Short Term Cliff Retreat at Quarteira-Vale do Lobo  
(Algarve – Southern Portugal)

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Abstract: The cliffed coast of Central Algarve (southern Portugal) is undergoing accelerated coastal erosion. In order to understand the variations in cliff retreat rates that have occurred in this area during the last three winter seasons, and its possible association with storm conditions, four adjacent sectors have been monitored since 1995, eastward of the coastal town of Quarteira. This area presents evidence of alongshore retreat variability. However, the medium-term result is a generalised tendency towards shoreline rectification. Also, there is suggestion of a buffering effect, due to high rates of sediment supply in previous winter periods, which probably strengthens the beaches and consequently protects the adjacent cliffs.

Introduction

In Portugal as in many other countries around the world shoreline retreat has been recognised as an important problem. A good example of the problems caused by the interaction between coastal erosion and human interests happens at the central area of Algarve, eastward of the coastal town of Quarteira (Fig. 1).

Figure 1  Location of the study area at the coastal town of Quarteira (Algarve, Southern Portugal).
The studied area is a cliffed coastal stretch, with the cliffs being cut in very heterogeneous plio-pleistocene sandstone (Bosky et al., 1993), differing significantly in degree of consolidation, and being breached by diaclases and faults. As a consequence of its low degree of lithification, the natural susceptibility towards erosion in this area is extremely high, with the cliffs suffering quick changes, which can be observed in an annual (or smaller) time scale (Correia et al., 1996).

The most significant coastal engineering interventions in this area were the construction of two jetties belonging to the Vilamoura marina (between 1971 and 1973, with 600 m and 500 m long), and twelve 140 m long groins, built in order to protect the oceanfront of Quarteira. These structures caused the interception of the longshore sand transport. Since the annual resultant of the littoral drift in this coast is from west to east, the direct result was an increase on coastal erosion rates in the downdrift (eastward) shoreline (Granja, 1984; Dias, 1984; Bettencourt, 1985; Correia et al., 1996).

Numerous studies have already been conducted in this area with the purpose of determining its recent evolution and the associated shoreline retreat rates (Granja, 1984; Dias, 1984, 1988; Bettencourt 1985; Andrade, 1990; Marques, 1991; Marques & Romariz, 1991; Dias & Neal, 1992, Correia et al., 1994, 1995, 1997 and Pereira et al., 1997). However, the role played by the occurrence of storms, the consequent sand erosion/recovery processes involving the protection of the cliffs by the adjacent beach, and its effect on the shoreline retreat rates, have not yet been fully understood. The main objective of this paper is to understand the variations in shoreline retreat rates that have occurred in this area during the last three stormy seasons, and its possible association with storm conditions.

Methods

For the present study, the area has been divided into four adjacent sectors (Fig. 1); from west to east, Forte Novo (FN), Trafal (TF), Central and Eastern Vale do Lobo (VLC and VLE). The study of a Western Vale do Lobo sub-sector was also carried out. However, several interventions associated with the development of the local touristic village made it impossible to continue. Each sector is separated from the contiguous one by the presence of creek valleys or by gullies.

The short-term erosion of each of those sectors is being monitored since 1995 through the use of periodic (approximately monthly) cliff edge retreat measurements in the field. For those measurements, a series of reference points have been defined along each sector. Trees, walls or other permanent landmarks have been chosen as reference points. Each reference point itself is referenced to other points, located further inland, so that the loss of a particular reference point does not compromise the monitoring of that location. The monitoring program consists in measuring the direct distance between the cliff edge and those points.

Although the cliff retreat behaviour presents significant differences from sector to sector, or even from place to place in a given sector, previous works (Pereira, et al., 1997) indicate that erosion occurs mainly during the stormy season. So, in order to assess the shoreline retreat that occurred during each of the last three stormy seasons (1995/96, 1996/97 and 1997/98), only the measurements from the beginning (October/November) until the end (April/May) of each stormy season were considered.
The sand volume contribution to littoral drift by cliff erosion was computed for each winter season, based on the method used by Correia et al. (1997) for the same study area. These authors used the following formula to determine the total eroded volumes ($E_v$):

$$E_v = R \cdot Mh \cdot L$$

in which $R$ is the average retreat rate, $Mh$ is the average cliff height and $L$ is the length of each sector. Based on differences between beach and cliff porosity, the authors determined that the percentage of sand contributing to the littoral drift by cliff erosion is about 90% of the total eroded volume.

Accordingly, in the present study, each sector's average winter retreats were used to determine the total eroded volumes, being multiplied by the proposed 0.9 factor to calculate the sand volume that entered the littoral drift during each winter.

It should be noted that the calculated volumes do not correspond to the total volumes that enter the littoral drift at a yearly rate, but to those that entered during the winter season. However, the most of the shoreline retreat occurs during winter seasons, as previously referred. Another sand contribution that was not included is the volume that result from the erosion of gullies and ravines (presumably important when heavy rain occurs). So, as a result, the calculated sand volumes are an underestimation of the effective yearly sand volumes that enter the littoral drift.

Another factor taken into account for this study, was the number of days during which there were storm conditions, for each winter season. For this purpose, only days during which waves with a significant wave height superior to 3 m occurred were considered, since this represents the threshold above which storm conditions are considered to exist in the Algarve coast.

### Results and discussion

Table 1 shows the average shoreline retreat in Forte Novo, Trafal, Central Vale do Lobo and Vale do Lobo East, during the 1995/96, 1996/97 and 1997/98 winter season. From the table analysis there is evidence of alongshore short-term retreat variability between the four sectors (Figure 2). In 1995/96, although the average retreat in Forte Novo was of approximately 5 m, in the adjacent sector of Trafal it was only 1.19 m, presenting successively higher values for central Vale do Lobo and Vale do Lobo east, 2.49 and 3.29 m, respectively.

**Table 1** Average, maximum, and minimum shoreline retreat (in meters) in Forte Novo (FN), Trafal (TF), Central Vale do Lobo (VLC) and Vale do Lobo East (VLE), during the last three winter seasons.

<table>
<thead>
<tr>
<th>Winter</th>
<th><strong>FN</strong></th>
<th><strong>TF</strong></th>
<th><strong>VLC</strong></th>
<th><strong>VLE</strong></th>
<th><strong>Total</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1995/96</td>
<td>5.08</td>
<td>7.15</td>
<td>2.60</td>
<td>1.19</td>
<td>2.16</td>
</tr>
<tr>
<td>1996/97</td>
<td>3.65</td>
<td>5.37</td>
<td>0.95</td>
<td>1.19</td>
<td>2.45</td>
</tr>
<tr>
<td>1997/98</td>
<td>1.88</td>
<td>2.90</td>
<td>0.38</td>
<td>2.05</td>
<td>5.24</td>
</tr>
</tbody>
</table>
In 1996/97 the shoreline retreat also showed high variations: Forte Novo and Central Vale do Lobo were the sectors with the highest average retreats, while Trafal (located between the other two) presented lower values; finally Vale do Lobo East, had the lowest average retreat. For the 1997/98 stormy season, the highest average retreats occurred at Trafal and Forte Novo, while at the other two sectors the retreats were lower.

This variability between consecutive sectors is in accordance with previous studies. Pereira et al. (1997) already referred this alongshore changes and also states that, the differences between reference points for the same sector are very significant.

Apparently a sector with high retreat rates during one or more winters, will tend to have lower retreat rates on subsequent winters, as was the case of Forte Novo with successively lower retreats during the 1996/97 and 1997/98 winters. The opposite also seems to be true, since Trafal presented low rates during 1995/96 and 1996/97 and the highest values in 1997/98.

![Figure 2](image)

**Figure 2** Shoreline retreat in Forte Novo (FN), Trafal (TF), Central Vale do Lobo (VLC), Vale do Lobo East (VLE) and the total average, for the last three winter seasons.

This could be the result of a generalised tendency towards medium-term shoreline rectification of the whole coastal stretch. Low retreat rates in a sector during one or more winters will increase its exposure to sea action, leading to higher retreats during subsequent winters. Conversely, sectors with initial high retreat rates will face relatively lower rates, in order to compensate its lower exposure.

Another aspect that can be observed from the gathered data, is that during the last three winter seasons, average cliff retreat along the total area has been decreasing (Tab 1, Fig. 3). While in the winter of 1995/96 the average retreat was about 2.96 m, in 1996/97 it decreased to 2.23 m, and finally in the last winter was only of 1.47 m.
Figure 3  Compared average shoreline retreat during the winter seasons of 1995/96, 1996/97 and 1997/98 for each sector.

This decrease could be the result of differences in the occurrence of storms in each winter season. However, the number of days with storm conditions (Table 2) does not present enough significant variations to justify those differences. During the winter season of 1995/96 storm conditions were registered during 23 days, and whereas in 1996/97 a decrease occurred (19 days), what might be seen as a possible justification for the reduction of average cliffed shoreline erosion. Finally, it should be noted that in the last season the number of stormy days was at least similar, if not superior, to the previous two winters, although the existing records do not reflect this, since they only report themselves to half of that season (November and December of 1997). Nevertheless, it is known that during January/February a very significant storm occurred, with a total duration of 4/5 days.

Table 2  Number of days during which storm conditions occurred (Hs > 3m) for each winter season.

<table>
<thead>
<tr>
<th>Season</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995/96</td>
<td>23</td>
</tr>
<tr>
<td>1996/97</td>
<td>19</td>
</tr>
<tr>
<td>1997/98</td>
<td>12*</td>
</tr>
</tbody>
</table>

* - this period only includes records of storms from November until 31 December 1997, although at least one important storm occurred until the end of the winter season (31 January – 4 February).

Another factor that can be related to the decrease in average cliff retreat, is the amount of sand supplied to the littoral drift by cliff erosion during each winter season (Table 3). It is noticeable that it has been continuously reducing, as a consequence of the decrease in average shoreline retreat.
Table 3  Approximate sand volumes contributed to the littoral drift by cliff erosion, in each sector, during the stormy seasons.

<table>
<thead>
<tr>
<th></th>
<th>FN</th>
<th>TF</th>
<th>VLC</th>
<th>VLE</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995/96</td>
<td>18299</td>
<td>3380.7</td>
<td>15756</td>
<td>14213</td>
<td>51648</td>
</tr>
<tr>
<td>1996/97</td>
<td>13144</td>
<td>3380.7</td>
<td>17860</td>
<td>4352.4</td>
<td>38737</td>
</tr>
<tr>
<td>1997/98</td>
<td>6782.4</td>
<td>5815.3</td>
<td>4407</td>
<td>5518.8</td>
<td>22524</td>
</tr>
</tbody>
</table>

However, during the first two winters, the amount of sediments that resulted from the cliff erosion (Table 3) was superior to what is referred to be the estimated annual contribution of the cliffs to the longshore sediment transport for this coast (around 37000 m$^3$/year according to Correia et al., 1997). This is even more significant if we consider that, as was previously mentioned, the calculated volumes do not correspond to the total volumes that enter the littoral drift at a yearly rate, but only to the ones that entered during the stormy season and that the erosion resulting from rain erosion were also not considered.

So, it is possible to consider that this surplus in sand supply was able to cause some accumulation in the adjacent beaches, probably acting as a buffer to protect the cliffs from storms that occurred during the last winter season.

From the four considered sectors, the ones with smaller buffering effect were the Forte Novo and Trafal sectors. However, even in the Forte Novo sector there was a significant reduction in the retreat rates when compared with the previous ones. As for the Trafal sector, that presented in 1997/98 the highest cliffed shoreline retreat for the three considered winters, the prevailing factor was apparently the above mentioned generalised tendency towards short-term shoreline rectification between sectors.

Conclusions

From the present work, the most important considerations that can be made regarding the variations in shoreline retreat rates that have occurred in this area during the last three winter seasons are:

- The alongshore short-term retreat variability between the four sectors was confirmed;
- This is apparently the result of medium-term shoreline rectification of the entire coastal stretch;
- The existence of high rates of sediment supply in a winter period can cause a sort of buffering effect, which probably protects the adjacent beaches from subsequent storms.

However it is necessary to continue the monitoring program during the next winter seasons, in order to confirm these results, and to integrate them in a more complete medium to long-term perspective of the evolutionary trends of this coastline.
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