

Sea Level Scenario on Vengurla Coast of Maharashtra

L.N. Dhavalikar

Abstract

The paper provides an overview of the local sea levels and their effects on Vengurla coast. The specific effects of local sea level trends in relation to other environmental changes along the said coast are significant especially, when viewed as short-term fluctuations. Moreover the variations were observed along a limited stretch of coastline extending not more than 40 km in length. The coast is vulnerable to short-term effects dictated by morphological, meteorological, biotic and sedimentological factors.

Local sea level variations are issues of great concern in the coastal zone and the local factors are the predominant causes of shoreline changes. From the viewpoint of a small region, it is not the eustatic sea level that is of relevance but the relative mean sea level. Local sea level effects are discussed with reference to historic evidences, morphological changes, inflection points, meteorological phenomena, sedimentation and redistribution of sand and the changes in biotic life.

The coast does not preserve striking evidences pointing to a higher sea level in the area but presents a confusing pattern of evidences that are governed by local factors.

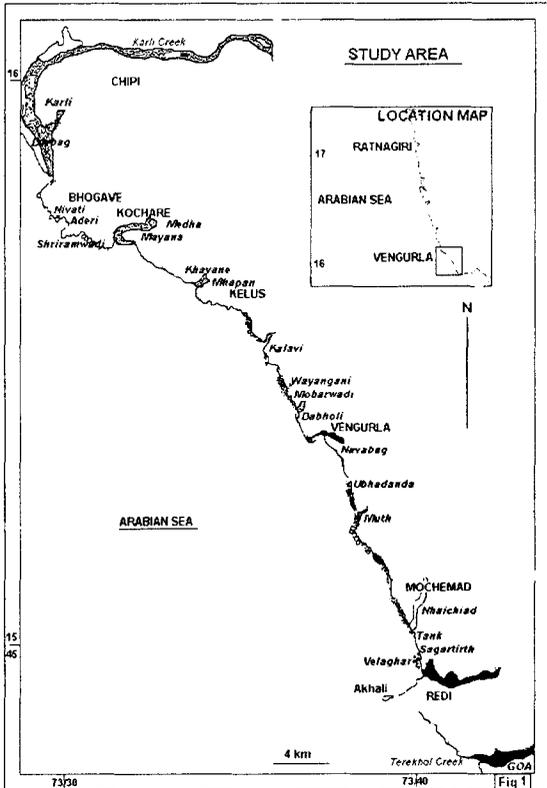
Study Area

Vengurla coast is a distinct geographic unit in Sindhudurg district of Maharashtra between Karli creek in the north and Terekhol creek in the south [15°44' to 16°0' N and 73°30' to 73°41'E]. River Karli borders the study region in the northern part and Karli creek to the northwest, which also separates the sand bar of Devbag from the mainland [Fig 1]. Terekhol creek forms the southern boundary of the region between Maharashtra and the state of Goa. It is bounded by coastal plateau margins and hill slopes to the east and Arabian Sea to the west. The shoreline is marked with small rocky headlands and cliffs, especially to the north of Vengurla. There is almost a regular sequence of small headlands and bays in the area up to Mochamad. Except for few hills and Redi headland, the southern part of the region is relatively flat and is covered with sand and coastal alluvium.

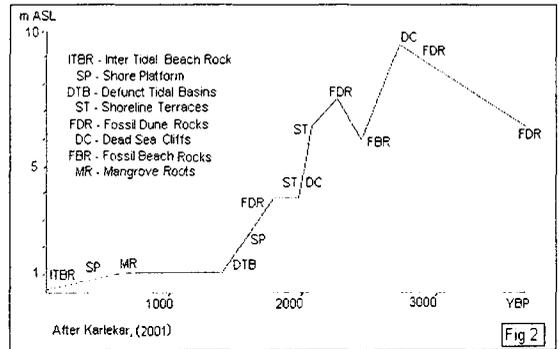
Introduction

An assessment of studies pertaining to sea level trends of the West Coast of India shows that it has been the centre of debate in the study of sea level fluctuations and scenario. Kale & Rajguru (1985) and Kar (1993) have discussed the significance of tectonic movements in Kutch, Saurashtra and Cambay Region. The coast south of Mumbai is supposed to be tectonically more stable. However, Sukhtankar et al. (1990) have suggested the influence of tectonic activities on the coastal landforms and changing sea level for this coast.

Many scholars such as Guzder 1975, Dikshit 1976, Kale & Rajguru 1985, Karlekar 1981, 2001, Vaidyanathan 1987, Sukhtankar et al 1990 and Agarwal 1990 have described sea level trends on the West Coast of India. The sea level of last 4000 years is a problem of more concern as regards the history of the region. Attempts



Magnitude of changes in sea level inferred from available dates on KONKAN COAST



Karlekar 1981, 2001, Bruckner 1987, Deswandikar 1993 and Shrikhande 1994). These suggest that in the Holocene, the sea was higher than the present around 2200 to 2400 YBP. During this period, the height attained by the sea probably varied from 1 to 3m above the present sea level. According to these studies, the present sea has most probably reoccupied the cliffed coastline that was abandoned earlier.

have been made to solve this problem by gathering information on absolute dates of beach rock. Kale & Rajguru (1985) Hashimi et al. (1995) and Karlekar (2001) have made use of beach rocks, surface sediments, oolitic limestone and material from the shore and coastal zone. In addition to these the morphological evidences in the coastal areas have also been used by Guzder 1975, Kale & Rajguru 1985 and Karlekar 1981, 1990, 2001 (Fig 2). The borehole data in estuaries, on marine terraces and continental shelves have proved to be very helpful. Based on these, the tentative sea level curves for different regions have been attempted. The average rise in sea level for India is suggested as 0.67 mm/year as against the global average of 1.8-mm/year (Pachuari 1996).

Karlekar (1981) has pointed out that the present coastal configuration along the Konkan coast is a result of slightly higher sea level. A rise in sea level by about 3m is suggested, so that a coastal strip of 30 to 40m widths can be easily inundated (Karlekar 1981, 2001). It is apparent that the present coastal features along the Konkan coast have a legacy of ancient slightly higher sea level around 3600 YBP and a slowly rising sea level since last 1000 years. There are evidences of weight related local subsidence and the rise in sea level from the other parts of Maharashtra coast (Karlekar 1986). However, such incidences are not reported on Vengurla coast.

Field studies on the Konkan coast of Maharashtra have provided reliable evidences of the various heights attained by the sea in the recent past (Guzder 1975, Dikshit 1976,

Raised beaches, at two distinct levels about 70 to 80 m inland, near Vengurla reported by Sukhtankar et al. (1986) were not seen anywhere in the area. Similarly there are no signs of "karal" south of Vengurla. The fossil dunes at Ubhadanda however present a convincing evidence of former higher sea level in the area. The

evidence of raised beaches at 2.5m and 25cm along Vengurla coast reported by Sukhtankar et al. (1986) is very obscure and cannot confirm higher sea levels in Quaternary.

Sakurkar (1999) has reported the occurrence of carbonaceous clays or lignites near Shiroda-Redi area. According to Sakurkar (1999) such clays on the West Coast date back to 30,000 to 40,000 YBP. The sites where such clays are seen possibly indicate ancient estuarine environments before neotectonic activity.

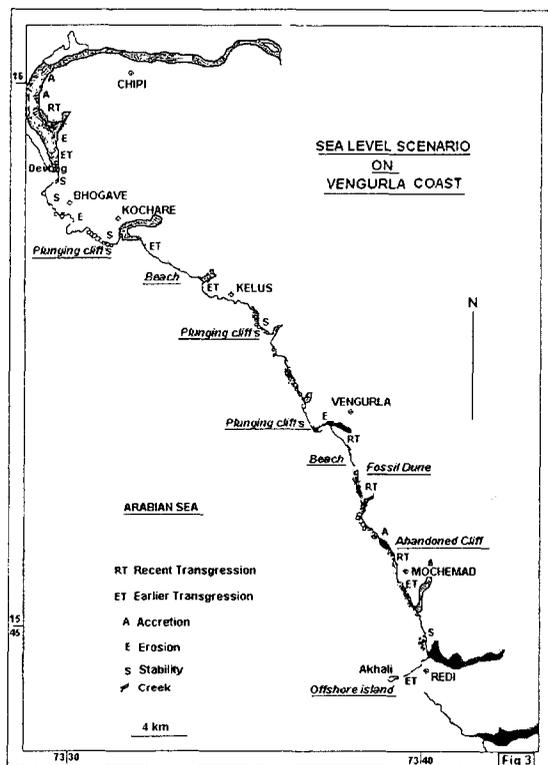
The distribution of modern coral reefs on the west coast of India particularly in the inter tidal zones and at sub tidal depths to a few meters at Ratnagiri, Malwan and Redi port were also used for reconstruction of Holocene sea levels (Wafar 1990). Submerged fossil reefs off Vijayadurg and Vengurla have also been used as the indicators of past sea levels (Vora et al. 1990).

Sea Levels On Vengurla Coast

A detailed investigation of available morphological and sedimentological evidences and the coastal forms along the coastline of the study area, suggest that it is a coastline of very recent submergence with evidences of earlier emergence. A very strong evidence of this transgression is in the form of drowned river mouths, deep outflow areas of the estuaries, a significant extent of saline wastelands and beach erosion.

The regularity of the shoreline, to the south of Vengurla has given rise to many wide sandy beaches such as Ubhadanda, Velaghar and Mochamad indicating earlier regression in the geological period. In the same region, recent transgression is indicated by the changes occurring in the estuarine sedimentation and the beach erosion e.g. at Kochare and Navabag respectively (Fig 3).

The present rise in the water level in the study area seems to be a complex phenomenon. The features like offshore Akhali Island and the plunging cliffs at Bhogave also indicate transgression. Rise in sea level has set in probably in



last 70 years. This is confirmed from the submergence of rocks in the near shore areas, especially near Mayana, Medhawadi and Aderi. Wide sandy beaches (eg. at Mochamad, Shiroda, Sagartirtha and Ubhadanda to the south of Vengurla) indicate earlier regression. In the same area, recent transgression is indicated by changes occurring in the estuaries and beaches.

The earlier regression indicated in southern part of the region by the ancient dunes is not suggested in the northern part. In the north, beaches are very small pocket beaches and there are no evidences of fossil dunes. However, recent regression is indicated in the estuaries, especially the siltation and the changing morphology of the creeks of Kochare and Kelus. In certain areas, earlier regression is clearly suggested by the presence of shoreline terraces (Kochare), the ancient sand dunes (Ubhadanda and Mochamad), wide sandy beaches and the regularity of the coastline (south of Vengurla).

Historic Evidences

The Gazetteer of Bombay Presidency, Ratnagiri and Savantwadi Districts (1996) mentions that Yashwantgad or Redi fort was surrounded by water and extended into the sea up to Mamabhacha Island. The swampy areas around Yashwantgad did not help in the fortification of the southern citadels. Today the fort is on the bank of the creek and a slight change in shape of the creek near the fort is seen. Aerial photos show that Redi creek has been filled up with small sandy islands in the creek and the location of the fort is right on bank of creek. Recent observations show that there is land area, suggesting regression of sea level. Yet another historic evidence is the 'Dutch Vakhar' at Vengurla, which was surrounded by water by about the same time. Such evidences can be related to the earlier higher sea levels in the study area.

There are many ferry points in the creeks and estuaries of the region that are defunct today due to considerable shallowing and the development of sand lenses and sand bars. Such evidences suggest deeper water along the coast.

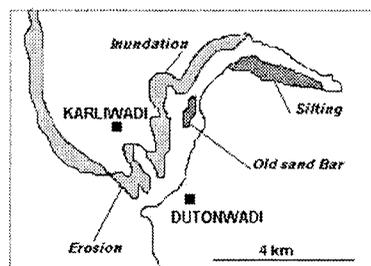
Morphological Evidences

The geomorphic changes in the estuaries and tidal inlets were identified for the period between 1893-1966 and 1966-1997 and used in assessing the possible variations in local relative sea levels on Vengurla coast. Changes in the coastal configuration near Karliwadi and Mhapan were mapped which show the specific areas of change in terms of erosion, siltation and inundation (Fig 4).

The region does not provide any dateable material. In the light of the absence of dateable material, only changes in the configuration could be used as evidences to identify the former sea level.

The effect of sea level stability is seen in the wide expanses of beaches, spits and also in the estuaries as it is an accretionary phase in sea level scenario. A slight rise in the sea level after

CHANGES IN COASTAL CONFIGURATION NEAR KARLI



CHANGES IN COASTAL CONFIGURATION NEAR MHAPAN

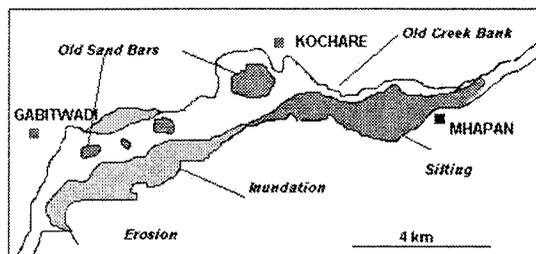


Fig. 4

the still stand phase is reflected in the earlier change in hydrodynamics and sedimentation in estuaries than on the beaches (NRC1987). South of Vengurla, numerous spits, bars and beaches have been formed. These indicate relative stability of sea level as beaches can be formed only when the sea level is stable and marine processes operate for a longer period.

At Sagareshwar, the absence of beach erosion and extension of beach seawards may suggest stability, as there are no other evidences of regression such as abandoned cliffs, raised beaches or raised terraces. Early Holocene transgression is indicated by palaeo-dunes. According to the local people, the temple at Sagareshwar built in the interdunal zone was subsequently covered by sand in last few years.

The ancient dunes in the area are essentially aeolian dunes. Wide dune systems at Wayangani, Mochamad and Chipi are evidences of stability. Recent stability at Vengurla, Mobarwadi and Kochare is indicated by the sand accumulation on the seaward side of estuary. Bhogave is an example of stability after regression where there

is an accumulation of fresh sand in pools and potholes on shore platform. The redistribution of sand in nearshore areas has made the sea shallow. Such changes on the local scale have been reported and discussed from other areas also (Jegellersma 1971).

Coastal erosion is the only indicator of recent rise in sea level. The present trend of rising sea level is inferred from the frequent breaching of sandy beaches, collapse of anti-erosion walls on beaches and the increase in salinity levels of the wells (Daily Tarun Bharat 28/2/1999).

The shoreline terraces are indicative of recent to sub recent higher sea level in the area. Their gentle seaward gradient and cover of sandy silt suggest marine origin. Landward margins of these terraces are irregular and suggest configuration of ancient coastline when the sea was slightly higher (south of Vengurla) and help in the identification of ancient bays or other tidal inlets like Kochare and Vengurla.

Sand removed from the beaches moves with the long shore drift, mainly in monsoon, and fills the concavities (Karlekar 1997, b). Accretional tendencies are significant along Kochare and Khavane coastal stretch. Closing of river mouths in post monsoon season at Mobarwadi and Mochemad is a significant morphological change associated with the seasonal wave dynamics of the region.

Inflection Points on Thalwegs

Inflection points in the river near the river mouths, especially those at 60-80 m (River Parule and River Pholphondekelus) can be attributed to Holocene changes in sea level. The longitudinal profiles show that there is a coastal plateau at 20m and another at 60m heights. Thalwegs of the rivers to the north of Vengurla do not suggest a recent regression unlike the rivers to the south. The nature of the longitudinal profiles reveals some important aspects of the environment in the area. Excessively concave profiles of River Kelus, Dabholi and Vengurla

are supposed to be suggestive of extensive estuarine deposition in Quaternary or Flandrian period (Richards 1982). Changes in relative mean sea levels also change the geometrics of rivers flowing into the ocean. A rising sea level greatly enhances the river's meandering tendency. The meandering of the rivers in the lower stretches to the south of Vengurla is more pronounced as compared to that in the north that is clearly seen near the mouth of River Talawada (Mochemad creek).

Meteorological Evidences

Storm surges occur frequently in the Arabian Sea. They are created by low atmospheric pressure and are coincidental with the onshore southwest monsoon winds. During a surge, the sea level rises and higher levels are recorded. Atmospheric pressure anomalies and temperature changes may also cause a rise or fall in sea level by 15 to 30 cms over few years. Such incidences have been reported in the news of 29th November 1999 and 5th December 1999 when sudden whirlpools in the sea off Wayangani and Navabag on Vengurla coast destroyed the fishing nets which were trapped and swirled down in the sea (Daily Tarun Bharat). Variation in wind speed also affected sea level, particularly in shallow water areas. The coastal areas are thus exposed to the risks of natural coastal hazards like strong winds, waves and episodic inundation from storm surges in the rainy season. Moreover the continental shelf is relatively shallow off the Vengurla coast. Due to this, storm surges affect large area of the coastal tract in the monsoon season, which is reported frequently in the regional newspaper (Daily Tarun Bharat, Sindhudurg edition).

The storms and the tidal surges inundate the beaches and shoreline terraces causing severe beach erosion at Ubhadanda, Muth Navabag and Kurlwadi (Daily Tarun Bharat 10/7/99). Moreover the coastal flooding is reported to result in the formation of pools and depressions in the area.

The northern parts and the sand bar of Devbag are affected by episodic inundation resulting from storm surges which are the result of anomalously high tides produced by low atmospheric pressure and wind driven waves in the months of June, July and August on New moon and Full moon. Sea level varies inversely with atmospheric pressure by 1 cm/mb (Gornitz 1990). In shallow water areas of Karli creek changes in wind stress on wave heights cause variations in wind speed which in turn alters sea level. The fetch and aspect of these waves is directly towards the south-west monsoon winds which cause massive destruction of the shore front, life and property.

Biotic Evidences

There is a diversity of habitat and different kinds of autotrophs and heterotrophs in the estuaries. Dwivedi (1990) attributes the abundance of biotic life along the southwest coast to the upwelling in the Indian Ocean, which has given rise to intensive proliferation of phytoplankton. In places where the wind induces an offshore current at the surface, it is inevitable that a compensatory upwelling of nutrient rich deeper water will occur close to land. Due to sea level rise and subsequent saline water intrusion the environment becomes more homogenous (Ramachandran et al. 1990). Information from local fishermen and newspaper items confirm this point.

Vengurla coast is richly endowed in marine organisms and is a prolific fishing zone. This factor is also attributed to a rising sea level. A very recent slight rise in sea level has favoured the increase in biotic life. Repeated news items of fishing by trawlers from Malwan and Goa coast on Vengurla coast (Daily Tarun Bharat 7/11/1999) during day and night reflects that the coast is rich in biotic life.

Sedimentary Evidences

Coastal sand dune systems, in a varying degree of preservation, are a clear evidence of ancient,

slightly higher sea level in the area. Due to the absence of any dateable material, no relative chronology is available for the area. Therefore the distance inland and the height of the dunes above present sea level are the only indicators of their relative age.

The sand dunes in the north between Chipi and Vengurla are invariably the recent sand dunes related to the present day sea level. These dunes are seen to a distance of 80m inland. Their height varies between 1.5 m (Bhogave) to 13m (Wayangani). An extensive dune slack between the second and third line of dune ridges at Wayangani is an indication of regression in Holocene.

The dunes to the south however are recent to sub recent as well as ancient. The recent dunes are found up to 150m inland, their height reaching to about 5m. Dunes between 150m to 300m can be related to a sub recent period of slightly higher sea level. The height of these dunes ranges from 40 cm to 6m, they are moderately dissected and do not show any signs of lithification.

Although these dunes are irregular, discontinuous and patchy in nature, their parallelism with the present day coast and the state of degradation do suggest that they are most ancient dunes in the area. In an area where average annual humidity is about 70%, dune systems of this scale are not expected. They can only be explained with the help of a regressive sea level and the high wind speed. Field investigations show that a lot of accretion has taken place on the dunes since 1978.

The earlier transgression indicated around Redi by the ancient dunes is not apparent in the area around Chipi. Number of plunging cliffs in the northern part may suggest a local submergence in Early Quaternary period. Fossil dunes are not found in this part of the area.

Shoreline terraces with an average height of 3 to 6m and average gradient of less than one degree indicate a higher sea level in the recent past. Frequent occurrence of salt deposits on the

lower parts of the terraces at Vengurla, Shiroda and Mochemad can also be related to the transgression of sea level in recent times. Near Shiroda, cultivation is restricted to river plains about 3km inland. These are most probably the ancient river mouth areas when the sea was slightly higher.

Saline wastelands are significant features and are an indirect indication of sea level rise. Saline water intrusion leads to degradation of the land and increases the salinity of the soils, making them infertile. Pockets of saline waste are distinctly seen all over the region especially in the south. The estuaries and the surrounding areas are affected to a considerable extent due to slight rise in sea level and the ingress of saline water. Salinization and water logging are important land use issues arising due to sea level changes.

The most common feature of saline wastelands on the littoral terraces is the appearance of white, grayish white or ash colored salt encrustations on the surface during dry period. The surface areas are devoid of vegetation and are seen only in patches. Salt tolerant grass is observed only in clayey patches on and around the littoral terrace of Vengurla. The areas are characterized by poor or impeded drainage with muddy water stagnating for long periods, which has resulted in low soil fertility at Vengurla. Salinity is one of the major land degradation processes that hamper the sustainable use of soils and land resources in the coastal areas.

There are many salt encrustations and salt deposits around Vengurla. Shallowing, stagnation and clogging of the tidal channel due to the growth of salt tolerant halophytes were observed in field study. The dominance of salt tolerant water plants is an indication of rising sea level. Accumulation of thick ancient mud on the banks of the tidal channel and meager growth of mangroves are characteristic features around Vengurla. A recent phenomenon is the cutting of ancient tidal shoreline terrace. Similar observations were made at Shriramwadi, Kochare,

Khavane, Mochemad and Nhaichiad. The configuration and morphological features and their associations indicate the nature of paleo-environment especially at Kochare and Vengurla.

Redistribution of sandy material within the tidal inlets and estuaries due to rise in sea level is not an uncommon phenomenon in the region. The initial width of Medha beach was 107 m. 80 m have been lost to the sea i.e. 74% of its shoreward margin has been eroded due to transgression and is redistributed on the coast in 30 years. At Mochemad the tidal channel is blocked due to a lot of sand influx. Moreover redistribution of sand has changed the shape of the sand bodies near the coast. The anthropogenic effects in the form of poor sand management practices at the channel entrances have accelerated the erosion rates.

Site-specific effects of sea level are observed at Kalavi Bandar. The rising sea level has submerged 40 to 60 m of shoreline area around Kalavi Bandar (Daily Ratnagiri Times 1995, Daily Tarun Bharat 1999). The height of the area submerged was confirmed with reference to the aerial photographs of the region. Since last few years, the waterfront is moving towards the settlement every year especially in the monsoon season. Flooding and breaching of kharbandharas is a major problem in many parts of the coastal areas especially Medhavadi and Niwati and this can be associated with sea level rise (Daily Tarun Bharat 12/7/1998, 1999).

To the north of study area, along the sandy stretch of Talashil at the entrance of Kalavali creek, the breaching and erosion was reported in monsoon of 1947, 1956, 1980 and 1997, and probably suggests a recurring activity along the said coast (Daily Tarun Bharat, 22/6/1998).

Conclusion

In the light of local and regional field evidences it can be concluded that the sea level in the study area is closely linked with certain aspects of coastal climate which play a vital role in

modifying the coastal environment. They are as follows [a] Wave action and high tides, [b] Recurrence of storm surges, [c] Storm tracks and frequencies.

Morphological changes as evidence for sea level fluctuations in the study area are significant. Spits, sand bars and beaches on the seaward margin of creeks such as Bhogave, Kochare, Khavane and Redi are the sites prone to erosion. The vulnerability of the coastal tracts in relation to periodic changes is very high. A study of the shoreline configuration with reference to estuaries, beaches from the S.O.I. toposheet of 1894 and 1966 brings out the distinct changes in morphology. The changes were also ascertained on IRS- 1C imagery of 1997.

Even after 1966, there are distinct changes in the coastal configuration. At some places it seems to be a result of redistribution of sand due to the drift, erosion by monsoon waves and accretion by post monsoon waves (Karlekar 1997). Human interference in the catchment areas of the rivers has increased the sediment input causing siltation of the lower reaches of the tidal mouths of estuaries. These changes are recorded only for a last century or so. Fluvial as well as tidal impact are significant in monsoon period. In fair weather tidal effect alters the morphology of inlets due to tidal circulation. Tidal currents redistribute the sediments till the onset of monsoon.

There is an urgent need for site-specific studies of sea level effects both at the regional and local scale (Bird 1990, Rajamanickam 1990, Karlekar 1996, 1997a, 1998, 2001). Local site-specific studies are essential in understanding the coastal environments and assessing the environmental effects of sea level changes along the said coast. Activities like reclamation of land and construction of roads must be dealt with caution. Suitable measures for controlling beach erosion can be suggested. Monitoring of relative sea level is very essential for the study area in future as the coast faces greater risk of accelerated sea level rise.

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Dr. Lakshmi N. Dhavalimar
Reader, Dept Of Geography,
Sir Parashurambhau College, Pune 30.