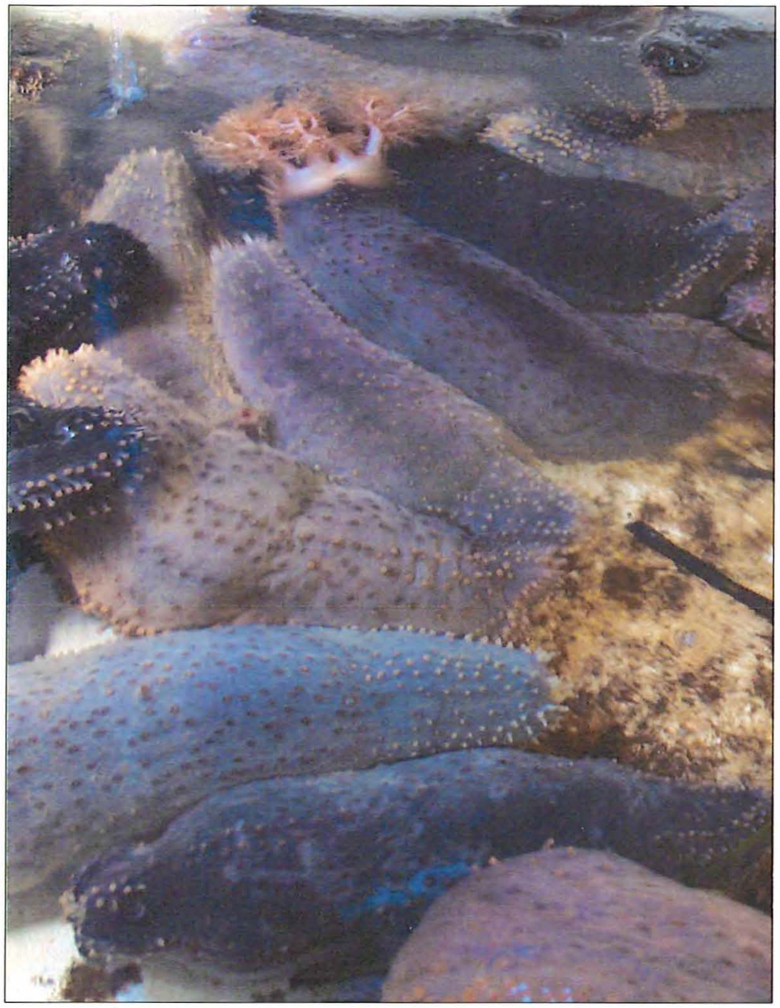

Status of the Maine Sea Cucumber (*Cucumaria frondosa*) Fishery

Submitted to: Standing Legislative Committee on Marine Resources

Submitted by: Department of Marine Resources

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SUMMARY

Background

Sea cucumbers were first harvested in Maine in 1988, but it was not until 1994 that the fishery began in earnest. Between 1997 and 2000, landings of sea cucumbers increased from less than 1 million pounds in 1997 to over 9 million pounds in 2000 as Asian markets opened. Concern over harvesting of sea cucumbers originated due to encounters with lobster gear. However, as the DMR examined the fishery, it became apparent that continued exploitation at that rate was likely unsustainable. The ecology of this species was poorly understood and little information had been collected on its distribution or biometrics that would allow for monitoring the fishery. This prompted the enactment of emergency regulations under the 1999 Sustainable Development of Emerging Fisheries Act (12 M.R.S. B 671-B) in March 2000 – limiting the fishing season, drag size, and number of endorsements issued for harvesting the species, and requiring submission of harvester logbooks.

Current status and research

The DMR collected and analyzed information for this fishery in 2001. The sea cucumber's body shape is variable and they cannot be aged. Seasonal fluctuations in body mass, skin thickness, and muscle weight, and variable amounts of water in live animals make meaningful measurements of body dimensions, biomass, mortality, growth, and age at sexual maturity difficult to obtain. Thus, part of the scientific work was to develop a size index (after Jordan, 1972) to allow for at-sea determination of size frequency. A series of dive and drag surveys in selected fished and historically fished areas provided information on habitat, by-catch, and population characteristics by area. A sea sampling trip and analysis of harvester logbooks provided current catch/effort information. Existing information was compiled from the scientific literature and interviews with stakeholders and fisherman. An industry meeting was held to gather input for management and research considerations. Information on by-catch, abundance, size frequencies by area, and current fishery statistics is presented here in support of management recommendations and comments on the long-term sustainability of the resource.

The fishery is currently market limited. Only one processor exists in the state compared to more than three in previous years, and only three boats are currently fishing, down from over fifteen in previous years. Statewide, the resource does not appear to be in danger. Landings as determined by harvester reports have decreased to 1994-1996 levels at approximately 2.6 million pounds in 2001. However, localized depletions are still a concern. Anecdotal reports of fished out areas (supported by some survey data), clumped distribution of current fishing effort, and the likelihood of continued demand from Asian markets call for a risk-averse approach and continued monitoring of this fishery. Due to the bulk nature of this fishery and dense aggregations sometimes formed, it is also important to monitor the stock so that high catch rates can be maintained if a boom and bust scenario is to be avoided. Further research is needed to develop a timeline of catch/effort data in this fishery and to better understand recruitment patterns, gear efficiency, and the impact of intensive harvesting on populations and associated communities.

Outlook and recommendations

The DMR recommends continuation of current regulations (for a period of at least 3 years) including logbook requirements and endorsement limitations, as they exist. While by-catch is not a great concern at present, the possibility of localized depletions and long recovery periods for this slow-growing species is.

Due to the bulk-scale/ low-value nature of the fishery and high harvest rates per boat, it is likely that this fishery will only support a small number of boats. Even with the current number of endorsement holders, landings could rise to past levels thought to be unsustainable if market conditions improved. Management plans for related species (e.g. the red sea cucumber in Washington State) indicate that some form of effort control is important. Logbook reporting requirements for monitoring purposes are also a key component to any management scenario.

Management by total harvest quotas would be problematic because of the patchy spatial component to this fishery and population. Setting regional harvest quotas would require extensive research and expensive landings verification for enforcement. Management by size regulations would hinder this marginally profitable fishery economically and would be opposed by the current industry. A legal standard for minimum sizes would also be difficult to work out for this shape-variable animal. Effort control through further gear limitations, such as a minimum twine top size, would provide only very broad selectivity and further research is needed to determine if this management option could be an effective conservation measure. With the current market situation, there is little need to invoke a more intensive management system at present. However, markets for this species are still maturing and global demand for sea cucumbers appears to be increasing. Renewal of the commissioner's authority to restrict the number of endorsements and continuation of reporting via harvester logbooks would provide a safeguard against the possibility of future uncontrolled harvest levels. Continuing research efforts by DMR and collaborating institutions (i.e.: College of the Atlantic, Coastside Bio-resources) should provide further information if management decisions need to be re-addressed in future years.

BACKGROUND

Biology

Cucumaria frondosa, also called orange-footed sea cucumbers or 'pickles' by fishermen, are the only commercially important sea cucumber among four other species found along Maine's shore. Along with sea urchins it is the only other echinoderm fished in the Gulf of Maine. This sea cucumber is distributed over a wide range (Box 1). It is a slow growing animal with few predators. Body shape is variable (Figure 1). When disturbed, the animal retracts its tentacles and contracts itself into a football shape (contracted state). When feeding, the animal is elongated into its 'active' state. When left out of water for some time, the animal expels water and flattens into a 'slump' state.

Box 1 – Biology Synopsis

Cucumaria frondosa; Phylum Echinodermata, Class Holothuroidea, Subclass Dendrochirotacea

Range: Wide distribution in North Atlantic and Arctic Ocean including the Norwegian, Barents and North Sea and in waters around Iceland. The southern range along the western Atlantic extends to Cape Cod and Nantucket. Population densities can reach to 5 individuals/ m^2 or 15 kg/ m^2. In some areas they comprise a large proportion (>50%) of the benthic biomass.

Depth: Intertidal to 300 meters (most commonly 30-60m). Juveniles in shallower areas.

Habitat: Found on many bottom types with some solid substrate (including loose gravel, shell debris, rocks, and even mud). Very fine silts are avoided and moderate current is preferred. Juveniles may be associated with shallow areas and kelp and mussel beds.

Feeding: Feeds passively on phytoplankton (especially diatoms) and organic detritus. Particles adhere to mucous coated set of 10 branched and retractable tentacles.

Body: Color ranges from dark brown, dark purple, black to grayish, yellowish, pink and albino (rare) with the dorsal side often lighter in color (Figure 2). Spicules found in body wall. Extremely flexible body.

Locomotion: Uses five rows of tube feet (more developed on the ventral side) or body contractions. Speeds to 0.5 m per minute.

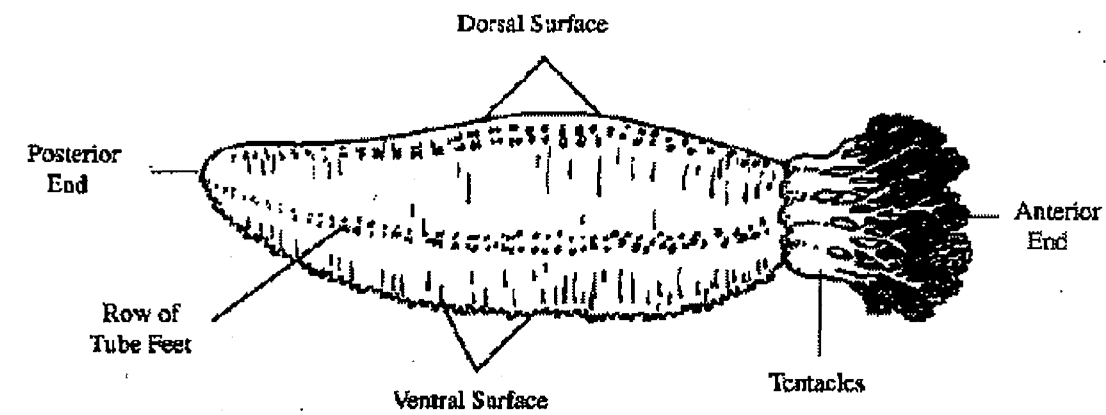
Physiology: Nutrients are distributed by a hemal system of vessels. Two large respiratory trees in body cavity extract oxygen from water circulated by cloacal muscles. Nerve ring near oral end. Animal retracts tentacles and contracts body when disturbed.

Growth: Slow growing. Grow to approximately 20 cm (active length - mouth to anus) or 500 g close to shore, and to 50 cm (1.5 - 2 kg) in deep offshore waters. In two years at a size of 3.5cm displays the full adult morphology. It takes an estimated 5.5 years to grow to 12 cm. Estimated life span is roughly 10 years. Unknown but presumed low natural mortality. Seasonal variations in growth are apparent.

Predators: Relatively few – especially for larger sized animals. Urchins and nereid worms may prey on small sea cucumbers, also starfish (*Asterias vulgaris* and *Solaster endeca*).

Reproduction: Broadcast spawners. Male and females are separate sexes (dioecious). Mature eggs are approximately 800 microns in diameter and large sea cucumbers may spawn approximately 9000 eggs. Spawning time varies with latitude. In Maine, spawning takes place sometime between Late March- early May (noted only at one location to date) to June in the Gulf of St. Lawrence. Animals exhibit modified direct development:

Time line:	0	72 hours	11 days	46 days	3-4 months
Egg	Zygote	Gastrula	Pentacula	Settlement	Juvenile



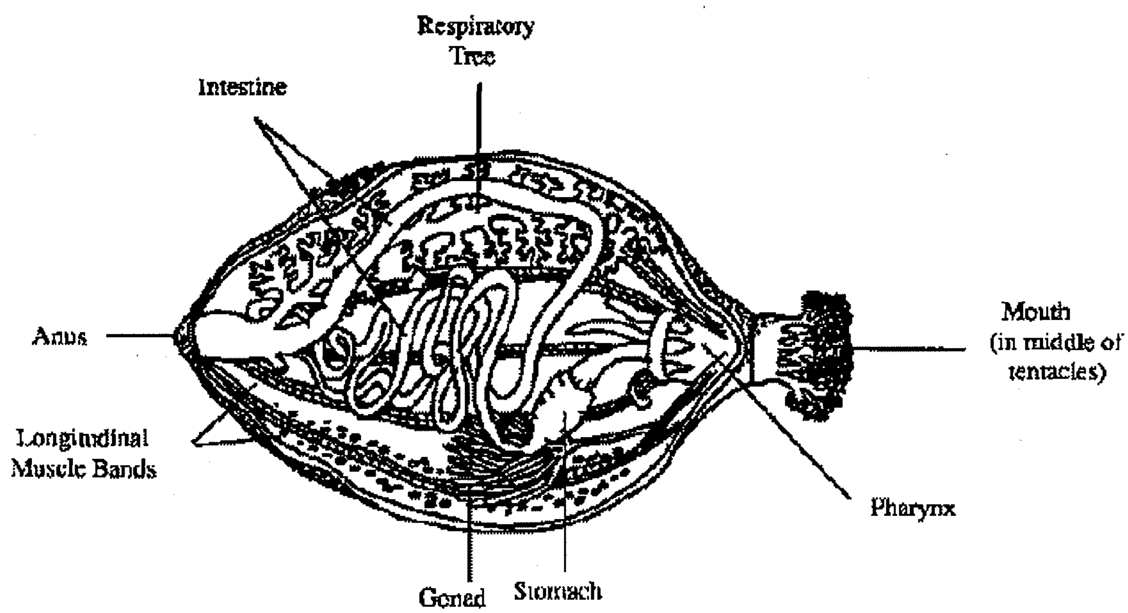


Figure 1. Body plan and anatomy of the sea cucumber, Cucumaria frondosa (from Chenoweth and McGowan, 1997).

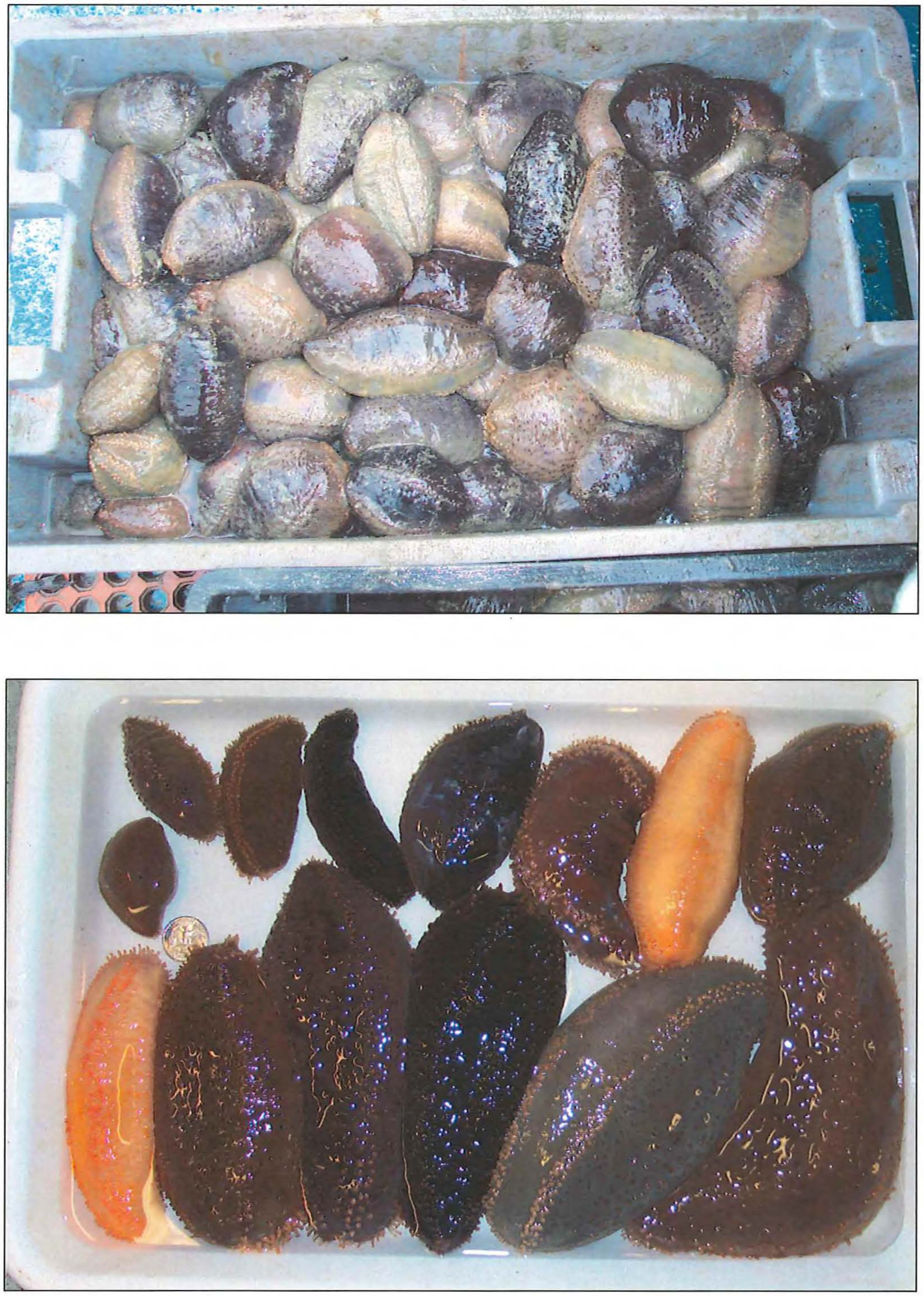


Figure 2. Sea cucumber shape/ color/ size variability.

Eggs are spawned in late March to May. The embryo develops into a blastula and 'hatches' out after 2-3 days. The larvae develop into planktonic, ciliated gastrula (called the vitellariae stage after the yolk reserves that the larvae feed on) and then further progress to the "pentacula" stage. After 43-48 days, these larvae slowly lose their cilia and sink to the bottom. Larvae 'explore' the substrate for a short time before permanently settling and growing into juveniles- essentially miniature adults. Little is known about their ecological role, but in some areas, sea cucumbers may be the dominant benthic organism.

History of the Fishery

The fishery in Maine began with one operation in Steuben in 1988, but started expanding in 1994 when Asian markets opened up (Chenoweth and McGowan, 1997). Boats ranged from 40-90 feet in length with the capacity to harvest between 70 and 200 totes of sea cucumbers per day. Either scallop chain sweeps or light urchin drags were used as gear. Activity was centered in Washington and Hancock Counties with catch landed in Winter Harbor, Jonesport and Beales Island and in Eastport. Three processors were active during this time, and product was also being trucked out of state for processing in Massachusetts and Seattle. There were also reports of other large operations interested in converting over to sea cucumbers. In 1995, the industry employed approximately 75-100 people in processing in addition to 15-20 fishermen harvesting. Between 1994-1996 recorded landings were between 1 and 3 million pounds. In 1999, reported landings were over 8 million pounds, and in 2000- over 9 million pounds (Figure 3).

In response to gear conflict issues between lobstermen and a growing number of sea cucumber draggers, the DMR met with concerned parties. On further evaluating this fishery there was great concern over a rapid depletion of the resource as interest in the industry peaked. This resulted in the enactment of regulations under the 1999 Sustainable Development of Emerging Fisheries Act (12 M.R.S. B 671-B) in March 2000– limiting the fishing season, drag size, and number of endorsements for this species and requiring the submission of harvester logbooks (Box 2).

Box 2 - Current Regulations

Drag configuration: Width limited to 5'6". Length limited to 22' from top of the head bail to the terminal end (figure 4). Head bail of drag must be constructed of less than 1.5" round steel stock.

Closed season: Season closed from July 1 to September 30, both days inclusive.

No night time harvesting

Endorsement required: Endorsement is non-transferable and the holder must be on board the harvesting vessel. Endorsements were granted to individuals who had landed and sold at least 250,000 lbs (round weight) of sea cucumbers between October 1, 1998 and September 30, 1999 and are renewable on request.

Reporting required: Reports to be submitted weekly including location (latitude, longitude), date fished, time at sea, catch (in # of totes or pounds), number of tows, port of landing, name of buyer and date of sale, price (as per tote or per pound), approximate depth fished, and length of tows in minutes. Inactivity reported as 'did not fish' on forms.

No incidental take of sea cucumbers

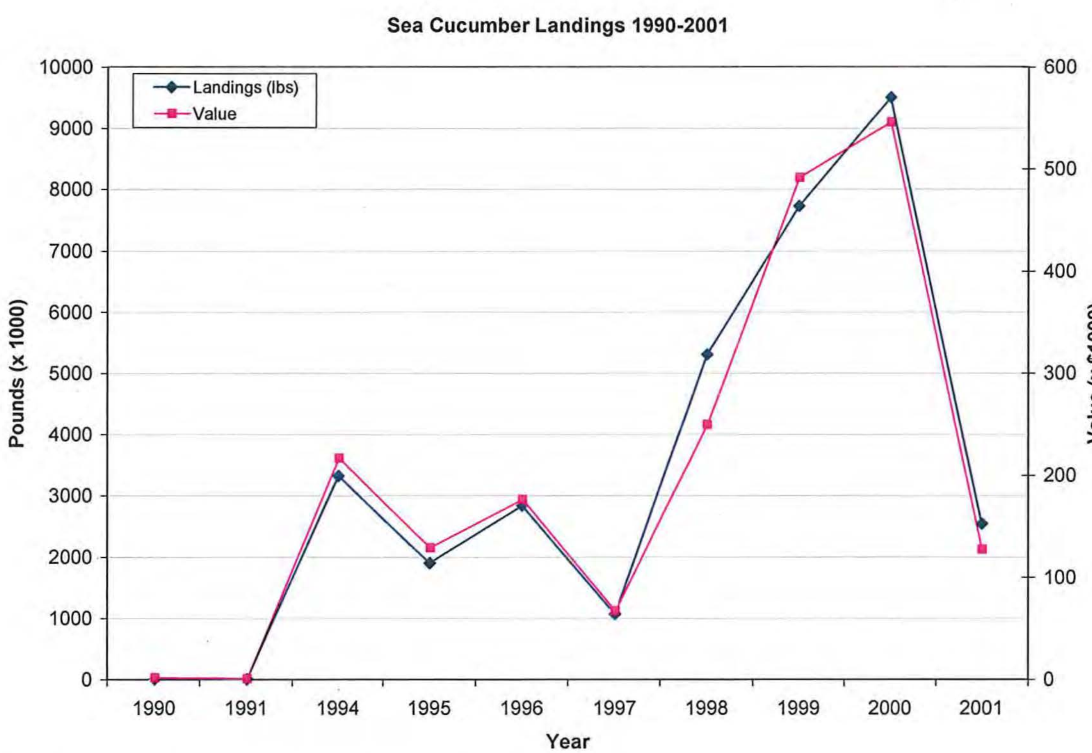


Figure 3. Maine Sea Cucumber Landings and Value.

Figure 4. Modified urchin drag used for harvesting sea cucumbers (left). A typical day's catch – 134 totes stacked 3 high on deck and weighing over 20,000 lbs (below).

Market

The sea cucumber is a low value - bulk fishery. The price paid to fishermen is currently $7 per tote (less than $0.05 per pound). Thus, large catches per boat are required for the fishery to be economically viable. Likewise processors need a minimum amount per day of operation to remain viable. Other species of sea cucumber are more valuable. For example, the red sea cucumber (*Parastichopus californicus* - indigenous to waters off of Washington, Alaska, British Columbia, and California) is worth $0.50 or more per pound.

Products derived from the sea cucumber include the internal muscle bands stretching along the length of the body (frozen) and the dried body wall, which is reconstituted and used in soups and stews. This latter product is known as Trepang in the Indo-Pacific or more common - *Beche-de-mer*. This is translated as "spade of the sea" and refers to the deposit feeding or 'sediment shoveling' behavior of some of the more traditionally harvested sea cucumber species. Major consuming countries include: China, Hong Kong, South Korea, Singapore, Taiwan and Japan. Yield from the sea cucumber is roughly 10-15 % of the drained whole weight (3-4% muscle mass; 10% body wall). The current price received for meats is $3.50/lb although it has been close to $5.00/lb in the past (Ray, personal communication). Out of this $3.50, processor workers may receive $1.00 and fishermen approximately $1-1.25, assuming a 5% yield from the raw product, leaving a gross profit of about $1.25 per pound of processed meats.

In order to process sea cucumbers: the end containing the tentacles is removed, the body is slit lengthwise, the viscera is removed, and the muscles scraped off the body wall. Muscles are packaged and frozen in plastic bags and the body wall is put through a drying process and packed in large burlap bags.

The by-product from processing is also used by a Stonington-based company as a nutritional supplement providing chondroitin - which purportedly aids in cartilage building. It is sold as a treatment for arthritis and is marketed for both humans and pets. By-product may also be marketed as compost. Protein is the major constituent of sea cucumbers and there has been some interest in the use of by-product in animal feeds.

Global context

Conand and Byrne (1993) reviewed world sea cucumber fisheries. Less than 15 of the over 1000 existing species are harvested commercially. In much of the world these are small-scale fisheries- some operating for nearly a thousand years. In more modern times these fisheries have often been poorly managed. Tropical sea cucumber fisheries are multi-species as compared to the more recent fisheries that occur in temperate water. Table 1, compiled from FAO statistics, shows the rapid rise in landings of the Northwest Atlantic (mainly Maine landings) over the last ten years. Production in our area was second only to island nations in the western central Pacific considered as a group. However, in monetary terms Maine is still a small player in global *beche-de-mer* production. The total global value of sea cucumber fisheries worldwide in 1994 was over 60 million dollars. The peak value of the Maine fishery was less than 1% of this figure (approximately $575,000 in 2000). Table 1 also shows that total global landings decreased between 1991 and 1999. This combined with recent interest in farming some sea cucumber species (Ahlgren, 1988) points to general growing demand and declining supply. China in particular has recently sought out lower valued product to satisfy its demands (Conand and Byrne, 1993). Although markets for Maine's product are still maturing, expansion in the future may be likely.

> "...anything found in the waters of the USA with a potential Asian market will quickly find people to fish it commercially, and the sea cucumber is no exception" – Seafood International 1997.

Management in other sea cucumber fisheries

Washington State was the first place in the U.S. where sea cucumbers were harvested through what began as a small dive fishery for the red sea cucumber (*Parastichopus californicus*) in 1970. This fishery was further pursued in California, British Columbia, and Alaska. Documents from these states/ provinces reveal how each have wrestled with an expanding fishery that was data-limited. Although a different, and more valuable species, the end product is similar to Maine's (frozen longitudinal muscles and dried body wall). In Washington state logbooks for periodic assessment purposes were the only management initiative until 1987. After signs of declining stocks, separate harvest areas were designated. A system of rotational harvest and a 6 month season was instigated which allowed each area to go unfished for 3.5 years in order for the animals to spawn at least once before being harvested. In 1990, entry was limited, although in 2000- there were still over 190 divers participating in the fishery. This was deemed by some to be the most important conservation effort (Conand and Byrne, 1993). Harvest areas now have specific respective quotas with landings reported daily to ensure that the quota is not exceeded. Other regions have followed suit. In Alaska, quotas are set based on very conservative numbers from real surveys. British Columbia manages with individual quotas (IQs), which are based on a conservative estimate of biomass using data from Alaska and Washington. They also initiated rotational management between 1993 and 1996 and restricted the fishery to 25% of the total coast (in non-contiguous areas) to guard against management mistakes. In the last ten years a number of assessments (Bradbury et al., 1996; Woodby et al., 1993; Zhou and Shirley, 1996; Phillips and Boutillier 1998, Campagna and Hand 1999, Cripps and Campbell, 2000) and research initiatives have made a more intensive management scenario possible for the red sea cucumber. This has also been made possible by the higher value of this species compared to *C. frondosa*. Although difficult to compare strictly, since Maine's is a drag fishery while the eastern Pacific fishery is limited for the most part to divers, Maine's landings have far surpassed those of western states in recent years, although its value is still lower. In 2000, 605,755 pounds of sea cucumbers were harvested in the state of Washington at a value of over $836,000. In Maine, for 2000, over 9.5 million pounds of *C. frondosa* were landed with a value of only $545,000.

Although recent information published on *C. frondosa* has added greatly to what was previously a poor information base for Maine's species, the east coast of the US and Canada is still coming to terms with this emerging fishery. In Newfoundland, sea cucumbers are occasionally harvested as scallop by-catch. There is also an inshore divers' license for the species that is limited to 12 divers and 24,000 lbs daily year round. Boats are allowed to target the species although there are few, and only part-time, buyers at present. The government of Newfoundland and Labrador has conducted some projects to determine the economic feasibility of expanding the fishery. They have also conducted some basic surveying to determine catch rates in a few areas (report pending; Brian Johnson, personal communication). However, even before development of the fishery they have license caps and effort limitations in place, as well as a performance clause preventing people from sitting on their license. A project done in Iceland where *C. frondosa* also resides in harvestable quantities concluded that the species was not valuable enough at this time to warrant a targeted fishery (Signy Sig, personal communication).

CURRENT STATUS AND RESEARCH

Landings and endorsements

Landings, as determined by harvester reports, have dropped from a high of 9.5 million pounds in 2000 to 2.6 million pounds (Figure 3). Monthly landings for 1999-2001 (Figure 5) show the effect of the closed summer season (July 1 to Sept 31) introduced in 2000. Landings were fairly steady month to month in 2000 and 2001. Landings were slightly less in October and November (fishing spots are occasionally limited in October until lobster traps are moved offshore for winter). Lower landings in January and February may be due to poorer weather during these months. Currently, there is only a single processor left in the state (Cherry Point Products owned by Lawrence Ray) employing migrant workers to process the catch. Two to three boats were fishing at any one time during the 2001 season. These boats use light urchin drags (with a mesh size of 3") over heavier scallop chain sweeps. There are 16 endorsement holders. Each endorsement holder was contacted during 2001 and 2 of them indicated that they will probably let their endorsement lapse. Others hope that the market opens up and they will have the opportunity to pursue the fishery again.

Logbook analysis

Logbook data (Table 2) shows an average catch per tow of 7.6 ± 3.5 (standard deviation) totes or 1139 ± 525 pounds per tow -assuming an average tote weight of 150 lbs. This is consistent with anecdotal reports of catches from interviews with fishermen. Mean depth fished was 48 ± 9.8 feet and time at sea 7.6 ± 1.6 hours. Catch per boat per day was just over 100 totes (15,900 pounds) with harvesters reporting an average of 16 (± 5) tows per day. There were 171 boat-fishing days in the 2001 season. Fishing locations reported in logbooks showed a relatively clumped distribution with substantial harvests coming out of a few select areas (figure 6). Major areas fished were in Frenchman Bay (Skillings River and around Bar and Cross Island adjacent to Bar Harbor) and near Dyer's Island. Additionally there were several scattered sites fished infrequently. No trends were evident in catch per unit effort. There was no apparent decrease in catch per tow relative to the number of days a particular area was fished. A longer time series of

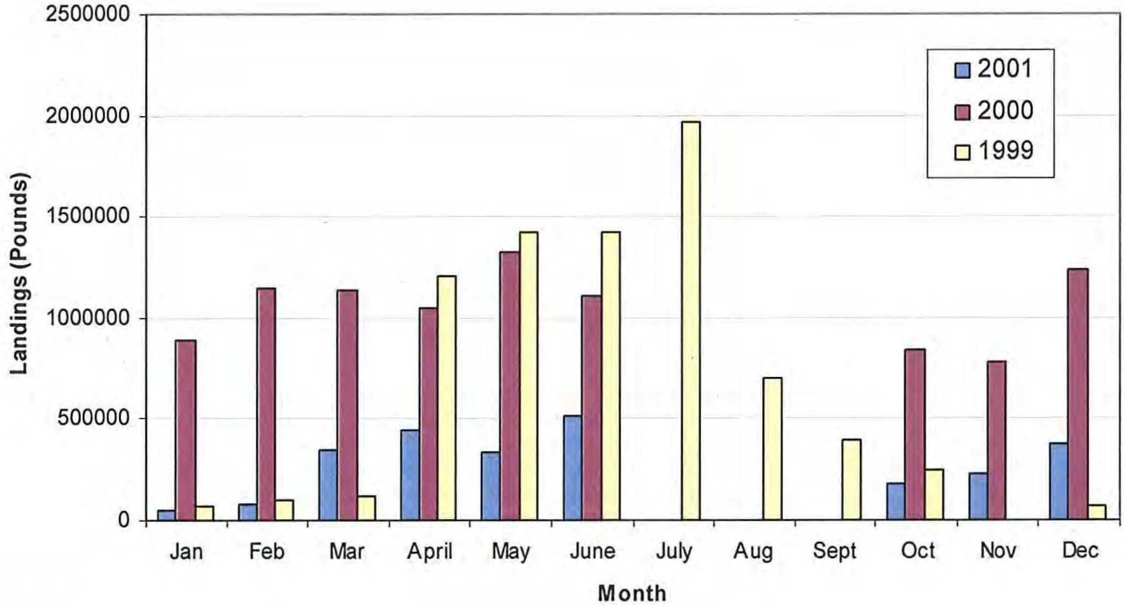


Figure 5. 1999-2001 Maine Sea Cucumber landings by month.

Table 1. Landings (metric tons) for sea cucumbers (all species) and rank score by country's landings for 1991, 1994, and 1999.

Country	Region	Landings			Rank		
		1999	1994	1991	1999	1994	1991
United States of America	Atlantic, Northwest	3504	1505	0.4	1	5	18
Indonesia	Pacific, Western Central	3120	2945	2383	2	1	3
Fiji Islands	Pacific, Western Central	880	400	589	3	10	7
Philippines	Pacific, Western Central	849	1497	3535	4	6	2
Solomon Islands	Pacific, Western Central	700	700	622	5	8	5
Papua New Guinea	Pacific, Western Central	600	2000	5000	6	2	1
Madagascar	Indian Ocean, Western	500	1800	600	7	3	6
New Caledonia	Pacific, Western Central	493	798	1240	8	7	4
Tanzania, United Rep. of	Indian Ocean, Western	280	1591	426	9	4	8
United States of America	Pacific, Northeast	228	636	-	10	9	
Sri Lanka	Indian Ocean, Eastern	155	92	65	11	11	13
Chile	Pacific, Southeast	108	4	-	12	19	
Indonesia	Indian Ocean, Eastern	90	85	82	13	12	11
Kiribati	Pacific, Western Central	89	-	-	14		
Maldives	Indian Ocean, Western	54	66	405	15	13	9
Vanuatu	Pacific, Western Central	50	40	50	16	16	14
Ecuador	Pacific, Southeast	15	12	29	17	17	15
Kenya	Indian Ocean, Western	15	41	78	17	15	12
Palau	Pacific, Western Central	7	6	5	19	18	16
Mozambique	Indian Ocean, Western	3	<0.5	5	20		16
Spain	Mediterranean and Black Sea	1	-	0	21		19
Yemen	Indian Ocean, Western	1	63	140	21	14	10
Tonga	Pacific, Eastern Central	<0.5		0			19
Iceland	Atlantic, Northeast	-	-	-			
Total		**11742**	**14281**	**15254.4**			

logbook reports will be important in determining the distribution of effort and shifts in areas fished. Currently, areas seem to be determined mainly by proximity to the only processor.

Sea sampling

To complement logbook data and gather information on current fishing practices, sea samplers were sent onboard one commercial boat out of Southwest Harbor targeting sea cucumbers in Somes Sound. Data from this trip corresponded to logbook data (Table 2). Mean catch rate was 5.4 totes per tow- slightly lower than the average rate reported in logbooks, with more tows per day. Tow duration was 10 minutes and speed 1.9-2.4 knots. Tow distance, measured by WAAS enabled GPS, averaged 0.44nm or 820 meters. The vessel stayed within a defined tow area of roughly 100,000 m^2. These numbers indicate a sea cucumber density of well over 1 animal/m^2. This is the density calculated if the drag were 100% efficient. Drag efficiency is more likely on the order of 10-25%, although this would vary by bottom type and has yet to be determined. Thus, actual sea cucumber abundance in this area was likely on the order of 5/ m^2 or higher. Abundances as high as 7/ m^2 were seen on diver surveys in some areas (Table 3). By-catch in this area was extremely low (Table 4; Figure 7a). Past trips observed by DMR employees have also observed low levels of by-catch, well under 5% (Chris Finlayson, unpublished data). Size frequencies were calculated as size index (Box 3; Figure 8) and averaged 310 – slightly smaller in comparison to other areas (Table 5). The captain of the boat indicated that these animals were too small to deal with a year or two prior. This may indicate sporadic recruitment in certain areas. Some scarring was evident on a small percentage of animals sampled - possibly indicating past interactions with gear. A small percentage of cucumbers coming up in the drag show damage that is likely lethal – but samples transported back to lab proved to be fairly tolerant of gear interaction.

Box 3
The size index is determined by multiplying the greatest diameter x diameter at right angles to this dimension x the length of the animal in it's contracted (disturbed) form (Jordan, 1972). This number is an estimation of animal volume and can be related back to wet or drained weight (figure 9a and 9b). The index allows for rapid at sea determination of size distributions.

Interviews and industry meeting

Informal interviews were conducted with several fishermen, the processor currently in operation (Drucilla and Lawrence Ray, Cherry Point Products), and Pete Collin owner of Coastside Bio-resources (manufacturer of sea cucumber nutriceuticals) in Stonington Maine. This information, added to that collected in the mid 1990s by Ted Creaser (formerly of DMR) provided a record of past fishing locations (Figure 6). Some of the boats fishing maintained that they were able to fish the same location for much of the season and catches remained consistent. This is at odds with other anecdotal evidence of several areas that have been "cleaned out" in the past (e.g.: the area between Black and Swans Island, Harrington River, and Sullivan Harbor).

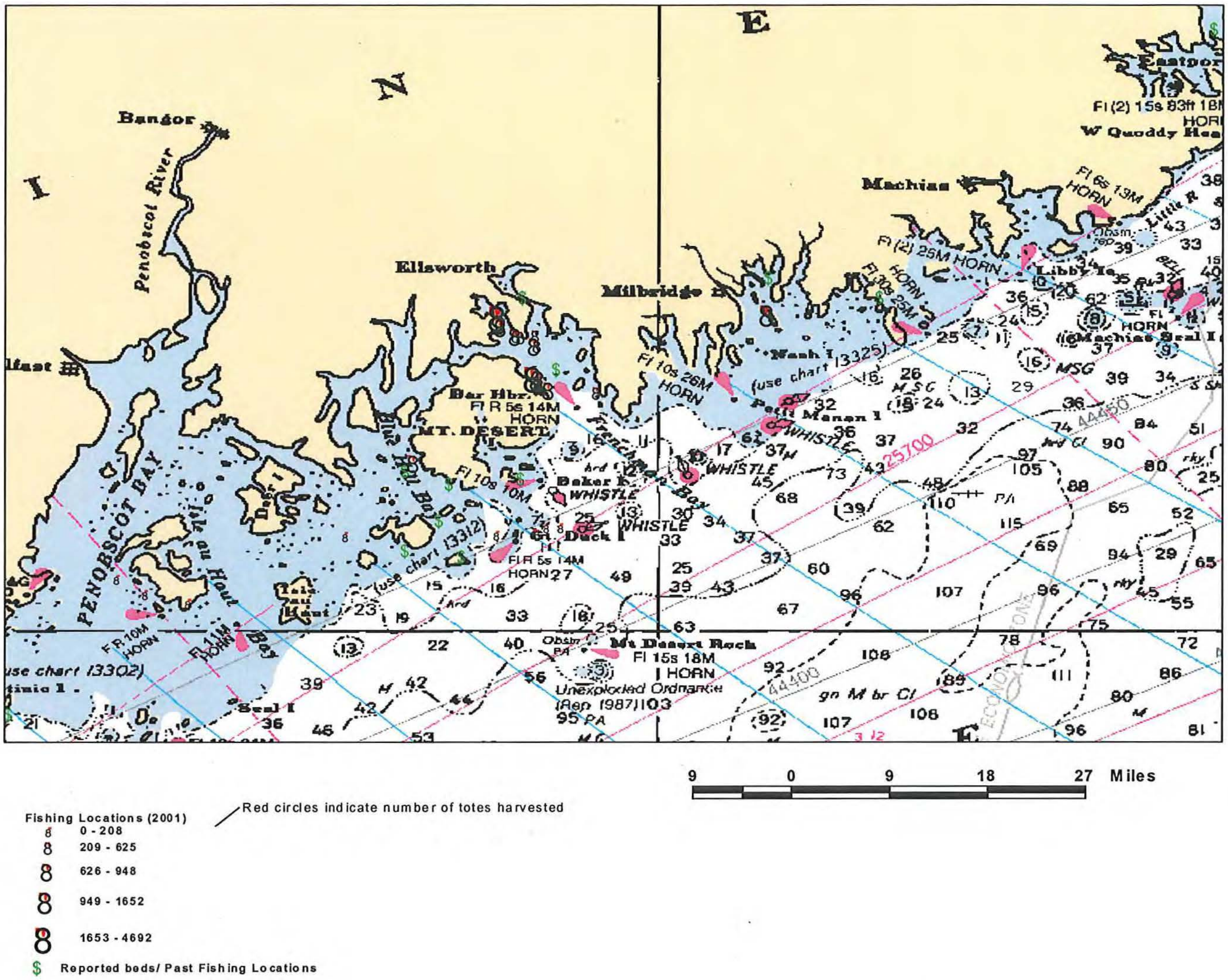


Figure 6. Fishing locations for 2001 (logbook data) and past reported fishing locations/ abundances.

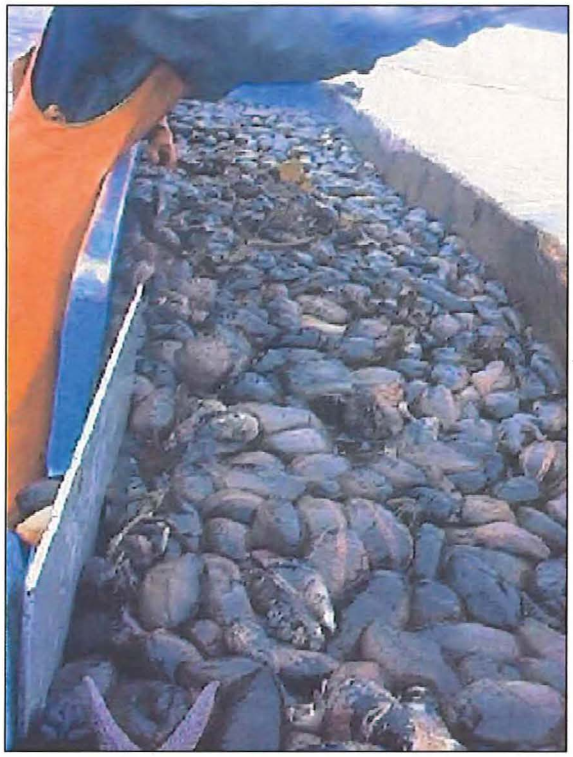


Figure 7. Photograph of typical tow from sea sample trip (a. above) and survey tow at a historically fished area (b. – below) showing low and higher amounts of by-catch respectively.

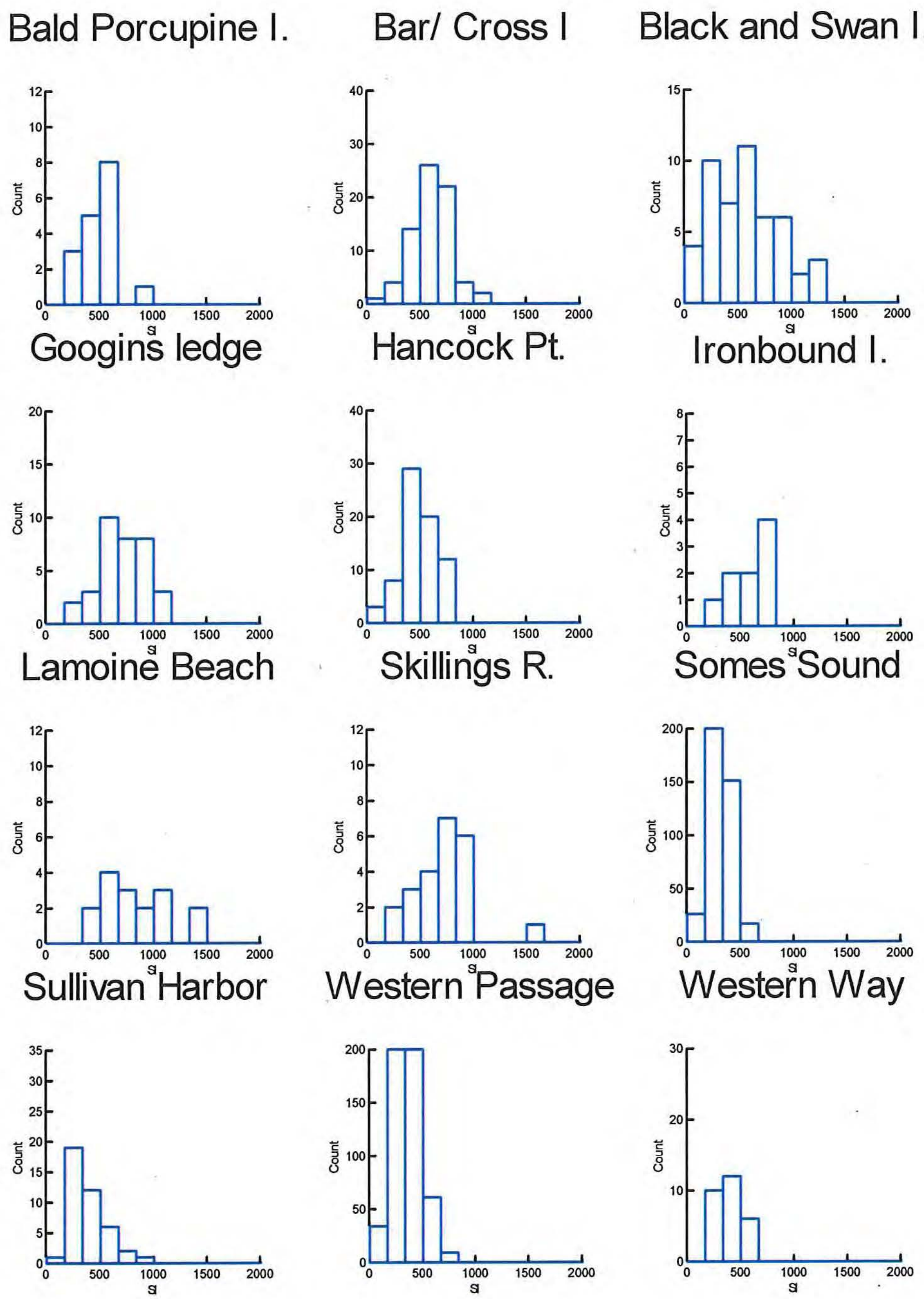


Figure 8. Size-index frequency distributions of survey sites.

Table 2. Summary statistics for logbook and sea sampling data.

	Sea sample data				Log book data			
	Mean (±SD)				*Mean (±SD)*			
Time at sea	6.5	*hours*			7.3 *(±1.6)*	*hours*		
Ave depth	30-80	*ft*			48 *(±9.8)*	*ft*		
Tows per fishing day	25	*tows*			15.8 *(±5.7)*	*tows*		
Catch per tow	5.4 *(±1.3)*	*totes*	810(±195)	*lbs*	7.6 *(±3.5)*	*totes*	1139(±525)	*lbs*
Catch per day	134	*totes*	20175	*lbs*	106 *(±25)*	*totes*	15900(±3750)	*lbs*
Catch per time at sea	20.6	*totes/hr*	3090	*lbs/hr*	14.7 *(3.6)*	*totes/hr*	2205(±540)	*lbs/hr*
Price	$7	*per tote*			$7	*per tote*		
Value per day	$938				$742 *(±$175)*			
Value/ Time at Sea	$144	*dollars/hr*			$103 *(±$25)*	*dollars/hr*		
Total boat days for 2001					171			
Total days in season					273			
# boats fishing					3			
# endorsements					16			
Drag width	5.5	*feet*						
Tow distance	0.44	*nm*	820	*m*				
Tow speed	2.2	*kn*						
Tow duration	10	*minutes*						
Tow area size	100000	*m^2*						
Area swept	33528	*m^2*						
Biomass density*	0.5153	*pounds/m^2*						
Sea cucumber density*	1.0 *(±0.2)*	*# animals/m^2*						

* assuming drag efficiency of 100%

Table 3. Calculated real abundance of sea cucumbers at dive survey sites.

Area	Transect	Abundance (#/m^2)	Depth (ft)	Ind wet weight* Mean (g) ± SD	Ind. Size index* Mean (cm^3) ± SD	Sample size* n
Lamoine Beach	1	no count	75	446 ±*154*	838 ±*306*	20
Lamoine Beach	2	0.03	55			
Lamoine Beach	3	0.77	35			
Lamoine Beach	4	0.05	35			
Mean		**0.28**				
SD		**0.42**				
Skillings River	1	1.82		373 ±*137*	702 ±*288*	25
Skillings River	2	0.16	25-10			
Skillings River	3	5.79				
Mean		**2.59**				
SD		**2.89**				
Sullivan Harbor	1	1.52	40-35	229 ±*82*	391 ±*161*	45
Sullivan Harbor	2	0.62	40			
Sullivan Harbor	3	7.45	52			
Sullivan Harbor	4	0.01	40-45			
Mean		**2.40**				
SD		**3.42**				

** Transect samples combined*

Table 4. Summary of By-catch Data for Survey and Sea Sample Locations

	Scallops	Urchins	Lobster	Mussels	Winter Flounder	Windowpane flounder	Monkfish	Starfish	Crab	Sand dollar	Whelk	Scarlet psolus	Anenome	Sponge	Sea Grape	Skate	Sculpin	Sea Robin	Devil's Apron	Kelp	Mussel shell	Sand	Mud	Gravel	Rock	Other	
Frenchman Bay	Usable							Discard											Trash			Bottom Characteristics					Comments
Bald Porcupine I.	2	3		2																							
Cross Island				2				2		2									3		3	x		x			
Hancock Pt.	2		2					2	2												3				x		
Googins ledge	3		2						3			3		3									x		x		
Off Sullivan Harbor																							x		x		
Ironbound Island	1							4	2			2	2						3					x	x		
Black and Swan	2		2	4				4	3					2					2					x	x		
Western Way	2	4	2	4				3	2										4			x		x	x		
Western Passage																											
A	3	4		2	2			2	2		1			2		1	1			2	3			x	x		high current (all)
B	2	5		2	3	1		2	2		1			2		1	1			2	3			x	x		
C	2	5		2	4	1	1	2	2		1			2		3				2	3			x	x		
D	2	4		2	2			2	2		1			2		1	1			2	3			x	x		
E	1	4		2	1			2	2		1			5				1		2	3			x	x		
F	1	4		2	2			2	2		3			4	4					2	3			x	x		
G	1	4		2				2	2		2			2	4					2	3			x	x		
H	1	2		2				2	2		2			2	4					2	3			x	x		
Somes Sound	1		1	1	1				2									1						x	x		
Dive Surveys																											
Lamoine Beach A	2		1					2															x		x		
Lamoine Beach B	2		1					2															x		x		
Lamoine Beach C	2		1					2														x		x	x		
Lamoine Beach D	2		1					2															x		x		
Skillings A	2	3						2	2											3	3			x	x		high current
Skillings B	2	3						3	2											2	2			x	x		periwinkles
Skillings C	2	3						2	2											3	3			x	x		high current
Sullivan Harbor A									2													x		x	x		
Sullivan Harbor B									2													x		x	x		
Sullivan Harbor C	2		1						2														x		x		
Sullivan Harbor D																							x				

1= rare; 2= occasional; 3= common; 4 = abundant; 5= very abundant

These areas will need to be surveyed more extensively to determine if the sea cucumber resource returns there. Survey work conducted this year will provide some basis for future monitoring efforts to gauge the impact of sea cucumber exploitation on these communities. Both anecdotal and survey results also point to variability in by-catch by site. Catch rates are said to have been 2-7 totes per tow in areas near Eastport (Western Passage) when that area was being harvested. Catch in the Frenchman Bay area was said to have been between 5-10 totes per tow. For the most part, those interviewed and the consensus at an industry meeting held in October 2001 indicated that fishermen believed the current rules in effect (i.e. – seasonal closure and limited entry) were "working". However, limitation into the fishery was certainly regarded as a necessary evil at best, and fishermen generally value the flexibility that licenses for multiple species confer.

Drag and Diver surveys

A number of sites were surveyed this year by employing either contracted vessels with urchin drags (3 survey days) or DMR divers (3 survey days). Survey sites centered on recently or historically fished sites in Frenchman Bay and adjoining areas (Figure 10) and in the Western Passage near Eastport (Figure 11).

In diver surveys, replicate transects of known length (400 feet) were laid perpendicular to the prevailing depth contours off haphazardly selected shore points. These were swum and the number of cucumbers within 1 meter either side of the transect were counted and videotaped. A representative sample of 25-50 sea cucumbers was taken to the surface to be measured and weighed. Drag surveys took place on three different days. In most cases, three replicate tows were made in the same area. Tow lengths were determined by GPS and catch rates standardized by dividing by the ratio of actual tow length to the standard tow length (800 m). By-catch was documented (summarized qualitatively in Table 4) and a haphazard sample of 15-50 animals per tow, depending on the catch amount, was measured and weighed to determine size frequencies (Figure 8). Color, sex (male gonads are pink and females are dark red or brown with the eggs just visible with the naked eye), and split wet-weight (drained-weight) were also recorded on a sub-sample of 5-25 animals that were sacrificed. A trip was planned with an underwater drop camera and quadrat to determine efficiency of the urchin drag. Unfortunately, weather concerns precluded this trip, but there are plans to perform this work at a later date.

Sea cucumbers exhibited patchy distribution. Real abundances of sea cucumbers as determined by dive surveys were highly variable at the scale of the transect (150 x 2 m). Variability between transects in the same area was higher than variability between different sites ($n = 10$, $F=0.6838$, $p= 0.53$ by ANOVA). Abundances ranged from 0.01 to 7.45 sea cucumbers/ m^2. This is near the upper range of abundance cited in the literature. This patchy distribution was also the case in recent drag surveys in Newfoundland (Brian Johnson, personal communication). Underwater observation revealed that sea cucumbers were often found in clusters, sometimes containing numerous individuals, and gathered preferentially on rocky substrate. Relative abundances measured by catch per standardized tow varied from 0 to 740 lbs. Site differences in size frequencies and average size/ weight were also evident (Tables 3 and 5; Figure 8). Occasionally, juveniles (10-40g and immature) were found. No general trends by depth were evident between

Table 5. Relative abundance of sea cucumbers at survey locations

Location	Depth (feet)	Catch (Lbs/stand. tow) ± SD	Ind. wet weight Mean (g) ± SD	Ind. size index Mean (cm^3) ± SD	Sample size n
Frenchman Bay Survey					
Bald Porcupine Island	30-70	40 *	311 ±*105*	513 ±*162*	17
Cross Island	30-50	332 ±*238*	372 ±*102*	609 ±*178*	86
Hancock Point	70-80	188 ±*41*	302 ±*94*	481 ±*159*	78
Googins ledge	40-60	433 ±*241*	432 ±*122*	696 ±*228*	49
Off Sullivan Harbor	100-115	0 *	- -	- -	-
Ironbound Island	90-100	26 *	387 ±*108*	613 ±*183*	16
Black and Swan	200-250	344 ±*145*	305 ±*141*	562 ±*303*	49
Western Way	20-40	740 *	253 ±*68*	405 ±*116*	28
Western Passage Survey					
Area A	130-155	336 ±*158*	190 ±*63*	302 ±*108*	150
Area B	200-230	329 ±*55*	209 ±*60*	344 ±*105*	150
Area C	115-140	340 ±*14*	212 ±*66*	344 ±*115*	150
Area D	90-110	268 ±*21*	264 ±*73*	442 ±*131*	70
Area E	210-230	40 *	250 ±*49*	416 ±*87*	25
Area F	90	158 *	261 ±*59*	423 ±*113*	25
Area G	60	37 *	289 ±*98*	510 ±*178*	20
Area H	210	33 *	176 ±*51*	277 ±*91*	25

* single tow

Sea Sampling Summary

Area	Depth (ft)	Catch (Lbs/stand. tow) ± SD	Min (lbs)	Max (lbs)	Ind. Size Index Mean (cm^3) ± SD	Sample Size n
Somes Sound	30 - 80	691 ±*137*	469	948	310 ±97	442

sites. However, at the site between Black and Swan's Island, the deeper water tow contained larger animals (mean wet weight 397 ± 125) compared to the shallower tow (mean weight 216 ± 90). The possibility of size-related migration of animals has been suggested in past studies including Jordan's (1972) at Lamoine Beach and needs to be investigated further. The size frequency distributions also show some sites dominated by a relatively small number of year classes (sporadic recruitment), while others have a more broad distribution (indicating more consistent recruitment) of size classes.
By-catch also varied between sites. Of commercially important species, scallops were most often encountered in tows – though never in very large numbers (Table 4). Large mussels were also fairly commonly overlapped with sea cucumber habitat. Meideros and Bergen (1997) showed that mussel beds were a source of refuge for newly settled and juvenile sea cucumbers. At a number of the survey sites, and nearly omnipresent in tows in the Western Passage were significant numbers of sea urchins. This is not unexpected as there is a degree of overlap between urchin and sea cucumber habitat. Dive surveys confirmed that in areas with hard bottom, urchins were often present with sea cucumbers. Whether the large numbers of urchins encountered in the Western Passage were due to small-scale variability in community structure - or a competitive interaction where sea urchins were able to increase in numbers as sea cucumbers were harvested out of the area is not known. There were also unusually large numbers of winter flounder in that area. In the Frenchman Bay area finfish rarely appeared in catches. Occasionally, lobsters were present in tows. Discarded species invariably consisted of varying numbers of crabs (green, jonah, and hermit), and sea stars (up to 5 different species). Two sites in Frenchman Bay commonly contained a second species of sea cucumber the Scarlet psolus. A few sites also showed a dominant organism in lieu of sea cucumbers such as sponge (*Isodictya* sp.) and sea squirts (*Halocynthia pyriformis*; Area F-H in the Western Passage) or sea colander (*Aqarum cribosum*) found in the Black and Swan's Island and Western Way sites.

In some areas (i.e. Somes Sound), sea cucumbers appear to be the dominant benthic organism. In these areas, by-catch is low (Figure 7a). Anecdotal reports and survey data reveal however that some sites do contain considerable by-catch – although this is usually dominated by discard species and damage to the animals is fairly low (Figure 7b, 12). If areas dominated by sea cucumber biomass were fished out however, by-catch could become a more important factor.

Biometrics

Depending on size, the number of sea cucumbers per fish tote varied between 130 and 256 (mean 220) (see Box 4– for conversions). Average weight of individual animals varied from 176 g to 446 g depending on the site surveyed. A sample of sea cucumbers of different sizes were selected and dried in a drying oven at 55 ˚C. The wet:dry weight ratio was 5.7 ± 0.36. The size index used in at-sea sampling can be related to wet weight or split wet weight (figures 9a and 9b). For larger sea cucumbers however, water content is more variable (figure 13) and more scatter is seen in the relationship. Active length (sometimes reported in the literature) is useful when measuring underwater or when in tanks if animals can remain undisturbed. However, active measurements are difficult to obtain during a drag survey. The size index correlations are very useful in this context.

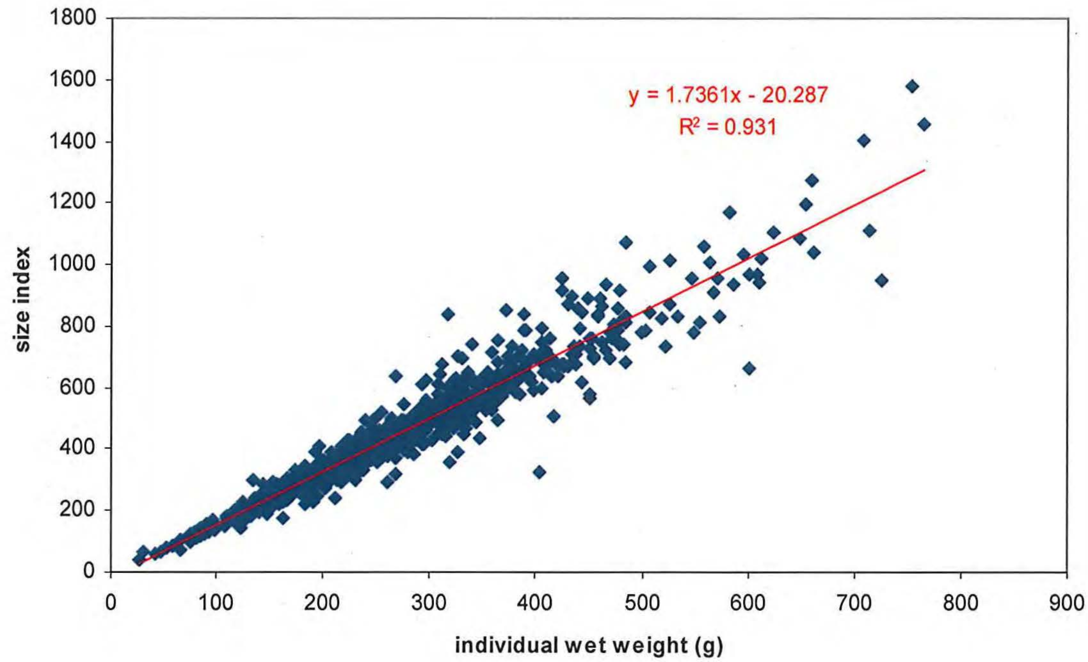


Figure 9. Size-index as a function of wet weight (a - above); Size-index as a function of split wet-weight (b-below)

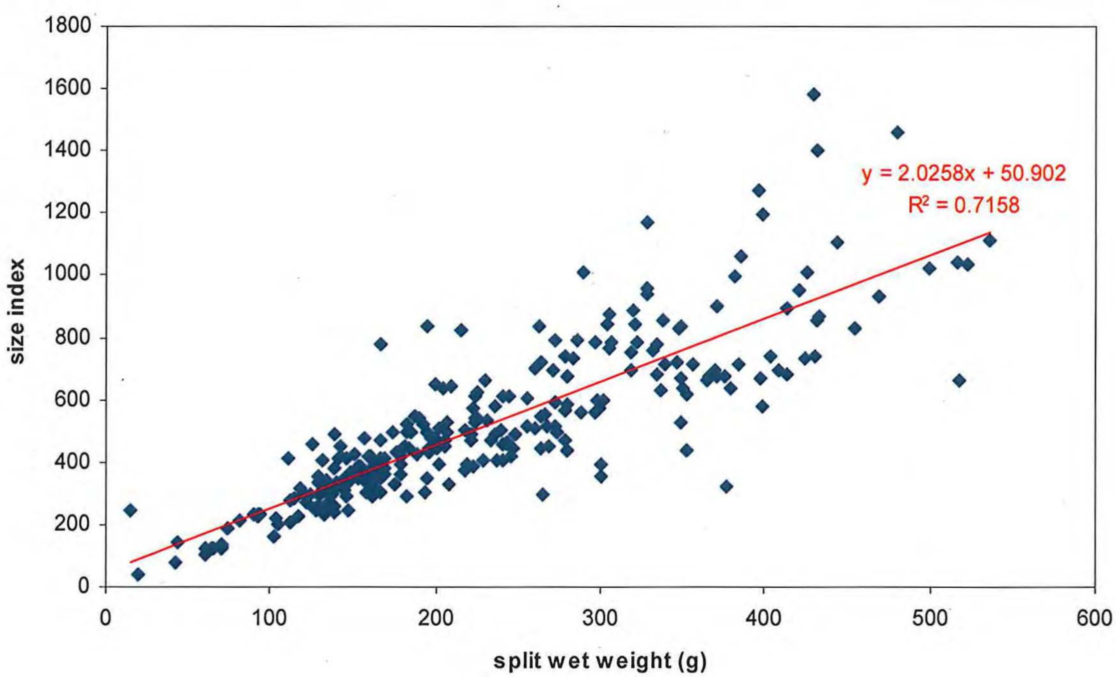


Figure 10. Sea Cucumber Survey Locations: Frenchman Bay area

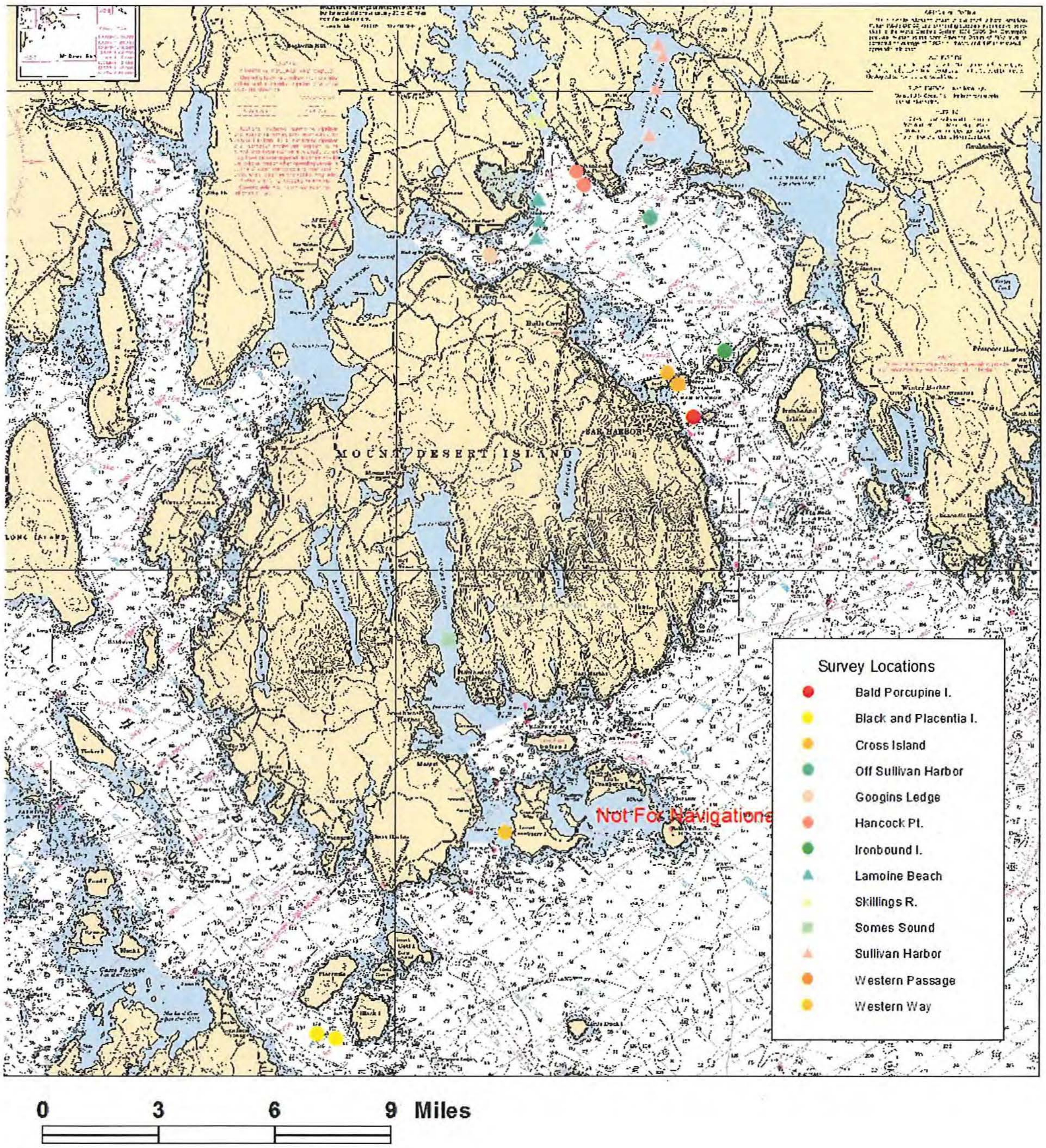
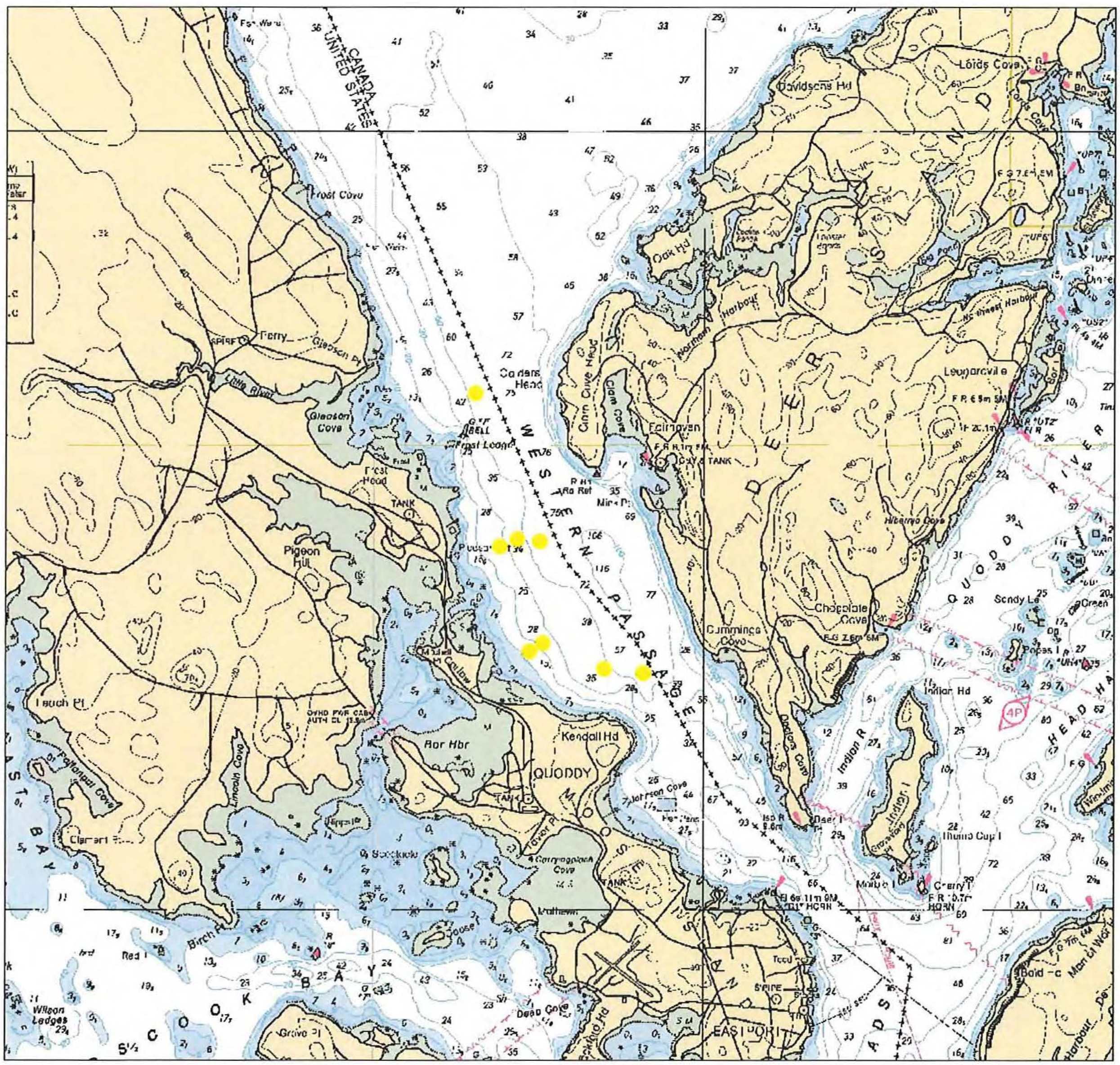


Figure 11. Sea Cucumber Survey Locations: Western Passage Drag Survey



0 0.7 1.4 2.1 Miles

Figure 12. Photographs of survey tows from soft bottom (top) and hard bottom (bottom) habitats and examples of by-catch.

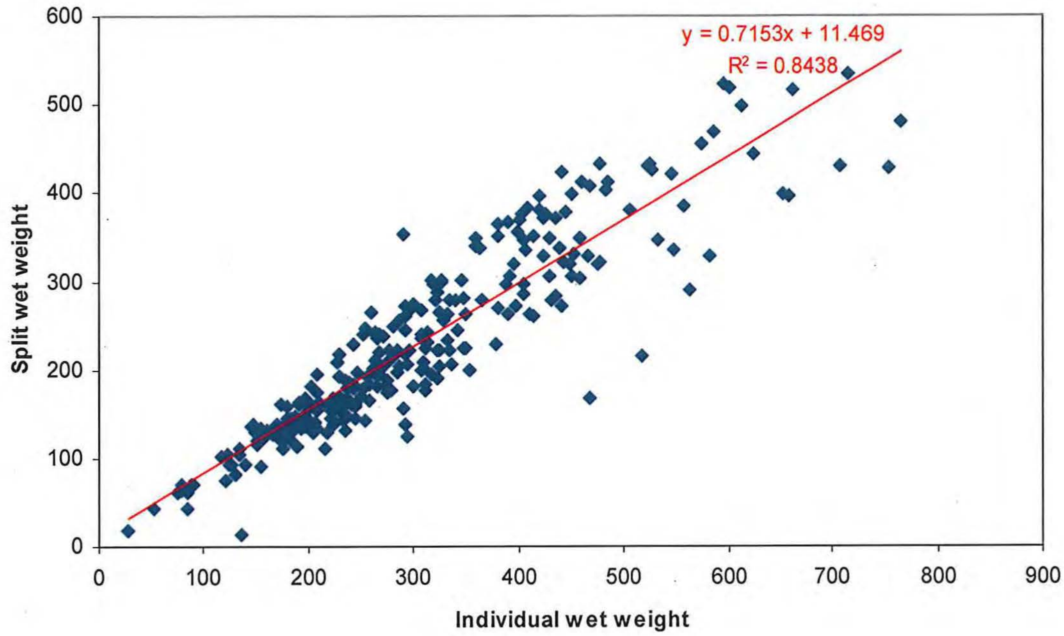


Figure 13. Split wet-weight as a function of whole wet-weight

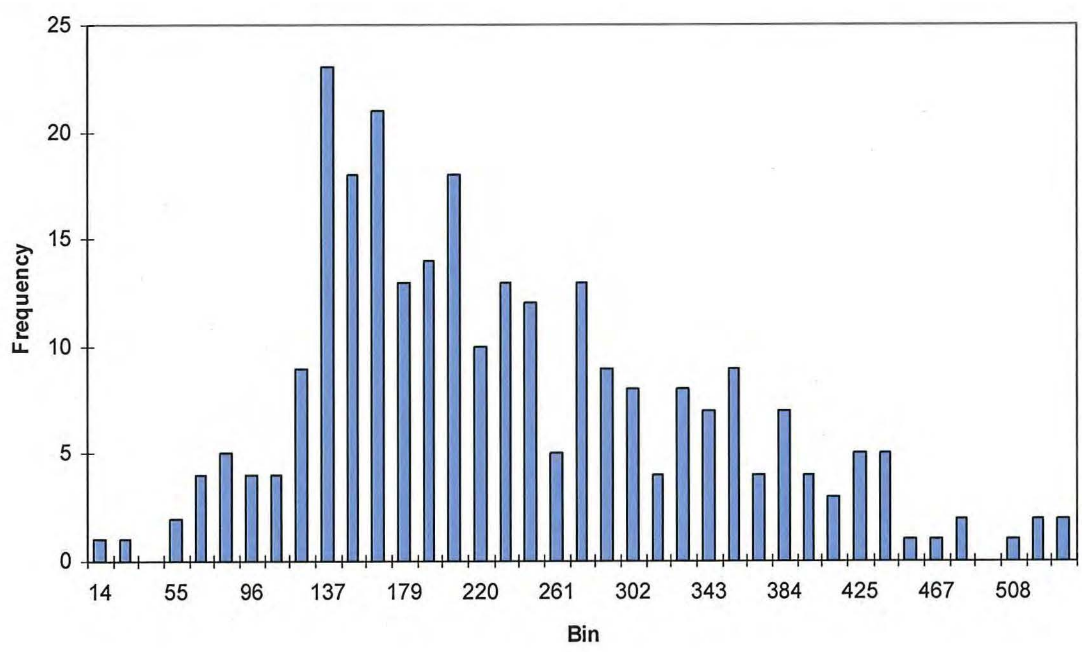


Figure 14a. Histogram: Split wet-weight frequencies (all samples combined)

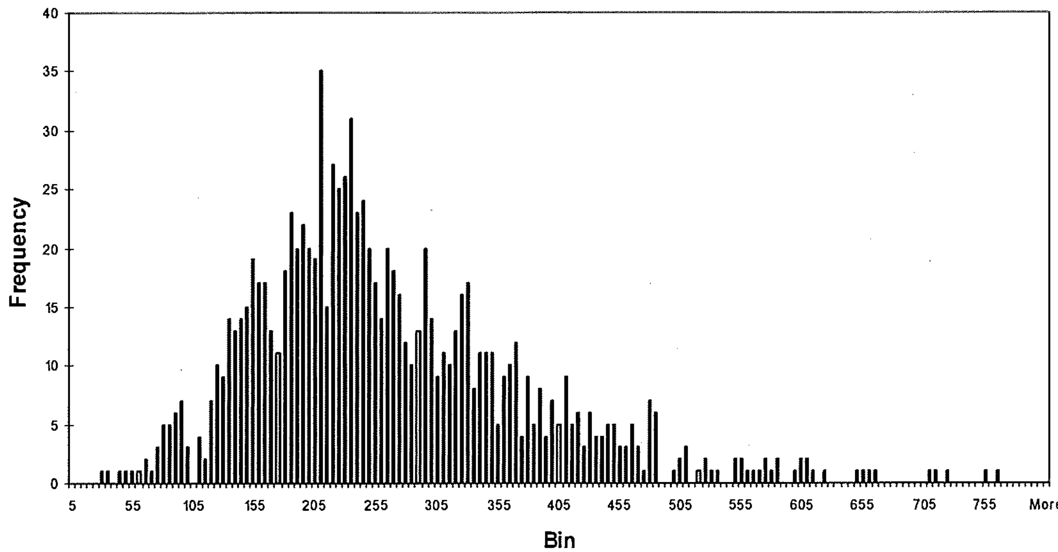


Figure 14b. Histogram: Individual wet-weight (g) frequencies (all samples combined)

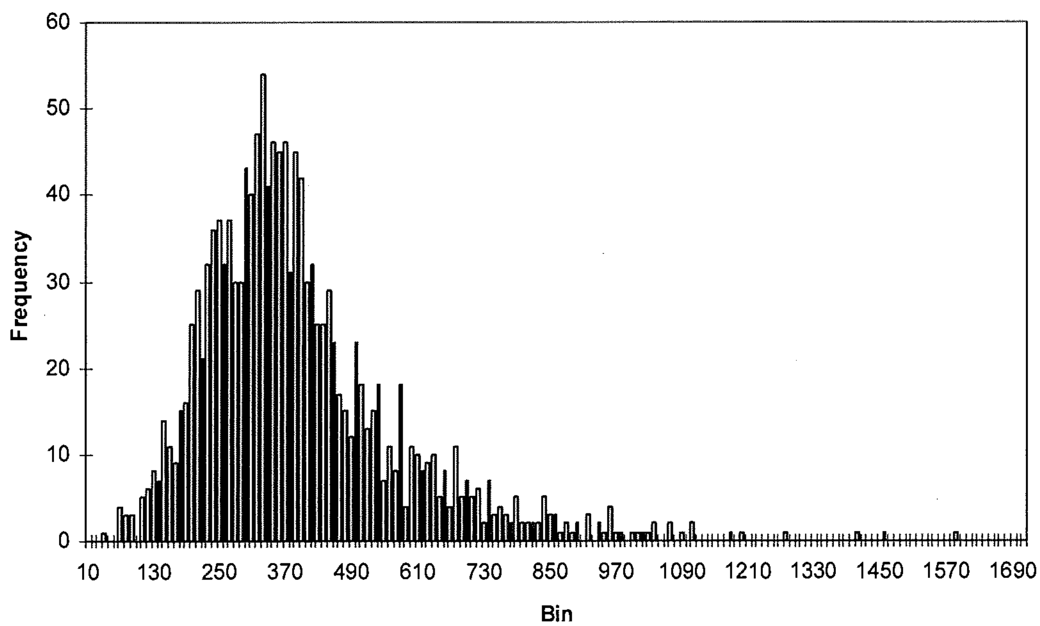


Figure 14c. Histogram: Size-index frequencies (all samples combined)

Although a full modal analysis could not be done on this data in order to assess age, a series of peaks may have started to emerge in size frequency histograms for the combined data (Figure 14a, b, and c) that appear to correspond roughly with the expected age at maximum size of these animals (10 years). A more thorough study to track predominate age classes over a period of years is needed to confirm if this is indeed akin to the actual age/ size structure of the stock. Data showed that the sex ratio did not differ from the expected 1:1. Although, not statistically analyzed, there were apparent skin color differences between survey sites. This may indicate different parent stock contributions to the various beds.

Review of past work

Recent studies have provided some useful information for *C. frondosa*, although work remains to determine how applicable these studies are to populations in Maine. The most comprehensive study of the ecology and behavior of *C. frondosa* in Maine was Jordan's (1972) PhD thesis for the University of Maine, Orono that examined a population at Lamoine Beach. More recently, Medeiros-Bergen and Miles (1997) examined recruitment in one location in the Gulf of Maine (near the New Hampshire Border). In Atlantic Canada (Gulf of St. Lawrence estuary), Hamel and Mercier have published a series of papers on spawning, development, and early growth (1996a,b), seasonal migrations and diet and feeding (1998; also Singh et al. 1998). Despite the preliminary work carried out by the DMR over the last year, there is still additional information needed in order to manage this species on a more scientific basis.

Research needed

Although a management fund for research on sea cucumbers has been set up, there are presently no funds in it. The DMR has applied for a number of grants in the past, and has one grant application currently under consideration to support further research on this fishery (examining reproductive timing using biochemical techniques). We are planning to conduct one more day of surveying using urchin drags and employing divers and/or an underwater camera set-up to estimate drag efficiency and convert relative abundances from drag surveys into real abundance estimates. In addition, we hope to map the benthic habitat of several known areas of concentration using ROXANN – an acoustics device coupled with software that allows for accurate mapping of sea bottom type. The DMR is working with other researchers interested in sea cucumbers. Dr. Chris Petersen at the College of the Atlantic is planning to study fertilization success under different animal density scenarios to help determine if exploitation significantly affects reproductive success. Strides made in working with the current industry will continue in order to monitor this fishery. Research needs include:

- An estimate of gear efficiency
- Investigation into reported size related migrations
- Documentation of time of reproduction and variability with depth or geographic location as well as variation in egg number with animal size class

- An estimation of age-stratified growth is needed in order to calculate MSY. Currently, there is only information on growth of sea cucumbers aged 1-4 (Hamel and Mercier, 1996b) for a Gulf of St. Lawrence site. Indications in the literature point to a large environmental component in growth rates for this species.

- Documentation of variability in skin thickness and meat size with depth and location

- Study of the effect of intensive harvest on dense aggregations and its impact on reproductive success (spawning synchrony, fertilization success)

- Further surveying focusing on juvenile stages to examine trends in recruitment

- Review of the economics of sea cucumber markets

OUTLOOK AND RECOMMENDATIONS

Though small in size, in terms of the present number of fishermen targeting the species, and in relative value, the sea cucumber fishery is important when total landings relative to other sea cucumber fisheries are considered (Table 1). It provides nearly full-time employment to 2-3 fishermen and part time employment to a few others in addition to truck drivers and 20-40 processor workers in regions of Maine in economic need (Hancock County and Washington counties). It may support more people in the future. The neutriceutical business based on sea cucumber by-product is also a notable venture with some promise of providing economic gains through value-added manufacturing in downeast Maine. The fishery does have the potential to continue to provide new opportunities and needed diversification for a number of fishermen, but not without management challenges.

Approaches to management for this particular fishery must be viewed in light of a few main facets:

1) *It is a "bulk" – low value fishery. In order to maintain itself as a profitable fishery, high catch rates per boat must be sustained and a minimum threshold of raw material is necessary to keep processors in business. Because harvest rates per boat are high (70-200 totes per boat per day), this fishery may only support a small number of boats – despite the fact that there are commercial concentrations not yet located.*

2) *There is a spatial component to the fishery due to the nature of these slow- moving invertebrates. Information in the literature and DMR survey results show that aggregations of these animals may be substantial – but are patchy in nature. It may not be wise to treat different sea cucumber beds as a single 'stock'.*

3) *There is still not enough information about this species in the Gulf of Maine to put management of the fishery on a solid scientific footing. As such, it is important to make decisions about the fishery in a risk-averse manner until more is known.*

Although there is a general lesson to be learned from management plans of the *Parastichopus californicus* fishery in the western states mentioned previously, none of the management plans can be strictly adapted to the Maine situation which differs in being a drag rather than a dive fishery, and a lower valued commodity.

Long-term sustainability of resource

Statewide, landings appear to have been reduced to 'safer' levels. Although the endorsement limits and other restrictions enacted certainly served to cool the expansion of the industry, current market realities may play just as important a role (Ray, personal communication). In fact there is still a sizeable latent capacity given that only 3 out of the 16 endorsement holders are presently fishing. Were all endorsements to be actively fished, landings could easily rise again to levels seen in 1999 and 2000. Additionally, there is still no scientific basis for even existing levels of harvest. An actual estimate of MSY will require funding and further work. Nonetheless, the current number of endorsements allows for routine compliance inquiries, makes monitoring of the fishery simpler, and is perhaps the smallest effective size that can keep a processing plant in operation.

The small number of currently fished locations guards against statewide over-harvest of the stock. However, localized depletions are still a concern. While logbooks do not show a decreased CPUE relative to the cumulative number of days fished at one location, sea sample data, the overall large catch rates, and anecdotal reports from fishermen reveal that it is indeed possible to deplete local areas to the point where commercial harvest is no longer economical. In one sense, the low value of this species may help protect against severe localized depletions, but we still know little about gear efficiency with this species, the effects on the benthic community after intensive harvest of sea cucumbers, the effect that reduced population density might have on the sea cucumber's reproductive success, or the nature of recruitment to these beds. Markets for this species are still developing in Maine.

It is likely that global demand will continue to grow *C. frondosa* despite the present low commercial value. This fishery may also develop slowly in neighboring regions such as Quebec (Hamel and Mercier, 1999) and Newfoundland and Labrador, and it is unclear whether this will stimulate or inhibit further market developments.

Impact of harvesting on other fisheries

Overall the sea cucumber drag fishery is a relatively clean one. This is in part due to the community structure of at least some fished sites where the benthic biomass is dominated by sea cucumbers. The preference for using urchin drags over scallop chain sweeps is also probably more ecologically sound. Survey data on by-catch shows that the majority of by-catch is discarded alive and undamaged. Survey data (and anecdotal reports) also show that by-catch varies considerably by site (i.e.: the Skillings River which was intensively fished in 2001 had a very diverse benthic community, and fishermen reported substantial culling there). If dense pockets of sea cucumbers are fished out, by-catch may become a greater concern. The conflict over lobster gear encounters seems to have been resolved with increased attention paid by draggers to avoiding gear and also with the enactment of the closed summer season.

Management recommendations and the ability to enforce and administer the program

The DMR recommends continuation of the current regulations (box 2). The closed season, while primarily intended to avoid conflicts with lobster traps also serves as a conservation measure – during a time when product quality is at its worst – in summer months. Harvester logbooks are also very important to the monitoring of this fishery and will provide a needed documentation of trends over time in the fishery.

Input controls on the fishery could include restrictions on gear, closed or rotational harvest areas, or limited entry. Output controls could take the form of a quota system placed on landings (or possibly on dealers buying) and/or a minimum size regulation. All of these have been used before in west-coast sea cucumber fisheries.

The DMR believes that limited entry is the most effective guard against unchecked levels of harvesting. Not enough is known about the currently used drag to enact gear restrictions intended to allow small cucumbers to escape. Due to the variable shape of sea cucumbers, selectivity would be very broad. This biological trait of the animal would also make it difficult to legislate a size standard that could be easily enforced. Furthermore, because of the bulk nature of the fishery, decreasing drag efficiency or instituting a minimum size that would require extensive culling would hurt this marginally profitable industry economically. Likewise, lack of resources to do the systematic survey work required to determine, enforce, and verify a sustainable quota would be prohibitive. To be effective, the coast would probably have to be broken down into harvest areas- each with its own quota. Stock assessment parameters would be largely speculative. There is also little need to invoke a more intensive management system at this juncture with the current market situation.

Future management considerations will need to be left open however should the market expand. There is room for growth with the current number of endorsement holders. A continuation of the current endorsement restrictions for a period of three years would allow further monitoring and research on this fishery. The DMR is pursuing grant-funded research for this species and will continue to work cooperatively with industry members to monitor the stock status.

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