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Estimating the potential habitat of coral reefs along the coastline of Pakistan using GIS and RS techniques

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Abstract
Pakistan's periled treasures of Coral reefs require protection from devastating anthropogenic activities, which can only be achieved through the identification of their habitat. The primary objective of this study is to identify the potential habitat of coral reefs along the coastline of Pakistan with the help of Geographical Information System (GIS) and Remote Sensing (RS) techniques. The results indicate that coral reefs are present throughout along the coastline, proving that Pakistan is rich in these diverse ecosystems. Pakistan being at important geo strategic position can also benefit from its vast coral reef and other coastal resources such as mangroves and fish varieties. Moreover, coastal zone management through involvement of the local community and establishment of Marine Protected Area (MPA) is the need of the hour to avoid destructive fishing, which can prove to be deadly damaging for the coral reefs near popular spots like Churna Island.

Keywords: Coral Reefs, Habitat, Pakistan, GIS, RS

1. Introduction
Coral reefs are submerged structures produced by using calcium carbonate, which is discharged by corals (*Cnidarians*). They are one of the Earth's most beautiful, ancient, and biologically diverse ecosystems. They are important for sustaining life in the sea [1]. They are unique and complex because they can be defined by both geological ("reef" structure) as well as biological ("coral" community) [2, 3]. The coral reefs cover less than 1% of earth's surface, but support 25% of marine species [4, 5, 6, 7, 8]. Coral reefs are more abundant in tropical and subtropical oceans (Atlantic and Indo-Pacific). Their geographical distribution is usually between the Tropic of Capricorn and Tropic of Cancer (30ºS, 30ºN latitude) [9]. According to the International Coral Reef Action Network (ICRAN) among the world's total coral reefs i.e. 284,300 km^2 [4, 6], 70-80% are found to be in developing countries [1], where the local communities depend upon these resources for their livelihoods [10]. Coral reefs are under threat [11] from climate change, ocean acidification, destructive fishing, other harmful human activities and rising Sea Surface Temperatures (SST) [12, 13]. According to IPCC's fourth assessment report, on an average global SST will increase 2°C by the end of 21st century [14] which will eventually make coral reefs more prone to bleaching. Geographical Information System (GIS) and Remote Sensing (RS) techniques are among the most important and effective tools for the coral reefs mapping, protection and management [15].

Revelation of coral reef in Pakistan along Makran coast, Churna Island, and Gwadar is a late action. Pakistan Wetlands Program in 2006 recognized the first ever coral reef ecosystem close to the Astola Island in Pakistan. Before this disclosure, it was aimlessly accepted that coral reef don't exist in Pakistan's purview of the Arabian Sea. Supported by this leap forward and on the premise of data gathered on coral reef from the angling regions near Gwadar, Pakistan Wetlands Programme (PWP) directed a review of the conceivable coral locales in February, 2011 and found huge range of deep ocean corals near Gwadar [16]. Therefore, In order to protect these treasured and important ecosystems, it is essential to identify and map our nation's coral reefs. Hence, mapping programme would be the first step toward protection and conservation of coral reefs. Without the identification of the potential habitat of coral reefs, managers cannot make informed decisions.

The primary objective of this study is to identify the potential habitat of coral reefs along the coastline of Pakistan. It will not only provide basic information to carry out further studies on early warning of, and monitor the extent of major stressful events such as climate change, oil spills, raised water temperature and associated coral bleaching but will also Provide basis for development, expansion and implementation of programs and strategies for conservation, restoration and management of coral reefs with their associated communities at national level.

2. Materials and Methods

2.1 Study Area

The study area covers whole coastline of Pakistan that is from Indian border on the east to the Iranian border on the west and Exclusive Economic Zone (EEZ) to the south [17]. Geographically Pakistan's coast is located between 23° 42′ 16.409″ to 25° 27′ 48.169″ North and 61° 27′ 58.407″ to 67° 57′ 6.773″ East (Figure-1). This coastline is 1100 km in length [18]. Pakistan's coastline has 24,000 km^2 EEZ and an additional continental shelf area of about 50,000 km^2. A total of 370 km of coastline stretches out along the area of Sindh between the Indian outskirts along Sir Creek on the east to Hub River drift on the west, and rest of coastline reaches out along the territory of Baluchistan between Hub stream drift on west to Jiwani and Iranian verge on east [17].

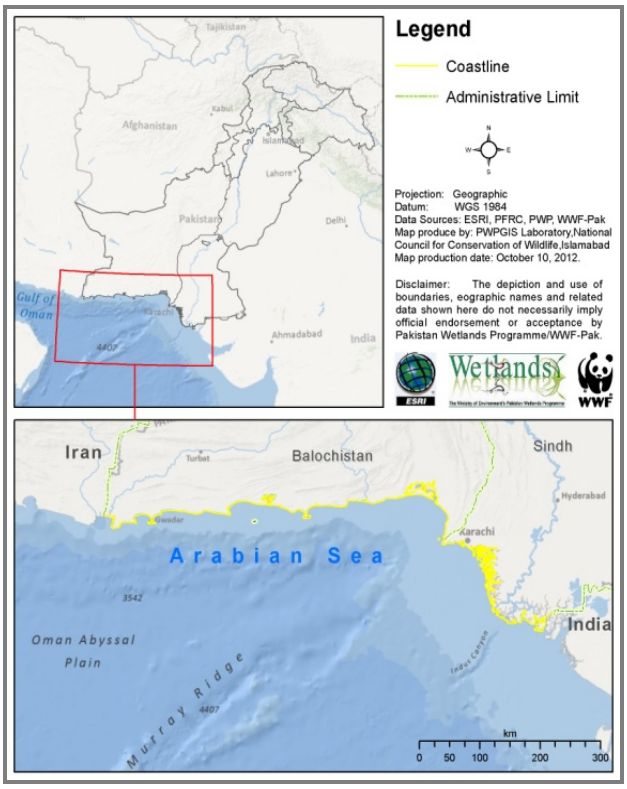

Fig 1: Study Area

2.2 Methodology

Identifying the potential habitat of coral reefs involved acquisition of Landsat-5 Thematic Mapper (TM) satellite images, Digitization of hydrographic charts and Sea bed topography. This data provided the sea depth, Sea Surface Temperature (SST), sea turbidity and sea bed topography information of the study site. Figure-2 represents the detailed methodology which was adopted for this study.

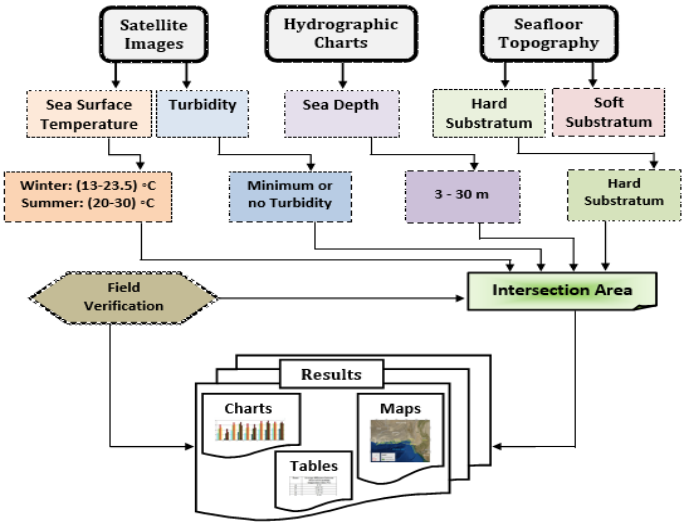

Fig 2: Methodology Adopted for this Study

Hydrographic charts were digitized on 1:20,000 scale for the sea depth points, contours and mainland boundary. The digitized vector data was then interpolated to raster data. As the coral have a symbiotic relationship with zooxanthellae algae, so sunlight is necessary for corals to thrive and grow, therefore, a coastal area with the depth of 3m to 30m was extracted [19].

Landsat-5 (TM) Satellite images were acquired from the USGS (United States Geological Survey). Its spatial resolution for Band 6 (thermal infrared) is 120 meters, but is resampled to 60-meter pixels. This band was used to extract SST and different turbidity levels along the coastline.

In order to calculate the sea surface temperature from Landsat thermal infrared band, ERDAS Imagine Spatial Modeller [20] was used. The first step in this model was to convert the Digital Number (DN) to Spectral Radiance (L) through L=LMIN+(LMAX-LMIN)(DN / 255). Where L is the Spectral radiance, LMIN is 1.238 (Spectral radiance of DN value 1) and LMAX is 15.600 (Spectral radiance of DN value 255). Second step was to convert Spectral Radiance to Temperature in Kelvin using the formulae i.e. $T_B=K_2/In\{(K_1/L)+1\}$. Where K_1 is Calibration Constant 1 i.e. 607.76, K_2 is Calibration Constant 2 i.e. 1260.56 and T_B is the Surface Temperature. Finally, in the last step, it converted Kelvin to Celsius through $T=T_B - 273$ [20]. As coral reefs require warm ocean temperatures, therefore, the optimum temperature for coral reef in winter season ranges between 13◦C to 23.5◦C and in summer season ranges between 20◦C to 30◦C. Hence, the optimum SST data for winter and summer season was extracted using ArcGIS software.

For the identification of turbidity levels of sea water from Landsat thermal infrared band, Normalized Difference Turbidity Index (NDTI) [21] model was run on ERDAS Imagine software. This model is based on band ratio i.e. NDTI = (Red - Green) / (Red + Green). After the execution of model, three sea turbidity levels were identified i.e. high, medium and low turbidity [21]. However, it is important to note that Coral reefs can tolerate low turbidity, but prefer no turbid areas in the sea. Although they can flourish in naturally turbid areas, but they cannot cope with anthropogenic high turbidity and sedimentation stress, because increased turbidity reduces the light for coral photosynthesis, which in turn results in reduced photosynthetic energy available for coral growth or reproduction [22]. In order to meet this criterion, the low turbid class was extracted using ArcGIS software.

Seafloor topography data was obtained from the Satellite Geodesy research group at the Cecil H. and Ida M. Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California San Diego. Coral reefs of Pakistan are not adapted to soft beds and prefer hard substrate [23]. Therefore, the landform classification technique [24] was applied on the satellite altimetry topography data which resulted in ten landform categories. Among these categories, seven were identified as hard substrate classes i.e. canyons, mid-slope drainages, upland drainages, mesas, local ridges, mid-slope ridges, and high ridges.

3. Results and Discussion

As discussed, 3-30 m is a suitable depth for the corals to thrive and grow. Thus, the data between these limits was extracted, which is shown in Figure-3(a).The optimum SST for coral reefs in winter season ranges between 13◦C to 23.5◦C, and in summer season ranges between 20◦C to 30◦C was extracted which is depicted in Figure-3(b). High and medium turbidity was observed adjacent to the coastline. However, it decreased gradually 10 to 15 km away from the coastline. The low or no turbid area was extracted which is shown in Figure-3(c).

The coastline of Pakistan is very rich with a variety of landforms. Some of the prominent features are lagoons, islands, mud flats, rocky ridges, headlands, bays, deltas, valleys etc. The selected topographic areas with hard substrate are shown in Figure-3(d). Cliffs and headlands are prominent in Jiwani, Pishukan, Gwadar, Ras jaddi, Ormara and Ras Malan of Balochistan. In Sindh Buleji, Manora Rocky Ledge, Cape Monze and some other small sites are with hard substratum**.** The entire Indus Delta comprises of mud flats. However Mud flats do also exist in Gawadar Bay, Kalmat Khor and Miani Hor lagoons [18].

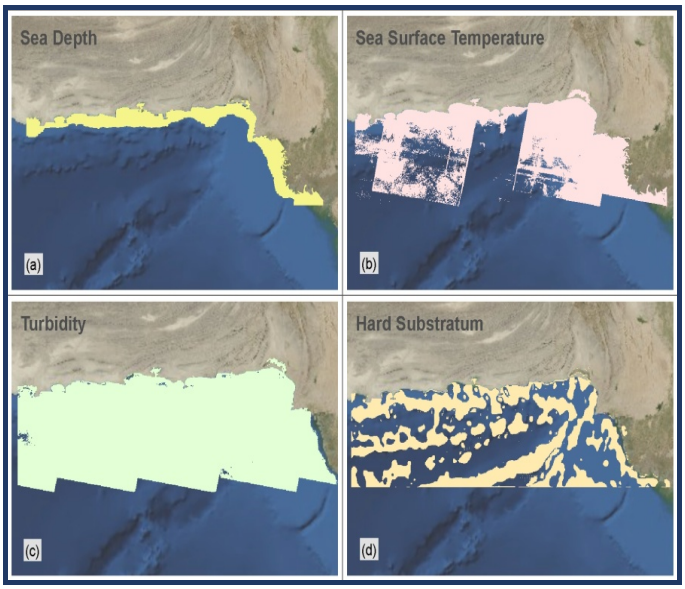

Fig 3: Parameters Used for this Study (a) 3-30 m depth (b) optimum SST (c) low turbidity (d) hard substratum

These extracted data sets (suitable sea depth, optimum SST, low turbid area and hard substratum) were then intersected which resulted in the potential habitat of coral reefs (figure-4)

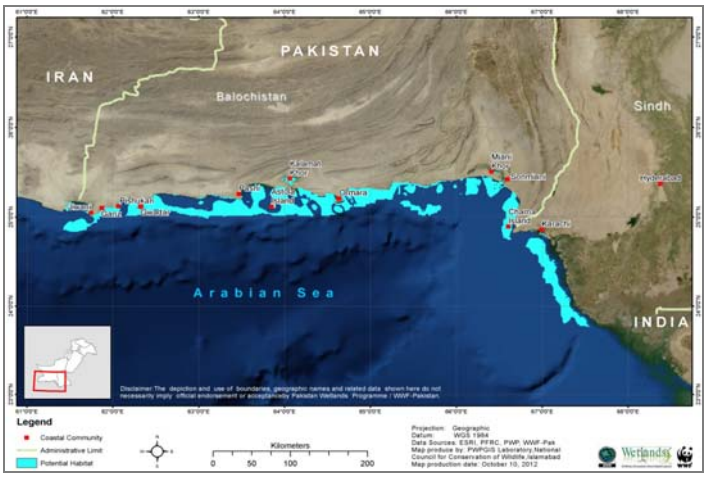

Fig 4: Potential Habitat of Coral Reefs

The total area resulted as potential habitat is 981267 hectares, from which 807849 hectares (82.33%) is mapped in Balochistan and 173418 hectares (17.67%) is in Sindh province (Figure-5).

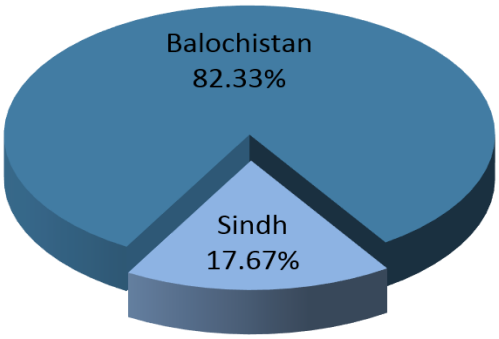

Fig 5: Provincial Distribution of Coral Reefs

The results of the study were quite encouraging and significant. The surveys conducted by PWP have found coral reefs on different sites along the coastline of Pakistan in Arabian Sea. The most significant sites are Ras Ganz, Cher Koh, Baladi Koh, Ganjabad, Tolagoo, Astola Island, Rodrigues Shoals and Charna Island [18, 19]. It is important to note that, the coral sites discovered by PWP fall within the potential habitat areas resulted in this study.

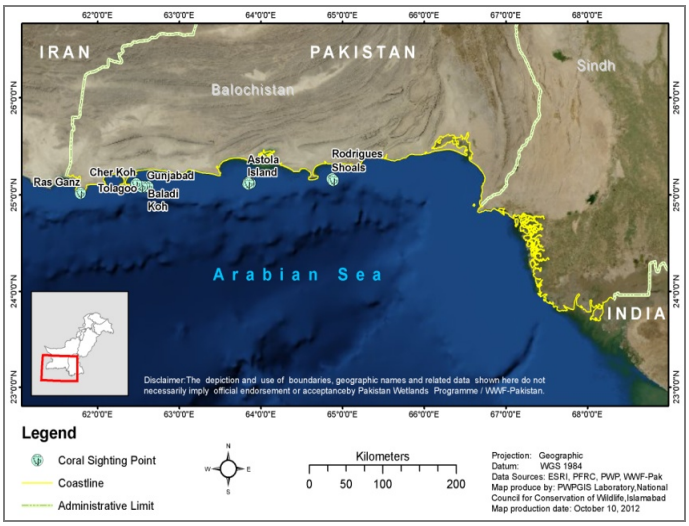

Fig 6: Sighting Points of Coral Reefs

An unanticipated finding emerged from this study is the occurrence of deltaic area as the potential habitat of coral reefs. The deltaic area is not being surveyed by PWP ever, and it is believed that coral reefs may or may not be present there. However, the presence of Coral reefs in Gulf of Kutch, India [25] that is adjacent to Pakistan's deltaic area supports the results of present study. It provides evidence that coral reefs can be present in deltaic area of Pakistan as well. Furthermore, deltas are among the areas with very high quantities of nutrients and sediments, which may be a factor for the presence of diverse coral reefs**.** Therefore, nutrient richness could be considered a major factor, if not the only one, causing the presence of coral reefs in deltaic area.

4. Conclusion

One of the significant findings to emerge from this study is that Pakistan being at important geo strategic position can also benefit from its vast coral reef and other coastal resources such as mangroves and fish varieties. An implication of this study is the possibility that having the vast resources of coral reefs, Pakistan is also rich in different varieties of marine fish, because coral reefs are source of food and habitat to fish varieties.

As, very few people in Pakistan have researched on the coral reefs, hence, the identified area will provide help during the surveys for coral reefs and will provide a basis for the establishment of first MPA in Pakistan. However, more research on this topic needs to be undertaken. Further research should be done by involving other parameters that determine the presence of coral reefs, such as pH of sea, Salinity, Sea waves, sediments/nutrients level etc. Moreover, a further study with more focus on deltaic area is suggested.

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