Fishery data collection, the example of the New Bedford scallop fishery.

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I thank the members of the subcommittee for the invitation to testify before you today. My name is Kevin Stokesbury. I am a professor of Fisheries Oceanography, in the School for Marine Science and Technology at the University of Massachusetts Dartmouth. I was asked to speak on fisheries data collection, specifically how we developed an alternative survey for the sea scallop fishery and if similar techniques could apply for other fisheries.

The critical thing about managing fisheries is collecting accurate data. The Magnuson-Stevens Act gives control of data collection to NOAA fisheries. However, I think there are cooperative ways of collecting accurate data.

The sea scallop stock has rebuilt from a low harvest of 5,500 metric tons in 1998 worth about $87 million to harvest above the estimated maximum sustainable yield. Landings from 2003 to 2010 averaged 26,000 metric tons worth about $455 million, annually (Fig. 1). New Bedford has been the number one fishing port by value in the US for the last 14 years, due largely to scallop landings; the fleet landed $289 million worth in 2010 and $297 million in 2011 just in New Bedford alone (Fig. 2).

The current situation with the groundfish industry is in stark contrast to the scallop fishery. The latest estimates of New England groundfish stocks are incredibly low, reductions of 60% to 77% for Georges Bank and Gulf of Maine cod, respectively. Yellowtail flounder quota, which is divided between Canada and the US, is so low that it could shut down both the groundfish and the scallop fishery due to by-catch. The scientific uncertainties in these estimates are huge and many people are questioning the Federal surveys and stock assessments. Many fishermen are saying, "This is it, it's over." The end of the fishery.

How did the scallop stock rebuild so quickly? Can the groundfish stock rebuild as well? To answer these questions we need to be able to accurately measure the abundance and spatial distributions of these animals.

Estimating the abundance of marine species is difficult. Traditional fisheries assessments generally use modified commercial gear or fisheries landing data to provide relative abundance estimates recorded in catch per unit effort such as kg per tow. These sampling approaches generally focus on the target species of the fishery, and collect information on other species incidentally (by-catch). The efficiency and selectivity of these collections are usually unknown. Selectivity is the range of sizes and morphologies of individuals captured by a specific gear, and efficiency is the proportion of individuals caught by the gear compared to the total number of individuals in the gear's path (Stokesbury et al 2008). Relative estimates are relative only to themselves. You have to compare one year to another, and if you see a change you assume it is occurring in nature because your sample design is the same. However, if you know the efficiency of the sampling gear you can use it to calculate an absolute estimate, the actual number of fish in the sample area. Then if you know the total area your resource covers you can multiply these values to give you the number of animals in the resource. It is this number (or biomass if it is in weight) that managers use to set the total allowable catch for a fishery. "There was an average of 1000 scallops per tow in 2012" doesn't mean anything unless you have other tows to compare it too. "There were 4 billion scallops on Georges Bank in 2012" clearly means something. You can compare that number to other years, other animals and you can decide how many of them you would like to harvest.

Each of the parameters has an associated error in measurement and these uncertainties are often so large that they frequently mask real changes in populations. Under the Magnuson-Stevens Act uncertainty in stock assessments leads to more conservative estimates of allowable catch.

I believe that fisheries researchers should return to fundamental principles of field ecology; seek absolute measures (numbers per unit area) and determine the associated uncertainties (Stokesbury et al 2008). I'll describe the implementation of these principles using a new technology to examine the sea scallop fishery of the Northeast Untied States.

The US Sea scallop Fishery

Two spatial management changes drastically altered fishing distribution replacing the traditional unrestricted movement of the fleet from one scallop aggregation to another. In 1977, the Hague Line divided eastern Georges Bank between Canada and the United States. In 1994 three large areas (17,000 km^2) of the United States portion of Georges Bank were closed to mobile gear fisheries in an effort to protect depleted groundfish stocks (Murawski et al. 2000). These changes substantially reduced the scallop grounds available to the fishing fleet and concentrated intense fishing pressure on the remaining open areas.

By 1998 the scallop fishery was facing severe restrictions. Fishermen were desperate for access into the large closed areas of Georges Bank that had supported their traditional fishery. However the National Marine Fisheries Service (NMFS) survey suggest that scallop abundance was not high within these areas (NEFMC 1999 SAFE Report page 93). There were several reasons for this: violation of the assumptions of the sampling design and huge uncertainties associated with the efficiency of the fishing gear used.

The NMFS scallop survey uses a modified New Bedford style commercial dredge towed by a scientific research vessel, and stations were selected using a stratified random survey design (Hart and Rago 2006). In a stratified random survey the population is divided into subpopulations which do not overlap and which together make up the entire population. The animals within each subpopulation are assumed to be relatively evenly distributed. Each subpopulation or "strata" is randomly sampled and then these values are combined. On Georges Bank, strata roughly follow depth contours. The establishment of closed areas cut across strata and with the number of animals increasing within the closed area, the assumption of an "even distribution within strata" was violated. This results in taking only a few samples in areas that have high densities of animals.

Another problem is that there is a great deal of uncertainty concerning the efficiency of the dredge, how many scallops a scallop dredge catches, and how many scallops it leaves on the sea floor. Small differences may have large effects on scallop estimates, especially when you are using samples to extrapolate estimates for an entire population.

The SMAST sea scallop video survey

Working cooperatively with the scallop fishermen, we set out to develop a video survey using quadrat techniques based on SCUBA diving studies (Stokesbury and Himmelman 1993; 1995) that would provide spatially explicit, accurate, precise, absolute estimates of sea scallop density and size distributions along the off-shore northeast waters of the United States including the Georges Bank Closed areas (Stokesbury 2002; Stokesbury et al 2004).

In designing this survey we tried to avoid the preconceived notions of formal fisheries stock assessments, such as:

1) Estimating biomass rather than the number of individuals
2) Assuming homogeneous densities within survey strata.

We met with fishermen who outlined their historic fishing grounds. We had very limited funds, so sampling gear had to be cheap and readily available. In addition, we wanted a portable system, deployable from any commercial scallop fishing vessel, and we wanted to avoid the permitting process required to sample in closed areas with fishing gear, which often results in delay (or denial).

Three scientific principles guided our design:

1) *Scale*: According to scallop population biology sampling grain needed to be at the scale of cm (individual distribution) and to the extent of 100 -1000 of km^2 (bed-level distribution) (Stokesbury and Himmelman 1993; 1995)
2) *Experimentation*: To measure the impact of the scallop fishery on the benthic habitats with a level of precision that allowed statistical testing a Before-After-Control-Impact experiment (Green 1979; Stokesbury and Harris 2006). We had to take enough measurements to be sure we could observe a change when it occurs.
3) *Continuity*: Sampling in an expandable way such that subsequent surveys would build a mosaic suitable for mapping benthic substrates and macroinvertebrates. We have added to our system with improved technology but we’ve keep the basic sampling unit the same so that all our samples can be compared to one another and combined.

We developed a video-quadrat sampling pyramid and selected a multistage centric systematic design with three station grid resolutions (1.6, 2.3 and 5.6 km). Since 1999, we have completed 150 video cruises surveying Georges Bank and the Mid Atlantic (>1000 days at sea) We began sampling the entire resource in 2003 and have done so until 2012 (Fig. 3). The system is composed of a mobile video recording system compatible with any scallop vessel wheelhouse layout, an electro-hydraulic winch and a sampling pyramid. In its present configuration the sampling pyramid, supports four cameras and eight lights (Stokesbury 2002; Stokesbury et al. 2004; Fig. 4).

Within each quadrat, macroinvertebrates and fish are counted and the substrates are identified (Stokesbury 2002; Stokesbury et al. 2004) (Fig. 5). Counts are standardized to individuals m^{-2}. This procedure has been published in 25 peer-reviewed scientific papers.

***Results of the video survey*.**

Small Scale surveys: Our initial work focused on estimating the density of sea scallops within the closed areas of Georges Bank. Sea scallops were highly grouped into patches (beds) on the scale of km^2 and strongly associated with coarse sand-granule-pebble substrates. The three areas surveyed contained approximately 650 million scallops representing 17,000 metric tons of harvestable scallop meats. These data assisted in developing an access program in 1999-2000 that provided an instant increase in harvest of 5.5 million lbs, worth $55 million (Stokesbury 2002).

Large Scale Surveys: In 2003, at the request of the scallop fishing industry we expanded our video survey to cover the entire scallop resource in US waters based on the footprint of the 2002 fishery. Sea scallop densities in the Mid-Atlantic and Georges Bank represented approximately 217,520 metric tons of scallop meats (approximately US $2.4 billion); twice that estimated by the NMFS (J. Boreman Director of NEFSC statement to The Standard Times, New Bedford, MA, USA, 4 November 2003). Sea scallops were highly aggregated in areas closed to mobile fishing gear. A large number of pre-recruit scallops were observed in the southern portion of the Hudson Canyon closed area extending south into open waters. This area, the Elephant Trunk, was closed in 2004 and sustained the fishery until 2011.

I don't think people realize what a cooperative effort this was with the fishermen, particularly the New Bedford fleet. We had no money for those first trips; they were all backed by individual fishermen, people donating their time, vessels, know-how, food and fuel. Now 150 week-long trips later and over 10 years of surveying the continental shelf from Virginia to the Canadian line 200 miles off shore on Georges Bank; that is still the case. The food, fuel, vessels and fishermen's labor are still all donated. The fishermen and my students have made our efforts a success. Our video survey is the largest in the world (that I know of). It provides an estimate of the numbers of scallops by size by location for the entire resource. This has enabled a rotational management plan that moves the fishing fleet around different closed areas on Georges Bank and in the Mid-Atlantic depending on how numerous and large the scallops are in each area. The system was presented at New England Fisheries Management Council sea scallop Plan and Development team meetings as well as the NMFS stock assessments. It was subjected to a number of critiques that resulted in further testing and development. Now, this system has been reviewed and accepted by the National Marine Fisheries Service and is combined with their research to provide yearly estimates of scallop abundance.

So "what is the future?" The closed areas may have played a part in the scallop recovery but there was also a huge recruitment in the Mid-Atlantic in 2003 that has sustained the scallop fishery for the last 10 years. There seems to be a cycle in scallop populations. The biggest scientific question in fisheries continues to be "what is the relationship between the spawning adults and the new recruits?" I think there are several underlying patterns to recruitment. There can be a relatively low annual recruitment equal to around 25% of the populations and then, when the correct environmental conditions occur, a huge year-class (Fig. 6).

That is what rebuilds a fishery. The trick is having the scientific techniques to see the recruitment as soon as it occurs and the management structure in place to act quickly and protect it. This just happened with scallops in 2012, we (our video survey and the NMFS scallops survey) saw another good recruitment in the mid-Atlantic and with the support of the fishermen, the management council quickly closed the area protecting the scallops and allowing them to grow undisturbed until they were ready to harvest. In considering the data requirements for the Magnuson-Stevens Act this should be considered, to look for and take advantage of significantly large year classes. It is very hard to rebuild a population with an average annual recruitment.

We're working on new ways to try and measure groundfish using acoustics and video techniques. We just conducted a preliminary survey placing a video camera system in the cod-end of a groundfish otter trawl to see if we could accurately identify and count the fish as they passed through (Fig. 7). The results look promising and if we can refine this technique we will be able to greatly increase the area sampled for groundfish, which should reduce the scientific uncertainty in these estimates. To me the way forward is to reduce the scientific uncertainty and the best way to do this is to get out there with the fishermen and measure what's going on. If we can use new technologies to look at these populations clearly and simply, perhaps we can start to grasp their underlying dynamics.

There is still an incredible amount of potential in the wild fisheries of New England, and the infrastructure and people willing to and invested in figuring out how to make it work sustainably.

I suggest the following criteria in designing surveys and experiments (Stokesbury et al 2008):

1. Always answer a question using a hypothesis driven approach with experimental design based on observations to determine the appropriate sampling design and scale; the temporal and spatial scales of the sampling design must match that of the hypotheses.
2. Use as much information as possible in collecting initial observations; include historic literature, perspective of non-scientists, and especially observations and perceptions from fishers and other resource users.
3. Start as simply as possible with a scalable sampling design and build a mosaic as knowledge increases.
4. Make your experimental design as adaptive to new technologies as possible; absolute measures are essential.
5. Incorporate spatial and temporal variability in your experimental design (strongly consider systematic sampling designs).
6. Use collection and analysis procedures that allow for the development and inclusion of your intuition and understanding of the ecosystem (automation can kill intuition) as well as new information and technology.

Thank you.

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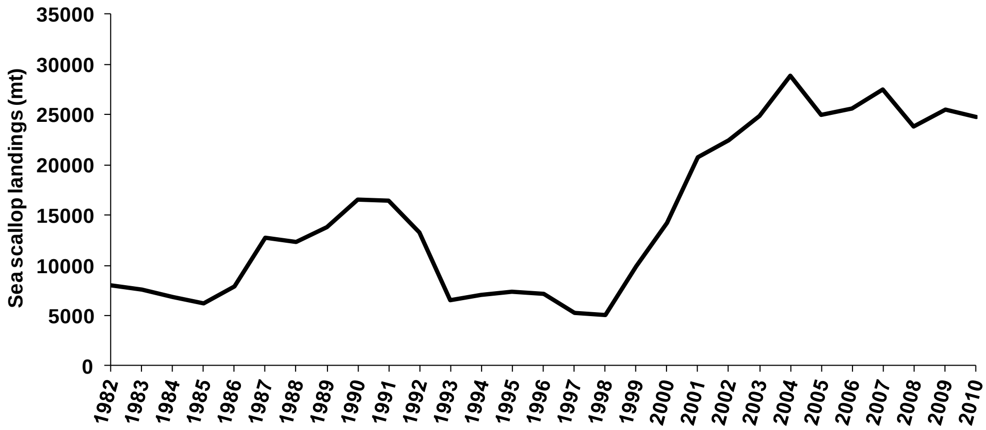

Figure 1. United States Sea scallop landings (source: NOAA).

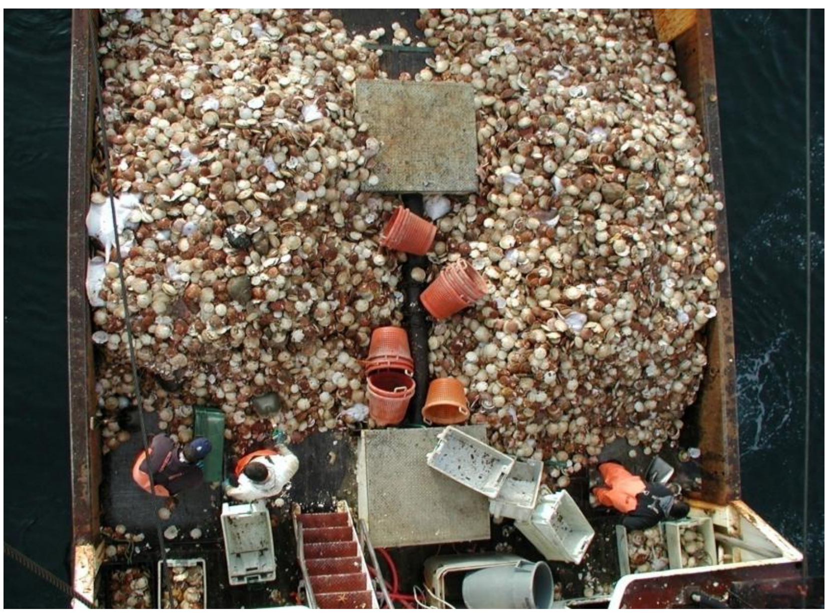

Figure 2. Deck load of scallops in the Nantucket Lightship area in 2006 during an access trip (photo by Brad Harris).

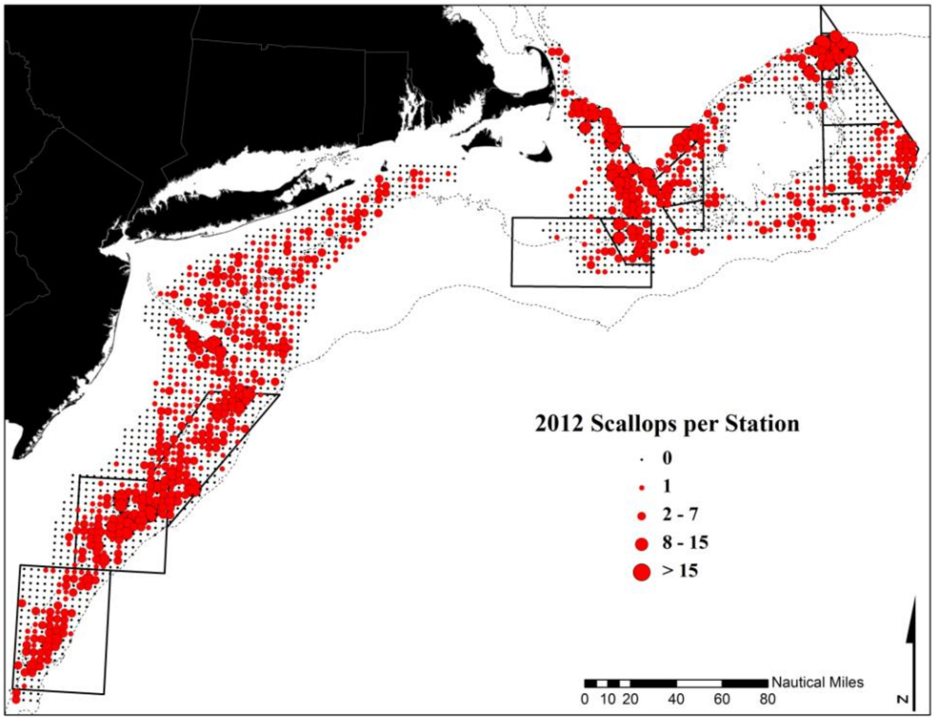

Figure 3. Map of the 2012 cooperative video survey, each dot represents 4 drops of the pyramid with 4 cameras recording data, red dots are the numbers of scallops per station.

Figure 4. The SMAST video sampling pyramid mounted on the side of a commercial fishing vessel.

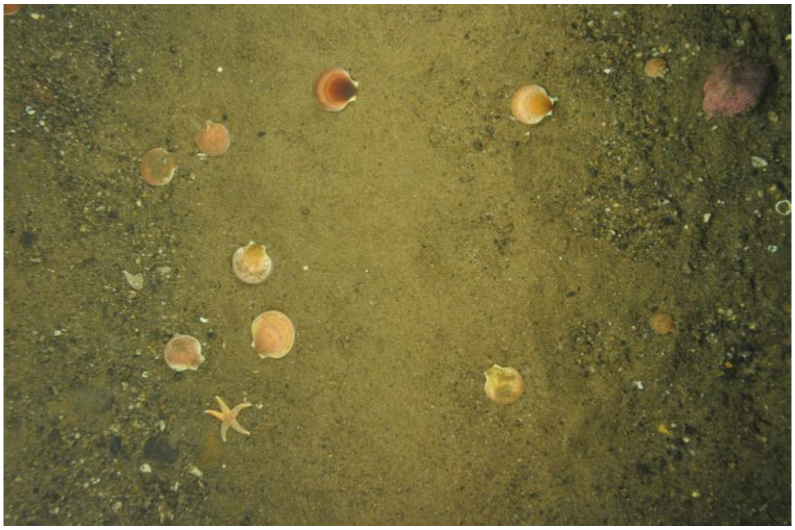

Figure 5 A digital still quadrat sample covering 1.13 m^2 with 11 scallops and 1 starfish.

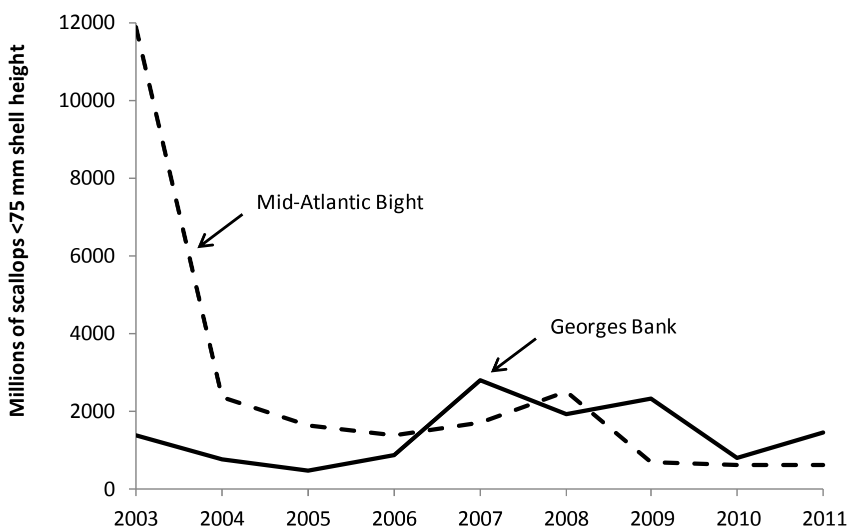

Figure 6. Recruitment of juvenile scallops form the sea scallop resource from 2003 to 2011 (Stokesbury 2012).

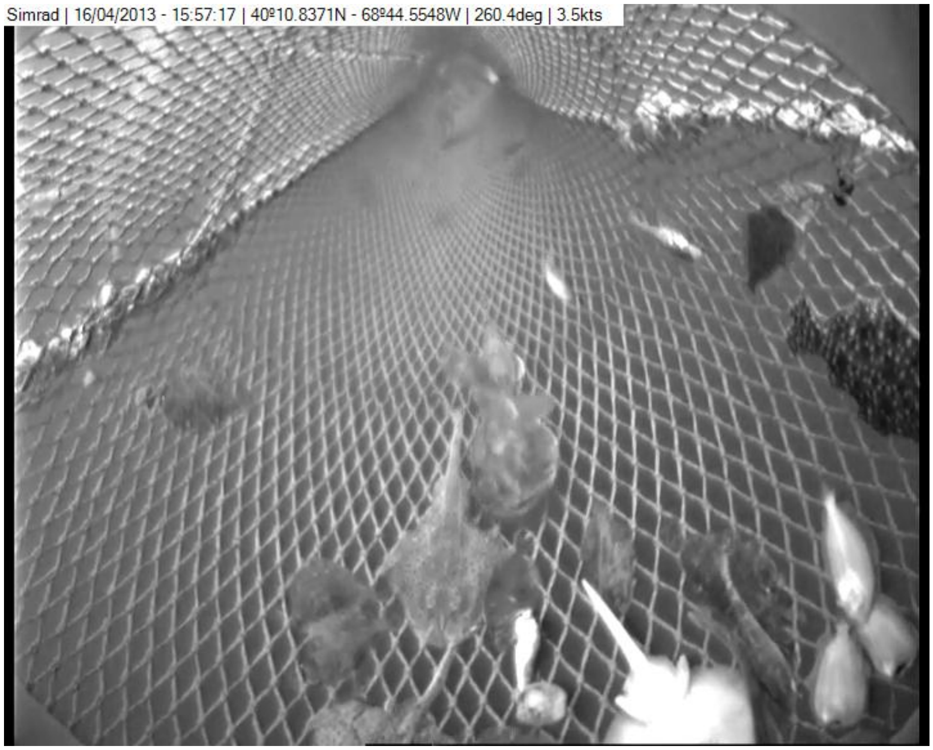

Figure 7. A Digital image of groundfish from a test system that may allow the sampling of fish as they pass through and then exit the net without damaging them.