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Diversity of marine life in three different habitats along the Tuticorin coast, gulf of Mannar

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Abstract
The present work aims to find out the biodiversity of marine organisms in three different types of habitat along the Tuticorin coast using biodiversity indices. These indices can be used more effectively in determining habitat qualities. For the present study the three study sites namely, Sandy shore, muddy shore, and Rocky shore located near Hare Island, Tuticorin coast, Gulf of Mannar were selected. Tuticorin beach is known to have very low tides. A total of 2380 individuals belonging 38 taxa were identified from sandy shore, 698 individuals belonging 13 taxa were identified from muddy shore and 630 individuals belonging to 9 taxa were identified from rocky shore of Tuticorin. The phylum Mollusca was the largest group on the sandy and rocky shore whereas the phylum Cnidaria was the largest group in muddy shore. The Species composition and quantitative characteristics of the marine organisms in Tutuicorin coast have been assessed by using biodiversity indices- Shannon index, Simpson, Margalef, Menhinick, Brillouin, Berger-Parker Index, Fisher-alpha, Pielou Evenness Indices and K dominance. The biodiversity was found to be high in all three habitats along the Tuticorin coast and highest in sandy coast followed by muddy and rocky coast.

Keywords: biodiversity indices, Tuticorin coast, marine organisms, sandy shore, muddy shore, rocky shore

Introduction

Marine ecosystems contain a diverse array of living organisms and abiotic processes. From massive marine mammals like whales to the tiny krill that form the bottom of the food chain, all life in the ocean is interconnected. While the ocean seems vast and unending, it is, in fact, finite; as the climate continues to change, we are learning more about those limits. Explore these resources to teach students about marine organisms, their relationship with one another, and with their environment. Corals are small marine animals. The "hard" type of coral grows with the help of algae, which gives it color and nutrients that help it form a sturdy, stony skeleton. Reefs, which form through the accumulation of hard coral, are a vital ecosystem, supporting an estimated 25 percent of ocean species. Corals face threats including ocean acidification and rising temperatures, and National Geographic Explorers are at the forefront of studying and protecting them.

A sandy beach is made up of minute grains of sand or crushed shells and rock. Because it is grainy, wind and water reshape a beach every day. Sandy shores are exciting places with life in and underneath the water. Sandy shores appear as beaches in enclosed bays between rocky headlands or as long stretches of sand adjacent to coastal dune systems or sandy spits. Sandy shores are highly dynamic environments, have a characteristic biodiversity and represent a unique gradient of habitats. Coastal sand dunes (CSD) are common in different parts of the world. CSD are natural structures protecting the coast from high waves and saltwater intrusions (Corre 1991) [3]. The plants living in sand dunes are called Psammophytes. These psammophytic species play a vital role in protecting the coast from erosion and floods (Desai 2000). The coastal length of India is 7500km with many lagoons, beaches, estuaries, and mangrove swamps, supporting rich biotic and abiotic micro-organisms. With respect to geographic location and physical distinctiveness, the coast of Thoothukudi District is part of the Gulf of Mannar Biosphere Reserve (08045'36"–9002'31"N & 78007'17"–78019'18"E). The recorded forest area is 169km2, which constitutes 3.66% of the geographic area of the district (Forest Survey Report 2005) [4]. There are different types of vegetation on the coast of Thoothukudi, this includes mangroves and their associates—scrub jungles, aquatic vegetation, and coastal sand dune vegetation. A sand dune is a mound, hill or ridge of sand that lies behind the part of the beach affected by tides. They are formed over many years when windblown sand is trapped by beach grasses. Dune grasses anchor the dunes with their roots, holding them temporarily in place, while their leaves trap sand, promoting dune expansion.

Rocky habitats are some of the most natural and untouched places. Often high up in the hills and hard to reach, they are havens for some of our rarest wildlife. Rocky habitats are mostly found in the uplands wherever the underlying rock reaches the surface. Together with the wind, sunlight and other physical factors it creates a complex environment. Organisms that live in this area experience large daily fluctuations in their environment. For this reason, they must be able to tolerate extreme changes in temperature, salinity, moisture and wave action to survive. They are home to many organisms, a nursery area for many fish and crustacean species. And shelter in areas where seaweeds reduce the wave power. Mixed environments with wave-exposed shores or sandy tidal flats alternating with mud-dominated tidal flats and deeper muddy areas are common, and require special.

Objective of present study

The objective of the present study was to quantify the abundance, species richness and diversity of marine organisms, to understand their ecological and economic importance to the local community of Thoothukudi, Tamil Nadu.

Study site

Thoothukudi (formerly Tuticorin) is a port city, a municipal corporation and an industrial city in Thoothukudi district in the Indian state of Tamil Nadu. The city lies in the Coromandel Coast of Bay of Bengal. It is the capital and headquarters of Thoothukudi district. And located about 590 kilometres (367 miles) southwest of Chennai, 190 kilometres (118 miles) northeast of Thiruvananthapuram and 580 kilometres (360 miles) southeast of Bangalore. The city is known as "Pearl City" due to the pearl fishing carried out in the town. It is a commercial seaport which serves the inland cities of Southern India and is one of the sea gateways of Tamil Nadu. The 21 islands between Thoothukudi and Rameswaram shores in the Gulf of Mannar are noted as the first Marine Biosphere Reserve of India, and have around 36,000 species of flora and fauna. This protected area is called Gulf of Mannar Marine National Park. Hare Island is the largest island in the Gulf of Mannar and is known for its healthy ecosystem of coral and sea grass. Hare Island, Harbour Estate, Thoothukudi is located between 8.773654 N and the longitude 78.187792 E.

Materials and methods

For the present study the three study shores namely, Sandy shore, muddy shore, and Rocky shore were located near Hare Island, Tuticorin coast, Gulf of Mannar. Tuticorin beach is known to have very low tides. The specimen collections were from January 17, 2023, to 19 January 2023, between 9.00 am to 3.30 pm. All individuals were identified to species, genus, and family level. Shannon, Simpson, Margalef, Menhinick, Brillouin, Berger-Parker Index, Fisher-alpha, Pielou Evenness Indices and K dominance were used for statistical analyses of biodiversity of organisms in Tuticorin coast.

Shannon Diversity Index: It's the most preferred index among the other diversity indices. The index values are between 0.0 – 5.0. Results are generally between 1.5 – 3.5, and it exceeds 4.5 very rarely. The values above 3.0 indicate that the structure of habitat is stable and balanced; the values under 1.0 indicate that there are pollution and degradation of habitat structure.

Simpson Diversity Index values are between 0 – 1. But while calculating, intial result is subtracted from 1 to correct the inverse proportion.

Margalef Diversity Index It has no limit value, and it shows a variation depending upon the number of species. Thus, it's used for comparison of sites.

Pielou Evenness Index (J): It was derived from Shannon index by Pielou in 1966. The ratio of the observed value of Shannon index to the maximum value gives the Pielou Evenness Index result. The values are between 0 – 1. When the value is getting closer to 1, it means that the individuals are distributed equally.

Berger-Parker Index expresses the proportional importance of the most abundant species. As with the Simpson index, the reciprocal form of the Berger-Parker index is usually adopted so that an increase in the value of the index accompanies an increase in diversity and a reduction in dominance.

The k-dominance shows the cumulative percentage in relation to species (k) rank or logspecies (k) rank. Here the sample representing the lower line has the higher dominance.

Observations and result

Biodiversity is the variety of life found in a place. It can be quantified in many different ways. But two main factors are usually taken in account while measuring the biodiversity - species richness and species evenness. Species richness is the measurement of the number of species present in a place. The more species present in a sample, the richer the sample is as it takes no account of the number of individuals of each species present and gives equal weight to those species which have very few individuals and those which have many individuals. Species evenness is the relative abundance of the different species making up the richness of an area. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. It is very difficult for us to judge by only the numbers. So, we use biodiversity indices which can quantify the biodiversity of a place and express it as a numerical value.

Sandy coast

A total of 2380 individuals belonging 38 taxa were identified from sandy shore of Tuticorin Table 1. Phylum-level distribution of these taxa is shown in Figure.1. The phylum Mollusca is the largest group on the sandy coast of Tuticorin from the samples collected. In respect to both diversity and abundance, this group is represented at high levels compared to other groups. Mollusca constituted 55% of all collections in this study.

Table 1: Collection from sandy coast in Tuticorin [Plate-I]

Phylum	Class	Order	Scientific Name	Common Name	No. of Individuals
Annelida	Polychaeta	Eunicida	*Eunice aphroditois*	Bobbit worm	46
		Amphinomida	*Eurythoe complanata*	Iridescent fire worm	76
Arthropoda	Malacostraca	Decapoda	*Alpheus mannarensis*	Clapping prawn	95
			Eupagures bernhardus	Hermit crab	94
			Lamarckdromia	Hairy crab	87
			Calappa calappa	Smooth box crab	78
Chordata	Reptilia	Squamata	*Hydrophis schistosus*	Beaked sea snake	1
		Testudines	*Chelonia mydas*	Green sea turtle	1
Cnidaria	Anthozoa	Actiniaria	*Actiniaria*	Sea anemone	47
		Scleractinia	*Goniastrea retiformis*	Lesser star coral	76
			Madrepora oculata	Zigzag coral	62
			Pocillopora damicornius	Flower coral	47
			Madrepora cerviconis	Staghorn coral	93
			Favia favus	Head coral	17

Echinodermata	Ophiuroidea	Amphilepidida	*Ophiactis savignyi*	Brittle star	90
	Holothuroidea	Holothurida	*Holothuria*	Sea cucumber	88
Mollusca	Bivalvia	Galeommatida	*Galeomma turtoni*	Small salt water clams	52
		Cardita	*Cardita floridana*	Broad ribbed carditid	84
		Venerida	*Paratapes textilis*	Carpet clam	67
		Venerida	*Pitar citrinus*	Pitar	35
		Veneroida	*Cardium ovale*	Heart shell	96
		Arcida	*Arca*	Ark clams	65
	Gastropoda	Trochida	*Turbo intercostalis*	Ribbed turban	79
		Cephalaspidea	*Bulla ampulla*	Pacific blue snail	41
		Sorbeoconcha	*Turitella cingulifera*	Sea snail	89
		Neogastropoda	*Turbinella pyrum*	Indian chank	78
			Murex trapa	Rock snails	98
			Chicoreus brunneus	Adusta murex	97
			Fusinus nicobaricus	Nicobar spindle	38
			Babylonia spirata	Spiral babylon	91
			Oliva oliva	Olive snail	31
			Hemifusus pugilinus	Crown conches	94
		Littorinimorpha	*Cymatium pyrum*	Pearl Triton	38
			Bursa spinosa	Spiny frog shell	56
			Cypraea moneta	Money cowrie	32
			Phalium glaucum	Grey bonnet	40
Porifera	Demospongiae	Haplosclerida	*Gelliodes fibrosa*	gelliodes	23
		Axinellida	*Axinella waltonsmithi*	Crumbled duster sponge	58

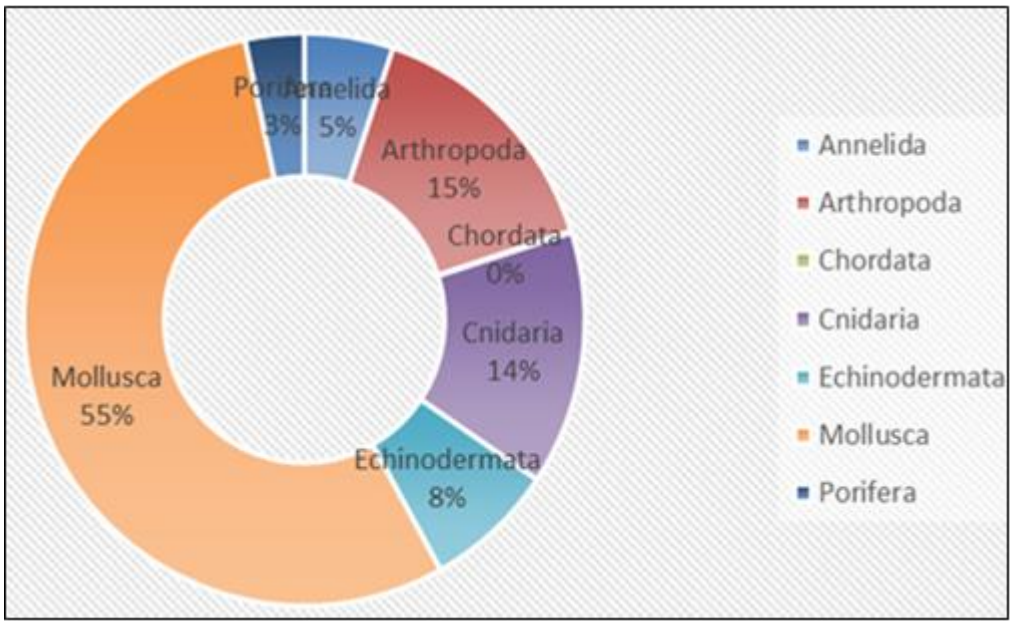

Fig 1: Phylum-level distribution of organisms in sandy coast

A diversity index is a quantitative measure that reflects how many different types (such as species) there are in a community. These indices are statistical representations of biodiversity in different aspects (richness, evenness, and dominance).

Simpsons diversity index (D) was very low (0.03155) and Simpson's index of diversity (1-D) was very high (0.9685) which indicates high biodiversity in the study area. The value of Shannon diversity usually falls between 1.5 to 3. 5 and rarely surpass 4.5. The value was found to be 3.513, which indicates high species diversity. Brillouin index of 3.469 also indicates high species diversity. A high species diversity may indicate a healthy environment. Evenness (E) is a measure of how similar the abundances of different species/categories are in a community. Evenness ranges from zero to one. When evenness is close to zero, it indicates that most of the individuals belong to one or a few species/categories. When the evenness is close to one, it indicates that each species/category consists of the same number of individuals. In sandy coast species evenness is 0.8826. As species richness and evenness increase, so diversity increases. Simpson's Diversity Index is a measure of diversity which takes into account both richness and evenness. The evenness of a community is represented by Pielou's evenness index (J) and in sandy coast the value of J was 0.9657, indicate higher levels of evenness in sandy coast.

Margalef Index is weighed towards species richness**.** The advantage of this index over the Simpson index is that the values can come more than 1 unlike in the other index where the values will be varying from 0 to 1. This way comparing the species richness between different samples collected from various habitats is easy. The Margalef Indexwas 4.759 which indicates a sandy coast is species rich. Species richness S is the simplest measure of

biodiversity and is just a count of the number of different species in a given area. This measure is strongly dependent on sampling size and effort. Two species richness indices are: Margalef's diversity index and Menhinick's diversity index. Menhinick's diversity index was 0.7789, Berger-Parker index 0.04118, Fisher index 6.421, and chao-1 as 38**.** K-dominance values points towards *Murex trepa* (4.118) and *Chicoreus brunneus* (8.193) being the most dominant species and *Chelone mydas* least dominant in sandy coast among the organisms collected.

Muddy coast

Total 698 individuals belonging 13 taxa were identified from muddy shore of Tuticorin (Table 2). Phylum-level distribution of these taxa was shown in Figure 2. The phylum Cnidaria is the largest group in muddy coast of Tuticorin from the samples collected. In respect to both diversity and abundance, this group is represented at high levels compared to other groups. The cnidarians constituted 55% of all collections in this study in muddy coast.

Table 2: Collection from muddy coast in Tuticorin

Phylum	Class	Order	Scientific Name	Common Name	No. Of Organism Observed
Chordata	Actinopterygii	Tetraodontiformes	*Diodon holocanthus*	Spiny puffer	55
Cnidaria	Hexacorallia	Antipatharia	*Antipatharia*	Black/Thorn coral	33
		Scleractinia	*Galaxea fasicularis*	Galaxy coral	35
		Scleractinia	*Turbinaria*	Cup coral	62
	Hydrozoa	Anthoathecata	*Millipora alcicomis*	Sea ginger	55
	Octocorallia	Alcyonacea	*Gorgonia ventalina*	Sea fan	37
	Octocorallia	Alcyonacea	*Leptogargia*	Sea wip	69
	Anthozoa	Scleralcyonacea	*Junceella juncea*	Monkey tail	73
Echinodermata	Asteroidea	Valvatida	*Protoreaster lincki*	Red spine star	63
	Echinoidea	Echinoida	*Echinus*	Sea urchin	65
Mollusca	Bivalvia	Pteriida	*Pinna carnea*	Amber pen shell	9
		Cardiida	*Limecola balthica*	Baltic macoma	65
		Cardiida	*Scrobicularia plana*	Peppery furrow shell	77

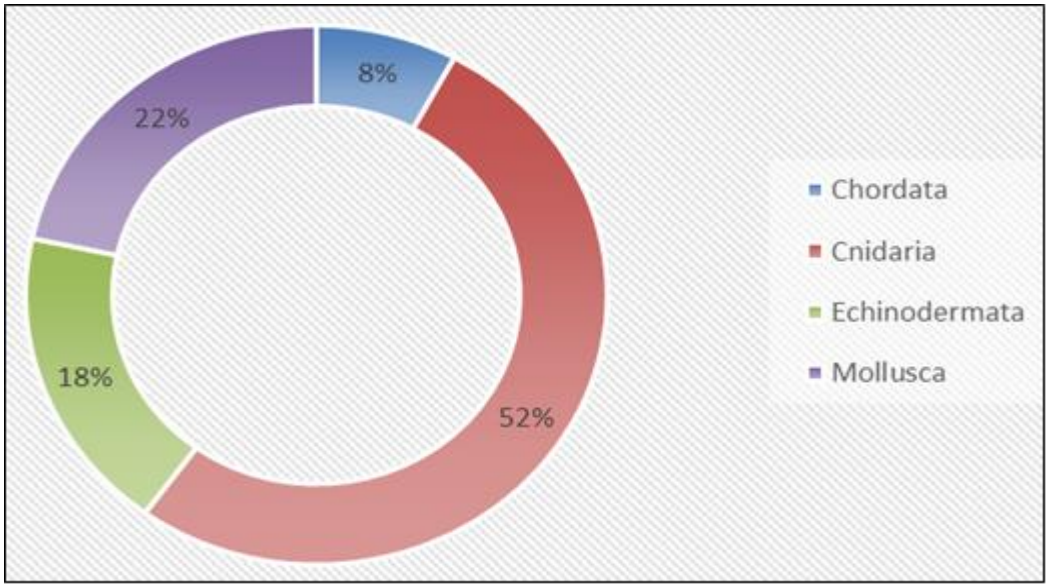

Fig 2: Phylum-level distribution of organisms in muddy coast

In muddy coast the Simpsons diversity index (D) was low (0.0864) and Simpson's index of diversity (1-D) was very high (0.9136) which indicates high biodiversity in the study area. The value of Shannon diversity was found to be 2.489, which indicates species diversity. Brillouin index of 2.442 also indicates species diversity being high. In muddy coast species evenness was 0.9268 which indicates that each species consists of the same number of individuals. As species richness and evenness increase, so diversity increases. The evenness of a community is represented by Pielou's evenness index (J) and in muddy coast the value of J was 0.9703, indicate higher levels of evenness in muddy coast. The Margalef Index was 1.833 which indicates a species richness in muddy coast. Menhinick's diversity index was 0.492, Berger -Parker index 0.113, Fisher index 2.268, and chao-1 as 13.

K-dominance values points towards *Scrobicularia plana* (11.032) and being the most dominant species and *Pinna carnea* least dominant in muddy coast among the organisms collected.

Rocky coast

A total of 630 individuals belonging to 9 taxa were identified from rocky shore of Tuticorin (Table 3). The phylum Mollusca is the largest group in the rocky shore of Tuticorin from the samples collected. In respect to both diversity and abundance, this group is represented at high levels compared to other groups. The Mollusca constituted 76% of all collections in this study (Figure3). The phylum-level distribution of organisms in rocky coast is 76% Mollusca and Arthropoda is 24%.

Table 3: Collection from rocky coast in Tuticorin

Phylum	Class	Order	Scientific Name	Common Name	No. Of Organism Observed
Arthropoda	Malacostraca	Isopoda	*Ligia oceanica*	Sea slater	54
	Thecostraca	Balanomorpha	*Semibalanus balanoides*	Common rock barnacle	100
Mollusc	Gastropoda	Aplysiida	*Aplysia*	Sea hares	45
		Littorinimorpha	*Littorina neritoides*	Small periwinkle	96
		Patelloidea	*Patella vulgata*	Common limpet	93
		Littorinimorpha	*Littorina rudis*	Common periwinkle	87
	Polyplacophora	Chitonida	*Chiton*	Chitons	43
	Bivalvia	Ostreoida	*Ostrea*	True oysters	47
Ascomycota	Eurotiomycetes	Verrucariales	*Verrucaria*	Crustose Lichen	65

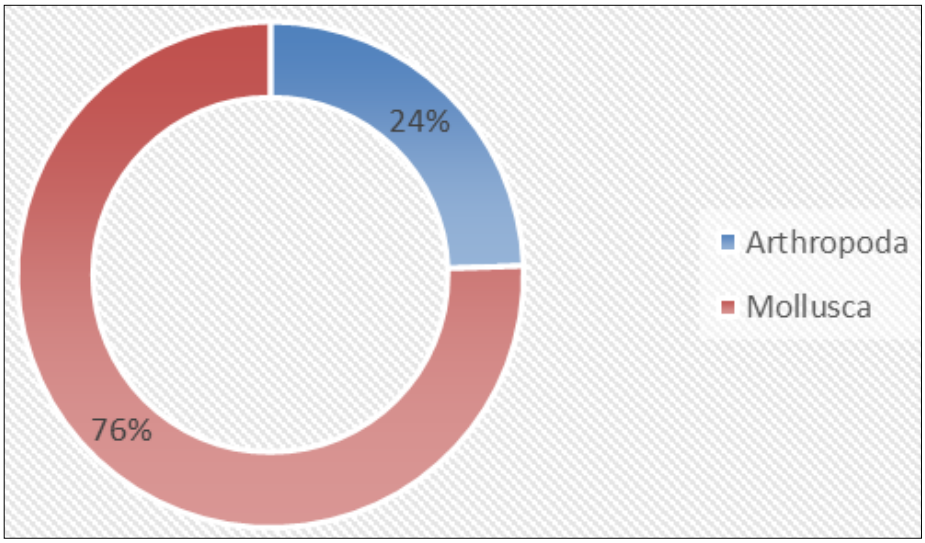

Fig 3: Phylum-level distribution of organisms in rocky coast

In rocky coast the Simpsons diversity index (D) was low (0.1226) and Simpson's index of diversity (1-D) was very high (0.8774) which indicates high biodiversity in the study area. The value of Shannon diversity was found to be 2.145, which indicates species diversity. Brillouin index of 2.108 also indicates species diversity was high. In rocky coast species evenness was 0.9491. In rocky coast the value of J was 0.9762, indicate higher levels of evenness in rocky coast. The Margalef Index was 1.241which indicate a species richness in rocky coast. Menhinick's diversity index was 0.3586, Berger -Parker index 0.1587, Fisher index 1.487, and chao-1 as 9.

K-dominance values points towards *Semibalanus balanoides* (15.873) and being the most dominant species and *Chiton* least dominant in rocky coast among the organisms collected.

Table 4: Comparison of Biodiversity indices in the three habitats

Biodiversity Indices	Sandy Coast	Muddy Coast	Rocky Coast
Taxa_S	38	13	9
Individuals	2380	698	630
Dominance_D	0.03155	0.0864	0.1226
Simpson_1-D	0.9685	0.9136	0.8774
Shannon_H	3.513	2.489	2.145
Evenness_e^H/S	0.8826	0.9268	0.9491
Brillouin	3.469	2.442	2.108
Menhinick	0.7789	0.4921	0.3586
Margalef	4.759	1.833	1.241
Equitability_J	0.9657	0.9703	0.9762
Fisher_alpha	6.421	2.268	1.487
Berger-Parker	0.04118	0.1103	0.1587
Chao-1	38	13	9

When the biodiversity indices of three habitats were compared (Table 4) the biodiversity was found to be highest in sandy coast as it has highest Shannon and Brillouin diversity index. The biodiversity was found to be high in all three habitats along the Tuticorin coast and highest in sandy coast followed by muddy and rocky coast. However, complete inventories of all species present at a certain location, is an almost unattainable goal in practical applications. High species diversity suggests that great number of successful species, a more stable ecosystem, more ecological niches are available and the environment is less likely to be hostile, contains complex food webs and environmental changes is less likely to be damaging to the ecosystem as a whole. Low species diversity suggests relatively fewer successful species in the habitat, environment is quite stressful, with relatively fewer ecological niches only few organisms are well adapted to that environment, food webs are relatively simple and any change in the environment may have serious effects on the ecosystem.

Discussion

Biodiversity is a central idea in the practice of quantifying the ecological status of different biotopes by known abundances of species (Ravindran,1999) [13]. However, in large-scale environmental protection, the species abundances are mostly unknown. In such cases we have to use so-called biological diversity measures, which are based on taxonomic relations or similar differences of species only. Here abundance conditions of the species are unessential. As for the term 'biological diversity', it dates back to the early 1980s.

All these biodiversity indices are based on new conceptions of species diversity. (Kurupswamy,2020) elaborated a new diversity index based on species abundance and functional relations between species. The new ecosystem diversity is defined as the sum of species diversity and structural diversity. Naturally, for concrete applications one should be informed about figures on numerous relations.

The Species composition and quantitative characteristics of the marine organisms in Tutuicorin coast have been assessed by using biodiversity indices- Shannon index, Simpson, Margalef, Menhinick, Brillouin, Berger-Parker Index, Fisher-alpha, Pielou Evenness Indices and K dominance. Samples were collected at 3 different coast of Tuticorin in January 2023. The samples from sandy shore consisted of 38 taxa and 2380 individuals belonging to seven phylum which were Arthropoda, Mollusca, Echinodermata, Chordata, Porifera, Annelida and Cnidaria. The phylum Mollusca was dominant in sandy coast. Total 698 individuals belonging 13 taxa were identified from muddy shore of Tuticorin belonging to four phylum which were Chordata, Cnidaria, Echinodermata and Mollusca. The phylum cnidaria was dominant in muddy coast. Total 630 individuals belonging 9 taxa were identified from rocky shore of Tuticorin mostly from Phylum Arthropoda and Mollusca. The phylum Mollusca is the largest group in rocky shore of Tuticorin from the samples collected.

The results of all biodiversity and evenness indices in this study were close and highly resemble to each other, and thus all of these indices can be used in studies of determining habitat qualities along Tuticorin Coast. Features of a population such as number of existing species (Richness), distribution of individuals equally (Evenness) and total number of existing individuals underlie the basis of diversity indices (Wilhm and Dorris 1968, Allan 1975) [16, 1]. Thus, any changes in any of these three features will affect the whole population, so that the diversity indices depending upon these features are used effectively to determine the changes in a population (Arumugam, 2006) [2]. The biodiversity was found to be high in all three habitats along the Tuticorin coast and highest in sandy coast followed by muddy and rocky coast. However, complete inventories of all species present at a certain location, is an almost unattainable goal in practical applications. High species diversity suggests that great number of successful species, a more stable ecosystem, more ecological niches are available (Koske, 1997) [6] and the environment is less likely to be hostile, contains complex food webs and environmental changes is less likely to be damaging to the ecosystem as a whole.

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