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# Spit evolution and shore drift direction along South Karnataka Coast, India

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## Abstract

Satellite images and topographic maps are studied to delineate spits of the southern coastal segment of Karnataka state situated along the west coast of India. An attempt is made to recognise possible factors which are responsible for spit formation and growth. Spit growth is used as drift direction indicator to identify drift cells and to determine net shore drift of the area. It is found that river drift and long-shore currents play a very significant role in shaping and growth of spit.

In the study area, spit growth direction indicates that long-shore drift is either towards north or south depending upon monsoon season. This bi-directional shore drift could be the primary agent for sediment redistribution and confinement within the region, thereby keeping this prograding coast straight, smooth and stable. Three generations of spit complexes, situated side-by-side, but oriented in opposite directions, suggest that the reversal of long-shore drift has taken place thrice in recent past.

KEY WORDS: Indian west coast, sediment transport, landsat images, coastal mapping, long-shore drift.

## Introduction

A qualitative understanding of net shore-drift direction, as well as the identification of areas of coastal erosion and sediment accumulation, is a prerequisite for any coastal land-use planning program or coastal engineering endeavor. Amongst different drift trend indicators, spits are the most reliable and useful geomorphic indicator (Taggart and Schwartz, 1988) available for determination of net shore drift.

According to Evans (1942), «a spit is a ridge or embankment of sediment attached to the land at one end and terminating in open water at the other. It is younger than the land mass to which it is attached». Schwartz (1984) has included an excellent collection of literature in his book *Spits and Bars*. It covers the historic growth, recent reports and divergent viewpoints of different authors on such a complex geomorphic structure as spits and bars. Bird (1984) in his book *Coast*, has summarized the evolution and description of various recurved spits, cusate spits, trailing spits, flying spits, paired spits on either sides of estuaries etc. He has also described possible origin for these spits. In India, spits have been a neglected shoreline features. Serious efforts to understand evolution and origin of spits are lacking, probably due to underestimation of importance of spit study or limited availability of

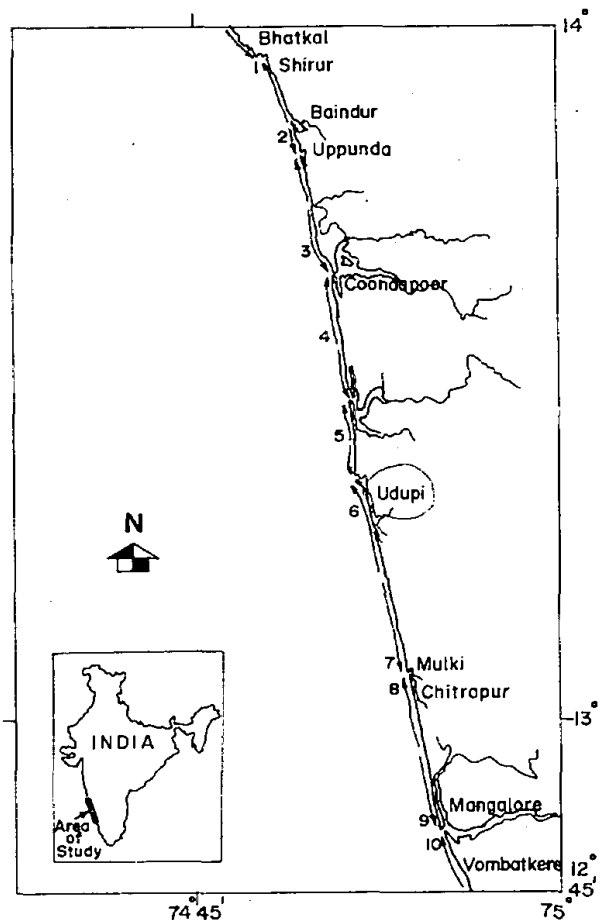


Fig. 1 - Location map of study area. Numbers 1 to 10 indicate location of major spits.

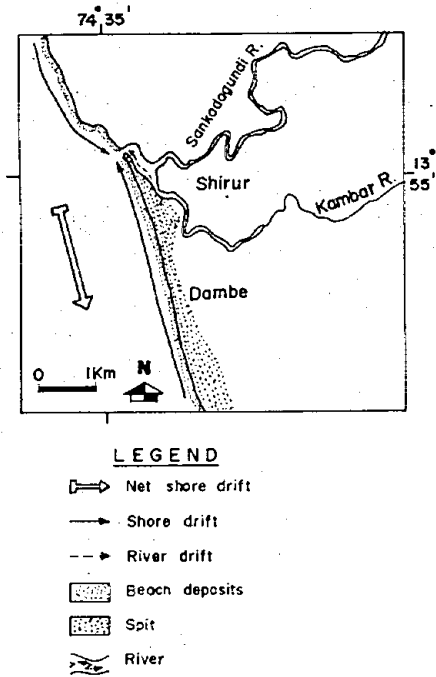


Fig. 2 - Simple sandy spit. Narrow distal end of the spit is protected by headland located to the north of it. Seaward margin is straight and smooth where as inner one is irregular.

proper historic recording of spit growth. Nevertheless, Ahmad (1972), while describing coastal geomorphology of Indian coast, has mentioned and described several spits. Other authors like Adiga (1989), Jayappa and Subrahmanya (1989), Rao *et al.* (1988), Subrahmanya and Jayappa (1987), have only dealt with spits as one of several other geomorphic landforms.

In this study on the southwest coast of India, spits are mapped using satellite images and topographic maps. Further, an attempt is made to recognise possible mechanism/factors which are responsible for their origin and growth. Finally, spit growth is used as drift direction indicator to mark drift cells and to determine net shore-drift of the area.

### Study site

The study area is a 130 km long strip situated in southern sector of Karnataka state along west coast of India (Fig. 1). It lies be-

tween 12°45' and 14°N latitude and is backed by the western Ghat escarpment on the east. The region is situated in tropics and enjoys a warm, equable and humid climate. The area receives a rainfall of about 3000 mm/year during southwest monsoon (June to September) season. The tides in this area are predominantly semi-diurnal. The average spring tidal range is about 2 m and the average neap tidal range is about 0.25 m. The mean wind speed varies from 5 to 10 knots with the maximum occurring during the southwest monsoon period.

The shoreline between Shirur and Srinivasnagar is irregular and indented. The characteristic coastal features include long spits, cliffs, promontories, etc. Geologically, this part of coast is covered by the Precambrian Dharwars, represented by schists, phyllites, quartzites and diorites, granite-gneisses, laterites, alluvial and littoral formations.

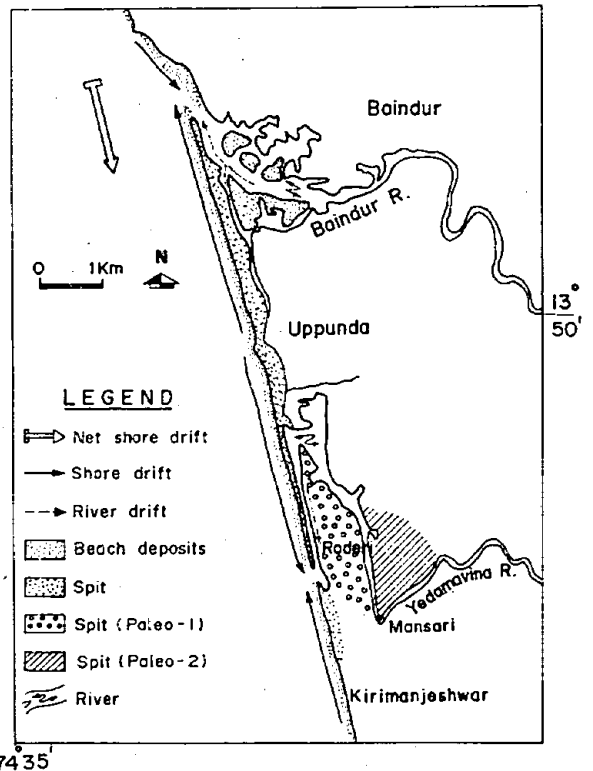
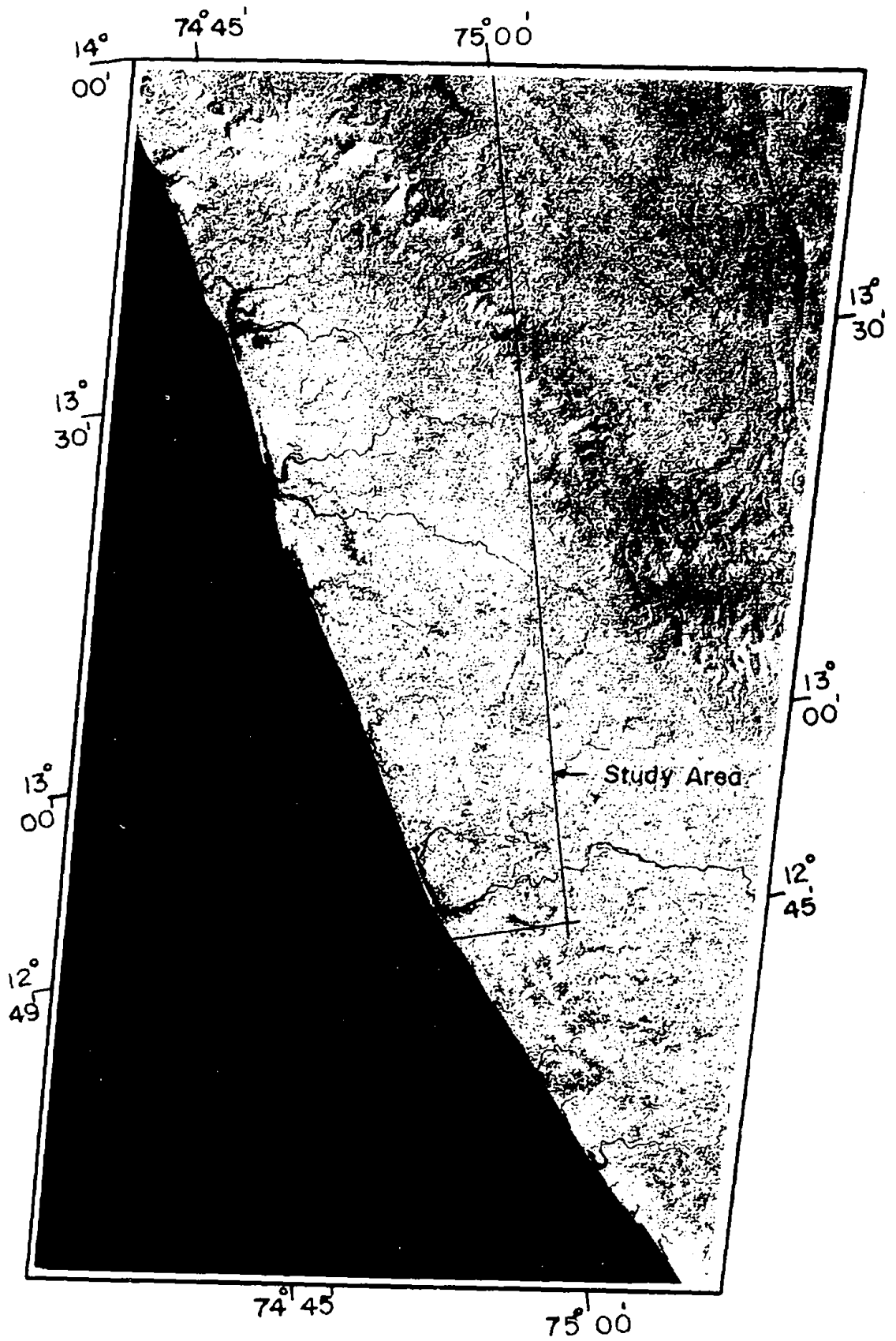


Fig. 3 - Uppunda spit is a «two wings spit». It is backed by 2 well stabilized generations of paleo-spits. River Yedamavina is diverted thrice before reaching sea by the three different generations of spits.



Pl. 1 - For explanation see text.

Tab. 1 - Description of spits in the study area.

No.	SPIT NAME	LOCATION		TOT AL LEN GTH	DISTAL END				DEFLECTION OF RIVER			SPIT TYPE
		Latitudes From	To		Len ght	Brea dth	Description	Poin ting	Name of River	Tow- ards	Dist ance	
1	VOMBATKERE	12°45'30"	12°50'30"	4.00	1.50	0.50	Thick, Blunt, Rounded	N	Netravati	N	1.50	Simple
2	MANGALORE	12°48'32"	12°58'45"	9.00	6.50	0.62	Thick, Blunt, Triangular	S	Gurpur River	S	7.50	Composite
3	SRINIVASNAGAR	13°00'55"	13°04'50"	7.50	6.00	0.32	Pointed, Narrow	N	Pavanje	N	5.00	Composite
4	MULKI	13°05'00"	13°06'20"	3.00	2.00	0.23	Thin, Blunt	S	Mulki	S	2.00	Simple, Hook Headed
5	UDUPI	13°15'00"	13°20'30"	10.50	7.50	0.10	Thin, Pointed	N	Kopla, Udiyari	N	7.5	Simple, Curved & sward shaped
6	MALAPE	13°21'45"	13°20'40"	2.00	0.50	0.18	Thick, Blunt, Loop	S	Creek	S	0.50	Composite, Hook & split Headed
7	PADUTONSE	13°24'00"	13°27'15"	10.00	4.00	0.13	Pointed, Narrow	N	Sati, Swarna	N	4.20	Simple Knief headed
8	PARAMPALLI	13°27'30"	13°33'00"	13.50	11.00	0.82	Pointed, Hook	S	Kodi	S	10.00	Double headed Hook type
9	KOTESHWARA	13°33'20"	13°38'00"	10.00	4.00	0.42	Thick, Blunt, Rounded	N	Haladi	N	2.00	Composite
10	GANGOLI	13°40'00"	13°38'15"	3.50	3.00	1.10	Thick, Blunt, Triangular	S	Kollar	S	2.50	Simple, Loop
11	UPPUNDA	13°49'50"	13°47'30"	5.20	3.10	0.05	Pointed, Narrow	S	Yedamavina	S	3.00	Simple, backed by paleo spit
12	BAINDJUR	13°50'00"	13°53'30"	5.30	4.50	0.36	Pointed Narrow	N	Baindur	N	4.00	Simple
13	SHIRUR	13°55'20"	13°53'30"	4.00	3.50	0.28	Narrow, Pointed	N	Shirur	N	3.00	Simple

1-2, 3-4, 5-6, 7-8 and 9-10 are paired spit and 6-7, 8-9, 11-12 are Two Wings spits.  
(All lengths, breadths and distances are in Kilometers)

## Materials and methods

Landsat images in 4 spectral bands pertaining to scene NASA ERTS E-1185-04502 dated 24.01.73 (Pl. 1), are studied to locate spits and other coastal features. On enlarged satellite imagery, the spits are identified based on their tone, shape, form, and associated coastal features. To confirm these findings, topographic maps of the study area were consulted. Among the different drift trend indicators reported in literature (Taggart and Schwartz, 1988), the only distinct indicator present in study area is spit growth. Based on spit growth direction, drift cells and shore drift directions are identified and marked on maps (Figs. 2-9). Extent of each cell is marked by length of arrow and its direction indicates shore drift direction.

## Results and discussion

### *Physiographic characteristic of spits*

The 130 km long coastal segment presents spectacular examples of spits of different sizes and variety of shapes (Tab. 1), covering nearly 85% of the shore line in study area. The spits are remarkably straight, with smooth seaward boundaries and at places crenulated margin on landward side. The seaward shore is mostly skirted by narrow strip of sand accumulation which on satellite imagery, looks like narrow white ribbon lining the coast. Some of the spits are open on the north and tied to the mainland at their southern end (Figs. 2, 7, 8, 9), others are tied to the land in the north and open in south (Figs. 4, 8, 9) and a few others are tied to the land in the centre and have distal

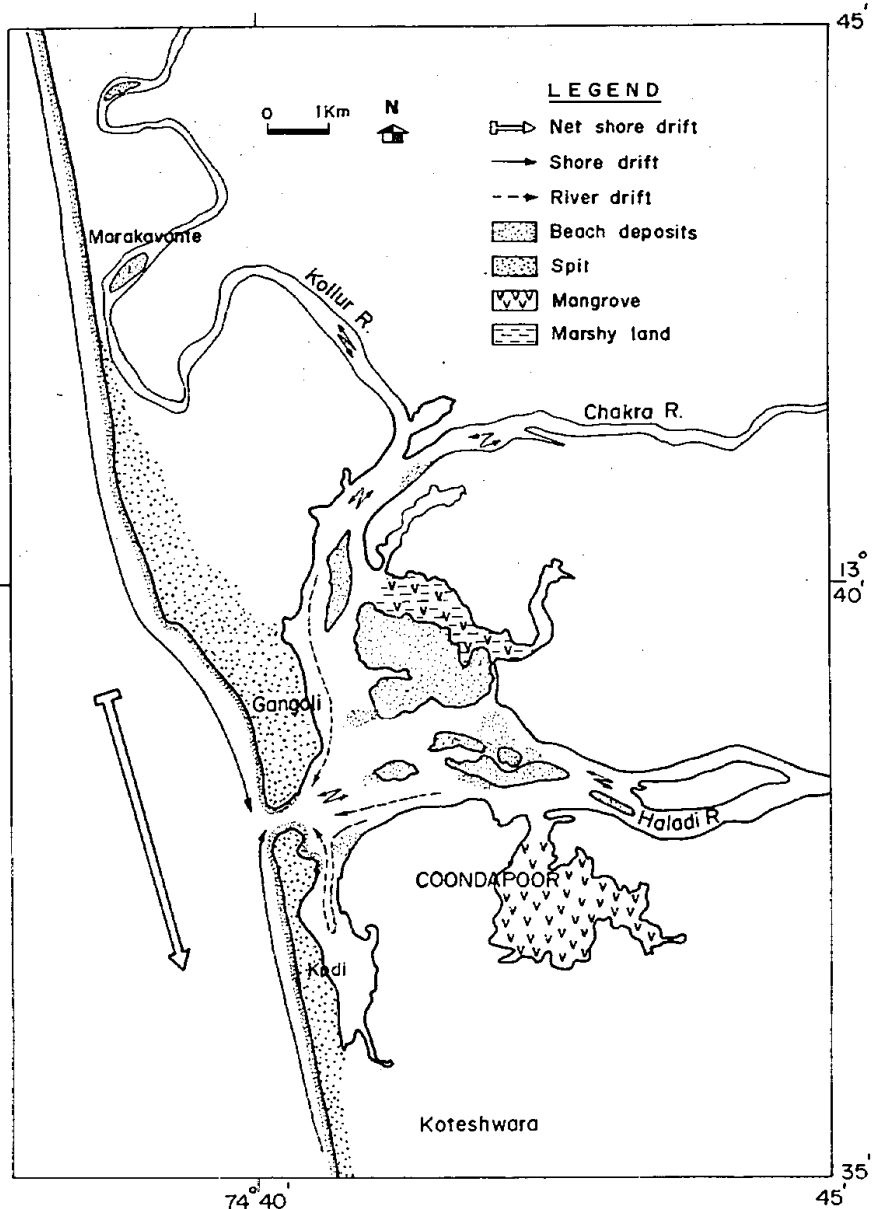


Fig. 4 - Paired spit across Haladi river mouth. Thick blunt distal end of Gangoli spit is deflected seawards where as distal end of Koteshwara composite spit is pointing landwards. Spits are likely to block Haladi river.

ends open on either side, called here, «two wings spit» (Figs. 3, 5, 6). In many cases, their distal ends have prograded from either banks of estuaries. These spits are described as «paired spits». All these spits are diverting river mouths either to north or to south. All spits, including the narrowest Udipi spit (Fig. 7), are crowded with settlements and densely populated.

*Spit formation and growth*

Factors responsible for origin and growth

of spit in general, and paired spits in particular, are not well understood. Different workers have expressed diversified views. While explaining growth and origin of spits of southwest coast of India, it was proposed (Ahmad, 1972) that predominant monsoonal winds blowing from a direction normal to the shore have brought sediments from the subnarine floor near the shore line and have built up ridges or barriers above the sea level. These barriers were pushed landward and converted to spits by their attachment to a headland.

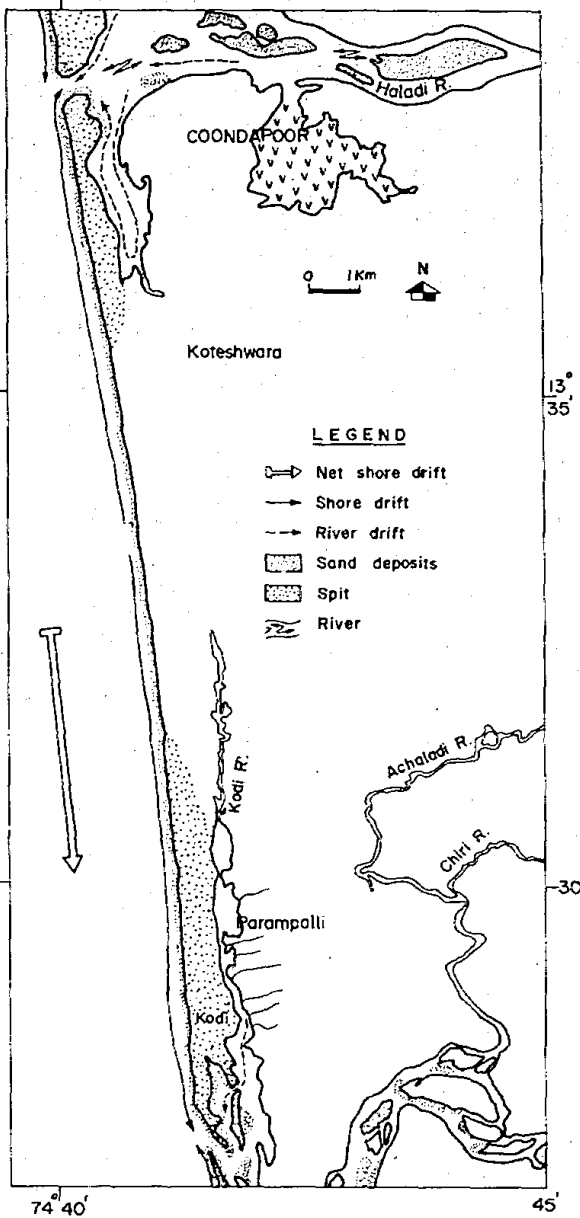


Fig. 5 - Koteshwara is a «two wings spit». Northern distal end is thick, blunt and of composite nature. South facing distal end is of recurved type and is deflected landwards. Part of inner distal end is cut off from the spit and is forming sandy island.

The thin, straight and long-shore barrier type nature of some of the spits (Uppunda, Koteshwara, Udipi) of the study area suggests that the above hypothesis is a reasonable way of explaining their origin. But then, these spits should have formed a forward shore line. In fact, in study area, azimuthal straightness of spits is noteworthy and all spits are in line with the shore line of the

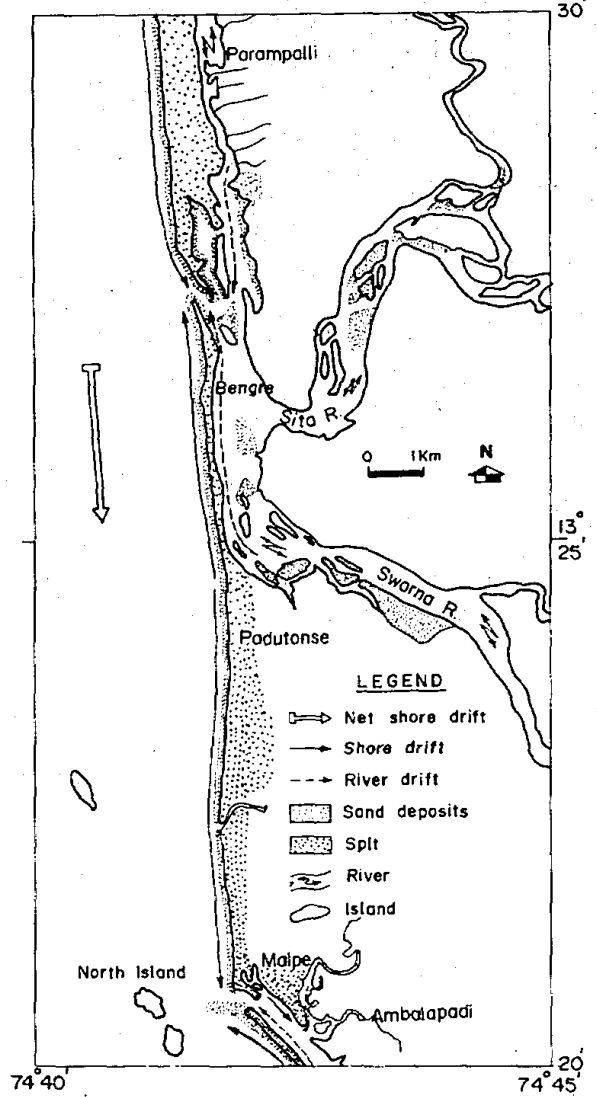


Fig. 6 - Padutonse spit is a «two wings spit». Northern distal end is narrow, long and is pointing seawards. The south spit has short recurved distal end and is pointing landwards. Southern portion of the spit backed by another well stabilized Malpe spit. Both distal ends have paired spit formation.

mainland to the north and south of these spits (Ahmad, 1972). Moreover, when size, shape and their attachment with mainland is observed, it is felt that this hypothesis fails to explain the origin and growth of other spits like Gangoli, Shirur and Vombatkerc (Figs. 2, 4, 9), which are situated in the same study area.

In the past, controversies have arisen concerning the way in which paired spits, which appear to grow from opposite banks of an inlet, have evolved. One school of thought

(Ward, 1922; Kidson, 1963), advocates that the paired spits have actually grown in opposite directions, whereas the other school of thought (Robinson, 1955; King, 1959) believes that they stemmed from the breaching of a single spit, giving appearance of growth from more than one direction.

Ward (1922) pointed out that the paired spits across many harbor entrances on the south coast of England have, in fact, grown towards each other. Steers (1948), referring to the recurves at the distal end, suggested that a local counter drift may be responsible for contrary growth of spits. Robinson (1955) strongly believed that paired spits are the result of unidirectional growth of spit, followed by breaching. King (1959) supported Robinson's opinion. Kidson (1963), concluded that opposing spits, which really grow towards each other, are not confined to sheltered situations. Breaching of a spit may provide the material from which another spit, pointing in opposite direction, develops. The growth of double spits across the mouth of an estuary must always owe something to counter drifting. Only occasionally is breaching important and only rarely is the dominant factor.

In a 130 km long coastal strip of study area, five paired spit formations are present (Tab. 1). Segments of distal ends of Koteswara, Padutonse, Mulki and Mangalore spits are (Figs. 5, 6, 8, 9) partially cut off and have formed sandy islands. The rivers which are diverted by Gangoli, Mulki, Srinivasnagar, and Mangalore spits are likely to cut those spits in future times (Figs. 4, 8, 9). These observations partially support Robinson's breaching hypothesis. However, large paired spit formations in the study area (Fig. 4, 6, 9), which have diverted a river for considerably large distances, rules out the possibility of breaching controlling their formation.

While controversy exists among scientists regarding origin of spits, there is a common agreement regarding their growth. Many workers including Evans (1942), Schwartz (1984), and Bird (1984) believe that growth of the spit is largely due to long-shore drift and length of spits above the water increases only when the waves and shore drift move sand from the direction of their land connection. Waves from any other direction tend to destroy them. In the study area, it is observed that, 1) spits are growing either to-

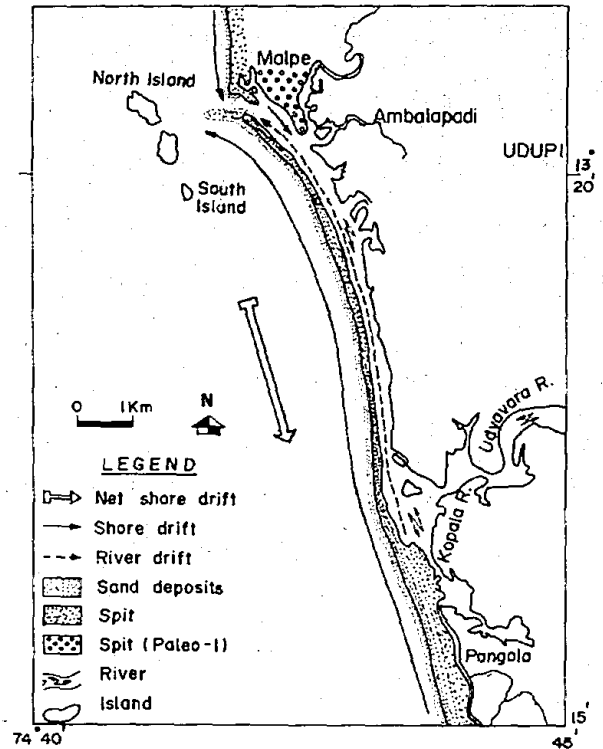


Fig. 7 - Sword shape, long, narrow, curved Udipi spit is a simple spit, pointing seawards. Spit is seen prograding towards north and south island. Udipi and Padutonse spits are forming paired spit combination.

wards north or south, 2) twin wing spits, like Uppunda, Koteswara, Padutonse etc., have growing distal ends in both north and south directions, 3) some paired spits (Figs. 4, 6, 7, 8, 9) are prograding from either bank of estuaries.

If the spit growth is ascribed to long-shore drift alone, then it is necessary to accept that 1) long-shore direction is towards north as well as south, 2) converging long-shore drift exists within very short distances and 3) diverging long-shore drift exists (as in case of development of Uppunda and Koteswara spits). It is difficult to believe such situation but then, as the southwest monsoon, which are dominant winds over west coast of India, is striking the coast orthogonally, a bidirectional (northward or southward) long-shore drift, due to variation in coastal orientation, is a reasonable assumption.

In this area it is interesting to note that all the spits are associated with river mouths. It is generally accepted that the material brought by long-shore drift and river discharge are the main contributors in building



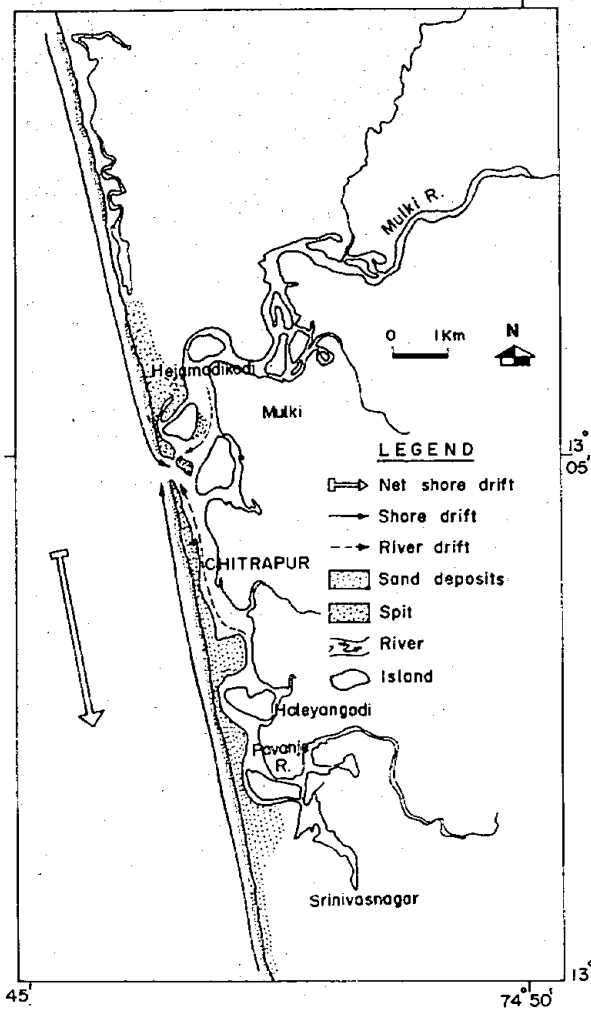


Fig. 8 - Srinivasnagar and Mulki spits have developed paired spit combination. Distal end of Mulki spit is recurved type, points landwards and is partly cut off from the spit forming sandy island. The knife shaped distal end of Srinivasnagar spit has diverted Pavanje river towards north for quite some distance before joining sea.

of the spit above water level. Shore drift is responsible for the accumulation of sediments on the seaward side of the spits. In case of Padutonse, Udipi and Koteshwara spits, sand accumulation is also visible on landward side which must have resulted from river drift. Based on this, in general, the spit development is to be looked on as result of both long-shore drift as well as river drift which is similar to development of cusped spit, which forms due to the long-shore drift acting from either sides.

Dominance of river drift over long-shore drift deflects distal end of spit seaward (as in

case of Udipi spit, Fig. 7) and *vice versa*. Shore drift and river drift of nearly equal strength help in growing longer spits (Fig. 8, 9). If the sediment supply by the river drift is more than that due to shore drift, then the spit widens the landward side (Fig. 6) and *vice versa*. If water discharge by the river is negligible, the material brought by long-shore drift succeeds in closing the river mouth (Fig. 8).

In short, there is a continual battle between river action and fluvial sediments on one hand and tide/currents and material transport along shore on the other hand. It may be reasonable to say that river drift, which was probably ignored by earlier workers, plays a very important role in shaping and growth of spit along with long-shore drift.

One distal end of all paired spits, in study area, is seen diverted seawards whereas other landwards. This indicates that marine as well as fluvial processes are responsible for shaping and development of spits.

It is interesting to note that the southern distal end of Uppunda spit (Fig. 3) is backed by Rode spit of an older generation (Paleo-1), which is again backed by Mansari spit of the oldest generation (Paleo-2). Mansari and Uppunda spits have their distal ends pointing towards south, whereas the distal end of Rode spit is pointing north. This has deflected Yadamavina river first towards south, then towards north and finally towards south before meeting the sea. These three generations of spits, situated side by side but oriented in opposite directions, suggest that the reversal of long-shore drift has taken place three times in recent past. A similar complex of paleo-spits was also observed at other localities.

It is worth noting that all spits are rather crowded with settlements, including the long, narrow Udipi spit. It was generally accepted that the present coast is of emergent nature. In the view of this, sediments of the spits that have emerged more above surrounding water, have stabilized in course of time, and hence could provide a firm foundation for settlements.

#### Drift direction determination

It is observed that out of 14 drift cells identified, 7 have shore drift direction to-

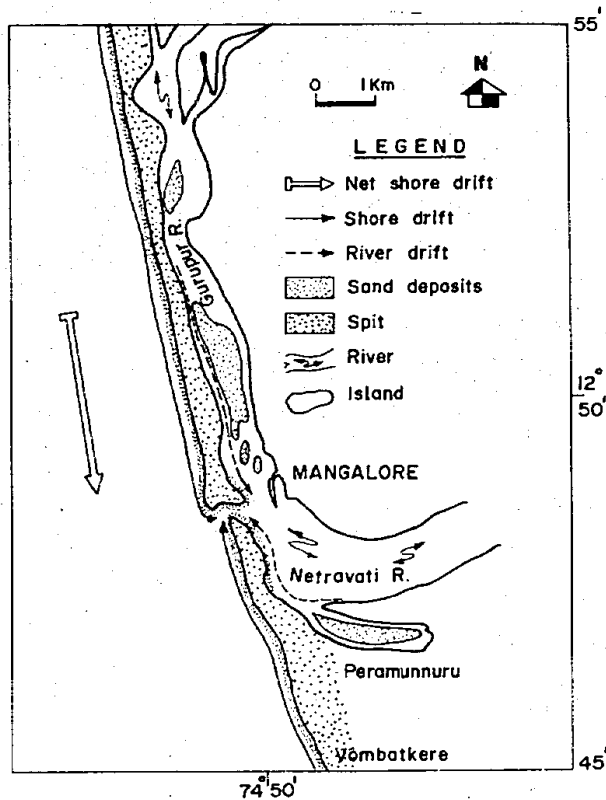


Fig. 9 - Paired spit across Netravati river mouth. Bone shaped distal end of Mangalore spit is pointing landwards whereas Vombatkere spit is pointing seawards.

wards north and rest have towards south. Many adjacent cells have converging as well as diverging drifts.

Ideally, each drift cell consists of three broad zones (Taggart and Schwartz, 1988), the zone of sediment supply, the zone of transport and zone of accumulation. The entire study area is covered with depositional features like beaches and spits and hence it is assumed that sediments are made available by 1) river discharge, 2) from the inner continental shelf and 3) the eroding sea cliff coast north of study area. These sediments are transported and deposited by long-shore drifts within drift cells.

The characteristic features of the winds over west coast of India is the reversal of the wind system known as the Monsoons. The monsoons produce south-westerly winds during May to September and north-wester-

ly direction during December to March with transition period in between. The coastal currents also have been reported to be northerly during northeast monsoon months, whereas it shows a reversal in direction during southwest monsoon period (HMSO, 1975). Hence, in study area, long-shore drift direction is either towards north or south, depending upon monsoonal winds. This differential distribution of long-shore current direction could be the primary cause for long-shore sediment to get redistributed and confined within the region, thereby keeping this prograding coast straight, smooth and stable.

## Conclusions

From the above, it may be concluded that:

- 1, though a few spits provide evidence for breaching hypothesis, the majority of spits indicates long-shore drift as prominent cause for formation and growth of spits of the study area;

- 2, river drift also plays a very significant role in shaping and growth of spits;

- 3, long-shore drift direction is either towards north or south depending upon monsoonal season;

- 4, this differential distribution of long-shore current direction could be the primary agent for sediment redistribution and confinement within the region, thereby keeping this prograded coast straight, smooth and stable;

- 5, three generations of spits, situated side by side but oriented in opposite direction, suggest that the reversal of long-shore drift has taken place three times in recent past.

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