A preliminary study of the Maine Sea Cucumber (*Cucumaria frondosa*) Fishery

Northeast Consortium Program Development Grant # 03-686 (total funding $25,000 and performance period 2003-2005)

Final report submitted to the Northeast Consortium on May 31, 2005

by

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Abstract

The sea cucumber is an emerging fishery in the state of Maine. The fishery began in 1988, but started expanding in 1994 when Asian markets opened up. Like other emerging fisheries, we have little knowledge about the key life history processes that determine the population dynamics of the sea cucumber, and limited data on the fishery and population. Sea cucumbers are unique in morphology, behavior and biology relative to other commercially harvested species, and a standardized procedure is therefore needed for collecting data and measuring biological characteristics. To facilitate the future studies, we proposed and conducted the project to develop, test, and identify a standardized procedure for biological sampling and surveying of the Maine sea cucumber.

Through theoretical, lab, and field work, we identified an optimal monitoring program for collecting sea cucumber fishery data and a cost-effective survey program to collect information about the Maine sea cucumber population. We tested the effectiveness of some tagging techniques for the study of cucumber growth, mortality, and movement. We also developed and tested a protocol for biological measurement of sea cucumber along the coast of Maine.

The results derived from this study were used in the development and implementation of a full project which is funded by the NEC and is currently under way. This project sets up the standard for future research related to the sea cucumber along the coast of Maine.

Introduction

The sea cucumber is an emerging fishery in the state of Maine. The fishery began in 1988, but started expanding in 1994 when Asian markets opened up (Chenoweth and McGowan, 1997). Scallop chain sweeps or light urchin drags were used as fishing gear. Fishing activity was centered in Washington and Hancock Counties with catch landed in Winter Harbor, Jonesport, Beals Island, and in Eastport. The fishery has recently experienced great increases in landings, corresponding to expanding export markets. Between 1994-1996 reported landings ranged from one to three million pounds (Fig. 1). In 1999, reported landings were over eight million pounds, rising to over nine million in 2000 (Feindel, 2002).

Like other emerging fisheries, we have little knowledge about the key life history processes that determine the population dynamics of the sea cucumber, and limited data on the fishery and population. Most research done so far has been done on the red sea cucumber (*Parastichopus californicus*) in the Northwestern USA and British Columbia (e.g., Bradbury, 1990; Zhou and Shirley, 1996; Boutillier et al., 1998; Philips and Boutillier, 1998; Perry et al.,1999; Cripps and Campbell, 2000). Limited research has been done along the eastern coast of North America, although some studies have added to knowledge on *C. frondosa*. A study of the ecology and behavior of the common sea cucumber, *Cucumaria frondosa*, was conducted in Maine by Jordan. More recent studies have focused on fertilization success and feeding behavior as it relates to aquaculture (Medeiros-Bergen and Miles, 1997; Hamel and Mercier, 1997; Singh et al., 1998). These studies improved our knowledge of C. frondosa, but still do not provide enough information on some key life history parameters, which quantify the population dynamics of sea cucumbers in Maine. As a result, we have a limited understanding of the current status of the resource. As interest in the industry peaked, concern over rapid depletion of the resource led to the enactment of regulations under the 1999 Sustainable Development of Emerging Fisheries Act (12 M.R.S.B671-B) in March 2000. The fishing season, drag size and the number of endorsements issued is now limited. Weekly submission of harvester logbooks is also required. Because information on life history processes is sparse, no stock assessment has been done. Impacts of the fishery on the resource and effectiveness of the current regulations remain unknown. Studies of sea cucumbers in other parts of the world suggest that they grow slowly. Without an appropriate management plan developed based on good understanding of sea cucumber biology, there is a danger of over-exploitation.

Sea cucumbers are unique in morphology, behavior and biology relative to other commercially harvested species, and a standardized procedure is therefore needed for collecting data and measuring biological characteristics. To facilitate the future studies, we developed a standardized procedure for biological sampling of the Maine sea cucumber (after dissecting and studying individuals sampled from the Maine sea cucumber fishery).

The lack of hard tissue that can be used for aging calls for a tagging study. Tagging studies of sea cucumbers are difficult since external tags are frequently lost and internal tags can be shed through the body wall. Sea cucumbers have been tagged in situ with limited success (Conand, 1991) using a small T-bar tag inserted through the body wall using a tagging gun . Previous studies of manual tags in P. californicus in Washington indicated that their presence had no significant influence on the sea cucumber's behavior and did not affect its ability to react to shifts

in the salinity of the experimental medium . Typically, localized necrosis of the tissue occurs and tags fall out within a few months . Morgan suggests this method may be adequate for tagging broodstock in captivity over short periods of time and recommends tag loss may be minimized by ensuring that the T-bar is pushed right through the dermis and that the puncture wound is as small and clean as possible. Schroeter et al. used tags to conduct a growth study of P. parvimensis in California by following individuals through repeated surveys at two sites. Only 17.6 % of 1224 tagged animals were recaptured over one year. These studies suggest manual tags may not be an effective means for studying growth due to high frequency of shedding by sea cucumbers.

Previous researchers have also used fluorescent dyes to stain the calcareous plates surrounding the buccal cavity of sea cucumbers with varied results (Campagna and Hand, 1999). Successful staining depended on the relative timing of injection of the dye and deposition of calcium for growth of the mouthparts (Morgan, 2000). Other work has suggested that fluorescent marking by dyeing the ossicle of the juveniles with tetracycline might be useful. However, these methods using injections are time-intensive and marks often become hard to discern after several months. Also, sea cucumbers could not be located soon after release in some follow-up investigations. Yanagisawa successfully used a hot wire to brand the sea cucumber *Stichopus japonicus*. Although most of the marked juveniles could be distinguished three months later, it seemed to be difficult to discern their marks after four months. The results of previous worldwide sea cucumber tagging studies vary in success by species, investigator, and location. It is also possible technique varied significantly for studies involving the same styles of tagging. Therefore, the conclusions of these previous tagging studies may not be applied to the Maine sea cucumber population. Factors such as dermal thickness and seasonal fluctuations likely alter the capacity to retain tags. To identify an effective way to tag the Maine sea cucumber, we conducted a study to testing and comparing the effectiveness of various tags.

Project objectives and scientific hypotheses

The objectives of this study are to (1) identify an optimal monitoring program to collect sea cucumber fishery data; (2) identify a cost-effective survey program to collect information about the Maine sea cucumber population; and (3) test the effectiveness of some tagging techniques for the study of cucumber growth, mortality, and movement.

Initially, we were trying to identify essential habitats for sea cucumber along the coast of Maine using the information of sea cucumber abundance and bottom types collected in the field-testing. Because the scale of the study is small, this study did not provide a conclusive result regarding the selection of bottom type by the Maine sea cucumber. This will be re-evaluated in the full project developed based on this Program Development Project and funded by NEC. Maine DMR has been conducting the extensive survey along the coast. With more data collected, we hope to yield a defenite conclusion regarding the key habitats of sea cucumber along the coast of Maine.

In addition to the above objectives defined in the original proposal, we have found that due to the sea cucumber's unique biology, behavior, and morphology, we cannot use methods commonly used for other fish species to study sea cucumbers. We need to develop an approach

that can accommodate the sea cucumber's unique biology and morphology. Thus we have developed a standard protocol for studying biology and ecology of the Maine sea cucumber population. The approach has been used in the current full project.

Participants

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Methods

The first two objectives were achieved by an approach of the combined theoretical design and field-testing.

The tag testing study was carried out April – September 2003 to determine the effectiveness of various tags. Initially, animals were tested using 1) injected orange and yellow fluorescent dyes; 2) long and short double T-bar tags; 3) dart tags; 4) streamer tags; 5) cinch-up tags; and 6) scarring with a rope gun. Animals were also punctured with the tagging gun as a control group to observe any mortality from the piercing. It was immediately evident that dart tags, streamer tags, and cinch-up tags would not stay within the cucumber body wall and these methods were not considered further. Although the rope gun created a noticeable brand, many animals already possessed significant markings from drags or field interactions and the scar would not stand out to an observer. The branding method was therefore also discarded.

The remaining tagging methods were studied using 70 sea cucumbers from the Gulf of Maine by following individual tag retention over time (Table 1). There were 10 animals injected with orange and yellow fluorescent dyes and an ultraviolet flashlight was used to observe them in a darkened room. Dye was injected within tube feet, along the body wall, and/or near the oral cavity. Dye did not spread and all marks were small pin points only visible under UV light.

Forty-five animals were punctured with long or short double T-bar tags. Long tags had 1 ¾” distance between T-bar ends. Short tags had ¾” distance between T-bar ends. 21 tags punctured the body wall just under the muscle so one end remained inside the animal. The remaining 24 passed completely through the body wall twice so both ends of the T-bar tags were

exposed. Finally, 15 control animals were punctured with the tagging gun including 9 with double punctures and 6 with single punctures.
Sea cucumbers were kept in tanks in the wet labs at the Maine Department of Marine Resources in Boothbay Harbor, Maine. Tag retention rates were recorded every day April-September by observing whether tags were still in place, partially in place, or no longer observable at all.

The standard protocol for studying biology and ecology of the Maine sea cucumber population was initially developed based on extensive literature reviews and help from a Russian scientist whose visit to Maine is supported by a small grant to the PI (Chen) from the Maine Sea Grant. We then tested this paper version of the protocol for their effectiveness using samples collected from the field and samples left from tag testing study. Using the information collected in the testing, we modified and finalized the protocol.

Results and Conclusions

Objective I: Identifying an optimal monitoring program to collect sea cucumber fishery

Because there are currently only a small number of fishermen involved in the Maine sea cucumber fishery in Maine and the fishing areas are rather concentrated, establishment of a monitoring program should be achievable. Currently DMR collects landing values in the fishery. For biological sampling of the catch, we plan to establish a port sampling program with landed catch being randomly sampled bi-weekly for their biological characteristics. Because of the uniqueness of the sea cucumber in its biology and morphology, measurements acquired through a port sampling program can be adjusted and fine-tuned using the sea cucumber biometric data derived in lab work.

The implementation of such a port-sampling program, however, requires a long-term commitment of the Maine Department of Marine Resources in manpower and financial resources. Although there is an account established by the Maine legislature for the sea cucumber fishery, there is no money in the account. This currently is the main impediment to implementation of any monitoring program.

Using the information derived from this study and a follow-up study also funded by the NEC, Maine Legislature has recently passed a bill to establish fund for establishing a monitoring system for data collection and research. Once the system is established, the monitoring program proposed in this project will be implemented and a cost-effective long-term data collection system will allows us to monitor the sea cucumber stock closely along the coast of Maine.

Objective II: Identifying a cost effective fishery-independent survey program

This has been accomplished. Based on this work, we have developed a full proposal (a planning letter has been submitted to the NEC) for conducting a fishery-independent survey along the coast of Maine. The program developed is summarized as follows.

Some initial data in the form of harvester logbooks and preliminary surveys are in place as an aid to mapping sea cucumber abundance and habitat along the Maine coast. These will be used as a starting point for site selection for proposed field studies.

Anecdotal information from fishers will also be collected and transferred into GIS format. Collection sites for tracking seasonal trends will be located in Frenchman Bay – in areas near to where commercial fishing activity currently takes place.

A focus group meeting was held in the first month of the project (on UMaine Machias campus). There were 9 people attending the meeting including licensed sea cucumber fishermen (4), scientists (2), manager (1), graduate student (1) and private companies that utilize the sea cucumber (one from the Coastwide Bio Resources in Stonington, Maine). The focus group was brainstormed for the objectives of this project, and the approach we plan to take to achieve the objectives. The focus group developed a list of potential sites that are critical to the sea cucumber fishery and are good candidates for surveys (sentinel sites) and for a before- and after-fishing comparative (BACI) study. The focus group also helped identify a list of the potential management strategies that may be applicable to the Maine sea cucumber fishery and provided their insights on the status of the cucumber resources.

Details have been developed and used for the survey, including

- Plot all commercial harvest locations (logbook data)
    - Plot sea cucumber data obtained in the preliminary study (scallop surveys) – selected sites with >100 cucumbers (equivalent to 1 tote of cukes per ½ commercial tow – estimated commercial densities)
- Use 500m coast grid (urchin grid)
- Selecte grids within 1000m (tried 2000 as well – but not as well defined) of plotted points. <u>This serves as the survey frame (areas of known commercial densities).</u> This approach also allows the frame to be expanded for future surveys if the footprint of the fishery expands. We are concerned with areas consisting of fishable densities of cucumbers (NOT the entire population in this case)
- Stratify grid into: 3 areas and greater and less than 20 m depths (centers) using bathy/union merge GIS file <u>(6 strata total).</u> Stratified design benefits: if survey coverage fails in one strata for logistical reasons – doesn't disrupt analysis of other strata; depth component has a biological and logistical (dive-able) basis; should provide more accurate biomass estimate. Note: because of possible season depth migration – the shallow and deep strata in each area should be conducted during the same season.
- Audit grid for un-towable areas
- Export stratified grid IDs to Excel and used "Sampling" data-analysis tool to randomly select stations within each stratum. It is usual practice to sample without replacement.
- Plot subsets of selected grids as separate shape files
- Add additional 'fixed station' sites in areas of interest (that weren't picked in the random scheme)
- Select 10% of sites in each area as 'fixed' stations (10 sites Frenchman, 3 sites 2 other areas) – possibly some permanent stations in Casco and Damariscotta River)

Survey strata have been defined as

- Stratum 1: Frenchman Bay, < 20m depth: 730 (500m grids); 67% total area; 67 sites
- Stratum 2: Frenchman Bay, > 20m depth: 354 (500m grids); 33% total area; 33 sites

Total area for the Frenchman Bay region (note: this includes Blue Hill and offshore regions) = 1084 squares; 100 total sites (@10 tows per day) represents approximately 10% station assignment coverage (survey texts indicate that this is a good sampling intensity – as a very rough guideline) = **27100 total Hectares.** Selected 10 additional stations as fixed stations

- Strata 3&4: Narraguagus Bay to Chandler Bay (<&> 20m); 185 squares (20% coverage)

- Strata 4&5: Cobscook and St. Croix River (<&>20m); 122 squares

30 sites (3 DAS) in each of these smaller areas also represent 20% or better survey coverage.

The detailed survey information is presented in Figures 2 – 7.

The data collected in the survey include the following information:

- Trip information (date, port, weather, samplers, time depart and return)
- Station information (tow track coordinates, depth, bottom type etc.)
- Cucumber catch information (number, volume, weight),
- Subsample – cucumber size index
- Bycatch info (species and abundance – weight/ number or qualitative scale)
- Biological measurement

Data will be entered in an Allegro computer in the filed. The methods described in the original proposal (including multivariate statistics and spatial statistical methods) will be used for data analyses.

Objective III: Test different tagging techniques

A tagging study has been conducted at the wet lab of the Maine Department of Marine Resources in Boothbay Harbor, Maine. We tagged about 80 individuals with seven different tagging techniques (Fig. 2). Some of tagging methods are shown in Figure 3. The results are summarized in Fig. 4.

The tagging study was successful in providing information on retention rates for the different tagging methods observed during the 140 days of the investigation (Fig. 3). Flourescent dye injections and single anchored long T-bar tags were the most successful means identified in tagging the Maine sea cucumber. Eighty percent with dye continued to fluoresce under the UV light. 65% of single anchored long T-bar tags remained embedded in the sea cucumbers at the close of the investigation on day 140. The T-bar method may be the most practical for short-term research on this species considering the time and expense of fluorescent dye injection.

Another advantage over injections is that the tagging gun technique is much more easily repeatable among subjects because dye is may be difficult to administer and the area of injection varied among animals depending on the location of soft tissue.

Double pass T-bar tags were expelled faster than the single anchor condition. In the double puncture, it appeared that the long portion of the tag under the animal's epidermis gradually moved upward until it was expelled outside of the skin without scarring the animal. The longer bars were pushed out the fastest and all were shed before day 50. Shorter T-bar tags took almost twice the amount of time to reach 0% retention as the longer T-bars in the double pass condition. This may be because shorter bars pinched the dermis tightly between tag bars while animals with the longer condition were able to relax their entire body wall. After tags were shed in all T-bar conditions, it was not possible to tell which experimental condition each individual had experienced. No mortality was observed to occur due to the tags or from the control punctures.
Five T-bar tagged animals experienced a punctured respiratory tree due to the tagging gun. After the initial puncture, no trace of the injury could be detected and no differences in appearance or behavior were noted throughout the investigation. Although it was not possible to track which individuals had a partially punctured respiratory tree [1], injured individuals may have shed tags at a different rate than their cohorts. Internal injuries may also affect the results of later growth and movement studies using manual tags. Using the largest possible sample size and careful placement of the tagging gun, this potential bias can be minimized. Additionally, it is important to consider that tag retention rate in the field may vary more than results observed in the laboratory.

We believe that the flourescent dye injections and single anchored long T-bar tagging methods identified in our investigation will likely prove effective over a longer-term study with additional preliminary tagging analysis. However, a more effective way to study the growth of sea cucumbers may be the combination of caging and tagging with tagged individuals of similar size being put in the same cage for monitoring the change in size. Future investigations will test different locations/methods of injected fluorescent dye and single anchored long T-bar tags and will help to further identify the best alternative. When the most successful method is determined, a long-term study will allow us to understand how individual animals grow, move, and change seasonally and annually.

(IV): Extra objectives identified as necessary during the study: Development of standardized protocol for measuring biological characteristics of the Maine sea cucumber.

(A): Measuring Biometry

[1] Having a partially punctured respiratory tree may not observable to the investigator. Under such circumstances, the tagging gun may have pierced the animal's respiratory tree internally with no visible outward signs and without protruding through the body wall.

Morphological characteristics of sea cucumbers, describing dimensions of different body components, will be measured periodically for the evaluation of their seasonal variations. The frequency distribution of these characteristics will be established and relationships between these characteristics will be evaluated.

Every four-eight weeks, animals will be collected from three areas consisting of varied habitats. A stratified sample of 200-250 *Cucumaria frondosa* sea cucumbers of various sizes could be measured to get biometrical parameters, and about 50 animals will be packed in a cooler and transported to the DMR Boothbay Harbor lab for biological analyses.

In March to April, when sea cucumbers are believed to spawn in Maine, sampling will occur bi-weekly. Half of the sample will be females and the other half males.

Samples will be processed for the following measurements: total weight, weight of body wall, weight of intestine, weight of respiratory tree tissues, weight of gonad and muscle bands; length, width and height (Jordan, 1972) of total body and circumference. The body and organ samples will be dried to constant mass at 55°C in an oven (Hamel, Mercier, 1996a). Regression analyses will be conducted to derive the relationship between the dry weight, the total wet weight, drained wet weight, and body wall wet weight (Hamel et al. 1993).

The wet mass of the body wall, without the aquapharyngeal bulb and the muscle bands, will be used as a denominator to establish different tissue indices, calculated as the ratio of wet organ mass to wet body-wall mass. The variations in these indices among individuals will be estimated.

On-board measurement:

The body of a stressed sea cucumber is often tightened into a more stable form. Its total length (TL) can be measured dorsally from mouth to anus by means of a flexible ruler to the nearest 1 mm, its circumference (C) to the nearest 1 mm, and total weight (TW), defined as wet weight of the whole animal after being out of the water for 15-20 minutes, to the nearest 1 g.

Measurement in lab:

Fifty individuals will be transported to lab in a cooler with the addition of magnesium chloride, a known sea cucumber relaxant. Specimens will be kept overnight in cold storage at temperature of 4°C. The samples will be examined for:

(1) total length (TL) to the nearest 1 mm, measured dorsally from mouth to anus by means of flexible ruler;
(2) total width (TW) and height (TH) to the nearest 1 mm, measured to the widest part of body;
(3) total weight (TW) to the nearest 1 g;
(4) drained weight (DW) to the nearest 1 g; the water in the body cavity was drained out, the weight includes all body organs;
(5) body wall weight (BW) (Jordan, 1972; Hamel, Mercier, 1996a) to the nearest 0.1 g;
(6) gonad weight (G) to the nearest 0.1 g; the gonad is removed from its point of attachment to the gonoduct;
(7) respiratory trees weight to the nearest 0.1 g; the respiratory tree is removed from its point of attachment to the cloaca;

(8) intestine weight to the nearest 0.1 g; the intestine (together with its contents) is removed from posterior end of the stomach to the beginning of the cloaca;
(9) muscle band weight to the nearest 0.1 g; the muscle bands of the body-wall and those of the aquapharyngeal bulb and cloaca were removed from the body wall last.

(B): Measuring reproduction

For reproduction we will focus on the determination of maturation, spawning season and fecundity. The reproductive characteristics that will be measured are described as follows:

(1) **Gross morphology of gonad**, which provides the knowledge about type and structure of gonad and their biometrical parameters, including type of gonad, type of tubules, length of tubules, number of tubules, and sex determination;

Each individual will be dissected and visually inspected to collect the following information: type of gonad (single or double tuft of tubules), type of tubules (uniform or varied tubules, and if varied, number of each type being counted), length of tubules which depend on the stage of maturity and age (measuring the lengths of approximately 100 random sampled tubules to the nearest 1.0 mm to determine the average length), length of the shortest and longest tubules, and total number of tubules in a gonad. Sex is determined by dissection of animals. The gonads of females and males have a different colour. Part of the tubules are opened and spread onto a shallow plate to determine the sex. The sex of a young animal will be determined by microscopic examination of gonopore or genital papillae of individuals relaxed with magnesium (Fig. 5). The gonopore is located near the feeding podia on the back side of animal (Fox, 2001). Since sea cucumbers are broadcast spawners, the success of fertilization depends on the sex ratio during the spawning period and the population density. Thus, sex ratio will also be determined for the samples.

(2) **gametogenesis or maturation stages** including stages of maturation and dynamics of gonadal index.

The study of gamete development during the sexual maturation cycle allows us to evaluate the rate of maturation and the spawning period. Since a histological study is considered to be too time consuming, the method that will be used in this study combines the notation of macroscopic characteristics of form, color and consistency with the microscopic observation of a fragment of gonad. If the animals cannot be dissected immediately, they will be preserved in 7-10% formalin in seawater and dissected about a month later. By this time, changes due to the preservation should have stabilized (Pitmann, Munroe, 1982). Maturation stages depend on the dynamics of annual egg development (Tanaka, 1958; Sewell, 1992; Hamel and Mercier, 1996a; Oganesyan and Grigorjev, 1998). Approximately 100 tubules taken randomly from each gonad will be examined. For each tubule three parts will be taken: the posterior part, middle part, and anterior part. In the case of females, the oocyte diameters are measured by means of an ocular micrometer in order to establish their frequency distribution. This approach will enable us to define the stages of sexual maturity for each specimen. Macroscopic (length, diameter, number

of tubules) and microscopic (diameter of oocytes, sperm-tail activity) examinations of tubules will also be considered in determining the maturation stages.

The gonad index (GI), expressed as a ratio of gonad weight to drained/body wall/dry weight, will be calculated (Hamel and Mercier, 1996). Fecundity will be determined by counting the number of eggs/oocytes per gram of ovary and then multipled by the total weight of the ovary or by counting the average number of eggs/oocytes within a single tubule and then multiplied by the total number of tubules (Hamel and Mercier, 1996a; Gudimova, 1999).

(C): Size at sexual maturity

The size of first sexual maturity, or size at which an individual may reproduce for the first time, is an important parameter for stock assessment and management (Hamel, Mercier, 1996). To estimate the size at sexual maturity, a few hundred of individuals across a large size range will be collected. The gonads of each individual over 100 g will be inspected under a microscope. Histological procedures will be used to determine the degree of maturity for smaller individuals. Sea cucumbers will be classified as mature when bearing having mature gametes, and as immature when bearing gametes in the early stage of development, and as non-differentiated when no gametes were present. Additionally, the percentage of individuals with developed or developing gonads will be plotted against classes of drained/body wall weight. A logistic model will be used to model the data (Chen and Paloheimo 1994) and the size at which 50% are mature will be estimated and used as an index of first maturity.

(D): Growth

Because the sea cucumber lacks hard tissue for age determination, the ability of recognizing and following each individual over a substantial period of time is essential for estimating their growth (i.e, the change in their sizes over time). We will conduct both caging and tagging experiments to estimate the growth of sea cucumber. For the caging experiment, sea cucumbers will be grouped by their sizes. Variations in size should be kept as small as possible within each group. Biometric measurements will be done for each individual.

Each group of animals will be put in a separate cage "in situ". All the animals will be measured every four weeks and the increments in weight/length/body volume are to be recorded. Changes in size will be calculated.

(E): Ecological variables

Information on the following ecological variables will be collected during the study: water depth, bottom habitat, coverage of vegetation, bottom water temperature and salinity, current velocity, intensity of illumination, and phytoplankton abundance.

Lessons learned

The uniqueness of the sea cucumber in its biology, behavior and morphology (e.g. lack of hard parts for aging, variable live weight and shape) make it difficult to adapt methods commonly used for the biometrics of other marine species. Our species of sea cucumber (*Cucumaria frondosa*) also differs from other commercially fished holothurians in its biology and behavior. . This has lead to the development of a proposed standard protocol (see results and conclusions) for various measures of the Maine sea cucumber.

Partnerships

This project is a program development project for testing and identifying scientific approaches that can be used in assessing the Maine sea cucumber resources. Although no industry members are listed as co-PIs in the project, the field-testing component of the project has been done in collaborations with the fishermen. Through the interactions with the fishermen, we have identified fishermen who later become our partners (i.e., PIs) of the NEC full proposal which is currently under way. The project also attracts attentions of industry members and other stakeholders of the sea cucumber fishery. Mr. Peter Collin, President of the Coastside Bio Resources (Stonington, Maine) whose company has used the sea cucumber for biomedical purposes has been very actively involved in the project and in the discussion.

Impacts and applications

This is the first funded study of sea cucumber fishery in Maine and an important step towards conducting an assessment and developing better management strategies for this fishery in future years. In this project, we have developed a standardized protocol for studying the Maine sea cucumber. Based on this project, we have developed a full proposal to evaluate the impacts of exploitation on the Maine sea cucumber resources, which is funded by the NEC. The information derived from this study and current full project has been provided to Maine DMR and used by the Maine Legislature in setting management laws for this fishery. The graduate student, Ms. Sheril Kirshenbaum who is involved in this program, has been very actively involved in this process, and has been invited to testify at the Maine Legislature. A bill has been passed by the Maine Legislature for future sea cucumber management including collecting fees that will be used in future research and monitoring program. The information derived in this study has played a central role in the process. This project sets up the standard for future research related to the sea cucumber along the coast of Maine.

Through this project, various sea cucumber stakeholders have shown interest in future of the fishery, including in state, out of state, and international seafood companies. The large volume of inquiries indicates a great deal of growing interest in the fishery.

Portland seafood processor (name not handy) contacted DMR about cukes. Has market but can’t get fishermen to fish Casco Bay with limited entry. Expressed need (along with Bob Peacock) for some form of license turn-over with limited entry-measures

Lawrence Ray, Dan Conley, and Peter Collins are stakeholders in the Maine Sea Cucumber fishery and have been working with us throughout this project.

We have also received numerous calls and emails from general public inquiring about this project. The questions range from general questions about biology of this species to potential health problems that may cause to workers (in particular those migratory workers) in processing the sea cucumber. We even received an inquiry from Iceland (they found this project from the NEC website) on the fishing gear used to harvest the sea cucumber.

Related projects

This project has lead to the development of funding of a full proposal that assesses the Maine sea cucumber resources and evaluates the impacts of exploitations. This project was done in association with a Maine Sea Grant Program Development project which provides funding ($5,500) for inviting a Russian sea cucumber scientist to involve in the project.

If readers have any question regarding the project, they can contact PI by email at ychen@maine.edu or by phone at (207) 581-4303. They can also find more information at www.marine.maine.edu/~chen/index.htm.

Presentations

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Student participation

Ms. Sheril Kirshenbaum is a graduate student who studies the sea cucumber in Chen's lab at the University of Maine. She is in the dual Masters degree program in Marine Biology and Marine Policy. She has been responsible for the lab work, has presented the work at various metings and conferences, and has answered the public enquires which we have received quite a lot over the last several months. She also plays a critical role in establishing a sea cucumber management structure by providing oral and written testimony at the 2005 Maine legislative hearing and working sessions on the Maine Sea Cucumber Fishery in Augusta, ME. Two undergraduate students of the University of Maine (Orono) were also involved in the lab work. Because of her wonderful work with the sea cucumber project, she has recently been selected as one of the nine John A. Knauss Marine Policy Fellowship receipients selected nationally for the Legislative Branch of the Federal government and will be working as an intern in one of the Senator's offices on Capitol Hill beginning February 2006.

Published reports and papers

Kirshenbaum, S., S. Feindel, and Y. Chen. 2005. A Study of Tagging Methods for the Maine Sea Cucumber (*Cucumaria frondosa*). Fishery Bulletin (in press)

Kirshenbaum, S., S. Feindel, and Y. Chen. 2005. Biological study of the Maine sea cucumber (*Cucumaria frondosa*). Fisheries Research (in preparation)

Kirshenbaum, S. and Y. Chen. 2005. Assessing the Maine sea cucumber fishery (in preparation and intend to submit it to Aquatic Sciences).

Kirshenbaum, S. 2006. Assessment and management of the Maine sea cucumber resources. MS thesis for the Dual MS degrees in Marine Biology and Marine Policy (in preparation).

Images

Figures have been included in the report.

Future research

The full project that was developed based on this program development project is currently under way. The full project will provide information of sea cucumber distribution,

abundance and size structure in key sea cucumber fishing grounds. Biological information such as maturation and fecundity and how they may be affected by factors such as size, water depth, and month will also be provided.

Future research should be focused on the estimation of other key life history parameters such as natural mortality, movement, and growth using tagging and caging methods identified in this project. Researches leading to a better understanding of recruitment process and critical habitats are also needed.

Table 1. Tagging study design. The number in the brackets is the sample size.

Tagging method			Total animals
Fluorescent Dyes			10
Double T-bar Tags	Double pass Long (9) Short (15)	Single pass Long (6) Short (15)	45
Control Tagging Gun Puncture	Double puncture (9)	Single puncture (6)	15
Total			70

Figure 1. Historical landings and values of the Maine sea cucumber fishery.

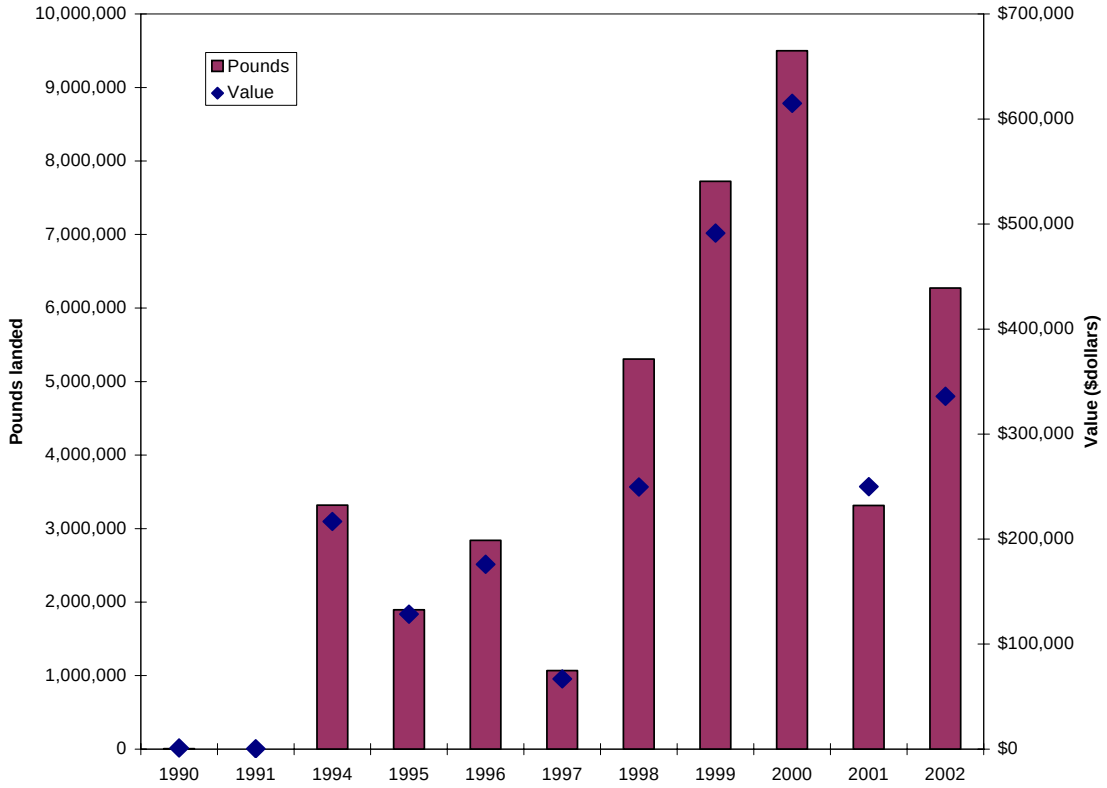

Figure 2. Different tagging techniques tested in the project.

Figure 3a. An illustration of one of the tagging techniques used.

Figure 3b. An illustration of one of the tagging techniques used (double T bar).

Figure 3c. An illustration of one of the tagging techniques used (dart tag).

Figure 3d. Tagged individuals after 50 days of tagging experiment.

Figure 4. Tagging retention for individual style tags.

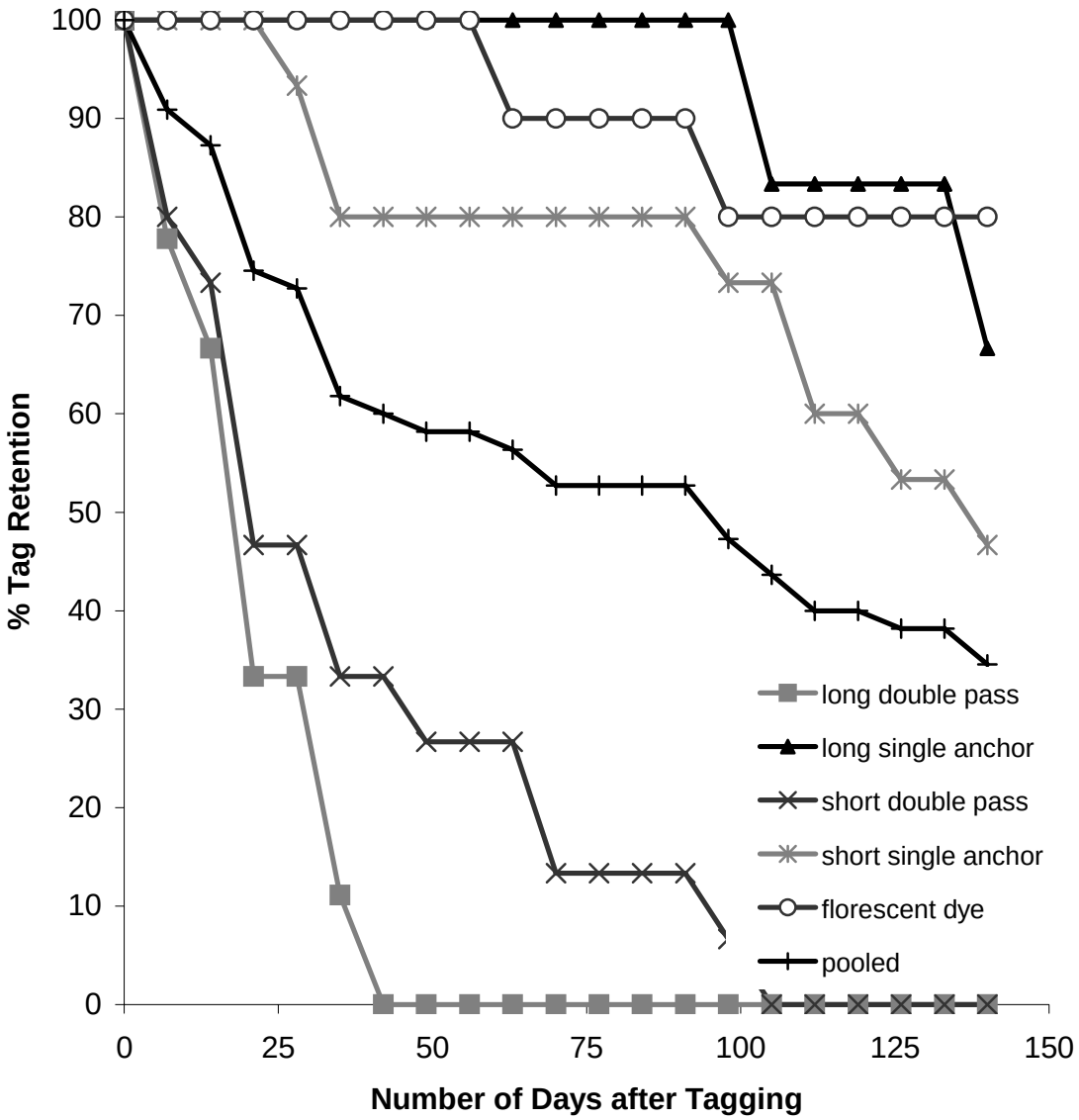

Figure 5a. Dissecting a male sea cucumber.

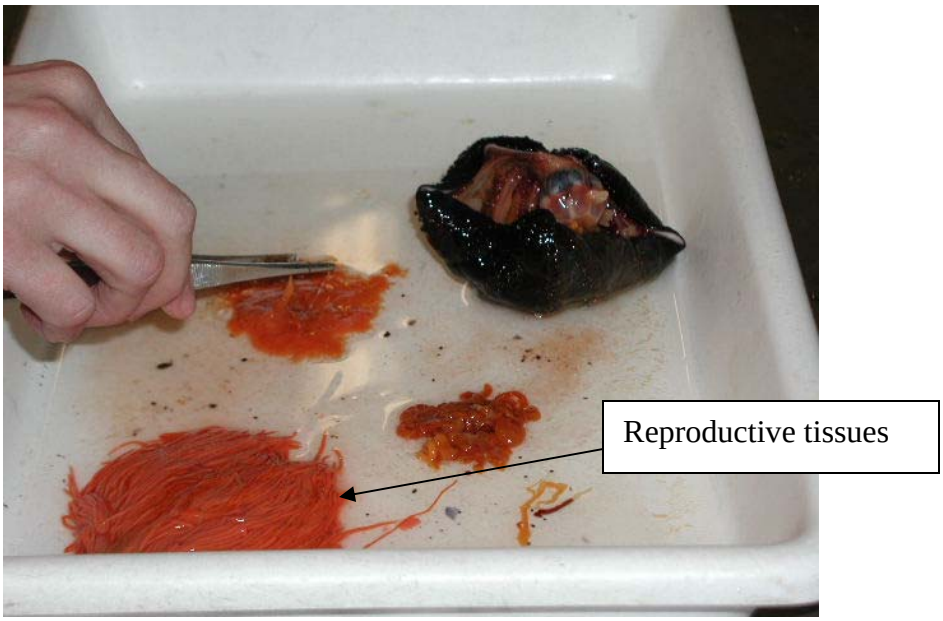

Figure 5b. Different body parts of a male sea cucumber.

Figure 5d. Different body parts of a female sea cucumber. Notice different colors of reproductive tissues between the male and female

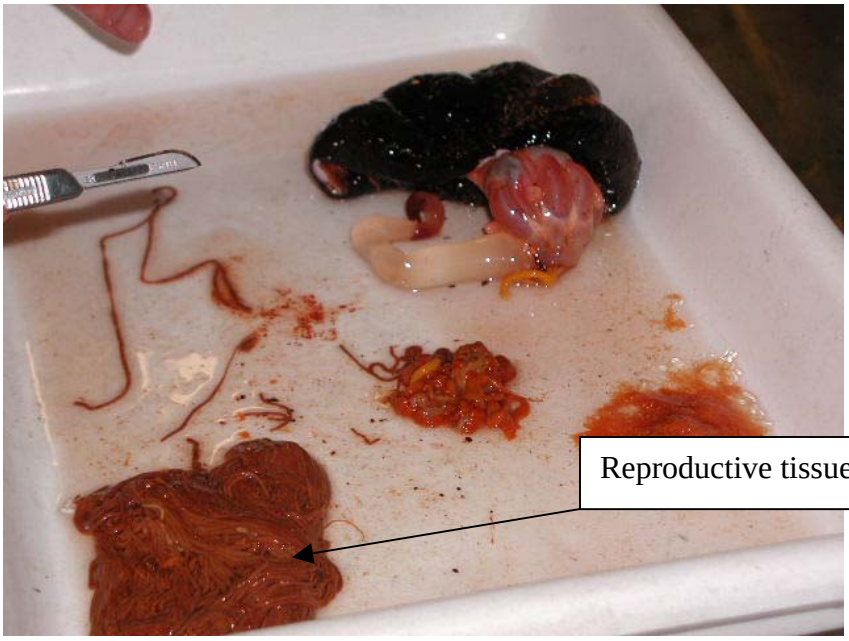

Figure 5c. Dissecting a female sea cucumber.

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