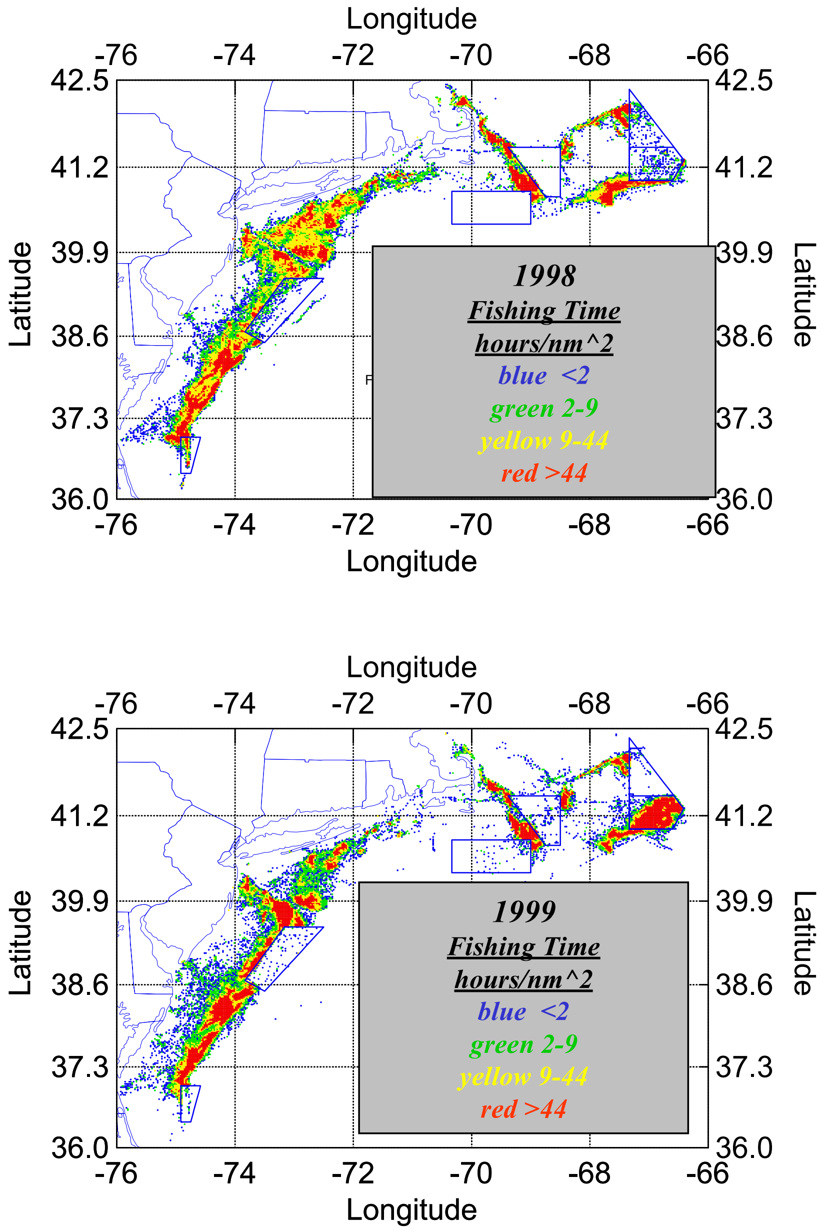

Fig. 1. Spatial distribution of fishing activity by sea scallop fleet in 1998 and 1999. Area II cooperative survey was conducted in 1998; Area I and Nantucket Lightship cooperative surveys were conducted in 1999. Area II was fished commercially in 1999.