ADAPTA BLUES

"Adaptation to climate change through management and restoration of European estuarine ecosystems".

A.1: GIS module: User guide for mapping estuarine areas under reclaimed or degraded conditions in three Atlantic EU regions. Characterization of the restoration potential to adapt to Climate Change

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[1]PU = Public; CO = Confidential, only for members of the consortium (including the Commission Services); CL = Classified, as referred to in Commission Decision 2001/844/EC

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1   SCOPE

The present protocol was developed under the scope of the LIFE project "*Adaptation to climate change through management and restoration of European estuarine ecosystems*" in support of "*Action 1. Mapping: To map estuarine areas under reclaimed or degraded conditions in three Atlantic European regions*".

The goal is to define the main characteristics of the geographical layers to be developed, which will be used to characterize the **historical estuarine area** in terms of surface, land use, property, territorial planning, habitats, conservation/degradation level, risk level for sea level changes. Ultimately, the layers will serve as baseline information in support of planned management actions to mitigate and/or adapt to climate change and sea level variation impacts.

2   GENERAL CHARACTERISTICS

- The Lambert Azimuthal Equal Area [ETRS-LAEA] (EPSG:3035)[1] is the recommended geographic Information system in accordance with the Directive Inspire (updated in case changes are made in the respective directive)[a].
- QGIS is the recommended software to produce the geographic layers and final maps regarding European Atlantic estuaries and their resilience to climate change.

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[1] https://spatialreference.org/ref/epsg/etrs89-etrs-laea/

3 LAYERS DESCRIPTION AND METHODOLOGY

3.1 Historical limits of the estuary

- The layer *historical limits of the estuary* corresponds to the geographical scope of each estuarine area included in the GIS Module. It should include areas that have been modified and transformed by humans for other uses (Figure 1).

- Data source: Official reports and datasets under the Water Framework Directive (WFD), as detailed under Annexes II and V.

- Geospatial data format: vector, shapefile

- Geometry type: polygon

- Recommended file name: [name_of_estuary], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 4 fields:

[name_of_estuary]	• ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer • Name | Mandatory. Type: String • Country | Mandatory. Type: String • Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

Table 1-Water Framework Directive database and reports, and national historical limits (Local, Regional and National level).

Data	Source	Link
WISE WFD database	EEA WISE Water Framework Directive	https://www.eea.europa.eu/data-and-maps/data/wise-wfd-4
WFD official report	European commission EUR-Lex	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060
Portugal Historical limits	APA (Agência Portuguesa do Ambiente)	https://sniambgeoportal.apambiente.pt
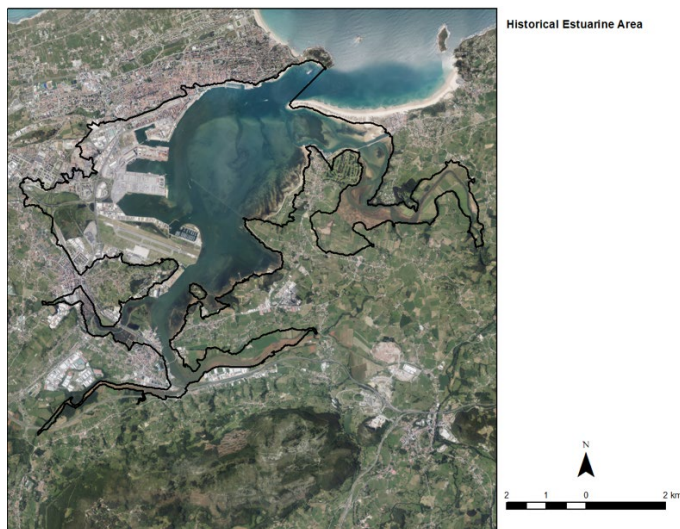
Figure 1 - Example of the Historical limits of the Santander Bay

3.2   Land use

- The *Land use* layer characterizes land use/land cover.

- Geographic boundaries: the limits of the flood risk area up to 6 meters above sea level (see subsection 8 and 9) (Figure 2).

- Data source: CORINE Land Cover (CLC) (2018) available from the Land Monitoring service of Copernicus[b].

  Other national land use/land cover maps may be used as a source of information, but only under the following three conditions:

  - o   the spatial resolution is higher;

  - o   the map is not older than 10 years than the most recent CLC;

  - o   A conversion table between the national land use categories and the CLC categories exists.

  If another land use map is used, other than the CLC, a short report with the conversion table must be delivered, clarifying the codes and name of land categories, and providing the bibliographic reference.

Table 2 - CORINE Land Cover (CLC) 2018 data source.

Data	Source	Link
CLC 2018	EEA Copernicus Land Monitoring Service	https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

- Geospatial data format: vector, shapefile

- Geometry type: polygon

- Recommended file name: LU_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 3 mandatory fields and 1 optional:

LU_[initials-of-estuary-name]

- ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer
- CLC_CODE | Corine Land Cover Code. Mandatory. CLC code level 3. Type: Integer
- Nat_CODE | National code. Optional. Lowest code level from the national land use map. Type: Integer and/or String
- Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places
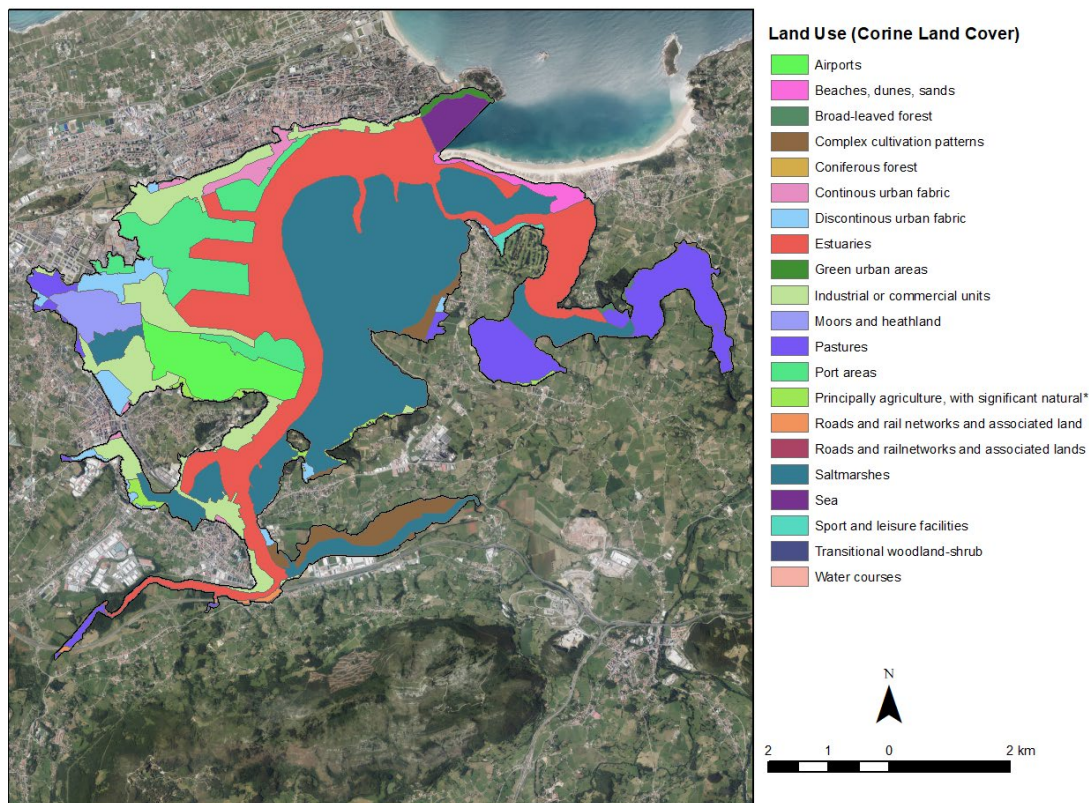
Figure 2 - Example of Corine land cover shapefile for the historical limits of Santander Bay.

3.3 Legal ownership

- The *Legal Ownership* layer characterizes the surface according to its legal property status (Public; Private; Concession).

- Geographic boundaries: the limits of the flood risk area up to 6 meters above sea level (see subsection 8 and 9).

- Data source: official information obtained with local, regional, or central administration, depending on the country system.

- Geospatial data format: vector, shapefile

- Geometry type: polygon

- Recommended file name: Owner_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 7 mandatory fields:

Owner_[initials-of-estuary-name]

- ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer
- Ownership| Type of ownership. Mandatory. Type: String
- Nr_Prop | Number of proprietaries. Mandatory. Type: Integer
- Conc | Concession ongoing (Yes/No). Mandatory. Type: String
- Start_Conc | Year. Mandatory. Type: Integer
- End_Conc | Year. Mandatory. Type: Integer
- Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

Table 3 – Legal Ownership data source.

Data	Source	Link
Legal ownership Mondego local level	MARE Institute	N.A. (Municipality archive)

- Further details on the attributes:
  - Ownership (Owner): attribute describing the type of ownership. The following options are possible:
    - Private
    - Public
  - Number of proprietaries sharing the ownership (Nr_Propr): attribute describing the number of proprietaries.
  - Concession (Conc): attribute describing whether there is an ongoing concession:
    - Yes
    - No
  - Beginning of Concession year (Start_Conc): attribute identifying the year in which the concession started. Insert NA if there is no ongoing concession.
  - End of Concession year (End_Conc): attribute identifying the year in which the concession is expected to end. Insert NA if there is no ongoing concession.
- The name of the proprietaries should be identified providing independent .CSV tables to allow for one-to-many and many-to-many relationships.
- Likewise, the identification of the entity(ies) to which the area has been concessioned, should be done providing independent .CSV tables to allow for one-to-many and many-to-many relationships.

3.4 Territorial planning

- The *Territorial Planning* layer characterizes land according to its definition in national/municipal land use planning.

- Two types of information are required:
  - *Planned land use* as defined by the municipal, regional or central administration strategy territorial plans.
  - *Current land use*, i.e., what is actually in place (we can have a designated area for industrialization but currently still covered by wild habitats).

- Geographic boundaries: the limits of the flood risk area up to 6 meters above sea level (see subsection 8 and 9).

- Data sources:
  - ⇒ *Planned land use category* (industrial, urban, agriculture, etc.): obtained from official documents/spatial datasets;
  - ⇒ *Current land use category*: information should be obtained through field work, using the CLC land categories as reference. Whenever the field work is not possible, the following sources of information are admissible: a) most recent CLC dataset or other national land use map; b) satellite images with no more than 5 years old and with a spatial resolution equal or higher than 20 meters.

- Geospatial data format: vector, shapefile

- Geometry type: polygon

- Recommended file name: TP_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 5 mandatory fields:

TP_[initials-of-estuary-name]	• ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer • TP_CODE | Land Category Code based on/obtained from the territorial plans. Mandatory. Type: Integer • TP_name| Description of Territorial Planning land category. Mandatory. Type: String • CTP_CODE | Current Land Use Category Code, based on CORINE Land cover codes. Mandatory. Type: Integer • Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

3.5   Protection Status

- The *Protection Status* layer classifies the study area according to its protection level (National classifications – each country has its own definition of protected areas; Natura2000; Ramsar; etc.).

- Geographic boundaries: the limits of the flood risk area up to 6 meters above sea level (see subsection 8 and 9).

- Layer independent from land use/land cover layers, hence allowing the observation of overlaps between the protection level and the current surface use/cover.

- Data sources: official geographic information. For European and International datasets, the following sources should be used:

Table 4 - Sources of European and International data on Protected Areas.

PL_type	PL_scope	Source	Link
Natura 2000	International	EEA	https://natura2000.eea.europa.eu/
RAMSAR	International	Ramsar	https://www.ramsar.org
IUCN	International	IUCN	https://www.iucn.org/theme/protected-areas/about/protected-area-categories
SCI	Europe	EC	https://natura2000.eea.europa.eu/

- Geospatial data format: vector, shapefile
- Geometry type: polygon

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- Recommended file name: EC_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 5 mandatory fields:

EC_[initials-of-estuary-name]	• ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer • PL_name| Name of the protection area. Mandatory. Type: String • PL_type| Designation of the protection level (e.g. Natura 2000; RAMSAR). Mandatory. Type: String • PL_scope| Geographic scope of protection type (Local, National, European, International). Mandatory. Type: String • Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

3.6 Habitats

- The *Habitats* layer classifies ecosystem types present based on the non-spatial EUNIS habitat classification system.

- In case the habitat is not included in the Natura 2000 Network the location is still serving as a base habitat for halophyte vegetation and coastal zones. Therefore, each country has its own definition of classification system (Natura2000; Ramsar; ICNF; etc.).

- According to criteria of the International Union for Conservation of Nature the inland aquatic habitats are based primarily on the classification system of wetlands types used by Ramsar Convention.

- Geographic boundaries: the limits of the flood risk area up to 6 meters above sea level (see subsection 8 and 9).

- Data sources:

Table 5 - Ecosystem types of Europe data source.

Data	Source	Link
Ecosystem types of Europe v3.1	EEA	https://www.eea.europa.eu/data-and-maps/data/ecosystem-types-of-europe-1
Ramsar Convention (Mondego estuary)	ICNF	https://sig.icnf.pt/portal/home/item.html?id=8eb4f474eab3491b9a0b40a11b83d170

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Data	Source	Link
Habitat classification scheme	IUCN	https://nc.iucnredlist.org/redlist/content/attachment_files/dec_2012_guidance_habitats_classification_scheme.pdf

⇒ Other national ecosystem/habitat maps;

⇒ Establishing a correspondence between national land use categories (see subsection 2) with resolution higher than the CLC map, and the habitat types according to the EUNIS classification system;

⇒ Spatial information obtained from field work;

⇒ Combination of the abovementioned datasets.

Sources 2, 3, 4 and 5 should only be used under the following three conditions:

- the spatial resolution is higher than 100m, which is the current Ecosystem types of Europe map resolution;

- the datasets are no older than 10 years than the most recent CLC;

- A conversion table between the national habitat categories and the EUNIS Level 1, Level 2 and Level 3 categories is provided.

- Geospatial data format: vector, shapefile. If using the EEA Ecosystem types map, the raster map should be converted to vector format.

- Geometry type: polygon

- Recommended file name: HAB_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 7 mandatory fields:

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HAB_[initials-of-estuary-name]

- ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer
- EUNIS_Code | Habitat code defned by the EUNIS classification system. Mandatory. Type: String
- EUNIS_level | EUNIS level of classification (1, 2 or 3). Mandatory. Type: Integer
- EUNIS_type | EUNIS major type (Marine / Terrestrial). Mandatory. Type: String
- HAB_Pri | Priority Habitat (Yes/No). Mandatory. Type: String
- HAB_CS | Habitat Conservation Status. Mandatory. Type: String
- Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

- Further details on the attributes:

  o EUNIS_Code: attribute identifying the habitat code defined by the EUNIS classification system. Mandatory. Type: String

  o EUNIS_level: EUNIS level of classification, according to the EEA classification scheme. One of the following options is possible:

    - 1

    - 2

    - 3

  o EUNIS_type: attribute describing the habitat major type according to EUNIS. One of the following options is possible:

    - Marine

    - Terrestrial

  o Priority Habitat (HAB_Pri): attribute identifying whether the habitat is classified as a Natural Priority Habitat in compliance with Article 17 of Habitats Directive and as defined by the Habitats Directive Annex I. One of the following options is possible:

    - Yes

    - No

- Habitat Conservation Status (HAB_CS): attribute describing the habitat conservation status under the IUCN criteria[c]. Should be identified for all habitats. If not possible, at least for the priority habitats. If the information is unavailable, insert ND (not defined).

3.7 Ecosystem margins

- The *Ecosystem margins* layer characterizes the margins of estuarine limits.

- Geographic boundaries: historical estuary limits (see subsection 1).

- Data sources: Field work and national datasets.

- Geospatial data format: vector, shapefile

- Geometry type: lines

- Recommended file name: EM_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 6 mandatory fields:

EM_[initials-of-estuary-name]

- ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer
- EM_cat | Type of margin (Natural/Anthropogenic). Mandatory. Type: String.
- EM_typ | Type of material under which the margin has been built. Mandatory. Type: String
- EM_fun| Function of the margin. Mandatory. Type: String
- EM_cons| Conservation status of the margin. Mandatory. Type: String
- Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

- Further details on the attributes:
  - Category (EM_cat): attribute describing whether the margin is natural-based or anthropogenic-based. Only one of two options are possible:
    - Natural
    - Anthropogenic
  - Typology (EM_typ): attribute describing the type of material under which the margin has been built. They differ between Anthropogenic and Natural margins.

For the material of anthropogenic margins, the following options are possible:

- Rip-rap
- Brick-laid stone
- Rock
- Concrete
- Wood
- Other

For natural margins material the following options are possible:

- Mud
- Sand
- Vegetation coverage
- Rock
- Other

- o Function (EM_fun): attribute describing the function of the material under which the margin has been built. The following options are possible:

  - Dike
  - Coastal margin
  - Commercial Port
  - Bridge
  - Embankment
  - Reinforced bank
  - Other

- o Conservation Status (EM_cons): attribute describing the conservation status of the margin. The following options are possible:

  - Degraded
  - Under pressure (although not degraded yet)
  - Not degraded

3.8 Flooding risk

- The *Flooding Risk* layer provides a set of spatial maps of flood risk by crossing the flooding layers with the exposure layers and applying the vulnerability function. The different risk levels are Numerical indicators on the population and the built capital for the climate scenarios of flooding.

- The influence of vegetation will be simulated through a vegetation module and included in the modelling results. Vegetation is represented by rigid objects that influence momentum and turbulence equations, which vary in the number of stems per unit area (stem density), the stem diameter and the stem height and the drag coefficient. For the selection of the suitable rate values to use it is essential to know the type of vegetation existing in the modelled area.

- This layer will classify areas according to: 1) their level of Flood Risk for population, presented as 5 classes in a colour scale ([0-25[; [25-50[; [50-75[; [75-100[; ≥100 persons); 2) their level of Flood Risk for build capital, presented as 5 classes in a colour scale ([0-1[; [1-2[; [2-3[; [3-4[; ≥4 million euros).

- The flooding risk is presented by contrasting topography with sea level rise scenarios. Sea level rise scenarios should be extracted from IPCC reports[d], using RCP4.5 and RCP8.5 (updating the models' information with future reports data). If there are local or regional data/models available these should be introduced (for example, there is a complete model projection for Portugal[e] which should also be used for the Mondego estuary).

- For Digital Terrain Model, a compilation of topographic information of the study area should be collected, using the information available from the source with the highest spatial resolution. When assembling the bathymetric information with the topographic information, all the information must be homogenized to the same reference level, making the necessary corrections.

- The typology of risk is presented to define the type of structures that might be affect by the flooding event.

- One layer per model/scenario should be generated.

- Geometry type: polygon

- Recommended file name: FR_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

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- Attribute table with 7 mandatory fields:

FR_[initials-of-estuary-name]	• ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer • Model| Model name according to the climate change senario used as baseline. Mandatory. Type: String • Source| Source of climate change scenario (IPCC of regional study). Mandatory. Type: String • PopRisk| Flood Population Risk levels ([0-25[; [25-50[; [50-75[; [75-100[; ≥100). Mandatory. Type: Integer •FBuiltRisk | Flood Built Risk levels ([0-1[; [1-2[; [2-3[; [3-4[; ≥4). Mandatory. Type: Integer •Typology_Risk| Typology of Risk (Built_capital, Population_capital). Mandatory. Type:String • Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

- Further details on the attributes:
  - Typology of Risk (Typology_Risk): attribute describing whether the type is Built capital or Population capital. Only one of two options are possible:
    - Built_capital
    - Population_capital

Note:

- The Built capital includes every type of building that is not used for human habitation. For example, Educational, Institutional, Assembly, Business, Mercantile, Industrial, Storage Buildings, etc…;
- The Population capital includes every type of residential building for human habitation.

3.9   Potential for Habitat migration

- The *Potential for Habitat Migration* layer provides information on the ability and potential for estuarine vegetation habitats to migrate and colonize adjacent areas.
- All areas located within the first 6 meters above sea level (altitude), with a natural connection to the estuarine area (not limited by anthropogenic structures such as levees or embankments), and nowadays covered by herbaceous habitats should be considered as potential migration areas.
- Geographic boundaries: Landward area close to the estuarine limits, located within the first 6 meters above sea level (altitude).

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- Data sources: Digital Terrain Model coupled with data from subsections 1 to 8. Overlapping spatial analysis should be used to find the potential migration areas.

- Geospatial data format: vector, shapefile

- Geometry type: polygon

- Recommended file name: PM_[initials-of-estuary-name], avoiding spaces and/or specific writing characters such as ç.

- Attribute table with 4 mandatory fields:

PM_[initials-of-estuary-name]	• ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer • PM_level| Potential migration WMP; NMP. Mandatory. Type: String • Just| Short justification for potential level. Mandatory. Type: String • Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

- Further details on the attributes:

Two possible outcomes are present: with migration potential (WMP), no migration potential (NMP). To be classified as WMP it must meet the following parameters:

⇒ landward area close to the estuarine limits;

⇒ located within the first 6 meters above sea level (altitude);

⇒ with a natural connection to the estuarine area (not limited by anthropogenic structures such as levees or embankments);

⇒ nowadays occupied by agricultural land, forests or intertidal areas.

The map display should output a two colours scheme for WMP and NMP:

Table 6 - Recommended colour scheme for WMP and NMP.

Migration potential	colour	RGB Code		
		R (Red)	G (Green)	B (Blue)
WMP	Green	0	176	80
NMP	Red	255	0	0

Sublayer for WMPs

However, to classify WMP areas three levels may be taken into account, since the real potential for habitat migration is not always the same even when all the above criteria are met. So, for WMP three potential migration levels are defined, describing the migration potential with the following options:

- High: can be rapidly colonized by estuarine ecosystems within less than 3 years;
- Moderate: where estuarine habitats would take more than 3 years to stabilize or where other parameters (e.g., type of sediments, presence of certain species, proximity of harmful anthropogenic activities) limit habitat migration;
- Low: when estuarine habitats would most likely fail to develop or when generating the adequate conditions would be highly costly or present potential environmental damage.

In case of a habitat migration scenario due to sea level rise, the following factors will contribute for colonization success and a fastest response:

- Habitat migration tends to move for nearby saltmarsh vegetation patches. The lack of competitive species, as the less competitive can only inhabit the areas where dominant species cannot survive[f];
- The tidal frame elevation, as elevation decreases the waterlogging time will cause stress and affect plants survival, growth, and distribution[g.h.i];
- The tidal network, thus the current velocity distributes nutrients, water, influences accretion rates[j], and control plants distribution which determines the propagule dispersal and fixation capacity[k.l];

- The sediment type is directly influenced by the current speed. The lack of soil moisture can limit halophyte colonization[m], in which the sandy soils are almost completely lacking in organic material that would retain both moisture and nutrients.

Therefore, is important to describe in a more practical way the importance of biotic and abiotic factors for each WPMs option. The following factors should be considered:

  - High: The presence of nearby saltmarsh plants; The waterlogging time should be relatively close to those in natural conditions. For example, the saltmarsh plant *Sueda heteroptera* needs for its growth around 1,56-2.87 h/d of waterlogging time[n]; The current velocity and turbulence should allow the propagules to fixate in the soil; The sediment type, which is directly correlated to the current speed must be based on mudflats, very fine sand, or sediment type able to keep soil moisture and nutrients;

  - Moderate: The speed current and the waterlogging time allow saltmarsh plants colonization and distribution;

  - Low: Even if it meets the WPMs parameters the environmental conditions are not the most appropriate. For example, absence of nearby saltmarsh plants; The current speed and waterlogging time does not allow propagules fixation; Sandy sediment type which will lack on nutrients and soil moisture.

WMP_[initials-of-estuary-name]	• ObjectID | Unique key constraint. Mandatory. Unique field, without NULL values. From 1 to max. Type: Integer • WMP_level| Potential migration levels (high, moderate, low. Mandatory. Type: String • Just| Short justification for potential level. Mandatory. Type: String • Area | Mandatory. Unit of area: hectares (ha). Type: Real, 4 decimal places

- Map display: The migration potential should be defined using a colour scheme for different potential levels:

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Table 7 - Recommended colour scheme for WMP different levels.

PM_level	colour	RGB Code		
		R (Red)	G (Green)	B (Blue)
High	Dark Green	0	100	0
Moderate	Forest Green	40	164	40
Low	Lime Green	50	205	50

4 REFERENCES

a- Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) https://inspire.ec.europa.eu/id/document/tg/rs

b- Kosztra B. Büttner G. Hazeu G. Arnold S. 2017. Updated CLC illustrated nomenclature guidelines. Service Contract No 3436/R0-Copernicus/EEA.57441 Task 3 D3.1 – Part 1. European Environment Agency.

c- Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J. and Rodríguez, J.P. (eds.) (2017). Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria, Version 1.1. Gland, Switzerland: IUCN. ix + 99pp.

d- Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

e- Antunes, C. 2019. Assessment of Sea Level Rise at West Coast of Portugal Mainland and Its Projection for the 21st Century. *J. Mar. Sci. Eng. 7*, 61. https://doi.org/10.3390/jmse7030061

f- Pennings, S.C., Callaway, R.M., 1992. Salt marsh plant zonation: The relative importance of competition and physical factors. Ecology 73(2), 681e690. https://doi.org/10.2307/1940774.

g- Silvestri, S., Defina, A., Marani, M., 2005. Tidal regime, salinity and salt marsh plant zonation. Estuar. Coast Shelf Sci. 62(1), 119e130. https://doi.org/10.1016/j.ecss.2004.08.010.

h- Pennings, S.C., Grant, M., Bertness, M.D., 2005. Plant zonation in low-latitude salt marshes: Disentangling the roles of flooding, salinity and competition. J. Ecol. 93(1), 159e167. https://doi.org/10.1111/j.1365-2745.2004.00959.x

i- Li, W., 2018. Responses and Thresholds of Typical Salt Marsh Species to Flooding-Salinity Stress in Yangtze Estuary. M. E. Dissertation. East China Normal University, Shanghai (in Chinese).

A.1: GIS module: User guide for mapping estuarine areas under reclaimed or degraded conditions in three Atlantic EU regions. Characterization of the restoration potential to adapt to Climate Change

j- Reed, D.J., Spencer, T., Murray, A.L., French, J.R., Leonard, L., 1999. Marsh surface sediment deposition and the role of tidal creeks: implications for created and managed coastal marshes. J. Coast. Conserv. 5, 81–90. http://dx.doi.org/10.1007/BF02802742.

k- Sanderson, E.W., Foin, T.C., Ustin, S.L., 2001. A simple empirical model of salt marsh plant spatial distributions with respect to a tidal channel network. Ecol. Model. 139 (2–3), 293–307. http://dx.doi.org/10.1016/S0304-3800(01)00253-8.

l- Zheng, Z., Zhou, Y., Tian, B., Ding, X., 2016. The spatial relationship between salt marsh vegetation patterns, soil elevation and tidal channels using remote sensing at Chongming Dongtan Nature Reserve, China. Acta Oceanol. Sin. 35 (4), 26–34. http://dx.doi.org/10.1007/s13131-016-0831-z.

m- He, Q.; Cui, B., and An, Y., 2012. Physical stress, not biotic interactions, preclude an invasive grass from establishing in forbdominated salt marshes. PLoS One, 7, e33164.

n- Hou, Wenhao & Zhang, Ruijin & Xi, Yanbin & Liang, Shu-xiu & Sun, Zhaochen. (2020). The role of waterlogging stress on the distribution of salt marsh plants in the Liao River estuary wetland. Global Ecology and Conservation. 23. e01100. http://dx.doi.org/10.1016/j.gecco.2020.e01100.