

Textural characteristics of foreshore sediments along Karnataka shoreline, west coast of India

G. Udhaba Dora, V. Sanil Kumar, C. Sajiv Philip, Glejin Johnson, P. Vinayaraj and R. Gowthaman

Ocean Engineering Division, National Institute of Oceanography (Council of Scientific & Industrial Research)
Dona Paula, Goa - 403 004 India

Tel: 0091 832 2450 327 Fax:0091 832 2450 604 Email: sanil@nio.org

Corresponding author:

V. Sanil Kumar; email:sanil@nio.org

ABSTRACT

Grain character analysis of beach sediments along three selected beaches (Pavinkurve, Kundapura and Padukare) of Karnataka coast, west coast of India is carried out in the present study. The objective was to identify the textural behavior of beach sediments during an annual cycle from March 2008 to February 2009. Grain characteristics such as central tendency, sorting, kurtosis and skewness were estimated using GRADISTAT and discussed. The maximum (62%) sediment samples were medium sand with unimodal and bimodal characters at all the three beaches. The median values varied in between -0.04ϕ and 2.74ϕ with an average value of 1.61ϕ . The beaches were characterized as well sorted, moderately well sorted and moderately sorted sediment environments. Sediments were identified as fine skewed to coarse skewed with platykurtic, mesokurtic and leptokurtic characters. Grain characteristics varied spatially and temporally along with beach orientation, foreshore slope and wave action. A negative correlation between mean and sorting is identified for maximum number samples along the study region but not very significant. The study shows that the sedimentary environment at Kundapura were influenced by relatively high wave action compared to Padukare and Pavinkurve beach and the beaches were under erosion or non-deposition with strong winnowing process.

KEYWORDS: Cumulative Percentage Distribution, Central Tendency, Sorting, Skewness, Kurtosis.

INTRODUCTION

The study of textural characteristics of beach sediments is used to categorize the sedimentary environments. The foreshore sediment is generally influenced by coastal processes, especially wave action and beach morphology (beach-face slope and shoreline orientation). The grain size characteristics in intertidal zone are changing with sediment transport especially deposal and removal of fine sediments. In tide dominated beaches the tidal current can play an important role to change the textural characteristics of beach sediments in an estuarine zone. Thakur and Ojha (2010) identified many rivers in Asia plays an important role for carriage of sediment loads. Minghui et al. (2010) studied on the stability of non-cohesive river bank while Hoque et al. (2010) identified the ebb tidal sediment fluxes are higher than flood tidal fluxes during spring tidal cycles. A statistical analysis of beach sediments is relevant to identify the sedimentary environments. Mean size, sorting and skewness are the most useful parameters to describe the sediments (Carranza-Edwards, 2001; Friedman, 1961). The composition of littoral sediments and their textural composition depend on waves, wind, longshore currents and source composition (Komar, 1976). The grain size statistics are used to distinguish between high and moderate energy environments (Nordstrom, 1977). The textural characteristics of beach sediment have been studied in the past by a number of researchers. Along west coast of India, the textural analysis of beach sediment was carried out by Kumar (1977), the sedimentology of beach sediment along Dwarka, Okha and Bombay (Mumbai) beaches were studied by Chaudhri et al. (1981) and the seasonal change of beach sand was studied by Samsuddin (1989). The sediment-size distributions of Goa beaches were analyzed by Murty et al. (1986). Along Kerala coast, Samsuddin (1986) observed that the high water line samples are bimodal, nearly symmetrical in their distribution and moderately sorted. The seasonal longshore transport direction through grain-size trends was studied by Prakash and Prithviraj (1988) & Narayana and Pandarinath (1991). Narayana et al. (2008) analyzed the nearshore sediment characteristics during three monsoon periods. Along Karnataka coast (west coast of India), the sedimentary environments were analyzed for small scale time period by few researchers. The textural studies of beach sediment around Kali estuary was analyzed by Mislankar et al. (1992). Hegde et al. (2006 and 2007) presented the distribution of sediments along Honnavar beach, Karnataka. The textural studies of nearshore sediment off Gangolli and Clay mineral & trace metal of Gangolli estuarine sediment was analysed by Pandarinath and Narayana (1991, 1992). The grain-size statistics and sediment transport direction off Gangoli were calculated by Pandarinath and Narayana (1993). The grain size and morphology of Gangavali beach was studied by Bhat et al. (2003). The textural characteristics of Padukare beach south of the Udyavara estuary has not been studied yet which is one of highly populated estuarine

zone and biggest fishing zone along Karnataka coast. The foreshore sedimentary environment of Pavinkurve (north of Sharavathi river mouth, Honnavar), Kundapura (south of Gangoli river mouth, Coondapoor) and Padukare (south of Udyavara river mouth, Malpe) beaches along Karnataka coast were considered for the present study. One year sediment samples were analyzed with an objective to identify the seasonal as well as alongshore textural behaviour of the beach sediments which further identifies that the beaches along the Karnataka coast are under deposition or erosion.

STUDY AREA

The study area covers three beaches namely Pavinkurve, Kundapura and Padukare from north to south along the Karnataka shoreline, west coast of India (Figure 1). Sharavathi River is connected to Pavinkurve whereas the Gangoli and Udyavara rivers are joining near Kundapura and Padukare beaches respectively. 75% of the coastline along the Karnataka coast is sandy beach (Kumar et al., 2006). The coastal segment along the study region is bounded by the Western Ghats in the east and the Arabian Sea in the west. The continental shelf off Karnataka has an average width of 80 km. The southwest monsoon during June to September influences the coastal processes along the study area which plays a major role on variation in textural characteristics. The coastline along Malpe to Honnavar is inclined 17° to the west from the true north. Along the Karnataka shoreline, there are few islands located off the coast and the major one is St. Mary's Island located 4 km off the coast near Malpe. As the seasonal and alongshore variation in textural characteristics depend upon the local wind, wave, tide and current patterns, a basic knowledge in these parameters of that particular area helps to further appropriate identification of sedimentary environments. The coast is exposed to seasonally reversing monsoon winds, blowing from the southwest direction during the southwest (summer) monsoon period and from the northeast during the northeast (winter) monsoon period. The southwest monsoon winds are strong and the annual average rainfall along the study region is 3 m. Tides in the region are mixed and predominantly semidiurnal, and the tidal range slightly increases from south to north (Kumar et al., 2011a). The average tidal range at Mangalore, which is 60 km south of Malpe, is 1.22 m during spring tide and 0.56 m during neap tide. The average tidal range at Karwar, which is 100 km north of Pavinkurve, is 1.58 m during spring tide and 0.72 m during neap tide. The average monthly sea level at Karwar varies from 1.06 m in September to 1.3 m in January (Indian Tide Table, 2011). Current measurements carried out between 0.5 and 1 km offshore along the coast indicate tidal currents of 0.2 m/s and non-tidal currents upto 0.4 m/s (Kumar et al., 2011b). Off the study region, the significant wave height varies from 0.2 to 5 m with an average value of 1.1

m (Kumar et al., 2003). The beach slopes were changing spatially and temporally along the study region due to the beach erosion and accretion, observed during the sampling time.

MATERIAL AND METHODS

The sediment samples were collected from 9 locations at water line (WL) and high water line (HWL) of three selected beaches (Figure 1) along Karnataka shoreline in monthly interval during March 2008 to February 2009. A total of 216 sediment samples were collected and analyzed. In the laboratory, dead shells were separated from sand and the mixed saline content was removed from the grains by washing with water. The grain size distribution was carried out using sieve shaker consisting of 7 sieves having mesh sizes 2, 1, 0.5, 0.425, 0.212, 0.125 and 0.075 mm. The sediment distribution is presented graphically as cumulative percentage curve with phi (ϕ) scale and the statistical parameters such as central tendency (mean, mode and median), standard deviation (sorting), skewness and kurtosis were calculated by Folk and Ward (1957) method using GRADISTAT (Blott and Pye, 2001). Most of the samples were collected during low-tide while the remaining samples were collected either during mid-tide or high-tide because of either the poor visibility or heavy rainfall during the low tide time.

At Pavinkurve, north of the Sharavathi river mouth, the study area covered ~1.5 km along the shoreline. From BM1 to BM2 and from BM2 to BM3, the distance is ~1.0 and ~0.5 km respectively. At Kundapura, the study area is in the south of Gangoli river mouth and the distance between BM1 and BM2 is ~0.8 km and that from BM2 to BM3 is ~2.2 km. Padukare beach is located south of the Udyavara river mouth at Malpe. At Padukare, from BM1 to BM2, the distance is ~4.1 km and from BM2 to BM3, the distance is ~2.1 km. The geographical positions of the locations were noted using Ceeducer Pro Manufactured by Bruttor International Pty. Ltd., Australia with an accuracy of 1 to 4 m in distance measurement. At all the beaches, the maximum beach width was observed during May 2008 and it varied from 45 to 150 m at different locations. The minimum beach width was during the southwest monsoon period (June/July) and it varied from 5 to 65 m (Table 1).

RESULTS AND DISCUSSIONS

Sediment Distribution

The grain size distribution of monthly collected sediment samples are presented with cumulative percentage distribution. It is observed that the monthly variation of grain size along HWL was less compared to that at WL (Figures 2 to 4) and also varied with respect to spatial and temporal. The

reason for difference in grain size distribution at different locations is due to the variation in wave energy reaching the location of sampling and the morphology of the beach (Bryant, 1982). One year average based on monthly data shows that the beach sediment was predominantly sand.

At Pavinkurve, the cumulative percentage distribution of monthly collected sediment samples indicates that along WL, the variation in grain size is more at BM1 compared to BM2 and BM3 (Figure 2). During transitional period of post and pre-monsoon the beach sediments along WL at BM1 is coarser compared to summer monsoon period. During summer monsoon, the waves from west and south-west were obstructed by the Basavarajdurg Island (BI) and the wave energy at BM1 was less than that at BM2 and BM3. At Kundapura and Padukare, the variations in grain size was more at BM1 compared to BM2 and that at BM2 was more than that at BM3 (Figures 3 and 4). The cumulative percentage distribution (Figures 2 to 4) shows the grain size of sediment samples was coarser in summer monsoon due to high wave energy condition and was finer in pre and post monsoon period along all three beaches.

Statistical parameters of sediment samples

Central Tendency (Mean, Median and Mode)

Along the study region, the median values varied from -0.04ϕ to 2.74ϕ with an average value of 1.61ϕ (Table 2). At Pavinkurve beach, the median value varied from 0.56ϕ to 2.68ϕ with an average value of 1.78ϕ whereas at Kundapura and Padukare it varied from -0.04ϕ to 2.43ϕ and 0.24ϕ to 2.74ϕ with average value of 1.33ϕ and 1.71ϕ respectively. The median size of Kundapura sediment samples was bigger than that of Pavinkurve and Padukare. Most of the time the grain size (diameter in mm scale) was bigger along WL compared to HWL along the study region. At Pavinkurve and Kundapura, 72.2% (26 from 36 samples) of collected samples were found as bigger grain size at WL than that at HWL whereas 67.3% (24 from 36 samples) were identified as bigger grain size at Padukare beach. From pre-monsoon to monsoon, the size of the sediment was increasing, and it was decreasing from monsoon to post-monsoon. The presence of coarse sediments during monsoon was due to the prevailing high wave energy condition.

The mean value suggest that most of the sediment along the three beaches varied in between fine to coarse sand whereas 1.4% of total samples were found very coarse sand at Kundapura beach. Along the study area, all the beaches were dominated by medium sand (62%) with average mean value of 1.63ϕ . Mean value varied from 0.72ϕ to 2.73ϕ at Pavinkurve, -0.01ϕ to 2.29ϕ at Kundapura and

0.19 ϕ to 2.85 ϕ at Padukare with an average value of 1.74 ϕ , 1.30 ϕ and 1.66 ϕ respectively (Figure 5). Along Pavinkurve and Padukare beach, medium sand was observed during 68.1% and 55.6% whereas at Kundapura beach, the coarse sand was found during 61.1% (Table 3). Hegde et al. (2006, 2007 and 2009) observed medium sand at Pavinkurve which is similar to the present observation.

Along Pavinkurve beach, the beach sediments were medium and coarse sand during the monsoon period. In pre and post-monsoon, the sands were identified as fine and medium sand with 1.4% as coarse sands. The average value of grain size shows that the grains (diameter in millimeter) were increasing from BM1 to BM3 during most of the time. The variation in grain sizes with respect to monsoon was the result of change in wave activity occurring along the coast. During monsoon, the waves from southwest and west approached directly to BM3 and BM2 which results in the bigger grain size compared to BM1.

The Kundapura beach is characterized as medium and coarse sand with 1.4% as very coarse sand during monsoon. In the pre-monsoon period, most of the sands were found as medium sand with less amount of coarse sand and in post-monsoon the beach was characterized with mixed sands (fine, medium and coarse sand). During post monsoon period, BM1 region was having 50% coarse, 37.5% medium and 12.5% of fine sand. BM2 region was identified with medium sands whereas BM3 was having equal amount of fine and medium sand. At Kundapura beach, along both WL and HWL, the mean size of the sediment was gradually decreasing from BM1 to BM3. The Kundapura beach is open and straight and hence the nearshore waves were same along the beach but the wave energy at breaking zone was varying with beach slope and has influenced on the grain size and shape. BM1 was very steep beach having comparatively less wave energy with maximum breaker height of 1 m and was showing towards coarser sands with reflective beach due to the gravity effect or shear sorting in backwash (Bryant, 1982). BM2 was moderate to steep beach with breakers around 1.5 m and having medium to coarse sand whereas BM3 was high energy beach having breakers of around 2 m with fine to medium sand.

At Padukare beach, both BM1 and BM2 were having medium and coarse sand and BM3 was having fine sand with few amount of medium sand during monsoon period. In pre-monsoon, the BM1 and BM3 were having fine sand with very less amount of medium sand where BM2 was having medium sand with very less amount of fine sand. During post-monsoon period, both BM1 and BM2 were consisting of mixed sand where BM3 was having fine to medium sand. It was observed that the mean size of sediment at BM3 was smaller compared to that at BM1 and BM2. The location BM3 was in the northern end of the beach and near to the coastal protection structure. Due to the change in

coastal orientation and being at the sheltered region of the St. Mary's Island, the beach at BM3 is under the action of relatively low waves compared to BM1 and BM2 and hence the size of the sediment at BM3 was relatively small showing as finer sand with dissipative beach. The sediment size was relatively smaller at BM2 than that at BM1 during monsoon and the reverse was the case during the remaining period due to the combined effect of wave activity and beach slope.

The average grain size along WL were 1.63ϕ , 1.21ϕ and 1.56ϕ respectively at Pavinkurve, Kundapura and Padukare and that at HWL were 1.85ϕ , 1.38ϕ and 1.77ϕ which shows that the grain size was relatively larger at WL than at HWL. Along the Karnataka shoreline it suggests that the grain size was relatively larger at Kundapura compared to other locations. During the annual cycle, the fine grains were observed when low wave energy condition prevailed with wide beach width and coarse grains were found when the beach width was minimum which corresponds to the south west monsoon period i.e., during the high wave energy condition (Figure 5). Large wave height during June triggers the erosion and sediments having smaller size are winnowed away and higher grain size is left out on the beach. When the wave activity is less, increase in beach volume and decrease in grain size is observed.

Along the study region, beach sediments were mainly unimodal (41%) and bimodal (58%) and only 1% of the samples were polymodal. Hegde et al. (2006) observed that the sediment samples at Honnavar (close to Pavinkurve beach) were bimodal to polymodal. The primary mode was identified at 1.74ϕ as 80, 51 and 61% of total samples respectively along Pavinkurve, Kundapura and Padukare beaches. The Pavinkurve beach was characterized as unimodal and bimodal during 56% and 44% of the total samples respectively. The Kundapura beach sediments were characterized as 19% of unimodal and 80% of bimodal with 1% of polymodal. The sediment environment of Padukare beach was identified as 47% of unimodal and 53% of bimodal characters. This results that the maximum bimodal character of sediment samples were identified at Kundapura beach with high wave energy activity along moderate to steep beach slope. In-other-word, the unimodal character of sediment samples was identified towards gently beach slope with less wave activity.

Sorting ($\sigma\phi$)

Sorting of a sediment sample is a classification of grains according to their shape and size. Standard deviation ($\sigma\phi$) measures the sorting of sediments and indicates the fluctuations in the kinetic energy or velocity conditions of the depositing agent (Sahu, 1964). The standard deviation values reveal that the beach sediments were very well to poorly sorted (Figure 6). Along the study area, 35% of the

total collected samples were moderately well sorted, 45% were moderately sorted and 12% samples were well sorted. At Pavinkurve, 1% of total collected samples have shown as very well sorted in post-monsoon period at BM2 along HWL, whereas all other samples were shown as well sorted (28%), moderately well sorted (36%) and moderately sorted (35%). The results at Pavinkurve were similar to the observations of Hegde et al. (2006, 2007). At Kundapura, maximum samples were moderately well sorted (36%) and moderately sorted (53%) whereas 8% were poorly sorted and 3% were well sorted. At Padukare, maximum samples were found moderately well sorted (33%) and moderately sorted (47%) whereas 14% were poorly sorted and 6% were well sorted. Chakrabarti (1977) and Chaudhri et al. (1981) has observed that moderately sorted sands are predominant on the beaches of the east and west coasts of India, respectively. The well sorted sediment samples were identified relatively more along HWL at Pavinkurve beach and also some samples were identified along WL during pre- and post-monsoon period with low wave energy activities. Maximum sediment samples of Kundapura and Padukare beaches were identified as moderately sorted and moderately well sorted with the influence of relatively high wave energy condition. Few samples were found as well sorted along HWL at both the beaches. In the study region, there was no single sample found as well sorted sediment along WL during monsoon. It reveals that, the sorting character of beach sediments directly related to wave activity approaching to the beaches along WL. The land-ward part of longshore current played an important role to make the sediments to better sorting along HWL where the more samples were found as well sorted. The present analysis shows that sorting character of sediment environments were decreasing with increasing wave energy.

Skewness and kurtosis

Skewness measures the asymmetry of the curve of the frequency distribution where kurtosis is the measure of peakedness or flatness of samples related to normal distribution. The beach sediments varied in between very fine skewed to very coarse skewed (Figure 7). 37% of the total samples were coarse skewed sediments and 27% samples were fine skewed (Table 4). Along the Pavinkurve, Kundapura and Padukare beaches, about 90%, 87% and 86% of the total samples varied in between fine to coarse skewed respectively whereas the remaining samples were very fine skewed and very coarse skewed. Hegde et al. (2006) observed that the sediments at Pavinkurve were negative (coarse) skewed to symmetrical. The above results shows that most of the samples varied in between fine to coarse skewed along Karnataka coast. The fine and coarse skewed sediments were nearly the same at both Pavinkurve and Padukare beaches. At Kundapura beach, the percentage of positive skewed samples were relatively less where negative skewed were relatively more, indicates that the beach

was undergoing erosion or non-deposition (Duane, 1964) as compared to other two beaches. The empirical estimation of skewness characteristic indicate that about 48% of total sediment samples from all the three beaches were negatively skewed (coarse skewed and vary coarse skewed) whereas the positively skewed (fine skewed and very fine skewed) samples were 29% and no skewed (symmetrical) samples were about 23%. Along the WL, the fine sand is winnowed away by waves causing the sand to be coarse (negative) skewed. The strongly fine skewed and fine skewed sediments generally imply the introduction of fine material or removal of coarser fraction (Friedman, 1961) or winnowing of sediments (Duane, 1964).

Along the shoreline all the samples varied in between very platykurtic to very leptokurtic (Figure 8). Most of the samples were shown as platykurtic (35%), mesokurtic (29%), and leptokurtic (32%) characters (Table 4) where platykurtic range varies between 0.67 and 0.90, mesokurtic range varies between 0.90 and 1.11 and leptokurtic range varies between 1.11 and 1.50 (Blott and Pye, 2001). During the annual cycle, the sediment samples at Pavinkurve beach represented all the three types of kurtosis characteristics in same percentage. At Kundapura, the maximum amount of leptokurtic samples (46%) was found and the Padukare beach was dominated with the mesokurtic samples (42%). The platykurtic character of all the three beaches was nearly same. The mesokurtic character of Kundapura sediment samples were about 0.6 times of Pavinkurve and 0.4 times of Padukare beach. With no change in platykurtic character, the leptokurtic character varies reversely with respect to mesokurtic character. The leptokurtic character at Kundapura beach is 1.4 times of Pavinkurve and 2.6 times of Padukare beach samples. Friedman (1962) suggested that extreme high or low values of kurtosis imply that part of the sediment achieved its sorting elsewhere in a high energy environment. The above result shows that the skewness was highly influenced by wave action at Kundapura beach compared to Padukare and Pavinkurve beach. More variation were found in leptokurtic and negative skewed characters which were linearly related ($Y = 1.12 * X - 17.6$) to each other with $r=0.9$ suggests that the negative skewed sands were increasing with increase in leptokurtic characters and vice-versa.

Mean ($M\phi$) versus Sorting ($\sigma\phi$)

Scatter plot of the mean versus sorting (Figure 9) of beach sediment samples show the variation in sorting character with change in mean grain size. Along the study region, maximum samples were fine sand to coarse sand with moderately sorted to moderately well sorted characters. In summer monsoon, the maximum number of sediment samples were moderately well sorted to moderately sorted with coarse to medium sand at most of the beaches. Some samples were well sorted sediments

with medium sand at Pavinkurve and Padukare beaches. Very few samples were found as poorly sorted with coarse sand and medium sand at Kundapura and Padukare Beaches. One sample identified as very well sorted with medium sand at Pavinkurve beach, one sample characterized as well sorted with coarse sand and one sample was moderately well sorted with very coarse sand at Kundapura beach. These three samples results that, the sorting character of sediment samples was decreasing with increasing in grain size. During summer monsoon, along WL, maximum samples were identified as moderately sorted and moderately well sorted with medium and coarse sand due to the influence of wave activity with less variation whereas during pre and post-monsoon the sediment samples were identified as a wide range of very well sorted to poorly sorted with fine sand to very coarse sand because of large variation in wave activity. Along the study area the sorting character of sediment sample was negatively correlated to mean with correlation coefficient of $r = -0.38$ ($r\text{-square} = 0.1444$) during summer monsoon and with correlation coefficient $r = -0.32$ ($r\text{-square} = 0.1024$) during pre and post-monsoon season. The low value of correlation coefficient indicates that the correlation between these parameters is not significant. The fitting line (red line for waterline sediment samples and blue line for high water line sediment samples) of mean and sorting correlation was deviating more along HWL compared to WL from benchmark to benchmark at all the three beaches. At Pavinkurve and Padukare beach the negative correlation between mean and sorting was slowly increasing towards river mouth (BM3) along both WL and HWL. At Kundapura the opposite result is identified due to the presence of maximum amount of coarse sand at river mouth (BM1).

CONCLUSIONS

The cumulative percentage distribution curves show that the grain size variation was more along WL due to the affect of wave activity compared to HWL. The central tendency (mean, median and mode) of collected sediment samples shows that the beaches along the study area were dominated by medium sand with unimodal and bimodal characters. The coarse sand with moderately well sorted and moderately sorted was found during high wave energy condition. The study showed that the negative (coarse) skewed sediment samples were 1.7 times of positive (fine) skewed samples indicating strong winnowing and erosion along the study region. The Pavinkurve beach showed moderately well sorted medium sand with coarse skewed platykurtic character. The Kundapur beach was moderately sorted medium sand with coarse skewed leptokurtic character. The Padukare beach was found to be moderately sorted medium sands with coarse skewed mesokurtic characters. The correlation coefficient (r) of maximum sediment samples indicates that the sorting was negatively

correlated with mean grain size but not very significant. The study shows that the sedimentary environment at Kundapura were influenced by relatively high wave action compared to Padukare and Pavinkurve beach and the beaches were under erosion or non-deposition with strong winnowing process.

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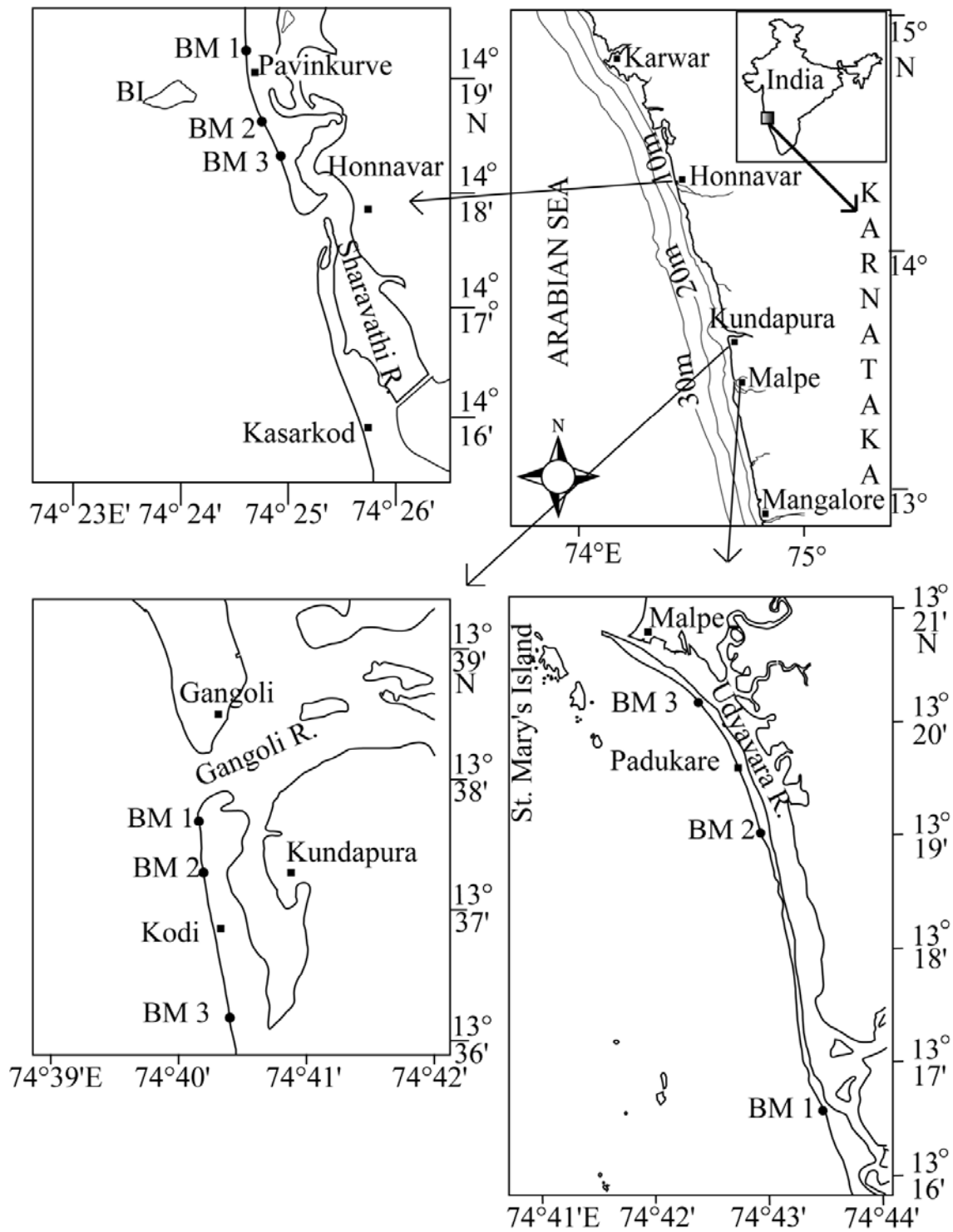


Figure 1. Map is showing the study area and locations of collected beach sediments.

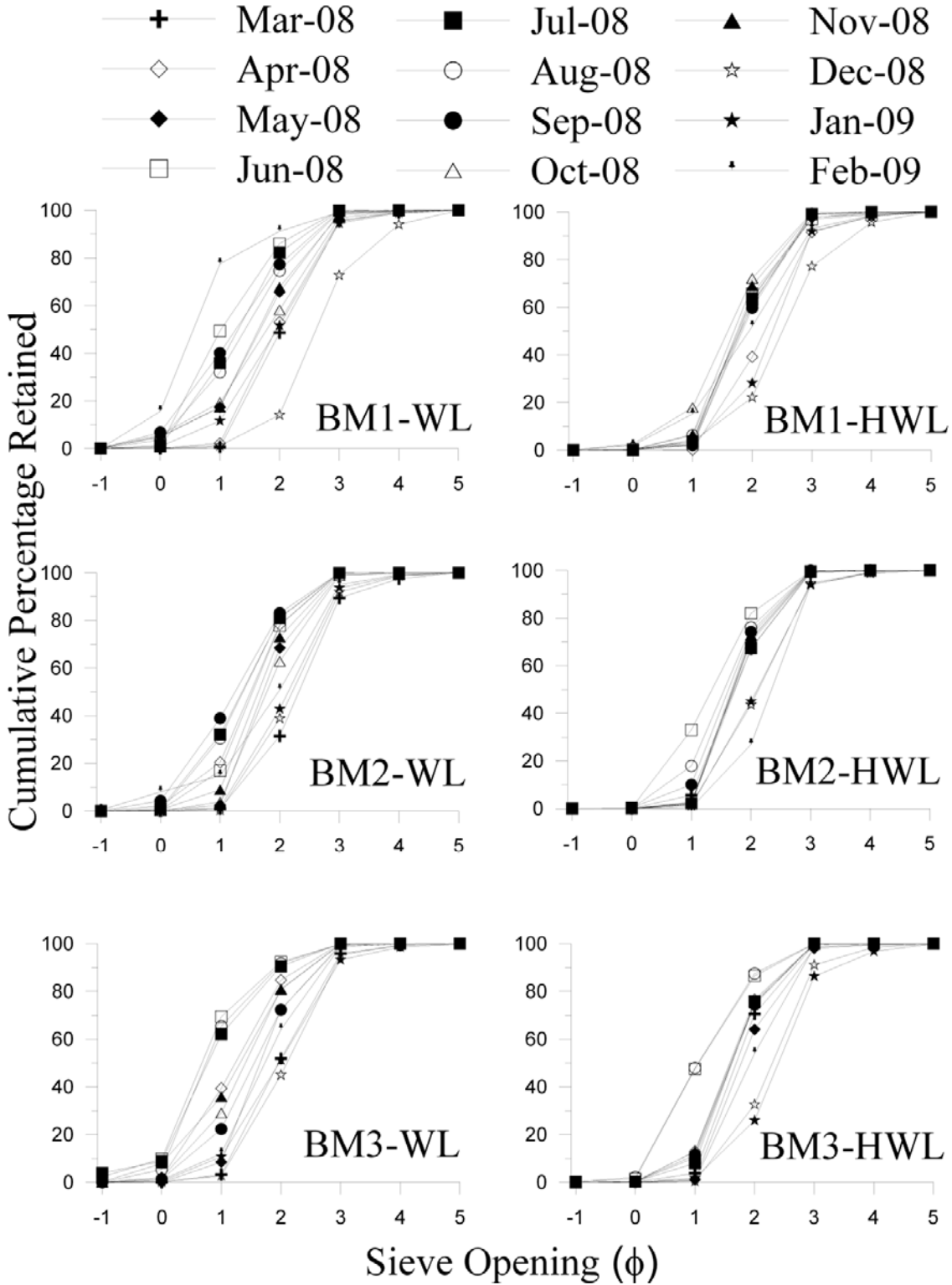


Figure 2. Cumulative percentage distribution of collected sediment samples along Pavinkurve beach.

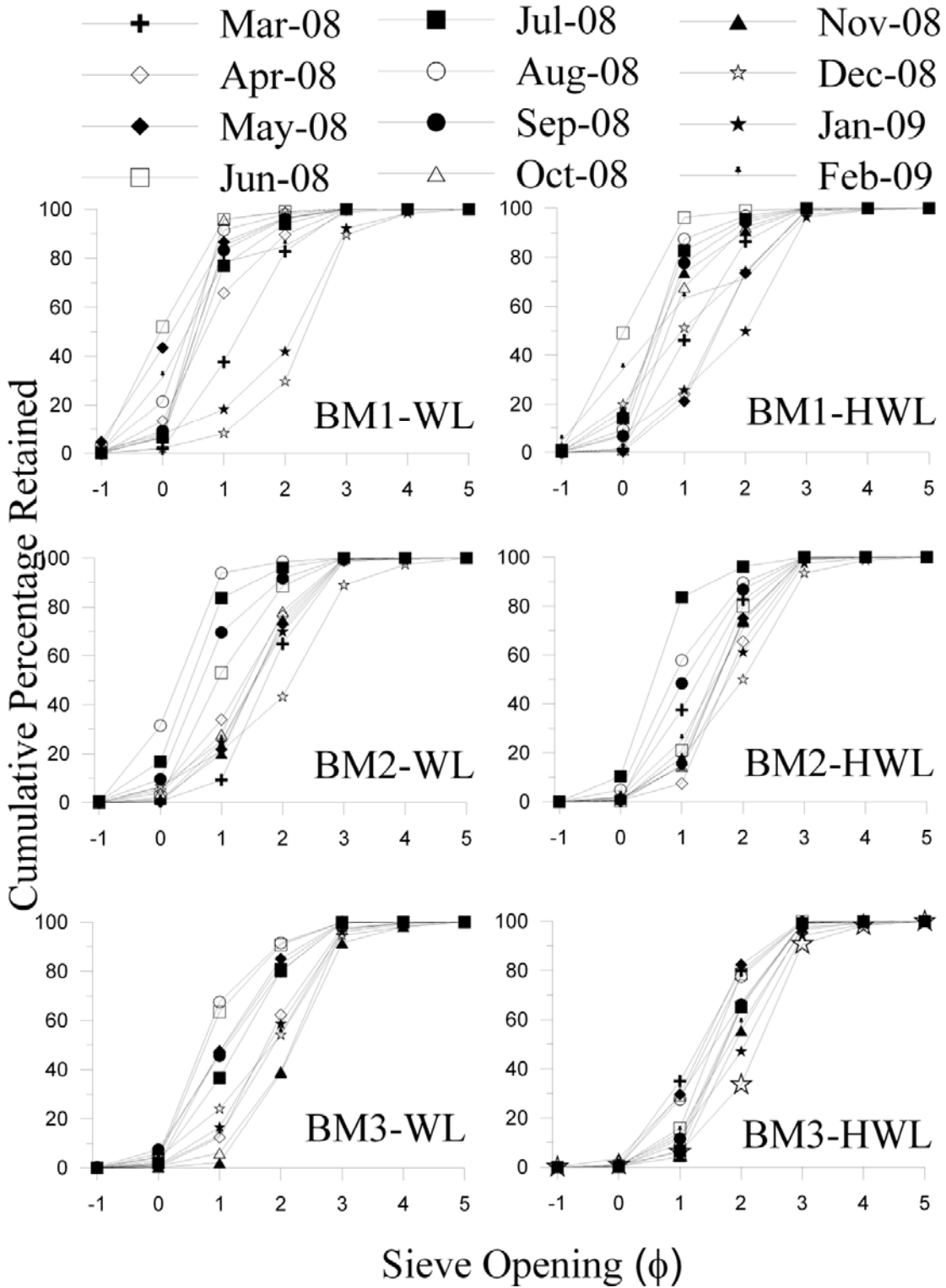


Figure 3. Cumulative percentage distribution of collected sediment samples along Kundapura beach.

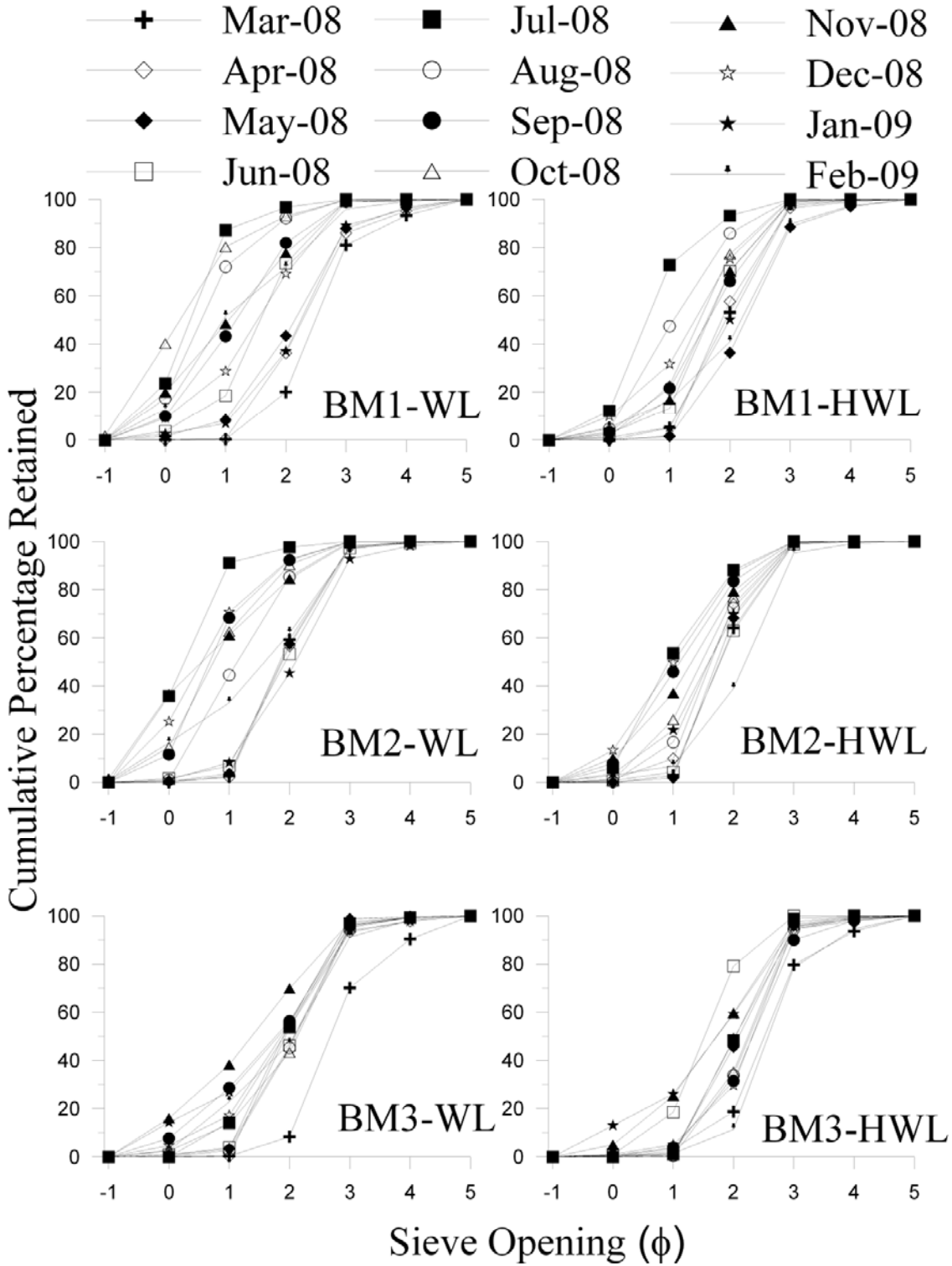


Figure 4. Cumulative percentage distribution of collected sediment samples along Padukare beach.

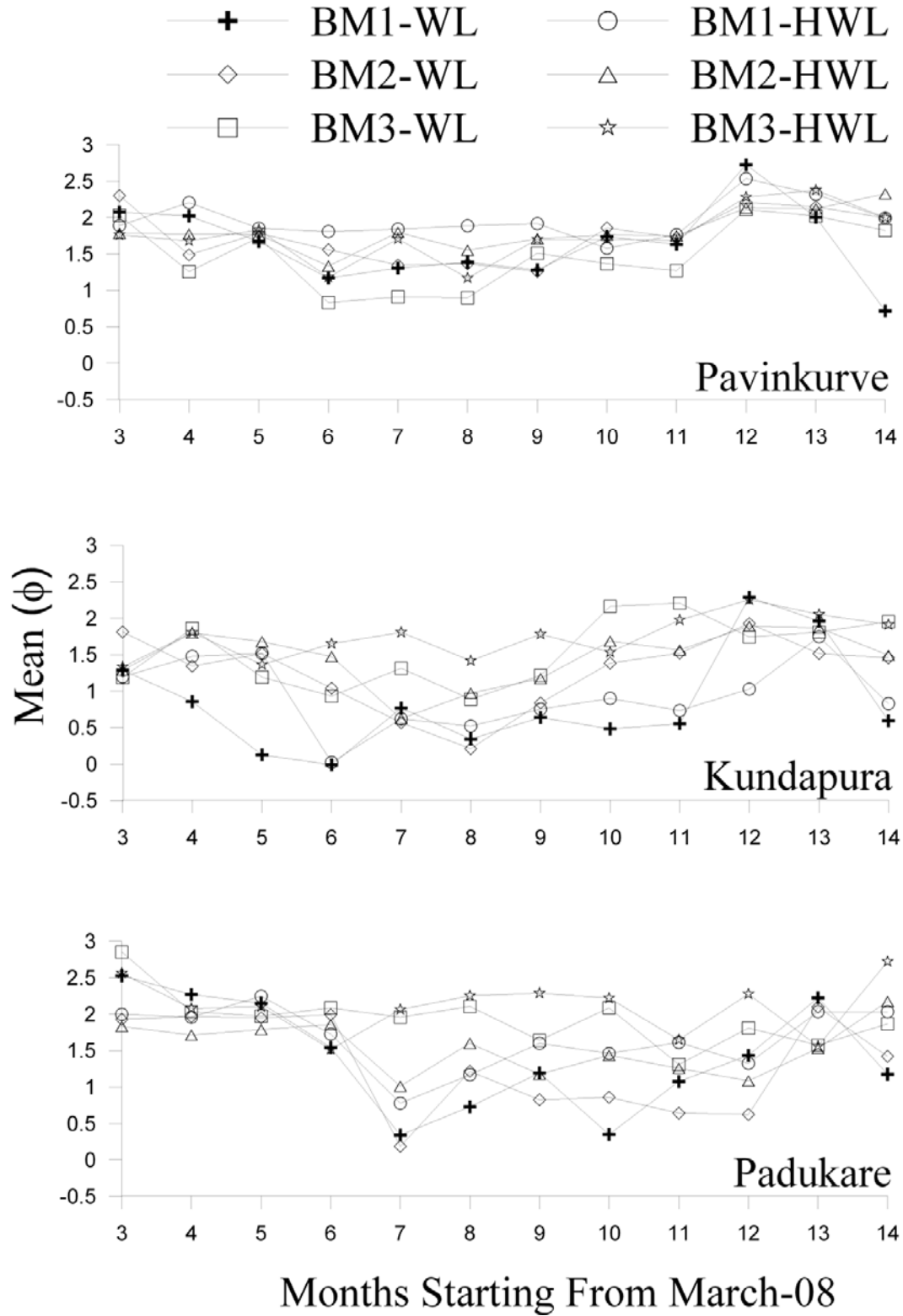


Figure 5. Mean size of collected sediment samples along Pavinkurve, Kundapura and Padukare.

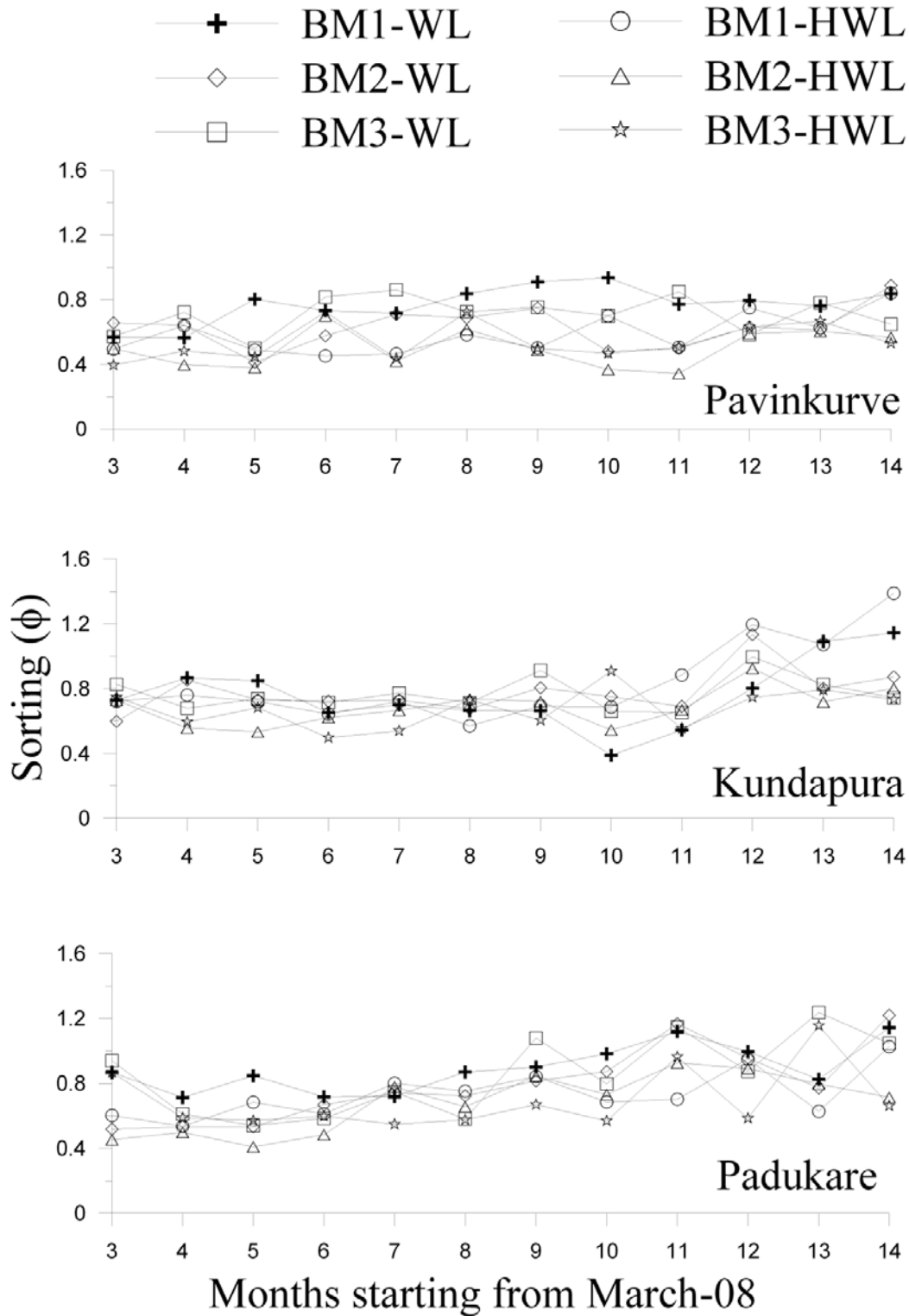


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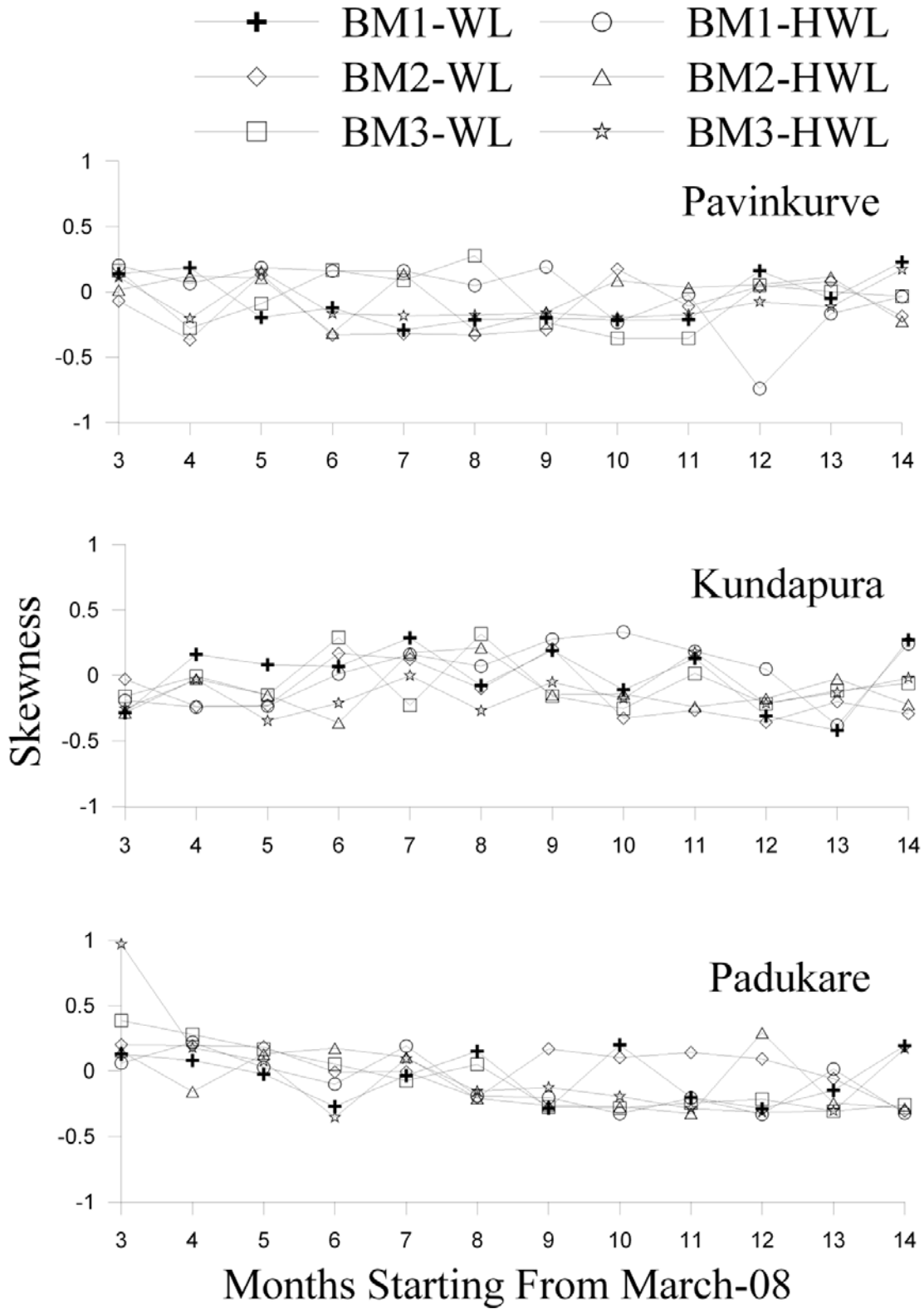


Figure 7. Skewness of collected sediment samples along Pavinkurve, Kundapura and Padukare.

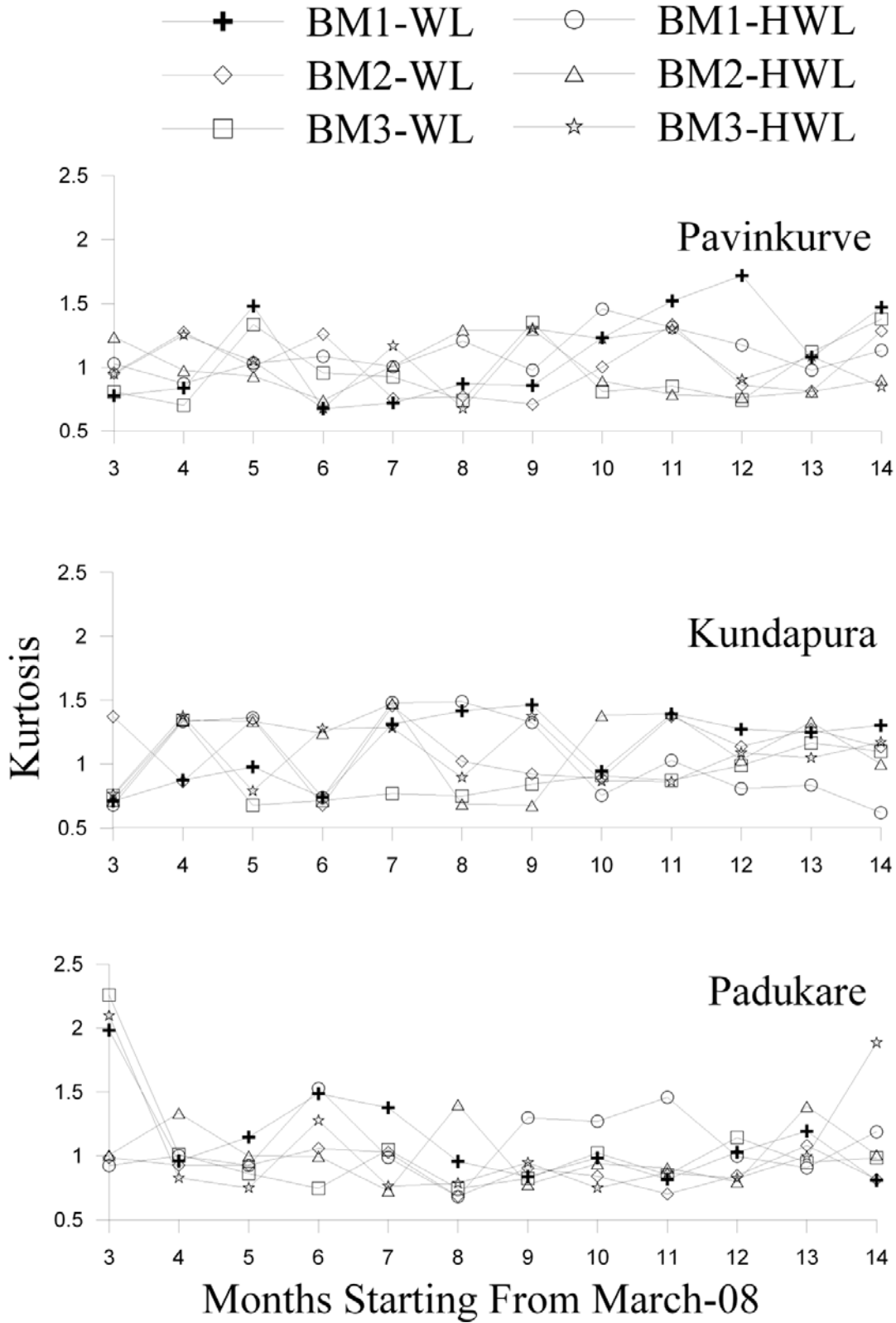


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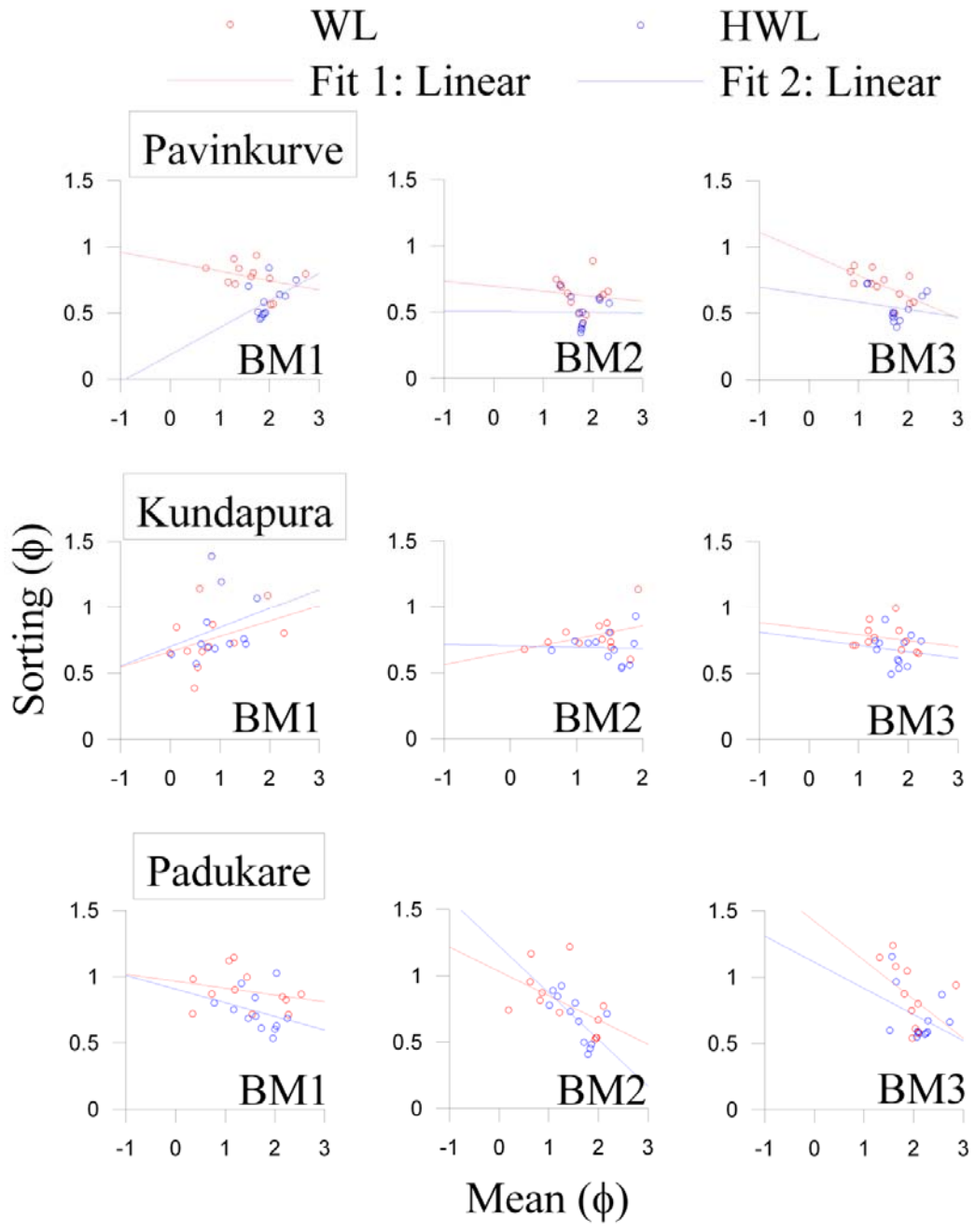


Figure 9. Mean versus sorting plot of collected sediment samples along Pavinkurve, Kundapura and Padukare beach.

Table 1. Minimum and maximum beach width at different stations

Beach	Station	Position		Minimum		Maximum	
		Latitude	Longitude	Width (m)	Month	Width (m)	Month
Honnaver	BM1	14° 19' 03.220"	74° 24' 50.332"	65	June	150	May
	BM2	14° 18' 35.347"	74° 25' 01.912"	30	June	90	May
	BM3	14° 18' 20.800"	74° 25' 08.091"	5	June	45	May
Kundapura	BM1	13° 37' 50.387"	74° 40' 10.346"	40	July	120	May
	BM2	13° 37' 25.817"	74° 40' 10.906"	45	July	90	May
	BM3	13° 36' 16.859"	74° 40' 21.767"	50	July	110	May
Padukare	BM1	13° 16' 50.876"	74° 43' 21.816"	15	July	85	May
	BM2	13° 19' 02.274"	74° 42' 57.437"	50	July	80	May
	BM3	13° 20' 05.450"	74° 42' 31.628"	35	July	95	May

Table 2. Median size of the beach sediments at different locations during different seasons

Name of beach	Station	Location of collection	Median size of the sediments in ϕ scale								
			Pre-Monsoon			Monsoon			Post-Monsoon		
			Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Honnaver	BM1	WL	0.56	2.02	1.57	1.25	1.56	1.43	1.73	2.68	2.05
		HWL	1.83	2.21	1.96	1.81	1.87	1.84	1.69	2.58	2.04
	BM2	WL	1.63	2.38	1.94	1.43	1.65	1.53	1.73	2.22	1.98
		HWL	1.77	2.43	1.94	1.5	1.8	1.67	1.75	2.12	1.93
	BM3	WL	1.41	1.97	1.73	0.74	1.66	0.99	1.48	2.09	1.77
		HWL	1.68	1.94	1.8	1.28	1.71	1.49	1.69	2.48	2.06
Kundapura	BM1	WL	0.15	1.48	0.67	-0.04	0.62	0.38	0.48	2.43	1.43
		HWL	0.55	1.66	1.29	0.02	0.61	0.42	0.58	2.01	1.07
	BM2	WL	1.52	1.79	1.66	0.3	0.94	0.6	1.57	2.23	1.78
		HWL	1.45	1.8	1.64	0.54	1.61	1.07	1.67	2	1.8
	BM3	WL	1.21	1.91	1.58	0.72	1.47	1.07	1.84	2.24	2.06
		HWL	1.49	1.86	1.67	1.58	1.8	1.7	1.66	2.36	2
Padukare	BM1	WL	0.96	2.57	1.99	0.41	1.67	1.01	0.24	2.3	1.36
		HWL	1.89	2.29	2.1	0.62	1.73	1.34	1.55	2	1.72
	BM2	WL	1.68	1.91	1.84	0.25	1.94	1.05	0.54	2.1	0.98
		HWL	1.71	2.25	1.9	0.92	1.83	1.44	1.24	1.69	1.5
	BM3	WL	1.92	2.74	2.18	1.82	2.09	1.98	1.52	2.17	1.86
		HWL	2.02	2.66	2.34	1.63	2.39	2.09	1.78	2.41	2.07

Table 3. Percentage of sand type at different beaches

Location	Percentage of sand type			
	Fine	Medium	Coarse	Very Coarse
Pavinkurve	26.4	68.1	05.5	0.0
Kundapura	06.9	30.6	61.1	1.4
Padukare	31.9	55.6	12.5	0.0

Table 4. Skewness and kurtosis characteristics of beach sediments at different locations

Beach	Station	Location	Skewness characteristics (% of total collected samples)					Kurtosis characteristics (% of total collected samples)				
			Very Fine Skewed	Fine Skewed	Symmetrical	Coarse Skewed	Very Coarse Skewed	Very Platykurtic	Platykurtic	Mesokurtic	Leptokurtic	Very Leptokurtic
Pavinkurve	BM1	WL	0	33	8	59	0	0	50	8	25	17
	BM2	WL	0	17	25	25	33	0	42	25	33	0
	BM3	WL	0	25	42	17	16	0	50	17	33	0
	BM1	HWL	0	42	33	17	8	0	8	50	42	0
	BM2	HWL	0	33	34	25	8	0	42	33	25	0
	BM3	HWL	0	25	8	67	0	0	25	33	42	0
Kundapura	BM1	WL	0	42	25	17	16	0	25	17	58	0
	BM2	WL	0	25	17	42	16	0	25	17	58	0
	BM3	WL	8	9	25	58	0	0	58	25	17	0
	BM1	HWL	8	33	26	25	8	8	42	8	42	0
	BM2	HWL	0	17	17	58	8	0	25	17	58	0
	BM3	HWL	0	9	33	50	8	0	41	17	42	0
Padukare	BM1	WL	0	33	25	42	0	0	26	33	33	8
	BM2	WL	0	50	33	9	8	0	42	58	0	0
	BM3	WL	8	17	25	42	8	0	42	42	8	8
	BM1	HWL	0	17	25	33	25	0	8	50	34	8
	BM2	HWL	0	42	0	50	8	0	25	50	25	0
	BM3	HWL	8	17	17	33	25	0	58	17	8	17