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Sea cucumbers

Status and culture potential in the Jaffna Lagoon, Sri Lanka

Sivashanthini Kuganathan

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Preface

Marine biodiversity in the Northern coastal waters has not been well studied so far, and particularly very less information is available on sea cucumbers though they are economically important. Details of species of sea cucumbers in the Jaffna Lagoon had not been documented fully so far. Sea cucumber fishery in the Jaffna Lagoon has increased steadily due to the high price of beche-de-mer and export demands in recent years. If the harvest of sea cucumbers continues as at present, it will create a situation of depleted resources in the future. To overcome this and to ensure sustainability of the sea cucumber resources initiating culture trials in the Jaffna Lagoon is an urgent need. Taking these into consideration the present research project was initiated to carry out two major activities, i) identifying sea cucumber species in the Jaffna Lagoon by fortnight sampling of sea cucumbers and documenting the results, and ii) drafting guidelines for site selection by assessment of ecological status of selected sea cucumber sites in the Jaffna Lagoon. Detail documentation for sea cucumber fauna is established from the identified species. The guidelines for site selection furnish knowledge for the fishermen, aqua culturists and researchers to initiate commercial culture trials in the Jaffna Lagoon which will be a boosting for enhancement of socio-economic status of fishermen. This book publication arising from this research project is to disseminate knowledge among the community not only in the Jaffna District but also in Sri Lanka. Consequently, this study on potential for sea cucumber culture in the Jaffna Lagoon is expected to improve the livelihood of the fishermen and further promote reconstruction and development of Fisheries sector in the Jaffna District.

Message from the retired Director, Centre for Development of Fisheries, University of Jaffna

Fishery resources from ancient times have been a major source of food for humanity and a provider of employment and economic benefits to those engaged in this activity. However, with increased knowledge through research findings, leading to dynamic development of fisheries, it has been realised that living aquatic resources, although renewable, are not infinite and need to be properly developed and effectively managed, if their contribution to nutritional economic and social well being of the increasing population is to be sustained. In this context the high price of beche-de-mer and export demand in recent years leading to uncontrolled increase in exploitation of sea cucumber in the Northern region of Sri Lanka, paying no attention to sustainability, have timely drawn the attention of Mangroves for the Future (MFF) initiative.

This study based on field assessments, technical analysis and colloquium with those involved in sea cucumber harvesting and beche-de-mer processing, provides valuable ecological knowledge on sea cucumber in the northern waters. Recommendations resulting from this study have indicated environmentally friendly strategies for sustainable sea cucumber aquaculture leading to maximum yields and personal incomes.

Thanks are due to all individuals and organisations that have contributed towards this study, formulation of this valuable document and for providing the technical assistance and the necessary financial support. This will serve as an extremely useful document for all interested in sea cucumber. By publishing this and making it widely available, MFF will be rendering a signal service to the Sri Lankan fishery community. I would like to acknowledge the inestimable efforts of Prof. Dr. Mrs. S. Kuganathan, Head of the Department of Fisheries, University of Jaffna, in this study and congratulate her.

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Prof. Mrs. S. Kuganathan
June 2014

Contents

Chapter 1

General Introduction

1.1 Sea cucumber fishery

Sea cucumbers are a highly diverse, valuable and charming group of animals included under class Holothuroidea. They are sluggish, harmless animals offering no resistance at time of capture. They live chiefly among corals but are also found among rocks and in muddy and sandy flats. They are distributed from the shore to the greatest depths. Their lengths range from a few millimeters to more than 2 m and they occur in all colour combinations: white, black, brown, red, pink, blue, green, yellow and violet. Some of them are really very beautiful while alive and are in great demand for aquaria.

Tropical sea cucumbers processed into beche-de-mer are a valuable source of income for many coastal communities in the developing nations of the Indo-Pacific. However increasing demand from China and inadequate management of sea cucumber stocks in many countries have resulted in severe over fishing. It is now apparent that depleted stocks can take decades to recover. Being a renewable resource continuous monitoring and implementation of new ways to manage and restore the stocks are essential (Conand, 1997; 2004). Restocking or stock enhancement is another possible way to maintain the stocks in a sustainable way.

In the Indian Ocean, sea cucumber fishery presently exists in 16 countries in the Western Indian Ocean and in two countries in the Eastern Indian Ocean (Conand, 2008). The fisheries are for the dried product “trepang” or “beche-de-mer” which is consumed by Chinese populations. Nearly thirty species are presently exploited (23 Holothuriidae; 6 Stichopodidae), with commercial value varying among the species. Species composition varies greatly between Indian and Pacific Ocean. Teatfish *Holothuria whitmaei* found only in the Pacific, and *Holothuria notabilis* and *Holothuria spinifera* in the Indian Ocean (Conand, 2008). Sea cucumber production data for different countries in the Indian Ocean for 12 years are presented in Table 1 (Toral-Granda *et al*., 2008).

Sea cucumber catches are often evaluated from exports. The principal sea cucumber export destinations are China, China Hong Kong Special Administrative Region (SAR), Singapore, Malaysia and Taiwan Province of China with some reciprocal changes between them (Conand and Byrne, 1993; Conand, 2004; 2006). When Sri Lanka is considered, the major export destinations of sea cucumbers are Singapore, Taiwan Province of China and China Hong Kong SAR, with Singapore being the dominant buyer from Sri Lanka since 1999. Taiwan is the second biggest market and China Hong Kong SAR is the third (Table 2) (Terney Pradeep Kumara *et al*., 2005). The mean annual export to these three major countries since 1997 is around 50 tonnes dry weight.

Table 1: Sea cucumber production data for different countries in the Indian Ocean (In tonnes)

(Source: Toral-Ganda *et al*, 2008)

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average 1994-2005	Percentage- world total
Egypt	-	-	-	-	-	-	20	139	2 310	527	15	5	502.7	3.4
Madagascar	5 400	5 400	5 400	5 400	1 446	1 500	1 500	1 500	500	500	500	500	2 462.2	1.8
Maldives	66	94	145	318	85	54	205	226	191	239	182	117	160.2	1.1
Tanzania	1 591	1 460	1 644	1 527	1 800	189	372	340	65	75	10	10	756.9	0.2
Kenya	41	55	15	41	38	15	30	13	68	27	28	18	32.4	0.2
Yemen	102	-	-	-	-	-	-	-	14	10	380	400	151.2	1.0
Mozambique	0	6	54	7	2	8	12	11	10	4	1	1	9.7	0.1
FAO Area 51	7 200	7 015	7 258	7 293	3 371	1 767	2 139	2 229	3 158	1 382	1 116	1 051	4 075	27.8
Indonesia	548	227	269	338	630	689	903	697	649	870	360	624	567.0	3.9
Sri Lanka	92	100	150	272	203	170	145	90	150	170	280	260	173.5	1.2
Malaysia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FAO Area 57	640	327	419	610	833	859	1 048	787	799	1 040	640	884	741	5.1
World total	**16 246**	**15 556**	**17 590**	**15 295**	**13 613**	**12 596**	**16 020**	**11 964**	**15 243**	**18 578**	**13 017**	**9 878**	**14 633**	**100**

Table 2. Annual dry sea cucumber exports (kg) from Sri Lanka to the main market destinations (Source: External trade statistics of the customs from Terney Pradeep Kumara *et al.* 2005)				
	Singapore	Taiwan Province of China	China Hong Kong SAR	Total
1996	73 266	27 457	69 803	170 526
1997	-	-	-	307 578
1998	88 959	68 330	46 424	203 713
1999	30 905	45 112	22 001	98 018
2000	16 479	39 626	29 530	85 635
2001	19 739	48 649	14 205	82 593
2002	25 519	50 593	40 057	116 169
2003	47 223	44 866	40 746	132 835

Export statistics of sea cucumbers by different countries in the FAO areas for the period 1995 – 2001 is presented in Table 3.

Table 3: Export of sea cucumbers by different countries in FAO areas (live/ frozen/ dried/ salted) (1995 – 2001) (Q=tonnes; V=US$'000) (Source: FAO, 2003)								
Country		1995	1996	1997	1998	1999	2000	2001
China PR	Q	-	16	11	21	88	298	653
	V	-	296	98	99	209	612	845
Hong Kong (China)	Q	31	116	-	-	-	53	
	V	88	200	-	19	-	108	-
Cuba	Q	-	-	-	-	-	21	14
	V	-	-	-	-	-	452	351
Fiji Islands	Q	454	666	862	127	141	-	1
	V	3 978	4 071	2 781	1 171	1 379	-	32
French Polynesia	Q	-	-	-	2	1	-	-
	V	1	-	-	14	13	-	7
India	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-

Indonesia	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
Kiribati	Q	40	74	39	3	4	9	14
	V	281	602	199	31	61	79	116
Korea, Rep.	Q	3	15	12	12	12	20	10
	V	21	60	47	59	116	165	92
Madagascar	Q	317	279	162	-	-	-	-
	V	1 254	751	452	-	-	-	-
Malaysia	Q	32	17	25	1	5	1	22
	V	142	49	136	1	11	5	84
Maldives	Q	94	145	318	85	54	-	-
	V	707	646	728	346	407	-	-
Marshall Islands	Q	-	55	29	-	-	-	-
	V	-	432	312	-	-	-	-
Mozambique	Q	-	43	-	25	3	-	2
	V	-	116	-	24	20	5	34
New Caledonia	Q	53	49	-	-	49	62	-
	V	1 300	930	-	-	593	1 170	-
Nigeria	Q	-	-	-	-	-	-	1
	V	-	-	-	-	-	-	6
Papua New Guinea	Q	-	-	453	-	379	-	-
	V	-	-	3 861		3 332	-	-
Philippines	Q	1 459	1 469	1 297	-	1 125	-	-
	V	4 803	4 827	4 505	-	3 653	-	-
Saint Helena	Q	-	6	-	-	-	-	-
	V	-	58	-	-	-	-	-
Samoa	Q	29	32	9	3	-	-	-
	V	80	70	34	5	-	-	-
Seychelles	Q	-	-	-	-	-	-	16
	V	-	-	-	-	-	-	247
Singapore	Q	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
Solomon Islands	Q	219	113	203	253	376	48	269
	V	509	354	664	853	393	253	1 749
Sri Lanka	Q	188	176	307	213	104	-	96
	V	2 028	2 936	6 352	4 260	2 547	-	1 936

Taiwan PC	Q	34	160	71	267	258	179	146
	V	562	863	828	1 025	1,150	1 503	1 704
Tanzania	Q	263	296	254	873	93	-	-
	V	359	438	685	201	262	-	-
Thailand	Q	12	8	40	87	225	242	121
	V	48	56	129	160	320	857	432
Tonga	Q	109	86	-	-	-	-	1
	V	911	719	-	-	-	-	7
United Arab Emirates	Q	-	3	22	-	-	11	-
	V	-	19	70	-	3	161	1
Vanuatu	Q	-	20	35	25	8	-	16
	V	-	123	121	130	33	-	102
Yemen	Q	-	6	-	-	-	-	77
	V	-	138	-	-	-	-	374
World total	**Q**	**3 337**	**3 890**	**4 149**	**1 999**	**2,925**	**944**	**1 459**
	V	**17 072**	**18 908**	**22 002**	**8 498**	**14,505**	**5 370**	**8 122**

Sri Lanka and India are the traditional beche–de–mer producers in the Eastern Indian Ocean. Beche–de–mer is the major commodity that is produced in Sri Lanka and the entire annual production is currently exported to Singapore, Hong Kong and China (Dissanayake and Athukorala, 2008).

Beche–de–mer production in Sri Lanka for the period 1992-2013 is given in Table 4 (Lovatelli *et al*., 2004; Customs Department Statistics). It is clear from the data from 1997 to 2001, beche–de–mer production decreased steadily and then the production slowly increased up to 2004 and again declined thereafter. Steep rises and declines in quantities exported are evident from published statistics of Sri Lanka Customs Department.

Table 4. Beche-de-mer production in Sri Lanka for the period 1992 - 2013

Year	Production (tonnes dry weight)
1992	65
1993	65
1994	92
1995	100
1996	100
1997	272
1998	203
1999	170
2000	145
2001	120
2002	150
2003	170
2004	280
2005	260
2006	Not available
2007	Not available
2008	Not available
2009	Not available
2010	Not available
2011	300
2012	281
2013	286

These fluctuations could be correlated with the discoveries of new sea cucumber grounds and their depletion as a result of unrestricted and intensive collection (Conand, 2008).

Although information on annual imports and exports of beche-de-mer have been documented in some FAO reports occasionally, there are no accurate separate published statistics for sea cucumber production in Jaffna or in other districts of Sri Lanka. Sea cucumber species are included under the ‘other’ category in the species wise fish production data according to the statement of government officials.

Though sea cucumbers are the most abundant resources in Sri Lanka the sea cucumber fishery is restricted to certain areas in the country. The fishing industry of the country steadily recovered after 2004 Tsunami disaster. With the opening of the A9 road, fishery in the Jaffna Lagoon was restored. Presently sea cucumber fishery in the Jaffna Lagoon developed further, especially for *Holothuria scabra*.

Due to the high price of beche-de-mer and export demands in recent years *H. scabra* and other species of sea cucumbers fished more intensively in the Jaffna Lagoon. If this situation continues, obviously the sea cucumber resources will face over exploitation. Those interested in the sea cucumber industry should be knowledgeable and in a position to regulate and maintain sea cucumber stocks at maximum sustainable levels. Thus an awareness to sustain the sea cucumber resources by identifying the most suitable sites for its culture becomes necessary at this stage in order to provide economic security to the fishermen in Jaffna Peninsula. Study on potential for sea cucumber culture in the Jaffna Lagoon further promotes reconstruction and development of fisheries sector in the Jaffna District.

The present study is a spatial analysis using any of the formal techniques which include their topological, geometric or geographic properties. It was formulated in order to carry out two major activities: 1) identifying sea cucumber species in the Jaffna Lagoon by fortnight sampling of sea cucumbers and documenting the results, 2) drafting guidelines for site selection by assessment of ecological status of selected sea cucumber sites in the Jaffna Lagoon.

1.2 The Jaffna context

Jaffna Peninsula is located in the northern most region of Sri Lanka and is separated from India by Palk Strait. The total land area including inland water bodies is 1025 km^2. The land is largely flat and low, with an average elevation of 5 m above sea level. There are more than 600 tanks and 2000 smaller ditches scattered all over the district. Jaffna District has a coastal belt of 292.2 km by length and a continental shelf of 3360 square miles. The fishing grounds around Jaffna District and the lagoons in the district are resourceful when compared to other parts of the country.

Jaffna is located in the dry zone; the island area of the district is particularly dry. In 2009, Jaffna recorded only 59 annual rainy days, which was the least among 20 major cities in Sri Lanka. The temperature ranges from 26°C to 33°C in Jaffna. In the months April to May and August to September, when the sun is overhead, the temperature stands at maximum. The coolest period occurs in December to January coinciding with the lowest sunlight.

Jaffna, Sri Lanka is located at 9.66845 latitude in decimal degrees and 80.0074 longitude in decimal degrees. The average elevation of Jaffna, Sri Lanka is 7 meters.

The fishing industry played a significant role in the economy of the Northern Province of Sri Lanka. The contribution of Jaffna District alone was more than 25 % of the total fishery production of the country in 1983. Fisheries sector plays an important role in terms of employment opportunities, income generation, foreign exchange earnings and provision of protein to the population. Trend in fish production in Jaffna District is presented in Figure 1. People living in Jaffna are poor to middle class families with minimum income. More than 70 % of the people living in Jaffna are Tamils.

With the eruption of ethnic conflict in Sri Lanka, since 1983, Tamil populated Jaffna District was under war zone until 2009. Due to security restrictions and wars, Jaffna fishing community faced multiple destructions in terms of lives and livelihood. The calamity was multiplied by Tsunami in 2004 too, resulting in the loss of valuable human lives, physical assets, and historical fishing territories.

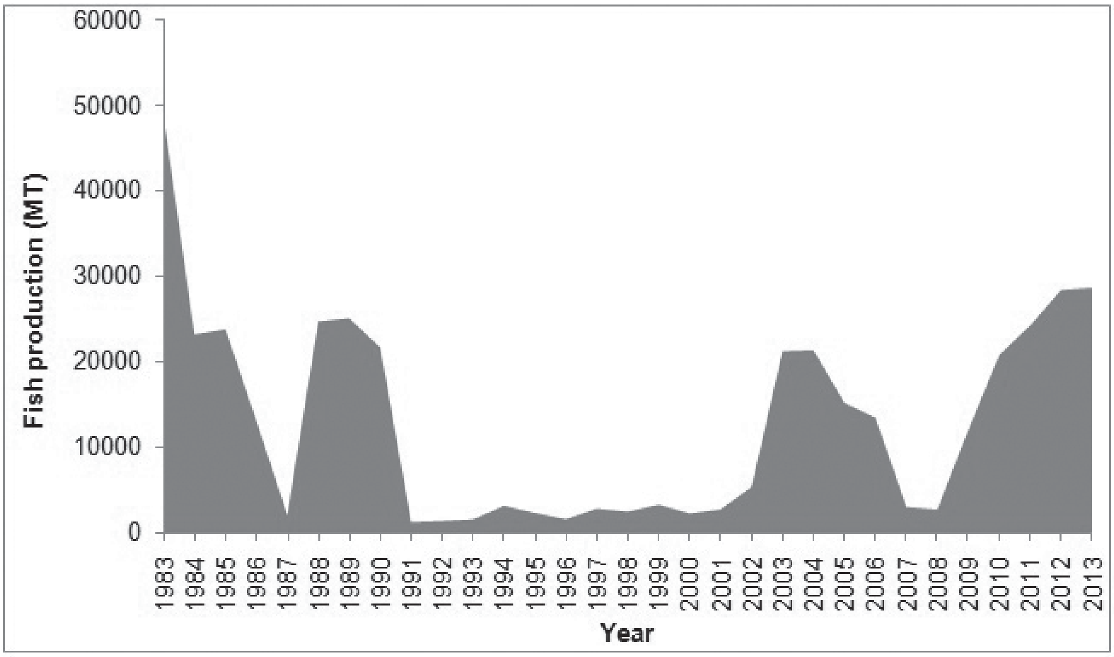


Figure 1. Trend in fish production in Jaffna District (Data source: Department of Fisheries and Aquatic Resources, Jaffna)

1.3 Description of project area

Jaffna Lagoon is situated 79˚ 52'E to 80˚ 38'E longitude and 9˚ 26'N to 9˚ 46'N latitude (Figure 2) and has an area of about 412 km^2 (160 square miles) and the depth does not exceed 4 m. Coastal length of Jaffna District is about 182 miles. The Jaffna Lagoon is the largest shallow water body located in the Northern Province of Sri Lanka. The Jaffna Lagoon extends from the fort Hammenhill in the east to the Elephant Pass and in the west as a narrow body of water separating the Jaffna Peninsula from the main land and a few neighboring Islands. The length of the coast is 140 km with abundant fishery resources and thus fishing villages are found all along the coast line. The lagoon has extensive mudflats, sea grass beds and some mangroves. The lagoon attracts a wide variety of fishery resources.

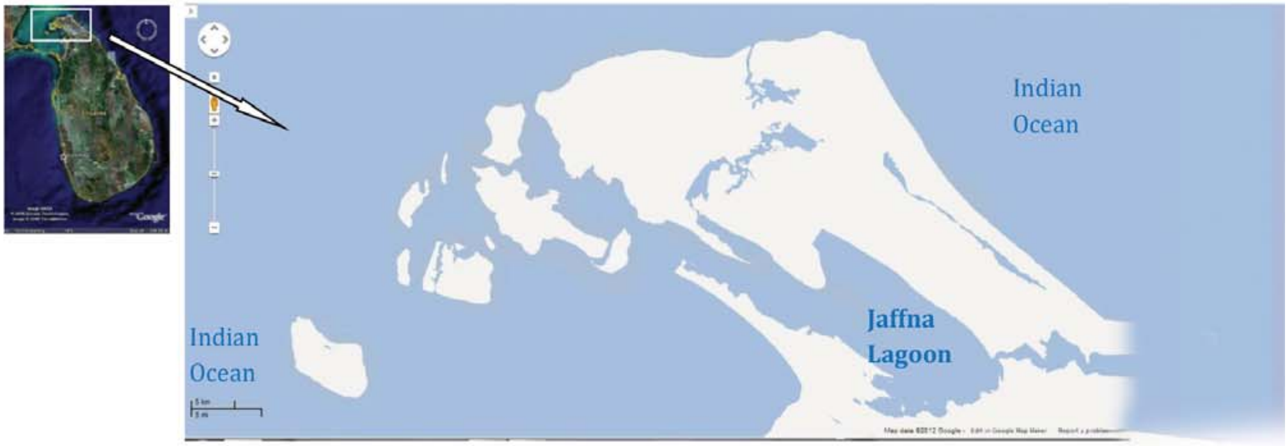


Figure 2. Map showing the Jaffna Lagoon

1.4 Sea cucumber fishery in the Jaffna Lagoon

Sea cucumbers are often caught by skin divers from coastal as well as offshore areas in the Jaffna Lagoon. In addition to skin diving sea cucumbers are also caught by using trawlers owned by Kurunagar fishermen. The trawlers go for fishing three days per week Monday, Wednesday and Saturday, to catch sea cucumber in the Northern waters of Sri Lanka off the Jaffna Lagoon especially at Palaitivu, Kakkadativu, Pallikuda and Naachchikuda.

At present, the fishermen are unable to collect considerable number of sea cucumbers from the Jaffna Lagoon and hence they move further distance towards deeper area for collection. It is an indication of population depletion of sea cucumbers. The trawlers leave Kurunagar area in the evening and reach the specific locations identified by the fishermen in the night and return with sea cucumbers on the following day morning at about 6.30 a.m. Sea cucumbers were observed in large quantities on Tuesdays, Thursdays and Sundays at the processing centers.

Local fishermen who hold license for diving, collected sea cucumbers by skin diving during early morning, evening and in the night; they collect few numbers of sea cucumbers and then sell them to the processors.

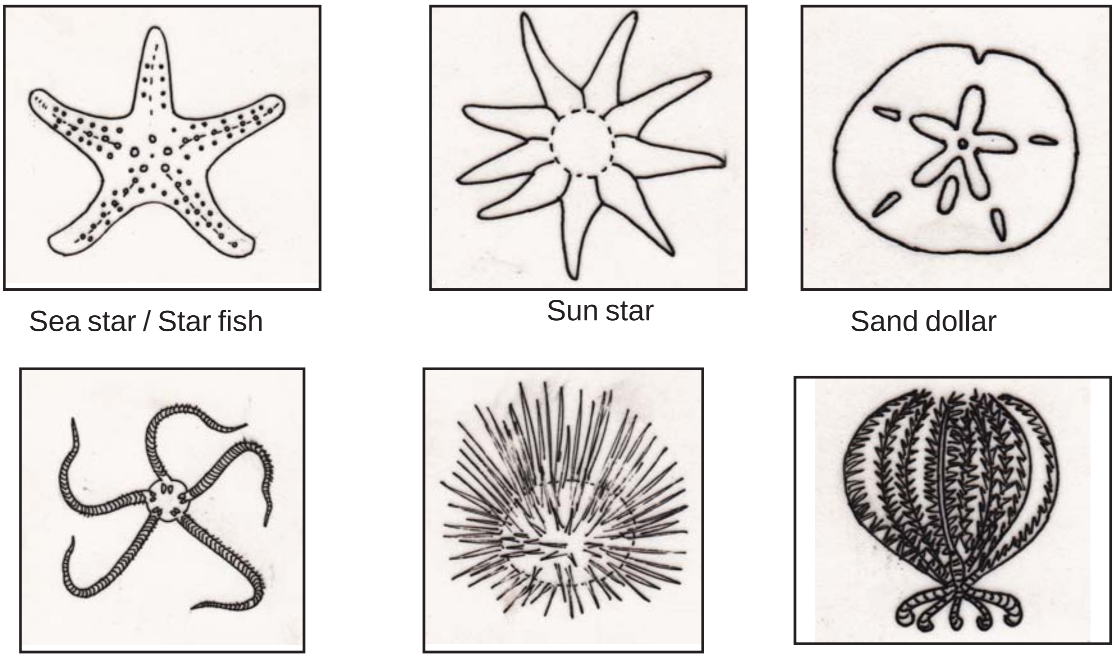
1.5 Taxonomy of sea cucumbers

Sea cucumbers are members of the class Holothuroidea within the invertebrate phylum Echinodermata. They are called as “spiny skins”. Other members (Figure 3) of phylum Echinodermata includes starfish (Class: Asteroidea), brittle stars (Class: Ophiuroidea), sea urchins (Class: Echinoidea) and crinoids (Class: Crinoidea).

Kingdom: Animalia

Phylum: Echinodermata

Phylum: Echinodermata
- Class: Asteroidea
Eg: Sea Star, Sun star, Sand dollar
- Class: Ophiuroidea Eg: Brittle star
- Class: Crinoidea Eg: Sea lily
- Class: Echinoidea Eg: Sea urchin
- Class: Holothuroidea Eg: Sea cucumber



Sea star / Star fish | Sun star | Sand dollar

Brittle star | Sea urchin | Sea lily

Figure 3. Other animals included under phylum Echinodermata

1.6 Biology of Sea cucumbers

External morphology

Sea cucumbers have an orally-aborally (longitudinally) elongated body. Echinoderms share a pentaradial symmetry that is unique to this phylum. When viewed end-on from the mouth to the anus they are symmetrically divided into five equal segments around a central crown. Holothuroidea do not have the body drawn out into arms, and the polar axis (distance between mouth and anus) is greatly lengthened.

Holothurians are soft bodied animals; they lack arms and head for overall coordination. Externally, echinoderms are covered by chalky plates just under the skin. The body of the sea cucumbers has five meridional ambulacra bearing podia, which are expanded aborally along the elongated polar axis. The ventral surface or creeping sole of the body is called as 'trivium', bears the locomotary podia. The dorsal surface of the body is called as 'bivium'; it is represented by papillae (Figure 4).

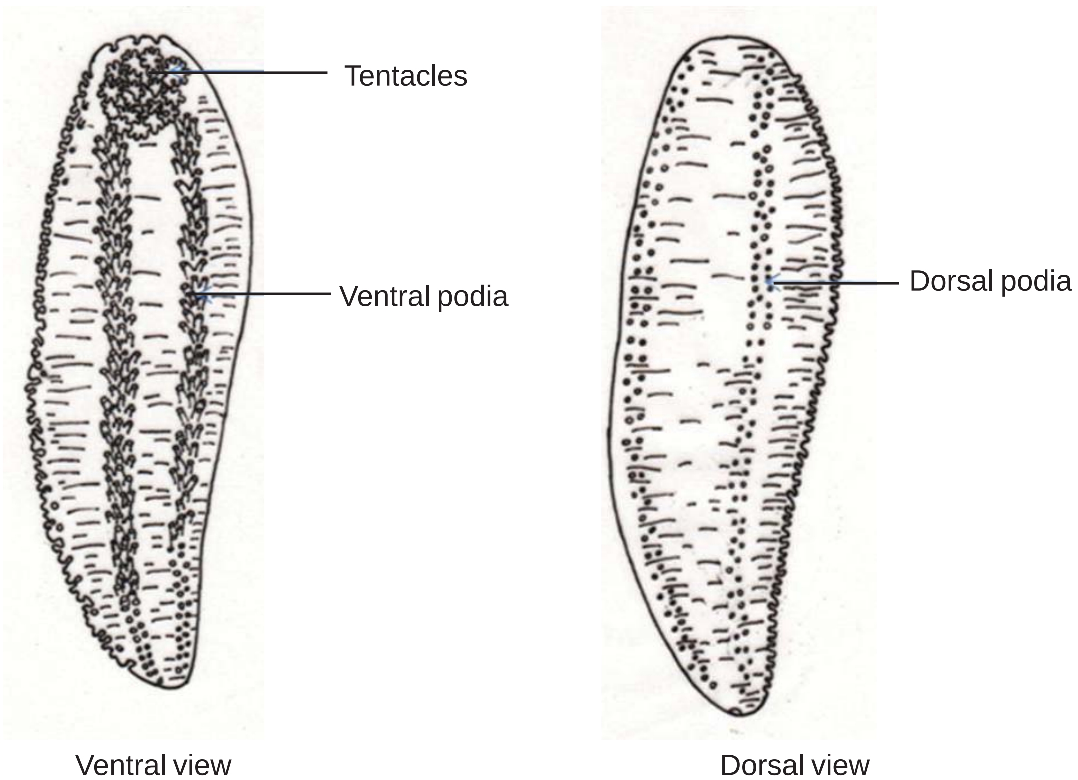


Figure 4. External appearance of sea cucumber

The mouth is at the anterior end, which has tentacles, their number varies between 10 and 30 while the anus is at the posterior end of the animal, which may be encircled by small papillae or heavily calcified papillae called anal teeth. The shape of the tentacles differs among the various orders and is used as a key identification character (Figure 5). The coloration varies between species and sometimes also between individuals of the same species. The ventral surface is often lighter in colour than the dorsal surface.

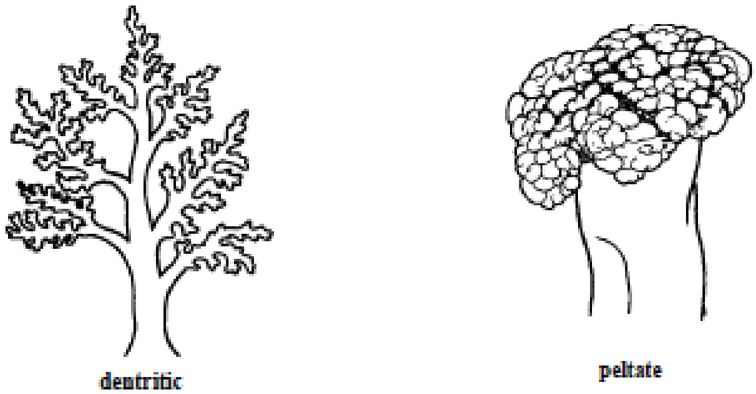


Figure 5. Different types of tentacles found in sea cucumbers

Body wall

The body wall is thin in some orders but thicker in other orders. It comprises the part of the body which is processed for human consumption. Commercial species are usually characterized by a thick body wall. It possesses a thin cuticle over the epidermis and a thick dermis underneath (Figure 6). The dermis is composed of connective tissue which encloses the endoskeletal spicules or ossicles. Below the dermis, there is a layer of circular muscles.

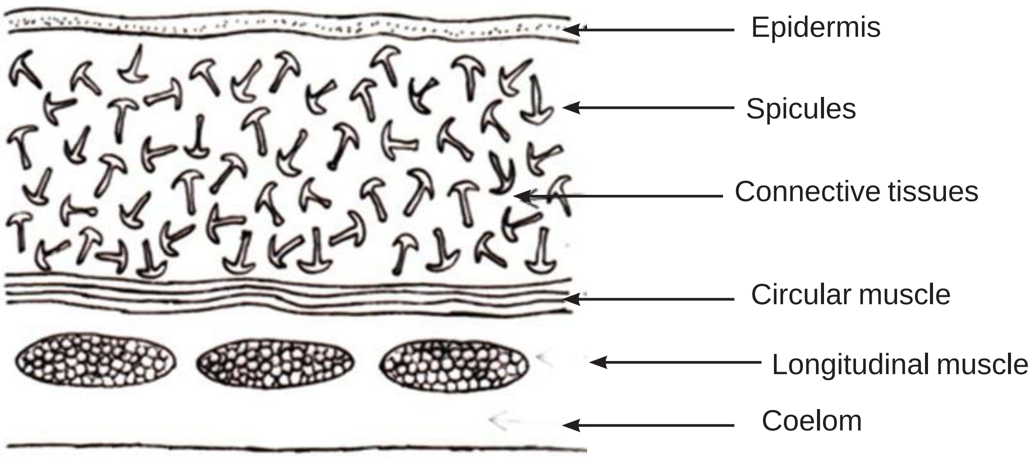
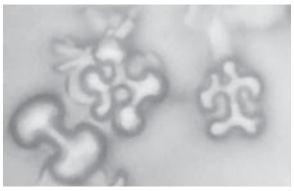


Figure 6. Cross section of body wall of a sea cucumber

Spicules

Spicules are also called as ossicles or deposits. These are the characteristic of the class and main feature for identification. These are perforated calcareous bits of microscopic size. Shapes of the spicules vary from simple to complex (Figure 7). Spicules are also found in the tentacles, the podia, the mesenteries or other internal organs. Their developmental stages can differ from the definitive shapes in the adults and therefore make the species identification difficult.



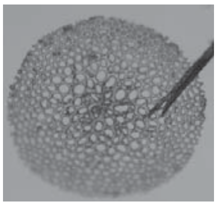


Figure 7. Diferent shapes of spicules found in sea cucumbers

Digestive system and nutrition of sea cucumbers

The digestive system is basically a long tubular gut, often coiled, with mouth and anus at opposite ends of the body (Figure 8). The mouth is in the center of a buccal membrane at the base of the buccal podia.

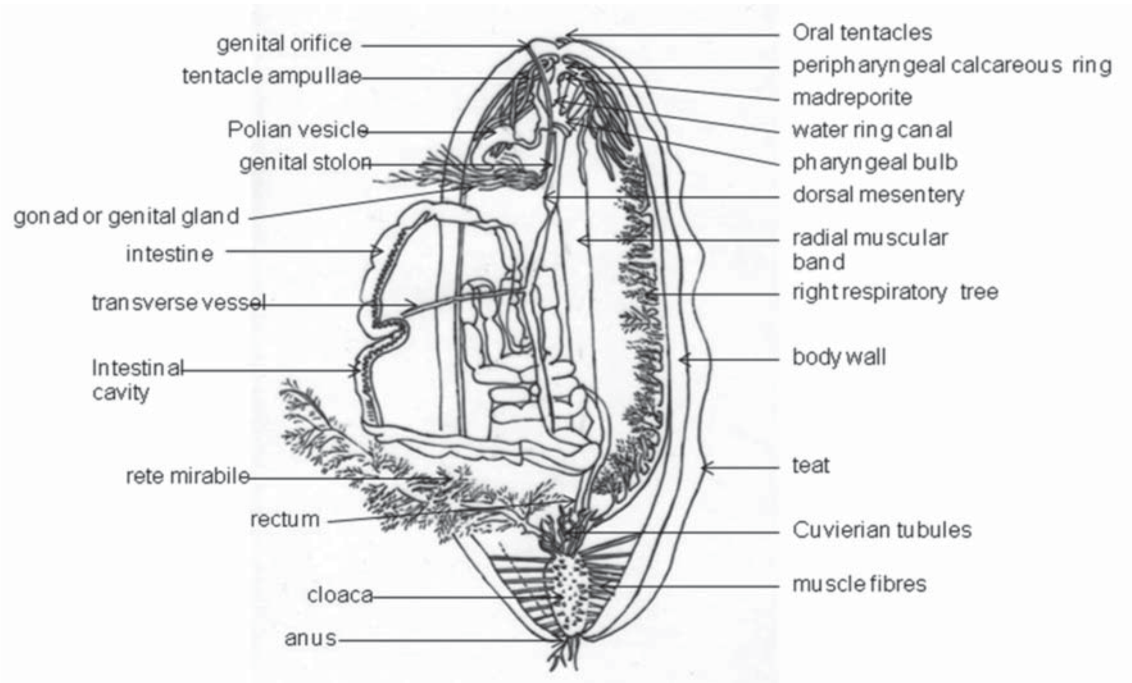


Figure 8. Internal anatomy of sea cucumber

The mouth opens into a muscular pharynx, which is surrounded anteriorly by a calcareous ring with 10 ossicles. The calcareous ring provides support for the pharynx. The calcarious ring is composed of alternating larger radial plates, opposite to the ambulacra and smaller inters radial plates (Figure 9). Longitudinal muscles are attached to the radial plates. In most species, the buccal podia and mouth can be retracted completely into the trunk when the animal is disturbed. Protrusion result from circular-muscle contraction and result in elevation of the coelomic fluid pressure.

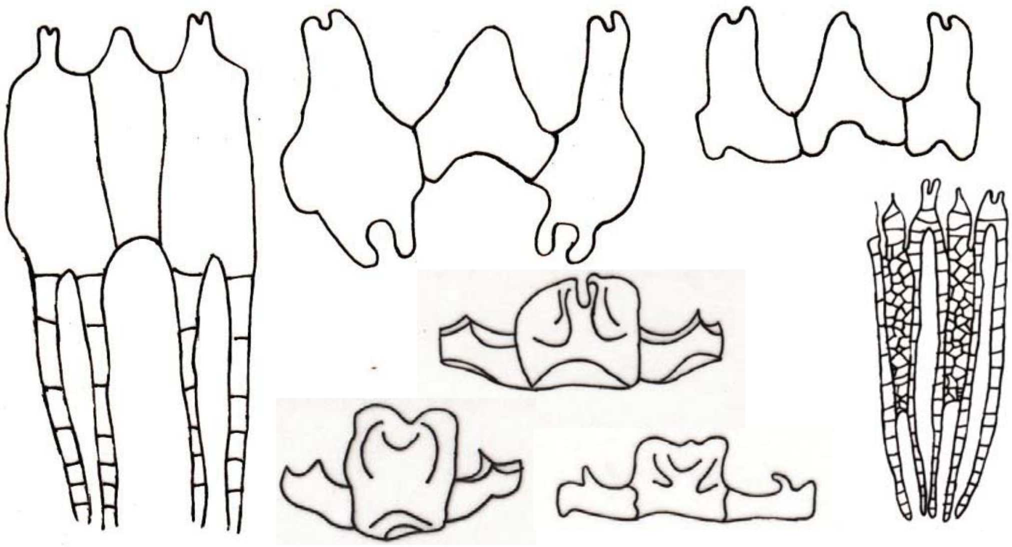


Figure 9. Different types of calcareous rings found in sea cucumbers

The pharynx opens into a short inconspicuous esophagus and then into a stomach. The stomach is absent in many holothuroids, but when present it is muscular and lined with a thick cuticle.

The rest of the gut is a long endodermal intestine which is thrown into a single major s-shaped bend before joining the anus.

From the stomach, the anterior intestine extends posteriorly as the descending anterior intestine, turns 180^0 anteriorly and continues as the ascending anterior intestine, which then turns 180^0 posteriorly to become the posterior intestine, which joins the cloaca and anus. The cloaca is an expanded rectum like chamber preceding the anus.

Digestion in sea cucumbers

Endocytosis and intracellular digestion occur. The pharynx and esophagus secrete mucus. The chief function of these structures are transporting the food towards the stomach. The stomach is a gizzard like structure, which triturates the food; if the stomach is absent, the pharynx may perform this function. Feces are formed in the cloaca or rectum.

In general, sea cucumbers are deposit or suspension feeders using their extended buccal podia. Once the podia have gathered food, they are stuffed into the pharynx, one at a time, and the adhering food particles are wiped off as the podia are withdrawn from the mouth. Suspension feeders have branched (dendritic) buccal podia and are represented by many sedentary burrowers and crevice dwellers, including species of *Sclerodactyla*, *Thyone*, *Eupentacta*, and *Cucumaria*. Mobile deposit feeders are generally epibenthic animals. Most have soles and stout buccal podia with broad mop like ends such as *Stichopus*, *Holothuria*, *Actinopyga* and the deep-sea elasipods.

Repoduction in sea cucumbers

Most species are dioecious, with separate male and female individuals. The reproductive system consists of a single gonad, consisting of a cluster of tubules emptying into a single duct that opens on the upper surface of the animal, close to the tentacles. Fertilization is external; takes place in the sea water. Most sea cucumbers reproduce by releasing sperm and ova into the ocean water. Depending on conditions, one organism can produce thousands of gametes. Some species catch the fertilized eggs with their buccal podia and transfer them to the dorsal body surface for incubation. At least 30 species, including the *Pseudocnella insolens*, fertilize their eggs internally and then pick up the fertilized zygote with one of their feeding tentacles. The egg is then inserted into a pouch on the adult's body, where it develops and eventually hatches from the pouch as a juvenile sea cucumber. Few species show viviparity. Fertilized eggs passed into the coelom and after development young sea cucumbers ruptures the body wall of (female) mother and comes to the external environment, for example *Thyone rubra* in California and *Leptosynapta* in North Sea.

Life cycle of sea cucumbers

In all other species, the egg develops through the process of gastrulation into a free-swimming larva, typically after around three days of development (Figure 10). The first stage of larval development is known as an auricularia, which have a ciliated band arranged in a characteristic form around the extremities of the body. The larva has a complete functional digestive tract with a large ciliated stomodeum, an esophagus, a stomach, an intestine, and an anus.

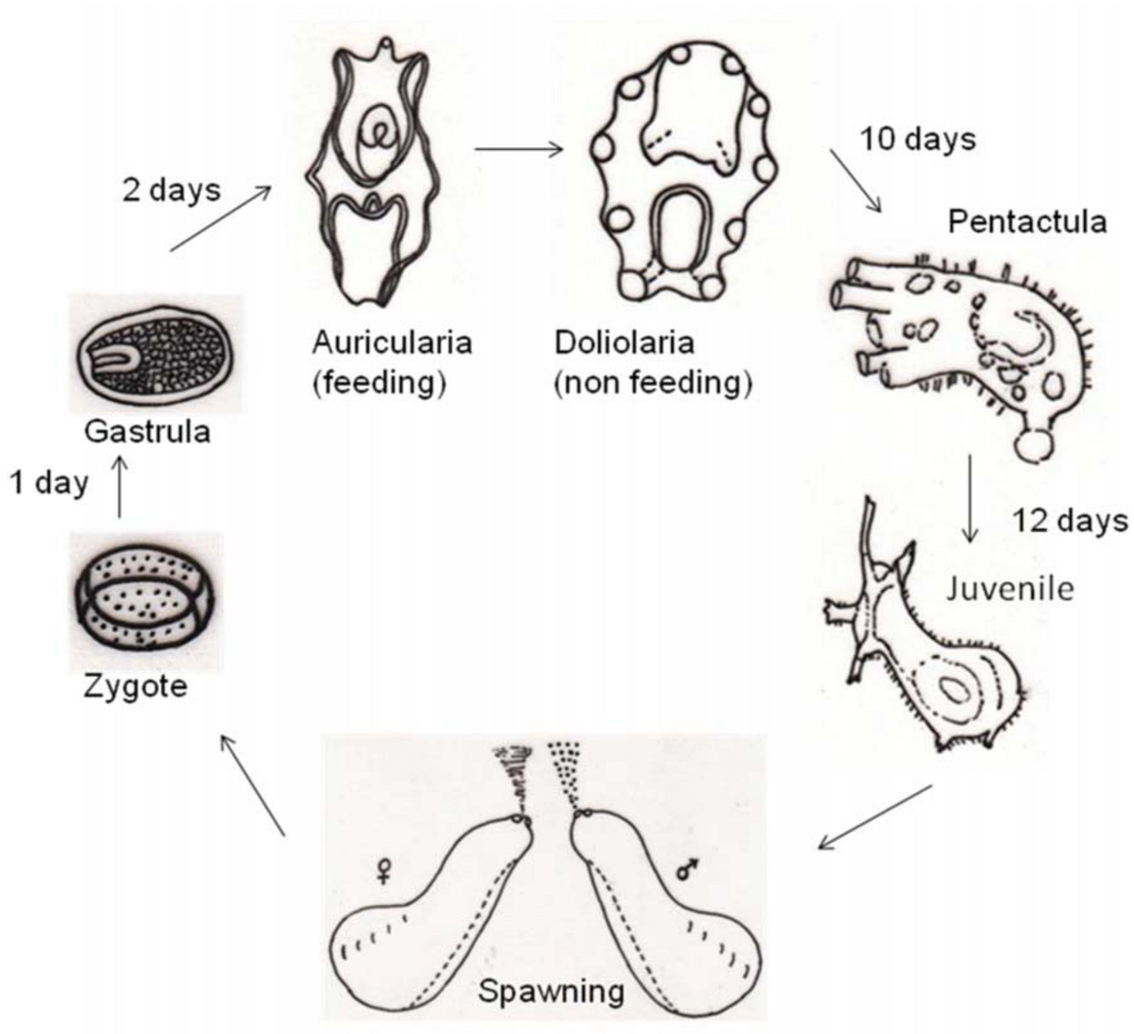


Figure 10. Life cycle of *Holothuria scabra*

As the larva grows it transforms into the doliolaria, with a barrel-shaped body and three to five separate rings of cilia. The tentacles are usually the first adult features to appear, before the regular tube feet. The doliolaria larva is typically less than half the size of the auricularia. The auricularia has ciliated locomotor band, then further develops into a larval stage called a doliolaria. The larva consists of ciliated band, which broken up into three to five ciliated girdles. It develops gradually into pentacularia. The pentacularia is the third larval stage of sea cucumber, where the tentacles appear. The tentacles are usually the first adult features to appear, before the regular tube feet. After larval metamorphosis, the young sea cucumbers ultimately settle on the substrate and become adults (Figure 10).

The water vascular system

The water vascular system (Figure 11) consists of a lumen of the buccal tentacles and the podia, a water ring around the esophagus, the radial canals, the madreporite canal and the Polian vesicles. The perivisceral coelom is a large cavity containing watery proteinaceous coelomic fluid and different forms of cells. The haemal system is well developed and composed of large haemal vessels along the gut, sinus and lacunae. The haemal vessels associated with the gut can form a complex meshwork with the left respiratory tree, the rete mirabile, suggesting different functions of nutrient and gas transfers.

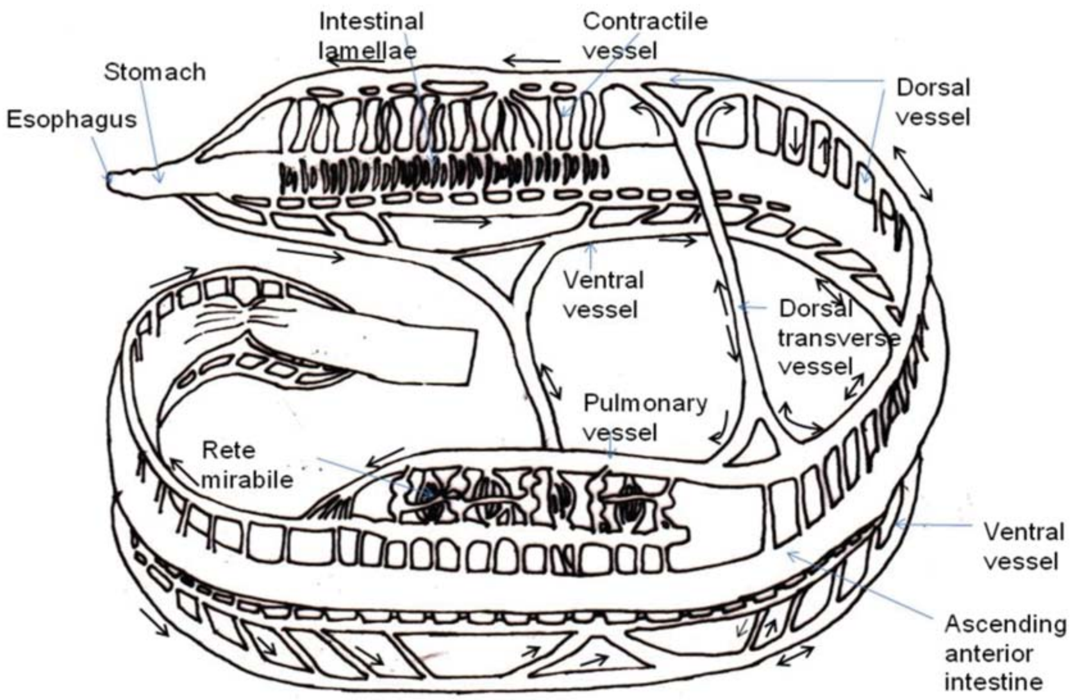


Figure 11. Water vascular system of a sea cucumber

Chapter 2

Species diversity and abundance of sea cucumbers

2.1 Field survey of the Jaffna Lagoon

Discussion with fishermen, fishermen co-operative societies and government officials

Two discussion meetings with either the Presidents or the Secretaries of Fishermen Co-operative Societies, Fishermen and Fishery Inspectors were held. One discussion meeting with Assistant Director of Department of Fisheries and Aquatic Resources and Assistant Director of National Aquatic Development Authority (NAQDA) was held. Sampling sites were chosen based on information gathered at the interviews and discussions with fishermen / Fishery Inspectors / Assistant Directors (Figure 12). Nautical charts were used for demarcation. From the discussion meetings eleven sites were demarcated. Those are Naachchikkuda, Pallikkuda, Kakkadativu, Palaitivu, Kurunagar, Mandaitivu, Allaipitty, Navanthurai, Kakkaitivu, Velanai and Sangupitty. Among them only seven sites such as Kurunagar, Mandaitivu, Allaipitty, Navanthurai, Kakkaitivu, Velanai and Sangupitty are within the Jaffna Lagoon. GPS positions of possible sea cucumber sites from the fishermen's diary were also collected to demarcate the sites.

a. Interviewing the fishermen

b. Meeting with the fishermen co-operative society members and government officials at the FFCSU

Figure 12. Gathering information to demarcate the survey locations

Lengthy trip for identification of sampling sites

Three lengthy trips were made along the lagoon to identify sampling sites. In the first lengthy trip places such as Kurunagar, Kallady, Mannithalai Aaru, Vajiruveenki, Pasaioor and Kolumputhurai were visited on 07th November 2013. In the second lengthy trip Pannai, Madaitivu, Navanthurai, Kakkaitivu and Araly were visited on 18th November 2013. The third trip was on 06th December 2013, during this trip Kolumbuthurai, Ariyalai and Poompuhar were visited. On 05th December 2013, the government announced cyclone alert for 48 hours to fishermen and it was rainy and windy on that day. A lengthy trip was under taken on 06th December 2013 and it had been accompanied by two members from the funding agency.

Fiberglass boat with outboard motor was hired during the lengthy visits. Two skin divers (Figure 13) were hired during each trip. Significantly, scuba divers are not in operation at the Jaffna Lagoon. Ministry of Fisheries, Sri Lanka granted permission only for skin divers without cylinders to operate in Jaffna. In Jaffna District only 350 fishermen were granted permission by the Director General, Department of Fisheries and Aquatic Resources, Colombo – 10 for harvesting sea cucumbers in 2013 (Source: Department of Fisheries and Aquatic Resources, Jaffna).

a. A skin diver ready to dive

b.Sea cucumber collection by skin diving

Figure 13. Collection of sea cucumbers by skin diver

2.2 Fortnight sampling, collection of samples and identification

Once the sampling sites have been identified by discussion at the meetings and the lengthy visits, fortnight sampling of sea cucumbers was made at the appropriate available or possible culture sites. Altogether thirteen field visits were made fortnightly during the six months study period from 21st October 2013 to 21st April 2014. During the thirteen visits, samples were collected from randomly selected 29 locations (Figure 14; Table 5). The field visits mainly concentrated on availability of sea cucumbers for species diversity studies as well as the stock abundance of sea cucumbers. All sites identified during the discussion meetings were visited. In addition to that some more sites were visited in order to study the water quality parameters and lagoon bed features to determine the suitability for sea cucumber culture and identify suitable areas for sea cucumber culture.

The boat was anchored at randomly selected locations. Sea cucumber abundance and distribution analysis was done in the lagoon near to the Jaffna Peninsula. Sea cucumber is sessile and shares a temporal and special specific distribution in the marine benthic environment.

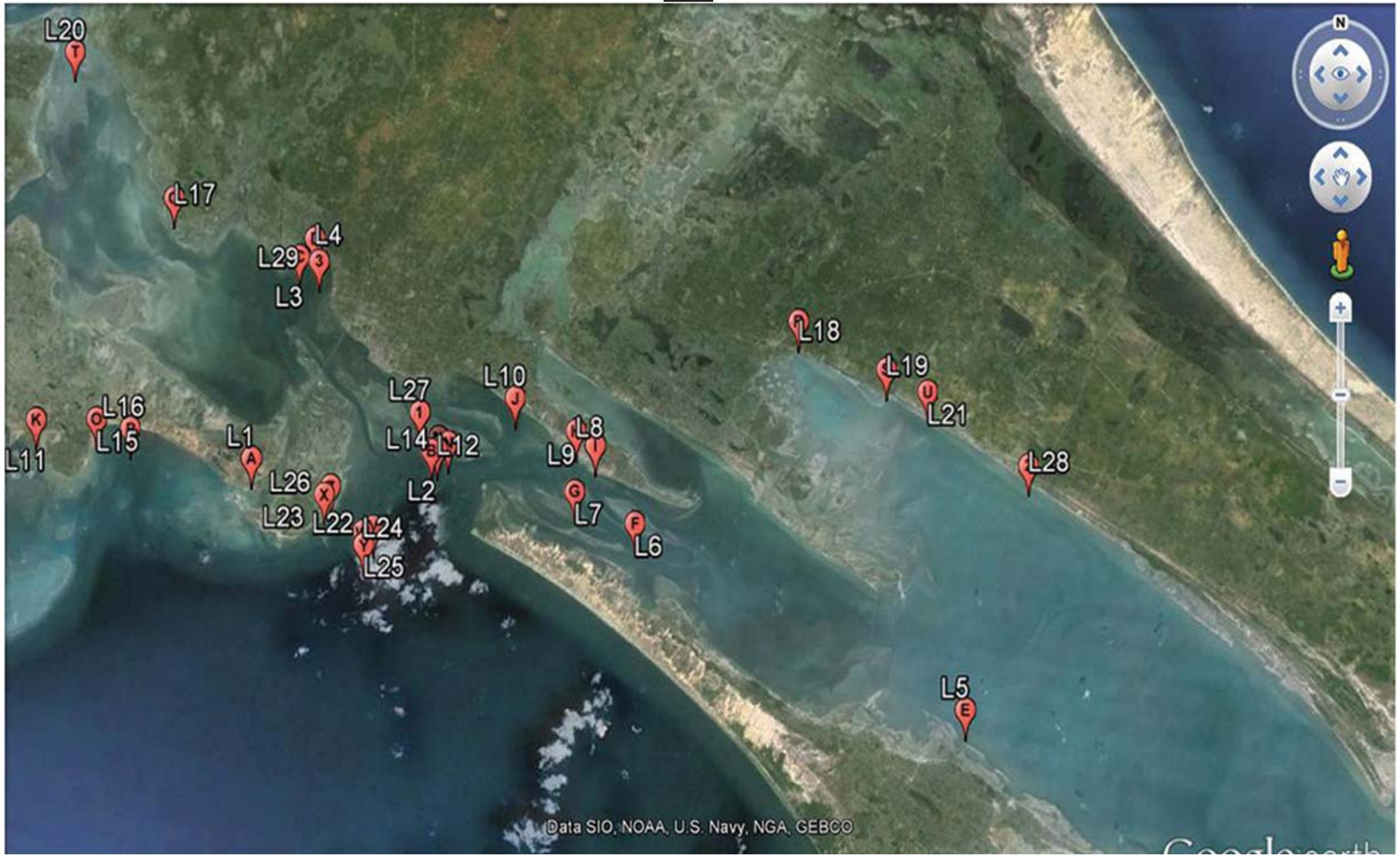


Figure 14. Sampling sites visited to collect sea cucumbers in the Jaffna Lagoon

Table 5. Names of the sites, L1 – L29 visited during the study period		
No.	Name of the site	Major landing center it belongs to
L1	Allaipitty	Velanai
L2	Kallady I	Kurunagar
L3	Madaaruku	Kakkaitivu
L4	Irandam Kaddai	Kakkaitivu
L5	Nagathevanthurai	Changuppitty-Pooneryn
L6	Kowtharimunai	Changuppitty-Pooneryn
L7	Poovarasamtivu	Changuppitty-Pooneryn
L8	Ariyalai	Columbuthurai
L9	Poompuhar I	Columbuthurai
L10	Poompuhar II	Columbuthurai
L11	Velanai I	Velanai
L12	Kallady II	Kurunagar
L13	Mannithalai Aaru	Kurunagar
L14	Vajiruveenki	Kurunagar
L15	Chettypulam	Velanai
L16	Velanai II	Velanai
L17	Aralythurai	Araly
L18	Chavakachcheri	Chavakachcheri
L19	Kachchai	Chavakachcheri
L20	Ponnalaithurai	Ponnalai
L21	Ketpali	Paalaavi
L22	Mandaitivu I	Mandaitivu
L23	Mandaitivu II	Mandaitivu
L24	Mandaitivu III	Mandaitivu
L25	Mandaitivu IV	Mandaitivu
L26	Mandaitivu V	Mandaitivu
L27	Mugathuvaram	Mandaitivu
L28	Vidaththal palai	Palai
L29	Navanthurai	Navanthurai

Sea cucumbers are not evenly distributed in the sea bottom. It holds a specific patchy distribution at the bottom. The hired divers actively participated in the survey activities. The research staff accompanied in the boat recorded and navigated the sampling sites (Figure 15) by using hand held GPS 12 Channel (GARMIN, USA). At each site fishermen were interviewed to gain more information about the fishing ground and habitat types.

Sea cucumber fishing is often carried out by skin diving in the Jaffna Lagoon. As such a survey was carried out in the present study by Underwater Visual Survey (UVS) with the help of skin divers as it is the most suitable technique to assess the populations which possess sedentary behavior.

2.3 Sea cucumber abundance

An attempt was made to count the number of sea cucumbers within 1 m^2 transect. It was not possible to collect or count the numbers due to the nature of its abundance. Most of the time efforts end up with ‘zero’ results. Therefore, divers dived and collected the samples within the 6 m x 200 m area and individuals per hectare were then computed.

The methodology which is used to study the pattern of distribution and abundance of sea cucumber is specific sampling design, which is self-fitted to the sea cucumber species. Using the longitudes and latitudes the exact point of location was demarcated, here. Likewise many samplings were done in different GPS locations. The population of sea cucumbers is expected to show an aggregated abundance regarding the depth and bottom characters.

From the recorded point two poles were used for demarcation of 200 m sampling strip at a width of 6 m (length of the boat). Then the skin divers were allowed to dive and collect samples along the 200 x 6 m^2 band strip. Divers dived and collected the samples within the 6 m x 200 m area and individuals per hectare were then computed. An underwater visual census (UVC) method (Curtis *et al.* 2004), was carried out to assess the status of sea cucumber in all the sampling sites.

Collected samples were identified on the spot and recorded. One specimen in each species was taken to the lab and the rest were released into the sea again. Samples that

Figure 15. Sea cucumber collection and data recording

cannot be identified were brought to the laboratory for further analysis and identified by ossicle preparation. In the field, the specimens were buffered with Manganese chloride ($Mncl_2$), taken to the laboratory and preserved in 10% formalin.

Species identifications were made using books, scientific journal articles and correspondence with internationally-renowned taxonomists (Adithiya, 1969; Conand, 2008). The sea cucumber identification sheets prepared was also used in the field for the species identification.

Meanwhile bottom substrate within each transect was visually analyzed for the presence of corals, rubbles, sand, silt-mud, sea grass, seaweed and mangroves.

2.4 Reported sea cucumber species in the Jaffna Lagoon

Among the 29 locations visited, live sea cucumbers were collected only from 10 locations. Sixteen species included under three families Holothuriidae, Stichopodidae and Cucumariidae were collected during the field visits. Among the collected specimens *Actinopyga miliaris, Actinopyga spinea, Bohadschia atra, Bohadschia vitiensis, Holothuria atra, Holothuria lessoni, Holothuria leucospilota, Holothuria scabra, Holothuria* sp. (type 'Pentard') and *Holothuria spinifera* are classified under Holothuriidae*; Stichopus hermanni, Thelenota anax, Stichopus monotuberculatus, Stichopus naso* and *Stichopus horrens* are classified under Stichopodidae and *Athyonidium chilensis* is classified under Cucumariidae.

Map showing the sea cucumber sample collected locations and percentage abundance of identified species are shown in Figure 16. The collected species from each site, their common name, local name and commercial value are tabulated in Table 6. Description of each sea cucumber identified and their natural habitat are explained below and the photographs of live specimens collected are shown in Figures 17a, b, c and d.

Of the collected sea cucumbers, *H. scabra* was collected from 08 locations whereas *S. naso* was found in 06 locations. *A. miliaris, H. atra* and *H. leucospilota* were found only in 02 locations, all other species were found only in 01 location.

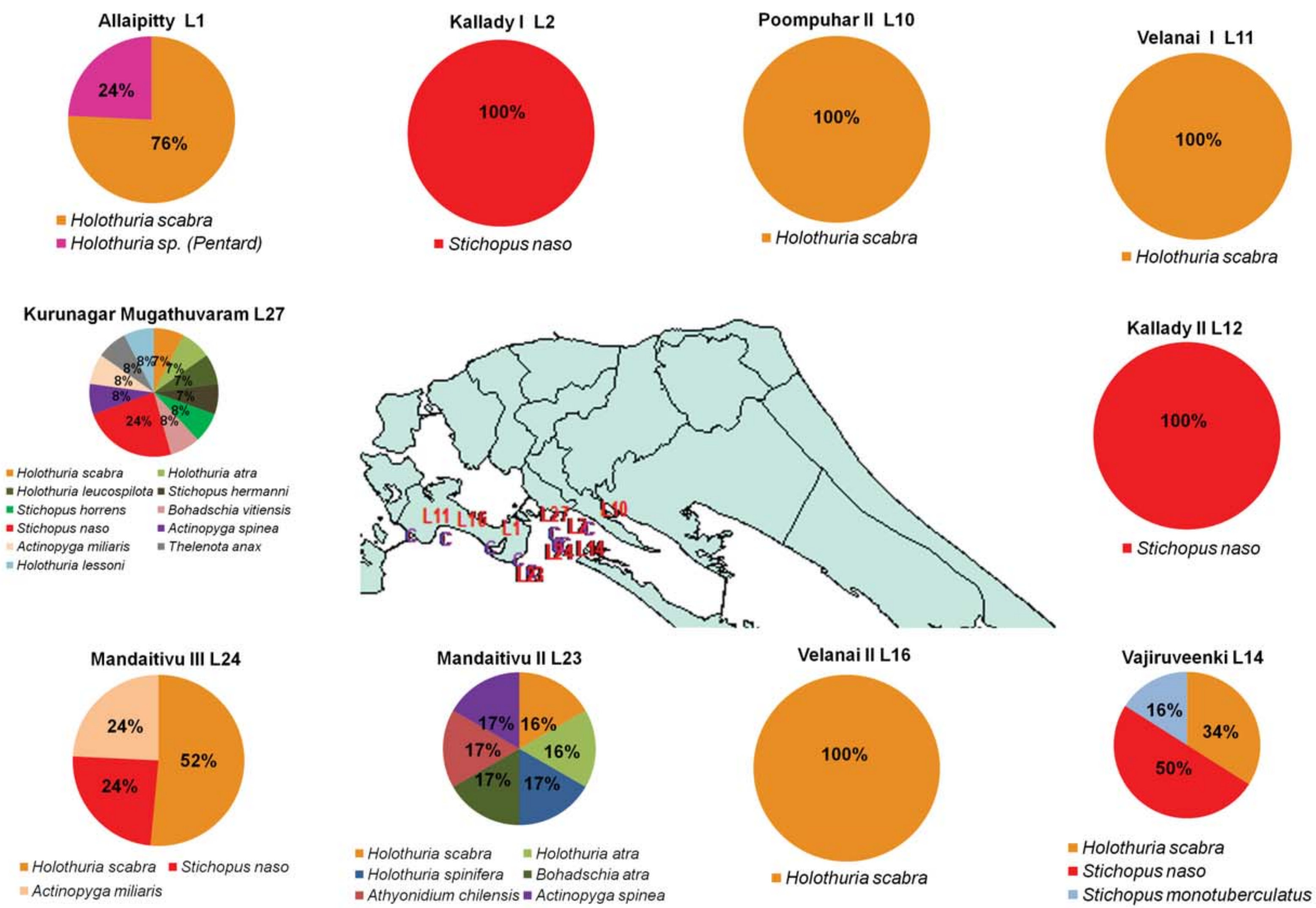


Figure 16. Sea cucumber locations and species abundance in the Jaffna Lagoon

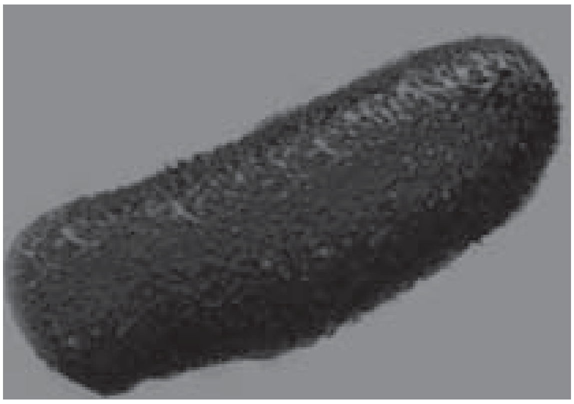
Table 6. Details of collected sea cucumber species from the Jaffna lagoon (L = Low value, M = Medium value, H = High value).

Species collected	Common name	Local name	Commercial value
Actinopyga miliaris	Black fish Hairy black fish	Karuppu attai	M
Actinopyga spinea	Burying black fish New Caledonia black fish	Karuppu attai	L
Athyonidium chilensis	Sea cucumber	--	L
Bohadschia atra	Tiger fish	--	L
Bohadschia vitiensis	Brown fish Brown sandfish	Nool attai	L
Holothuria atra	Black lollyfish Lollyfish	Kuchii attai	L
Holothuria lessoni	Golden sandfish	--	L
Holothuria leucospilota	White threadsfish	Paambu attai	L
Holothuria scabra	Sand fish	Vella attai Jaffna attai	H
Holothuria sp. (type 'Pentard')	Flower teat fish	Preema Bathik attai	H
Holothuria spinifera	Brown fish	Raja attai Disco attai	M
Stichopus hermanni	Curry fish	Mul attai	M
Stichopus horrens	Selanka's sea cucumber Warty sea cucumber (Ecuador), Dragonfish (India, Papua New Guinea),	Mul attai	L
Stichopus monotuberculatus	Warty sea cucumber	Mul attai	L
Stichopus naso	Warty sea cucumber	Mul attai	L
Thelenota anax	Amber fish	Poona attai	M

From the results, it can be inferred that the most abundant two species were *H. scabra* and *S. naso*. More attention is therefore paid to these two species for selecting suitable sites for culture.

Description of identified species and their natural habitat

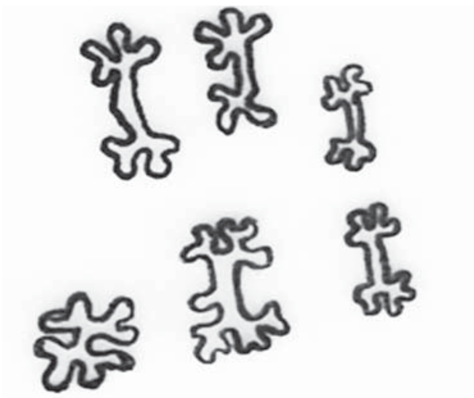
1. *Actinopyga miliaris* (Quoy and Gaimard, 1833)



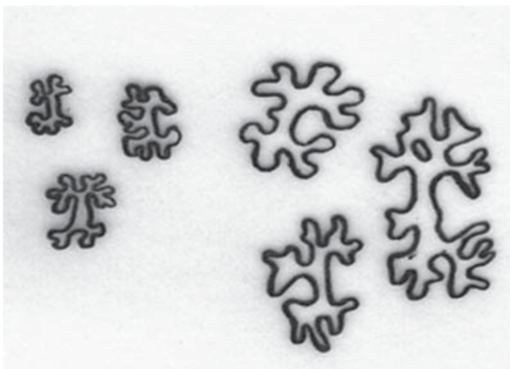
1.1 Habitat: It is found in sandy beds and sea grass bed with coral sand rubbles in shallow water between 0 and 5 m depth. It does not bury in sand.

1.2 Distinguishing characters:

Body of this species is slightly arched anteriorly, stout and cylindrical. The whole body of this species is uniformly brown to black in colour. Possesses very thick black tegument. It appears as hairy due to long slender podia around the body. Dorsal body of the species is covered by fine sand. Mouth ventral, and encircled by 20 stout, brown to black, tentacles. Yellow to orange 5 strong conical anal teeth are bordered in the anus. Dorsal and ventral body wall with similar rosettes. Dorsal papillae with rosettes of the same size as those in the body wall, and some are large rosettes.



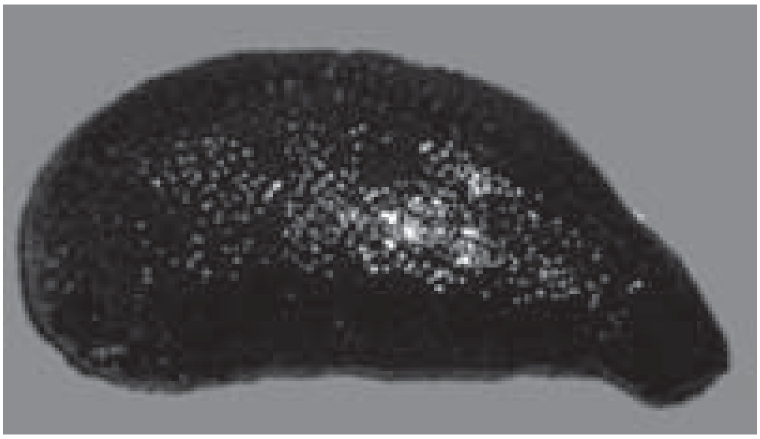
Spicules of dorsal and ventral body wall



Spicules of dorsal papillae

1.3 Size: Maximum length of the species is about 200 mm. Fresh weight is about 0.5 kg. It is distributed as school like *H. scabra*. It has moderate value and suitable for processing.

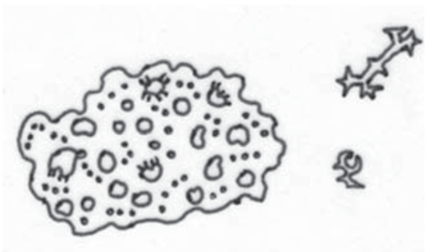
2. *Actinopyga spinea* (Cherbonnier, 1980)



2.1 Habitat: Commonly found on muddy-sand habitats, where it buries. It can occur in 1 to 5 m.

2.2 Distinguishing characters:

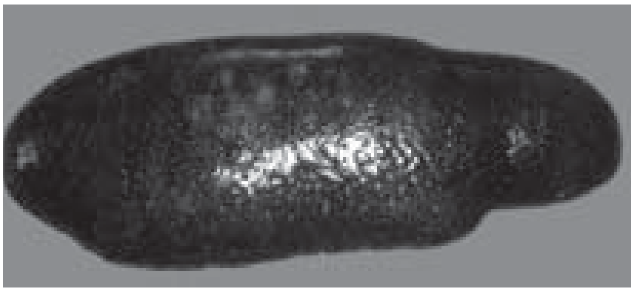
Body is subcylindrical and flattened slightly ventrally with numerous short ventral podia and covered by fine sand. Entire body is uniform rusty brown to dark brownish black in colour. Dorsal surface is covered by thin fairly long dorsal papillae. Mouth is surrounded by 20 dark brown tentacles. Anus subdorsal with five prominent, yellowish, nodular teeth. Dorsal body wall with few forked spiny rods, and spiny plates of various sizes.



Spicules of dorsal body wall

2.3 Size: Maximum length about 40 cm, commonly to about 30 cm; Fresh weight: 720 g.

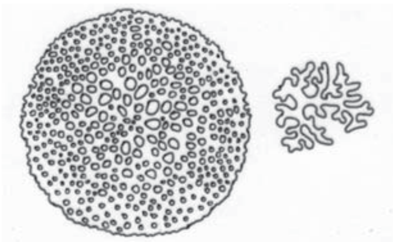
3. *Athyonidium chilensis* (Semper, 1868)



3.1 Habitat: It buries in the intertidal zone from 1 to 5 m depth in other rocky habitats with high quantity of detritus.

3.2 Distinguishing characters:

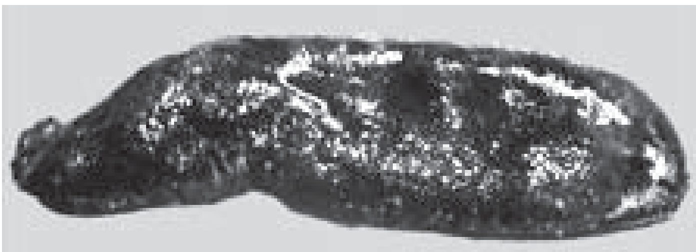
Body is cylindrical and narrowed in both end. Coloration is brown to grayish-brown, or light grey in adult but juveniles are greenish. Terminal mouth is surrounded by 5 pairs of greenish- black branched tentacles and arranged in two rows. Podia are arranged in longitudinal rows along the body wall. Dorsal and ventral body wall with perforated rods that are somewhat enlarged at the extremities. Ventral podia only have an end - plate.



Spicules of dorsal body wall

3.3 Size: Length about 30 cm, fresh weight: 250 g.

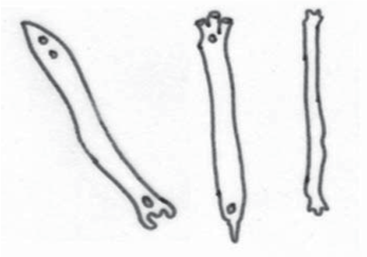
4. *Bohadschia atra* (Conand and Samyn, 1999)



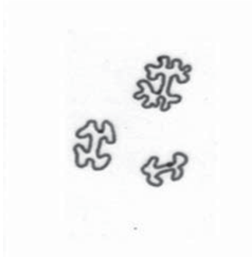
4.1 Habitat: They are found in shallow waters with seagrass beds and sandy areas .

4.2 Distinguishing characters:

Body is large and elongated cylindrical body arched dosally and flattened ventrally. Dorsal body surface contains dense podia and often covered by sediment. Colour is deep brown to black dorsally, with numerous brown to red spots surrounding black dorsal papillae. The ventral surface is light brown in colour. It is a relatively large holothurian. Mouth is ventral with 20 black tentacles. Anus is dorsal and devoid of anal teeth. Numerous cuvierian tubules are found. Dorsal body wall with relatively simple rosettes. Ventral podia with numerous straight rods.



Spicules of ventral podia

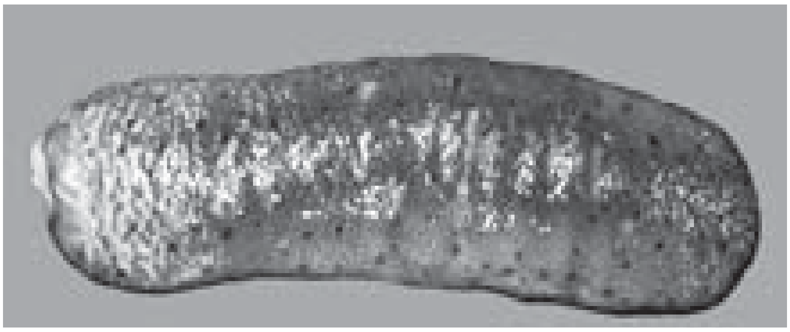


Spicules of dorsal body wall

4.3 Size: Body length up to 40 cm. Fresh weight: 500 g

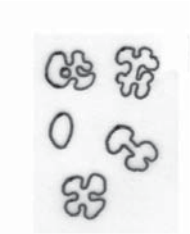
5. *Bohadschia vitiensis* (Semper, 1868)

5.1 Habitat: Found in shallow lagoon on sand and abundant in sandy muddy sediments where it buried. Found occasionally among coral and rubbles.

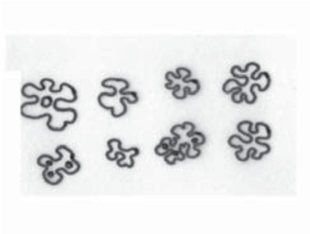


5.2 Distinguishing characters:

Body is oval and arched dorsally and flattened ventrally. Sometime covered by fine sediment. Cream yellow to brown with numerous brown to black spots dorsally and whitish ventrally. Mouth is ventral with 20 short yellowish tentacles. Anus is large and situated sub dorsally. Cuvierian tubules are numerous and large. It ejects cuvierian tubules when they are disturbed. Dorsal body wall with rather stout rosettes. Ventral body wall with grains that can be ovoid and more irregular shaped.



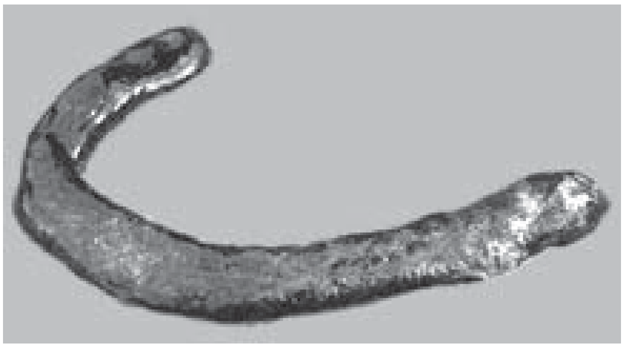
Spicules of ventral body wall



Spicules of dorsal body wall

5.3 Size: Maximum length is about 40 cm and reach nearly 400 and 800 g.

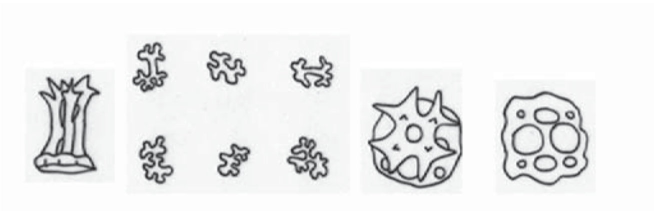
6. *Holothuria atra* (Jaeger, 1833)



6.1 Habitat: It is found in shallow lagoon, sand mud, and sea grass. Mostly inhabit areas with calcareous algae species.

6.2 Distinguishing characters:

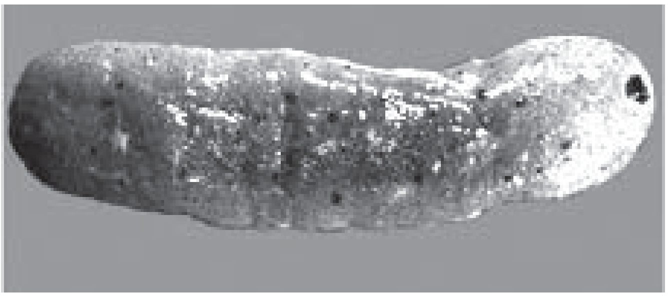
It possesses elongated cylindrical body, rounded in both ends. Entire body is uniformly black and some portions appear red in colour. This species can be distinguished from other species by reddish fluid or dye released from its body when rubbing or handling the body. Body is covered by sand. There are black tentacles. Dorsal and ventral body wall with same type of tables. Tables of ventral body wall with larger, more spinose disc. Ventral podia with pseudo - plates.



Spicules of dorsal body wall

6.3 Size: It can grow up to 400 mm in length and average weight of about 400 g.

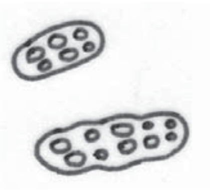
7. *Holothuria lessoni* (Massin, Uthicke, Purvell Rowe and Samyn, 2009)



7.1 Habitat: Commonly found in shallow water sea grass bed and muddy-sand habitats, where it buries during parts of the day. It occurs in 1 to 25 m depths.

7.2 Distinguishing characters:

Body is relatively stout and flattened ventrally and rounded in both end and covered by fine sediment and mucus. Dorsal surface is arched. Colouration variable from grey black to beige with black blotches and spots on dorsal and whitish or grey in the ventral surface. Vental mouth is surrounded by 20 dark short grey tentacles. Dorsal papillae are less in number, black in colour and fairly large, ventral podia are brownish in colour and fairly high in number. Terminal anus is surrouned by five group of papillae. Cuvierian tubules are absent. Dorsal body wall with buttons which have 3- 4 pairs of small holes. Ventral podia with tables and buttons as in body wall.



Spicules of ventral podia   Spicules of dorsal body wall

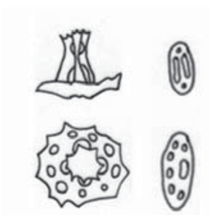
7.3 Size: Maximum length about 45 cm, commonly to about 27 cm; Fresh weight: 1000 g.

8. *Holothuria leucospilota* (Brandt, 1835)

8.1.Habitat: It is distributed along shallow coastal lagoon, seagrass beds, muddy and sandy bottom with rubble.

8.2 Distinguishing characters:

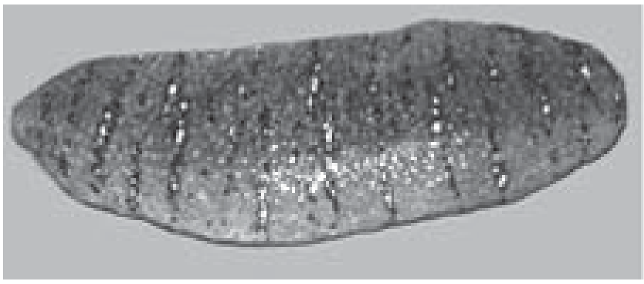
Body of the species is elongated tapering in both ends however posterior half of the body broader than the anterior region. Dorsal surface covered with long podia and papillae. Ventral podia are numerous. Body is uniformly black. Ventral mouth contains 20 large, black tentacles. Anus is terminal and long cuvierian tubules eject through anus. Dorsal and ventral body wall with similar buttons with 2- 5 pairs of irregular holes. Ventral podia with similar buttons and with large perforated plates.



Spicules of dorsal body wall   Spicules of ventral podia

8.3 Size: It can grow up to 450 mm in length with an average weight of about 400 g.

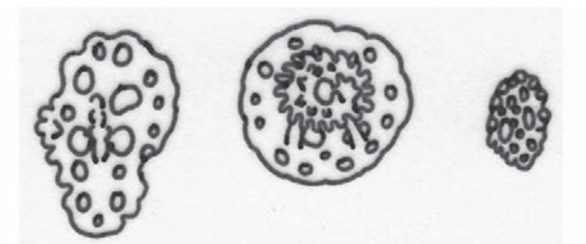
9. *Holothuria scabra* (Jaeger,1833)



9.1 Habitat: Mostly found in muddy sand substrates with sea grass beds. It prefers muddy sand however, it is also found in sandy bottom with less silt mud. In some sites adult and juvenile are buried under sand or mud. At most localities, it buries in sand or sandy mud. But occasionally, it lives in inter-tidal zone to about 10 m in depth. Juveniles are found near coastal shore and adults are found in deep area for reproduction in ground.

9.2 Distinguishing characters:

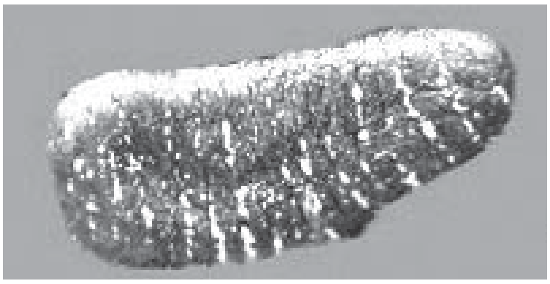
Body is oval and is often covered by fine sand. Dorsal surface of the body is arched with deep wrinkle and short papillae. Black to grey in colour with white or yellow transverse stripes, while the ventral surface is flattened, white with fine dark spots. Ventral mouth has 20 projecting small grayish tentacles with terminal anus not containing teeth. Dorsal and ventral body wall with tables and buttons. Ventral body wall tables are rare but in dorsal body wall have similar tables and smaller buttons.



Spicules of dorsal body wall

9.3 Size: It is the widely distributed species and has high market value in Jaffna district. It grows approximately to about 240 mm in length and maximum to about 400 mm length. Maximum fresh weight is up to 2 kg.

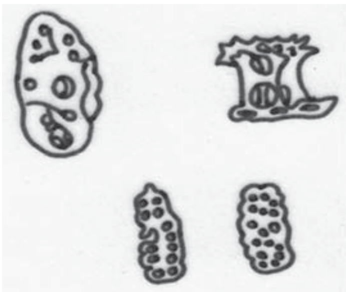
10. *Holothuria* sp. (type 'Pentard')



10.1 Habitat: It is found in lagoon over sandy bottoms between 5 and 50 m deep.

10.2 Distinguishing characters:

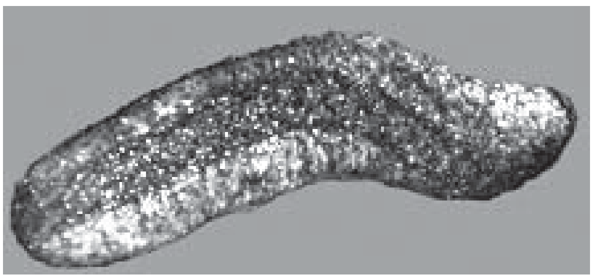
Body is oval. Dorsal surface is arched and mottled with irregular-shaped, cream coloured or light coloured blotches with dark brown dorsal surface, flattened ventrally. Dorsal body wall with buttons and simple ellipsoid buttons. Buttons are smooth with medium sized knobs which have 4 – 8 pairs of holes.



Spicules of dorsal body wall

10.3 Size: Fresh length is 30 cm. Fresh weight is about 1 675 g. It is a high value species.

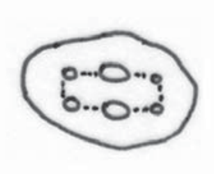
11. *Holothuria spinifera* (Theel, 1886)



11.1 Habitat: It is found in sandy shallow waters and completely buried under sand.

11.2 Distinguishing characters:

Dorsal surface of the body is brown in which the middle is dark brown and both sides are lighter brown; ventral surface become lighter in colour. The entire body is covered with finely sharp small papillae. It is one of the best species for processing. Dorsal and ventral body wall with the same type of tables and buttons. Buttons are very nodulous, generally with 3 pairs of holes. Characteristic for this species are large tack – like tables of the dorsal anal papillae.

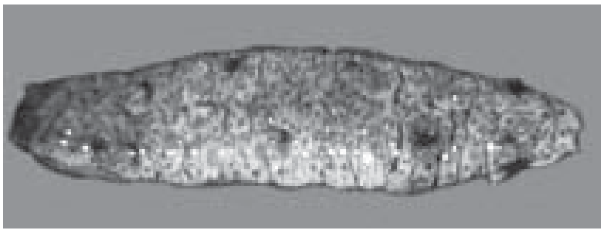


Spicules of dorsal body wall

Spicules of anal papillae

11.3 Size: Maximum length of the species is about 300 mm. Average weight of the species is 400 g. It is a medium value species.

12. *Stichopus herrmanni* (Semper,1868)



12.1 Habitat: It is found in shallow lagoons seagrass beds, rubble and sandy-muddy bottoms between 0 and 5 m.

12.2 Distinguishing characters:

Body is moderately elongate and quadrangular in cross-section. Colour varies from light mustard-yellow, light brown or olive green dorsally with two double rows of larger wart-like papillae, bordered by fine dark rings and lighter ventrally. Several black spots are scattered over the entire body; Podia are numerous ventrally. Body is relatively firm. Mouth is ventral with 8–16 stout green tentacles. Anus is terminal, with no teeth nor surrounding papillae. Dorsal and ventral body wall with the same type of tables, C- shaped rods and rosettes.

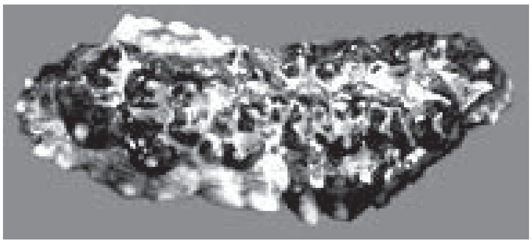
Dorsal papillae with C- shaped ossicles similar in size and shape as those of the body wall but tables up to twice the size as those of the body wall.

Spicules of dorsal body wall

Spicules of anal papillae

12.3 Size: Maximum size 55 cm, mostly 20–40 cm. Fresh weight: 1 000 g.

13.*Stichopus horrens* (Selenka, 1868)

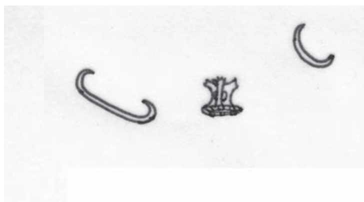


13.1 Habitat: This species found in rocky substrate combine with sandy bottom between 5 and 10 m depth.

13.2 Distinguishing characters:

Body long and narrow. The body of this species is grey to beige to black with blotches or band or greenish brown dorsally. Wart like papillae is found in two rows along the upper dorsal surface and a row of large papillae along the lateral margins of the ventral. Ventral podia are large and numerous. Ventral mouth contains 20 tentacles. Dorsal body wall with numerous tables and few C – shaped rods. Ventral podia with large perforated plates.

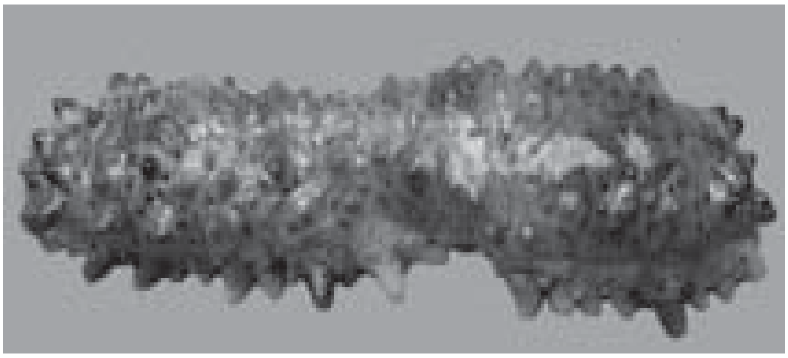
Spicules of ventral podia



Spicules of dorsal body wall

13.3 Size: The length of these species available in Jaffna is about 20 cm and the weight is about 200 g.

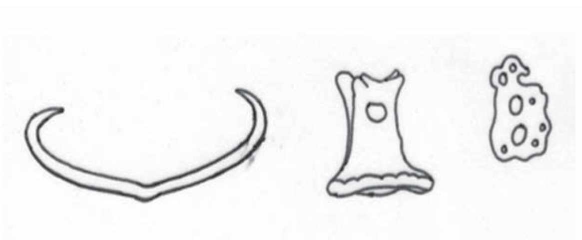
14.*Stichopus monotuberculatus* (Quoy and Gaimard, 1833)



14.1 Habitat: It is found in shallow lagoon. It hides in crevices at day time and comes out at night.

14.2 Distinguishing characters:

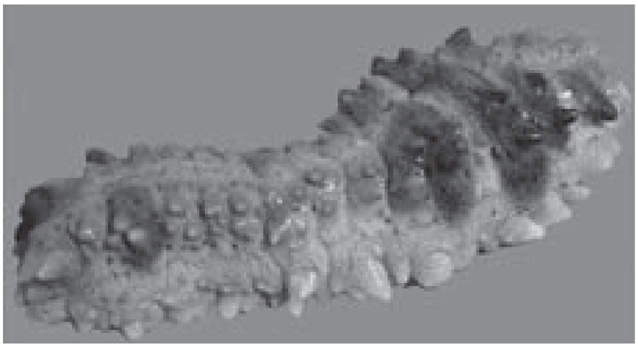
Body is trapezoidal to rectangular in cross section. The dorsal surface of the body is grey to beige to yellowish in colour with black blotch arranged in two rows along the body. Brown with black spots are scattered along the dorsal and ventral sides. Ventral side has three longitudinal rows of large podia and mouth surrounded by 20 tentacles. Prominent wart like papillae are found in the ventral side. Dorsal wall with tables, plate and C- shaped ossicles. Ventral body wall with tables of similar shape and size as those of the body wall.



Spicules of dorsal body wall

14.3 Size: Fresh length and weight of this species available in Jaffna is 20 cm and 200 g respectively.

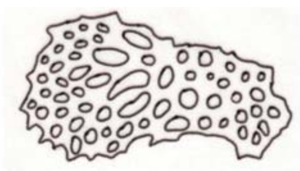
15. *Stichopus naso*(Semper, 1868)



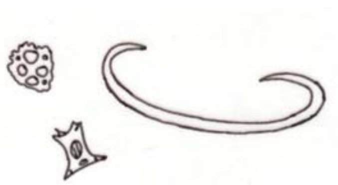
15.1 Habitat: It is found in shallow water which is 20 m in depth with sea grass bed. It has low market value.

15.2 Distinguishing characters:

Body is trapezoidal to rectangular in cross section. Dorsal surface of the body is light or dark brown or grey with yellow in colour. Laterally lighter and ventral surface light brown in colour. Longitudinal band running between the rows of podia, the tip of the papillae is dark in colour. Tips of podia and dorsal papillae are dark brown. Small specimens are nearly uniformly grey, sometimes with a pair of reddish dorsolateral papillae. Fission products appear truncate anteriorly or posteriorly. Dorsal surface is lightly arched with squat, conical dorsolateral papillae. Individuals of this species are usually relatively small. Numerous, large podia are arranged in longitudinal rows and occur on the ventral surface. The mouth is ventral with 18–20 tentacles. Anus terminal and unguarded by papillae. Dorsal body wall with tables, rosettes and C- shaped rods. Ventral and dorsal podia has perforated plates with spiny edges.



Spicules of ventral podia



Spicules of dorsal body wall

Spicules of dorsal papillae

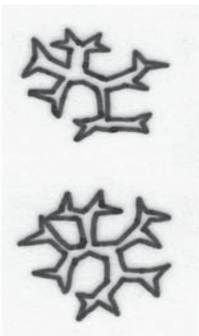
15.3 Size: Maximum length of this species is 20 cm and fresh weight of this is about 200 g.

16. *Thelenota anax* (Clark,1921)

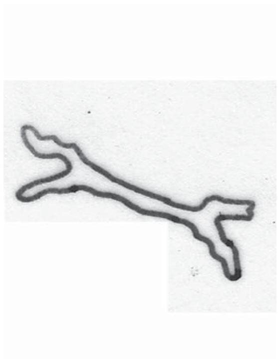
16.1 Habitat: It is found in shallow lagoons on sandy bottoms or hard bottom between 4-5 m depth.

16.2 Distinguishing characters:

Body is quadrangular in cross-section. Body is creamy white beige to light brown with dark brown or black and blotches dorsally. In dorsal side number of light coloured wart-like thickening occurs mostly in rows along either side of the dorsal surface. Large, white papillae are located along the ventro-lateral margins. Ventral surface is flat and contain numerous long podia. The mouth is ventral and is surrrounded by 18–20 tentacles. The anus is terminal. Ventral and dorsal body wall with dichotomously branched rods.



Spicules of dorsal and ventral body wall



Spicules of ventral podia

16.3 Size: Maximum length: 89 cm

Summary of ecological information of the collected sea cucumber species from the Jaffna Lagoon, species collected and their geographical distribution are summarized in Table 7.

Table 7. Summary of ecological information for collected sea cucumber species from the Jaffna Lagoon (W = Wide distribution, R = Restricted to few locations)

Species collected	Locations collected	Geographical distribution	Habitat	Substrate
Actinopyga miliaris	Mandaitivu II Mugathuvaram	R	Sea grass	Silt mud coral and rubble
Actinopyga spinea	Mugathuvaram	R	Sea grass	Silt mud coral and rubble
Athyonidium chilensis	Mandaitivu II	R	Sea grass and sea weed	Silt mud and coral
Bohadschia atra	Mandaitivu II	R	Sea grass and sea weed	Silt mud and coral
Bohadschia vitiensis	Mugathuvaram	R	Sea grass	Silt mud coral and rubble
Holothuria atra	Mandaitivu II Mugathuvaram	R	Sea grass and sea weed	Silt mud and Coral
Holothuria lessoni	Mugathuvaram	R	Sea grass	Silt mud, coral and rubble
Holothuria leucospilota	Mandaitivu II Mugathuvaram	R	Sea grass and sea weed	Silt mud and Coral
Holothuria scabra	Allaipitty I, II Poompuhar III Vajiruveenki Velanai Mandaitivu I, II Mugathuvaram	W	Sea grass	Silt mud
Holothuria sp. (type 'Pentard')	Allaipitty I	R	Sea grass	Silt mud
Holothuria spinifera	Mandaitivu II	R	Sea grass and sea weed	Silt mud and Coral

Stichopus hermanni	Mugathuvaram	R	Sea grass	Silt mud, coral and rubble
Stichopus horrens	Mugathuvaram	R	Sea grass	Silt mud, coral and rubble
Stichopus monotuber-culatus	Vajiruveenki	R	Sea grass	Silt mud
Stichopus naso	Kallady I, II Vajiruveenki Mandaitivu II Mugathuvaram	W	Sea grass	Silt mud and coral
Thelenota anax	Mugathuvaram	R	Sea grass	Silt mud, Coral and rubble

Among the sixteen species reported during the present study, seven species *Stichopus naso*, *S. monotuberculatus, H. lessoni, S. horrens, A. chilensis, A.spinea* and *B.vitiensis* are recorded for the first time in Sri Lanka.

From the results it can be inferred that *H. scabra* is the most abundant species, widely distributed, found in majority of the studied locations. *H. scabra* are the large, thick walled sea cucumbers, fetch a high price in the market, and hold high consumer demand in all Asian Countries. It is amazing that this species is abundant in the Jaffna Lagoon as well as off Jaffna Lagoon but scarcely found in western and eastern part of Sri Lanka. It is often called as “Jaffna attai” in the Northern part of Sri Lanka. Eventhough it prefers muddy sand bottom it can live in sandy bottom, too.

The next abundant species is *S. naso*, which is also found in muddy sand with coral reefs. It could be noted that this species is reported in the IUCN red list as the least concern or extant species (http://www.iucnredlist.org/details/180476/0). Interestingly it was collected from five locations out of ten locations sampled and ranked second in the abundant list. The reason for no records of this species is due to lack of studies carried out in the Northern coastal waters due to the conflict situation that prevailed since 1983.

Based on the present study, site selection for the two species *H. scabra* and *S. naso* is considered in detail during the workshops with stake holders and the guidelines for culture in the Jaffna Lagoon finalized.

Actinopyga miliaris
(live)

Actinopyga spinea
(live)

Athyonidium chilensis
(live)

Bohadschia atra
(live)

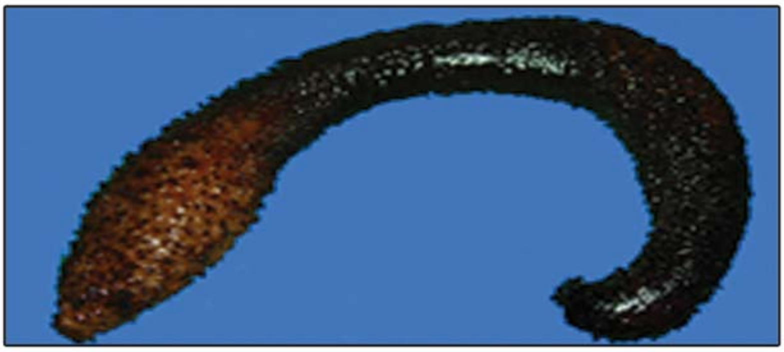
Figure 17a. Collected sea cucumbers from the Jaffna Lagoon

(Photo by : Sivashanthini . K)

Bohadschia vitiensis
(live)

Holothuria atra
(live)

Holothuria lessoni
(live)



Holothuria leucospilota
(live)

Figure 17b. Collected sea cucumbers from the Jaffna Lagoon (continued)

(Photo by : Sivashanthini . K)

Holothuria scabra
(live)

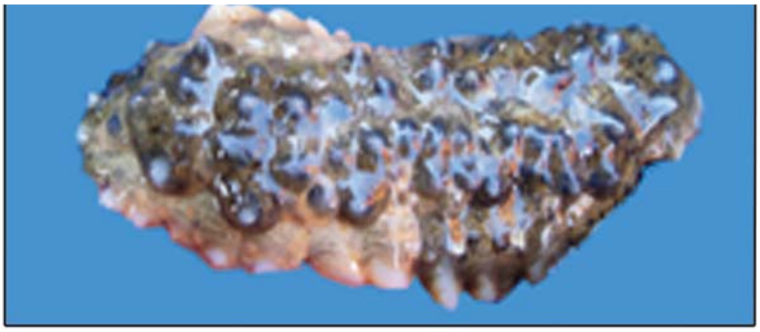
Holothuria sp. (Pentrad)
(live)

Holothuria spinifera
(live)

Stichopus hermanni
(live)

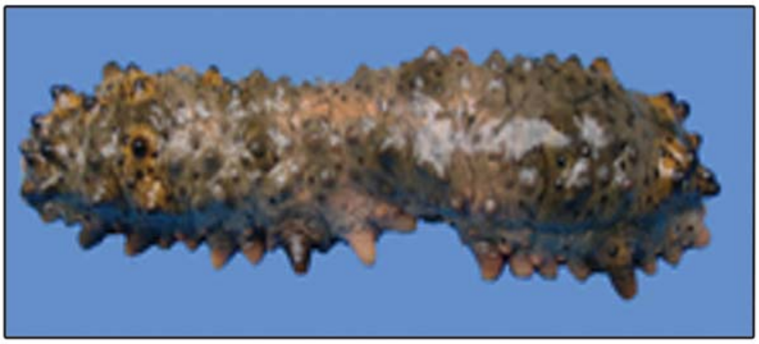
Figure 17c . Collected sea cucumbers from the Jaffna Lagoon (continued)

(Photo by : Sivashanthini . K)



Stichopus horrens

(live)



*Stichopus monotuber-
culatus*

(live)

Stichopus naso

(live)

Thelenota anax

(live)

Figure 17d . Collected sea cucumbers from the Jaffna Lgoon (continued)

(Photo by : Sivashanthini . K)

2.5 Summary

In 1983, Elanganayagam performed a diversity study on sea cucumbers from Sri Lanka. In her study she found that the numerical abundance of *H. scabra* from the Jaffna Lagoon for the period between 1980 and 1981 varied between 20 and 160 individuals per square meter (Elanganayagam, 1983). Comparison of this result with that of the present study revealed, that there is a major decline in stocks over the past three decades.

Considering the available information from the different countries on densities, CPUE, catches and other more or less anecdotal information, the status of sea cucumber resources in the region is summarized by Toral-Granda *et al*., 2008. According to Toral-Granda *et al*., (2008) it appears that in Sri Lanka the sea cucumber resources are presently over-exploited (at least for the main commercial species).

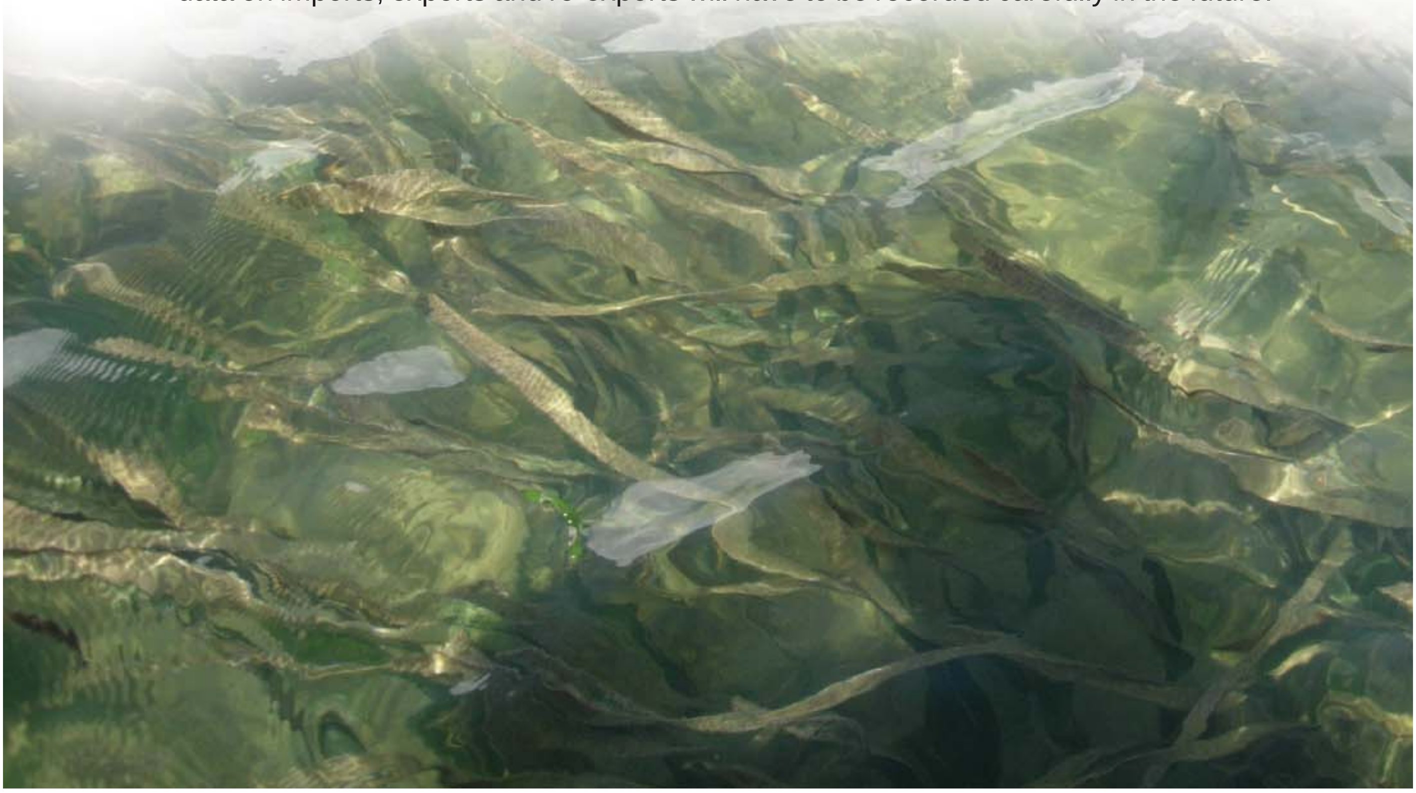
There are no large scale assessments of stocks of sea cucumbers in Sri Lanka as for marine finfish. Therefore there are no definite management measures implemented in the country except issuing license for divers, processors and exporters.

As sea cucumbers have become rare in the shallow habitats recently, fishermen move towards distant locations for their fishery. The fishery is open access and no regulation or precautionary approach is used for management. The fishery is totally unregulated. There are indications for population depletion especially for high value species and subsequently fishermen travel further distance for collection. The sustainability of the fishery is an urgent concern.

In Jaffna District, in 2010 there were only 05 multiday boats whereas in 2014 there are 43 (Source: Department of Fisheries and Aquatic Resources, Jaffna). OFRP boats that were in operation in 2010 were 2046 and in 2014 it was 3647 (Source: Department of Fisheries and Aquatic Resources, Jaffna). It is an indication of increasing fishing effort and harvesting more resources in Jaffna District at present. However these fishing vessels are not harvesting only sea cucumbers but they undergo multispecies fishery. At some occasions trawlers catch sea cucumbers as by-catch species. On the other hand some valuable marine resources, sea turtle, lobsters and rock fishes are fished along with the sea cucumber fishery.

Poaching is another major threat to sea cucumber resources, Indian trawlers which intrude into Sri Lankan territory drag the bottom and fished out most of the sea cucumber resources whereas trawl fishing is again banned in Jaffna, since 15th of February 2014. This problem has to be rectified by some diplomatic talks between both countries in order to sustain the resources of Northern Sri Lanka.

Customs statistics for the whole country suggests that import of sea cucumbers in Sri Lanka commenced in 1996, with small quantities from the Maldives (collected by Sri Lankans) for processing and re-export. The imported quantity gradually increased to 23 609 kilograms in 2000. The source of imports has not been established, but probably reflects clandestine operations. This makes the interpretation of the available data difficult. Hence data on imports, exports and re-exports will have to be recorded carefully in the future.



Chapter 3

Ecological status of selected sites

3.1 Habitat of sea cucumbers

Holothurians are found throughout all oceans and seas, at all latitudes, from the shore down to abyssal plains (Purcell *et al.*, 2012), but their greatest abundance occurs in the tropical Indo-Pacific region (Conand, 2004). They are highly diverse and abundant, and play crucial roles in the recycling of nutrients in marine benthic communities (Preston, 1993). The adult stages living on the sea bottom are benthic. Some species live on hard substrates, rocks, coral reefs, or as epizoites on plants or invertebrates. Most of the species inhabit soft bottoms, or sediment surfaces or buried in the sediment (Purcell *et al*., 2012). Few sea cucumber species are found in muddy habitats, despite the abundance of organic detritus (Zhou and Shirley, 1996; Dissanayake and Stefansson, 2012). In sandy or muddy biotopes, the distribution of particle sizes, richness in bacteria and organic matter – the components of the nutritional composition of the sediment are important factors in determining the distribution of adult holothuroids. In rocky biotopes where there is little sediment, the presence of numerous microhabitats seems to be more important than the amount of food available (Massin, 1982).

Number of studies on holothurians have indicated that the selection of habitat is for smaller or larger grain sizes (Rhoads and Young, 1971; Hauksson, 1979; Roberts, 1979). This habitat selection feature has been mainly attributed to the organic material content and particle size of the sediment (Dissanayake and Stefansson, 2012 ; Zhou and Shirley, 1996). A main component of formulated feeds in sea cucumber aquaculture (Liu *et al*., 2009; Xia *et al*., 2012) is mud rich in microalgae and decaying organic matter. Due to the increasing demand for raw materials, most sea cucumber species, including undersized animals, have been exploited indiscriminately, resulting in overexploitation and depletion of stocks in many parts of the world (Bruckner, 2006 ; Conand, 2004; Lovatelli *et al.*, 2004). Therefore, the depleted population has to be restored by making efficient aquaculture and stock enhancement programmes.

3.2. Water quality parameters in the Jaffna Lagoon

Physical parameters, such as salinity, water temperature, turbidity of the water and depth at which species occur, as well as nutrient composition, may have a direct impact on sea cucumber distribution and occurrence (Katrin, 2013). Water samples were collected from the surface water in each location. Physico-chemical parameters such as water temperature, salinity, pH and oxygen content were measured using portable instruments (Figure 18). Salinity (in ppt) was estimated using a hand held refractometer (Atago, S/Mill-E, Japan), pH of water was measured directly by a digital electronic pH meter (Eco Testr), water temperature was measured by a multi parameter meter (Sension MM 150/ Hach, Crison instruments, S.A). Dissolved oxygen (DO) was measured by Winklers' method. Depth of the water was determined by lowering a rope which is tied up with a weight.

Distribution of ecological parameters

Ecological parameters of 29 locations were interpolated with ArcGIS 10.0 software in order to find out the distribution of ecological parameters along the Jaffna Lagoon.

Relationship between habitat variable and the density of two sea cucumber species

The results obtained were analyzed using 'Rcmdr' library in R statistical software (R i386 3.0.3) and Kruskal–Wallis test in Statistica software version 6. The generalized linear model (GLM) was used to examine the relationship between the habitat variable and the density of the most abundant commercially important two species of sea cucumbers.

Measurement of salinity

Location positioned

by GPS

Measurement of pH

Figure 18. Analysis of water parameters

The number of sea cucumbers in each transect (individuals per hectare - density) was used as the dependent variable and the depth, salinity, temperature, dissolved oxygen, organic matter and grain sizes were used as independent variables. It was assumed that the response variable (density) followed a Poisson distribution which is normally appropriate for describing the count data (Faraway, 2006). The Poisson response with the log-link function (scale = -1) was used to construct the GLMs. In the first step a GLM was constructed using single predictor to identify the relationship between individual habitat predictor and the density of each sea cucumber species. Each predictor was prioritized according to the percentage residual deviance explained (0 -100 % , the lowest was considered as the best). The best predictors for the final model were selected based on the above prioritization.

As GLMs allow for fitting a single response variable to multiple predictors, a series of GLMs were constructed with multiple predictors to model the density of *H. scabra* and *S. naso* based on the species abundance study. The best model for each species was selected on the basis of the level of deviance explained and AIC score (Akaike Information Criterion).

The density of each species in different habitat types was also compared using Kruskal – Wallis test in Statistica software.

Distribution of depth in the Jaffna Lagoon

According to the ArcGIS 10.0 software, five ranges of depth in cm are presented, which are range I (40 -182), range 2 (183-324), range 3 (325-466), range 4 (467-608) and range 5 (609-750) (Figure 19). All 29 locations visited, categorized under the different ranges are presented below (Table 8).

Table 8. Ranges of depth (cm) for different locations

No	Range	Locations
01	40 -182	L1, L5, L6, L9, L11, L15, L17, L18, L19, L20, L21, L23, L24, L25, L26, L27, L28, L29
02	183-324	L3, L4, L7, L8, L10, L13, L14, L16
03	325-466	………
04	467-608	………
05	609-750	L2, L12, L22

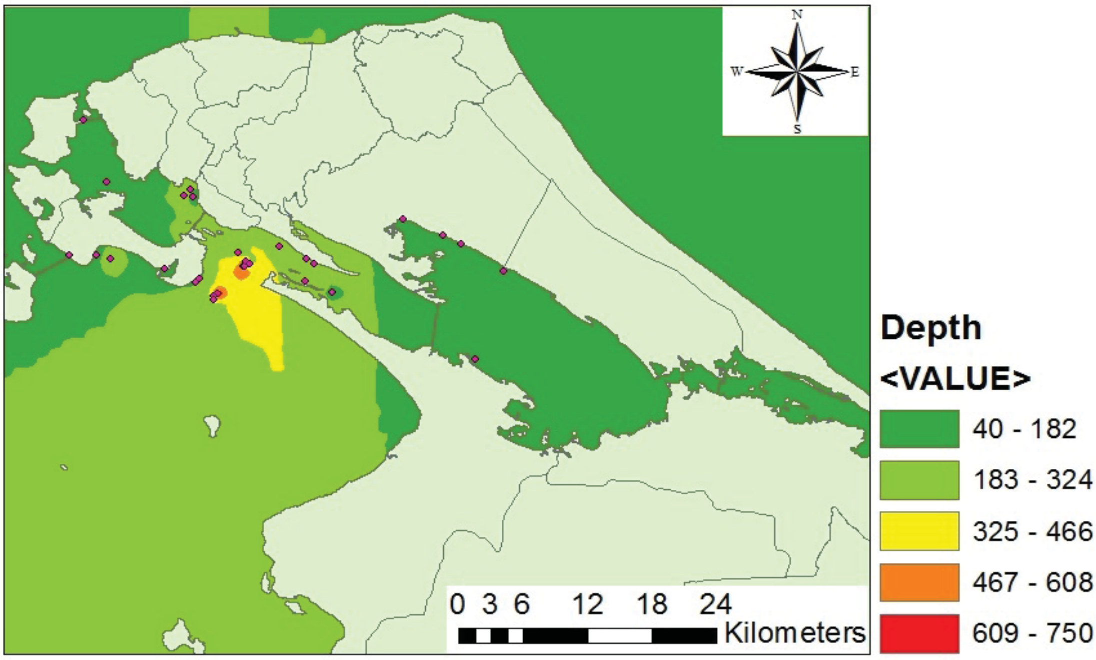


Figure 19. Depth distribution in the Jaffna Lagoon, Sri Lanka

The lowest depth was recorded in location 5 Nagathevanthurai - poonerynwhile the highest depth was recorded in location 22 Mandaitivu I. The mean depth of all 29 sampling sites is 206.55 ± 195.64 cm. Most of the locations visited in the present study are included under range 1 (Table 8).

Distribution of dissolved oxygen in the Jaffna Lagoon

According to the ArcGIS 10.0 software, five ranges were categorized for dissolved oxygen in mg/l. Those are range I (7.14 -9.69), range 2 (9.7-12.24), range 3 (12.25-14.78), range 4 (14.79-17.33) and range 5 (17.34-19.87) (Figure 20). A total of 29 locations visited are categorized under the above mentioned ranges (Table 9).

Table 9. Ranges of dissolved oxygen (mg/l) (DO) for different sampling locations

No	Range	Locations
01	7.14 -9.69	L2, L3, L4, L6, L7, L8, L9, L10, L11, L12, L13, L17, L20, L24, L25, L27, L29
02	9.7-12.24	L1, L14, L22, L23, L26, L28
03	12.25-14.78	L18, L19, L21
04	14.79-17.33	L5
05	17.34-19.87	L15, L16

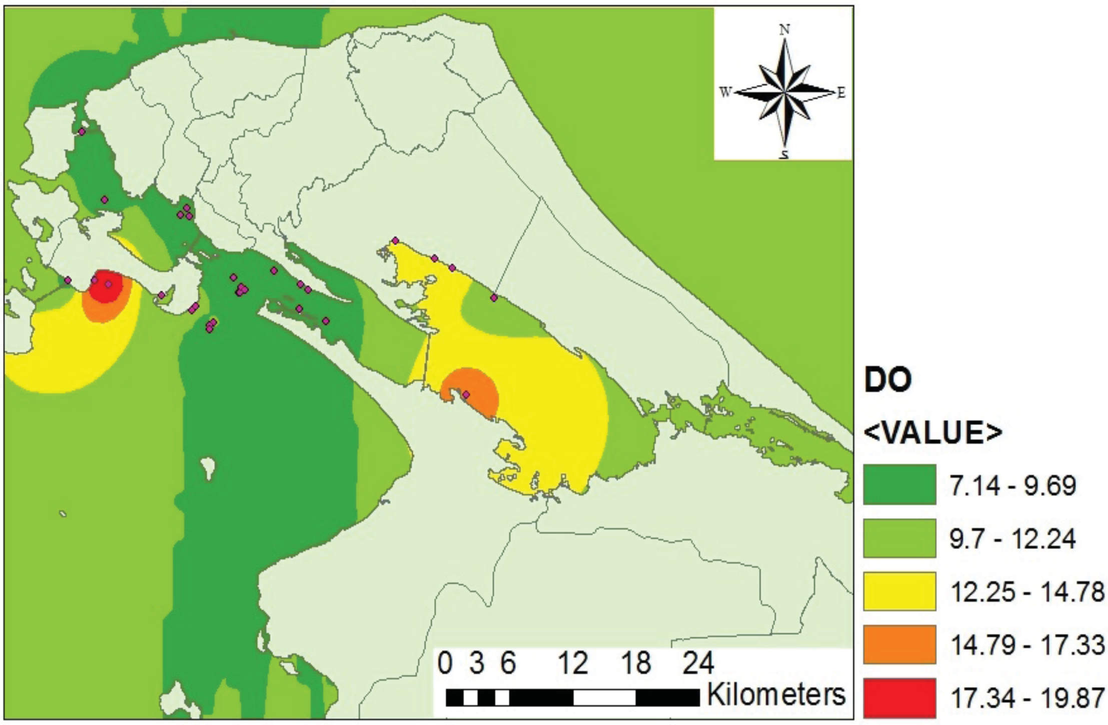


Figure 20. Dissolved oxygen distribution in the Jaffna Lagoon

A total of 17 locations are included under the range of 7.14 and 9.69 mg/l. The lowest value of dissolved oxygen in the present study was reported in the location L7 – Poovarasamtivu - Pooneryn, while the highest value was in the location L15 and 16 Chettipulam -Velanai. The mean value of dissolved oxygen is 10.37 ± 3.58 mg/l.

Salinity distribution in the Jaffna Lagoon

Five ranges of salinity were found in the Jaffna Lagoon, which are range I (32.53 -37.94), range 2 (37.95-43.35), range 3 (43.36-48.76), range 4 (48.77-54.17) and range 5 (54.18-59.58) (Figure 21). A total of 29 locations visited are categorized under the above mentioned ranges (Table 10).

The lowest value of salinity in the present study was reported in the location L26 *Mandaitivu*. The highest value of salinity was recorded in the location L18 Chavakachcheri.

Salinity in 29 sampling sites fall under these five ranges (Table 10). Salinity of most of the locations are included under range I (32.53-37.94) and range II (37.95-43.35).

Table 10. Ranges of salinity (ppt) for different locations		
No	Range	Locations
01	32.53-37.94	L1, L2, L11, L12, L13, L14, L15, L20, L23, L24, L25, L26, L27, L29
02	37.95-43.35	L3, L4, L5, L6, L7, L8, L9, L10, L16, L17, L22
03	43.36-48.76	L21, L28
04	48.77-54.17	………
05	54.18-59.58	L18, L19

pH Distribution in the Jaffna Lagoon

Five ranges of pH were provided by the software, which are range I (7.01 -7.45), range 2 (7.46-7.89), range 3 (7.9-8.34), range 4 (8.35-8.78) and range 5 (8.79-9.23) (Figure 22).

The lowest value of pH was recorded in the location L9 - Poompuhar - Ariyalai, which was 6.89. The highest value 9.29 was observed in the location L4 – Irandamkaddai - Kakkaitivu. The mean value of pH in the present study was 7.93 ± 0.77. The pH value obtained in 29 locations included under these five ranges, are shown in Table 11.

Table 11 Ranges of pH for different sampling locations		
No	Range	Locations
01	7.01-7.45	L9, L17, L18, L19, L20, L21, L22, L24, L25,L28
02	7.46-7.89	L10, L23, L26
03	7.90-8.34	L5, L6, L7, L11, L15, L16
04	8.35-8.78	L1, L2, L12, L13, L14
05	8.79-9.22	L3, L4, L8, L27, L29

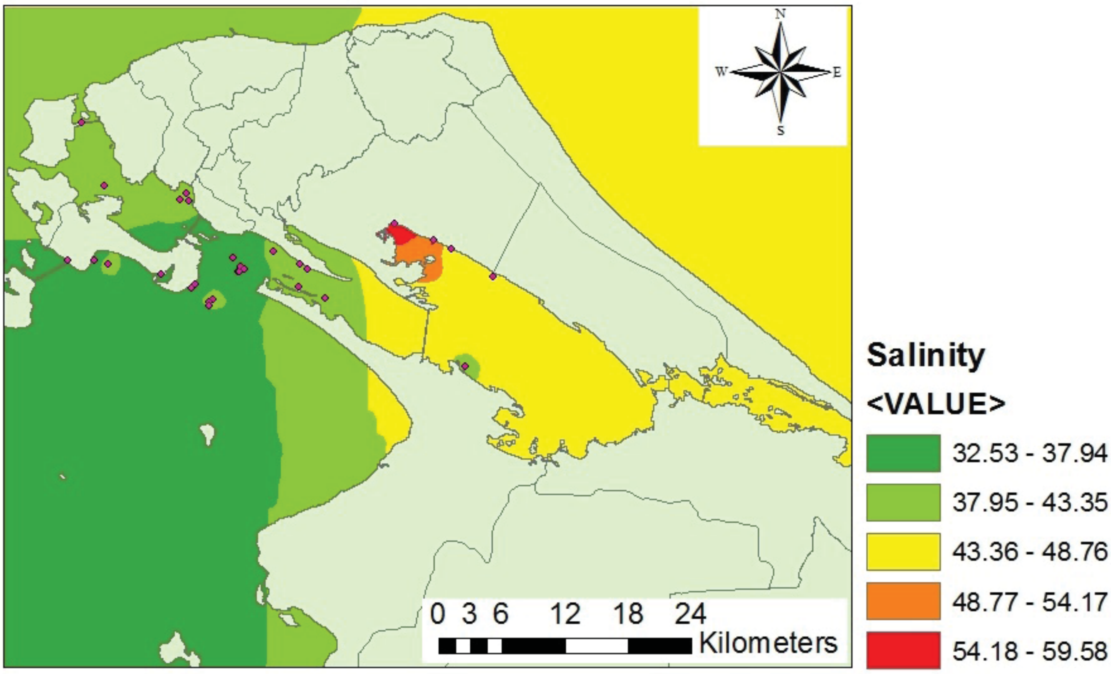


Figure 21. Distribution of salinity in the Jaffna Lagoon, Sri Lanka

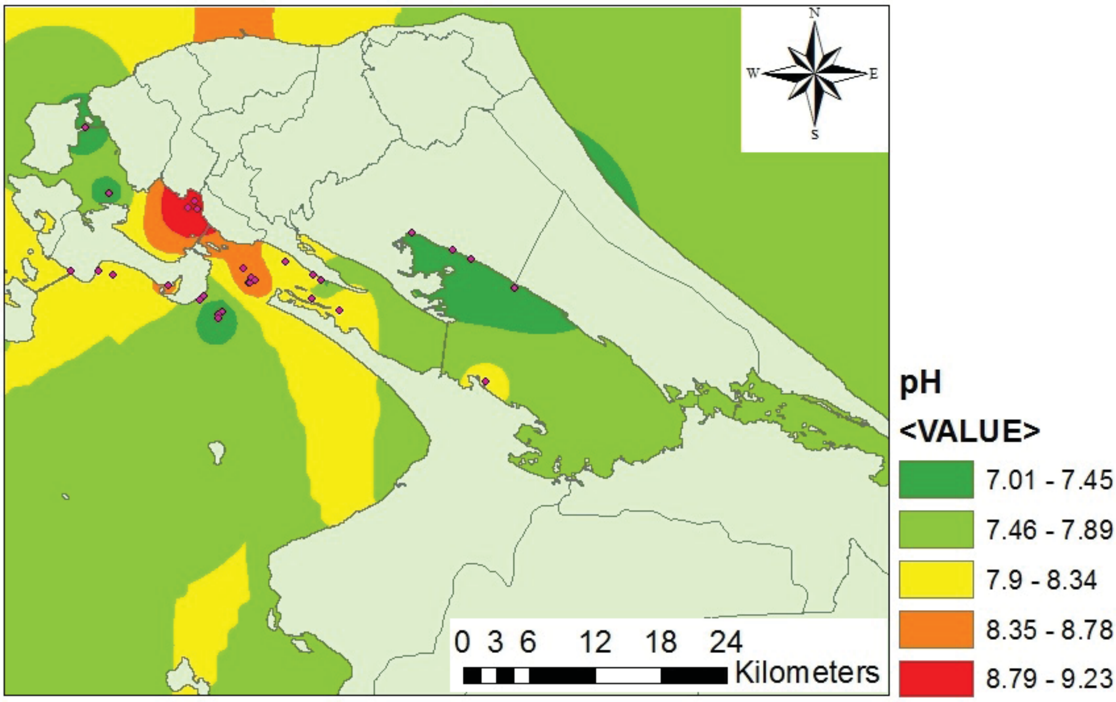


Figure 22. Distribution of pH in the Jaffna Lagoon, Sri Lanka

Distribution of temperature in the Jaffna Lagoon

According to the ArcGIS 10.0 software, five ranges of temperature were recorded, which are range I (22.41 -24.30), range 2 (24.31-26.18), range 3 (26.19-28.07), range 4 (28.08-29.96) and range 5 (29.97-31.85) (Figure 23).

The lowest temperature was recorded in the location L20 – Ponnalai. The highest value was recorded in the location L1 – Allaipity - Velanai. The mean value of temperature was 28.65 ± 1.89^{0}C. All 29 locations are categorized under these ranges (Table 12).

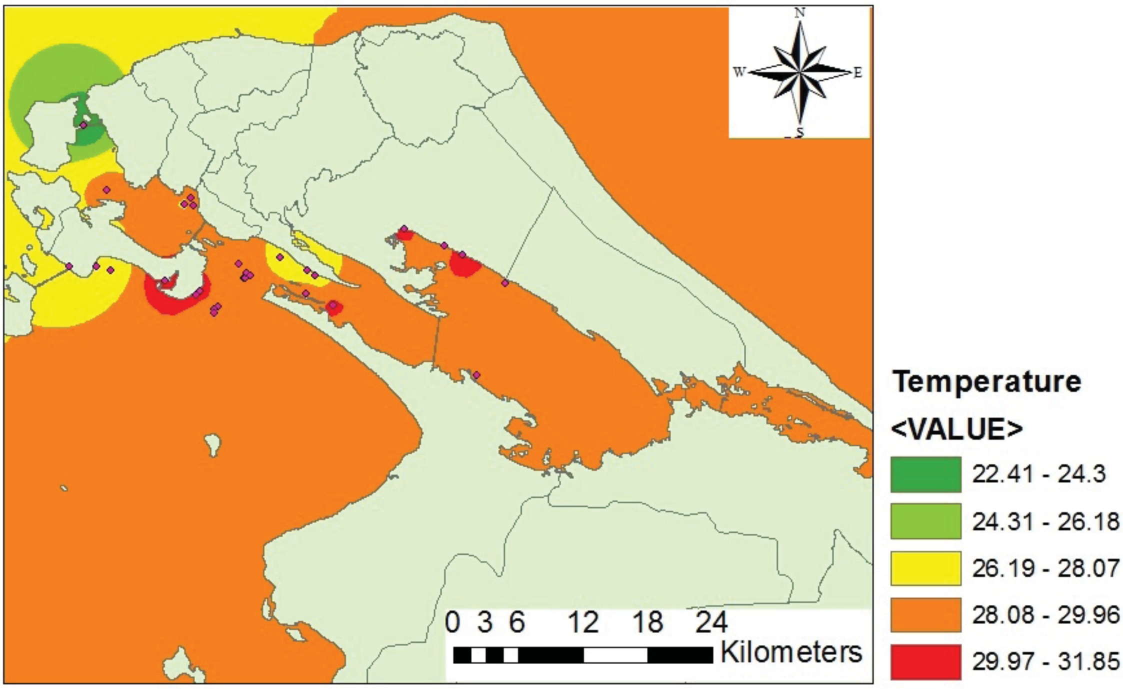


Figure 23. Distribution of temperature in the Jaffna Lagoon, Sri Lanka

Table 12. Ranges of temperature (^{0}C) for different locations		
No	Range	Locations
01	22.41-24.30	L20
02	24.31-26.18	……..
03	26.19-28.07	L3, L8, L9, L10, L11, L15, L16
04	28.08-29.96	L2, L4, L5, L12, L13, L14, L17, L19, L22, L25, L27, L28, L29
05	29.97-31.85	L1, L6, L7, L18, L21, L23, L24, L26

3.3. Lagoon bed features in the Jaffna Lagoon

Micro habitats of the Jaffna Lagoon

About 200 g each soil sediment samples were collected using a grab mud sampler (Ekman bottom grab sampler) from the bottom sediment of each site (Figure 24). The collected sediment samples were brought to the laboratory for further analysis. It was then subjected to grain size analysis and organic matter analysis.

At the same time bottom substrate within each transects was visually examined by divers in terms of sand, silt-mud, coral reef, sea grass, mangroves and sea weeds. Altogether, six microhabitat types were formulated and are given in Table 13. Each sampling site was categorized into one of these microhabitats by considering the estimated percentage cover of each component. Dominant component or components were taken into consideration while categorizing.

Table 13. Different microhabitat categories

Number	Habitat type
01	Sea grass with silt mud
02	Sea grass with silt mud and corals
03	Sea grass bed associated with mangroves and sand
04	Sea grass with sand
05	Sea grass with silt mud, sea weed and corals
06	Sea grass with silt mud, coral and rubbles

Analysis on grain size and organic matter content were carried out in order to characterize the various sediment structures at all selection sites. Sediment samples collected were dried in an oven (YCO-010, Taiwan) for 72 hours at 60°C. A sample of dry sediment was sieved using soil sieve set (Seichess, UK) with sieves spanning from 0.0039 mm to 64 mm (Figure 24). To determine the organic matter, the dried sediment was weighed and charred in a muffle furnace (Navyug, India) for 4 hours at 500°C and then reweighed (Tsiresy *et al*., 2011) (Figure 24). The organic matter was calculated as a percentage weight loss following combustion.

Collection of mud

Measurement of grain size

Measurement of organic matter

Figure 24. Analysis of soil parameters

Organic matter distribution in the Jaffna Lagoon

According to the ArcGIS 10.0 software, five ranges of organic matter in percentage were observed (Table 14) which are range I (1.12 -2.17), range 2 (2.18-3.21), range 3 (3.22-4.26), range 4 (4.27-5.3) and range 5 (5.31-6.35) (Figure 25).

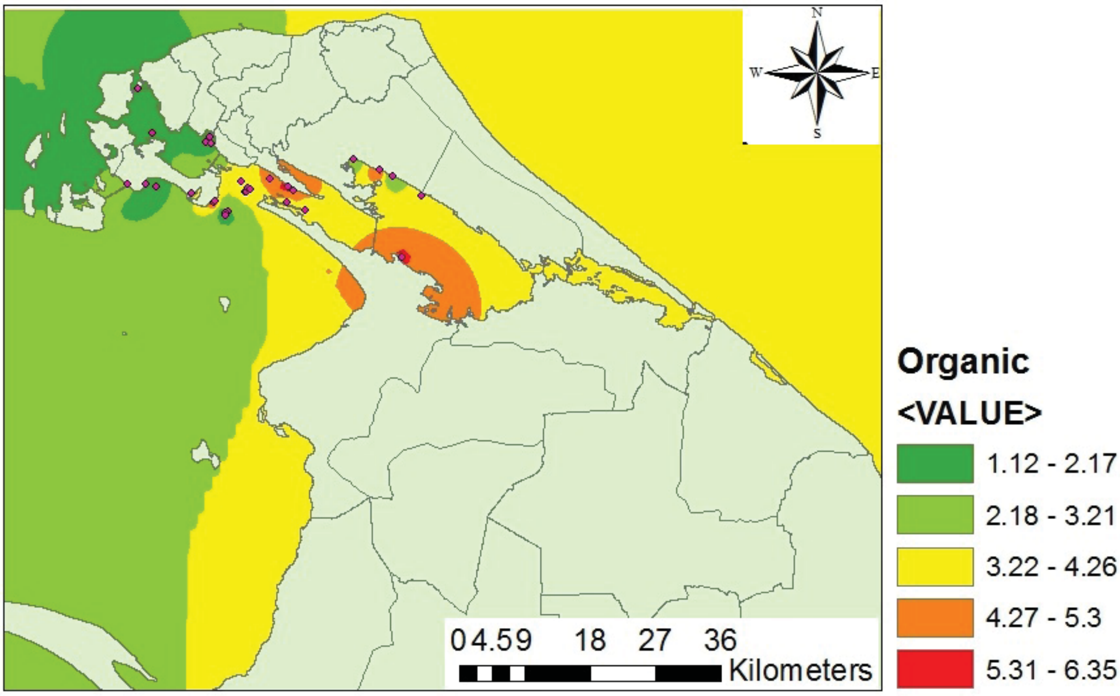


Figure 25. Distribution of organic matter in the Jaffna Lagoon, Sri Lanka

Table 14. Ranges of organic matter (%) for different sampling locations.		
No	Range	Locations
01	1.12-2.17	L3, L4, L15, L16, L17, L18, L20, L2, L24, L25
02	2.18-3.21	L1, L11, L14, L22, L26, L29
03	3.22-4.26	L2, L6, L7, L12, L13, L27, L28
04	4.27-5.3	………
05	5.31-6.35	L5, L8, L9, L10, L19, L23

3.4. Habitat preference of *Holothuria scabra*

Micro habitat preference of *Holothuria scabra*

H. scabra preferred four habitat categories, those are category 1 - sea grass with silt mud , category 4 - sea grass with sand, category 5 - sea grass with silt mud, sea weed and corals, and category 6 - sea grass with silt mud, coral and rubbles (Table 13) ; (Figure 26). The density of *H. scabra* between the habitat categories is not significantly ($p<0.05$) different. The highest density of *H. scabra* was observed in category 1 - sea grass with silt mud habitat followed by category 5 - sea grass with silt mud, sea weed and corals.

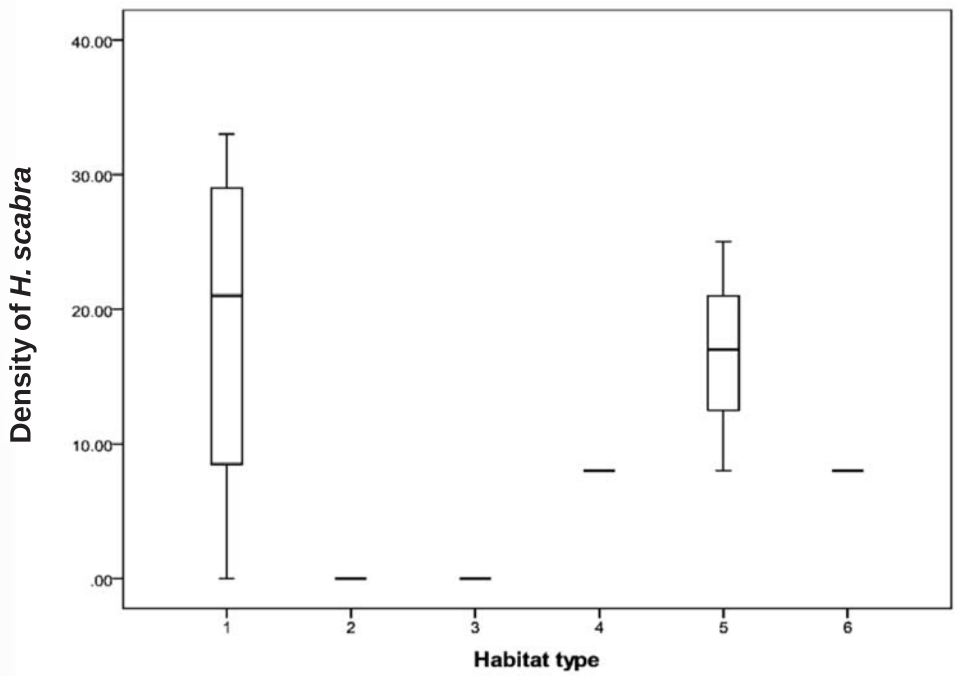


Figure 26. Box and Whisker plot to show the density (ind. ha^{-1}) of *Holothuria scabra* in the different habitat categories in the Jaffna Lagoon, Sri Lanka

Analytical approach in habitat preference of *Holothuria scabra*

According to the generalized linear model with single predictor fit, the percentage of residual deviance, AIC score and significant difference of all ecological parameters (predictors) for *H. scabra* are shown in Table 15.

The organic content (% of dry weight) had the highest influence on the density of *H. scabra* followed by depth (cm), silt mud (%), gravel (%), salinity (ppt) and the dissolved oxygen (mg/l) (Table 15).

Table 15. The percentage of deviance of each predictor of the generalized linear model constructed for *Holothuria scabra*. Significance codes: '*' - 0.001 and '*' - 0.05**

No	Parameters	*Holothuria scabra*		
		% Residual deviance	AIC score	p
01	Temperature (T)	35.780	76.422	0.65
02	Sand (S)	35.522	76.164	0.50
03	Water pH (Wp)	34.596	75.239	0.24
04	Clay mud (CM)	34.322	74.965	0.25
05	Dissolved oxygen (DO)	33.684	74.327	0.11
06	Salinity (SA)	32.885	73.528	0.08
07	Gravel (G)	32.617	73.260	0.07
08	Silt mud (SM)	32.530	73.172	0.06
09	Depth (D)	30.878	71.520	0.02 *
10	Organic matter (OM)	23.028	63.670	0.000404 ***

According to the generalized linear model with multiple predictor fit, the combination of four predictors; organic matter, silt mud, salinity and dissolved oxygen have a significant effect on the density of *H. scabra* ($P < 0.05$) (Table 16). The quality of the model increased up to four predictors, the latter combination resulted to the final model. These four predictors explained 14.234 % of the residual deviance and 60.876 AIC score in the final model (Table 17).

Table 16. Results of the final generalized linear model constructed for the density of *Holothuria scabra*		
No	Predictors	P value
01	SA	0.038*
02	DO	0.0081 **
03	SM	0.0049 **
04	OM	0.0045 **

Table 17. Multiple predictors generalized linear model fits for *Holothuria scabra*. (The percentage of deviance and the AIC score for each predictor are given)			
No	Predictors	*Holothuria scabra*	
		% residual deviance	AIC score
01	OM	23.028	63.670
02	OM + SM	21.150	63.793
03	OM + SM + SA	21.149	65.791
04	OM + SM + SA + DO	14.234	60.876

Relationship between ecological parameters and density of *Holothuria scabra*

According to the final generalized linear model for density of *H. scabra,* only four parameters are dependent on the habitat preference of this species. The variations of the density of *H. scabra* with individual variables are shown in Figure 27 and 28.

Dissolved oxygen

The range of the dissolved oxygen varied from 07.14 to 19.87 mg/l. The mean value of dissolved oxygen was 10.37 ± 3.58 mg/l. According to the GLM outputs, the highest densities of *H. scabra* were concentrated between the dissolved oxygen of 8 and 14.5 mg/l (Figure 27).

Salinity

The range of the salinity varies from 33 to 59 ppt. the mean value of salinity is 39.8 ± 6.33 ppt. The highest density of *H. scabra* was recorded between 35 to 38 ppt salinity (Figure 27).

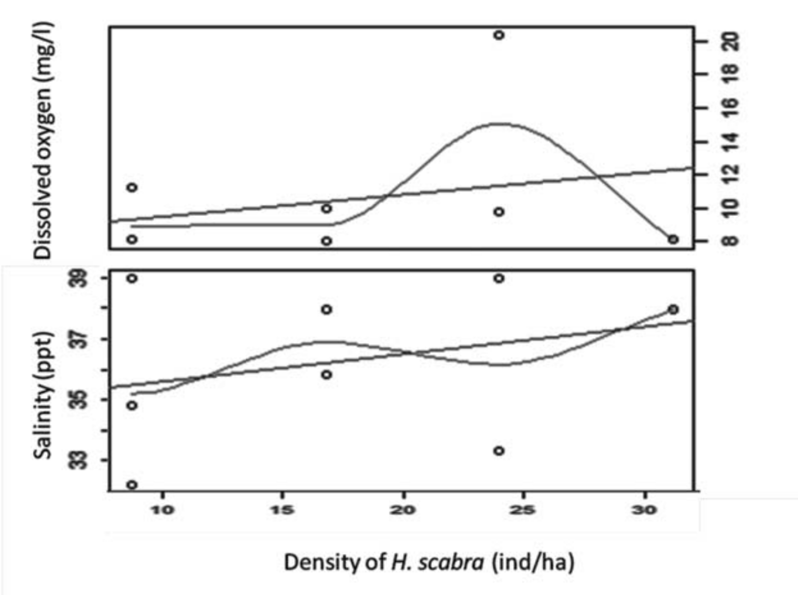


Figure 27. Relationship between density (ind. ha^{-1}) of *Holothuria scabra* and individual variables, salinity (ppt) and dissolved oxygen – DO (mg/l) in the Jaffna Lagoon, Sri Lanka

Organic matter

The range of the organic matter varied from 1.12 to 6.35 % in dry weight. The mean value of organic matter was 3.22 ± 1.56 % in dry weight. According to the GLM outputs, the lowest densities of *H. scabra* were concentrated in the greatest value, which was 5 % in dry weight and the highest densities of *H. scabra* were found in the organic matter of 2.5 % in dry weight (Figure 28).

Silt mud

The range of the silt mud varied from 8.69 to 85.5 %. The mean value of silt mud was 47.8 ± 16.8 %. According to the GLM outputs, the highest densities of *H. scabra* were concentrated between the silt mud of 45 and 60 % (Figure 28).

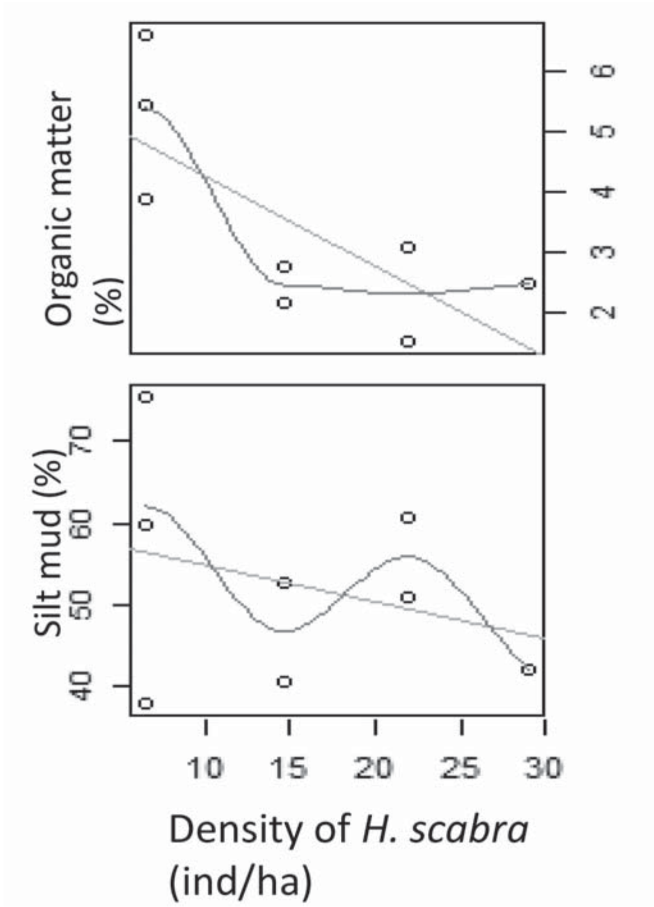


Figure 28. Relationship between density (ind. ha^{-1}) of *Holothuria scabra* and individual variables, organic matter (% dry weight) and silt mud (%) in the Jaffna Lagoon, Sri Lanka

3.5. Habitat preference of *Stichopus naso*

Micro habitat preference of *Stichopus naso*

S. naso preferred all habitat categories except in category 3 - sea grass bed associated with mangroves and sand (Figure 29). The density of *S. naso* between different habitat types is not significantly different. The highest density of *S. naso* was observed in category 4 – sea grass with sand and 6 - sea grass with silt mud, coral and rubbles followed by category 2 - sea grass with silt mud and corals, category 1 - sea grass with silt mud and category 5 - sea grass with silt mud, sea weed and corals.

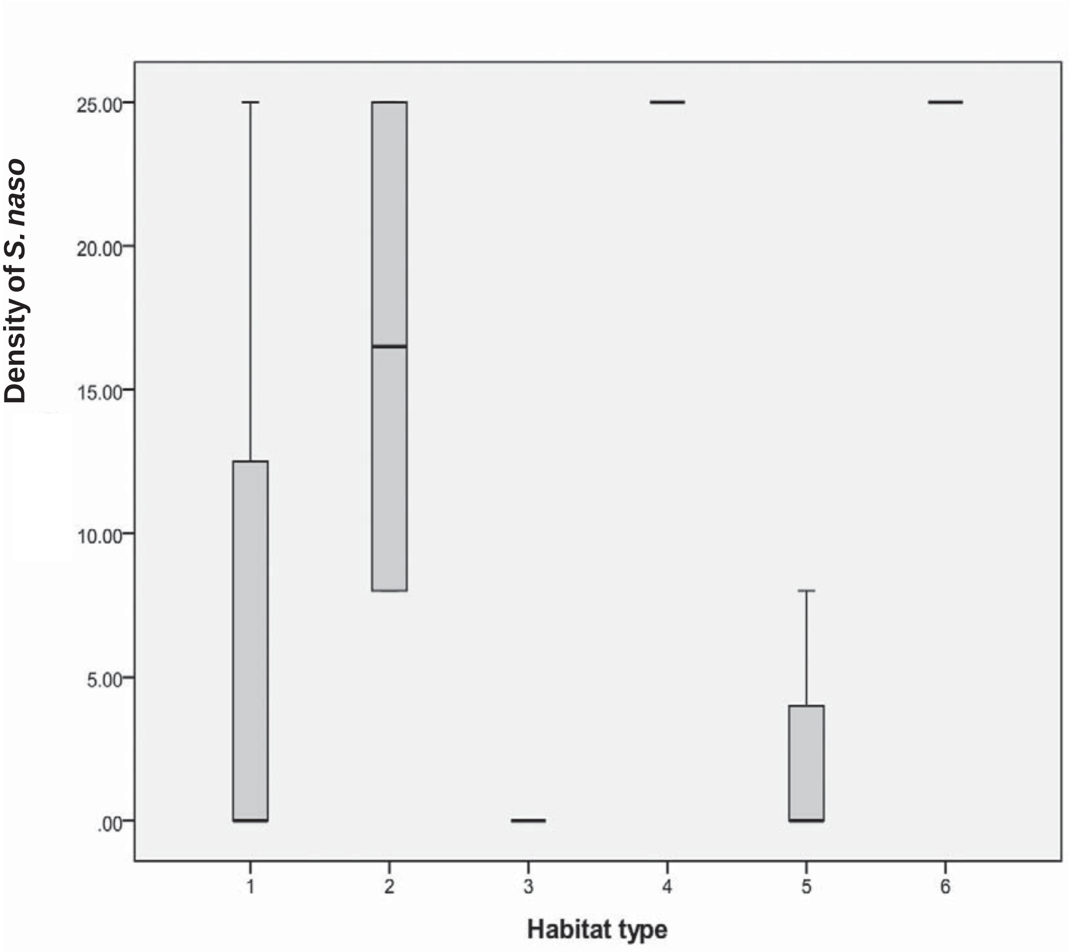


Figure 29. Box and Whisker plot to show the density (ind. ha^{-1}) of *Stichopus naso* in the different habitat categories in the Jaffna Lagoon, Sri Lanka.

Analytical approach in habitat preference of *Stichopus naso*

According to the generalized linear model with single predictor fit, the percentage of residual deviance, AIC score and significant difference of all ecological parameters (predictors) for *S. naso* are shown in Table 18.

The sand was the best predictor in spatial distribution of *S. naso.* Furthermore, gravel, water pH, salinity and Temperature were the other variables that affect the density of *S. naso* (Table 18).

Table 18. The percentage of deviance of each predictor of the generalized linear model constructed for ***Stichopus naso***. Significance codes: '*' - 0.05				
No	Parameters	*Stichopus naso*		
		% Residual deviance	AIC score	p
01	Silt mud (SM)	23.088	55.218	0.77
02	Depth (D)	22.702	54.832	0.49
03	Clay mud (CM)	21.315	53.440	0.20
04	Organic matter (OM)	20.732	52.862	0.12
05	Dissolved oxygen (DO)	20.596	52.726	0.096
06	Temperature (T)	19.265	51.395	0.041 *
07	Salinity (SA)	18.957	51.087	0.038*
08	Water pH (Wp)	18.899	51.029	0.048 *
09	Gravel (G)	18.136	50.266	0.034 *
10	Sand (S)	17.779	49.909	0.022 *

The quality of the model increased with increasing number of predictors (Table 19). The four variables; gravel, sand, water pH and salinity have significant influence on the density of *S. naso* ($p < 0.05$) (Table 20) while the other predictors were not. The final model explained 7.10×10^{-15} % residual deviance and 38.13 AIC score (Table 19).

Table 19. Multiple predictors generalized linear model fits for ***Stichopus naso***. (The percentage of deviance and the AIC score for each predictor are given)			
No	Predictors	*Stichopus naso*	
		% residual deviance	AIC score
01	S	17.779	49.909
02	S + Wp	15.544	49.674
03	S + Wp + G	11.586	47.716
04	S + Wp+ G + Sa	7.10×10^{-15}	38.13

Table 20. Results of the final generalized linear model constructed for the density of *Stichopus naso*		
No	Predictors	P value
01	Sand	0.0085 **
02	Water pH	0.0080 **
03	Gravel	0.0068 **
04	Salinity	0.0027 **

Relationship between ecological parameters and density of *S.naso*

According to the final generalized linear model for density of *S. naso*, only four parameters are dependent on the habitat preference of this species. Figures 30 and 31 show the variations of the density of *S. naso* with individual variables.

Water pH

The range of the water pH varied from 6.8 to 9.29. The mean value of pH was 7.92 ± 0.77. According to the GLM outputs, the highest densities of *S. naso* were concentrated between the pH of 7.9 and 8.4 (Figure 30).

Salinity

The range of the salinity varies from 32 to 60 ppt. The mean value of salinity is 39.8 ± 6.33 ppt. The highest density of *S. naso* was recorded between the salinity of 35 and 37 ppt (Figure 30).

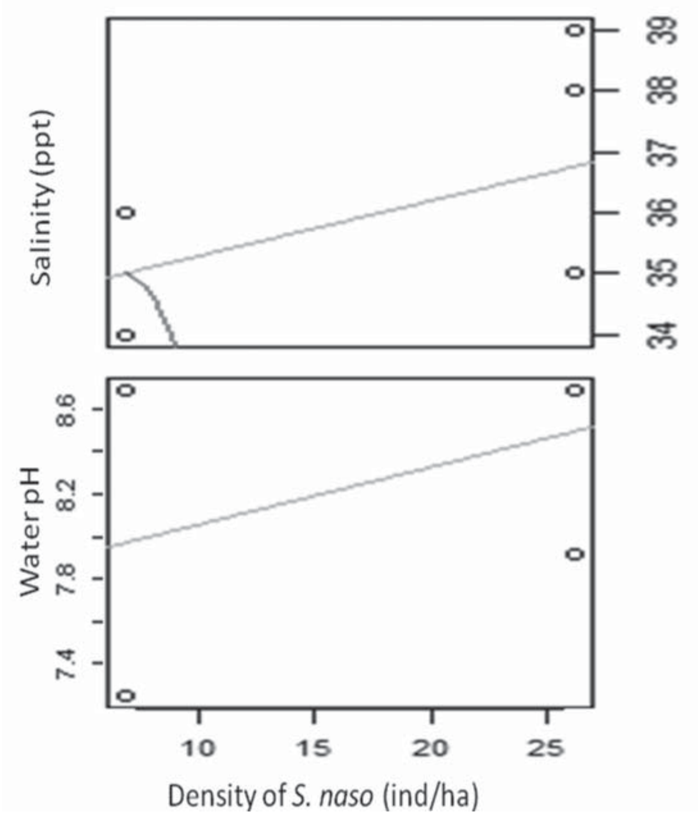


Figure 30. Relationship between density (ind.ha^{-1}) of *Stichopus naso* and individual variables, salinity (ppt) and water pH in the Jaffna Lagoon, Sri Lanka

Sand

The range of the sand varied from 3.82 to 58 %. The mean value of sand was 24.57 ± 13.20. According to the GLM outputs, the highest densities of *S. naso* were concentrated between the sand of 20 and 25 % (Figure 31).

Gravel

The range of the gravel varied from 0.49 to 29.02 %. The mean value of gravel was 8.91 ± 7.60. According to the GLM outputs, the highest densities of *S. naso* were concentrated between the gravel of 4.5 and 9 % (Figure 31).

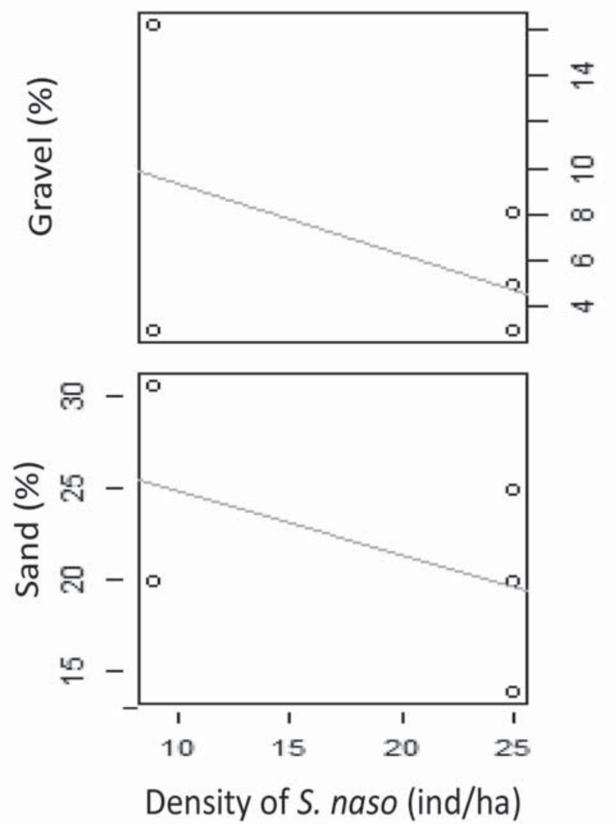


Figure 31. Relationship between density (ind. ha^{-1}) of *Stichopus naso* and individual variables sand (%) and gravel (%) in the Jaffna Lagoon, Sri Lanka.

3.6 Summary

The habitat preference of sea cucumbers has been reported to vary from species to species and even within the different life stages of the same species (Conand, 2008; Purcell *et al*., 2009; Slater and Jeffs, 2010). According to the present study, only four different ecological parameters have been found to influence the habitat preference of *H.scabra* and *S. naso*.

The high density of *H. scabra* was observed in sea grass with silt mud habitat. The density of *H. scabra* is influenced by the four ecological parameters than the others. The parameters are organic matter, silt mud, salinity and dissolved oxygen. Dense aggregation of

H. scabra was observed between the organic matter of 2.5 and 5 % in dry weight, between the dissolved oxygen of 8 and 14.5 mg/l, between the salinity of 35 to 38 ppt and between the silt mud of 45 and 60 %.

The highest density of *S. naso* was observed in category 4 – sea grass with sand. Preferable ecological parameters of *S. naso* are gravel, sand, water pH and salinity. These parameters influenced the density of *S. naso*. The highest densities of *S. naso* were found between the pH of 7.9 and 8.4, between the salinity of 35 and 37 ppt, between the sand of 20 and 25 % and between the gravel of 4.5 and 9 %. These are the optimum ecological parameters, which influence the habitat of *S. naso.*

The habitat preference and spatial distribution of the two sea cucumber species - *H. scabra* and *S. naso*, seemed to be influenced by the water and bottom sediment characteristics, and the optimum conditions have varied from species to species.

The present study provides information to identify the preferable habitat of each species and implement the successful rehabilitation programmes by initiating aquaculture system in the Jaffna Lagoon.

Chapter 4

Catch abundance and processing

4.1. Sea cucumber production

The demand for dried sea cucumber product has increased recently, in many Southeast Asian countries (FAO, 2003). The export product of sea cucumber is known as beche-de-mer or trepang. Global stocks of sea cucumbers have declined over the last few years, mostly due to overharvesting in many countries (Lovatelli *et al*., 2004).

There is no tradition of consuming sea cucumbers in Sri Lanka. The entire harvested product is processed as beche-de-mer and exported to other Asian countries. China Hong Kong SAR imported 107 tonnes dry weight of beche-de-mer in 2004 and 78 tonnes dry weight in 2005, from Sri Lanka. From 1996 to 2005 China Hong Kong SAR imported 619 tonnes dry weight of beche-de-mer from Sri Lanka (Toral-Granda *et al*., 2008).

Originally fishermen walk along the coastal areas during the low tide period and collected sea cucumbers by hand picking. Later from the early 1980s, fishers moved further offshore using snorkeling and scuba or skin diving as shallow water stocks became depleted (Kumara *et al*., 2005). The decline of high-value species and entry of new sea cucumber species to the fishery were reported, particularly in the vicinity of Kalpitiya off the northwest coast, where the number of targeted species has increased from 8 to 16 during 1990 to 2002 (Dissanayake and Wijeyaratne, 2007; Joseph and Moiyadeen, 1990). Currently, sea cucumbers are of interest in multi-species fisheries along the coastal areas of Sri Lanka and sea cucumber fishing activities are predominant in the off north, northwestern and eastern region of Sri Lanka (Dissanayake and Wijeyaratne, 2007).

World capture fisheries production of sea cucumbers increased from 4 300 tones in 1950 to a peak of 23 400 tones in 2000, subsequently decreasing to about 18 900 tones in 2001. About 66 % of world production of wild caught sea cucumbers originated from Asia in 2001. The bulk of the sea cucumber production was caught in the Pacific Ocean, in particular in the Northwest Pacific (43 %) and in the Western Central Pacific (32 %) (Stefania, 2004).

As no detailed studies have been carried out in Jaffna, the present research was carried out to report the catch abundance of sea cucumbers in Jaffna district by collecting the data from the processing centers.

4.2. Processing centers in Jaffna District

Lists of registered processing centers were obtained from the Department of Fisheries and Aquatic Resources in Jaffna. Two processing centers are registered in Jaffna district and involved in processing. One is Suganth processing center located at Jaffna town near the TILKO hotel and another one is Annai sea food processing center at Navanthurai (Figure 32 and 33).

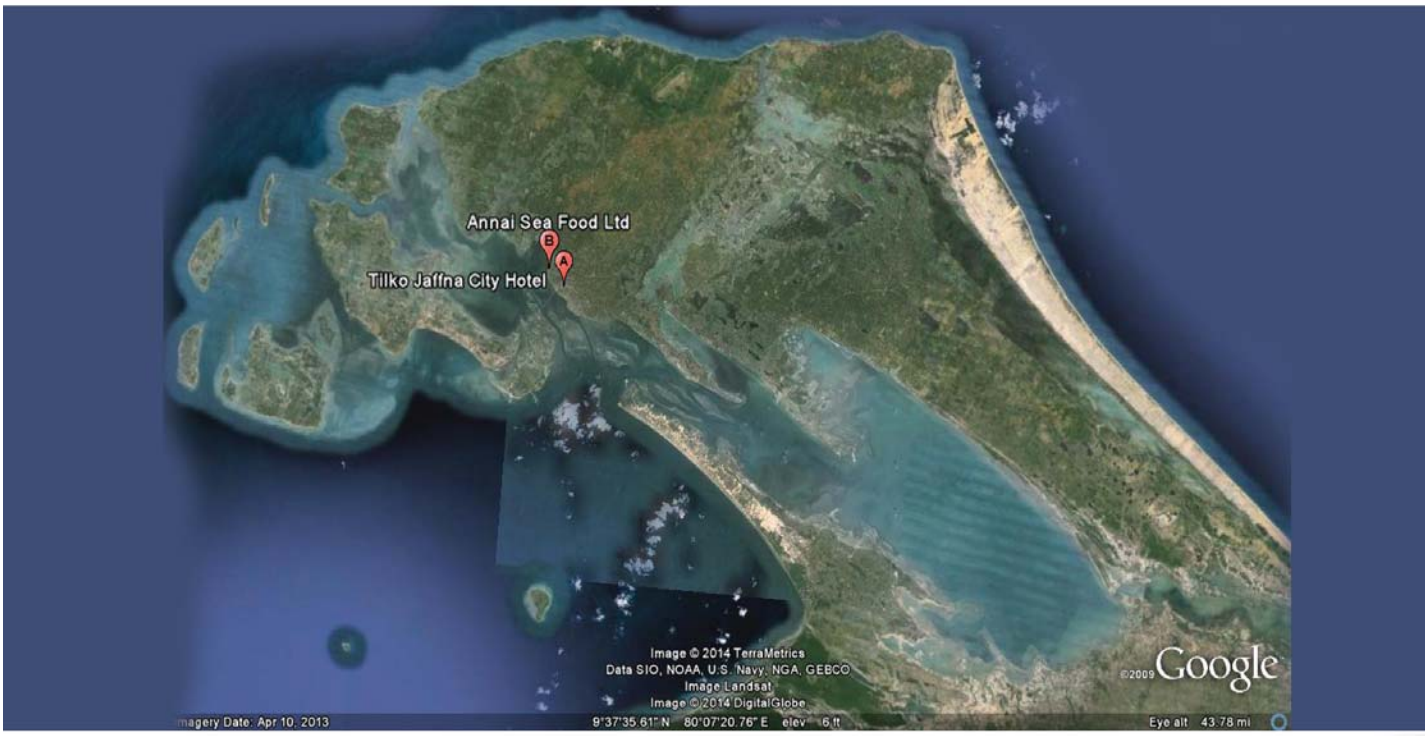


Figure 32. Map showing locations of processing centers at Jaffna.

Annai Sea food Processing center

Suganth Processing center

Figure 33. Processing centers at Jaffna

Since fresh sea cucumbers are not auctioned by the fishermen and are not purchased by the people for their consumption, weekly visits were made to the two sea cucumber processing centers at Jaffna and Navanthurai. Fishermen use trawlers and OFRP boats to catch sea cucumbers (Figure 34) form the lagoon or off the lagoon. Places where these trawlers collect sea cucumbers are shown in Figure 35.

Figure 34. Trawlers and OFRP boats used for sea cucumber fishing

Figure 35. Map showing the locations where the trawlers drag sea cucumbers

4.3. Status of sea cucumber production in Jaffna District

Six main species of sea cucumbers under families of Stichopodidae and Holothuriidae are recorded from the processing centers. Those are *H. scabra, H. spinifera, H. atra, H. leucospilota, A. miliaris* and *S. naso*.

Trend of numerical catch abundance of sea cucumber collected based on supplies received by Suganth processing center and Annai sea food processing centers are shown in Figure 36 and 37 respectively.

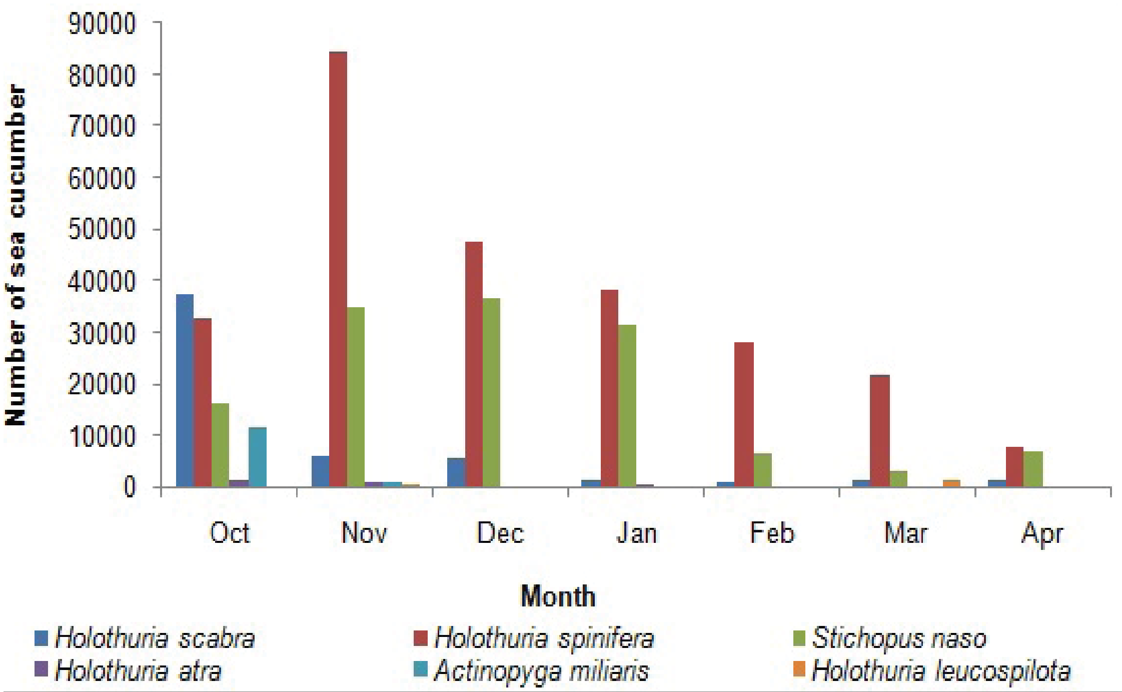


Figure 36. Catch abundance of sea cucumbers at Suganth processing center

In Suganth processing center, the most abundant species observed were *H. spinifera, S. naso* and *H. scabra.* Of these *H. spinifera* was the most abundant species except in October 2013 and followed by *S. naso* and *H. scabra.*

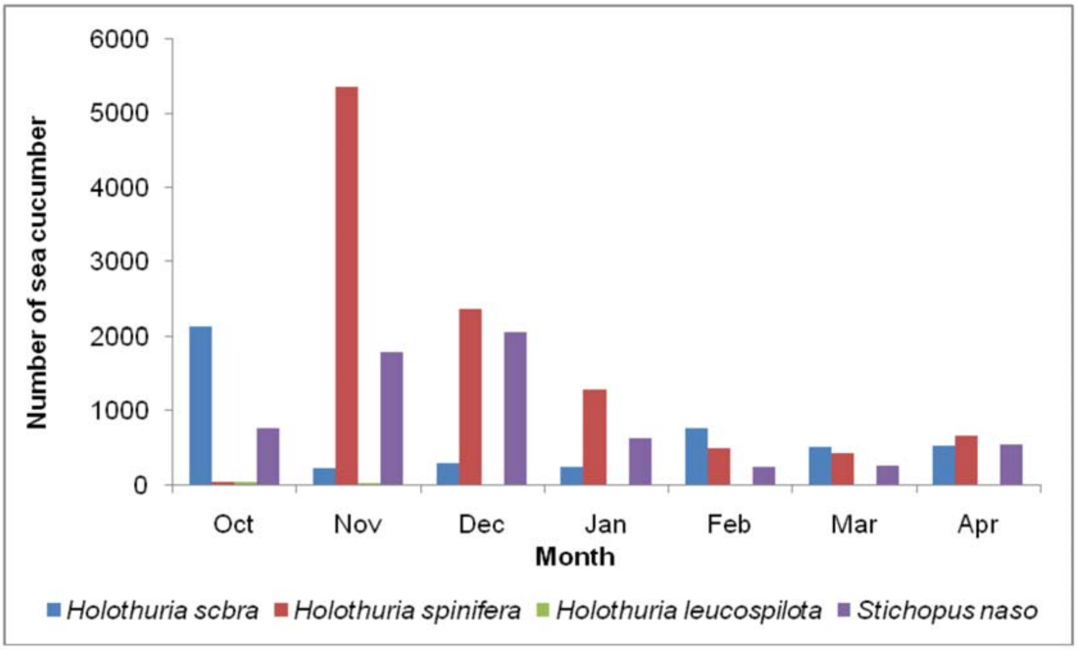


Figure 37. Catch abundance of sea cucumbers at Annai sea food processing center

The numerical catch abundance of *H. spinifera* significantly increased from 32,572 in October to a peak of 84,622 in November 2013, and then decreased to about 47,656 in December 2013. A further dramatic decline was observed from December to March 2014, the least number being 17,204.

Numerical catch abundance of *S. naso* was 15,981 in October 2013, it significantly increased to a peak of 36,337 in December 2013. A slight decrease to 31, 277 was observed in January. A remarkable decline was observed from January to March 2014.

Similar trend was observed from October 2013 to March 2014 for *H. scabra, H. atra, H. leucospilota* and *A. miliaris.* Highest numerical catch abundance (37,502) of *H. scabra* was recorded in October 2013 and it declined dramatically after wards. Similarly, the numerical abundance of *A. miliaris* was higher in October 2013. The numerical catch abundance of *H. atra* and *H. leucospilota* was significantly lower than that of the other species.

In Annai sea food processing center, the highest numerical catch abundance of *H. spinifera* was observed in November 2013 and thereafter gradually decreased. The numerical catch abundance of *S. naso* peaked at December 2013 and then declined. In the case of *H. scabra*, compared with other species, higher numerical abundance was recorded in October 2013 but it dramatically declined after wards.

4.4. Processing of sea cucumbers

In processing, the live sea cucumbers are transformed into a product suitable for consumption. Processing of sea cucumbers more often results in a dried product named beche– de–mer, which can be more easily stored and transported and is a way of value adding to raw products suitable to the market. Different species of sea cucumbers are processed in different ways worldwide (Purcell *et al*., 2010). The processing procedure of sea cucumbers in Jaffna processing centers involves the following steps:

1. Purchasing sea cucumbers

Sea cucumbers are caught by fishers from Kurunagar, Velanai, Mandaitheevu, Palai theevu, Punkudutheevu and Melinchimunai using both trawlers and skin diving in the early morning, evening and night. They bring the catches to the landing centers of the respective places, keep them inside barrels and sell them to process.

2. Grading and cleaning

Grading of each sea cucumber takes place according to their size and species, and then cleaned in sea water to remove dried slime, sand and other extraneous particles. Especially *S. naso* is submerged in boiled water to prevent the body disorientation and then sold to processers. The price is determined according to their size and species.

3. Evisceration

Evisceration is carried out after cleaning. Sea cucumbers of some species for examples *S. naso* and *H. spinifera* are gently squeezed to remove water, gut and body content while longitudinal string muscles are not removed. In some species, for example *H. scabra* and *H. atra*, a small slit is made near the posterior end with a sharp knife and then gut and body content are removed by squeezing the body.

4. Boiling (first time)

After evisceration, sea cucumbers are boiled in a clean barrel. Initially, water is boiled upto $100^{0}C$, then sea cucumbers are put into the barrel in the ratio of number of sea cucumber: water = 50:50 L .Sea cucumbers are stirred using wooden pole during boiling and boiled for half an hour until that swell. The boiling time depends on the species and then a wire mesh basket is used to take the boiled product from the basin. Then transferred into cleaned basin to filter the water.

5. Drying

Drying is the most important operation during the processing of sea cucumbers. Sun drying is considered to be better when compared to smoking. Sun drying is very common. The boiled sea cucumbers are transferred to drying platforms or sacks for sun drying for 6 hours.

6. Rotting

Dried sea cucumbers are kept in a basin containing water and kept submerged in water for 12 hours.

7. Boiling (second time)

All the sea cucumbers are boiled once again for 1 hour to destroy all remnants of bacteria which are able to digest the outer layer of sea cucumbers. A wire mesh basket is used to take the boiled product from the basin and transfered into another cleaned basin to filter the water.

8.Rubbing

The sea cucumbers are allowed to cool at room temperature. Fishers especially, women involve in rubbing the sea cucumber. They rub the sea cucumbers by hands on stone to remove the hard calcium from the skin. Any remaining hard particles on the skin are gently brushed off using a plastic brush.

9. Salting

The boiled products are stored in salt for a minimum of 2 days to deactivate the bacterial decomposition. Sea cucumbers are placed in a basin with the addition of some salt, based on the species. Storage time and salt amount depend on the species. For example, a total of 1000 *H. scabra* is stored in 10 kg salt with 100 L water for 2 days.

10. Boiling (Third time)

Salted sea cucumbers are placed in boiling freshwater and boiled for 10 minutes. A wooden pole is used to stir the sea cucumbers during boiling.

11. Drying

Sun drying is again performed. Boiled sea cucumbers are transferred to dry platforms or sack for sun drying. Drying of sea cucumbers continue for 6 days.

12. Washing and drying

Dried sea cucumbers are washed in hot water for 5 minutes. Sun drying again performed for 1 day.

13. Packing

Dried sea cucumbers are vacuum packed in food grade polythene for export.

Different species of processed sea cucumbers are shown in Figure 38.

a.Processed *Holothuria scabra*

b.Processed *Holothuria leucospilota*

c. Processed *Stichopus naso*

d. Processed *Holothuria Spinifera*

Figure 38. Processed Sea cucumbers

4.5 Market value of commercial sea cucumbers

Market values of fresh and processed sea cucumbers vary for different species. Selling prices of fresh sea cucumber species is given in Table 21. *H. scabra* hold high market value whereas *H. spinifera* and *A. miliaris* holds moderate value and, S. *naso*, *H. leucospilota* and *H. atra* holds a low value. These values are determined by the size and the thickness of the sea cucumbers.

Table 21. Selling prices of commercial sea cucumbers in Jaffna during October 2013 to April 2014

Name	Price (LKR)/Piece
Holothuria scabra	1200.00
Holothuria spinifera	180.00
Holothuria atra	25.00
Holothuria leucospilota	70.00
Actinopyga miliaris	120.00
Stichopus naso	50.00

4.6 Summary

Catch abundance of sea cucumbers is an indication of the number of harvested sea cucumbers from Northern coastal waters of Sri Lanka. Main sea cucumber fishing season is controlled by the monsoon pattern of the country. The main fishing season in Jaffna is from October to April which is identical to northwest coast fishery but different from east coast fishery (May to September) as reported by Dissanayake and Athukorala (2008) for northwest and east coast fishery.

The data collected from the processing centers revealed that the catch abundance was higher in November 2013 than the other months. It dramatically declined in March 2014.

The abundance of *H. spinifera, S. naso* and *H. scabra* were higher than the other species. Suganth processing center purchased higher number of sea cucumbers than Annai processing centre during the study period.

Dissanayake and Wijeyaratne (2007) reported that there are 16 commercially important sea cucumber species in the North western coast of Sri Lanka. Of these *H. scabra* and *H. spinifera* are the most abundant species in the Mannar area while the other 14 species are most abundant in the Kalpitiya area. They also reported the monthly variation of sea cucumber production in northwest coast of Sri Lanka. They recorded that *H. spinifera* holds the highest numerical production than the other species. They also specified that the production of all sea cucumbers declined in April. The present results are in conformity with the above reported data.

Overall, it is evident that the sea cucumber resources are severely overfished in Jaffna Lagoon in terms of high valued species in the recent years and therefore implementing effective control measures is necessary to sustain the sea cucumber resources in the Jaffna Lagoon, Sri Lanka.

Chapter 5

Selection of suitable sites for sea cucumber culture

Selection of culture site is an important basic requirement for establishing a viable culture. The success of aquaculture practice depends mainly on water quality parameters and lagoon bed features of the respective sites.

5.1 Formulation of guidelines for site selection

Guidelines for site selection were prepared 1) based on the results obtained during the present research activity from October 2013 to April 2014 and 2) by discussion at the stakeholder workshop.

Attention is paid for the most abundant, commercially important species when drafting the guidelines for sea cucumber. In the present study *H. scabra* and *S. naso* are selected as the suitable cultivable species as these are the most abundant species. Out of these, *H. scabra* hold a high market value compared to *S. naso*.

The results obtained from the present study were discussed with stakeholders in the project's workshop at the main hall of Federation of Fishermen Co-operative Societies' Union (FFCSU), Jaffna, on 02nd May 2014. Assistant Director of Department of Fisheries and Aquatic Resources, Fishery Extension Officers, members from Nongovernmental Organizations, Fishermen, Processors, Aqua culturists and Researchers participated in this workshop. A total of 63 participants were present for the workshop.

The objectives of the workshop were to,

1) formulate guidelines for site selection and

2) identify suitable areas for sea cucumber culture in the Jaffna Lagoon

The results obtained for water quality parameters in different sites and the lagoon bed features were explained in details to the participants in order to validate the results. This was preceded by discussion of the need for culture of two species of sea cucumbers, the possibilities and problems faced in the culture systems and depletion of sea cucumber resources in the Jaffna Lagoon.

The sea cucumber species collected from the Jaffna Lagoon were shown to the participants and they all agreed on the assessment of it. They were in agreement with the local names provided for each species and the respective habitat specified.

Based on the collected data on abundance of sea cucumbers and catch abundance, workshop participants agreed that the sea cucumber resources are getting depleted in the Jaffna Lagoon and there is an urgent need to culture these species in order to increase the economic status of fishermen and ensure sustainability.

It was unanimously agreed to ban trawl fishing on sea cucumber habitat and impose a ban 1) on harvesting of small sized sea cucumbers, 2) a ban on skin diving with light and 3) on sea cucumber harvest from May to September which is the off season.

Another concept agreed by the participants was the need to take suitable steps to maintain the stock of sea cucumbers in the Jaffna Lagoon. The reality behind this is that the National Aquatic Development Authority (NAQDA) has recently instigated moratoriums on fishing undersized sea cucumbers because stocks became depleted through unregulated or imprudent fishing.

5. 2 Final guidelines for site selection

Finalized guidelines for sea cucumber culture were delivered to the stakeholders at the workshop conducted on 23rd May 2014 at the Main Hall of FFCSU's.

Primary general requirements for culture sites

Following are the primary requirements that have to be considered, while selecting a site for the culture:

1. The sea cucumber culture site must be located near the coastal area free from pollutants, suspended particles and sewages and at the same time the culture site should have direct contact with the deep sea.
2. The culture site should be within the low tide area.
3. Site should be away from industrial and domestic sewages and from river mouth to avoid dilution of seawater during monsoon.
4. Accessible road must be available for easy transport.
5. The chosen area should not be affected by cyclones and other natural calamities like sea or soil erosion.
6. Site should possess easy access to obtain electricity in order to provide protection from theft in the nights. A backup generator should be made available to be used in case of electricity failure.
7. The chosen area for culture should be free from fishing operations and sailing.
8. The culture sites should not possess predators like crabs or lobsters.
9. The bottom of the culture site should possess sea grasses and silt mud but shouldnot possess stones.

Primary requirements on ecological and lagoon bed features for culture practices

Distribution and abundance of sea cucumbers are influenced by physical, chemical and biological factors of the environment. Nature of the substrate and hydrodynamic features of the coastal areas, are some of the most conspicuous factors. Population of sea cucumbers is limited mostly by habitat parameters than by food, competition or predation (James and Mustafa, 2001). Therefore attention should be paid to such environmental factors before initiating a commercially successful aquaculture.

The present study reveals that salinity, dissolved oxygen, organic matter and silt-mud are the most important influencing factors for selection of culture sites in the case of *H.scabra* whereas salinity, pH, sand and gravel are determining factors for selection of culture sites for *S. naso*.

a) Salinity for *Holothuria scabra* and *Stichopus naso*

Normally salinity of sea water is 35 ppt. Too high or too low salinity adversely affects the normal development of the sea cucumbers, resulting in large number of deformed organisms causing death. The optimum salinity for culture of *H. scabra* ranges from 35 to 38 ppt and for culture of *S. naso* ranges from 35 to 37 ppt. Salinity estimation is, therefore an important aspect that has to be monitored throughout culture practices at the selected locations.

b) Grain size for *Holothuria scabra* and *Stichopus naso*

According to the present study, the highest density of *H. scabra* was observed in the silt-mud bed substrate with aggregation of sea grass bed, which was between 45 and 60 %. The silt-mud substrate with sea grass bed, which is rich in organic detritus and microbes, is favorable for the feeding and growth of *H. scabra*.

The highest aggregation of *S. naso* in some locations of the Jaffna Lagoon provides some evidence of their preference towards the particular level of grain sized particles such as sand and gravel. The optimum amount of sand preferred by this species is between 20 and 25 % and optimum amount of gravel between 4.5 and 9 %.

c) Dissolved oxygen content for *Holothuria scabra*

In the marine environment dissolved oxygen level varies with water temperature. The water temperature is inversely proportional to the dissolved oxygen level. The normal range for dissolved oxygen is 5-6 mg/l. In the present study *H. scabra* mostly preferred higher oxygen level, which was between 8.5 and 14.5 mg/l.

d) Organic matter content for *Holothuria scabra*

Sea cucumber is a deposit feeder, preferentially inhabiting areas of the seabed that are covered with sea grass. The organic detritus found in the sea bed provides the main source of nutrition for sea cucumbers. The optimum organic matter suitable for culture of sea cucumber is between 2.5 % to 5.5 % in dry weight.

e) pH value for *Stichopus naso*

The *S. naso* is adapted to live in fairly wide range of pH, varying from 6.8 to 9.29.

Even though the above specified factors contribute significantly in selection of culture sites, the following environmental parameters could also play an important role in the aquaculture.

f) Depth

Depth is also an important factor in determining the culture site as it is an essential factor for harvesting the sea cucumbers. The selected culture site should have at least 0.5 - 2 m water depth, to ensure light penetration and easy harvesting.

g) Temperature

The ideal temperature for culture of sea cucumbers could be 28 to 32° C. The lowest temperature may hinder the growth and survival of sea cucumbers. Therefore an optimum temperature is essential for feasible culture of sea cucumbers. Temperature is also an important factor in the spawning activities of the sea cucumbers. The temperature of the water should be noted twice a day in the morning as well as in the afternoon in a sea cucumber hatchery.

5.3. Forecasting suitable culture sites in the Jaffna Lagoon

From the discussions with the Fishermen, Processors and Researchers, the suitable culture sites recommended for culture of *H. scabra* in the Jaffna Lagoon are Mandaitivu, Navanthurai, Kurunagar, Pasaioor, Chettipulam, Velanai thurai, Poompuhar, Kaudharimunai, Karainagar and Chulipuram. These locations are plotted in the Figure 39.

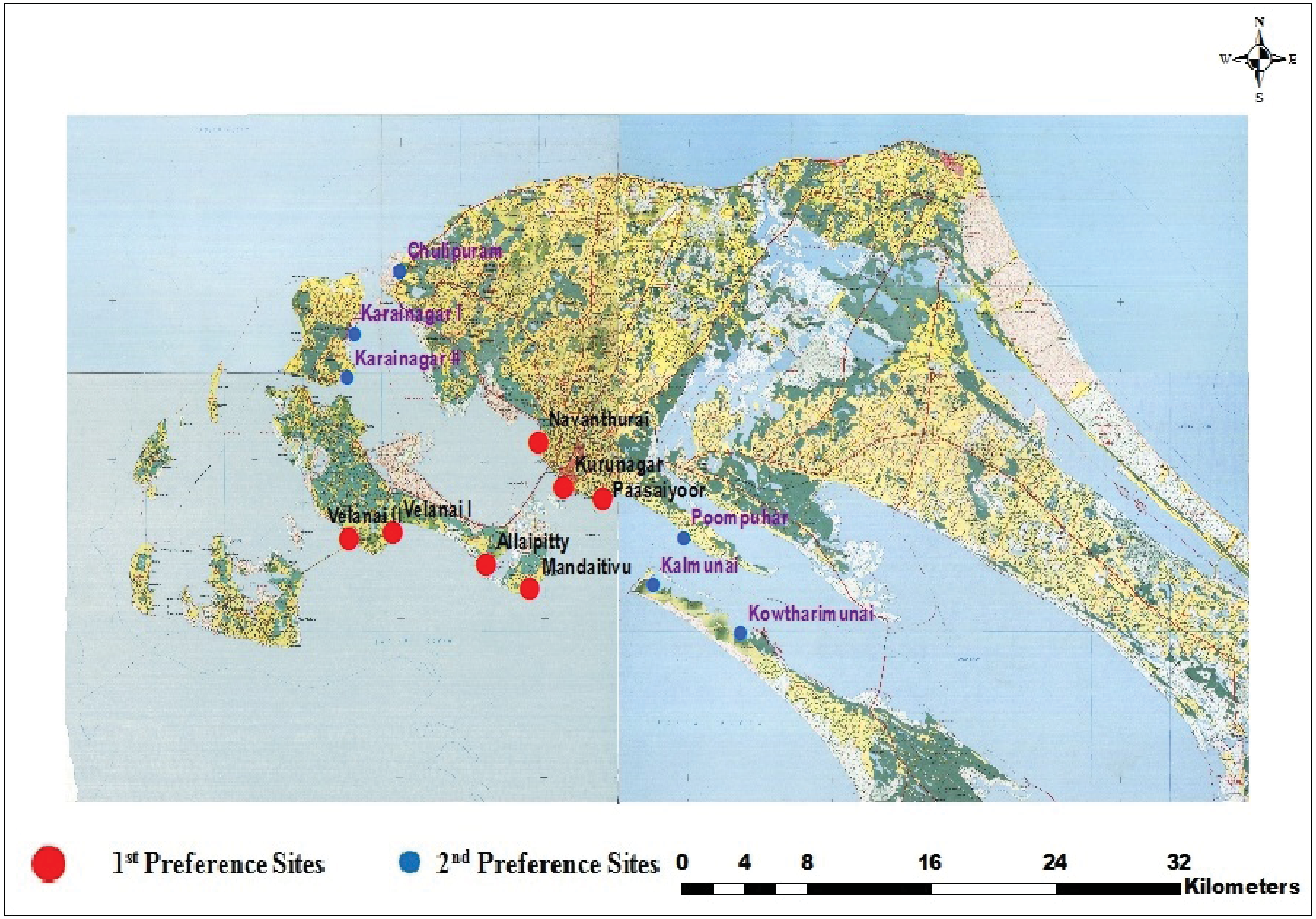


Figure 39: Suitable sites for sea cucumber culture at Jaffna Lagoon.

The participants are of the opinion that *H. scabra* is the only suitable species for culture in the Jaffna Lagoon due to its high market value. Even though the researchers suggested *S. naso* as the second suitable species for culture, it has not been accepted by any of the fishermen or participant who attended the workshop. The fishermen or aqua culturists strongly expressed their view that culturing *S. naso* has no benefit for them due to its low market value.

Among the recommended culture sites Mandaitivu, Allaipitty, Kurunagar, Pasaioor, Navanthurai, Chettipulam and Velanai thurai are the most suitable sites for *H. scabra*. These sites possess high silt-mud content with a relatively less percentage of sand. However Kaudharimunai and Poompuhar possess relatively high percentage of sand and less percentage of silt-mud. Considering the number of fishing vessels that are in operation in these areas it could be considered as a suitable place for juvenile culture. In the discussion meeting fishermen suggested Karainagar and Chulipuram are also suitable for culture since there were sea cumbers earlier and depleted now.

There is a possibility of collecting juvenile sea cucumbers from the Kalmunai region which is very close to Kaudharimunai for stocking them at Kaudharimunai. However, the recent moratoriums on fishing undersized sea cucumbers instigated by NAQDA prevent this idea. To initiate a culture the juveniles has to be purchased from the hatchery or breeding center situated at Puttalam or Chilaw. There are no hatcheries in the northern part of Sri Lanka and it is a drawback in initiating a culture system in this area.

When considering the medium value species *H. spinifera*, these species have not been collected from the Jaffna Lagoon during the study period except one accidental occurrence at Mandaitivu. It could be noticed from the literature that these species prefer sandy habitat. Most of the locations in the Jaffna Lagoon possess silt mud with sandy bottom rather than sandy habitat. Therefore *H. spinifera* cannot be cultured in the Jaffna Lagoon though it holds a medium market value.

Fishermen suggested in the discussion meeting that the culture system should not be a private property and it has to be initiated in a way to provide income for all fishermen residing in that particular area. Consequently, they recommended initiating culture systems in the future through the respective fishermen co-operative societies in that particular village.

5.4 Conclusion

Based on the present study trial culture systems can be initiated in order to increase the economic status of fishermen and conserve the sea cucumber species. The apprehensions are that the coastal fishing ground could be depleted in the near future owing to ever increasing numbers of small fishing craft that continue to exploit the fishing ground. Taking into consideration the above facts, implementation of aquaculture pilot projects for sea cucumber with the objective to educate residents in coastal communities has to be initiated in the future.

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9	A trawler leaving to catch sea cucumbers from Kurunagar, Jaffna	Sivashanthini K © DF, UJ
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72	Birds at Pooneryn	Sivashanthini K © DF, UJ
75	Leaving to sample collection from Kurunagar	Sivashanthini K © DF, UJ
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88	Sun drying sea cucumbers	Sivashanthini K © DF, UJ
89	Sea bottom with sea grass and rubbles at Mugathuvaram, Jaffna	Sivashanthini K © DF, UJ
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Mangroves for the Future
INVESTING IN COASTAL ECOSYSTEMS

Mangroves for the Future

Mangroves for the Future (MFF) is a unique partner-led initiative to promote investment in coastal ecosystem conservation for sustainable development. Co-chaired by IUCN and UNDP, MFF provides a platform for collaboration among the many different agencies, sectors and countries which are addressing challenges to coastal ecosystem and livelihood issues. The goal is to promote an integrated ocean-wide approach to coastal management and to building the resilience of ecosystem-dependent coastal communities.

MFF builds on a history of coastal management interventions before and after the 2004 Indian Ocean tsunami. It initially focused on the countries that were worst affected by the tsunami -- India, Indonesia, Maldives, Seychelles, Sri Lanka and Thailand. More recently it has expanded to include Bangladesh, Cambodia, Pakistan and Viet Nam.

Mangroves are the flagship of the initiative, but MFF is inclusive of all types of coastal ecosystem, such as coral reefs, estuaries, lagoons, sandy beaches, sea grasses and wetlands.

The MFF grants facility offers small, medium and large grants to support initiatives that provide practical, hands-on demonstrations of effective coastal management in action. Each country manages its own MFF programme through a National Coordinating Body which includes representation from government, NGOs and the private sector.

MFF addresses priorities for long-term sustainable coastal ecosystem management which include, among others: climate change adaptation and mitigation, disaster risk reduction, promotion of ecosystem health, development of sustainable livelihoods, and active engagement of the private sector in developing sustainable business practices. The emphasis is on generating knowledge, empowering local communities and advocating for policy solutions that will support best practice in integrated coastal management.

Moving forward, MFF will increasingly focus on building resilience of ecosystem-dependent coastal communities by promoting nature based solutions and by showcasing the climate change adaptation and mitigation benefits that can be achieved with healthy mangrove forests and other types of coastal vegetation.

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Harikanan, Jaffna.