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Assessment of the Exploratory Fishery for Sea Cucumber (*Cucumaria frondosa*) in Southwest New Brunswick

Évaluation de la pêche exploratoire de l'holothurie (*Cucumaria frondosa*) dans le sud-ouest du Nouveau-Brunswick

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ABSTRACT

The southwest New Brunswick (SWNB) developmental sea cucumber fishery has evolved since 1999 to a Stage II Exploratory fishery under the New Emerging Fisheries Policy, with a recent 5 year average in landings of approximately 1200 t by 2 licence holders. A science review was requested of the sustainability and ecosystem effects of this fishery. Specifically, Department of Fisheries and Oceans (DFO) Maritimes Fisheries and Aquaculture Management Branch asked Science and Oceans, Habitat and Species at Risk branches: "What are the potential ecosystem (stock, habitat, and by-catch) impacts of the harvest of 1000-1300 t of sea cucumber in SWNB within the identified areas of recent fishing? Characterise and provide quantitive and/or qualitative information of the relative risk to the stock, habitat, and by-catch from this harvest."

There is very limited information on life history and stock structure of sea cucumber in the Maritimes Region. Sustainable exploitation rates and other reference points are unknown, as are the consequences of removals on ecosystem structure and function.

Since 1999, more than 80% of the catch and 90% of the fishing effort was in a single fishing zone known as 'The Passages'. Landings increased to a peak of approximately 1600 t in 2005 and have since remained around 1100 t, which may be a function of specified fishing zones and an overall Total Allowable Catch (TAC) of 1370 t being implemented prior to the 2006 fishing season. Effort peaked in 2005 and remained at lower levels during 2006-2008. Catch rates peaked at 4877 kg/hr in 2002 and remained similar to the long term average of 4292 kg/hr in 2007 and 2008. While catch rates have been maintained, there are uncertainties in whether catch rates in this fishery are reflective of population abundance.

A survey in 2004 revealed that large aggregations of sea cucumbers were relatively localized with highest catches found in the northern area of Deer Island, where the majority of the 2000-2004 fishing effort was directed. Because of the patchy nature of sea cucumber distribution and the lack of a systematic survey across the fishing area, it is not possible to establish a total population abundance estimate at this time.

There was an indication of a decrease in the size of animals landed over time, although the significance of these results has not been established and additional investigation is warranted. If the size of animals landed has decreased over time, this would result in an increase in the exploitation rate associated with the TAC of 1370 t.

The predominant by-catch species in the SWNB sea cucumber fishery was sea urchin, with catches estimated at 34 t during 2008. By comparison, 1028 t of sea urchin was landed in LFA 36 during the directed fishery in 2007-2008. The sea cucumber fishery returns all species other than sea cucumber to the water, although survival of by-catch has not been evaluated for this fishery. At-sea observers provided more detailed descriptions of by-catch than recorded in Sea Cucumber Science Logs and continued at-sea observer coverage is recommended.

The environment in which the SWNB sea cucumber fishery is conducted is considered to be productive and diverse, with very patchy distribution of benthic organisms and features. Immediate, localized impacts of the sea cucumber fishing gear on benthic habitat were

observed (e.g., disturbance of periphyton layer), but the longer-term community implications and rates of recovery are not known and are worthy of further investigation. Risks of habitat impacts within the current fishing areas could be reduced by investigating the location/extent of any particularly sensitive habitat features and investigating the rates of recovery for known habitat types within these areas.

Given the number of uncertainties associated with this fishery, a cautious approach is advised.

RÉSUMÉ

La pêche expérimentale de l'holothurie dans le Sud-Ouest du Nouveau Brunswick (SONB) a évolué depuis 1999, progressant vers une pêche exploratoire de stade II, conformément à la nouvelle politique sur les pêches émergentes. La moyenne des débarquements des cinq dernières années totalise environ 1 200 tonnes, capturées par deux titulaires de permis. Une demande d'évaluation scientifique a été présentée afin de connaître la durabilité de cette pêche et ses effets sur les écosystèmes. Plus précisément, la Direction de la gestion des pêches et de l'aquaculture de la Région des Maritimes du MPO a posé aux directions des sciences, des océans, de l'habitat et des espèces en péril la question suivante : « Quels sont les effets écosystémiques potentiels (stock, habitat et prises accessoires) de la pêche de 1 000 à 1 300 tonnes d'holothuries dans les zones de pêche récemment identifiées du SONB? Caractérisez le risque relatif que représente cette pêche pour le stock, l'habitat et les prises accessoires et fournissez de l'information quantitative et/ou qualitative à ce sujet. »

On connaît peu le cycle biologique et la structure du stock d'holothuries dans la Région des Maritimes. Les taux d'exploitation durables et autres points de référence sont inconnus, tout comme les conséquences de la pêche sur la structure et la fonction de l'écosystème.

Depuis 1999, plus de 80 % des prises et 90 % de l'effort de pêche concernent la seule zone de pêche appelée « Les Passages ». Les débarquements ont atteint un sommet d'environ 1 600 tonnes en 2005 pour se stabiliser aux environs de 1 100 tonnes depuis, ce qui pourrait s'expliquer par les zones de pêche définies et la mise en place d'un total autorisé de captures (TAC) global de 1 370 tonnes avant la saison de pêche de 2006. L'effort de pêche a atteint un point culminant en 2005, avant de se stabiliser à des niveaux inférieurs de 2006 à 2008. Les taux de prises ont culminé à 4 877 kg/h en 2002, puis se sont maintenus à un niveau proche de la moyenne à long terme de 4 292 kg/h en 2007 et 2008. Si les taux de prises sont restés soutenus, ils suscitent néanmoins des incertitudes, quant à savoir s'ils correspondent véritablement au niveau d'abondance de la population.

Un relevé réalisé en 2004 a révélé que les grands bancs d'holothuries étaient relativement circonscrits, les plus fortes prises provenant du secteur situé au nord de l'île Deer, où la plus grande partie de l'effort de pêche a été déployée entre 2000 et 2004. Étant donné la nature irrégulière de la répartition de l'holothurie et l'absence de relevés systématiques sur toute la zone de pêche, il est impossible d'établir une estimation de l'abondance de la population totale pour le moment.

On a observé des signes de diminution progressive dans le temps de la taille des animaux débarqués, bien que la valeur de ces observations n'ait pas été établie et que des études additionnelles soient requises. Si la taille des animaux débarqués a véritablement diminué avec le temps, cela signifie une hausse du taux d'exploitation associé au TAC de 1 370 tonnes.

L'espèce la plus couramment sujette à des prises accessoires au cours de la pêche de l'holothurie dans le SONB est l'oursin, avec des prises estimées à 34 tonnes en 2008. En comparaison, 1 028 tonnes d'oursins ont été débarquées dans le cadre de la pêche ciblée sur la ZPH 36 en 2007-2008. Les pêcheurs d'holothurie remettent à la mer toutes les prises d'autres espèces, bien que la survie de ces dernières n'ait pas été évaluée dans le cadre de cette pêche. Des observateurs en mer ayant fourni des descriptions plus détaillées des prises accessoires que celles qui sont consignées dans les journaux scientifiques de la pêche de l'holothurie, le maintien de la présence des observateurs en mer est recommandé.

Le milieu dans lequel la pêche de l'holothurie dans le SONB est pratiquée est considéré comme étant productif et diversifié, affichant une répartition très irrégulière des organismes et caractéristiques benthiques. Des effets immédiats et circonscrits des engins de pêche de l'holothurie sur l'habitat benthique ont été observés (notamment, perturbation de la couche de périphyton), mais les répercussions à long terme sur les communautés et leur taux de récupération sont inconnus et nécessiteront un examen plus approfondi. Il serait possible de réduire les risques d'impact sur l'habitat dans les zones de pêche actuelles, si l'on étudiait l'emplacement ou l'étendue des habitats vulnérables, ainsi que le taux de rétablissement de types d'habitats connus dans ces mêmes zones.

Étant donné le nombre d'incertitudes associées à cette pêche, une démarche extrêmement prudente est recommandée.

INTRODUCTION

CONTEXT

The southwest New Brunswick (SWNB) developmental sea cucumber fishery (Figure 1) has evolved since 1999 to a Stage II Exploratory fishery under the New Emerging Fisheries Policy, with a recent 5 year average in landings of approximately 1200 t by 2 licence holders. A science review was requested of the sustainability and ecosystem effects of this fishery. Specifically, DFO Maritimes Fisheries and Aquaculture Management Branch asked Science and Oceans, Habitat, and Species at Risk branches: "What are the potential ecosystem (stock, habitat, and by-catch) impacts of the harvest of 1000-1300 t of sea cucumber in SWNB within the identified areas of recent fishing? Characterise and provide quantitive and/or qualitative information of the relative risk to the stock, habitat, and by-catch from this harvest."

This is the first assessment of the Stage II Exploratory sea cucumber fishery in this area, though DFO Science advice was provided on this fishery in 2006, before it moved from Stage I Experimental to Stage II Exploratory status (DFO 2006a). In addition, a science workshop on sea cucumber was held at the Bedford Institute of Oceanograph, Dartmouth, NS, on 17-18 June 2008.

RATIONALE FOR ASSESSMENT

Advice was requested by Fisheries and Aquaculture Management on the status of the SWNB Stage II Exploratory sea cucumber fishery. Specifically, the objectives for the assessment were as follows:

- Assess the impact of the SWNB sea cucumber fishery on the sea cucumber population(s) in this area, taking into account any available commercial or survey information including:
  - Catch rates.
  - Morphometric data.
  - Known life-history characteristics.

- Evaluate the by-catch of non-sea cucumber species in this fishery.

- Evaluate the impacts of this fishery on benthic habitat.

BIOLOGY

The sea cucumber (*Cucumaria frondosa*) harvested in SWNB is small and thin-walled, relative to other sea cucumber species commonly harvested elsewhere. Adults attach to the bottom using tube feet, filter feed plankton from the water column, and are thought to exhibit low rates of movement. Eggs and larvae are pelagic. There is very limited information on the life history characteristics of *C. frondosa* in the Maritimes Region (Singh et al. 1999, 2001). Much of our understanding of this species comes from research in other areas, particularly the St. Lawrence estuary (Hamel and Mercier 1995, 1996a, 1996b, 1996c, 1997, 1998). While some of this information will be applicable to SWNB, site-specific verification is required. For example, *C. frondosa* in Passamaquoddy Bay spawns each spring in May or June (Singh et al. 2001), which is similar to the timing of spawning (late spring/early summer) in the St. Lawrence estuary (Hamel and Mercier 1995, 1996c). Other life history characteristics of interest include: growth rate, age at maturity, size at maturity, recruitment, and natural mortality.

Growth rates for *C. frondosa* in SWNB have not been determined. However, in the St. Lawrence

estuary, the maximum size after 5 years was 10.7 cm at 20 m depth and less than 5 cm at shallower depths (Hamel and Mercier 1996a). These rates are lower than have been reported for other sea cucumber species (Therkildsen and Petersen 2006). Studies in the St. Lawrence estuary indicated that growth of *C. frondosa* was mainly influenced by environmental conditions (Hamel and Mercier 1996a), meaning wide application of growth estimates from different areas is not appropriate.

Age at maturity for *C. frondosa* in SWNB has not been determined. However, in the St. Lawrence estuary, the age at maturity was found to be about 5 years old at 20 m depth. Individuals observed at shallower depths did not reach maturity within a 5 year time frame (Hamel and Mercier 1996a). Age at maturity of *C. frondosa* is comparable to some other sea cucumber species (*Parastichopus californicus, Holothuria fuscogilva, Isostichopus fuscus*), but is also later than some sea cucumber species (*Holothuria scabra, Stichopus japonicus*), which mature within 1-2 years (Therkildsen and Petersen 2006).

Size at maturity for *C. frondosa* in SWNB has not been determined. However, the size at maturity for C. *frondosa* was determined to be between 80 and 102 mm in the St. Lawrence estuary (Hamel and Mercier 1996a).

Nothing is known about recruitment rates or natural mortality of sea cucumber in SWNB. Nothing was found in the literature that would provide some preliminary indication of what these might be.

The stock structure of *C. frondosa* (i.e., the relationship of individuals in this area to adjacent areas) is unknown.

THE FISHERY

During 1999-2006, a Stage I Experimental sea cucumber fishery consisting of 2 licence holders using variations of modified scallop/urchin gear was permitted in the Lobster Fishing Area (LFA) 36 portion of SWNB. The purpose of this experimental fishery was to test gear performance and market potential. In every year except 2002, the experimental sea cucumber fishery took place from January to March. In 2002, the fishery was extended until June. Since 1999, each licence holder has been required to submit a dockside monitoring document and a DFO Sea Cucumber Science Log, including tow locations, catch, depth, and wave height.

In 2006, 5 zones were created around the areas of primary fishing effort (Figure 1). One of these zones, St. Andrews Harbour, was closed to the fishery as a possible research area. The other 4 zones were each assigned a total allowable catch (TAC) for experimental fishing during the 2006 season (1010 t in The Passages and 120 t in each of the 3 remaining zones – Magaguadavic River, South Deer Island, and Upper Passamaquoddy Bay) based on the average annual landings during the previous 5 years.

Prior to the 2007 fishing season, the SWNB sea cucumber fishery was authorized by DFO to move from Stage I Experimental to Stage II Exploratory status. Science and monitoring requirements that were established in Stage I continued during 2007-2008, and TACs and fishing zones remained in place.

In the subsequent summary, any fishing activity that occurred outside the 5 sea cucumber zones is grouped as “Area Outside of Zones”.

FISHING METHODS

The 2 licence holders fish using different variations of modified scallop/urchin gear. One licence holder uses Green Gear, which is defined as a bag-like net of steel meshes and/or twine meshes, a 3.0 m wide steel frame with a mouth opening 25 cm high, the bottom of the drag consisting of up to 1.3 cm hardened chain forming a chain sweep, and the top of the drag consisting of 5 cm mesh twine running back to a metal gate (Figure 2).

The second licence holder uses Tinker Gear, which is described as 11 pieces of 1 cm metal cut in a triangular shape, 49.5 cm deep and 50.8 cm long, lying on their side with the pointed end toward the mouth of the drag. These pieces are welded to a metal tube leaving a distance of 29.2 cm between each plate. The metal plates are also reinforced by a metal strip welded along each edge of the plates. A 7.6 cm shaft approximately 3.3 m long is inserted into the tube and capped so it cannot be removed, but allows the drag to pivot. Four chains, 2 attached to the shaft and 2 attached to the metal tube, are shackled to the main cable from the vessel. Attached to the blunt edge of the metal plates are links of 3.81 cm chain, 6 links deep and 6 links between each metal plate; these are used to attach the holding area of the drag, which is approximately 3.1 m wide, 49.5 cm deep, and 3.3 m long, made from scallop rings with rubber washers attached. Two pieces of 1.3 cm by 7.6 cm metal, approximately 22.8 cm in length, are attached to the scallop rings at the bottom of the drag – these are fastened together while dragging, and then released to empty the catch.

LANDINGS

Landings information pertaining to the SWNB sea cucumber fishery is available from both the dockside monitoring documents and the Sea Cucumber Science Logs. In the dockside monitoring documents, the weight of the sea cucumber catch is provided for each trip. By comparison, the number of totes (approximately 70 L plastic boxes in which captured sea cucumbers are stowed during fishing activities) of sea cucumber retained in each tow is reported in the Sea Cucumber Science Logs, and the catch weight must be calculated using a conversion factor of 68 kg per tote (based on data from the SWNB fishery). Although landings data reported in the dockside monitoring documents were not identical to those contained in the Sea Cucumber Science Logs, there was reasonably good correspondence between the 2 data sources in most years, and the overall trend in landings was similar (Figure 3; tables 1-3).

Since 1999, more than 80% of the catch (tables 1-3; Figure 4) and 90% of the fishing effort (Figure 5) was in a single fishing zone known as ‘The Passages’. Landings increased to a peak of approximately 1600 t in 2005, and have since remained around 1100 t, which may be a function of specified fishing zones and an overall TAC of 1370 t being implemented prior to the 2006 fishing season. Effort peaked in 2005 and remained at lower levels during 2006-2008 (Figure 5). In Upper Passamaquoddy Bay, South Deer Island, and Magaguadavic River, there has been little effort (8, 87, and 19 hours, respectively) due to winter ice cover and poor weather conditions.

ASSESSMENT

ABUNDANCE AND DISTRIBUTION

There has been only 1 survey of sea cucumber in SWNB (conducted in 2004) and, as a result, catch rates in the fishery provide the only potential metric of sea cucumber abundance over time.

Fishery catch rates were calculated using the number of totes caught per hour of towing as reported in the Sea Cucumber Science Logs. For all SWNB fishing areas combined, catch per unit effort (CPUE) peaked at 4877 kg/hr (71.7 totes/hr) in 2002, and has remained at similar levels since this time (Figure 6). Catch rates in 2007 and 2008 were similar to the long term average of 4292 kg/hr (63 totes/hr) (Table 4). In The Passages, catch rates during 2007 and 2008 were also near or above the zone average of 4434 kg/hr (65 totes/hr) (Table 4). Low effort in Upper Passamaquoddy Bay, South Deer Island, and Magaguadavic River makes annual variation in CPUE in these zones difficult to interpret.

A survey was conducted 27-29 July 2004 aboard the *F/V Sue & Ken* (owned and operated by Harvey Richardson, Leonardville, Deer Island, NB) to determine catch rates and relative abundance of sea cucumber in the Passamaquoddy Bay area. The survey covered known areas of high sea cucumber abundance and explored some areas not previously fished by the licence holders. Tow locations were selected throughout the area by the licence holders based on their local knowledge. A total of 112 tows were completed using a 2.4 m drag. Each tow was 2-5 minutes in duration depending on bottom hardness. Start and end locations of tows were recorded, as well as the distance towed. At the end of each tow, the number of totes of sea cucumber captured was recorded (or number of animals if <50). The number of sea cucumbers per tote was determined for 6 totes approximately 6 hours after capture and the mean (245 sea cucumbers per tote) was used to prorate the catch from number of totes to number of sea cucumbers in a standard 200 m tow length.

Sea cucumber catches varied throughout the survey area from 0 to 4900 animals per standardized 200 m tow (mean ± standard deviation: 876.6 ± 1249.1; total: 98183). Large aggregations of sea cucumbers were relatively localized (Figure 7). Highest catches (>8 totes/tow) were found in the northern area of Deer Island, where the majority of the 2000-2004 fishing effort was directed. Other areas of high sea cucumber densities were recorded in the northern area of Passamaquoddy Bay, an area that had not received experimental fishing effort, and in St. Andrews Harbour, an area which had received minimal fishing effort.

Maximum densities found were 4900 individuals per tow, which translates into roughly 10 sea cucumbers per m^2 (using a standardized tow area of 492 m^2). This is comparable to the densities determined by Singh et al. (2001) of 5-15 individuals per m^2, though they identified local densities of up to 50 individuals per m^2 in Passamaquoddy Bay. Given that the standardized tow area was small (492 m^2), a catch of 2 totes (>500 sea cucumbers) was considered commercially viable (Harvey Richardson, personal communication). Because of the patchy nature of sea cucumber distribution and the lack of a systematic survey across the fishing area, it is not possible to establish a total population abundance estimate at this time.

SIZE COMPOSITION

As of 2004, licence conditions required a sample of 20 randomly selected sea cucumbers to be taken from 1 tow each fishing day for size measurements. During experimental fishing, 52, 85, 71, 57, and 84 daily samples were collected in 2004, 2005, 2006, 2007, and 2008, respectively.

Samples were processed at G.E.M. Fisheries Ltd., Caraquet, NB, or Matthews Seafoods Ltd., Campobello Island, NB. The variables measured were: length, wet weight, circumference, body wall thickness, meat weight, body wall weight, and viscera weight. Before measuring length and wet weight, sea cucumbers were allowed to rest, undisturbed, until the majority of the water they contained was expelled. The meat was removed by scraping it from the body wall or skin. Body wall thickness and body wall weight were measured after the meat and viscera were removed. Circumference was determined by laying the split body wall flat and measuring the distance at its widest point.

Standard measuring procedures were employed but because sea cucumbers are comprised of 80-90% water and are able to swell and contract, there was considerable variability in the data. Nonetheless, there was indication of a decrease in the size of animals landed over time (Table 5) that merits additional investigation. In the Bay of Fundy, protein content in the body wall has been reported to increase during the feeding period (suggesting that *C. frondosa* has the ability to accumulate energy reserves in the body wall; David and MacDonald 2002) and this may explain some of the annual variation in size measurements. In addition, samples were derived from different areas, potentially of varying depth, which may also attribute to variation.

ECOSYSTEM IMPACTS

BY-CATCH

During experimental and exploratory fishing activities, by-catch is recorded in the Sea Cucumber Science Log at each fishing location. During 1999-2005 experimental fishing, 10 by-catch items (including shells and rocks) were reported (DFO 2006a). Sea urchins were the largest component of by-catch in all zones. Other reported by-catch organisms included: seastars, crabs, sea scallop (*Placopecten magellanicus*), Iceland scallop (*Chlamys islandica*), lobster (*Homarus americanus*), and octopus. In each zone, the tows that reported no by-catch ranged from 54% in St. Andrews Harbour to 86% in The Passages. Instances where no by-catch was reported can be interpreted in 2 ways, either there was no by-catch for those tows or there was by-catch but it was not recorded. Time constraints did not permit a similarly detailed analysis of the by-catch reported in Sea Cucumber Science Logs during 2006-2008 although, the following species were observed: sea urchin, scallop, seastars, lobster, mussels, and shells.

DFO certified at-sea observers monitored the sea cucumber fishery during 8 exploratory fishing trips in 2008. These trips monitored a total of 280 fishing sets during the fishery. Of these 280 sets, 273 were located in The Passages, 5 in Magaguadavic River, and 2 in Upper Passamaquoddy. At-sea observers recorded a total of 10 species captured in the SWNB sea cucumber fishery (Table 6). Sea cucumber was the most abundant species by weight. Sea urchin was the most significant by-catch species by weight and represented approximately 3% of the sea cucumber catch. Prorating the observed catch to total landings reported during the 2008 fishery, it is estimated that up to 34 t of sea urchin may have been encountered as by-catch (Table 7). However, because observer protocols dictate that sets containing a small quantity (<1 kg) of a species be recorded as 1 kg, the observed catch and adjusted catch values presented are likely overestimates of the catches of by-catch species within the fishery. This is particularly true for some of the smaller-bodied species (e.g., toad crab, hermit crab, sea potato, and seastars).

In The Passages, sea cucumber, sea potato, toad crab, seastars, and sea urchin were caught in all observed sea cucumber fishery sets (Table 8). Winter flounder (*Pseudopleuronectes americanus*) and lobster were caught in approximately 1% of sets. Hermit crab, sculpin, and

rock crab were caught in 59%, 41%, and 32% of sets, respectively. There were few observed sets in Magaguadavic River and Upper Passamaquoddy although sea potato, toad crab, hermit crab, and seastars were caught in all sets suggesting that these species may be common in these areas. Sea urchins were not observed in either of the 2 sets in Upper Passamaquoddy but were observed in all sets in Magaguadavic River.

The sea cucumber fishery returns all species other than sea cucumber to the water. Observers did not assess the condition of by-catch species; thus, survival of by-catch returned to the water is unknown.

HABITAT IMPACTS

Description of the Area in Passamaquoddy Bay Where the Sea Cucumber Fishery has Occurred

Geomorphology, along with large tidal range, results in the generation of very high surface current velocities in portions of the area where the sea cucumber fishery has occurred, particularly within The Passages (Trites and Garrett 1983). Subtidal bedrock may be covered by boulders, gravel, sand, mud, and shell hash. Sand and mud occur at depths below 30 m and in sheltered areas where the current is decreased and sedimentation occurs (Logan et al. 1983). Hard substrates (i.e., bedrock, boulder, gravel, and shell hash) occur in shallow and deep areas experiencing high currents (Logan 1988). A diverse benthic community carpets the rocky substrate, particularly in the deeper channels with high currents where the encrusting crustose coralline algae that dominate hard substrates from the mean low water mark down to about 14 m are replaced by communities of brachiopod (*Terebratulina septentrionalis*) and a large biomass of suspension feeders. The highly diverse and abundant faunal community includes branching bryozoans, annelids, molluscs, crustaceans, echinoderms, and tunicates. Cnidarians (hydroids), soft corals, and anemones are common on steep cliff faces. In moderate to strong currents, a rich and diverse fauna of sponges occurs (Ginn et al. 2000). In The Passages, most sponges are of the encrusting type, followed by those having a massive and upright morphology (Ginn 1997).

Potential Benthic Impacts of Sea Cucumber Fishing

Monitoring area swept over time is important, as this measure may provide a potential indicator of benthic habitat impacts and may also be an early indicator of stock depletion, given that fishery catch rates can sometimes be maintained by increasing the area fished. An analysis of area swept during the SWNB sea cucumber fishery revealed a few tow tracks that crossed multiple sea cucumber fishing zones and landmass, as well as tracklines that were outside the designated fishing zones established for the 2006 fishery (figures 8 and 9; Table 9). The total area towed for all track lines ranged from approximately 3 to 5 km^2 per year (Table 10). Because the area of overlap among track lines was not estimated, this represents an overestimate of the actual area impacted by the fishery. Given that the fishery occurs almost entirely in The Passages, it is noted that no more than 10% per year of the area of this zone was swept by a sea cucumber drag, and a portion of this area could have been swept multiple times per year. Note that the total area of The Passages used in these calculations includes intertidal areas that are not likely to be dragged during the fishery.

Mobile bottom-contacting fishing gear, such as that used in the sea cucumber fishery, can alter or damage physical features of the seafloor, as well as benthic populations and communities. Initial impacts are greater on sand and mud bottoms than on hard bottoms, although duration of the impacts is longest on hard complex bottoms (DFO 2006b). In The Passages, it could be

expected that impacts would be greater on surface-living species than populations of burrowing infaunal species. By-catch recorded for the SWNB fishery included sea urchins, seastars, sea potatoes, and crabs and, given the high biodiversity of The Passages, it could be assumed that the many upright and encrusting organisms smaller than that retained by the gear are also encountered. Impacts to organisms such as sponges and tunicates that are dislodged, torn, scraped, or overturned during fishing activities may not be adequately documented by examining by-catch, although it may be assumed that such structurally fragile species would be negatively impacted by the gear. Sublethal effects (i.e., injury, exposure) may increase the vulnerability of these individuals to other sources of mortality or lower their fitness. Mobile bottom-contacting fishing gear, such as that used in the sea cucumber fishery, is considered to be among the most destructive gear types in terms of habitat change and by-catch (DFO 2006b). Drags affect the seafloor community structure, reducing benthic biomass, biodiversity, and habitat complexity, and have ecosystem-level impacts on productivity and nutrient cycling.

As part of a depletion study, 76 tows were completed over the same narrow strip of bottom in the main channel of St. Andrews Harbour (between the shore of St. Andrews and Navy Island) over 4 fishing days during 19-24 October 2006. Following the fishing activity, 8 transects were run perpendicular to the drag path on 26 October 2006, using towed video equipment (as described in Vandermeulen 2007). Sea cucumbers were patchily distributed and seen as highly aggregated clusters, frequently associated with larger rocks or boulders on a gravel or sand/silt bottom (figures 10 and 11). Drag marks were clearly visible on sand/silt bottom areas as indicated by scrape marks about 5-10 cm deep, where the drag removed sea urchins, sea cucumbers, and a lush periphyton layer on the surface of the sediment (figures 10D and 12). The periphyton layer (probably diatoms and other microalgae) is very common in the channel and sea urchins appear to feed from it (as indicated by clear patches or 'feeding trails' extending out behind individual urchins). The recovery time for the periphyton following dragging events is not known. Drag marks on harder rock or gravel surfaces were more difficult to distinguish, but could be seen as disturbed rocks or scrape marks on rocks.

SOURCES OF UNCERTAINTY

Population structure is unknown, including source of recruits and the extent of movement among areas.

There is no directed survey for sea cucumber and a fishery-independent abundance estimate is lacking.

A reliable estimate of sea cucumber catchability is unavailable for use in estimating exploitation.

Productivity, size at maturity, sustainable exploitation rates, and other reference points are all unknown.

Survival of by-catch returned to the water has not been evaluated for this fishery.

The consequences of removals on ecosystem structure and function are unknown, particularly with respect to longer-term benthic community and biodiversity implications and related rates of recovery.

Habitat impacts of this fishery relative to other fisheries in the area, including scallop, sea urchin, and groundfish fisheries, have not been evaluated. Neither has the additive impact of the sea cucumber fishery on the ecosystem been assessed.

CONCLUSIONS AND ADVICE

Indicators of status of sea cucumbers within the area of interest are limited. While catch rates have been maintained over time, there are uncertainties in whether catch rates in this fishery are reflective of population abundance. There was indication of a decrease in the size of animals landed over time, although the significance of these results has not been established, and additional investigation is warranted. If the size of animals landed has decreased over time, this would result in an increase in the exploitation rate associated with the TAC of 1370 t. Research would be required to determine whether reductions in size were a result of changes in environmental conditions, fishing patterns (e.g., fishing in deeper waters) or as an effect of fishing on the population.

The predominant by-catch species in the SWNB sea cucumber fishery was sea urchin with catches estimated at 34 t during 2008. By comparison, 1028 t of sea urchin was landed in LFA 36 during the directed fishery in 2007-2008. At-sea observers provided more detailed descriptions of by-catch than recorded in Sea Cucumber Science Logs, and continued at-sea observer coverage is recommended.

The environment in which the SWNB sea cucumber fishery is conducted is considered to be productive and diverse, with very patchy distribution of benthic organisms and features (DFO 2004, Buzeta et al. 2003, Buzeta and Singh 2008). Buzeta et al. (2003) reviewed potentially significant areas in the Bay of Fundy and approaches and found The Passages to be an area of high benthic diversity with complex biogenic habitat including upright and large encrusting sponges and previously unrecorded sponge species. In addition, the South Deer Island sea cucumber fishing zone overlaps with the West Isles, which were recognized for high benthic diversity, some geographically rare species, complex biogenic habitat, and marine mammal sightings (Buzeta et al. 2003).

Immediate, localized impacts of the sea cucumber fishing gear on benthic habitat were observed (e.g., disturbance of periphyton layer), but the longer-term community implications and rates of recovery are not known and are worthy of further investigation. This is consistent with advice provided previously by DFO Science on this type of gear (DFO 2006b). Risks of habitat impacts within the current fishing areas could be reduced by investigating the location/extent of any particularly sensitive habitat features and investigating the rates of recovery for known habitat types within these areas. Additional studies conducted before expansion of fishing activity beyond the existing zones may reduce risk of potential habitat and biodiversity impacts. Studies could include benthic habitat mapping, mapping of other local fishing activities that use mobile bottom-contacting gear, and development of indicators of impact (e.g., area of impact by habitat type, or related to recovery rates).

Given the number of uncertainties associated with this fishery, a cautious approach is advised.

ACKNOWLEDGEMENTS

We are grateful to the licence holders and processors for their ongoing support with respect to scientific data collection for this emerging fishery. Funding for the depletion study was provided by the Province of New Brunswick. Alan Logan provided valuable information that assisted in describing the ecology of Passamaquoddy Bay, and Stan Johnson contributed to the determination of area swept.

REFERENCES

Buzeta, M.-I., and R. Singh. 2008. Identification of Ecologically and Biologically Significant Areas in the Bay of Fundy, Gulf of Maine. Volume 1: Areas identified for review and assessment of the Quoddy Region. Can. Tech. Rep. Fish. Aquat. Sci. 2788**.**

Buzeta, M.-I., R. Singh, and S. Young-Lai. 2003. Identification of significant marine and coastal areas in the Bay of Fundy. Can. Manuscr. Rep. Fish. Aquat. Sci. 2635.

David, V.M.M., and B.A. MacDonald. 2002. Seasonal biochemical composition of tissues from *Cucumaria frondosa* collected in the Bay of Fundy, Canada: feeding activity and reproduction. J. Mar. Biol. Assess. U. K. 82: 141-147.

DFO. 2004. Identification of Ecologically and Biologically Significant Areas. DFO Can. Sci. Advis. Sec. Ecosys. Stat. Rep. 2004/006.

DFO. 2006a. Southwest New Brunswick sea cucumber fishery. DFO Mar. Reg. Sci. Resp. 2006/13.

DFO. 2006b. Impacts of trawl gears and scallop dredges on benthic habitats, populations and communities. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/025.

Ginn, B.K. 1997. Ecology, systematics, and feeding rates of sponges on subtidal hard substrates in Little Letite Passage, Deer Island, New Brunswick. M.Sc. Thesis. University of New Brunswick, Saint John, New Brunswick, Canada.

Ginn B.K., A. Logan, and M.L.H. Thomas. 2000. Sponge ecology on sublittoral hard substrates in a high current velocity area. Estuar. Coast. Shelf Sci. 50: 403-414.

Hamel, J.F., and A. Mercier. 1995. Spawning of the sea cucumber *Cucumaria frondosa* in the St. Lawrence estuary, eastern Canada. SPC Beche-de-mer Info. Bull. 7: 12-18.

Hamel, J.F., and A. Mercier. 1996a. Early development, settlement, growth, and spatial distribution of the sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea). Can. J. Fish. Aquat. Sci. 53: 253-271.

Hamel, J.F., and A. Mercier. 1996b. Gamete dispersion and fertilization success of the sea cucumber *Cucumaria frondosa*. SPC Beche-de-mer Info. Bull. 8: 34-40.

Hamel, J.F., and A. Mercier. 1996c. Studies on the reproductive biology of the Atlantic sea cucumber *Cucumaria frondosa*. SPC Beche-de-mer Info. Bull. 8: 22-33.

Hamel, J.F., and A. Mercier. 1997. Sea cucumbers: current fishery and prospects for aquaculture. Aquacult. Mag. 23: 42-53.

Hamel, J.F., and A. Mercier. 1998. Diet and feeding behaviour of the sea cucumber *Cucumaria frondosa* in the St. Lawrence estuary, eastern Canada. Can. J. Zool. 76: 1194-1198.

Logan, A. 1988. A sublittoral hard substrate epibenthic community below 30m in Head Harbour Passage, New Brunswick, Canada. Estuar. Coast. Shelf Sci. 18: 571-592.

Logan, A., A.A. MacKay, and J.P.A. Noble. 1983. Sublittoral hard substrates. In M.L.H. Thomas (Ed.). Marine and Coastal Systems of the Quoddy Region, New Brunswick. Can. Spec. Publ. Fish. Aquat. Sci. 64: 119-139.

Singh, R., B.A. MacDonald, M.L.H. Thomas, and P. Lawton. 1999. Patterns of seasonal and tidal feeding activity in the dendrochirote sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea) in the Bay of Fundy. Mar. Ecol. Prog. Ser. 187: 133-145.

Singh, R., B.A. MacDonald, P. Lawton, and M.L.H. Thomas. 2001. The reproductive biology of the dendrochirote sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea) using new quantitative methods. Inv. Rep. Dev. 40(2-3): 125-141.

Therkildsen, N.O., and C.W. Petersen. 2006. A review of the emerging fishery for the sea cucumber *Cucumaria frondosa*: biology, policy, and future prospects. SPC Beche-de-mer Info. Bull. 23: 16-25.

Trites, R.W., and C.J.R. Garrett. 1983. Physical oceanography of Quoddy Region. In M.L.H. Thomas (Ed.). Marine and Coastal Systems of the Quoddy Region, New Brunswick. Can. Spec. Publ. Fish. Aquat. Sci. 64: 9-34.

Vandermeulen, H. 2007. Drop and towed camera systems for ground-truthing high frequency sidescan in shallow waters. Can. Tech. Rep. Fish. Aquat. Sci. 2687.

Table 1. Sea cucumber landings (t) by year and fishing zone, as reported in dockside monitoring documents and stored in Zif (pre-2002) and Marfis (2002-present). TACs were implemented in 2006 and are included in parentheses.

	Zone						
Year	Magaguadavic River	The Passages	St. Andrews Harbour	South Deer Island	Upper Passamaquoddy Bay	Area Outside of Zones	Total
1999							
2000						651	651
2001		465				172	637
2002		725				72	797
2003		802				49	851
2004		1142				62	1204
2005	8	1410		40		200	1657
2006	35 (120)	926 (1010)		61 (120)	(120)	99	1122 (1370)
2007	(120)	1002 (1010)		29 (120)	(120)	36	1067 (1370)
2008	2 (120)	975 (1010)		32 (120)	(120)	65	1074 (1370)
Total	45	7636		163		1438	9281

Table 2. Sea cucumber landings (totes) by year and fishing zone, as reported in Sea Cucumber Science Logs.

	Zone						
Year	Magaguadavic River	The Passages	St. Andrews Harbour	South Deer Island	Upper Passamaquoddy Bay	Area Outside of Zones	Total
1999						66	66
2000		7562	150	2		148	7862
2001		8727		0		255	8982
2002		11495	0	0		1089	12584
2003		11689				400	12089
2004		15985		416		57	16458
2005	116	20315	733	764	609	783	23320
2006	529	14746		1068	70	6	16419
2007		12686		300		197	13183
2008	37	14683		918	0	154	15845*
Total	682	117888	883	3468	679	3155	126808

* 53 totes were reported as landed in SWNB during 2008, but without geographic coordinates.

Table 3. Sea cucumber landings (t) by year and fishing zone, as derived from Sea Cucumber Science Logs (reporting catch as number of totes and converted to landed weight based on 1 tote = 68 kg). TACs were implemented in 2006 and are included in parentheses.

Year	Zone						Total
	Magaguadavic River	The Passages	St. Andrews Harbour	South Deer Island	Upper Passamaquoddy Bay	Area Outside of Zones	
1999						4	4
2000		514	10	<1		10	535
2001		593				17	611
2002		782				74	856
2003		795				27	822
2004		1087		28		4	1119
2005	8	1381	50	52	41	53	1586
2006	36 (120)	1003 (1010)		73 (120)	5 (120)	<1	1116 (1370)
2007	(120)	863 (1010)		20 (120)	(120)	13	896 (1370)
2008	3 (120)	998 (1010)		62 (120)	(120)	10	1077* (1370)
Total	46	8016	60	236	46	215	8623

* 4 t were reported as landed in SWNB during 2008, but without geographic coordinates.

Table 4. CPUE (kg/hour) of sea cucumber in each SWNB fishing zone from 1999 to 2008 (111 records were removed due to insufficient information to calculate CPUE).

	Zone						
Year	Magaguadavic River	The Passages	St. Andrews Harbour	South Deer Island	Upper Passamaquoddy Bay	Area Outside of Zones	Total
1999						504	504
2000		3154	3400	816		1702	3106
2001		4268				8400	4307
2002		5001				3849	4877
2003		3780				3264	3760
2004		4275		2351		2802	4181
2005	4303	4858	6971	4048	8255	3111	4830
2006	2705	5268		2878	1576	271	4783
2007		4389		3517		3033	4335
2008	612	4769		2031		3481	4345
Total	2420	4434	5916	2717	5738	2786	4292

Table 5. Summary (mean ± standard deviation) of sea cucumber morphometric data from all fishing areas for 2004-2008.

	Trait							
Year	Length (mm)	Wet weight (g)	Circumference (mm)	Body wall thickness (mm)	Meat weight (g)	Body wall weight (g)	Viscera weight (g)	Number of animals
2004	163.6 ± 28.9	255.6 ± 92.2	126.0 ± 14.7	3.1 ± 0.8	22.9 ± 7.5			1040
2005	156.4 ± 36.5	235.6 ± 78.0	124.2 ± 20.6	2.9 ± 0.8	21.1 ± 7.6			1699
2006	169.5 ± 31.2	208.3 ± 71.4	125.0 ± 15.5	2.6 ± 0.7	18.6 ± 5.4	55.6 ± 16.9	41.1 ± 18.0	1420
2007	158.2 ± 30.8	236.2 ± 69.9	128.1 ± 15.7	1.9 ± 0.6	17.6 ± 4.8	53.0 ± 14.2		1140
2008	154.6 ± 37.7	225.2 ± 84.2	123.9 ± 24.3	1.8 ± 0.9	18.6 ± 7.0	52.3 ± 17.5	46.5 ± 21.2	1660

Table 6. Catch (kg) by species in observed sets during the 2008 SWNB sea cucumber fishery by fishing zone.

	Zone			
	Magaguadavic River	The Passages	Upper Passamaquoddy Bay	Total
Number of sets	5	273	2	280
Species				
Sea cucumber	408	115880	210	116498
Sea urchin	70	3740		3810
Seastar	5	1315	11	1331
Sea potato	5	1301	2	1308
Toad crab	5	273	2	280
Hermit crab	5	160	2	167
Sculpin		113		113
Rock crab		87		87
Winter flounder		3		3
Lobster		3		3

Table 7. Adjusted catch (t) by species during the 2008 SWNB sea cucumber fishery by fishing zone. Adjusted catch is the observed catch (Table 6) prorated to total landings for the 2008 season.

	Zone			
	Magaguadavic River	The Passages	Upper Passamaquoddy Bay	Total
Number of sets	5	273	2	280
Species				
Sea cucumber	2.2	975.0	0.2	1058.9
Sea urchin	0.4	31.5	0.0	34.5
Seastar	< 0.1	11.1	< 0.1	12.0
Sea potato	< 0.1	10.9	< 0.1	11.9
Toad crab	< 0.1	2.3	< 0.1	2.5
Hermit crab	< 0.1	1.3	< 0.1	1.5
Sculpin	0.0	1.0	0.0	1.0
Rock crab	0.0	0.7	0.0	0.8
Winter flounder	0.0	< 0.1	0.0	< 0.1
Lobster	0.0	< 0.1	0.0	< 0.1

Table 8. Percentage of observed sets in which observers detected various species during the 2008 SWNB sea cucumber fishery.

	Zone			
	Magaguadavic River	The Passages	Upper Passamaquoddy Bay	Total
Number of sets	5	273	2	280
Species				
Sea cucumber	80.0	100.0	100.0	99.6
Sea urchin	100.0	100.0	0.0	99.3
Seastar	100.0	100.0	100.0	100.0
Sea potato	100.0	100.0	100.0	100.0
Toad crab	100.0	100.0	100.0	100.0
Hermit crab	100.0	58.6	100.0	59.6
Sculpin	0.0	41.1	0.0	40.0
Rock crab	0.0	31.9	0.0	31.1
Winter flounder	0.0	1.1	0.0	1.1
Lobster	0.0	1.1	0.0	1.1

Table 9. Area of sea cucumber fishing zones in Passamaquoddy Bay, including intertidal areas but excluding overlapping land.

Zone	Area (km^2)
Magaguadavic River	5.93
The Passages	44.60
South Deer Island	8.78
Upper Passamaquoddy Bay	7.59

Table 10. Cumulative area swept by drags (km^2) in Passamaquoddy Bay, 1999-2008.

Year	Cumulative area swept (km^2)	
	Tow tracks trimmed to land only	Tow tracks trimmed to zones and land
1999	0.18	no data in zones
2000	1.95	1.73
2001	3.90	3.54
2002	9.10	4.77
2003	7.02	5.20
2004	5.57	5.40
2005	4.92	4.73
2006	4.37	3.78
2007	3.03	3.02
2008	4.65	4.41
Unknown	0.06	N/A
Total	44.76	36.60

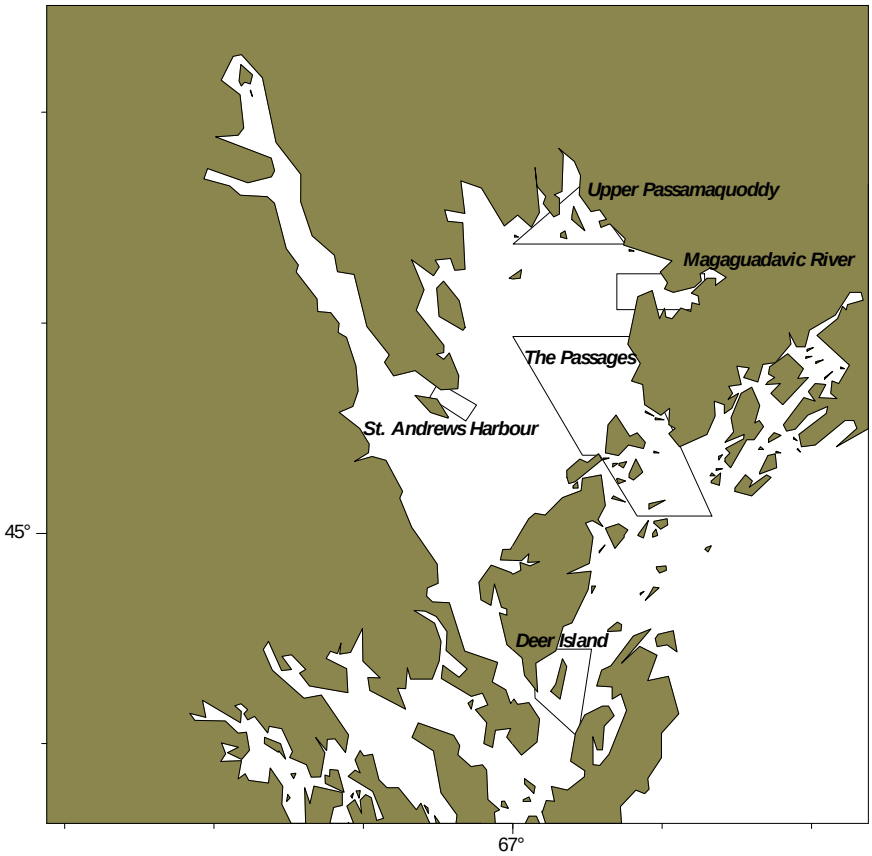

Figure 1. Inshore sea cucumber fishing zones implemented in 2006 in the Lobster Fishing Area (LFA) 36 portion of SWNB.

Figure 2. Example of sea cucumber fishing gear (Green Gear) used in SWNB.

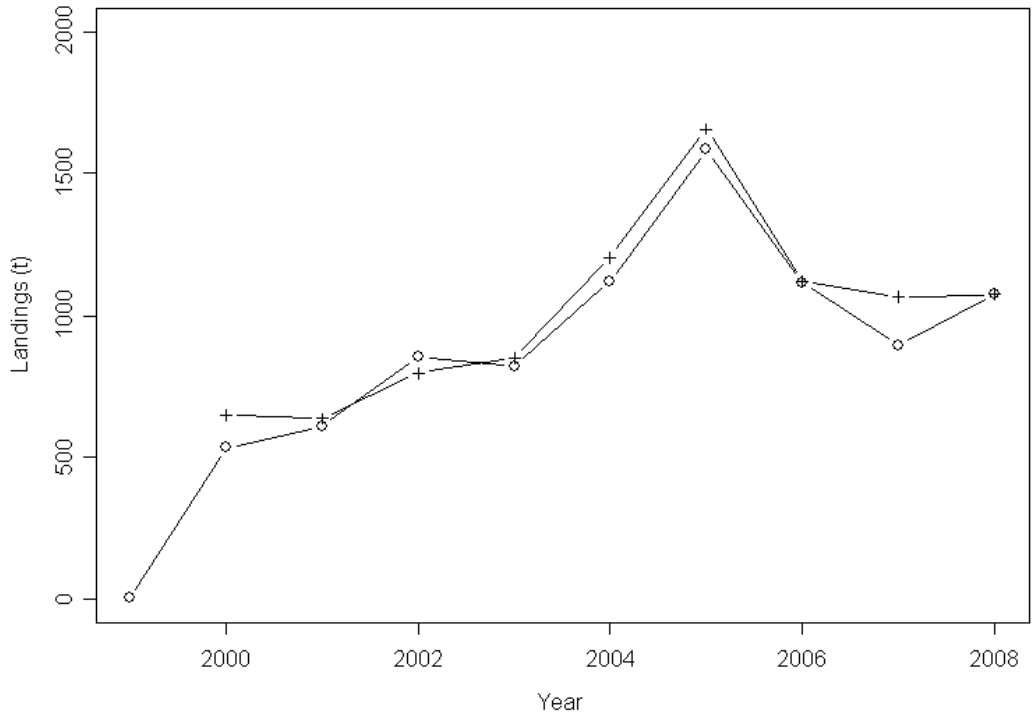

Figure 3. Sea cucumber landings (t) from the SWNB fishery. Landings data derived from dockside monitoring documents and stored in Zif (pre-2002) and Marfis (2002-present) are represented by crosses. Landings data derived from Sea Cucumber Science Logs (reporting catch as number of totes and converted to landed weight based on 1 tote = 68 kg) are represented by circles. A precautionary TAC of 1370 t per year was implemented for the 2006-2008 fishing seasons.

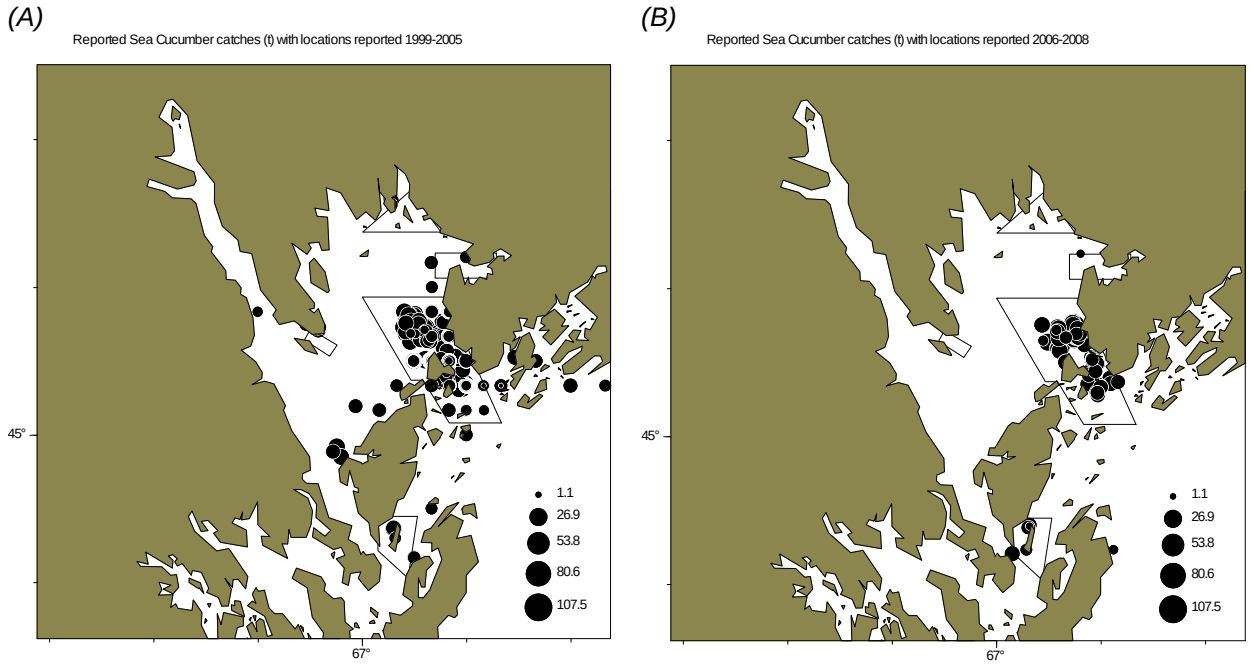

Figure 4. Distribution of catch in the SWNB sea cucumber fishery (A) 1999-2005, and (B) 2006-2008.

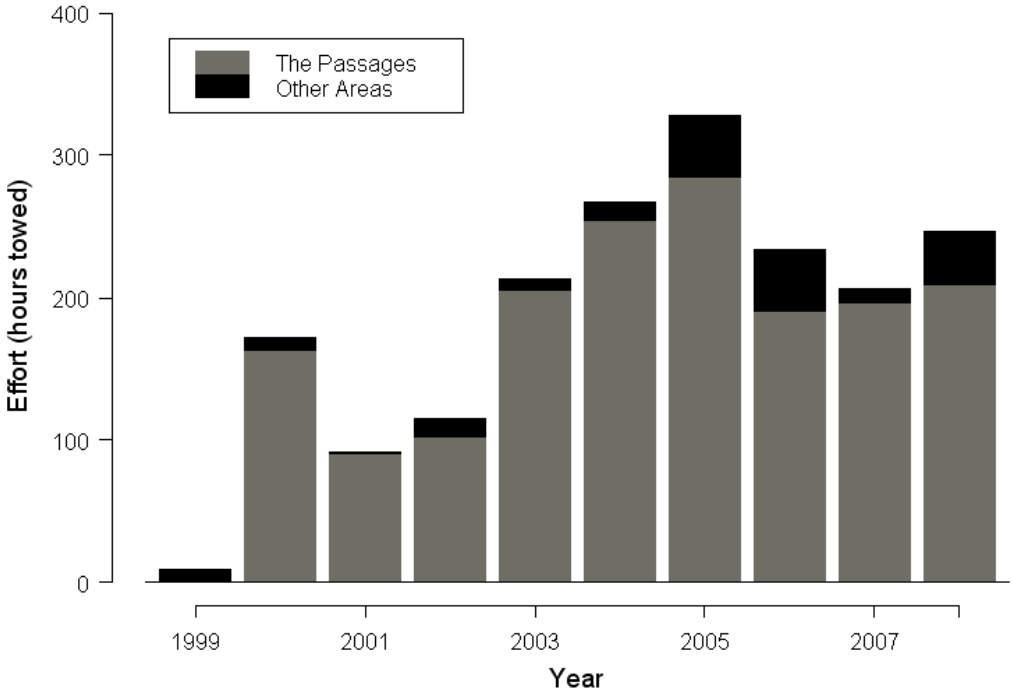

Figure 5. Effort directed towards sea cucumber in the SWNB fishery.

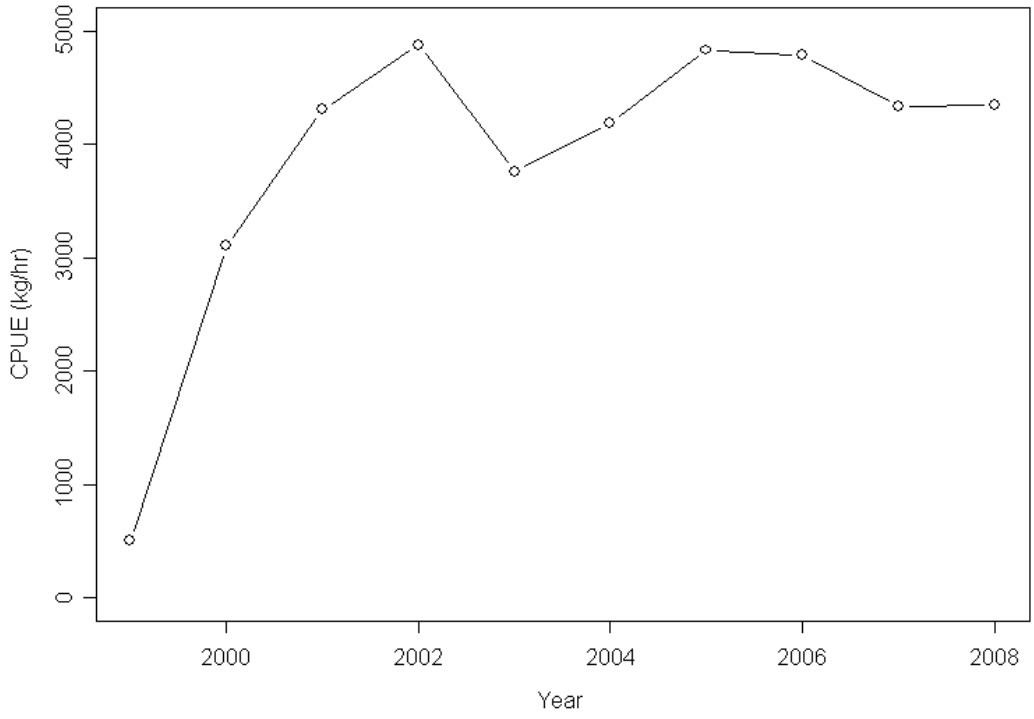

Figure 6. CPUE for sea cucumber in all fishing areas within the SWNB fishery.

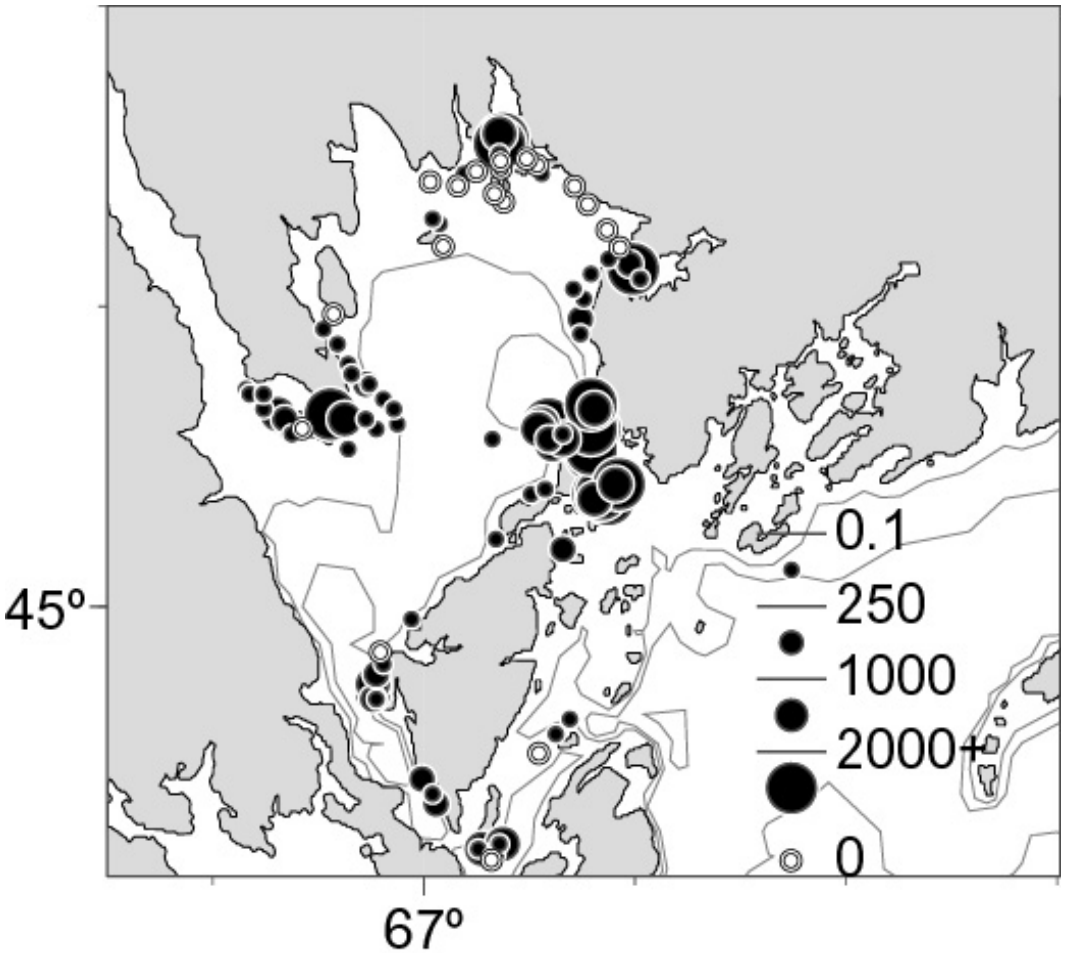

Figure 7. Number of sea cucumber caught per standard tow during July 2004 survey.

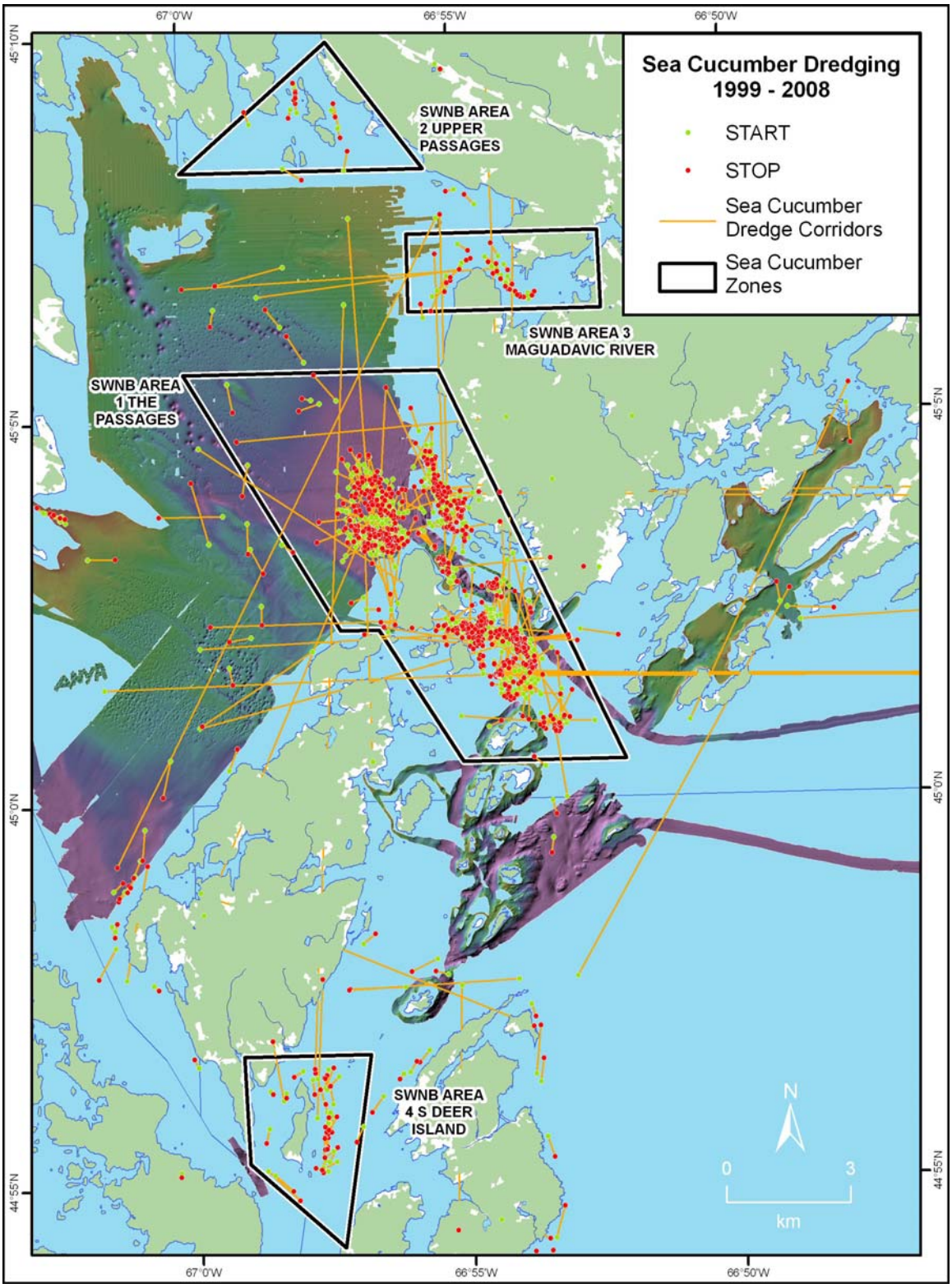

Figure 8. Start points, stop points, and tracklines for tows in all 4 SWNB sea cucumber fishing zones on multibeam bathymetry, 1999-2008.

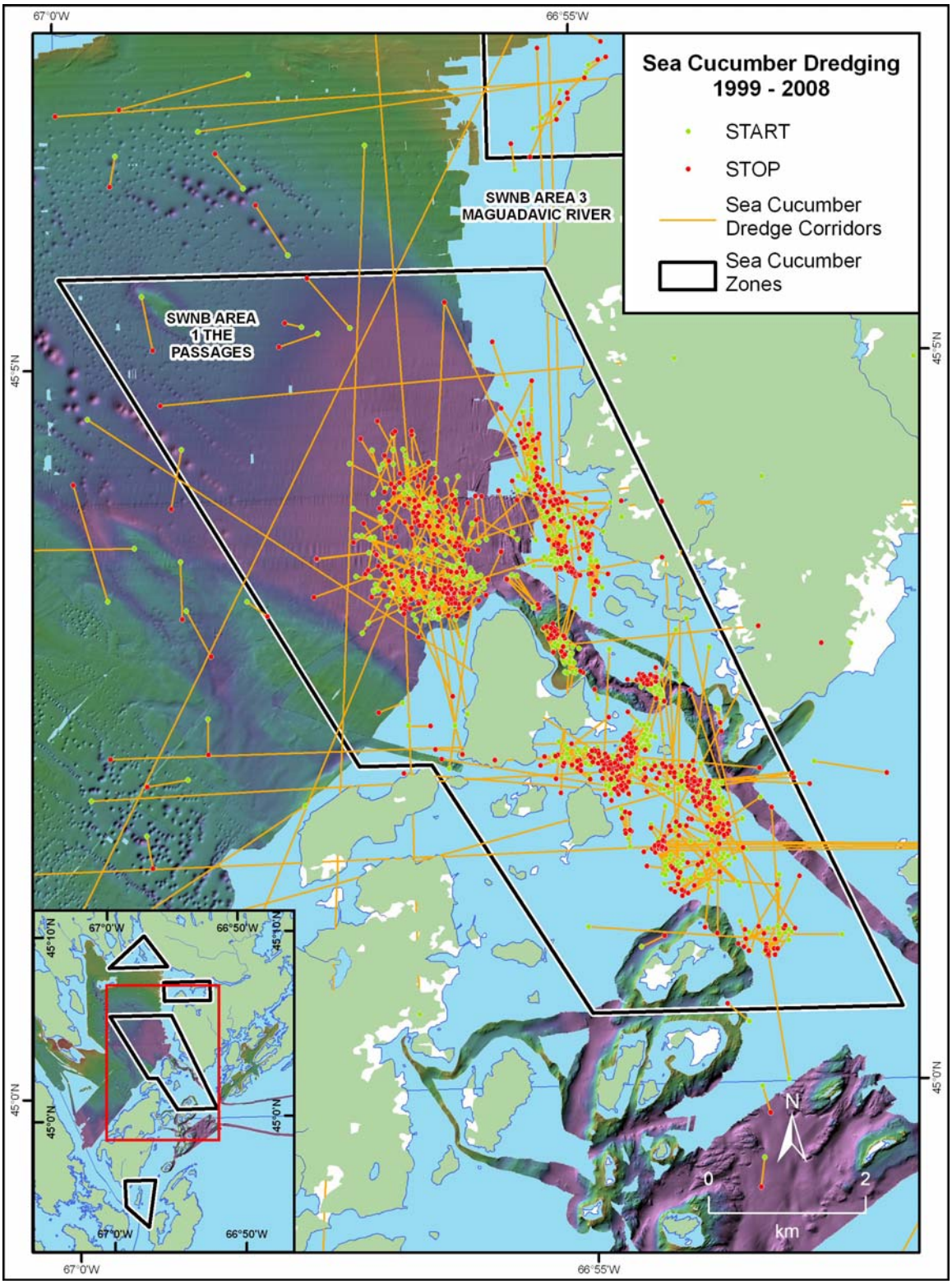

Figure 9. Start points, stop points, and tracklines for tows in The Passages on multibeam bathymetry, 1999-2008.

Figure 10. Video observations made along 8 transects, as part of a depletion experiment in St. Andrews Harbour in 2006 revealed that sea cucumbers were patchily distributed and seen as highly aggregated clusters, frequently associated with larger rocks or boulders on a gravel or sand/silt bottom. Clusters were of low (A), medium (B), and high (C) density. Drag marks from fishing activities were visible on sand/silt bottom areas, as indicated by scrape marks about 5-10 cm deep, where the drag removed sea urchins, sea cucumbers, and a lush periphyton layer on the surface of the sediment (D). The undisturbed periphyton layer is seen as a darker color in the background.

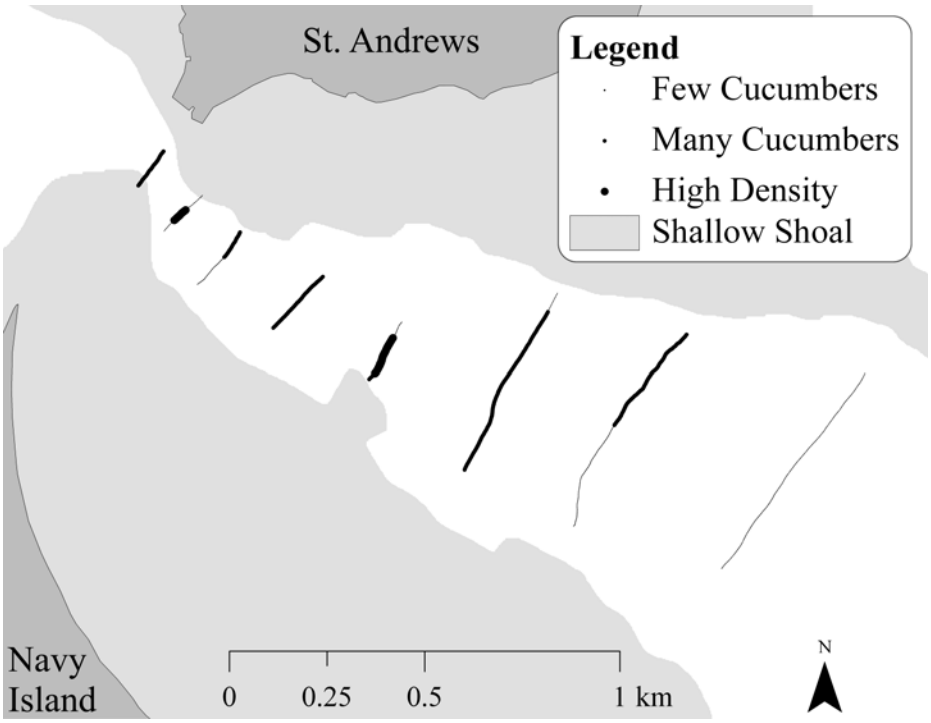

Figure 11. Sea cucumber density as revealed by video observations made along 8 transects, as part of a depletion experiment in St. Andrews Harbour in 2006.

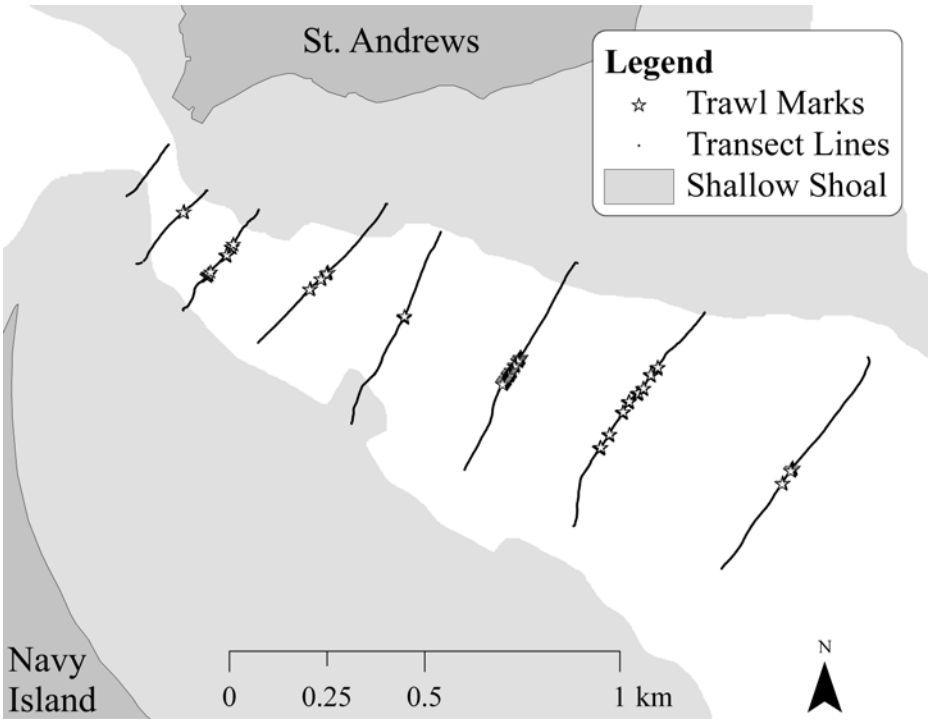

Figure 12. Location of drag marks from fishing activities as revealed by video observations made along 8 transects, as part of a depletion experiment in St. Andrews Harbour in 2006.