Shoreline changes in three groin fields on the Eastern Black Sea Coast

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SHORELINE CHANGES IN THREE GROIN FIELDS ON THE EASTERN BLACK SEA COAST

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ABSTRACT

The objectives of this study are to evaluate and compare the sediment capture characteristics in three T-head groin systems. 31 T-head groins evaluated are located at Kıyıcık (13), Eskipazar (10), and İyidere (8) which are on the Eastern Coast of Black Sea in Turkey. In this study, interactive effects of the groins, groin fill characteristics, and variations in sediment depths between the left and right heels of the groins were evaluated. Since their construction in 2000, there has been a significant sediment accumulation at each groin system. Sediment accretion analyses show that the Kıyıcık and İyidere groin systems have the most significant sediment accretion characteristics. The comparison of the sediment depth profiles indicates that sediment depth in the groin fields is still increasing. However, at the Eskipazar groin system the sediment depth in the groin field has not showed a significant change since 2009. At the Eskipazar groin system there are significant variations in the sediment levels amongst the individual groins due to the frequent and uncontrolled removal of the sediments. The groin system in İyidere is the most balanced in terms of sediment depths at the left and right heels and also has the minimum human interference due to the limited access to the coastline.

KEYWORDS:
Groin, Shoreline, Sediment, Groin characteristics, Black Sea

INTRODUCTION

Groins are long and narrow structures generally constructed perpendicular to the shoreline to prevent shoreline erosion. They are used to reduce the littoral drift in the surf zone, and to retain the sand depending on the available sediment budget [1, 2]. A series of similar groins may be constructed to form a groin field which can protect a stretch of coast against erosion. The effectiveness of straight groins can be increased by modifying the shape of groins (L and T-head groins or bent groins) to reduce the wave energy into the compartments and to reduce the formation of rip currents near the groin heads [3, 4, 5].

T-head groins are effective in stabilizing beaches by holding the sand directly located on either side of the structures [6, 7, 8, 9]. Length, height, permeability, type of material, and groin configuration are all factors that affect a terminal groin's influence on sedimentary process [10].

Although coastal groins are designed for shoreline protection and beach formation, there are cases where T-head groins have resulted in significant shoreline erosion. [11]. The numerical studies (i.e., modelling) are often limited in predicting the long-term changes depending on the data availability of wave and sediment characteristics [12]. Long-term monitoring of sediment levels is needed to ensure the functional effectiveness of the shoreline protection structures [13, 14].

To provide shoreline protection for the Black Sea Coast in northern Turkey, T-head groins were constructed along the coast line. The objective of this study is to evaluate the morphological effects on the groin fields of three T-head groin groups based on sediment capture. The performances of the T-head groin systems located at Kıyıcık (13 T-head groins), Eskipazar (10 T-head groins), and İyidere (8 T-head groins), located on the Eastern Black Sea coast, were analyzed. Interactive effects of the groins, sediment depth profiles, and variations in sediment depths between the left and right heels of the groins were evaluated and compared [15].

MATERIALS AND METHODS

In the related research, T-head groin locations and characteristics were described. Wind and wave characteristics, coastal and sea floor morphology, coastal ecology and ecological impacts, coastal sediment budget, depth survey and field inspection details were given.

Description of T-head Groin Locations; The three T-groin systems studied are located at the coastline of the towns of Kıyıcık, Eskipazar and İyidere in Turkey, extending about 14 km on the Eastern Black Sea coast. The T-head groins were constructed in 2000 in a similar manner and dimensions during the construction of the Black Sea Double Motorway to protect the highway. The groin system at Kıyıcık consists of 13 T-head groins with coverage of approximately 2.5 km of coastline. This

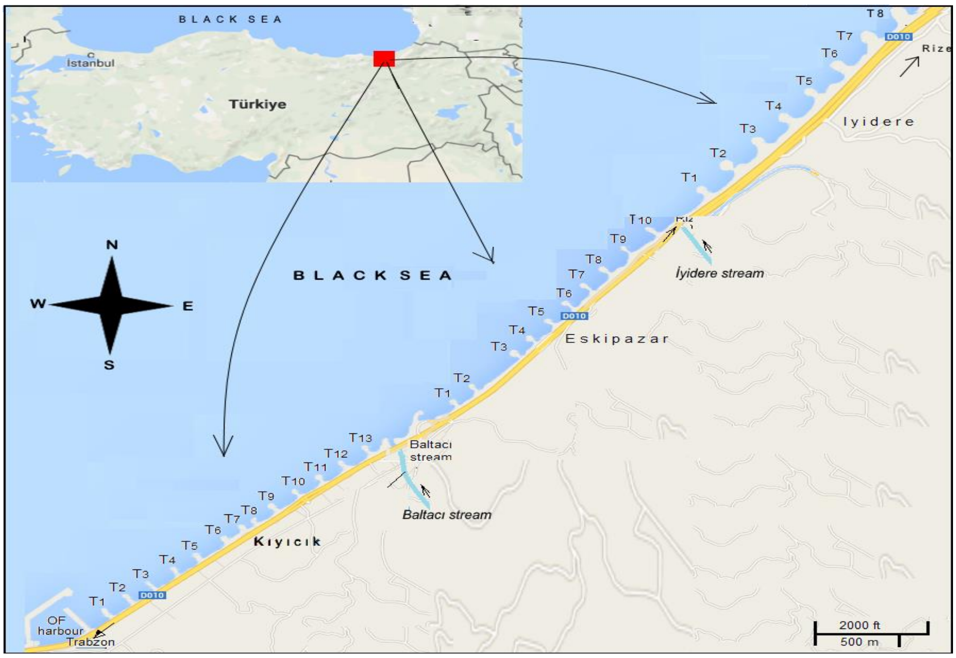

FIGURE 1
T-groin systems, a. Kıyıcık (13), b. Eskipazar (10), c. İyidere (8). (There are three groin groups; 13 units Kıyıcık group, 10 Eskipazar group, 8 İyidere group, and there are total 31 T-head groins in the study area).

groin system is located between two small streams (Solaklı and Baltacı Rivers). A large fishing shelter and a public beach are located in the west of the groin system (Figure 1a).

The groin system in Eskipazar consists of 10 T-head groins covering approximately 1.8 km of coastline. This groin system is also located between two streams (Baltacı River and İyidere Creek) which serve as the sediment sources. There is a small fishing shelter located in the west of this groin system, (Figure 1b). The coastal area in Eskipazar is also used as a public beach.

The groin system in İyidere consists of 8 T-head groins covering approximately 1 km of coastline. It is separated from Eskipazar by İyidere Bridge. İyidere Creek serves as the sediment source for this groin system (Figure 1c).

This area is not used as a beach due to the high level of pollution. There are frequent water discharges from a gas station at this location during routine cleaning activities and occasional leaks. There is also a small marble craftwork industry which contributes to the coastal pollution. The water at this location is therefore not suitable for public use. There are several small streams which discharge into the area.

There are also several natural large rock formations along the coast line. Among the three locations, this area is the most vulnerable to wave erosion due to its position to receive direct direction waves.

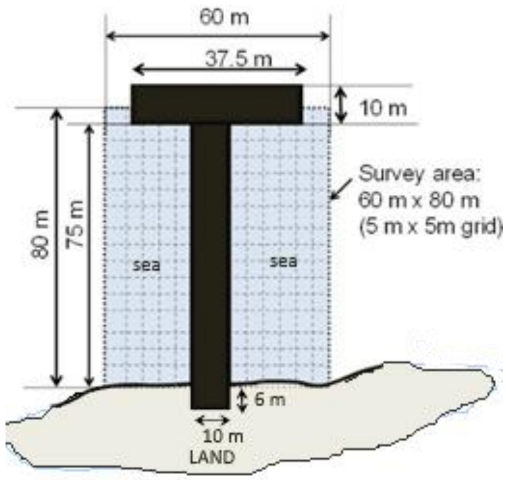

FIGURE 2
Groin dimensions and grid used for depth surveys. (Around T-spur the sea depth measurement that was performed using 5x5 m grid formed by sonar. For example, if depth of 1.2 m, is 5,5,1.2 the coordinates of that point).

T-head Groin Characteristics; The construction of the T-head groins along the Eastern Black Sea coast in Turkey began in 2000. Prior to the construction of the groins, riprap was placed 6 meters inland from the shoreline. Each groin was built 10 m wide at elevations between 1.0 and 1.5 m from the sea level. Figure 2 presents the typical dimensions of the T-head groins [16].

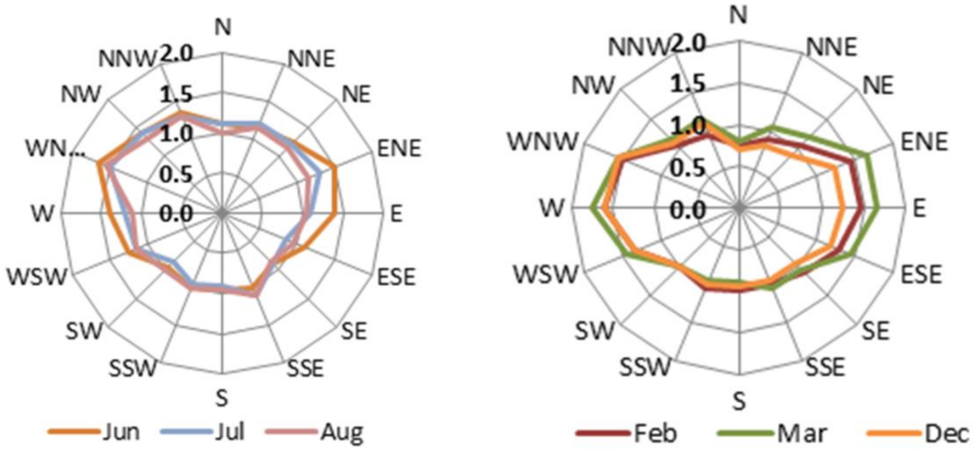

FIGURE 3
Monthly average of prevalent wind directions and speed (m/s). (The monthly average of prevailing wind direction and speed of research are based on the State Meteorological Station data of the study area)

Wind and Wave Characteristics: Figure 3 presents the wave characteristics based on the 15-year sea state data collected in Rize, Turkey. The prevalent wind directions in the area are west-northwest (WNW), northwest (NW) and north-northwest (NNW). The incoming waves are generally in the same direction as the prevalent wind direction. According to the Turkish Coast Deep Sea Wind and Wave Atlas [18] the largest waves occur in the NW direction.

The waves coming from the WNW direction break before reaching the coast and hence have less energy in comparison to the waves coming from the NW and NNW directions. The 5, 10, 50 and 100-year return periods correspond to the wave heights of 4.3, 5.1, 6.3 and 6.9 meters, respectively, for wave periods between 8.0 and 10.0 seconds [17].

Coastal and Sea Floor Morphology; The groins are located along the 14 km long stretch where the coastline exhibits very jagged characteristics due to the mountainous geography and erosion caused by wind-driven waves. The steep Pontic Mountains (known locally as Eastern Black Sea Mountains) run roughly east-west, parallel and close to the Black Sea coast. The mountain system is about 400 km long and up to 100 km wide. The mountains consist of several parallel ranges, which are separated by longitudinal valleys and chains of inter montane basins, with numerous gorges and water gaps created by rivers and creeks. The elevations of the ranges increase from west to east from 2,000–2,500 to 3,000–3,500 m.

The steep mountains along the coast result in significant quantities of sediments being transported by the rivers and discharged into the Black Sea. Coastal currents in general are from NW to SE. Construction of the Black Sea Double Motorway along the coastline, along with the construction of the T-head groins, and new facilities in coastal fill areas have resulted in significant changes in the coastline and sediment transport characteristics.

Coastal Ecology and Ecological Impacts; Some areas along the coastline were filled for construction of the motorway. These fill areas and construction of groins have reduced both the variety and population of fish inhabiting the coastal waters. However, there has been a noticeable increase in the variety of sea animals that live in rocky or sandy bottoms and use the groin rocks for shelter [18].

Coastal Sediment Budget: The comprehensive assessments of the river basins discharging into the Black Sea were initiated in 1980 for water resources management. These studies focused on the transport of sediments, flow conditions and suitability of the rivers for hydroelectric power generation. In recent years, due to construction of numerous hydroelectric power generation facilities and dams, and withdrawal of water for industrial purposes (i.e., cement factories), sediment transport characteristics of the rivers have been altered significantly. It is estimated that over 17 million cubic meters of sediments are captured each year by the rivers discharging into the Black Sea. The amount of sediments that are transported to the Black Sea is estimated as 25 million cubic meters per year. Transport of larger particles (i.e., sand and gravel) by river currents is significantly reduced [19].

Sediment Depth Survey and Field Inspections: Sediment depths in each groin field were measured by sonar using a 5×5 m grid for 60 m x 80 m area around each groin as presented in Figure 2. The field measurements were conducted in 2000, immediately after the groins were constructed, and during 2009 and 2013. The water depth data sets were transposed to generate the contour maps using NetCAD and AutoCAD [20].

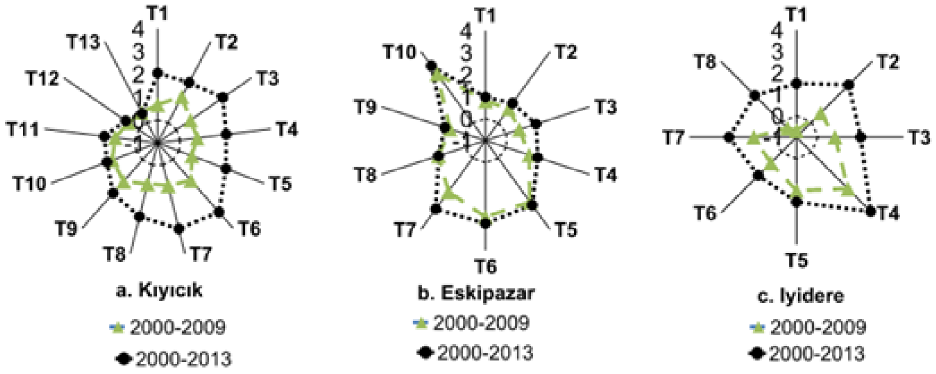

FIGURE 4
Average sediment depth change (m) at each groin field. (The graphically shown seasonal average sediment depth change (m at each groin field during 2000, 2009 and 2000, 2013)

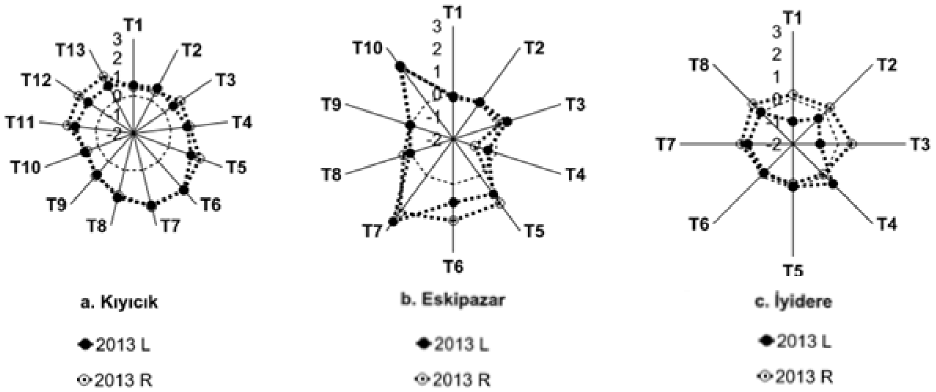

FIGURE 5
Sediment depth at the left and right heels. (The graphically shown seasonal average sediment depth change (m) at the left and right heels during the year of 2013).

RESULS AND DISCUSSION

Figure 4 presents the comparison of the average sediment depth change at each groin system from 2000 to 2013. The changes in sediment depthprofiles in each groin field shows sediment accumulation in each groin field. However, there were also significant differences in the sediment depths at the individual groins in each groin field. Sediment accretion analyses showed that the Kıyıcık groin system showed the most accretion characteristics of sediments (Figure 4a). The comparison of the sediment depth profiles of 2000-2009 and 2000-2013 periods shows that the sediment depth in the groin field is still increasing. The first 9 groins (T1-T9) showed the most significant changes throughout the groin zone. However, the last four groins showed decreasing sediment accumulation profiles in relation to the order of the groins with the smallest accumulation of sediments at T13. Based on the visual observations, the least 3 groins (T11-T13) are located next to the Baltacı Bridge that provides easy access for trucks to remove the accumulated sediments, which is an uncontrolled practice which creates significant impacts on the coastline.

At the Eskipazar groin system, the comparison of the sediment depth profiles during the 2000- 2009 and 2000-2013 periods shows that the sediment depth in the groin field did not change significantly during the 2009-2013 period. During the 2000-2013 period T10 accreted the most significant characteristics (Figure 4b). On the other hand, at T8 and T9 the sediment depth appears to have the smallest change insediment depth. This is primarily due to the uncontrolled frequent removal of the sediments due to the ease of access to these groins. The İyidere stream provides the sediments for the system, constantly replenishing the sediments.

At the İyidere groin system the comparison of the sediment depth profiles during 2000, 2009 and 2000, 2013 show that the sediment depth in the groin field is still increasing in a relatively uniform manner across the groin field. The most significant accretion has been observed at the T4 followed by T3 and T5 since its construction (Figure 4c).

Figure 5 presents the comparison of sediment accretion characteristics on the left and right heels at each T-head groin system. By 2013, at the Kıyıcık

T-head groin system, the sediment accretion characteristics had not showed a significant difference between the left and right heels of the groins. At the last 3 groins located on the east part of the groin system (T11, T12, and T13), the sediment levels on the right side of the heels are higher in comparison to those on the left side of the heels. In this groin system occasional sand removal by the public (for construction use), an uncontrolled practice, disturbs the accumulation balance between the left and right heels (Figure 5a). In general, sediment capture increased from T1 to T13 due to the proximity of this groin group to the harbour (City of Of), transport of sediments from open seas, and proximity of the T13 to the Baltacı river.

At the Eskipazar groin system; there were significant variations in the sediment levels between individual groins (Figure 5b). However, the accumulation profile showed that the sediment levels between the left and right groins were similar with the exception of the two groins located in the middle of the groin system (T5 and T6), which showed higher sediment depths on the right side of the heels. The T4 groin had sediment loss at the heels due to the frequent and uncontrolled removal of the captured sediments by the public for other uses (i.e., construction).

The groins T7 and T10 had the highest amount of sediments accumulating at the heels. The fisherman shelter prevents the transport of the sediments to the groins T1-T3, hence these groins had relatively insignificant sediment accumulation.

The İyidere groin system is the most balanced in terms of sediment accretion at the left and right heels (Figure 5c).

This groin system has the minimum human interference in sediment accumulation due to limited access to the coastline. In general, the right heels have higher sediment accretion potential, especially at the first three groins which capture the sediments carried by the İyidere stream.

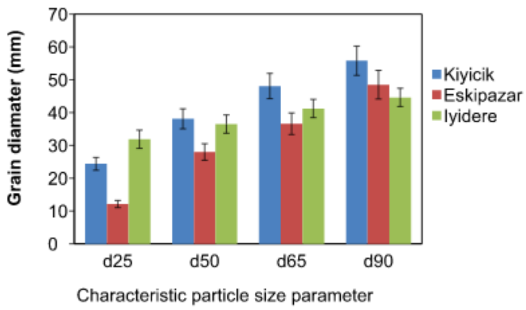

FIGURE 6
Comparison of grain size characteristics of the sediments accumulating at the groin systems. (Sediment samples have been analyzed in the laboratory to determine the diameters characteristics like d25, d50, d65, d90).

The groins T5, T6 and T7 have complex water mixing patterns due to the effects of discharge from the İyidere stream on the west and several smaller streams to the east. The predominant wave direction is parallel to the groin heads, however, sediments from the open seas do not reach this groin system.

The sediment transport in the groin systems in general is from NW to SE. The particle size characteristics of the sediments collected from the three groins systems are presented in Figure 6. The grain size distribution of sediments collected in the Kıyıcık and Eskipazar groin systems show a wide range of grain size distribution, while the sediments accumulating at the İyidere groin system exhibit well graded sediments with relatively small variations in grain size.

CONCLUSION

The sediment accretion characteristics in three T-head groin groups located on the Eastern Black Sea coast in Turkey were compared. Since their construction in 2000 there has been significant sediment accumulation at each groin system.

Sediment accretion analyses show that the Kıyıcık and İyidere groin systems had the most significant accretion characteristics of sediments. The comparison of the sediment depth profiles between 2000 and 2009 as well as 2000 and 2013 periods shows that the sediment depth in the groin field is still increasing. However, at the Eskipazar groin system the sediment depth in the groin field has not shown a significant change since 2009.

At the Eskipazar groin system, there are significant variations in the sediment levels amongst the individual groins due to the frequent and uncontrolled removal of the captured sediments.

The groin system at İyidere is the most balanced in terms of sediment accretion at the left and right heels. This groin system has also the minimum human interference with the coastline due to limited access to the area.

Average grain size is between 10-50 mm and sediment deposition varies seasonally. This grain size can be regarded normal at the coastal areas and beaches. The data about the sediment accumulating are important (Table 1). Especially, the occupancy rate is very high for the T-head groins at the Eskipazar and Kıyıcık areas in this system because sand and gravel (sediment) to the T-spur system is carried by the Baltacı and İyidere streams (Figure 6).

T5, T6, T7, T10 and T13 on the groins accumulated in the sand (0.25-10 mm) reached 1.5-2 m height. Approximately 1000-4000 m3 sand has been accumulated in only one T-head groin and this area is 1787.5 m2. The total accumulated sand volume is between 40000 and 60000 cubic meters [21].

TABLE 1
Quantity of sediments accumulated at the selected groins estimated (using a 5x5 m grid) based on depth measurements

Location and groin no		Year	Groin field (m^2)	Average water depth (m)	Period	Depth difference (m)	Sediment volume (m^3)	Sediments accumulated during 2000-2013 (m3)
Kıyıcık	T1	2000	1787.5	-2.89	-	-	-	3521
		2009		-1.26	2000-2009	-1.63	2914	
		2013		-0.92	2009-2013	-0.34	608	
	T7	2000	1787.5	-2.9	-	-	-	3504
		2009		-1.3	2000-2009	-1.6	2860	
		2013		-0.94	2009-2013	-0.36	644	
	T10	2000	1787.5	-2.88	-	-	-	3468
		2009		-1.2	2000-2009	-1.68	3003	
		2013		-0.94	2009-2013	-0.26	465	
	T13	2000	1787.5	-2.93	-	-	-	3539
		2009		-1.2	2000-2009	-1.73	3092	
		2013		-0.95	2009-2013	-0.25	447	
Eskipazar	T1	2000	1787.5	-2.18	-	-	-	2154
		2009		-1.27	2000-2009	-0.9	1614	
		2013		-0.97	2009-2013	-0.3	540	
	T7	2000	1787.5	-2.17	-	-	-	2270
		2009		-1.16	2000-2009	-1.01	1805	
		2013		-0.9	2009-2013	-0.26	465	
	T10	2000	1787.5	-1.94	-	-	-	1720
		2009		-1.19	2000-2009	-0.75	1303	
		2013		-0.95	2009-2013	-0.24	417	

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