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# Seagrasses as a source of energy to marine and terrestrial organisms of Gulf of Mannar and Palk Bay, East Coast of India

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**Abstract**
Nutrients availability in the surrounding environment had influences on the morphology and seasonal cycling of seagrass communities. Live seagrasses are consumed by dugongs, sea turtles, fishes, sea urchins and crustaceans. Dead seagrasses are breakdown by sea cucumbers, gastropods, worms, crabs and filter feeders. The seagrass in general, contain fairly good nutrition with lipid content varying from 1.54 to 9.92%, protein 4.3 to 22.98% and carbohydrate 9.77 to 28.71%. Total nitrogen (N) content in seagrasses varied from 0.66 to 2.93%, carbon (C) 31.72 to 41.18% and phosphorous (P) 0.125 to 0.622%. Na content in seagrasses varied from 2.13 (*E. acoroides*) to 39.25 mg/g (*T. hemprichii*), K 0.34 to12.41mg/g (*C. serrulata* from Thonithurai) while Ca 1.30 (*E. acoroides*) to 18.23 mg/g (*S. isoetifolium* of Thonithurai). These constituents level implies as a good source of nutrients for the aquatic ecosystem and judicious utilization would benefit the human being as well.

**Keywords:** Lipid, protein, carbohydrate, macro elements and seagrasses

## 1. Introduction
Seagrasses are marine angiosperms that grow in the tidal and sub tidal coastal areas except in the Polar Regions (Chanthini *et al*., 2015) [8]. This natural resource in the Gulf of Mannar region, East coast of India is an important habitat which provides shelter to marine animals (fishes, sponges, dugongs, turtles etc), protecting the coastline (seagrass meadows against beating waves, storms and cyclones), regulating the local climate, producing food (through photosynthesis), preventing erosion, trapping carbon dioxide (seagrasses as carbon sinks), maintaining soil productivity and supporting traditional livelihoods (seagrass meadows support traditional fisheries) (Miththapala Sriyanie, 2012; Maheswari *et al*., 2011; Manikandan *et al*., 2011a) [37, 32]. The nearby region, Palk Bay is also rich in biodiversity and important groups associated with seagrass meadows includes algae sponges, gorgonids, corals, crustaceans, molluscs, fishes, turtles, birds and mammals (Kumaraguru *et al*., 2008; Manikandan *et al*., 2011b) [24, 33]. Nutrients availability in the surroundings environment had influences on morphology and seasonal cycling of seagrass communities (Sulochanan *et al*., 2011) [45]. The primary production rates of seagrasses are comparable to the rates of associated fisheries (Govindasamy *et al*., 2011) [14].
Seagrasses gives supports to not only to the aquatic ecosystem but also to people living along the coast. Seagrasses are used as feed for animals mainly goats and pigs, along with few species had an importance in their culture (de la Torre-Castro and Ronnback, 2004) [11] and also as fertilizer for coconut and tobacco plantations (Newmaster *et al*., 2011; de la Torre-Castro and Ronnback, 2004) [39, 11]. In India, fishing communities of Cuddalore and Nagapattinam districts of Tamil Nadu used seagrasses as medicine for the treatment of skin diseases, burns and boils (Newmaster *et al*., 2011) [39]. Seagrasses form a source of food for organisms in the marine as well as terrestrial ecosystem (Primefact 629, 2007) [40]. So, the carbon sources from seagrass ecosystem form a source energy to the associated flora and fauna either in direct or indirect pathways. Any changes in seagrass ecosystem will affect the biodiversity and ecosystem functioning. In context of these facts, this study characterizes the biochemical constituents, elemental composition and macro elements present in seagrasses from Gulf of Mannar and Palk Bay, east coast of India.

## 2. Materials and Methods

Seagrasses were collected from four stations [Thonithurai (area where seaweed farming is going on) and Chinnappalm (fishermen living area, boats and trawlers harbor) situated on the Gulf of Mannar] during November 2010 and [Munaikkadu (Farm pond) (geographically near to a lagoon) and Mathacovil (seaweeds and corals are growing along with seagrasses on the Palk Bay side) during June 2011. The latitude of stations were ranged from $9^0$ 16' to $9^0$ 18 N' while longitude from $79^0$ 08 to $79^0$ 13' E and geographical location of the study area is given in figure 1. During south west monsoon, high waves are noticed at Gulf of Mannar while Palk Bay showed high waves during north east monsoon (Gowthaman *et al*., 2013) [15]. Sampling of seagrasses was not possible during north east monsoon at Palk Bay side due to strong waves and during south west monsoon at Gulf of Mannar side.

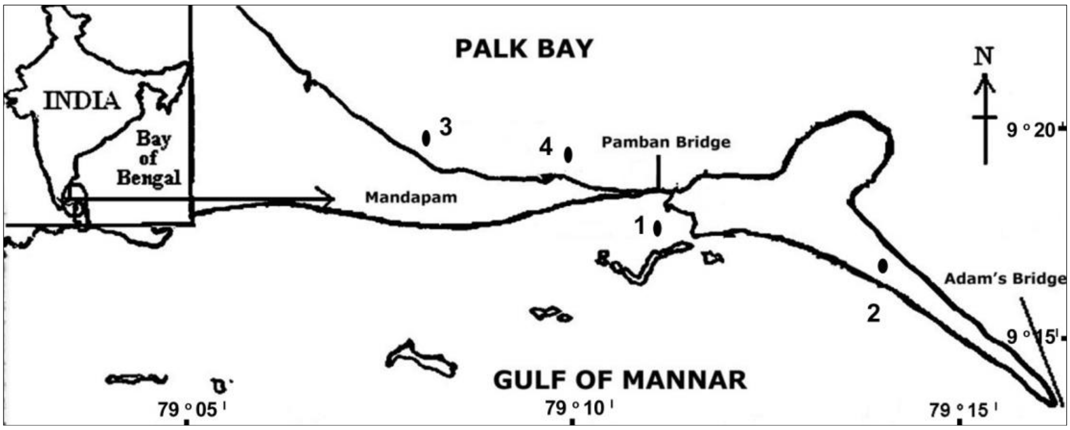


**Fig 1:** Geographical representation of the study area (1) Thonithurai, (2) Chinnappalam, (3) Munaikkadu and (4) Mathacovil)

Seagrasses were collected from the stations during low tide by the use of a 0.25m$^2$ quadrate (Lewis and Stoner, 1981). Collected seagrasses were washed in seawater and carried to the laboratory in chilled condition. Each experiment consisted of three sampling of seagrasses from different seagrass meadows of same region and each sample was treated as separate. Seagrasses were washed with tap water followed by distilled water to remove sand particles and epiphytes. Seagrasses were dried in an air oven at 50 ˚C for 12 hours (Khamsah *et al*., 2006) [23]. Spectrophotometric methods were employed for the determination of biochemical components in seagrasses. Analysis of total proteins were carried out following the procedure of Lowry *et al*. (1951) [28], as modified by Rice (1982) [42] with Bovine Serum albumin as the calibration standard. Total carbohydrates were analysed using the Dubois *et al*., (1956) [12] method, using glucose as the standard. Total lipids were extracted according to Bligh and Dyer (1959) [6], and estimated according to Barnes and Blackstock (1973) [5] using cholesterol as the standard. Total carbon and nitrogen was determined using CHNS Analyser (Vario EL III). Macro elements of Na, K, Ca and Li were estimated using Flame Photometer (BWB Technologies, UK Ltd) and Mg using ICP-OES (iCAP 600 Series, Thermo Scientific) after digestion using 1:5 $HClO_4$: $HNO_3$ (Loring and Rantala, 1992) [27]. Analysis was done in triplicates and average values were reported with standard deviation.

## 3. Results

### 3.1 Biochemical composition

The lipid content in seagrasses varied from 1.54 to 9.92%, protein 4.3to 22.98% and carbohydrate 9.77 to 28.71% (Table 1&2). The low lipid and protein contents were reported in the roots and rhizomes of *Enhalus acoroides*. The protein and lipid contents in *Thalassia hemprichii* were higher than *Syringodium isoetifolium* and lower than that of *Cymodocea serrulata* from Palk Bay. The leaves of *C. serrulata* contained comparatively high content of lipid at Mathacovil (9.92%), protein at Munaikkadu (22.56%) and carbohydrate at Chinnappalam (18.21%). The roots and rhizomes of *C. serrulata* also showed high lipid of 5.31%, protein 22.98% and carbohydrate 26.44% at same stations. Slight differences were noticed in the biochemical composition of *S. isoetifolium* from Thonithurai and Mathacovil, comparatively higher concentrations of carbohydrates noticed at Mathacovil except carbohydrate. The total energy contributed from biomolecules was higher in *C. serrulata* (2.49 Kcal/g) from Munaikkadu and low at Thonithurai *S. isoetifolium* (0.87 Kcal/g).

**Table 1:** Biochemical composition of seagrasses from Gulf of Mannar (dry weight basis %)

| Species | Station | Lipid | Protein | Carbohydrate |
|---|---|---|---|---|
| *C. serrulata* (leaf) | Thonithurai | 2.28±0.08 | 10.86±0.58 | 13.66±0.11 |
| *C. serrulata* (leaf) | Chinnappalam | 3.61±0.12 | 8.35±0.62 | 18.21±0.12 |
| *C. serrulata* (R&R) | Thonithurai | 2.42±0.09 | 19.8±0.88 | 21.17±0.15 |
| *C. serrulata* (R&R) | Chinnappalam | 2.64±0.11 | 9.58±0.44 | 26.44±0.20 |
| *S. isoetifolium* | Thonithurai | 1.9±0.09 | 4.8±0.53 | 10.65±0.09 |
| *E. acoroides* (leaf) | Chinnappalam | 3.58±0.14 | 8.65±0.61 | 11.61±0.08 |
| *E. acoroides* (Rh) | Chinnappalam | 1.54±0.12 | 4.3±0.48 | 28.71±0.12 |
| *E. acoroides* (Rt) | Chinnappalam | 3.04±0.10 | 6.74±0.58 | 23.05±0.08 |

**Table 2:** Biochemical composition of seagrasses from Palk Bay (dry weight basis %)

| Species | Station | Lipid | Protein | Carbohydrate |
|---|---|---|---|---|
| *C. serrulata* (leaf) | Munaikkadu | 8.67±0.11 | 22.56±0.52 | 9.77±0.08 |
| *C. serrulata* (leaf) | Mathacovil | 9.92±0.14 | 14.03±0.48 | 12.87±0.12 |
| *C. serrulata* (R&R) | Munaikkadu | 3.43±0.10 | 22.98±0.62 | 9.79±0.09 |
| *C. serrulata* (R&R) | Mathacovil | 5.31±0.15 | 16.98±0.46 | 12.78±0.12 |
| *S. isoetifolium* | Mathacovil | 2.03±0.08 | 6.6±0.21 | 9.79±0.08 |
| *T. hemprichii* | Munaikkadu | 3.56±0.11 | 10.06±0.28 | 10.98±0.11 |

### 3.2 Elemental composition

Total nitrogen (N) content in seagrasses varied from 0.66 to 2.93%, carbon (C) 31.72 to 41.18% and phosphorous (P) 0.125 to 0.622%. Leaves of *C. serrulata* showed high N content at Chinnapalam (2.93%) and low at Mathacovil (1.49%) (Table 3&4). No wide variations were observed in the elemental composition of seagrasses between species as well as different body parts, and slightly more observed at Gulf of Mannar than Palk Bay. Elemental compositions in seagrasses were comparatively higher noticed in leaves than roots and rhizomes. N content in roots and rhizomes of *C. serrulata* varied from 0.77 (Munaikkadu) to 1.37% (Chinnappalam). In *S. isoetifolium* carbon content exhibited high quantity at Mathacovil while the rest of them were higher at Thonithurai. Seagrasses of *E. acoroides* and *T. hemprichii* showed relatively enhanced levels of elements.

**Table 3:** Elemental compositions of seagrasses of Gulf of Mannar (dry weight basis %)

| Species | Station | N | C | P |
|---|---|---|---|---|
| *C. serrulata* (leaf) | Thonithurai | 2.14±0.10 | 31.84±0.25 | 0.227±0.02 |
| *C. serrulata* (leaf) | Chinnappalam | 2.93±0.12 | 40.18±0.45 | 0.245±0.02 |
| *C. serrulata* (R&R) | Thonithurai | 0.89±0.08 | 31.72±0.28 | 0.187±0.02 |
| *C. serrulata* (R&R) | Chinnappalam | 1.37±0.09 | 39.87±0.41 | 0.213±.32 |
| *S. isoetifolium* | Thonithurai | 2.26±0.10 | 32.37±0.22 | 0.274±0.02 |
| *E. acoroides* (leaf) | Chinnappalam | 2.70±0.13 | 40.47±0.48 | 0.453±0.13 |
| *E. acoroides* (Rh) | Chinnappalam | 0.66±0.07 | 34.87±0.32 | 0.126±0.02 |
| *E. acoroides* (Rt) | Chinnappalam | 1.58±0.10 | 33.02±0.36 | 0.369±0.23 |

**Table 4:** Elemental compositions of seagrasses of Palk Bay (dry weight basis %)

| Species | Station | N | C | P |
|---|---|---|---|---|
| *C. serrulata* (leaf) | Munaikkadu | 1.58±0.09 | 41.18±0.51 | 0.466±0.03 |
| *C. serrulata* (leaf) | Mathacovil | 1.49±0.10 | 40.98±0.48 | 0.313±0.02 |
| *C. serrulata* (R&R) | Munaikkadu | 0.77±0.06 | 40.23±0.44 | 0.622±0.04 |
| *C. serrulata* (R&R) | Mathacovil | 0.85±0.07 | 38.78±0.38 | 0.407±0.03 |
| *S. isoetifolium* | Mathacovil | 1.19±0.08 | 35.21±0.28 | 0.125±0.02 |
| *T. hemprichii* | Munaikkadu | 1.19±0.10 | 35.21±0.29 | 0.166±0.02 |

### 3.3 Macro elements

Na content in seagrasses varied from 2.13 (*E. acoroides*) to 39.25mg/g (*T. hemprichii*), K 0.34 to12.41mg/g (*C. serrulata* from Thonithurai) while Ca 1.30 (*E. acoroides*) to 18.23 mg/g (*S. isoetifolium* of Thonithurai) (Table 5&6). Among the seagrasses under investigations very low concentrations of macro elements were found in leaves of *E. acoroides* and Li were not detected in any of the samples of seagrasses. The leaves of *C. serrulata* of Thonithurai exhibited wide variation with respect to composition and stations. Comparison of *C. serrulata* leaves with roots and rhizomes, Na, Ca and Mg contents were comparatively higher in roots and rhizomes than leaves except at Thonithurai; while K contents were higher in roots and rhizomes than leaves. Sodium and potassium concentrations were relatively higher in *S. isoetifolium* of Mathacovil and comparatively high contents of Na, K, Ca and Mg in *T. hemprichii*.

**Table 5:** Macro elements in seagrasses of Gulf of Mannar (dry weight basis mg/g)

| Species | Station | Na | K | Ca | Mg |
|---|---|---|---|---|---|
| *C. serrulata* (leaf) | Thonithurai | 24.54±0.41 | 6.29±0.12 | 15.94±0.28 | 7.59±0.16 |
| *C. serrulata* (leaf) | Chinnappalam | 4.99±0.39 | 0.83±0.09 | 11.16±0.58 | 5.03±0.10 |
| *C. serrulata* (R&R) | Thonithurai | 19.92±0.28 | 12.41±0.36 | 9.40±0.79 | 6.26±0.64 |
| *C. serrulata* (R&R) | Chinnappalam | 7.99±0.12 | 1.29±0.08 | 11.86±0.18 | 6.22±0.22 |
| *S. isoetifolium* | Thonithurai | 16.20±0.24 | 1.01±0.09 | 18.23±0.36 | 8.90±0.28 |
| *E. acoroides* (leaf) | Chinnappalam | 2.13±0.10 | 0.34±0.06 | 1.30±0.09 | 1.37±0.11 |
| *E. acoroides* (Rh) | Chinnappalam | 10.32±0.16 | 4.82±0.09 | 6.57±0.13 | 3.23±0.12 |
| *E. acoroides* (Rt) | Chinnappalam | 6.63±0.22 | 2.72±0.16 | 16.85±0.55 | 6.85±0.47 |

**Table 6:** Macro elements in seagrasses of Palk Bay (dry weight basis mg/g)

| Species | Station | Na | K | Ca | Mg |
|---|---|---|---|---|---|
| *C. serrulata* (leaf) | Munaikkadu | 6.23±0.18 | 2.16±0.06 | 4.72±0.10 | 2.59±0.09 |
| *C. serrulata* (leaf) | Mathacovil | 4.71±0.11 | 3.44±0.08 | 5.66±0.14 | 2.36±0.06 |
| *C. serrulata* (R&R) | Munaikkadu | 8.99±0.16 | 3.79±0.10 | 6.99±0.18 | 3.39±0.08 |
| *C. serrulata* (R&R) | Mathacovil | 8.63±0.18 | 7.32±0.16 | 3.80±0.09 | 4.06±0.10 |
| *S. isoetifolium* | Mathacovil | 21.55±0.62 | 5.93±0.10 | 13.47±0.29 | 5.79±0.11 |
| *T. hemprichii* | Munaikkadu | 39.25±0.88 | 7.85±0.52 | 17.21±0.38 | 6.54±0.12 |

R&R- Roots &Rhizomes, Rh- Rhizomes and Rt- Roots

## 4. Discussion

Variations in the composition of different elements were reported in seagrasses from different areas. Comparatively higher concentrations of lipid, protein and carbohydrate were observed in the present study than the earlier reports (Table 7) (Torbatinejad and Sabine, 2001; Abd El-Hady *et al*., 2007; Athiperumalsami *et al*., 2008; Kannan *et al*., 2010a; Pradheeba *et al*., 2011) [1, 2, 22, 46, 41]. Season as well as species wise variations in biochemical compositions were noticed in this study and it compares well with the earlier study (Pradheeba *et al*., 2011) [41], and also variations were noticed between different body parts of seagrasses. These differences in the biochemical composition of seagrasses were attributed to nutrient availability, environmental conditions (salinity and temperature which directly related to photosynthetic rate), age of plant, stage of growth and ecology (Athiperumalsami *et al*., 2008; Pradheeba *et al*., 2011; El Din and El-Sherif, 2013; Hernández *et al*., 2016) [2, 13, 41]. *E. acoroides* from Gulf of Mannar showed higher carbohydrate and lower protein content while vice versa was observed in *E. acoroides* from Palk Bay (Kannan and Kannan, 2002) [21]. Rhizomes of seagrasses normally act as photosynthetic storage tissue and stored carbons were used for respiratory demands and plant growth (Lee and Dunton, 1996) [25]. In this study, *E. acoroides* with large leaf had high lipid content followed by *C. serrulata* and *S. isoetifolium* of spherical shaped leaf, and also leaves predominated over roots and rhizomes except *C. serrulata* from Thonithurai. Seagrasses of slowest growth rate showed relatively lower variation in lipid level and it was in the order of leaf blade followed by roots, rhizomes and leaf sheath (Yamamuro and Chirapart, 2005) [49]. Species as well as location wise variation in protein content was more obtained in seagrasses from Palk Bay than Gulf of Mannar. Noticeable differences in protein content could be due to strong allelopathic effect of seagrasses (Abd El-Hady and Khalifa, 2015) [1]. Seagrasses of Gulf of Mannar and Palk Bay showed wide variations between total carbohydrate and protein content except *T. hemprichii*. Distinguishable variation between total carbohydrate and protein was attributed to the factors of depth, light intensity, turbidity and nutrient availability in the water column, its uptake and translocation to different body parts of the plant (El Din and El-Sherif, 2013) [13].

**Table 7:** Comparison of biochemical composition of seagrasses

| Sl. No. | Species | Location | Protein % | Carbohydrate % | Lipid % | Reference |
|---|---|---|---|---|---|---|
| 1 | Seagrasses leaves<br>Seagrasses rhizomes<br>(*E. acoroides, H. beccarii, H. ovalis, C. rotundata, C. serrulata, H. uninervis, H. pinifolia* and *S. isoetifolium*) | Palk Bay<br>Palk Bay | 0.01-0.59<br>0.06-7.2 | 0.2-0.87<br>0.3-0.91 | 0.1-3.2<br>0.03-4.1 | Pradheeba *et al*., 2011 [41] |
| 2 | Seagrasses<br>(*C. serrulata, H. ovalis, H. pinifolia* and *S. isoetifolium*) | Gulf of Mannar | 0.263-1.575 | 0.014-0.318 | 0.002-0.003 | Athiperumalsami *et al*., 2008 [2] |
| 3 | Seagrasses (*C. serrulata, H. pinifolia* and *H. stipulacea*) | Mandapam coast | 6.79-7.89 | 6.01-6.32 | 0.92-1.02 | Kannan *et al*., 2010a [21] |
| 4 | Seagrasses leaf blade<br>Leaf sheath<br>Roots/rhizomes<br>(*E. acoroides, H. ovalis, C. rotundata* and *T. hemprichii*) | Thailand<br>Thailand<br>Thailand | ---<br>---<br>--- | ---<br>---<br>--- | 0.28-0.38<br>0.53-0.71<br>0.17-0.35 | Yamamuro and Chirapart, 2005 [49] |
| 5 | Seaweeds<br>*P. australis* | South Australia<br>South Australia | 4.4-7.3<br>4.8-6.8 | ---<br>24.4-28.8 | 1.1-1.7<br>5.5 | Torbatinejad and Sabine, 2001 [46]<br>Torbatinejad and Sabine, 2001 [46] |
| 6 | *C. nodosa* and *R. cirrhosa* | Egypt | 13-18.6 | 6.2-13 | 1.5-3.65 | Abd El - Hady *et al* ., 2007 [1] |
| 7 | Macro algae<br>*P. torreyi* | Baja California<br>Baja California | 11.25-19.18<br>12.53 | ---<br>--- | 0.68-0.88<br>0.45 | Serviere -Zaragoza *et al.*, 2002 [44]<br>Serviere -Zaragoza *et al.*, 2002 [44] |
| 8 | *H. engelmannii* | Florida | 4.2-11.5 | 5.2-34.7 | 0.1-1.5 | Dawes *et al*., 1987 [9] |
| 9 | *E. accordies* | Philippines | 0.8-8.8 | 72.4-87.6 | 0.1-0.2 | Montano *et al*., 1999 [38] |
| 10 | *C. nodosa* and *P. oceanica* | Egypt | 51-60.8 | 2.90-4.722 | 4.05-10.08 | El Din and El Sherif, 2013 [13] |
| 11 | *P. australis* | Australia | 4.81-6.11 | 20-30 | --- | Torbatinejad *et al*., 2007 [47] |
| 12 | Seagrasses<br>(*E. acoroides, C. serrulata* and *S. isoetifolium*) | Gulf of Mannar | 4.3-19.8 | 10.65-26.44 | 1.54-3.61 | Present study |
| 13 | Seagrasses<br>(*C. serrulata, T. hemprichii* and *S. isoetifolium*) | Palk Bay | 6.6-22.98 | 9.77-12.87 | 2.03-9.92 | Present study |

Comparatively higher elemental compositions were noticed in the present study compared to earlier reports in C (Table 8) (Mateo *et al*., 2003; Yamamuro and Chirapart, 2005; Athiperumalsami *et al*., 2008; Campbell *et al*., 2012; El Din and El-Sherif, 2013) [35, 2, 13, 49], N (Table 8) (Spencer and Ksander, 1994; Athiperumalsami *et al*., 2008; Campbell *et al*., 2012; El Din and El-Sherif, 2013; Wan Hazma *et al*., 2015) [2, 13] and P contents (Table 8) (Mateo *et al*., 2003; Campbell *et al*., 2012; El Din and El-Sherif, 2013; Wan Hazma *et al*., 2015) [35, 13]. Species wise variations in elemental compositions were noticed and comparatively higher concentrations were noticed in the leaves than roots and rhizomes except *C. serrulata* from Palk Bay. Variations in N, C and P levels were reported in seagrass species (Udy *et al*., 1999; Campbell *et al*., 2012; Wan Hazma *et al*., 2015). The environmental parameters (salinity, temperature, pH and sediment characteristics with respect to season) have strong influence in elemental composition of seagrasses (leaves, roots and rhizomes), and relatively lower changes noticed in roots and rhizomes (Sousa *et al*., 2017). Seagrass species of *S. isoetifolium* and *C. rotundata* are preferred by fishes due to their relatively higher contents of carbon as well as low carbon fibre whereas sea urchins prefer long lived seagrasses of *T. hemprichii* and *T. testudinum* (Valentine and Heck, 1991) [16]. The elemental composition of seagrass *P. oceanica* leaves were reported to be abundant in P content whereas in leaf litter (banquette) C and N predominated (Mateo *et al*., 2003) [35]. Decay kinetics of C, P and N content in scales and rhizomes of *P. oceanic*a showed that C loss with time was very lower in rhizomes and scales, and a sharp decrease was observed in P and N content in rhizomes (Romeo *et al*., 1995). Nutrient availability in seagrasses increased to meet the needs and was enriched in nitrogen and phosphorous with respect to carbon content.

**Table 8:** Comparison of elemental composition of seagrasses

| Sl. No. | Species | Location | C % | N % | P % | References |
|---|---|---|---|---|---|---|
| 1 | *T. testudinum* | America | 34.6-37.9 | 2.14-3.02 | 0.09-0.70 | Campbell *et al*., 2012 |
| 2 | *H. uninervis* and *S. isoetifolium* (leaves)<br>*H. uninervis* and *S. isoetifolium* (rhizomes) | Australia | ---<br>--- | 1.60-3.0<br>0.50-1.60 | 0.26-0.30<br>--- | Udy *et al*., 1999<br>Udy *et al*., 1999 |
| 3 | Seagrasses (*H. uninervis*, *T. ciliatum*, *C. rotundata* and *S. isoetifolium*) | Kenya | 36.6-42.1 | 2-3.1 | --- | Mariani and Alcoverro, 1999 |
| 4 | *P. oceanica* | Spain | 28-39.1 | 0.70-1.48 | 0.021-1.24 | Mateo *et al*., 2003 [35] |
| 5 | Seagrasses (27 species average) | | 33.6 | 1.92 | 0.23 | Duarte, 1990 [16] |
| 6 | *Potamogeton nodosus* and *Hydrilla verticillate* | California | 40.1-43 | 1.3-3.1 | --- | Spencer and Ksander, 1994 |
| 7 | Seagrasses leaf blades leaf sheath roots and rhizomes *(E. acoroides, H. ovalis, C. rotundata and T. hemprichii)* | Thailand<br>Thailand<br>Thailand | 31.4-38.9<br>29.6-34.3<br>17.7-36 | 1.90-3.02<br>1.38-1.72<br>0.41-0.86 | 0.236-0.264<br>0.217-0.23<br>0.041-0.18 | Yamamuro and Chirapart, 2005 [49] |
| 8 | Seagrasses *(C. serrulata, H. ovalis, H. pinifolia and S. isoetifolium)* | Gulf of Mannar | 1.76-3.35 (OC) | 0.56-2.22 | --- | Athiperumalsami *et al* ., 2008 [2] |
| 9 | *C. nodosa* and *P. oceanica* | Egypt | 12.4-13.23 | 8.45-10.6 | 1.21-2.13 | El Din and El Sherif, 2013 [13] |
| 10 | *Halophila ovalis, H. spinulosa* and *Halodule uninervis* | Johore, Malaysia | --- | 0.81-1.73 | 0.15-0.31 | Wan Hazma *et al*., 2015 |
| 11 | Seagrasses *(E. acoroides, C. serrulata and S. isoetifolium)* | Gulf of Mannar | 31.72-40.47 | 0.66-2.93 | 0.126-0.453 | Present study |
| 12 | Seagrasses *(C. serrulata, T. hemprichii and S. isoetifolium)* | Palk Bay | 35.21-41.18 | 0.77-1.58 | 0.125-0.622 | Present study |

Most of the macro elements studied was in lower concentrations than similar earlier reports (Table 9) (Hocking *et al*., 1980; Malea, 1998; Jeevitha *et al*., 2013; El Din and El Sherif, 2013; Wan Hazma *et al*., 2015) [17, 31, 13]. Distribution pattern of macro elements in the present study showed predominance of Na followed by Ca, K and Mg and was similar to earlier report (Malea, 1998) [31]. Differences in the level of macro elements in seagrasses varied with respect to age of plants, their time of collection and environmental factors (pH, salinity, temperature, etc.) which influence metal uptake (Malea, 1998) [31]. In this study, relatively higher concentrations of K, Ca and Mg noticed in seagrasses at Gulf of Mannar while higher Na at Palk Bay. Species as well as location wise variations in the level of macro elements were observed in this study and it was more pronounced at Gulf of Mannar rather than Palk Bay, and it could be due to differences in minerals related to metabolic reactions, environmental conditions, seasonal variations and differences of minerals required for the growth of plants. Moreover concentration of minerals in interstitial as well as overlying waters was attributed due to the uptake minerals from these areas by roots and translocated to different body parts (El Din and El-Sherif, 2013) [13]. Distribution of macro elements in *E. acoroides* showed higher contents of Na and K in rhizomes followed by roots and leaves whereas Ca and Mg followed the order roots>rhizomes>leaves in this study. Mg concentration in the leaves of selected seagrass species from Gulf of Aqaba (Jordan) followed the order of *H. stipulacea*>*H. ovalis*>*H. uninervis* whereas distribution in organs in the order leaves>roots>rhizomes (Wahbeh, 1984) [48], and also similar observations by Jagtap, 1983 and Kannan *et al*., 2011 [21, 18].

**Table 9:** Comparison of macro elements in seagrasses (µg/g)

| Sl. No. | Species | Location | Na | K | Ca | Mg | References |
|---|---|---|---|---|---|---|---|
| 1 | Seagrasses (*H . stipulacea*, *P. oceanica* and *C. nodosa*) | Greece | 20557-62596 | 13023-24320 | 13285-25533 | 6791-11788 | Malea,1998 [31] |
| 2 | *P. australis* | Australia | 40956 | 26532 | 88013 | 5406 | Hocking *et al*.,1980 [17] |
| 3 | *P. oceanica* | Tunisia | --- | 350 | 14200 | 18000 | Saidane *et al*.,1979 [43] |
| 4 | Seagrasses leaves rhizomes roots (*H. stipulacea*, *H. ovalis* and *H. uninervis*) | Jordan<br>Jordan<br>Jordan | ---<br>---<br>--- | ---<br>---<br>--- | ---<br>---<br>--- | 12574-15760<br>9508-11003<br>14086-14408 | Wahbeh, 1984 [48] |
| 5 | *H. beccarii* | India | 2650-7750 | 3150-6500 | 275-4475 | 7225-9800 | Jagtap, 1983 [18] |
| 6 | Seagrasses (*E. acoroides*, *H. pinifolia*, *C. rotundata*, *C. serrulata*, *T. herprichii*, and *S. isoetifolium*) | Gulf of Mannar | 30-690 | 10-300 | 19-220 | 91-912 | Kannan *et al*., 2011 [21] |
| 7 | Seagrasses (*C. serrulata*, *H. ovalis*, *H. pinifolia* and *S. isoetifolium*) | Tuticorin | 18300-60600 | 17300-37400 | 11700-28100 | 17800-39800 | Jeevitha *et al*., 2013 |
| 8 | *E. acoroides* | Philippines | --- | --- | 320-923 | --- | Montano *et al*.,1999 [38] |
| 9 | *C. nodosa* and *P. oceanica* | Egypt | 10444-27650 | 4816-6754 | 24700-38900 | --- | El Din and El Sherif, 2013 [13] |
| 10 | Seagrasses (*H. decipiens, C. rotundata, C. serrulata, H. uninervis, T. hemprichii , H. pinifolia* and *S. isoetifolium)* | Lakshadweep | --- | --- | --- | 5123-10368 | Thangaradjou *et al*., 2013 |
| 11 | *Halophila ovalis*, *H. spinulosa* and *Halodule uninervis* | Johore, Malaysia | --- | 4126-10942 | 4705-10576 | 3244- 3534 | Wan Hazma *et al*., 2015 |
| 12 | Seagrasses (*E. acoroides*, *C. serrulata* and *S. isoetifolium*) | Gulf of Mannar | 2130-24540 | 340-12410 | 1300-18230 | 1370-8900 | Present study |
| 13 | Seagrasses (*C. serrulata*, *T. hemprichii* and *S. isoetifolium*) | Palk Bay | 4710-39250 | 2160-7850 | 3800-17210 | 2360-6540 | Present study |

Marine organisms of isopods, decapods, gastropods and small fishes consumes live seagrasses and these are consumed by larger predators mainly fishes to forage at seagrass beds (Heck Jr. *et al*., 2008) [16]. Nearly 50% of seagrasses are consumed by organisms of the marine flora and fauna and rest of them deposited in the shore (Mateo *et al*., 2003; 2006) [35-36]. Animal proteins are used as source for essential amino acids over plant protein due to lack of essential amino acids, but it contains lots of phytochemicals which leads to higher health benefits (Day, 2013) [10]. The total protein content in seagrasses of Gulf of Mannar and Palk Bay in this study showed medium to high level. Seagrasses are producing large number of leaves from a single shoots which further leads to seagrass litter. These litters slowly accumulate in the beaches and it regarded as an environmental problem in many countries (Borum *et al*., 2004; Torbatinejad *et al*., 2007) [7, 47]. Most of them utilized the litters as animal feed and the study carried out by Torbatinejad *et al*. (2007) [47] showed no remarkable differences between green and unwashed seagrasses (6.11% and 5.65% respectively), but its tannin contents (1.74-1.85%) exceeds the limits for conventional feedstuffs such as legumes and pasture grasses ranged from 0.1 to 0.4%. It causes protein precipitation which leads to decrease in palatability, food intake and digestibility compared to other grasses. According to Baby *et al*. (2017b) [4], tannin content in seagrasses of Gulf of Mannar and Palk Bay showed a maximum of 5.02mg/100g. Seagrasses namely *C. rotundata*, *C. serrulata*, *E. acoroides*, *H. pinifolia*, *H. uninervis* and *S. isoetifolium* are used as feed for goats, sheep and pigs in the coastal areas of Tamilnadu, India (Newmaster *et al*., 2011) [39].

## 5. Conclusion

Species wise as well as location wise variations in biochemical composition were observed in seagrasses of Gulf of Mannar and Palk Bay, and it might be due to changes in environmental conditions of seagrass meadows and differences were noticed in the energy contribution of seagrasses from both sides. Comparatively higher carbohydrate content was found in roots and rhizomes than leaves. Among the different body parts, relatively higher concentrations of N, C and P were noticed in leaves rather than roots and rhizomes except P content. Species to species variations were noticed in C and N content of seagrasses from Gulf of Mannar while P content at Palk Bay. Macro elements in seagrasses followed the order Na> Ca> K> Mg and comparatively more station wise variations in concentration of these elements were noticed at Gulf of Mannar rather than Palk Bay. Among these elements K, Ca and Mg were abundant in Palk Bay while Na in Gulf of Mannar. The present study showed that seagrasses of Gulf of Mannar and Palk Bay can be used as an animal feed.

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## 7. Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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