MOBILE

# 1st Year Progress Report

**Reporting period:** 24/07/2025-23/07/2026

Project title: reduced complexity **mo**delling of **b**arrier **i**sland adaptation to **se**a level rise - MOBILE

Project reference: 16266
Operation codes: ALGARVE-FEDER-00742700 & LISBOA2030-FEDER-00742700

23 August 2026

2030 ALGARVE PROGRAMA REGIONAL DO ALGARVE
2030 Lisboa PROGRAMA REGIONAL DE LISBOA
PORTUGAL 2030
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# 1. Project Identification

reduced complexity **MO**delling of **B**arrier **I**sland adaptation to sea **LE**vel rise

**Project Funding:** Fundação para a Ciência e a Tecnologia (FCT)

**Scientific Domain:** Natural sciences

**Funding Program:** Concurso de Projetos de IC&DT em Todos os Domínios Científicos 2023

**Project reference:** 2023.16941.ICDT

**Project DOI:** https://doi.org/10.54499/2023.16941.ICDT

**Webpage:** https://cima.ualg.pt/mobile/

| | | |
|---|---|---|
| **Report Title** | **1st Annual Progress Report** | |
| **Reporting Period** | 24/07/2025 to 23/07/2026 | |
| **Delivery Date** | 23/08/2026 | |
| **Related Tasks** | Tasks 1, 2, 3, 4 & 6 | |
| **Objective** | Short description of completed and ongoing work and justification of deviations from the approved proposal | |
| **Author:** | Aikaterini Kompiadou (a.k.a. Katerina Kombiadou; PI) | |
| **Participants** | **Partner** | **Members** |
| | CIMA – UAlg | Aikaterini Kompiadou (AK), Susana Costas (SC), Carlos Loureiro (CL), Jaqueline Santos (JS) |
| | FCiências.ID | Rui Taborda (RT), Maria da Conceição Freitas (MCF), João Cascalho (JC) |
| | IPMA | Teresa Drago (TD), Tanya Silveira (TS) |

## Contents

## 1. Project identification

Principal investigator (PI): Aikaterini Kompiadou

Project title in PT: Modelação de complexidade reduzida da adaptação de ilhas-barreira à subida do nível do mar

Project title in EN: Reduced complexity modelling of barrier island adaptation to sea level rise

Project acronym: MOBILE

Project typology: Scientific research and technological development (SR&TD) | Investigação científica e desenvolvimento tecnológico (IC&DT)

Scientific domain: Natural Sciences

Scientific area: Earth and Related Environmental Sciences

Scientific sub-area: Geosciences, Multidisciplinary

Start date: 24/07/2025

End date: 22/07/2028

Economic activity of operation: **72190** - Other research and development in the physical and natural sciences | Outra investigação e desenvolvimento das ciências físicas e naturais

Principal contractor (Institution | Research Unit): Universidade do Algarve (UAlg) | Centro de Investigação Marinha e Ambiental (CIMA)

Collaborative institution (Institution): FCiênciasID - Associação para a Investigação e Desenvolvimento de Ciências (Fciências.ID)

Collaborative institution (Institution): Instituto Português do Mar e da Atmosfera (IPMA)

Project No.: 16266

Operation Codes: LISBOA2030-FEDER-00742700, ALGARVE-FEDER-00742700, COMPETE2030-FEDER-00742700

DOI: https://doi.org/10.54499/2023.16941.ICDT

Funding: FCT, FEDER

## 2. Summary of Implemented Work | Resumo dos trabalhos

The updated, with the actual start date, chronogram and milestone list are given in Annex I (in Figure A 1 and Table A 1). In terms of completed Milestones, M1 (project kick-off meeting) and M2 (logo and website: https://cima.ualg.pt/mobile/) were reached on 1st day of the project, whileM3 and M4 are underway. Below is an analysis of the progress made in the individual project tasks during the 1st year of the project (Task 5 is not mentioned, as it starts in the 23rd month of the project, that is July 2027 (Figure A 1)).

### 2.1 Progress in Task 1: Project coordination

Since the beginning of the project, four meetings were held to coordinate and monitor progress.

Meeting 1 - Project kick-off meeting, on 24/07/2025:

- The PI made a brief presentation of the project structure and the timeline, revised after the definition and approval of the project Terms of Acceptance from the consortium and the funding programme agencies. The presentation included key dates, project milestones and indicators of project implementation and of outcomes. The members were reminded of the main objectives of each task, the task leaders, as well as the timings, milestones and deliverables of the project.
- Special attention was given to the deliverables of Task 6 (Dissemination and outreach), with brief discussions on the outreach activities planned for students and stakeholders and the indicators determined at project submission.
- The MOBILE logo and website (https://cima.ualg.pt/mobile/) were officially presented to the project members, marking the fulfilment of project milestone M2.
- Administrative issues related to the project and its economic management were also briefly discussed, with information shared on available procedures and guides.
- The members also discussed the student scholarships (bolsas; 3 foreseen in the project) and the allocation of time between participants and within the project duration and its tasks.
- Finally, the members discussed briefly the field data collection and analysis planned within Task 2, with the decisions on details remaining to be finalised in the 2nd project meeting.

Meeting 2 - 2nd project meeting, on 16/09/2025: The team discussed the methodology, location and planning of the core extraction campaigns, to be implemented within Task 2 (data collection) over backbarrier marsh transects. The following were agreed upon:

- Focus on the backbarrier marsh of Tavira island, due to its age and accessibility. If possible, core samples from both sides of the navigable channel will be collected. Three (3) potential sampling locations were identified.
- Conduct preliminary campaigns in these areas, to verify their suitability in terms of accessibility and substrate: reconnaissance sediment cores will be collected using a gauge auger and photographed in the field, to identify the sediment composition and the location of the sandy platform (i.e., assessing core height to be collected).
- Available tools for core-collection to be used during the main fieldwork campaigns and scheduling / personnel issues were also briefly discussed.

Meeting 3 - 1st Modelling approach and progress meeting, on 02/07/2026: The meeting was held online between AK, SC, CL and RT. The PI (AK) presented preliminary modelling results from the hindcasting tests while potential issues and solutions, as well as steps to be taken next in the context of T3, were discussed between the participating members. Details on the progress made so far in data collection (Task 2) and modelling (Tasks 3 and 4) are given in subsections 2.2, 2.3 and 2.4, respectively.

Meeting 4 - 3rd project meeting, on 22/07/2026: The meeting had the objective of providing a short summary of the status of the project and to organise the fieldwork for the core collection in Tavira Island (T2). The campaign was set for August 31st and September 1st and will be conducted by members of all participating institutions (CIMA-UAlg, FCiências.ID and IPMA).

Additionally, administrative procedures regarding human resources were undertaken within T1, and more specifically the following:

- Contracting of PhD researcher in the framework of the project by CIMA-UAlg: The process was initiated just 1 day after the project beginning (the call was opened on July 25th 2025 https://www.bep.gov.pt/pages/oferta/Oferta_Detalhes.aspx?CodOferta=138869) and the process (candidature collection, evaluation, publication, acceptance, drafting of the contract by the UAlg Human Resources Department) was finalised as soon as possible, following the timings and rules governing the Legal Framework for Academic Employment, with the contract commencing on October 13th, 2025.
- Bachelor's Research Fellowship by IPMA: The call was open between May 6th and 19th, 2026 (https://www.ipma.pt/pt/recrutamento/bolsas/docs/2026/IPMA-2026-006-BI.pdf) and one application was received. However, the application was rejected as the bachelor's degree certificate (necessary requirement for admission) was not submitted by the candidate. A new call for the Fellowship will be opened again in the next months. The fellow will primarily contribute to Task 2 (and at a lower degree to Task 4).
- Master's Research Fellowship by FCiências.ID: The call was open between October 13th to 27th, 2025 and the selected candidate started their fellowship in November 2025 (for a duration of 6 months with a possibility for extension up to 22 months). The fellow will primarily contribute to Task 3 (and at a lower degree to Tasks 2 and 4).

## 2.2 Progress in Task 2: Data collection

### Geomorphological data

**Barrier island shorelines** (oceanic and backbarrier shorelines, dune toe seaward boundaries and backbarrier marsh landward edge locations) collected during the EVREST project (1952-2014; https://doi.org/10.17632/96sfy77s3z.1) were included to the project morphological database, along with shorelines digitised on historical maps (1915-6). This database will be complemented with satellite-derived shorelines from the CREST project (2015-2025; underway, with data for 2015-2024 ready). These shorelines are being used to perform hindcasting simulations over the multidecadal scale (Figure A 2) within T4.

Available LiDAR **topographic data** from 2011 and 2024 (https://cdd.dgterritorio.gov.pt/dgt-fe) were also included in the datasets, along with **bathymetric data** digitised from the historic maps (of 1873 and 1915) for the centennial simulations of T4.3 and from EMODnet (https://emodnet.ec.europa.eu/en) and COSMO (https://cosmo.apambiente.pt/), to be used for input and validation of inlet depths for the interannual simulations. **Sedimentological data** (median grain sizes) were obtained from the IBAM-Sed database (https://doi.org/10.5194/essd-10-1185-2018).

## Hindcasting forcing data

**Wave conditions** (average significant wave height and peak period and fractions of easterly and oblique waves) were obtained from wave records from the Faro buoy (1993 to 2025), complemented with hindcasting results of the SIMAR (Spanish State Port Authority) system, selecting the grid point closest to the Faro buoy position (SIMAR point 5019020; (SIMAR, 2026)). The dataset was uniformised, correcting the hindcasting against the buoy data for the period that the two datasets overlap (1993-2014).

**Sea-level timeseries** from the Lagos tide-gauge between 1908 and 2000, analysed in the context of the EVREST project, indicate an average sea-level (SL) rise rate of 2.2 mm/y.

## Forecasting forcing data

**Total SL projections** relative to 1995-2014 (baseline) for the closest tide gauge to the Ria Formosa system (Lagos), based on data from the sixth IPCC Assessment Report (https://www.ipcc.ch/assessment-report/ar6/) for the 5 different SSP scenarios were downloaded from the 'IPCC AR6 Sea Level Projection Tool – NASA Sea Level Change Portal' (https://sealevel.nasa.gov/data_tools/17). Among these, scenarios SSP1-1.9, SSP1-2.6 and SSP2-4.5 have medium confidence level and scenarios SSP3-7.0 and SSP5-8.5 are considered as low confidence scenarios.

**Wave projections** were downloaded from the Copernicus Climate Change Service (C3S; https://doi.org/10.24381/cds.572bf382), obtaining wave climate indicators ($90^{th}$, $95^{th}$ and $99^{th}$ percentiles and 100-year return periods for peak wave period and significant wave height) computed along the 20 m bathymetric contour of the European coastline, using the ECMWF's Wave Model (Stand Alone WAM, SAW) forced by surface wind and accounting for ice coverage in polar latitudes. The dataset considers two Representative Concentration Pathway (RCP) scenarios that correspond to an optimistic emission scenario where emissions start declining beyond 2040 (RCP4.5) and a pessimistic scenario where emissions continue to rise throughout the century often called the business-as-usual scenario (RCP8.5).

Total SL and wave projections will be used for the model projections of barrier adaptation of Task 5. It is noted that wave and SL projections from other potential sources (e.g., the Coupled Model Intercomparison Project (CMIP); https://wcrp-cmip.org/cmip-phases/cmip7/) will continue to be sought for the duration of T2.

## Preliminary core-collection campaign

Campaign 1 was conducted in Tavira Island on December 9th, 2025, focusing on the backbarrier marsh near the Pedras del Rei settlement. This site is selected based on its location (middle of the island, over the most stable and old sector) and the easiness of access. To identify the sediment composition and the suitability of each site for the final core collection, three reconnaissance sediment cores (Tav1, Tav2 & Tav3) were extracted using gauge augers and photographed in the field.

Tav1 was collected from the mid-lower marsh. The sediment extraction showed a highly uniform layer of clayey sediment that extended throughout the sampled depth (i.e., from around 0.8 m from the top to around 3.5 m, which is the total depth sampled). The identified substrate structure indicates that Tav1 is suitable for core collection.

Tav2 was collected from the low marsh (at around 50 m from Tav1 toward the main channel). During sampling, 2 layers were identified, a top layer of silt extending from the surface to around 1 m, followed by a layer of clay that extended throughout the sampled depth (3.0 m from the surface). The identified substrate structure indicates that Tav2 is suitable for core collection.

Tav3 was collected from the high marsh (near the transition to dune vegetation, at around 35 m seawards from Tav1). The sediment extracted (5 full Dutch auger cores) was sandy, with high water content, causing the borehole to collapse. This indicates that the site is unsuitable for core collection.

**Core-collection campaign**

As mentioned in section 2.1, the main core collection campaign is planned for August 31st and September 1st, 2026. The sedimentological analysis of the cores (to be analysed in the laboratory using X-ray scanning and sedimentological analysis to obtain detailed stratigraphic and compositional data) will follow. This timing is well within the timeline (Figure A 1).

## 2.3 Progress in Task 3: Model development and testing

The activities outlined within Task 3 in the approved project plan have been progressing according to the timeline and the project planning. Initial tests were performed, considering simplified barrier morphologies to verify that the model can reproduce critical barrier morphodynamic processes, including:

- Tidal inlet migration
- Overwash
- Shoreline retreat / advance
- Transgression toward the mainland

New model parameterisations have been implemented and tested regarding:

- The **impact of shore-vertical structures** to the longshore sediment transport was modelled through a hybrid approach, maintaining the explicit implicit solution of BRIE throughout the coast, only reducing diffusion across the groin proportionally to the length of the groin that is exposed to the flow and then correcting the solution by explicitly imposing zero-sediment flux along the groin.
- The presence of **artificially stabilised inlets** with jetties (e.g., Faro-Olhão and Tavira Inlets) and their combined influences on cross-shore shoreline change and the tidal prism balance between the inlets.
- The inclusion of the **dune morphologic unit**, assuming simplified equations of vertical growth and sand redistribution within the barrier.

Model results were compared against analytical solutions (Pelnard-Considère) and idealised scenarios with very good agreement.

Currently, the inclusion of several new morphologic units within the lagoon is under implementation and testing. More specifically, lagoon deposits that are indirectly parameterised as a uniform and static **lagoon depth** (Figure A 3b) in BRIE, will be included as a new morphological unit with dimensions that change in space (alongshore) and in time. The **flood delta**, whose expansion by sediment influx through the inlet is presently assimilated into the backbarrier shoreline (Figure A 3a), will be parameterised separately, producing changes to the lagoon depth and allowing for the eventual growth of **marshes**.

## 2.4 Progress in Task 4: Model calibration and validation – hindcasting mode

Various tests have been performed at the multidecadal model scale (see Figure A 2). Details are provided below.

**Migrating inlet: the case of Ancão barrier and inlet**

Simplified tests showed that the balance between incident wave energy and inlet tidal prism controls the inlet migration velocity, while inlet width is highly impacted by the inlet aspect (inlet depth to width ratio) parameter. The best results were obtained with linear increase of marsh cover between 60% and 75% during the simulation period and a linear decrease of the inlet aspect ratio (between 0.12 and 0.014) with the observed inlet width. Model accuracy in terms of predicting the inlet location and width during the simulation period was very good, with the model successfully simulating the 3 migration cycles of the inlet between 1952 and 2014 and the timing of increased sediment influx to the lagoon and the location of the subsequent flood deposits.

**Updrift barrier elongation after tidal prism loss: the case of Culatra island and Armona inlet**

The elongation of Culatra island and the reduction of the Armona inlet width between 1958 and 2014, was simulated assuming logarithmic reduction of inlet tidal prism and linear increase of the aspect ratio with time. Overall, the approximation of observations by the simulations is considered quite good, especially given the simplicity of the solution (e.g., average wave conditions). The average longshore sediment supply for this simulation was $4{\cdot}10^5 m^3/yr$, value slightly higher, but comparable to the upper limit of estimates for the east flank of Ria Formosa.

Considering that the inlet aspect, width and depth are interlinked parameters, simulations were performed considering the former as the dependent variable, calculated during model execution as the ratio of inlet depth to width (independent parameters). A series of tests for the evolution of Armona inlet for different values of the inlet depth parameter and considering inlet prism reduction proportional to the observed inlet width with time, showed near perfect agreement of simulated and observed inlet widths for an inlet depth value of 3.5 m (uniform depth assumed along the backbarrier). This test provided indication that, assuming that the inlet tidal prism loss in Armona inlet was proportional to the inlet width reduction, the multidecadal evolution of the Culatra island and Armona inlet can be sufficiently reproduced by assigning a stable inlet depth value, set equal to the backbarrier depth.

**Barrier drowning and recovery: the case of Cabanas-Cacela**

To assess the model ability to reproduce the destruction of part of the Cacela Peninsula after the stabilisation of the Tavira Inlet with jetties, and the subsequent formation of the Cabanas Island at a landward position, a simplified approximation was initially tested, considering only the stretch that is currently occupied by the Cabanas-Cacela barriers and imposing a negative marsh cover to account for the increase in tidal prism captured by Tavira Inlet after the (not included in the domain). The best results were obtained by varying both the marsh cover (i.e., the inlet prism) and the inlet aspect inversely with the measured inlet width, between -90% and -60% and 0.005

and 0.08 (for minimum and maximum inlet widths), respectively. The location of the inlet was reasonably well reproduced, but with high model error and average skill in simulating inlet width, albeit accurately reproducing value range (min and max widths).

The parameterisation of the interference of the jetties to the littoral drift was introduced to the BRIE model, extending the domain in the updrift dimension to include the Tavira artificially stabilised inlet and part of the Tavira barrier island. The stabilised inlet was forced to maintain its position and width, while the remaining parameters (depth, velocity, tidal prism) were calculated using the same parameterisations for natural inlets. In terms of inlet morphodynamics, the sediment distribution fractions α, δ, βr & δr (fractions of sediment drift deposited as new barrier, flood tidal delta and of eroded barrier deposited at the downdrift zone and in flood tidal delta, respectively; see Figure A 3a) were set to zero and β (bypass fraction) was set to 1. Overall, the model successfully reproduced inlet migration and width, while considering the influence of the stabilised inlet to both tidal prism and sediment distribution.

**Triangular lagoon approximation**

Given that Ria Formosa is a triangular lagoon and that distance from the mainland is a critical parameter for barrier island adaptation during transgression by rising sea levels, the original BRIE assumption of a uniform lagoon length needs to be changed. At present this work is underway, with very good results obtained from preliminary tests including the barrier island chain stretch from Barreta to Armona. Limitations, potential solutions, alternative approaches and next steps were discussed during the 1st modelling meeting (July 2nd, 2026) and are currently being implemented and tested.

**Ongoing work**

After initial testing and validation, the parameterisations of new geomorphic units and the related model adjustments that are being carried out within Task 3 will be incorporated in the hindcasting tests of Task 4 over the multidecadal scale. After the completion of the barrier shoreline dataset (incorporation of satellite shorelines from project CREST in Task 2), these tests will be extended over the interannual and centennial scales (Figure A 2).

## 2.5 Progress in Task 6: Dissemination and outreach

As mentioned previously, the **website** and **logo** of the project (Milestone 2), planned within Task 6, were delivered within the 1st month of the project.

The project was **disseminated via Instagram** through the CIMA, ARNET, and CBMA official accounts (the post and a related QR code are given in Figure A 4).

Also, **1 scientific publication**, stemming from the work implemented up to now in MOBILE was submitted to the conference 'Jornadas de Geomorfología Litoral 2026' and was accepted for oral presentation (programmed for September 23rd, 2026; the full article can be found in the Annex):

Kombiadou, K., Costas, S., Loureiro, C. and Taborda, R. (2026). Reduced-complexity modelling of the Culatra barrier island evolution. *In Conference Proceedings*: XIII Jornadas de Geomorfología Litoral. Cádiz, 23-25 de septiembre de 2026. https://doi.org/10.01/GEOLIT26

## 3. Deviations from the Approved Proposal | Desvios à Proposta Aprovada

There have been no deviations from the approved proposal to report. The only delays were related to contracting of human resources (Contracted PhD Researcher and Research Fellow at a Bachelor level) have been the result of administrative and bureaucratic processes (mentioned in section 2.1):

- The contracted researcher (by CIMA-UAlg) started working in MOBILE on October 13th, 2025, that is 81 days after the beginning of the project. This delay, however, has not impacted the progress of the planned work, with the remaining team members making advances in the project tasks according to the planned timeline during the contracting delay.
- The recruitment process for a research fellowship at a bachelor level (by IPMA) closed without a suitable candidate and will be repeated in the next months. Given that the main objective of the fellowship is to assist in sedimentological analysis, processing and interpretation of sediment cores (core collection planned for beginning of September 2026), a fruitful 2nd recruitment process will allow to maintain the original planning within Task 2 (Figure A 1).

# 4. Indicators | Indicadores

## 4.1 Implementation indicators | Indicadores de realização

The indicators of project implementation during the reporting period (Year 1) are given in the following table (Table 1). In terms of project activities that have been carried out (code RPO035; goal of 100 at the end of the project) to date, as analysed previously, the project is progressing according to plan, with minimal adjustments over the timeline (value attained: 33.33). In terms of research institute participation, the goal of 3 was realized with the signing of the collaboration protocol and the project terms of acceptance by the 3 project partners (UAlg, IPMA and FCiências.ID) and the project PI.

Table 1. Project implementation indicators: code, description, goal value foreseen to be attained by the end of the project, and value achieved during the reporting period (Year 1)

| Code \| Código | Description \| Designação | Goal Year 3 \| Meta Ano 3 | Realized Year 1 \| Realizado Ano 1 |
|---|---|---|---|
| **RPO035** | Degree to which the foreseen project activities have been carried out \| Grau de concretização das atividades previstas no projeto | 100 | 100/3 |
| **RCO07** | Research institutions participating in joint research projects \| Organizações de investigação que participam em projetos de investigação conjunta | 3 | 3 |

## 4.2 Result indicators | Indicadores de resultados

Table 2. Project output indicators: code, description, goal value foreseen to be attained by the end of the project, and value achieved during the reporting period (Year 1)

| Code \| Código | Description \| Designação | Goal Year 3 \| Meta Ano 3 | Realized Year 1 \| Realizado Ano 1 |
|---|---|---|---|
| **RCR102** | Research posts created in the organisations receiving support \| Empregos de investigação criados nas entidades apoiadas | 1 | 1/3* |
| **RCR06** | Patent applications filed \| Pedidos de patente apresentados | 0 | 0 |
| **RCR08** | Publications resulting from supported projects \| Publicações resultantes de projetos apoiados | 6 | 1 |

* The value mentioned in the table (1/3) refers to the person contracted (by UAlg) within the framework of the project (contact celebrated on the 13th of October 2025)

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# Annex I – Figures and Tables

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ALGARVE 2030 Lisboa 2030 PROGRAMA REGIONAL DE LISBOA PORTUGAL 2030 Cofinanciado pela União Europeia fct Fundação para a Ciência e a Tecnologia

| Task Nº | Task Denomination | Start | End | Duration | Date start | Date end |
|---|---|---|---|---|---|---|
| 1 | Project coordination | 1 | 36 | 36 | 24/07/25 | 23/07/28 |
| 2 | Data collection | 1 | 18 | 18 | 24/07/25 | 23/01/27 |
| 3 | Model development and testing | 1 | 28 | 28 | 24/07/25 | 23/11/27 |
| 4 | Model calibration and validation – hindcasting mode | 6 | 28 | 23 | 24/12/25 | 23/11/27 |
| 5 | Model projections of future barrier adaptation | 23 | 34 | 12 | 24/05/27 | 23/05/28 |
| 6 | Dissemination and outreach | 2 | 36 | 35 | 24/08/25 | 23/07/28 |

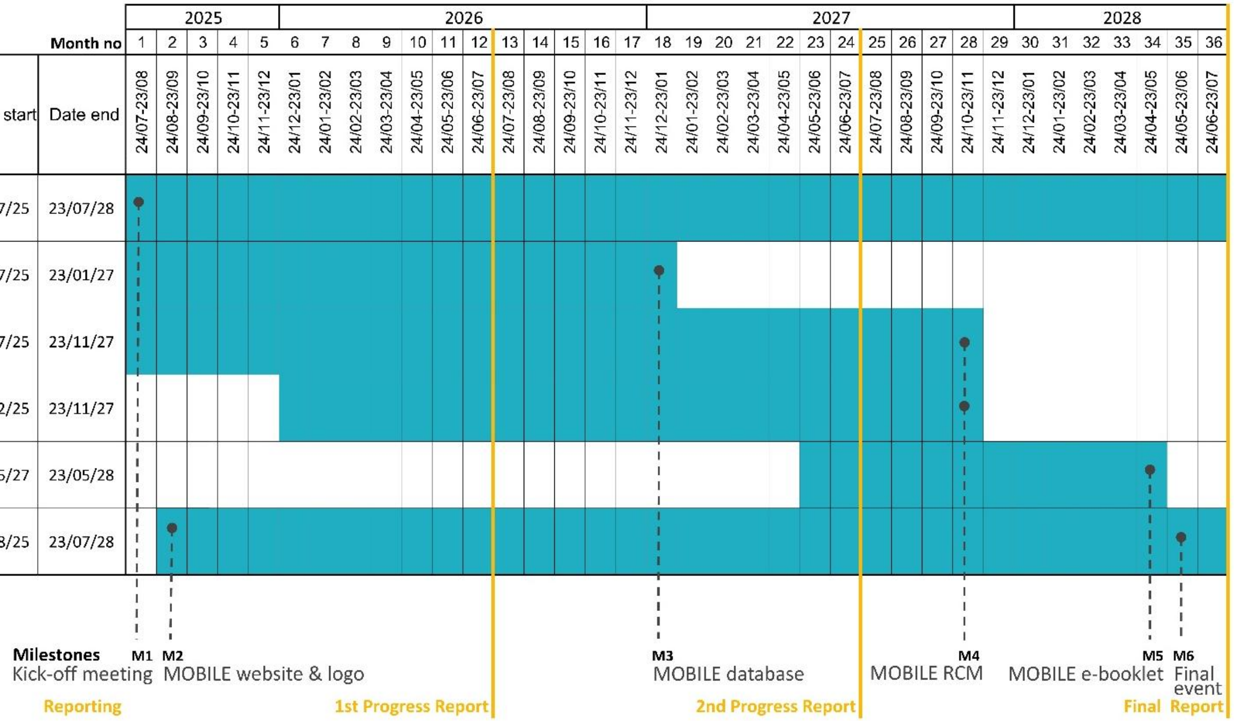


Figure A 1. Project timeline, updated with the actual project start date, and showing project Tasks, Milestones and Deliverables.

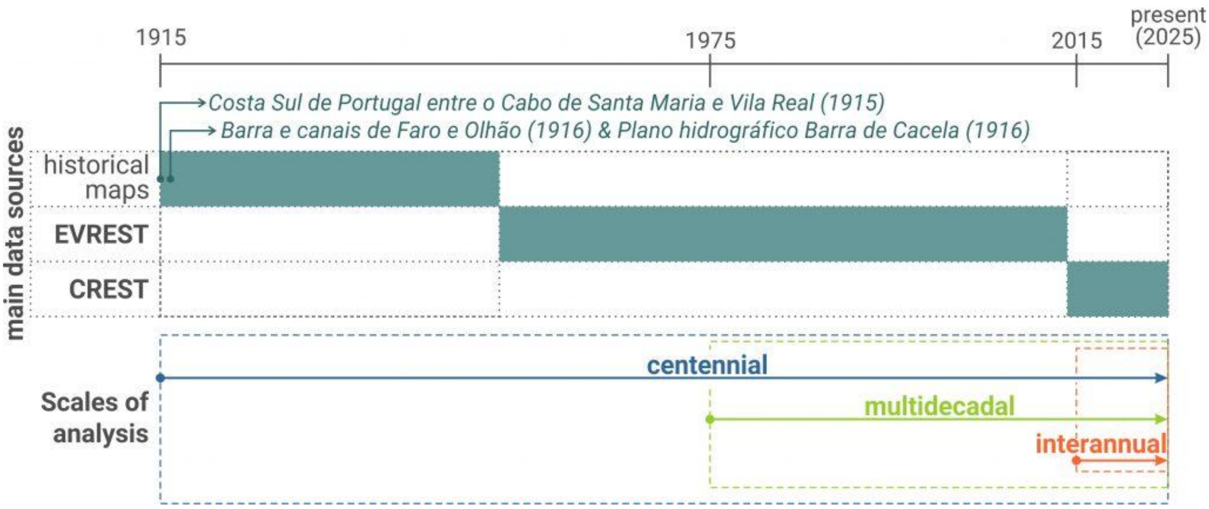


Figure A 2. Main data sources of morphological unit change data (collected in T2 from historical maps and previous FCT projects) and links to temporal scales of analysis (to be performed in T4).

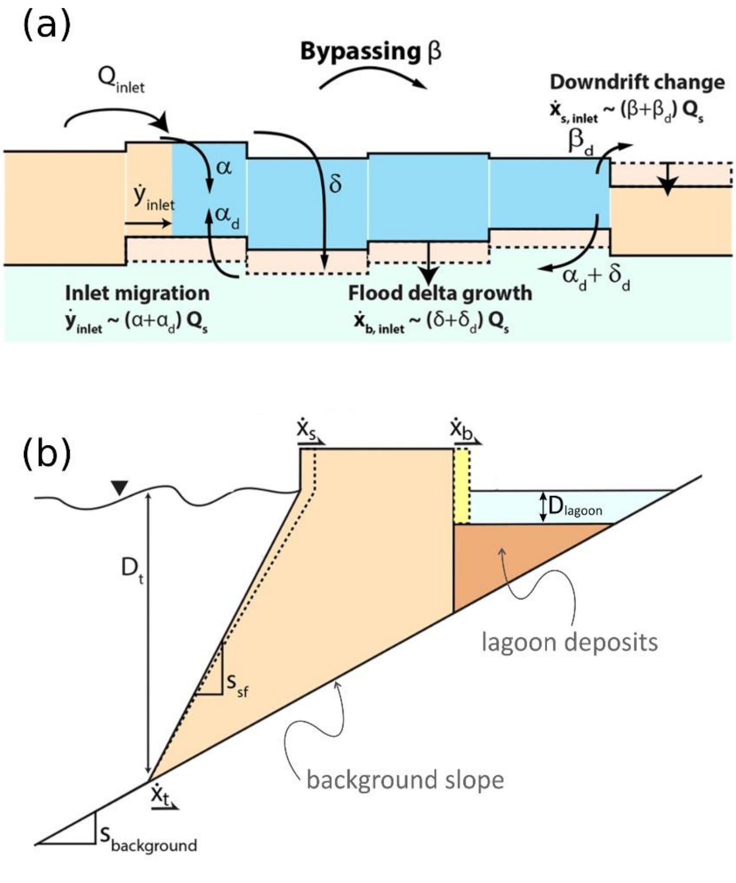


Figure A 3. Model domain in plan (a) and cross-section (b) views of the model domain, showing: (a) the partitioning of the longshore sediment supply (Qs) at the vicinity of a tidal inlet into fractions that cause morphologic changes to the barriers on either side ($\alpha$, $\alpha_d$, $\beta$, $\beta_d$ & $\delta_d$) and to the flood delta ($\delta$ & $\delta_d$) and (b) the morphology of the lagoon, indicating the unit of lagoon deposits that will be added to the model.

POST SHARED ON APR 23, 2026
BY ARNET_LA


Figure A 4. QR code and snapshot of the post about MOBILE in Instagram.

Table A 1. Project Milestone list with target and completion dates.

| ID | Name | Description | Date | |
|---|---|---|---|---|
| | | | target | realized |
| **M1** | Kick-off meeting | Kick-off meeting off the project. (T1) | 08/2025 | 24/07/2025 |
| **M2** | MOBILE website | Project logo and website, where all news, activities, outputs and deliverables will be publicised. (T6) | 09/2025 | 10/08/2025 |
| **M3** | MOBILE database | Compiled data on barrier unit geomorphology, backbarrier marsh stratigraphy and ocean forcing conditions (waves and sea-levels) during the last century (T2) | 01/2027 | ongoing |
| **M4** | MOBILE final RCM | RCM after development and testing (in T3) and hindcasting calibration and validation (in T4). | 11/2027 | ongoing |
| **M5** | MOBILE e-booklet | Electronic short publication that will communicate the main results on the future resilience and adaptation of the east Ria Formosa barriers to sea-level rise to the public, made available through the project webpage. (T5) | 05/2028 | n/a (T5 has not started) |
| **M6** | Final event of MOBILE | MOBILE workshop where the results from the future simulations (T5) and potential mitigation measures will be discussed with targeted stakeholders, enhancing the relevance of the results to decision-making. (T6) | 06/2028 | n/a (T5 has not started) |

## Annex I – Conference Article

GEOLIT26

XIII Jornadas de Geomorfología Litoral
23-25 de septiembre de 2026. Cádiz
DOI: https://doi.org/

# Reduced-complexity modelling of the Culatra barrier island evolution

*Modelización de complejidad reducida de evolución de la isla barrera de Culatra*

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**Abstract:** Projections of long-term barrier island evolution are critical for preserving associated ecosystem services, yet they remain challenging to implement because of the computational costs and uncertainties associated with process-based modelling. Reduced-complexity models offer a practical way to simulate multidecadal morphological change by simplifying key physical processes while retaining predictive capacity. Here we test the ability of BRIE, a 2D barrier island model that incorporates longshore and cross-shore sediment fluxes and tidal inlet morphodynamics, to reproduce the elongation of Culatra island between 1958 and 2014, initiated by shifts in the tidal inlet prism balance in the Ria Formosa barrier system (S. Portugal). By imposing a gradual reduction of tidal prism in the Armona inlet and calculating the inlet aspect as the ratio of a stable inlet depth to the simulated inlet width, the model captured the evolution of barrier island elongation and inlet width reduction with very good accuracy (RMSE~200 m and Brier Skill Score~0.9). These results provide the first validation of BRIE against a real-world barrier island example, supporting its applicability over broader temporal and spatial scales.
**Keywords:** morphodynamics; barrier island; tidal inlet; equilibrium model; Ria Formosa.

**Resumen:** *Proyectar la evolución de islas barrera a largo plazo es fundamental para preservar sus servicios ecosistémicos, sin embargo, la modelización basada en procesos conlleva altos costes computacionales e incertidumbres. Los modelos de complejidad reducida ofrecen una vía práctica para simular cambios multi-decadales, simplificando procesos físicos y manteniendo la capacidad predictiva. En este trabajo evaluamos la capacidad de BRIE, un modelo 2D que incorpora flujos de sedimento litorales y transversales y la morfodinámica de canales de marea, para replicar el alargamiento de la isla de Culatra entre 1958 y 2014, iniciado por cambios en el equilibrio del prisma de marea en el sistema de Ria Formosa (sur de Portugal). Aplicando una reducción gradual del prisma de marea en la entrada de Armona y calculando su aspecto como la proporción de una profundidad estable de la entrada y la anchura simulada de la misma, el modelo capturó el alargamiento de la isla barrera y la reducción de la anchura de la entrada con muy buena precisión (RMSE~200 m y Brier Skill Score~0.9). Estos resultados proporcionan la primera validación de BRIE con un ejemplo real de islas barrera, respaldando su aplicabilidad en escalas temporales y espaciales más amplias.*
**Palabras clave**: *morfodinámica; isla barrera; canal de marea; modelo de equilibrio; Ria Formosa.*

### 1. Introduction

Barrier islands and the important ecosystem services they offer (e.g., coastal habitats, storm protection) are threatened by sea-level rise and deficient sand supply and could undergo rapid deterioration in the future (Vinent et al., 2021). Still, there is a critical gap in our ability to predict how these coastal landforms will respond to future conditions (Nienhuis & Lorenzo-Trueba, 2019b). Given that full-scale morphodynamic simulations over decadal to centennial timescales have significant challenges and limitations (e.g., high computational costs and uncertainties, error accumulation), an effective approach is to adopt simpler and faster numerical models —known as reduced-complexity models (RCMs)— that use simplified descriptions of fundamental system physics to



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estimate system response to forcing (Ranasinghe, 2020).

There are two main approaches in RCMs of long-term coastal morphologic change: coastline and equilibrium profile models. The former account for coastline changes due to wave-induced sediment transport. Examples are ShorelineS (Roelvink et al., 2020), that resolves processes of littoral drift, overwash, landward migration and inlet dynamics, and CoSMoS-COAST, a dynamic shoreline model with satellite-derived data assimilation (Vitousek et al., 2017). The latter resolve longshore fluxes along the coast and assess the morphological adjustment of the shoreface and cross-shore fluxes due to perturbations around the equilibrium. These include slope-driven transport (in response to the active shoreface adjustment) and overwash sediment fluxes (Lorenzo-Trueba & Ashton, 2014), tidal inlet dynamics (formation, migration, closure and tidal deposition) (Nienhuis & Ashton, 2016), and interactions between barrier, the backbarrier marsh and the lagoon (Lorenzo-Trueba & Mariotti, 2017). Several of these were integrated into BRIE (BarrieR Inlet Environment; Nienhuis & Lorenzo-Trueba (2019b)), to date the most holistic 2D barrier island RCM that incorporates overwash processes and shoreface adjustment, alongshore sediment transport, inlet dynamics and flood-delta deposition. To obtain, however, meaningful projections of barrier island adaptation to future climate, RCMs need to be tested against real-world cases, various forcing conditions and across a range of spatio-temporal scales (Nienhuis & Lorenzo-Trueba, 2019a). This work undertakes the challenge of testing the ability of BRIE to reproduce barrier island morphological changes from the Ria Formosa system over multi-decadal scales.

## 2. Study area

This study focuses on the eastern flank of the Ria Formosa barrier system (S. Portugal), where significant morphological changes took place in recent decades, and specifically on the stretch covering Culatra and Armona islands and the (Armona) tidal inlet separating them (Figure 1). Following its stabilization (1920s), the updrift Faro-Olhão inlet started capturing increasing portions of the tidal prism from the Armona inlet, triggering morphologic shifts (Pacheco et al., 2010). Sand began accumulating in the form of recurving spits at the islands on either side of the inlet, and primarily along the eastern edge of Culatra, resulting to island elongation and narrowing of the tidal inlet. Mapped shorelines (Figure 1) show that between 1952 and 2014 Culatra island elongated by around 3 km, while the Armona inlet narrowed from 4 to roughly 0.5 km (Kombiadou et al., 2019).

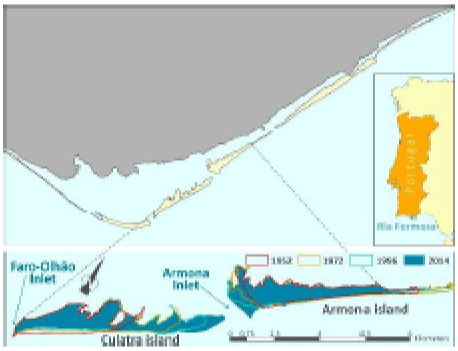


*Figure 1. The Ria Formosa barrier islands (top) and the evolution of Culatra and Armona during the study period (1952-2014; bottom).*

## 3. Methodology

BRIE was implemented in a simplified set of conditions, considering mean waves and tide amplitudes and simplified barrier morphologies at model initialisation. Wave climate data (average significant wave height and peak period and fractions of easterly and oblique waves) was obtained from offshore wave timeseries (Faro buoy recordings (1993 to 2025) and hindcasting results of the SIMAR (1958 to 1992) system; SIMAR (2026)). Barrier morphologies (alongshore width distribution), used for model initialisation and evaluation, were derived from oceanic and backbarrier shorelines from Kombiadou et al. (2019).

The model domain was limited to the Armona inlet and the 2 barriers on either side (Figure 1), extending landwards to 3.5 km (backbarrier lagoon width), which is the mean distance between Culatra island and the mainland. Setting the basement slope parameter (uniform cross-shore gradient) of BRIE to 0.0015, the lagoon depths range from around 5 m at the backbarrier to 0 m at the mainland. Sediment median grain sizes were obtained from Costas et al. (2018).

To impose a reduction of the tidal prism within this simplified application considering a single tidal inlet, we increased the fraction of the lagoon



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area occupied by marsh ($f_{marsh}$) with time, thereby decreasing the area contributing to tidal exchange. It is noted that the values do not reflect actual marsh growth in the lagoon.

#### 4. Results

The model sensitivity to the inlet aspect ratio ($\gamma_{aspect}$; depth to width) parameter values was evaluated, assuming $f_{marsh}$ varying between 0 and 0.6 with simulation time (Figure 2). Parameter $\gamma_{aspect}$ is an independent constant in the original BRIE formulation and, along with simulated width, is used to calculate inlet depth. It follows that inlet depth decreases with inlet narrowing under this approximation, however the results in Figure 2 show that simulated inlet narrowing is slower than the observations. These results indicate that $\gamma_{aspect}$ is a critical tuning parameter that must vary (increase) with simulation time to capture the observed reduction in inlet width.

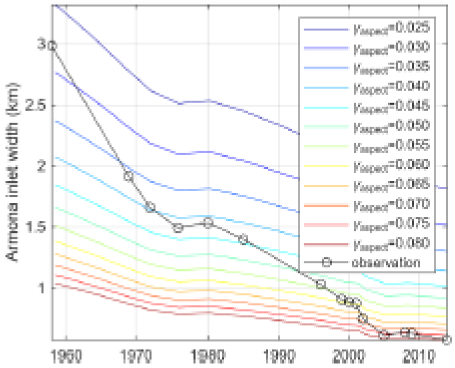


*Figure 2. Evolution of observed and simulated inlet width for different values of $\gamma_{aspect}$.*

To enforce this variability, the BRIE formulation was modified, calculating $\gamma_{aspect}$ as the ratio of a stable inlet depth to the simulated width. The best results were obtained for an inlet depth of 2.5 m a tidal prism reduction (marsh cover increase) of 0 to 70% and are shown in Figure 3 for the Armona inlet width and the Culatra island elongation. The Root Mean Square Error (RMSE) is 182 m for the (Armona) inlet width and 173 m for the (Culatra) island length. The Brier Skill Score (BSS) exceeds 0.9, indicating excellent model performance (van Rijn et al., 2003). It is noted that the Armona island length (not shown in Figure 3; representing the rest of the domain) is simulated with similar precision.

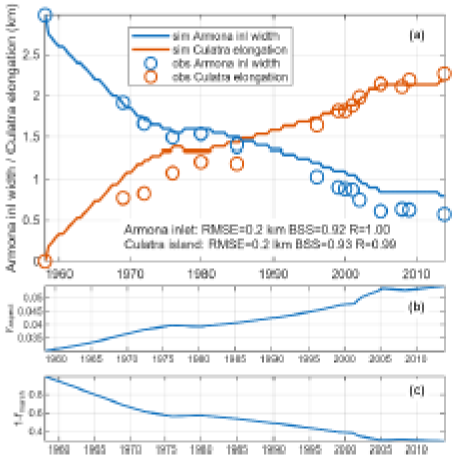


*Figure 3. Simulated versus observed Armona inlet width and Culatra island elongation (a) for varying inlet aspect ratio (b; $\gamma_{aspect}$) and tidal prism reduction (c; 1-$f_{marsh}$) with time.*

#### 5. Discussion and Conclusions

The analysis shows that even though BRIE is an RCM that lacks explicit representation of ebb delta dynamics, it was able to reproduce the multidecadal adaptation of Culatra barrier island to the reduction of the tidal prism of the adjacent Armona inlet with good accuracy. Among the tuning parameters tested, the fraction of the backbarrier lagoon covered with marsh ($f_{marsh}$) was key to simulating the prism reduction and consequent narrowing of Armona inlet and elongation of Culatra island. Increasing values of the ratio of inlet depth to width ($\gamma_{aspect}$) with simulation time allowed to control the morphological adjustment of the inlet during prism reduction. By maintaining the value of the ratio constant, BRIE assumes that inlet depths and widths change in pace with each other. Sensitivity tests, however, showed that this approximation likely does not hold true for the Armona inlet, resulting to slower inlet narrowing than the observations. Setting a constant inlet depth value and calculating inlet aspect with time, allowed to accurately reproduce the morphological evolution for both the inlet undergoing tidal prism loss and the adjacent barrier islands. As the first real-world validation of BRIE to the authors' knowledge, these results are encouraging for its applicability over larger spatio-temporal scales and different barrier forcing conditions.



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