

COMPREHENSIVE STUDY OF A COASTAL INLET EVOLUTION AND ITS DRIVING FACTORS

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INTRODUCTION

Coastal inlets are highly dynamic environments influenced by both maritime (waves and tides) and continental (river discharge) factors. This dynamic has implications on navigation, ecological processes, morphological processes on adjacent beaches and floodings upstream. Therefore, coastal managers are increasingly demanding more knowledge about it, leading to studies such as Duc Anh et al., (2020) and Nguyen et al., (2022) among others.

The recently developed open-source toolkit InletTracker (Heimhuber et al., 2021) allows obtaining information on the evolution of coastal inlets over the last 30+ years from Landsat and Sentinel-2 imagery. Specifically, long-term time series of the inlet state (open or closed), and its location when is open, can be obtained. The present work proposes a cross-analysis of these information with those corresponding to the driving factors of the system during the same period. The driver's series were generated by conducting hindcasts, and the cross-analysis is guided by the following questions: What conditions favor the inlet to remain open or closed? What conditions favor the occurrence of an opening or a closure? What influences the sandspit migration rate? And after closure, where does it reopen?

This approach was applied to gain insights into the behavior of the Mauricio River mouth in Uruguay (34.71°S-56.69°W). The Mauricio River is a small watercourse that discharges into the Río de la Plata through an intermittent mouth, which has shifted along a 1 km stretch of coastline over the last 30 years. This behavior has prompted calls for interventions from fisheries seeking access to the sea through the river, from residents occupying properties at risk of flooding, and from those utilizing adjacent beaches.

MATERIALS AND METHODS

InletTracker was applied to obtain long-term time series of location and state (i.e. open vs closed) of the inlet. Figure 1 displays the various detected locations and the local coordinate system, aligned with the coastline, used for the analysis.

The considered driving factors were river discharge (Q), total water level at the shoreline (TWL) and littoral transport (LST). The Q time series was generated with the daily lumped rainfall-runoff model GR4J (Perrin et al., 2003), which was fed with precipitation and evapotranspiration data measured in the basin. Regional calibrated parameters proposed by Narbondo et al. (2020) were assigned in the model. To generate the TWL and LST time series, local hindcasts of sea level (surge and tides) and waves were initially performed. For the former, GSTM-ERA5 data were corrected with a quantile-quantile method

using sea level measurements at the port of Montevideo (40 km approx. from the study site). Meanwhile, for the latter, ERA5 reanalysis data were downscaled to the study site using the SWAN model. Then, based on these series, on one hand, wave set-up and run-up were calculated with Stockdon et al., (2006) and added to sea level to obtain TWL. On the other hand, LST was calculated using the CERC formula corrected by Mil-Homens et al., (2013). In this way, five time series: Q, TWL, LST, location and state of the inlet, covering the period from 2000 to 2020, were made available for cross-analysis.

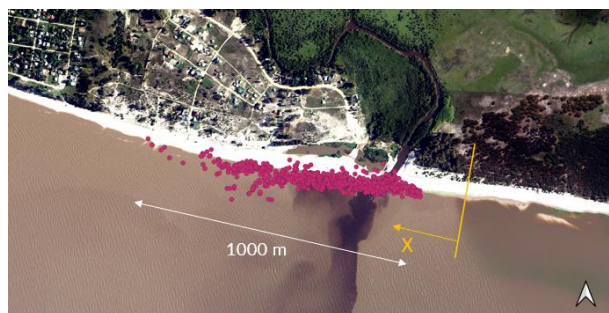


Figure 1 - Historical locations of the Mauricio River mouth (magenta dots). Local coordinate system (orange).

For the cross-analysis, sub-periods were defined and grouped into four categories: i) the inlet remained open, ii) remained closed, iii) the inlet closed, and iv) the inlet opened. For each sub-period, different statistics of the explanatory variables (i.e. Q, TWL, LST) were calculated and jointly analyzed.

RESULTS AND DISCUSSION

Throughout the analyzed period, the inlet remains open 81% of the time. Nonetheless, as depicted in Figure 2, there's considerable inter-annual variability, with certain years showing a predominant occurrence of closed states.

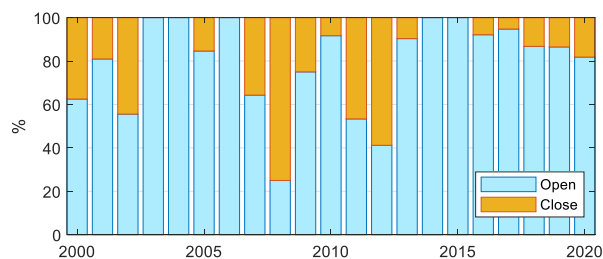


Figure 2 - Annual occurrence frequency of open and closed inlet states.

Figure 3 shows the evolution of the inlet location using the

X coordinate defined in Figure 1. A westward migration trend is observed, consistent with the direction of net littoral transport (LST_{net}), with migration rates varying between 50 and 180 m/year. It is also observed that openings mostly occur near the inlet's previous position before closure. There are a few instances where the inlet opens away and eastward from its previous location. Upon reviewing the images, these seems to be artificial cuts, which was confirmed by the local government for the last two occurrences (i.e., 2016 and 2020).

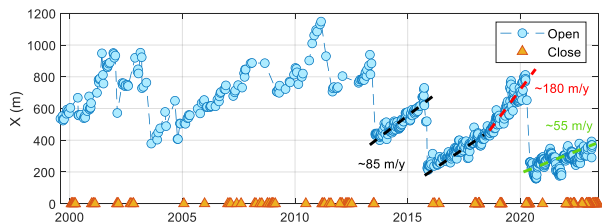


Figure 3 - Historical evolution of the location of the Mauricio River mouth in the local coordinate system.

Mean discharge vs Mean net littoral transport and vs maximum TWL for the different sub-periods are depicted in Figures 4 and 5 respectively. It is observed that in all sub-periods where the inlet remains closed or a closure occurred, the mean discharges are lower than the overall period's average (i.e. Total Q_{mean}). In most sub-periods where the inlet remains open or experiences an opening, the mean discharges are higher than total Q_{mean} . Openings that occur with mean discharges lower than total Q_{mean} present maximum TWL likely to exceed the sandspit berm elevation (approx. +1.5 m). The three sub-periods in which closure occurs with mean discharges close to the average exhibit high littoral transport.

For the sub-periods where the inlet remained open, its average westward migration rate was quantified as the difference between the inlet positions at the end and start of the sub-period divided by its duration. The obtained results were compared with statistics of the driver factors, revealing a positive correlation with the net littoral transport and a negative correlation with the discharge (see Figure 6).

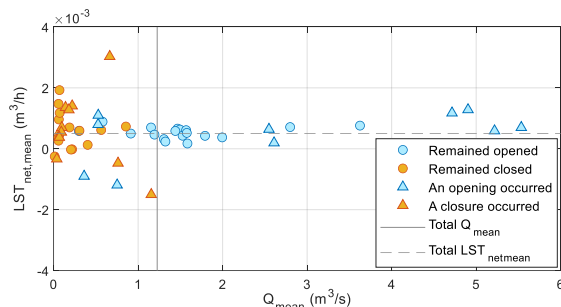


Figure 4 - Mean discharge vs mean net littoral transport for the different sub-periods.

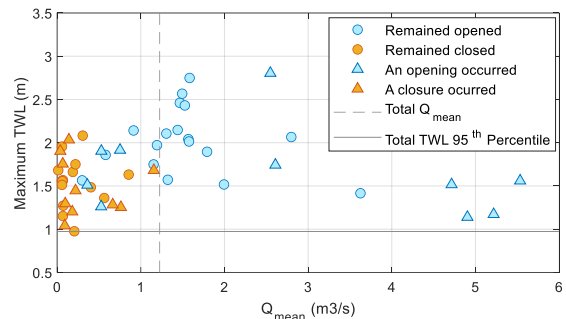


Figure 5 - Mean discharge vs maximum TWL (referenced to the local mean sea level) for the different sub-periods.

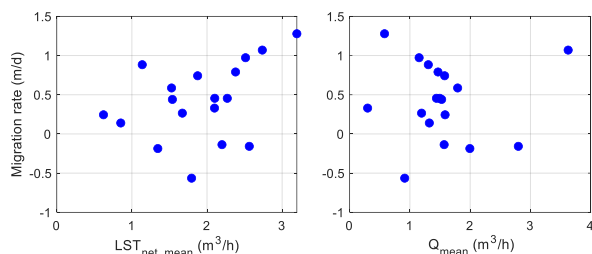


Figure 6 - Westward migration rates vs Mean net littoral transport (left), vs Mean discharge (right).

The approach presented, which analyzes the driver factors for several sub-periods defined by the remotely sensed state of the inlet, yields valuable insights for managing the coastal inlet of the Mauricio River. Moreover, it holds potential for application in other coastal inlets.

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