



# Status of Coastal Marine Biodiversity of Goa and Challenges for Sustainable Management - An Overview

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## Abstract

Degradation of marine and coastal ecosystem can be seen everywhere and Goa is no exception. Biodiversity provide important services to mankind and needs to be protected. Goa is endowed with varied microhabitats along its 105 long coast line. These habitats are home to diverse forms of life about which little is known. The coastal waters serve as nursery to fishes and other animals which are exploited commercially. The present communication reviews the current status on the taxonomic knowledge of the coastal biodiversity of Goa. The coastal water of Goa abound in flora and fauna. The information on major fauna and flora of Goa is sufficiently available. There is, however, some lacunae in our knowledge on invertebrate subgroups, such as sponges, octocorals, ctenophores, and tunicates and minor phyla. The biodiversity of specialized ecosystems continued to be inadequately known and remains a challenge to specialists from Goa coast. Threat to coastal and marine biodiversity due to climate change and environmental degradation are intensifying with time. The anthropogenic activities are causing damage to pristine coastal ecosystems. The loss of biodiversity will be felt in greater strength by future generation. The present knowledge on coastal biodiversity warrants continued taxonomic research in the least-studied or unknown groups of hot spot areas in the light of existing threats to marine biodiversity. It is suggested that further research on new species occurrences in the least studied groups should be continued to update the data and improve our knowledge. The appropriate measures will be required to protect the rich biodiversity resources of Goa.

**Keywords:** Biodiversity, Conservation, Disturbance, Ecosystem, Goa

## 1. Introduction

Marine and coastal ecosystems are important habitat with a distinct structural diversity and flow of energy. The salt marshes, mangroves, wetland, estuaries and bays form the main area of coastal ecosystem with high biodiversity<sup>1</sup>. Of all the factors affecting the health and sustainability of the ocean, the status of protection of threatened, vulnerable and endangered species may be the most familiar problem<sup>2</sup>. In spite of the sustained efforts to save the coastal biodiversity, there are some species such as dolphins, turtles, sharks, sea cow and horseshoe crab showing the sign of degradation and extinction. A greater role of human being comes in conserving the coastal and marine biodiversity because they are vital components

for maintaining life on earth. We should try to halt the further losses of coastal biodiversity and ensure a stable coastal ecosystem as soon as possible.

The Indian coast has wide range of habitats that support commercial fishery. There are large number of species of flora and fauna adapted to a wide range of coastal ecosystems<sup>3</sup>. These ecosystems serve as nurseries for both inshore and offshore fish and other animals, many of which are commercially exploited. Marine and coastal ecosystems are important habitat with a distinct structural diversity and flow of energy. Our knowledge about the fauna and flora of marine origin is far from satisfactory. There is apparently lower biodiversity of marine species compared to the terrestrial species. This may be justified as an artifact of inadequate exploration of deep seas and

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taxonomic studies<sup>4</sup>. In this communication major issues on coastal biodiversity loss and its conservation for Goa is discussed.

## 2. Biological Diversity

The Convention on Biological Diversity (Article 2) defined biological diversity or biodiversity “as the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”<sup>2</sup>. Marine biodiversity shows different trends in different geographical areas. The benthic realm of coastal water has the highest biodiversity as compared to pelagic system. Recent taxonomic research in India has brought to light the higher number of marine species in each group in which are many unidentified (Table 1). According to de Fontaubert *et al.*,<sup>5</sup> biodiversity can be more specifically defined as the “variability among the living organisms from all sources including terrestrial marine and other aquatic *inter alia* ecosystems and the ecological complexes of which they are apart. There are three main category of biodiversity; (1) Genetic diversity, (2) species diversity (3) habitat diversity. The survival each is linked to the health of other two, and together they comprise the wealth of the ecosystem. These components will explain how biodiversity encompasses organisms at different scale ranging from gene to the ecosystem. The marine ecosystem functioning is dictated largely by biodiversity and community structure of the marine environment<sup>6</sup>.

### 2.1 Importance of Biodiversity

The Indian Ocean includes the Arabian sea and Bay of Bengal. It falls under tropics and has several important oceanographic features which govern the high biodiversity. The high abundance of phytoplankton and primary productivity leads to high secondary production of consumers in the form of zooplankton and benthos<sup>7</sup>. The commercially exploitable fisheries can be regarded as the final link in the diverse assemblage of producers and consumers. Coastal Biodiversity has several important linkages such as (1) adaptation (2) food (3) Raw material (4) Climate (5) Knowledge. It can yield benefits and help to mankind during the testing time of climate change<sup>8</sup>.

**Table 1.** Estimated Indian marine faunal biodiversity

Sr.no.	Taxa	No. Species
1	Porifera	512
2	Cnideria	1385
3	Ctenophora	19
4	Platihelminthes	832
5	Pelyclad	46
6	Gastrotricha	61
7	Rotifera	47
8	Acanthocephala	229
9	Nematoda	356
10	Mollusca	3400
11	Opisthobranchia	389
12	Annelida	510
13	Arthropoda	3956
14	Sipuncula	41
15	Tardigrada	8
16	Bryozoa	272
17	Brachiopoda	8
18	Echinodermata	777
19	Chaetognatha	44
20	Hemichordata	14
21	Urochordata	516
22	Pisces	3267
23	Reptiles	32
24	Mammals	33

Source: Zoological survey of India, 2017

The nektonic and benthic life (sessile and sedentary) of the ocean defends themselves through chemical means. It is possible that chemicals for pharmaceuticals such as prostaglandin, arothionin, bromine, iodine and amoebocyte lysate could be obtained from marine organisms<sup>9</sup>. There are other animals which secrete chemicals of complex nature. Marine Ecosystems play important role in controlling global climate. The biogeochemical process is controlled by the living biota existing on earth of which the marine realm is extremely important. The preservation of biological diversity for the sake of knowledge itself is important. There are possibly 80 different marine habitats that continued to be discovered in the present day. The discovery and invention of new species previously thought to be non-existence, not only add to the list of biodiversity but are example of new knowledge.

### 3. Coastal Marine Biodiversity of Goa

The small state of Goa, is endowed with a dazzling array of marine biodiversity along its coast. It is influenced by the coast on the one hand and the Western Ghat on the other. It has three major eco-regions of the state; the coastal plains rich with mangroves, estuaries and intertidal ecosystem, the middle plateaus and the low lying river basins and wetlands and the mountainous Sahayadri region<sup>10</sup>. Even in this small geographic area a diversity of ecosystems and habitats ranging from wet evergreen forests, rocky and sandy coast, rivers, wetlands, estuaries, and mangroves with their unique floral and faunal assemblages abound. The salient feature of Goa is given in (Table 2). The state supports six watersheds, nine rivers and their 42 tributaries. The two big rivers of the state Mandovi and Zuari together drain some 2557sq km (70%) of the geographic area of the state. The uniqueness of the river systems of Goa is the influence of both the saline tidal water and the rain fed fresh water that forms a major ecotone to support a diverse floral and faunal representation. Biodiversity of the state is reflected in its endemism of many species. The important identified coastal and marine biodiversity area in Goa is provided in (Table 3). Anthropogenic changes in the form of replacement of natural vegetation and large scale mining for minerals has already taken a toll of the state biodiversity. Added to this are threats from climate change will bring in additional pressures on the coastal and marine habitats.

#### 3.1 Microniches

These are some specialized habitats adapted by the particular species for a living, foraging and other needs during routine life of the organisms. These includes rocky shore, (rocky cliff, pool, boulder, rocky platform)

**Table 2.** Salient feature of Goa

Length of coast	105 km
Coastal wet land	8486 ha
Sandy shore	519 ha
Rivers	9
Khazan land	1700 ha
River bank	5000 ha
Mangrove	2000 ha
Beaches and sand dunes	4000 ha

crevices, and sandy and muddy shores. These niches provide space for shelter and food to large variety of life such as caprellidae, sea slugs, pycnogonida, hydrozoans, bryozoans, molluscs, sea urchins, holothurians and polychaete worms. There is no clear understanding of the biodiversity of these micro-habitats. Recent taxonomic research on lower and higher marine organisms has brought to light many new species (Table 4). The most interesting thing about marine biodiversity is the variation in size within taxa which suggest a large extinction of marine life in the prehistoric past.

#### 3.2 Phytoplankton

The phytoplankton are important component of marine food chain. There is good knowledge about the ecology and production of phytoplankton of Goa coast<sup>11,12</sup>. The phytoplankton population consisted of Centrales and Pennales of major groups Bacillariophyceans, Dinophyceans and Cyanophyceans. A total of 96 species belonging to diatoms, dinoflagellates and blue green algae have been recorded from estuaries and coastal waters of Goa. Pinnate diatoms were found to dominant the phytoplankton. The population was dominated by Genera of *Chaetoceros*, *Skeletonema costatum*, *Navicula*

**Table 3.** Important identified coastal and marine biodiversity areas in Goa

District	Name	Coordinate Lat. Long.	Habitat	Area
North Goa	Morjim	15°37.019 73°44.007	Turtle nesting beach	110.57 CCR estuarine mangrove
North Goa	Zuari-Mandovi	15°27.989 73°48.297	Estuarine complex	84.5 CCR mangrove isles, bird sanctuary
South Goa	Galgibag	14°57.877 74°03.201	Turtle nesting beach	3.5 0.57 CCR, sheltered mangrove rocky shoreline

Source: Saravanan *et al.*, 2013<sup>40</sup>

**Table 4.** Explored marine and coastal Biodiversity of Goa

FLORA	
Marinefungi	78
Marine Algae	145
Mangrove	15
Sand dune vegetation	106
Seagrass	2
Phytoplankton	96
FAUNA	
Invertebrata	
Porifera	6
Bryozoa	3
Nematoda	10
Polychaeta	140
Crustacea	
Decapoda	17
Brachyuran	51
Copepoda	66
Cirripedia	7
Mollusca	
Bivalvia	19
Gastropoda	86
Cephalopoda	2
Echinodermata	16
Chordata	
Pisces	224
Reptilia	4
Mammalia	3

*Nitzschia*, *Prorocentrum dentatum* and *Rhizosolenia sp.*. The dinoflagellates were represented by *Gymnodinium* and *Gyrodinium sp.*

### 3.3 Zooplankton

Zooplankton forms the secondary level of production of the marine environment. The ecology, seasonal distribution and species diversity of zooplankton community of Goa coast is studied in detail<sup>13,14</sup>. It is dominated Crustacea particularly copepod. They form more than 50% of all zooplankton group. The copepod formed the numerical dominance by families Acartiidae, Pseudodiaptomidae and Paracalanidae. The dominant species of copepod were *Acartia centrura*,

*Pseudodiaptomus bowmeni*, *Paracalanus sp.* and *Oithona sp.* About 15 species of copepod was recorded from the estuaries and 45 species from coastal water of Goa. Other groups were hydromedusae, siphonophores, ctenophores and chaetognatha. The chaetognatha had 7 species and the dominant species was *Sagittabedoti*. The constituents of zooplankton showed seasonal variation and are controlled by hydrographic parameters.

### 3.4 Benthos

Benthic organisms are the most diverse group of organisms occupy the sea floor. They form the secondary level of production. A number of benthic organism are exploited for food. The benthic organisms of Goa coast are very well studied<sup>15-18</sup>. The macrobenthic organisms comprised of several groups of invertebrate phyla, dominated by Annelida, crustacean and mollusca. Nearly 90 species of polychaeta are reported from Goa. The dominant species are *Paraprionospio pinnata*, *Magelona sp.*, *Tharyx sp.*, *Cossura sp.*, *Diopatra neapolitana* and *Glycera alba*. There are several important benthic bivalves and gastropods. The crustacean is dominated by shrimp, crab, stomatopoda, and hermit crab. The benthic echinodermata include starfish, brittle star, sea urchin and holothurian. Two species of holothurian are reported from Goa coast. Others include minor phyla like sipuncula, Echiurid worm benthic isopods, amphipods etc. In a recent study by Mahabaleshwar *et al.*,<sup>19</sup>. About 84 new records of benthic organisms have been reported from Goa coast. The meiobenthos has a rich biodiversity and is represented by nematode, benthic copepod, tardigrada, turbellaria, gastrotricha, foraminifera, polychaete, oligochaete and kinorhyncha<sup>16</sup>.

### 3.5 Marine Fisheries

Goa produced about 127 thousand metric tonnes of fish during financial year 2018 (Directorate of fisheries, Goa government, 2019). There are 224 species of fishes recorded from Goa coast<sup>20</sup>. Fisheries contribute about 2.5% of the total GDP of Goa and play an important role in the socio-economic development. The fisheries comprised and contributed by pelagic and demersal catches. The pelagic group forms more than 53% of the total landing with remaining constituted by demersal group. The pelagic resources are mainly contributed by oil sardine (*Sardinella longiceps*) and Indian mackerel (*Rastrelliger kanagurta*), seer fishes, tuna and ribbon

fishes (*Trichiurus lepturus*). Some species of pelagic fishes are the main target by fishing fleet. The demersal resources are mainly shrimps, pomfrets, scaenids and flat fishes. Goa coast is rich in ornamental fishes such as *Abudefduf* sp, *Chaetodon collaris*, *Heniochus acuminatus* etc.

The decapoda (shrimp and crab) of Goa coast has high biodiversity. It is represented by 17 species of shrimps 51 species of crabs. The crustacean fishery is supported by *Metapenaeus dobsoni*, *M. affinis*, *Parapeneopsisstylifera*, and *P. merguinensis*<sup>21</sup>. The crab fishery is supported by *Portunu spelagicus*, *P. sanguinolentus*, *Charybdis sp.* and *Scylla cerreta*. About 51 species of Brachyuran crabs are reported from Goa coast<sup>22</sup>. A new species, *Charybdis goaensis* has been recorded. Goa coast has a high biodiversity of mollusca<sup>18,23</sup>. About 86 gastropoda and 19 bivalves are recorded. Among bivalves 6 species, *Perna viridis*, *Villorita cyprinoides*, *Meretrix casta*, *Paphia malabarica*, giant oyster *Crassostrea gryphoides* and mangrove clam (*Polymesoda erosa*) form some smaller fishery and exploited regularly. The deteriorating water quality of the estuaries is effecting the shellfishes of Goa coast.

A list of endangered marine organism including fish is given in (Table 5). The fish species like *Carcharhinus hemiodon*, *C. limabus*, *C. melanopterus*, *Galeocerdo cuvieri*, *Hippocampus kuda*, *Rhinodontypus*, *Rhynchobatus djiddensis* are put under the category of IUCN critically endangered or near threatened. These species need special attention.

## 4. Marine Vegetation

### 4.1 Sand Dune Vegetation of Goa

The accumulation of sand grain shaped into a mound by wind is the sand dune. They are protected by vegetation. It is important to keep the dune vegetation to protect the beach. Without vegetation, this natural protective barrier would be lost to the effects of wind and coastal erosion. Dune vegetation adapts to live in an environment where they are exposed to salt spray, sand blasts, strong winds, high temperatures and flooding by adapting their root systems, protective waxy and hairy coverings on their leaves and stems to reduce water loss. There are 91 genera and 106 species of dune vegetation found in Goa. The common and abundant genera are *Spinifex*, *Ipomea*, and *Pandanus*. Dune vegetation is vulnerable to mechanical impacts caused by tramping. This tiny vegetation also supports many life.

### 4.2 Seagrasses

Seagrass is an important but under-rated resource. They have important ecological role in the coastal water. Besides protecting our coastline from wave and tides they play a key role in nutrient cycle for fisheries. Biologically they provide habitat for fish, shellfish, dugong and green turtle. In addition they provide shelter and refuge for epiphytic sedentary organisms such as porifera and tubicolous worms. There are 2 species of seagrass reported from Goa coast. They are *Halophila beccarii* and *H. ovalis*<sup>24</sup>.

### 4.3 Mangroves

Goa has a coastal wetland area of 8486 ha (MOEF, 2011) and mangrove are important component of wet land vegetation. There are 15 species of mangrove recorded in Goa, dominated by *Rhizophora sp.* and *Avicinnia sp.* the mangrove forest in Goa is spread in an area of 500 ha along the course of Mandovi and Zuari rivers with a healthy growth along the stretch of Cumbarjua canal. Goa has been declared as Reserved forest under the Indian forest Act 1927 to protect and conserve the mangrove forest. The mangroves of Goa have been accorded most vulnerable status in the event of an oil spill, by the Environment Sensitivity Index (ESI).

The existing life in the mangrove ecosystem display adaptability to environmental disturbances and follow

**Table 5.** List of protected marine species under Wild Life Protection Act 1972, India

Faunal group	No. of species	Schedule
Porifera	10	Schedule III
Coelenterata	618	Schedule I
Robber crab	1	Schedule I
Horseshoe crab	2	Schedule IV
Gastropodas	20	Schedule I, IV
Bivalvia	4	Schedule I, IV
Sea cucumber	163	Schedule I
Sharks and Rays	10	Schedule I
Seahorse	23	Schedule I
Giant grouper	1	Schedule I
Marine Turtles	5	Schedule I
Salt water crocodile	1	Schedule I
Marine Mammals	26	Schedule I,II

Source: ENVIS Wild Life Institute of India, 2014

distinct zonation pattern<sup>25,26</sup>. Mangroves are known for their high productivity and biodiversity. They are inhabited by some important species. Some species like crocodiles, lizard, turtle and mud clam, inhabiting the mangroves of Goa have been listed as “threatened” while snakes, otters, jackals, mud crab, oysters, white clam, tiger prawn listed as “endangered”. Similarly among the fish, the giant perch, mullet, sand whiting, snapper, grouper and threadfin are grouped under “threatened” and are placed in the high risk category. Roots, stems and tree, hollows of mangrove plant are occupied by varied group of organisms. Roots and lower part of stem have algae, barnacles, oysters attached. The pulmonate molluscs, crabs are found with stem and littorinid gastropods are attached with leaves. There is also information on the fungi associated with mangrove<sup>27</sup>. About 62 species of fungi are reported from Goa coast.

#### 4.4 Seaweed

Seaweeds are the marine macrophytes under three major groups, namely Brown algae, (Phaeophyta), Red algae (Rhodophyta) and Green algae (Chlorophyta). The study of seaweed of Goa coast is limited despite the fact that

macroalgae have many applications in our day to day life. Seaweeds are important raw material for fodder, fertilizer, chemical and food. They provide additional habitat for many faunal group and help maintain high coastal biodiversity. Goa coast has rich source of seaweeds. There are 145 species of seaweeds reported from Goa coast<sup>28,29</sup>. Species of *Sargassum*, *Ulva*, *Gracillaria* and *Porphyra* abound the Goa coast.

### 5. Corals

Corals and coral reefs have the greatest biodiversity recorded from marine environment. Corals have been reported from Grande Island. About 24 varieties and three species of azooxanthellate scleractinian corals have been reported from Goa<sup>30</sup>. Common inhabitants of coral reef are snails, clams, sponges, anemones, crabs, starfish, shrimp, sea lilies and algae.

### 6. Threat to Biodiversity of Goa

The estuaries and coastal areas of Goa are getting degraded. The estuarine hydrological regime and its biological resources have undergone major changes due to outbreak

**Table 6.** Threats perception to ecosystems and biodiversity of Goa

Type of Ecosystem	Existing and perceived Threats
Continental Shelf	Supertanker traffic, oil pollution, bilge washings, overfishing, depleting fisheries stocks, agricultural runoff, red-tides.
Sediment	plume with heavy metal oxides, clay colloids, sewage
Beaches and sand dunes levelling	Mass tourism, water sports, constructions, sand removal, solid waste, sewage discharges, dumping of constructional debris, exotic weeds, land
Intertidal rock pools	Oil pollution, solid waste, sewage Estuarine islands Breaches in embankments, flooding, exotic weeds, dumping of waste, cutting of mangroves, destruction of watersheds
Marine islands	Cutting of trees, fires, solid waste
Mangroves	Oil pollution, dumping of plastic waste, constructional debris, fire, deforestation and land reclamation, exotic weeds
Khazans	Damage to bundhs, sluice gates, flooding, illegal pisci-culture, soil erosion, land filling and reclamation, solid waste dumping, scrapyards
Riverbanks and floodplains	Encroachments, blast fisheries, solid waste and sewage disposal, oil pollution Lateritic grasslands (plateaus) Deforestation, housing, industries, fires, exotic weeds
Forests	Deforestation, mining, quarrying, dams, roads, kumeri cultivation, monoculture plantations, artificial breaks, exotic weeds, fires, floods, soil erosion, poaching
Lotic freshwater	Alluvial sand mining, Sediment from mining rejects, high turbidity, oil, grease, heavy metals, nitrates, sewage, solid waste, blast fisheries Lotic freshwater ( springs, fountains) Watershed destruction, housing, industries, Washing of vehicles, sewage
Lentic freshwater	Eutrophication, reclamation, encroachments, impact of religious practices (immersion of idols)
Salt pans	Oil, PHC, heavy metals, sediments, solid waste, flooding, erosion

of estuarine pollution and other man-made changes<sup>31</sup>. The threat perception for the loss of biodiversity for Goa comes from many sources and is given in (Table 6). The biogeographically varied complex marine habitats are gradually decreasing due to anthropogenic activities<sup>32</sup>. It is established that climate change and biodiversity are closely linked and changes in climate bears negative impacts on biodiversity. Coastal ecosystems are characterized by distinct structures, diversity and flow of energy. Our knowledge about the coastal biodiversity of Goa is not as good as terrestrial biodiversity<sup>10</sup>. The threat to the ecosystem of Goa has been acknowledged by planner and environmentalist<sup>33</sup>. Coastal marine life is subjected to increasing pressure from anthropic stressors resulting in habitat loss<sup>34</sup>. Developmental activities along the coast produce dramatic changes in coastal marine biodiversity. The habitat destruction is a major problem of the coastal region estuaries and must be looked as a major threat for coastal biodiversity in the near future<sup>35</sup>.

## 6.1 Habitat Loss

The habitat loss is proposed into (1) loss of native resident species (2) loss of food resources (3) loss of environmental complexity and related ecosystem function<sup>34</sup>. The marine environment and habitats are dominated by primary producers which are responsible for the exportation of significant amounts of C, N and P to adjacent areas<sup>35</sup>. The loss of these food sources may have a direct or indirect

negative effect on the productivity marine food chain. The loss of habitat complexity thus will effect numerous functions that shape the physical environment.

### 6.1.1 Consequences of Biodiversity Loss

The loss of species from the ecosystem is a loss for ever. This way we can expect loss of many species of plants of medicinal, horticultural and biological importance. In an ecosystem, all plants, animals and microbes are in a dynamic equilibrium and any disturbance in one gives rise to imbalance in others<sup>36</sup>. Thus a vanishing species can take with it 10-30 dependent species. The loss of one or even a few species may not affect an ecosystem. But the cumulative effect of many such losses may lead to serious destabilization of natural ecosystems. The time is too short for new species to evolve that are more suited to the new environmental conditions.

### 6.1.2 Effects on Coastal and Estuarine Fishes

The nektonic communities are usually less impacted by local changes due to their displacement ability, which enables them to migrate to other areas where they find optimum ranges in environmental parameters. The highest biodiversity is recorded in the benthic ecosystem. However, the fact is that there is high rate of mortality of benthos due to disturbance caused by fishing trawlers<sup>37</sup>. Shellfishes are among the most severely depleted of all

**Table 7.** Proximate causes for coastal biodiversity loss

Causes	Effects
Overfishing	Decline in yield, loss of local species
Target fishing	Wastage in the form of by-catch
Non-adherence to mesh size	Loss of juveniles
Non-use of exclusion device during fishing	Incidental catch of other species including threatened ones
Fishing in banned areas	Heavy loss of breeding stock and net loss of recruitment
Destructive method of fishing (unregulated use of fishing gear)	Skewed sex ratio and loss of resident biodiversity
Reclamation, deforestation of mangroves for aquaculture and mining	Habitat loss and modification, increased in sediment load , siltation, mortality of animals and loss of resident biodiversity
Use of anti- fouling paint	Toxicity to fauna and flora
Discharge of domestic effluent and eutrophication	Anoxic condition in estuaries and occurrence of algal blooms
Marine pollution	Toxicity/mortality
Invasive species	Elimination of local species.
Dredging of estuaries and harbor	Loss of local biodiversity
Poor institutional coordination and effective implementation of existing law	Loss of habitat, loss of biodiversity

coastal living resources. Overfishing combined with outbreak of estuarine pollution and other man made changes to the environment are responsible factors<sup>38</sup>. There are many reasons for a particular marine species to become endanger. The proximate causes for the loss of biological diversity is presented in (Table 7). The responsible factors for endangerment of local fauna and flora are habitat destruction, introduction of exotic species, overexploitation, disease, offshore activities and pollution<sup>39</sup>.

There is direct interaction of environmental variables which determine the biodiversity of coastal ecosystem<sup>1</sup>. The coastal biodiversity of Goa is facing severe problems due to ongoing pollution in estuaries, damage to beach ecology by trampling, destruction of Mangroves and Khazan land. The conservation strategy of government of India states that land falling within 10 km of any protected area should be declared as an ecologically fragile zone. It is considerable irony that Goa consistently ignores, overlooks and neglects its bounty of environmental riches while pursuing the fast buck in the worst possible way via extraction, construction and bog standard tourisms. There is a need for the concerned departments to enact and implement laws to protect the coastal biodiversity of Goa. The researchers and planners have bigger role in stemming the tide of biodiversity loss by joining the groups advocating for biodiversity conservation. The effect of environmental degradation will be felt in greater strength by further degradation if we continue to exploit the environment unsustainably and do not understand the true value of biodiversity.

There are plethora of laws for the protection of our biodiversity. However, there is absence of effective implementation due to which a number of activities have been found violating these laws. The threat to the ecosystem of Goa has been acknowledged from time to time by planner and environmentalist with suggestion to conserve the biodiversity. With increasing marine pollution and coastal developmental activities the need for an effective check and strict implementation of legislation cannot be over-emphasized. There is absence of authentic data on loss of biodiversity for the last 50 years. It is of utmost importance that the key human actors and politicians and decision makers establish close relationships among each other and attain a common objective of environmental policy reinforcement if we are to save the coastal marine biodiversity.

From the presented review the important points of consideration for biodiversity conservation and management are

- Goa needs an all tax biodiversity inventory. The present status of coastal marine biodiversity and the threatened habitats need to be recorded and mapped.
- Close monitoring of fragile ecosystems and the adverse effect of tourism, and anthropogenic disturbances like mechanical beach cleaning on biodiversity needs to be carried out.
- Improvement of coastal biodiversity by creating artificial reefs, awareness program in the society, and at school and college level needs to be introduced. Competitive participation should be organized.
- Biodiversity should form a component of environmental education at school and university level.
- A provision to provide alternative livelihood for the local population particularly the fishermen community to avoid over exploitation of resources.
- A holistic ecosystem approach towards the management measures for the deteriorating water quality of the estuaries and redevelopment graded coastal ecosystem is needed.
- Innovative research essential for the ecosystem development for Goa and other programme to detect invasive species and indicator organisms of ecosystem health needs to be developed.
- Hot spots areas need to be identified to check the erosion and loss of biodiversity and Remedial action.
- Biodiversity impact Assessment should be made compulsory for all

## 6.2 Developmental Projects in the Coastal Region

On the occasion of the “World Biological Diversity 2020” celebration in Goa the Environment Minister, conveyed a loud message which read “we depend on biodiversity not only for food, medicine, recreation and life support but we are integrated part of web of life. We shall survive only if our surroundings are conducive for all other species to exist”. We conclude “Goa spectacular but



gravely imperilled Biodiversity needs to be protected and preserved for our future generation”.

## 7. Ethical Approval

It is not required because no animal was used in the study.

## 8. Consent for Publication

The authors give consent to publish the paper.

## 9. Conflict of Interest

The authors declare that they have no conflict of interest.

## 10. Authors Contribution

Both authors contributed equally in the study and manuscript preparation.

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