HABITAT PREFERENCE OF PHAEOPHYCEAE SPECIES: *IYENGARIA STELLATA* (BØRGESEN) BØRGESEN (1939) IN GUJARAT COAST (INDIA)

*Dimpal SANGHVI *, Nandini Ray CHAUDHURY *** and *Bhanukumar JAIN ***

* Mafatlal Gagalal Science Institute, Department of Botany, Navarangpura, Ahmedabad, Gujarat, India, IN-300009, dimpalsanghvi@gmail.com

** Space Applications Centre, Indian Space Research Organisation, Jodhpur Tekra, Ambavadi Vistar, Ahmedabad, Gujarat, India, IN-380015, nandinirc@sac.isro.gov.in, bkjain_mgsc@yahoo.com

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KEYWORDS: Macroalgae, variation, growth, habitat, shore platform, reef flat.

ABSTRACT

Many species of phaeophyta are found at Dwarka and at the Bet-Shankhodhar coast, Gujarat, India. For the study of *Iyengaria stellata*, the shore platform and reef flat were divided into three sections: Dwarka in i) North, ii) Centre and iii) South sections and Bet-Shankhodhar in i) West, ii) Centre and iii) East sections. *I. stellata* was monitored based on systematic random sampling for two years (April, 2013 to February, 2015). In the months of December and February, *I. stellata* was recorded with high frequencies of reef, flat zones and shore platforms. When compared to shore platform, the frequency of *I. stallata* was highest in coral reef and flat zones. This study supports that reef flat is very suitable for growth of *I. stellata*. *I. stellata*'s growth cycle corresponds with local winter season.

ZUSAMMENFASSUNG: Habitat Präferenzen der Braunalgen-Phaeophyceae-Art *Iyengaria stellata* (Børgesen) Børgesen (1939) an der Gujarat Küste (Indien).

An der Dwarka und der Bet-Shankhodhar Küste, Gujarat, Indien wurden zahlreiche Braunalgenarten festgestellt. Für die Untersuchungen betreffend die Braunalge *Iyengaria stellata*, wurde die Küstenplattform und die Riff Flächen in drei Abschnitte eingeteilt: Dwarka in einen i) nördlichen, ii) zentralen und iii) einen südlichen und Bet-Shankhodhar in i) einen westlichen, ii) einen zentralen und iii) einen östlichen Abschnitt. *I. stellata* wurde mit Hilfe systematischer Stichproben verteilt über zwei Jahre – von April 2013 bis February 2015 – untersucht. Die Art wurde jeweils mit hoher Frequenz während der Monate Dezember und Februar in den Bereichen der Riffniederungen und dem Küstensockel festgestellt. Die höchste Frequenz von *I. stellata* wurde im Vergleich zum Küstensockel in den Flächen der Korallenriffe festgestellt. Die Untersuchung unterstützt die Annahme, dass die Flächen des Riffs für die Entwicklung von *I. stellata* sehr geeignet sind. Der Wachstumszyklus dieser Art entspricht der lokalen Winterzeit.

REZUMAT: Preferințele de habitat a speciei de algă brună *Iyengaria stellata* (Børgesen) Børgesen (1939), Phaeophyceae, pe coasta Gujarat (India).

În sectoarele de coastă Dwarka și Bet-Shankhodhar din zona costieră Gujarat, India, au fost găsite numeroase specii de alge brune. Pentru studiul speciei *Iyengaria stellata*, platforma costieră și câmpul recifelor a fost divizat în trei secțiuni: Dwarka într-o secțiune i) nordică, ii) centrală și iii) sudică și Bet-Shankhodhar într-o secțiune i) vestică, ii) centrală și iii) estică. *I. stellata* a fost studiată cu ajutorul unor probe de sondaj sistematic pe o perioadă de doi ani (din aprilie 2013 până în februarie 2015). Specia *I. stellata* a fost găsită cu frecvență mare în luna decembrie și februarie în zona câmpului recifelor, și a platformei costiere. Frecvența cea mai mare a speciei a fost găsită în câmpul recifului coralier față de cea a platformei costiere. Acest studiu confirmă că întinderea recifelor este foarte favorabilă pentru dezvoltarea speciei *I. stellata*, ciclul ei de creștere corespunzând sezonului local de iarnă.

INTRODUCTION

Algae are relatively simple photosynthetic plants with unicellular reproductive structures; they range from unicellular organisms to non-vascular filamentous or thalloid plants (Thahira, 2011).

Seaweeds (macroalgae) are large algae that grow in the marine environment and lack true stems, roots and leaves; they commonly grow on coral reefs, in rocky landscape or at significant depth if sunlight can penetrate through the water above. Most of the seaweeds can be seen thriving in underwater beds floating along the sea surface attached to rocks. (Thahira, 2011)

Seaweeds are biologically and ecologically important in the marine ecosystems. They make a substantial contribution to marine primary production and provide habitat for near shore benthic communities. Seaweeds are key space occupiers of rocky shore and interact with other organisms; hence, they play a key role in overall coastal biodiversity (Satheesh and Wesley, 2012). Seaweeds are well known and have been used since ancient times as food, fodder, fertilizer and also a source of medicinal drugs; today seaweeds are the raw material for industrial production of agar, algin and carrageenan (Manivannan et al., 2009).

Chlorophyta, Phaeophyta and Rhodophyta are major groups of seaweeds. These groups are recognized according to their pigments that absorb light of a particular wavelength which in turn, gives them their characteristic colour of green, brown and red. Out of these three, brown algae (Phaeophyta) are multi-cellular and are found in a variety of different physical forms including crusts and filaments. They contain green pigment such as chlorophyll, brown pigment like fucoxanthin, and gold pigment. (Thahira, 2011)

Numerous species of phaeophyta are found at Dwarka and Bet-Shankhodhar coast in Gujarat, India. *Iyengaria stellata* has looked very different compared to other species of phaeophyta. It has a dark brown, multi-cellular and semi-stellate, spongy and hollow thallus with hollow projections. *Iyengaria stellata* possess pronounced antidepressant and an anxiolytic property (Bushra et al., 2014). Chronic administration of *Iyengaria stellata* yields stimulant effects on hematopoietic system which is very beneficial (Bushra et al., 2014). It has been found to have less density and growth on Dwarka coast, in the shore platform area, and high density and growth in Bet-Shankhodhar coast, in the reef flat area.

The present study concentrates on spatial and seasonal variations of seaweed of *Iyengaria stellata* (Børgesen) Børgesen, brown alga on Dwarka and Bet-Shankhodhar (or Bet-Dwarka) coast, Gujarat, India.

It was carried out with the following principal objectives: to study the spatial variation of *I. stellata* in Dwarka and Bet-Shankhodhar; to study the temporal variation of *I. stellata* in Dwarka and Bet-Shankhodhar; to record the stages of growth of *I. stellata* with respect to the sampling seasons.

MATERIALS AND METHODS

Study area

For the seaweeds' growth, the geographical, geological, topographical and physical nature of the shore is very important. The rocky and coral reef coasts provide a good platform and stable coastal environments compared to that of soft sediment coasts such as beaches and spits. Shore platform and coral reef represent a case environment where the majority of seaweeds grow with a firm substratum attachment.

The Gujarat coast of India represents the north-western most part of the peninsular India. This coastline occurs within the geographical limits of 20°00'-24°45'N and 68°00'-78°30'E. It is 1,650 km long with 164,200 km^2 continental shelf (Jha et al., 2009). It extends in the form of four major coastal ecologic components: i) Kori creek ii) Gulf of Kachchh iii) Saurashtra coast from Okha to Porbandar and iv) Gulf of Khambhat.

The substratum is rocky in many parts, which provides suitable environment for macroalgae growth (Chakraborty and Bhattacharya, 2012).

The Saurashtra coast, which runs for an approximate length of 985 km, is characterized by rocky, sandy and muddy intertidal zones, harbouring rich and varied flora and fauna (Gohil and Kundu, 2012). The Gulf of Kachchh (GoK) is the largest coastal habitat in the Gujarat coastal area and contains 42 islands (Jha et al., 2009). It has an approximate length of 1,000 km and is delimited in the north by the Kachchh region and in the south by the Saurashtra region. The Marine National Park and Marine Sanctuary are situated along the southern shore of the Gulf from Okha and extends eastwards to the vicinity of Khijadia. The islands are fringed with corals, mangroves, mudflats, sandflats, coastal salt marsh, sand and rocky beaches which support great diversity of flora and fauna. (Jha et al., 2009; *, http://www.annauniv.edu/iom/iomour/EIA's%20gujarat.htm)

The present study was carried out on the shore platform of Dwarka, located on the Suarashtra coast and the coral reef adjacent to Bet-Shankhodhar Island, located on the Kachchh Gulf, to study *Iyengaria stellata* (Fig. 1). This is about five km north of the mainland of Okhamandal and to the east of Okha port (Fig. 2). Bet-Shankhodhar Island is also known as Bet-Dwarka. The eastern part of the island is comprised of sand-hills and bushes and is known as Hanumandandi point. On this island, 28 hectares' areas were covered by the coral reefs. (Satyanarayana Ramakrishna, 2009)

Geographical location and total area of study sites are given in table 1.

Table 1: Details of area of the study sites Dwarka and Bet-Shankhodhar.

Sr. no.	Sites	Geographical location		Total study area		
		Latitude	Longitude	Length (m)	Maximum width (m)	Surface area (m^2)
1	Dwarka	22˚14'22"N to 22˚14'38"N	68˚57'15"E to 68˚57'25"E	572.28	143.8	82,293.86
2	Bet-Shankhodhar	22˚28'14"N to 22˚28'56"N	68˚06'17"E to 68˚09'76"E	1606.45	338.5	543,783.33

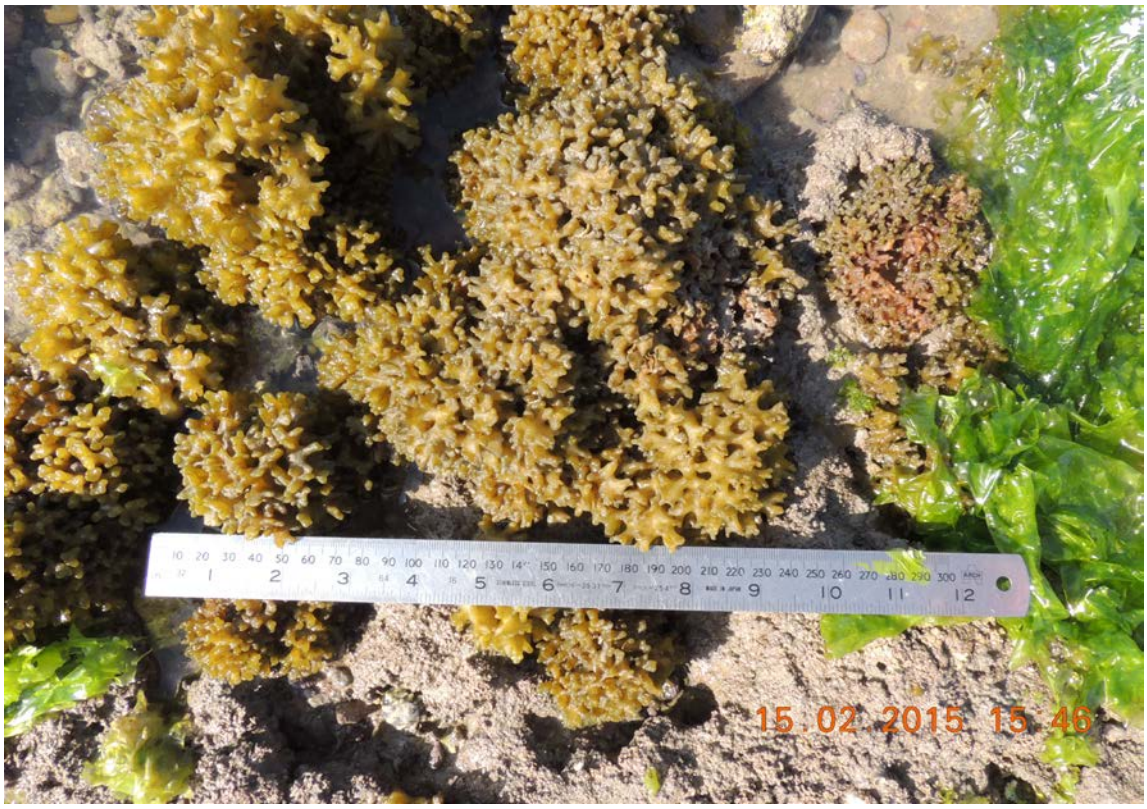

Figure 1: *Iyengaria stellata*.

Figure 2a: Shore Platform, Dwarka.

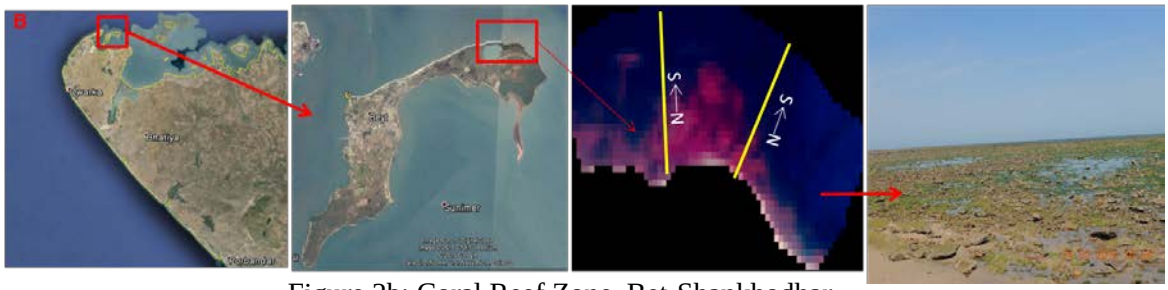

Figure 2b: Coral Reef Zone, Bet-Shankhodhar.

Field data collection

For the study of *I. stellata*, the shore platform of Dwarka was divided into three sections (in North-South direction): i) Northern, ii) Central, and iii) Southern; Bet-Shankhodhar was also divided into three sections (in East-West direction): i) Western ii) Central, and iii) Eastern for convenience of field sampling. Field sampling of seaweeds was done from April, 2013 to February, 2015 (April, June, October, and December, 2013; December, 2014, and February, 2015). Field survey and/or sampling were performed during the low tides. For qualitative and quantitative assessment, the GPS (Spheroid and Datum: WGS 84) tagged line transect.

Maximum and minimum transect length survey and maximum depth of the subtidal zone sampled for macroalgae are given in table 2 for Dwarka and Bet-Shankhodhar. Length of transect lines depended on the tidal exposure of the shore platform during the field surveys.

Table 1: Information about transect length and depth of subtidal zone of Dwarka and Bet-Shakhodhar.

Sr. no.	Study site	Maximum transect length (m)	Minimum transect length (m)	Maximum depth of the subtidal zone
1	Dwarka Coast	143.8	24	0.5
2	Bet-Shankhodhar Coast	338.5	52	1

For quantitative assessment of the *I. stellata* in the given area, line transects was laid perpendicular to the coast from land to sea with the help of a long rope (50 m) (Dhargalkar and Kavlekar, 2004). A sampling point along the rope is marked depending on the gradient and exposure of intertidal and subtidal areas. In Saurashtra coast, the tidal amplitude is very high as compared to other parts of the western coast and the entire east coast of India (Jha et al., 2009). Growth of seaweeds in intertidal and shallow subtidal regions can be easily observed in this area as the spring tides expose the intertidal area up to a maximum length of one km (Jha et al., 2009). Each of the three sections at Dwarka and Bet-Shankhodhar were represented by one transect line and quadrates of one m^2 were positioned on the transect lines. Wherever the algae growth, density and diversity were high (Tab. 3). GPS tagged photos of quadrates were taken for further analysis. Seaweeds present within the quadrates were sampled. All specimens were identified and the specific numbers of individuals were registered for quantitative assessment of frequency.

Table 2: Total transects lines and quadrates on study sites.

Sr. no.	Study sites	Total transect Lines	Total quadrates
1	Dwarka Coast	18	111
2	Bet-Shankhodhar Coast	13	83

Field data analysis

For the study of *I. stellata*, collected seaweeds samples from the field were taken to the laboratory for preparation of herbarium sheets and specimen identification. Morphological criteria were analysed for taxa identification. To understand their spatial variation, quadrate data was analysed and were graphically represented as cross profile on shore platform and coral reef with embedded bar charts showing frequency of different months. Frequency of *I. stellata* encountered at the transect intercepts is represented as bar charts. X-axis of the bar chart represents in which months and sections *I. stellata* present while Y-axis shows their respective frequencies (in percentage) (Figs. 2 and 3).

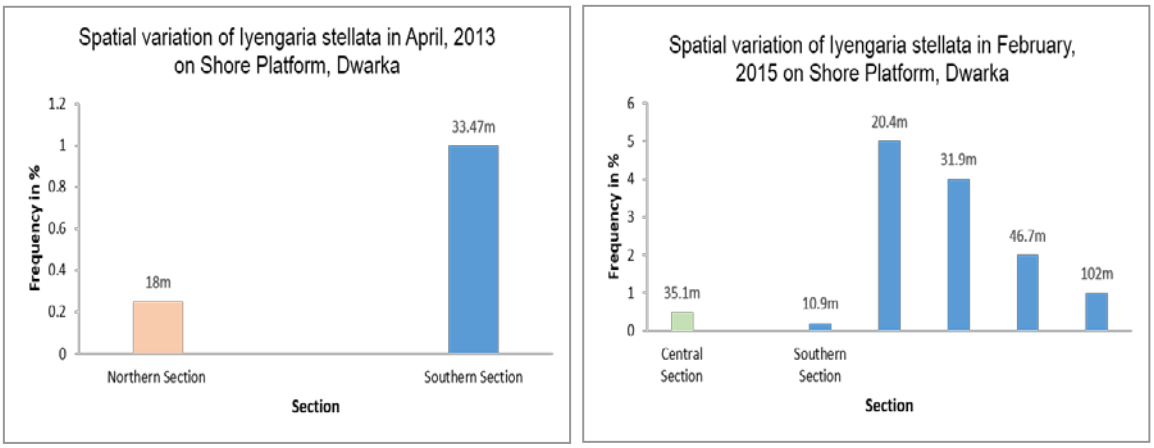

Figure 2: Spatial variation of *I. stellata* on Shore Platform, Dwarka.

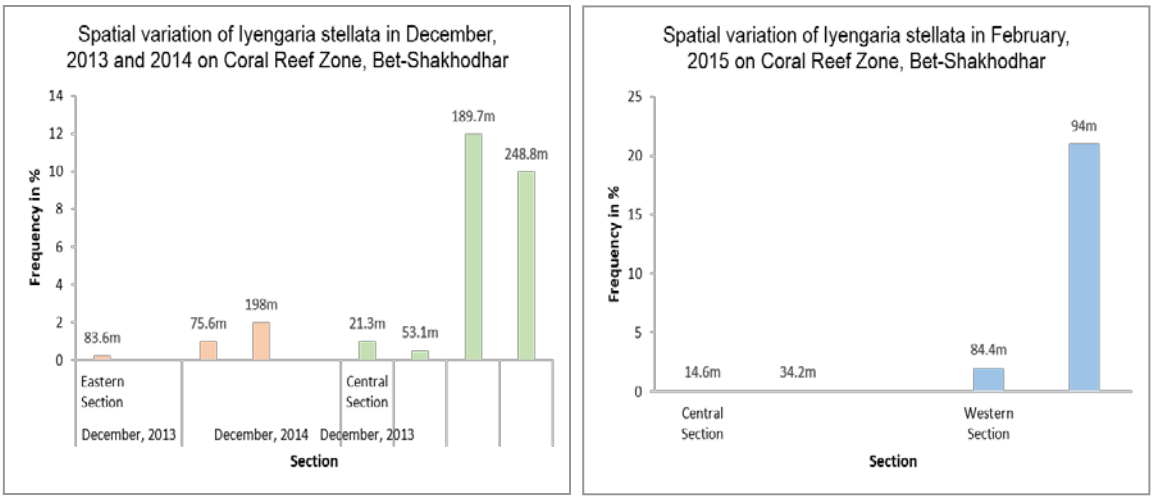

Figure 3: Spatial variation of *I. stellata* on Coral Reef Zone, Bet-Shankhodhar.

RESULTS AND DISCUSSION

Shore platform and coral reef zones

From the field data, it emerged that the shore platform and coral reef flat can be divided into three zones (in North-South direction and East-West direction respectively) based on areas the groups of seaweed were observed. The shore platform and reef flat can be divided into: i) cliff base part, ii) an intertidal mixed zone, and iii) a subtidal zone from the land to the sea. In shore platform, it was found that phaeophyta in rock pools (these pools were found in less numbers in the northern section) dominate the cliff base zone. The cliff base is followed by a mixed intertidal area, where there is a transition from phaeophyta (dominant in the intertidal zone) to chlorophyta (dominant in the subtidal zone). The subtidal zone dominated by chlorophyta, is found at the seafront.

In the case of coral reef flat, it was found that phaeophyta dominates in land front and chlorophyta and rhodophyta is dominated in subtidal zone. The intertidal zone is again a mixed zone (followed phaeophyta to chlorophyta and rhodophyta).

Spatial variation of *I. stellata*

As discussed the shore platform and coral reef flats were divided into three sections for the convenience of field sampling: the results are reported here section wise.

Shore platform: Dwarka

Northern section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 2. During April, 2013 profile *I. stellata* was recorded at 18 m with 25% frequency. In other months *I. stellata* was not detected in northern section.

Central section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 2. During February, 2015 profile *I. stellata* was observed at 35.1 m with 0.5% frequency. In other months *I. stellata* was not detected in the central section.

Southern section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 2. During April, 2013 profile *I. stellata* was found at 33.47 m with 1% frequency. In February profile *I. stellata* was recorded at 10.9 m (0.2%), 20.4 m (5%), 31.9 m (4%), 46.7 m (2%), 102 m (1%). In February profile, frequency was increased at 10.9 m to 20.4 m and at 31.9 m to 102 m, frequency got decreased. In other months *I. stellata* was not detected in the southern section. *I. stellata* was found highest in the southern section.

Coral reef zone: Bet-Shankhodhar

Western section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February 2015) of field survey are showed in table 4 and figure 3. During February profile *I. stellata* was observed at 84.4 m (2%) and 94 m (21%) with increased frequency. In the months April and June, *I. stellata* was not recorded; data was not available for October and December months. In western section *I. stellata* was recorded with highest frequency.

Central section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 3. During December, 2013 profile *I. stellata* was found at 21.3 m and 53.1 m with less frequency and at 189.7 m and 248.8 m, it was recorded with high frequency. In February, *I. stellata* was recorded at 14.6 m and 34.2 m (0.1%) with same frequency. Data was not seen in December, 2014 and in other months, *I. stellata* was not present.

Eastern section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 3. In December, 2013 profile *I. stellata* was recorded at 83.6 m with 0.25% frequency and in December, 2014 *I. stellata* was recorded at 75.6 m and 198 m with 1% and 2% frequency respectively. In April, June and October, *I. stellata* was absent and in February, data was not available.

Table 4: Frequency of *I. stellata* based on line transects and quadrate survey on the shore platform, Dwarka and coral reef zone, Bet-Shankhodhar.

Study sites	Month	Sections	Frequency (%)	Quadrate Distance on transects (m)
Dwarka	April, 2013	Northern section	0.25	18
		Southern section	1	33.47
	February, 2015	Central section	0.5	35.1
		Southern section	0.2	10.9
			5	20.4
			4	31.9
			2	46.7
			1	102
Bet-Shankhodhar	December, 2013	Eastern section	0.25	83.6
	December, 2014		–	–
			1	75.6
			2	198
	December, 2013	Central section	1	21.3
			0.5	53.1
			12	189.7
			10	248.8
	February, 2015	Central section	0.1	14.6
			0.1	34.2
		Western section	2	84.4
			21	94

Temporal variation of *I. stellata*

Temporal variation of *I. stellata* in the three sections of shore platform, Dwarka are presented in table 4 and figure 4. In the northern section, a total of twenty-nine quadrates were studied in the six sampling months, while in the central section thirty-eight quadrates were studied and for the southern section forty-four were studied. In the northern and central sections *I. stellata* was found highest in April and was highest in the southern section in February. On shore platform *I. stellata* was highly recorded in the February, while during in June to November it was absent.

Temporal variation of *I. stellata* in section three of coral reef zone, Bet-Shankhodhar is presented in table 4 and also in figure 4. In eastern section, total thirty-one quadrates were studied in the six sampling months, while in central section thirty-four quadrates were studied and for western section eighteen were studied. In central section *I. stellata* was found with highest values in December and in western section in February. *I. stellata* was absent from June to October. So, we found that *I. stellata* grows during January to February.

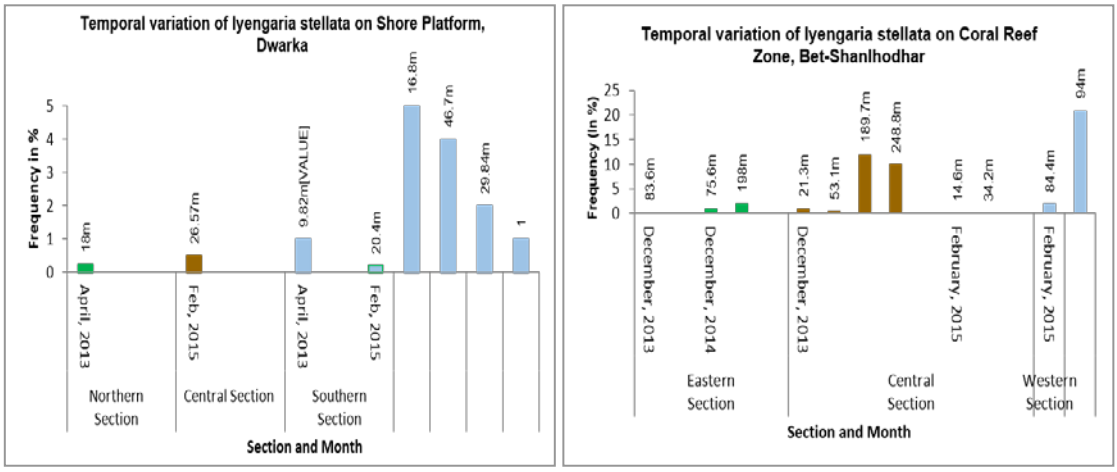

Figure 4: Temporal variation of *I. stellata* on Shor platform, Dwarka and coral reef zone, Bet-Shankhodhar.

Stage of growth of *I. stellata*

On the shore platform of Dwarka and reef flat zone of Bet-Shankhodhar, the occurrence of *I. stellata* was noted during six sampling months. Out of these six months, *I. stellata* was only found between December to April. The highest frequency was recorded in February and *I. stellata* decreased in April.

The present study shows the presence of *I. stellata* from December to April and growth in full phase in February on the shore platform. On reef flat zone *I. stellata* was present in November-March period growing in full phase in January and February. Density of *I. stellata* was higher in reef flat of Bet-Shankhodhar as compared to shore platform of Dwarka.

Numerous researchers have studied the distribution of marine macroalgae on seasons in India. They researched seasonal variation of macroalgae in the east and west coasts but not the *I. stellata* growth cycle. Usmanghani et al. (1987) has worked on the sterols of a brown seaweed *I. stellata* from Pakistan. They were studied for sterol composition of *I. stellata*; they found two sterols (ergosterol and cholesterol) for the first time from brown seaweed. Bushra et al. (2014) has studied an evaluation of nephrotoxic potential of *I. stellata*. The species was very effective on renal function. They gave one dose every thirty days of *I. stellate* to rabbits and the level of urea and creatinine measured showed an increased level of urea after continued administration of *I. stellate*. *I. stellata* has nephroprotective effect.

Kesava Roa and Singbal (1995) have worked on the seasonal variation in halides and their ratio were estimated in three marine brown algae, namely *Cystoseira indica* (Thivy and Doshi) Mairh, *Sargassum tenerrimum* Agardh J. G. and *Sargassum johnstonii* Setchell and Gardner from Porbandar and Okha coasts (NW coast of India). Halides were found higher in early stages of growth in this study. This study showed Br: F (Bromine: Fluoride) ratio was higher in the reproductive stage indicating that algae tend to accumulate Br compared to F during this stage than at early and senescent stages, though Br level in ambient medium is not a limiting factors. Bhanderi and Trivedi (1975) have worked on the seaweed resources of Hanumandandi Reef and Vumani Reef near Okha Port, Gujarat. This study computed quantities of seaweeds peak periods of the growth and projected twice proper for harvesting of each economic seaweed. In this study, edible seaweeds, the two species of genus Ulva, i.e. *Ulva lactuca* Linnaeus and *Ulva fasciata* Delile, were available in maximum quantity in different months on Hanumandandi reef, while on Vumani reef. Only *U. fasciata* was available throughout the season and the maximum availability was 9.077 tons in February, 1974. The peak period of growth was observed during October, 1973 and February, 1974 on Vumani Reef while it was only observed in March, 1974 on Hanumandandi reef. Agarophytes and iodine-yielding algae were less on both the reefs as compared to the edible seaweeds. Maximum availability of agarophytes was estimated in January, 1974 on Hanumandandi reef. On Vumani reef, different agarophytes species showed peak growth in different months. Iodine-yielding plants were observed maximum on both reefs in December, 1993.

This study reports seasonal, temporal and growth stages of *I. stellata* on the basis of systematic field inventory. This kind of study, when done on routine annual basis, can bring out the variability on spatial and temporal/seasonal province for the study area. Additionally, same species have been spotted and identify on paga and pirotan.

CONCLUSIONS

This study shows the frequency of *I. stellata* is high on reef flat zone as compared to shore platform. Reef flat zone is very suitable for growth of *I. stellata*. Its growth cycle is in the winter. This study is to help further studies about *I. stellate*, because it is an important species for extraction of two type of sterols used for pharmaceutic/medicinal purposes.

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