CleanAtlantic

Tackling Marine Litter
in the Atlantic Area

WP 6: On the distribution of marine litter along the Ría de Arousa coastline using modelling and mapping

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DISCLAIMER

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On the distribution of marine litter along the ria de Arousa coastline using modelling and mapping

1. BACKGROUND

Marine litter (ML) has been defined by the UN Environment as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; accidentally lost, including material lost at sea in bad weather (fishing gear, cargo); or deliberately left by people on beaches and shores.”)

Marine litter represents a huge problem in our oceans, coasts and consequently, a serious environmental deterioration, effects on health and great economic losses of those sectors related to the marine environment.

The European Union, aware of this problem, includes in its Marine Strategy Framework Directive (MSFD) as one of the qualitative descriptors to determine good environmental status "The properties and quantities of marine litter do not cause harm to the coastal and marine environment". Periodic assessments of the state of the marine environment, monitoring and formulation of environmental objectives are perceived as part of the adaptive management process within THE MSFD and within the Regional Maritime Convention (CSR) Action Plans, and have become a major concern for Marine Protected Areas (MPAs).

The European CleanAtlantic project aims to protect biodiversity and ecosystem services in the Atlantic Area by improving capabilities to monitor, prevent and remove (macro) marine litter. The project will also contribute to raise awareness and change attitudes among stakeholders and to improve marine litter managing systems.

2. OBJECTIVES

Among its specific objectives CleanAtlantic aims to develop maps of accumulation zones (hotspots) based on the study of the circulation of floating litter. To achieve it, numerical models will be used both to predict the behaviour of drifting garbage and to map hotspots.

The document describes the methodology developed for the location of the accumulation zones of marine litter in the Ría de Arousa using numerical models, a local scenario located in Galicia, NW of Spain. The same scenario has also used to test the different sampling strategies for the location of areas of marine litter accumulation that INTECMAR has carried out within the work package 5 of the project: Monitoring and Data Management. (CleanAtlantic, 2021)

Thus, after obtaining the results of the modelling these can be compared with the results obtained in the different sampling strategies in order to analyse the correspondence of one technique with the other.

3. STUDY AREA

The present study was developed in Galicia has a coastline whose length is 2,555 km that are composed of 1,659 km of coastal perimeter, 432 km of islands and 464 km of marshes. Geographically, one of the peculiarities of Galicia is the presence of the rias, inlets on the coast in which the sea flooded river valleys due to a decrease in land level (relative rise in sea level). The Galician have great fishing importance, contributing to the Galician coast being one of the most important fishing and shellfish areas in the world. In addition, most of the population lives in the surroundings of the rias, where the largest urban centers and their areas of influence are located. The rias are traditionally divided into “Rías Altas” and “Rías Baixas” according to their position regarding Finisterre, the western most point of Galicia.

The study of the different methodologies presented here has focused on the Ría de Arousa which is the most extensive of the four Rías Baixas and with high socio-economic importance (Fig. 1).

3.1. Ocean-meteorological characteristics of the Ría de Arousa

The Ría de Arousa covers 33.1 km long, an area of 2.39 x 108 m^2 and an average volume of 4.8 x 109 m^3. Its orientation is EN-S. The width of the estuary ranges from 4 km in the narrowest part to 15 km in the widest part. The Ría de Arousa, is not only the largest but also the deepest, reaching more than 67 m in its central area.

Fig. 1 Ria de Arousa

The climate of the Ría de Arousa is favourably influenced by the current of the Canary Islands, southern branch of the Gulf Stream, which begins precisely off the Galician coast. The climate is of a temperate rainy type with a maritime Mediterranean rainfall regime, with abundant rainfall in autumn, winter and spring and dry season in summer.

The average oscillation of sea level is around 3 m, being therefore a mesotidal estuary (between 2 and 4 m of tidal range). This tidal range goes from more than 3.5 m at spring tides to 1.5 m during neap tides. These variations in sea level height give rise to cyclical movements of water inflow and outflow, called tidal currents, which can become of great intensity.

On the other hand, if the Ría de Arousa is considered as a partially mixed estuary and averaging the currents during several tidal cycles, the residual circulation obtained is positive in two layers: a saltwater inflow bottom current from the ocean and a brackish water outward current on the surface. In the Ría de Arousa there are also several sources of stratification: the contributions of fresh water, the flow of heat through the atmosphere-estuary interface and the water exchanges that are established between the platform and the estuary. All of them give rise to longitudinal density gradients, which act as motors of the positive circulation described.

There is also a great influence of the winds in the variability of the residual circulation both in the platform and in the estuary, being able to cause three different scenarios: reinforced positive circulation when north component winds dominate, relaxation situation in transition periods with a very slow positive circulation maintained for days and reverse or negative circulation favoured by the south winds.

As summary, the Ría de Arousa behaves as an extension of the continental shelf, responding directly to the coastal wind. Its physical configuration also allows a high production of phytoplankton, with a characteristic marine flow, which makes this estuary famous for its marine wealth.

3.2. Sources of marine litter in the study area

The main sources of marine litter that can be assumed in the Ría de Arousa are:

- Litter coming from the Atlantic facade and that enters dragged into the flows of water from the platform.
- Population centers settled in the coastal zone. Among which the most important riverside towns of the Ría de Arousa (Ribeira, Pobra do Caramiñal, Boiro and Rianxo in the north and Vilagarcía de Arousa, Vilanova de Arousa, Cambados and O Grove in the south, and Arousa on the homonymous island) stand out, which add up to a population of 143,193 inhabitants (2019).
- Contribution dragged by the rivers that flow into the Ría among which it is worth highlighting in its inner part the Ulla River, one of the largest that flow into the Rías Baixas de Galicia with an average flow of 78.8 m3s-1. In addition to this river, we must consider the Umia River, which flows into the southern part of the estuary with a flow of 13.4 m^3s^{-1}.
- Garbage from activities related to the use and enjoyment of the estuary. In it takes place a great shellfish activity with 20 polygons with more than 2800 rafts, mainly dedicated to the cultivation of mussels, 4 areas of shellfish shoals, bivalves' treatment plants and marine fish farms. Also, this ria hosts an important fishing activity and numerous nautical leisure activities. The maritime traffic that supports this area is relevant with special importance the transit of ships related to the activity of the Port of Vilagarcía de Arousa.

4. METHODOLOGY FOR THE MAPPING AND MODELING OF MARINE LITTER

It is widely known that the distribution of marine litter is heavily influenced by both currents and prevailing winds. Hence, each ocean-meteorological situation can correspond to a specific debris distribution pattern. In addition, there are areas that, due to their geographical position and the ocean-meteorological conditions they experiment, tend to accumulate floating waste systematically, becoming accumulation zones.

The detection of these accumulation zones can be useful for managers to minimize efforts when planning the cleaning and collection of marine litter. To review which areas are in the Ría de Arousa, the following methodology has been tested, based on the use of numerical models, and which has been developed with the intention of being transferable to other regions.

4.1. Description of the used models

Marine litter will be modelled as a passive tracer carried by currents by using the circulation models available at INTECMAR.

As a forcing of the Lagrangian model, the results of MeteoGalicia hydrodynamic prediction operational system were used. This operational system runs daily the MOHIDWater model (https://mohid.com) (Martins, Leitão, Silva, & Neves, 2001) (Braunschweig, Martins, Chambel, & Neves, 2003) (Carracedo, et al., 2006) for the simulation of the currents, salinity and temperature fields on the local scale, for several Galician rias. In the case of the Ría de Arousa, the spatial resolution is approximately 300 m. At the vertical level, the model uses generic vertical coordinates, using two domains: one with Cartesian coordinates extended from the bottom to 8.68 m and with 18 layers and another domain from that level to the surface with 16 sigma layers, with variable depth. The surface layer is approximately 9 cm thick on average, from 7 to 11 cm thick. The model is a baroclinical model, so it is able to simulate the free surface elevation, current velocities, and salinity and temperature.

The hydrodynamic model receives surface boundary conditions from the daily execution of the WRF atmospheric model, which covers the entire area with a resolution of 1.2 km. In addition, the model is forced by the discharges of the Ulla and Úmia rivers through the SWAT model and the influence of the open ocean from the results of free surface, velocities, temperature, and salinity predicted by the ROMS coastal model, also included in the MeteoGalicia prediction system.

The hydrodynamic model is run every day predicting for d+0, d+1 and d+2 days. For the Lagrangian simulation, the first 24 hours of each output file of the hydrodynamic model are chosen. As example, next images show the surface and 10 m depth current forecasted by the MeteoGalicia system.

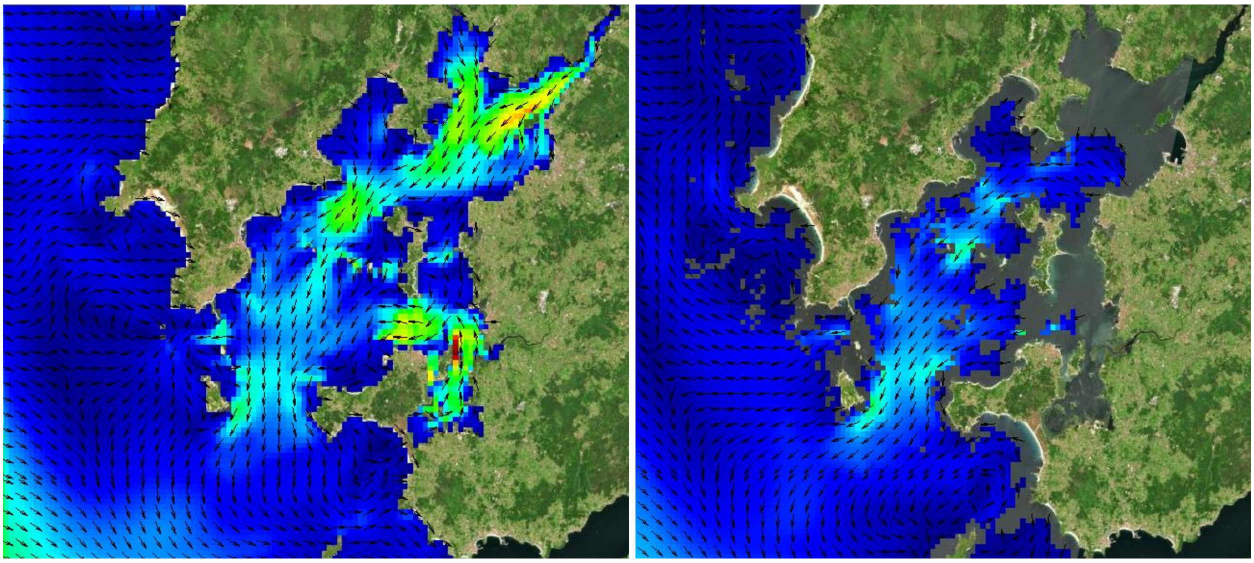


Fig. 2. Example of surface current and 10 m depth generated by MeteoGalicia's MOHID operational model.

The litter debris has been simulated through the MOHIDWater system, and more specifically in its Lagrangian transport module (Leitão, 1996). Particle advection was calculated from the prescribed surface velocity fields from the operational hydrodynamic model. A diffusion contribution to subgrid mixing processes was included following (Allen, 1982). Because we are focused on transport in the upper layer of the ocean, the particles were forced to remain in the surface layer of the model. The direct effect of the wind on the particles was not considered. Therefore, modelled Lagrangian tracers must be representative of litter with neutral buoyancy within the top few centimetres of the water column. Although the

Lagrangian model is not forced directly by the wind, due to the high discretization of the surface layers (the surface layer has a maximum thickness of 11 cm) most of this influence is collected by the surface boundary layer of the hydrodynamic model, which is forced by the meteorological model WRF. It is daily run by MeteoGalicia for several grids. In the case of Rias Baixas area, the modelled surface wind field has a 1.3 km space step.

4.2. Origin of particles

Considering the sources of marine litter described in section 3.2 and starting from the fact that the exact instant in which the litter is released is not known, in the present analysis it is assumed that the marine litter is distributed homogeneously throughout the Ría de Arousa.

An emission box, defined by a polygon covering all the Ría de Arousa, was used to simulate this scenario.

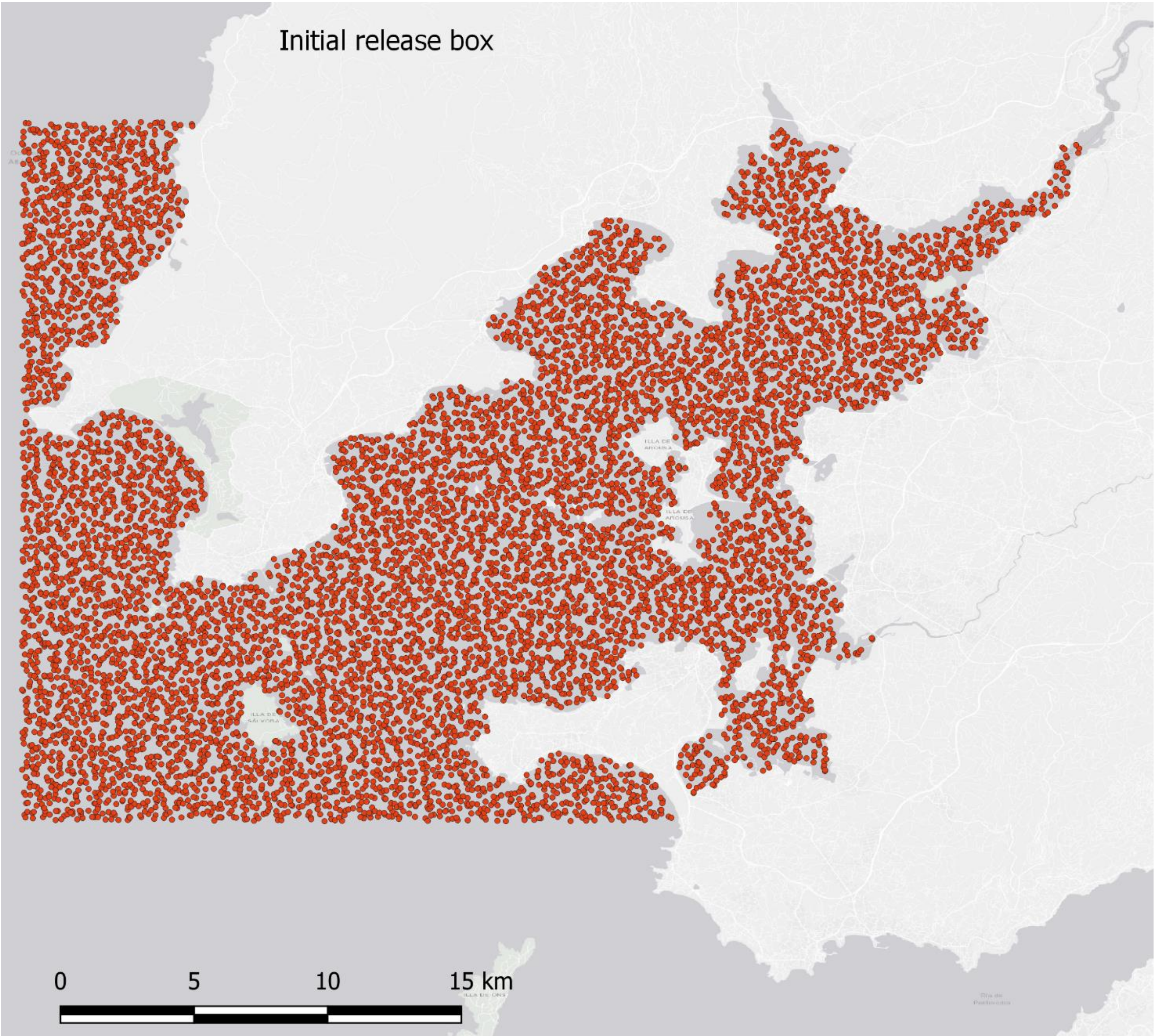


Fig. 3 Initial release box: this emission box is filled by particles for each model start.

To know the influence of the frequency of emission of particles on the result of the modelling, two emission scenarios have been compared:

- Emission of 300 particles in the initial release box every hour
- Emission of 1000 particles in the initial release box every 3 hours

As can be seen in the following plot, the two simulations give very similar results, not significantly influencing the result.

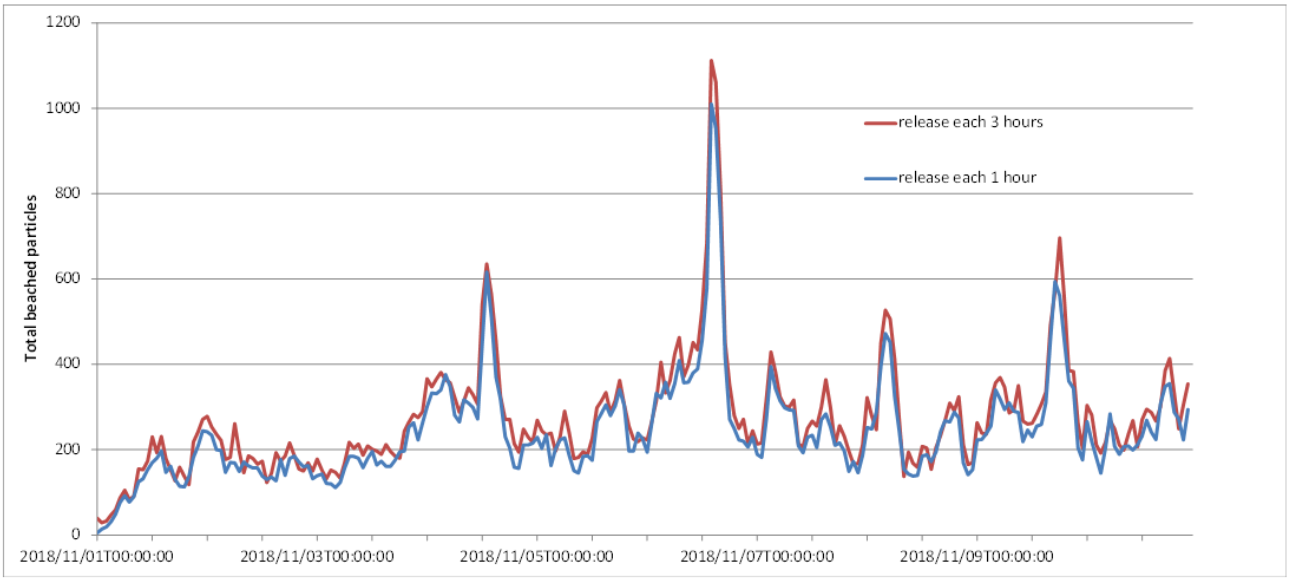


Fig. 4. Comparison of the total number of particles stranded on the coast of the Ría de Arousa over time for two similar simulations: 300 particles released every hour in blue, 1000 particles released every 3 hours in red.

In addition, to know how much spin-up time is necessary, i.e., how long it takes to the model to warm up the simulation, the same period has been simulated, but with 3 different start times, a t = 0 hours, t = 24 hours, and t = 72 hours. It is verified that a regime like the initial one is acquired in less than 36 hours for each of the cases.

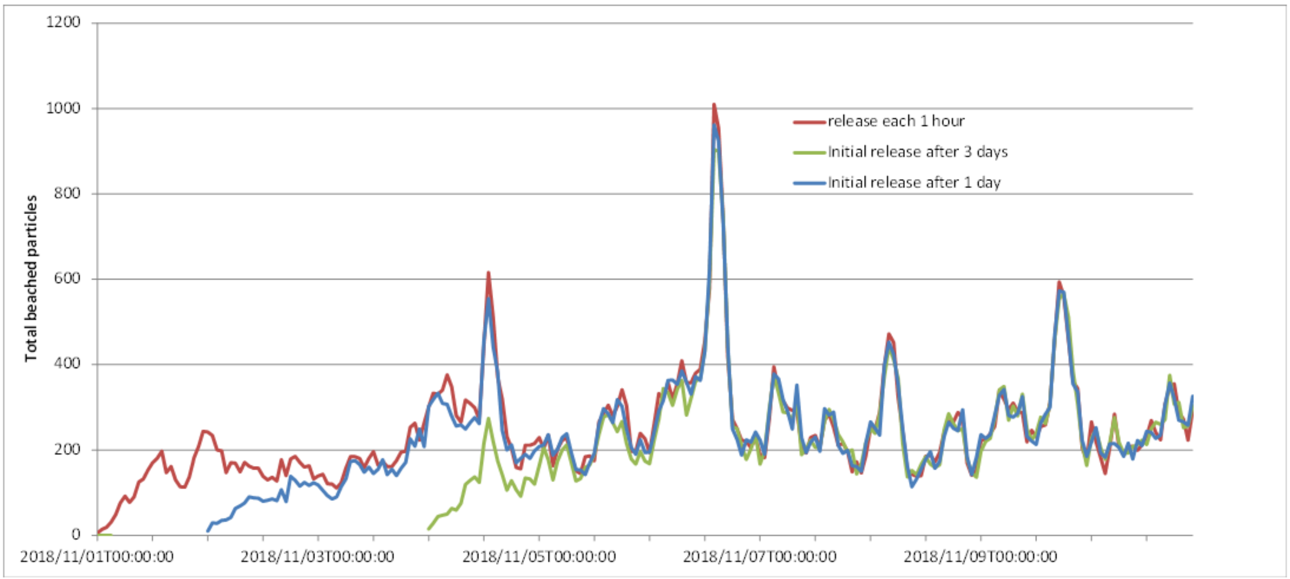


Fig. 5. Comparison of the total number of particles beached on the coast of the Ría de Arousa over time for three similar simulations, but with different start times: in red, t = t0, in blue t = t0 + 24h and in green, t = t0 + 72h.

Finally, after these tests were done, the first option has been chosen: 300 Lagrangian particles are released per hour for an entire year (October 2018-October 2019). As an example, a result map is shown for a given instant of one output, with the beaching tracers in blue.

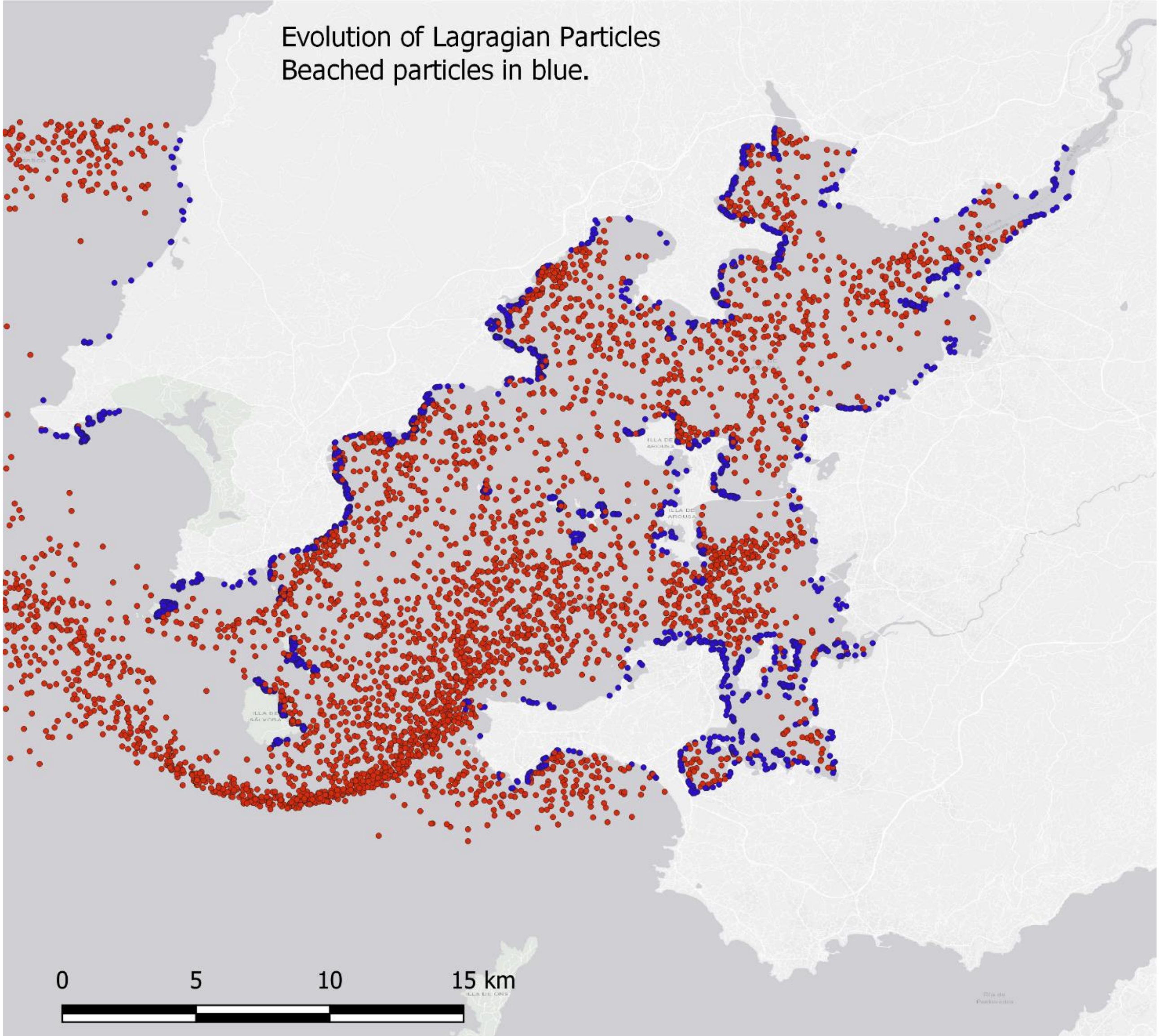


Fig. 6. Map of the evolution of lagrangian particles for a given instant. The particles that have been beached are represented in blue.

4.3. Shoreline Zoning

The entire coast of the Ría de Arousa has been segmented into sections. Each section is actually a polygon, of 1000 m long by 100 m wide, which is where the particle is considered to be beached.

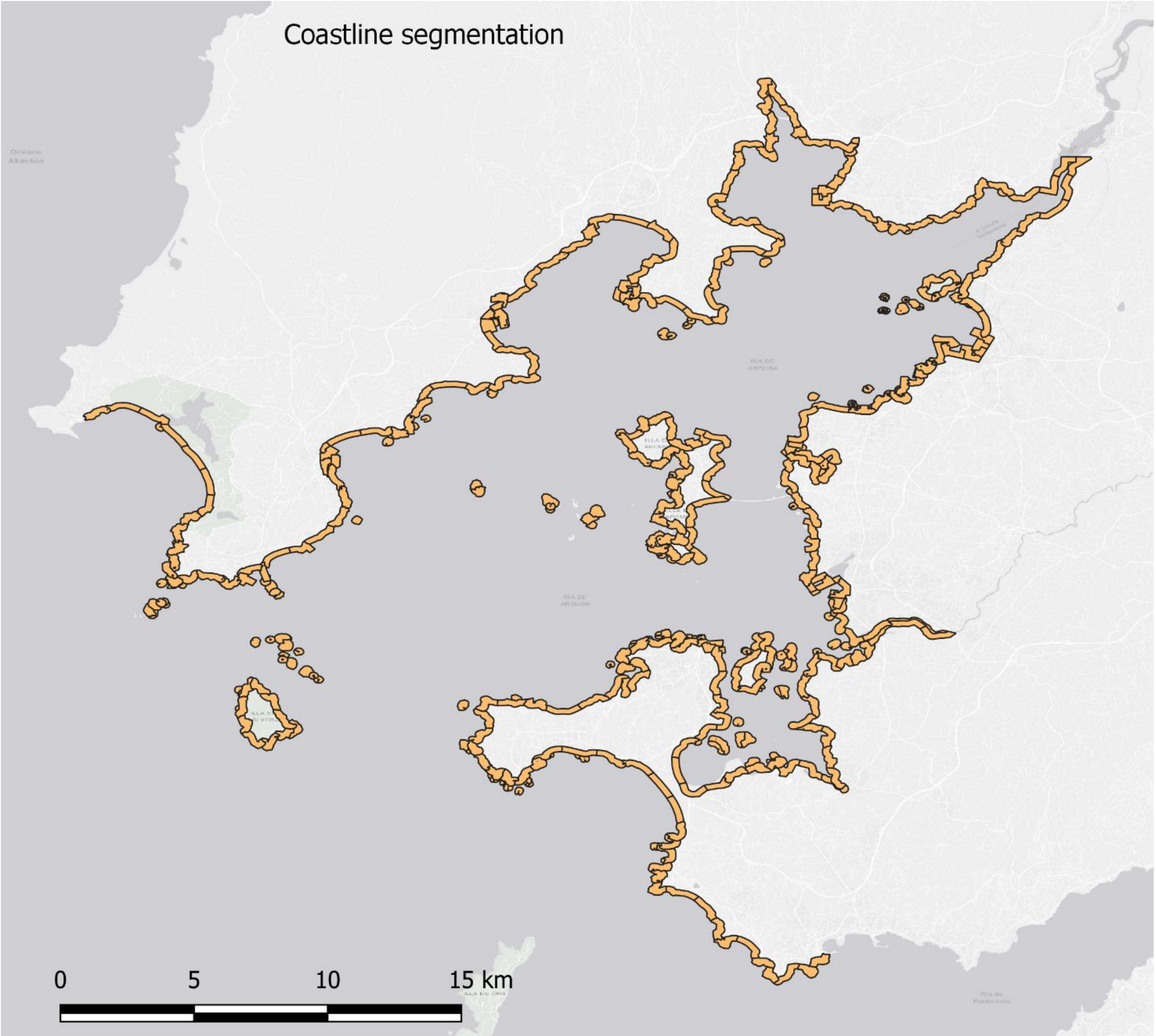


Fig. 7. Segmentation of the coastline of the Ría de Arousa used for the analysis of beached particles. The sections are 1000 m long by 100 m wide.

The creation of these sections or segments has been done using the QGIS program(https://qgis.org/), an application of professional Open-Source GIS under the GNU-General Public License.

This segmentation can be done manually or automatically. In order to extend this methodology to other partners, it has been considered of interest the development of a guide for the segmentation of the coastline. (CleanAtlantic, 2021)

4.1. Arrival of the particles to the coast (Beaching)

To determine the affectation to the different segments of the coast by the arrival of litter, the module of the MOHIDWater system called MOHIDLitter has been used. The particles have been programmed to have a 50% chance of beaching when they are located within 100 m from the coast (the same wide as segments designed before). Those no-beached particles keep moving, being able to beach in the future. However, when a particle is less than 100 m from the coast it is highly probable that it will beach, since the beaching algorithm is calculated for each step that the particle remains in the buffer.

The model saves the time and position of each tracer every 24h and processes the results of the Lagrangian simulations, counting the beached particles in each buffer. All this process can be done automatically thanks to the scripts developed by INTECMAR: The information of the buffers and the number of beached particles in them is stored in a PostGIS database, which is compatible with the standards of the Open Geospatial Consortium (OGC).

This system (scripts and database structure) allows a simple import and export of data, is fast, secure and there are many desktop GIS clients and web map servers that can work with it. Therefore, it was considered that it provided a good solution for the storage, management, and maintenance of this data.

All the code developed, as well as the necessary requirements for its implementation, has been made available for interested users through: https://github.com/pedromontero/CLEANATLANTIC.

5. RESULTS

5.1. Ría de Arousa

Once all the simulations have been executed, a table is obtained in which the number of particles that each buffer has accumulated over the 365 simulated days (October 2018-October 2019) is stored.

Galicia is clearly influenced by wide pressure centres, annually low pressures affect 42% of the days, high pressures in 53% of cases, while in 5% of days there is a transition between them.

Low pressures are usually associated with winds of south and west component, of moderate or strong intensity while in high pressures the winds are predominantly from the east and north and usually with less intensity, even with situations of calm and very local effects.

As an example, in the following images we can see three days with different wind situations, corresponding to wind situations of W, SW and NE, respectively. Keep in mind that at the end of the simulated year, 365 maps have been obtained as follows.

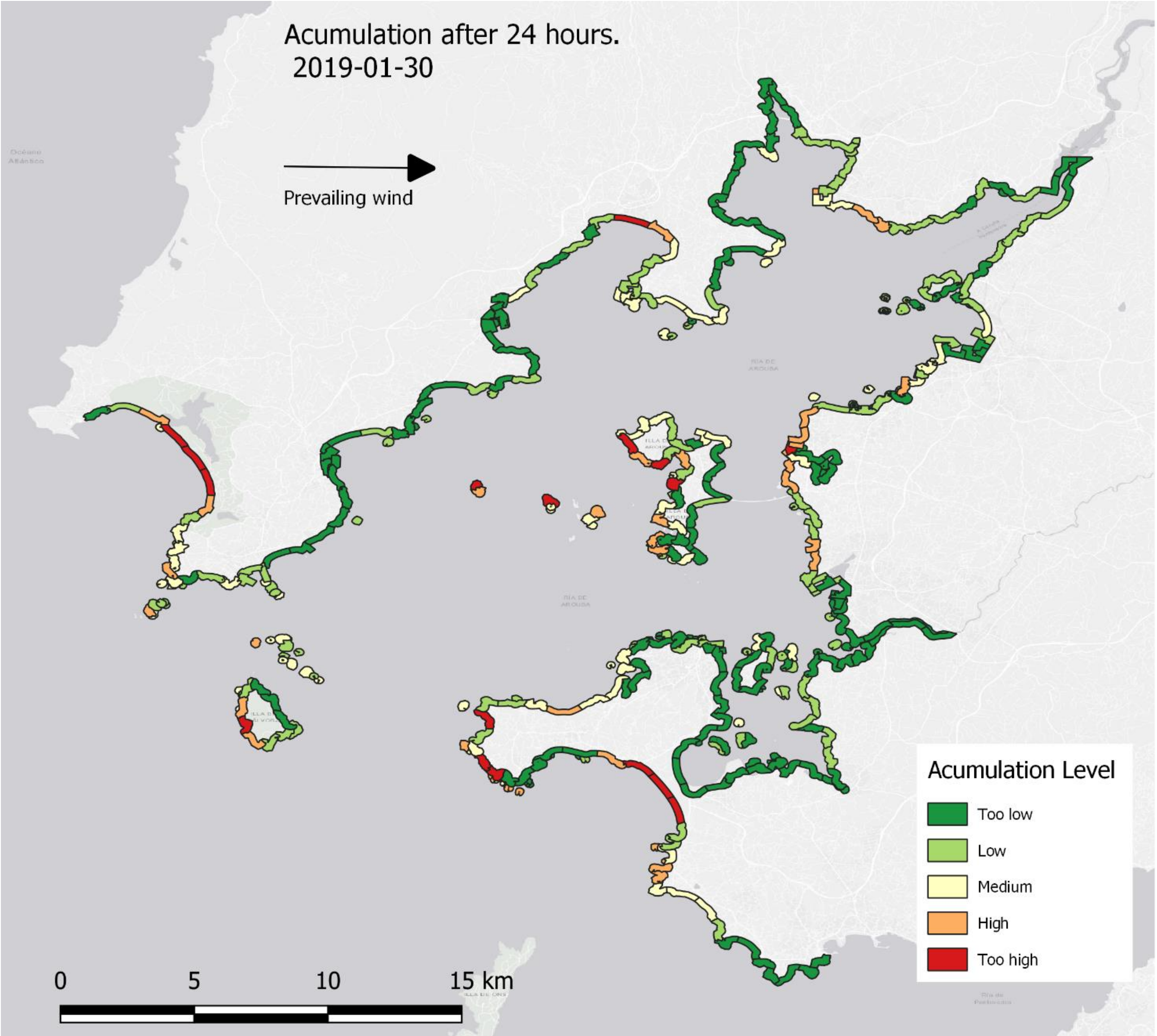


Fig. 8. Accumulation segments after 24 hours for the day 30-01-2019, corresponding to a situation with a prevalent wind of the W.

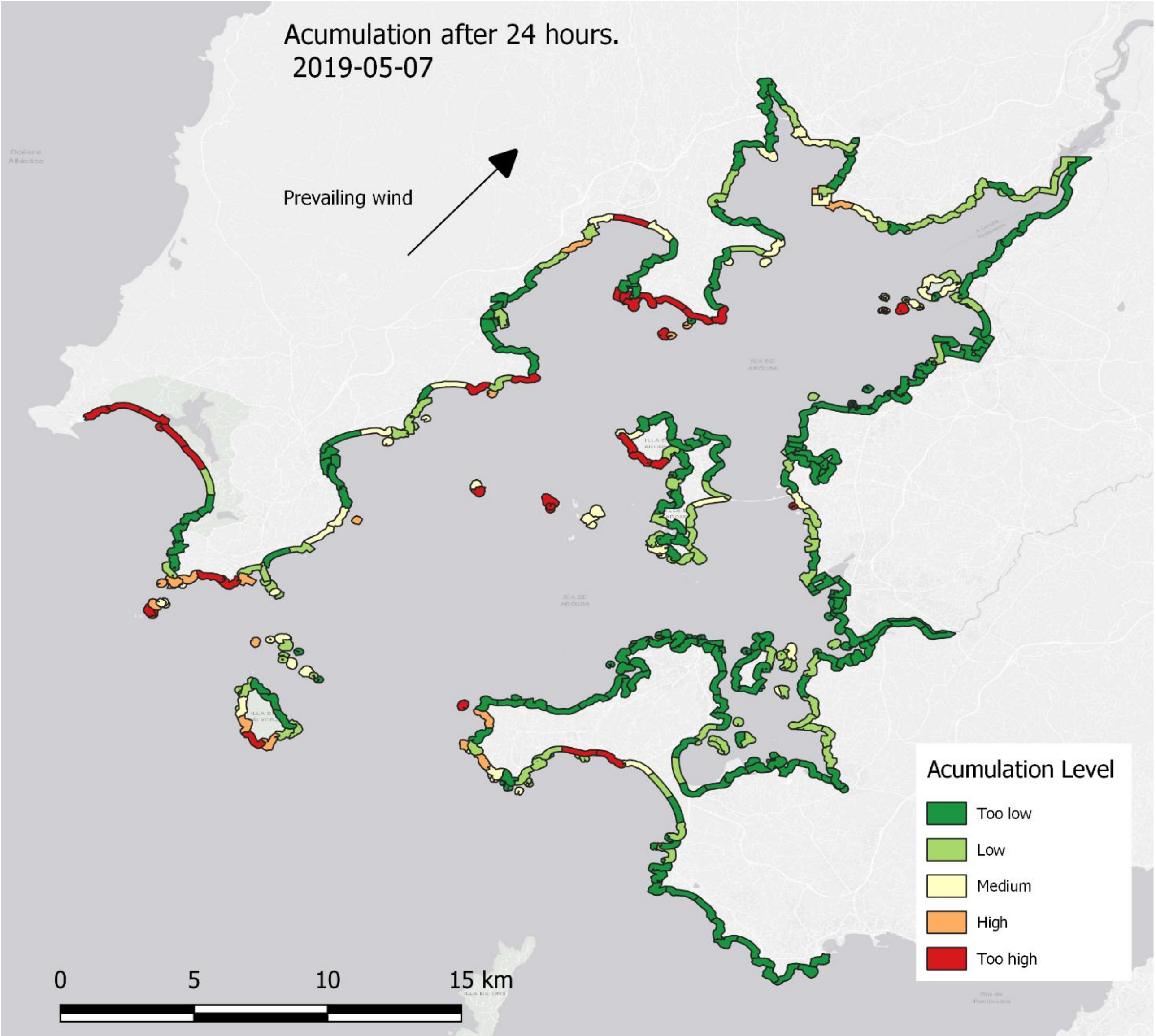


Fig. 9. Accumulation segments after 24 hours for the day 07-05-2019, corresponding to a situation with a prevalent SW wind.

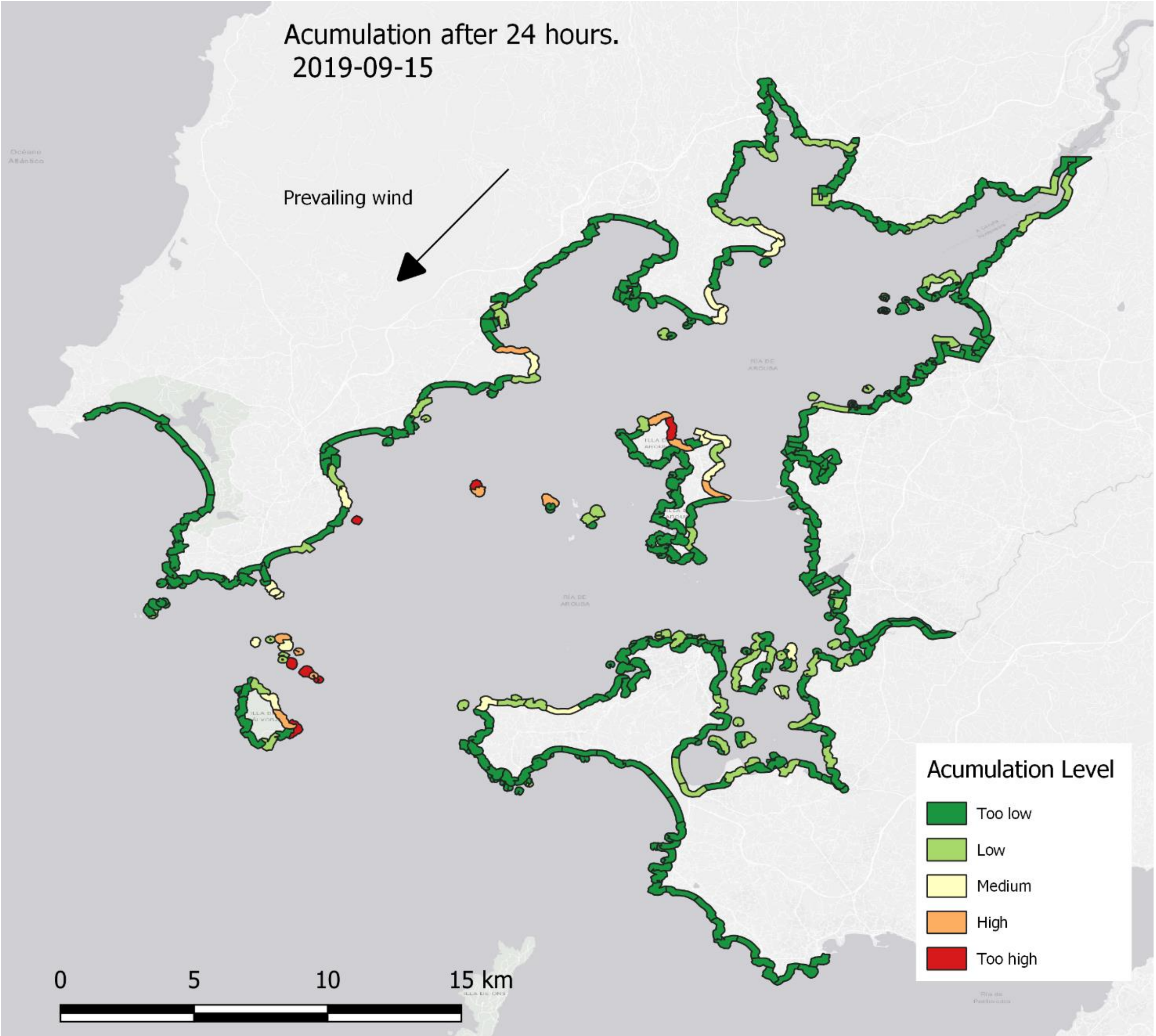


Fig. 10. Accumulation segments after 24 hours for the day 15-09-2019, corresponding to a situation with a prevalent NW wind.

With the intention of revealing those areas that due to their geographical position and their usual ocean-meteorological conditions, tend to accumulate floating litter systematically, becoming accumulation zones, the number of days in which the segments reach the maximum accumulation after 24 hours (map of maximums, from now on) and the average value of beached particles in each segment (average map, from now on) have been calculated. Both have been presented in the following maps:

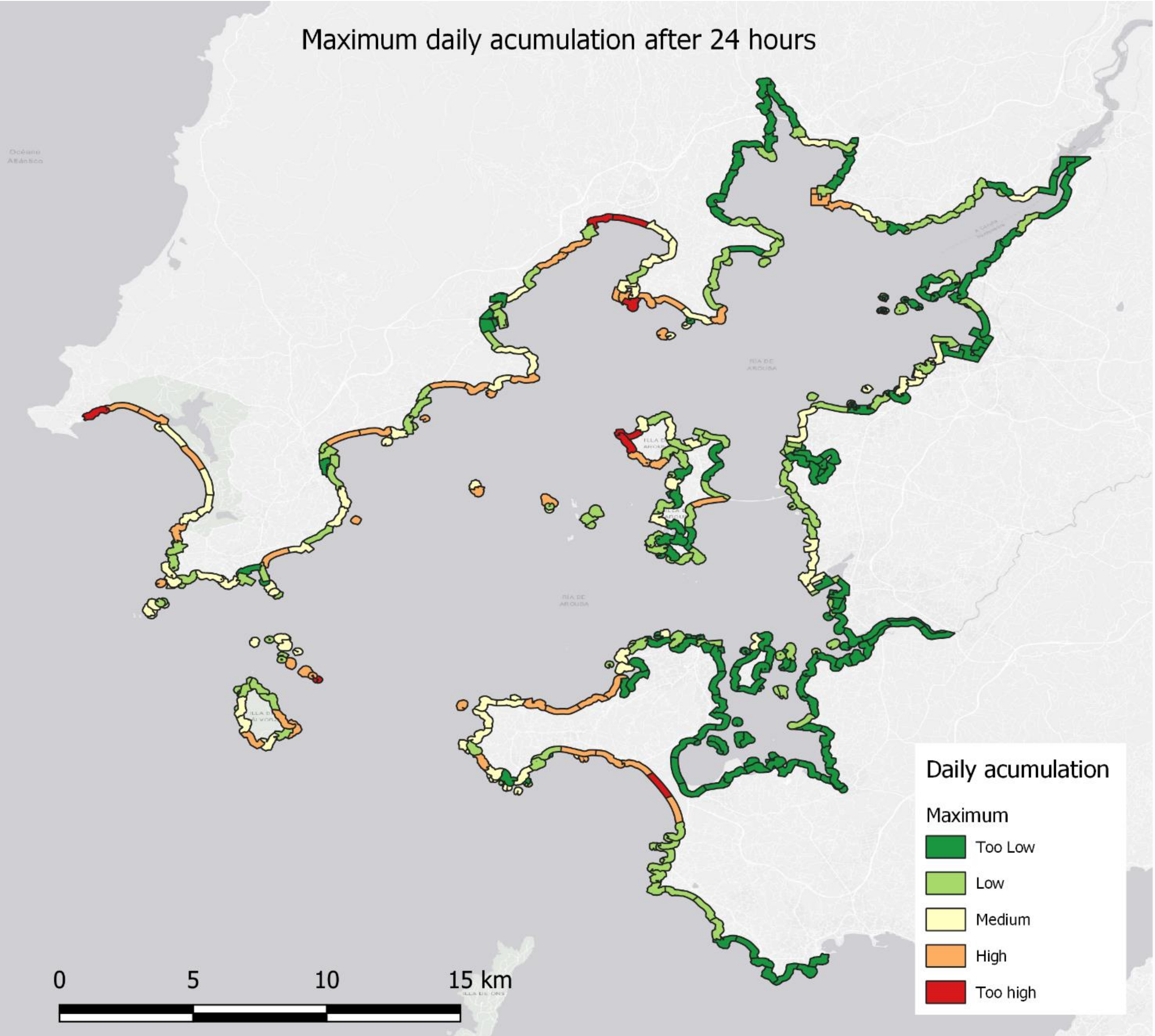


Fig. 11. Number of days in which the segments have been the maximum accumulation after 24 hours, from Oct. 2018 - Oct. 2019 (maximums).

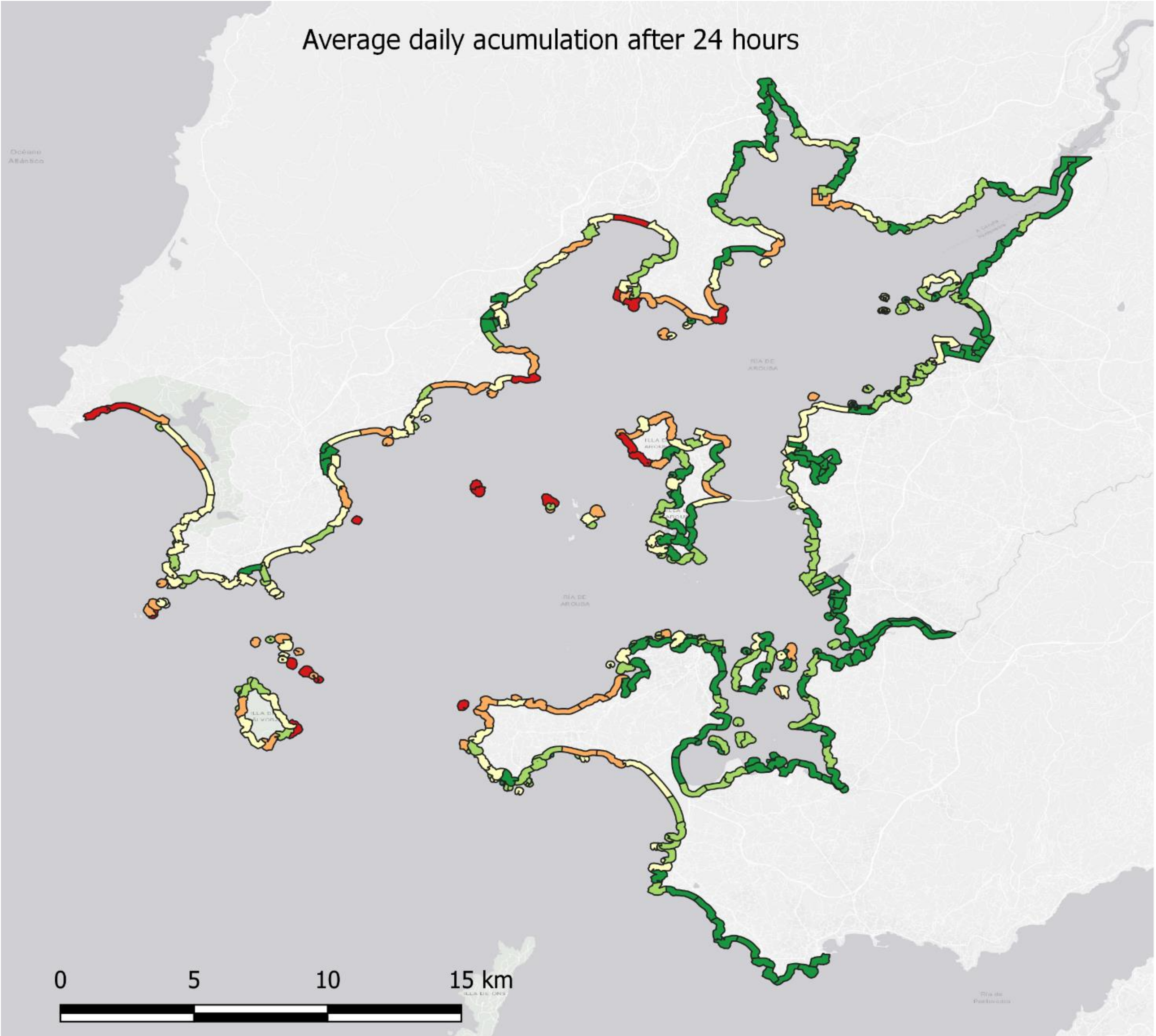


Fig. 12. Average accumulation in 24 hours during Oct. 2018 – Oct. 2019 (average).

These pictures show that, the map of maximums corresponds, without being the same, with areas that are in the high or very high range of the table of averages.

The difference between the map of average and maximums in the rest of the zones, denotes that the maximums of accumulation are always obtained in certain areas and are not equally distributed along the ria. These specific maximums correspond to specific ocean-meteorological situations, to which that area is more exposed, however, this does not mean that it is an area with a clear pattern of accumulation of marine litter.

To find out which are those segments that are continuously receiving marine litter even without reaching those maximum levels, the calculation of an accumulation threshold is proposed. The calculation of this threshold is done through the 95th percentile, calculated on the distribution of the particles in each of the modelled days. Those segments receiving particles above this threshold are marked as accumulation zones. In this way we select the segments that accumulate the most each day, regardless of the number of particles. Analysing how many times each segment is marked, we can determine if the segment is an accumulation area or not. The results are shown in the following map (named p95, from now on):

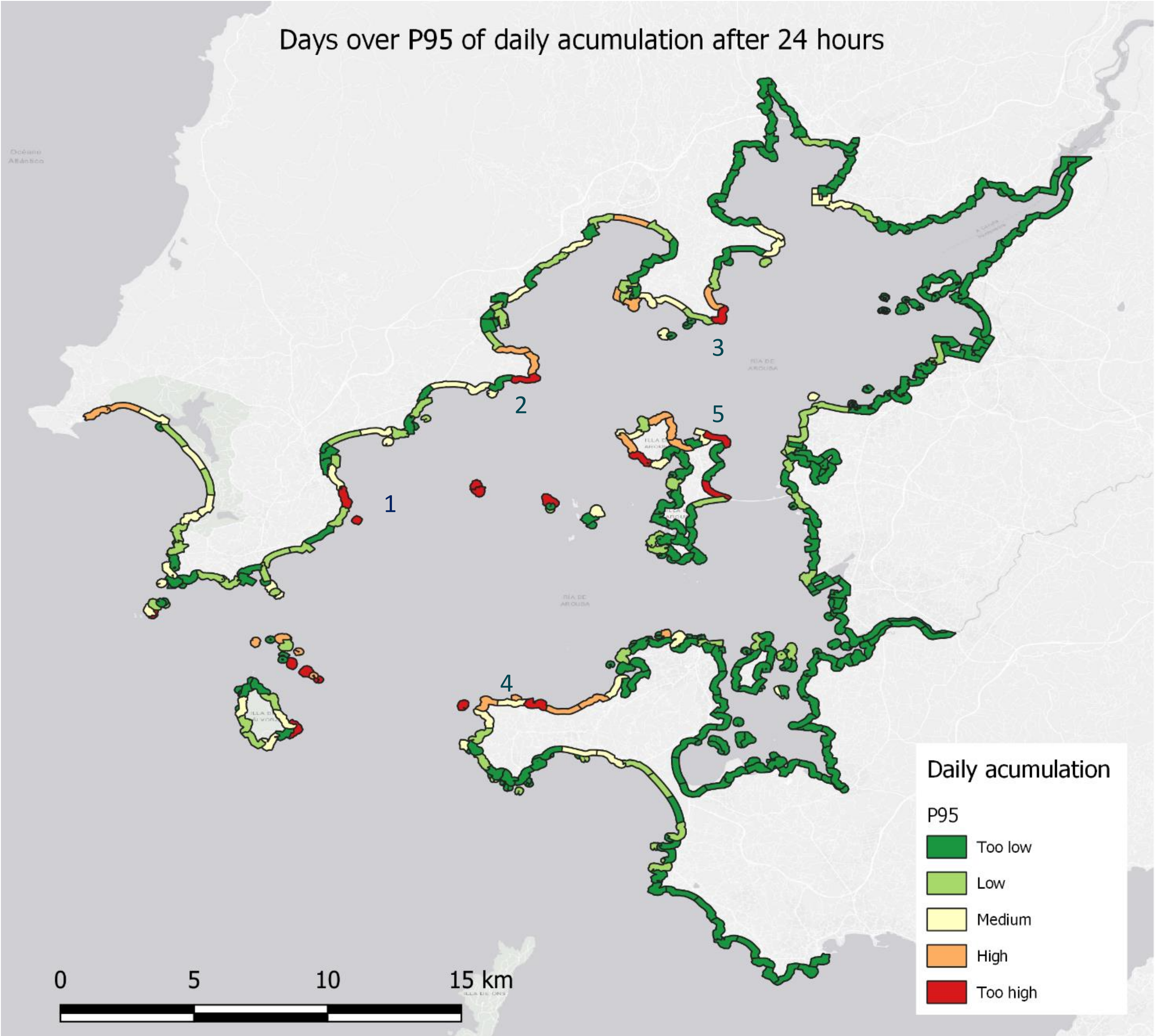


Fig. 13. Number of days when the daily accumulation exceeds the 95th percentile during Oct. 2018 – Oct. 2019 (p95). Numbers explained in the text.

As these last pictures show, the new map does not exactly match the maximums map. The new red and orange segments that appear now and did not appear on the map of maximums denote those areas that, usually accumulating, did not reach the maximum. On the contrary, areas that are not in red now, but were on the map of maximums are marking the sporadic character of a large accumulation.

In conclusion, there are zones with a trend to accumulate throughout the year, regardless of the emission and the situation. These are concentrated on the capes and points (numbers on p95 map) on the northern margin, such as Touro (1) in Ribeira, Cabío (2), Punta do Chazo(3) in Cabo de Cruz. On the southern margin, the largest accumulation zone is concentrated in the extension to the west of Meloxo (4), on O Grove peninsula. Regarding the islands, all of them accumulate, especially the area north of the Illa de Arousa (5) , but this will be seen in detail in the following section.

5.2. Illa de Arousa (Arousa Island)

The following section presents in more detail the results of the same modelling on the coast of the Illa de Arousa.

The Illa de Arousa is an island in the middle of the ria with a coastline cut by large sandy areas, marshes, and rocky coves. It is also the most populated island of those that are inhabited in Galicia with a population in 2019 of 4,926 inhabitants and that has 7 km^2 of surface. The fact that it is an island means that its coast is exposed to the four quadrants, being the north and west those that are in the main channel of the Ría de Arousa.

Marine resources are its main source of income, highlighting the mussel harvesting sector, on foot and on boat shellfishing, in addition to other minor fishing gear. So, there exists an interest to carry out a specific marine litter hotspot mapping for this island, focusing on the distribution of them and their correlation to meteorological conditions.

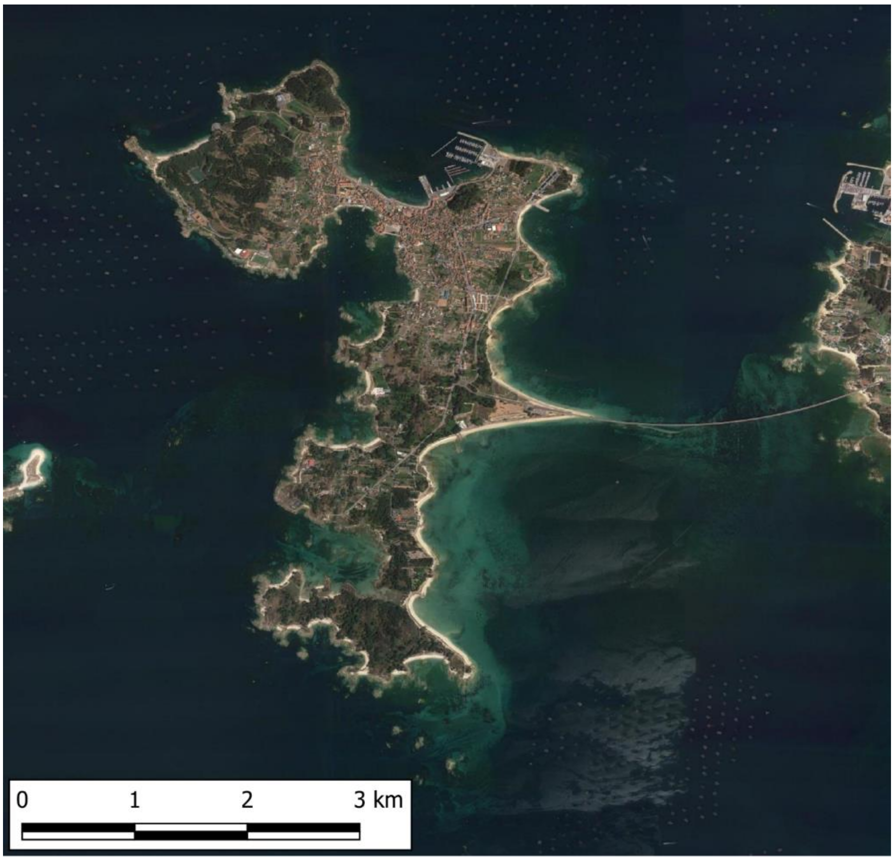
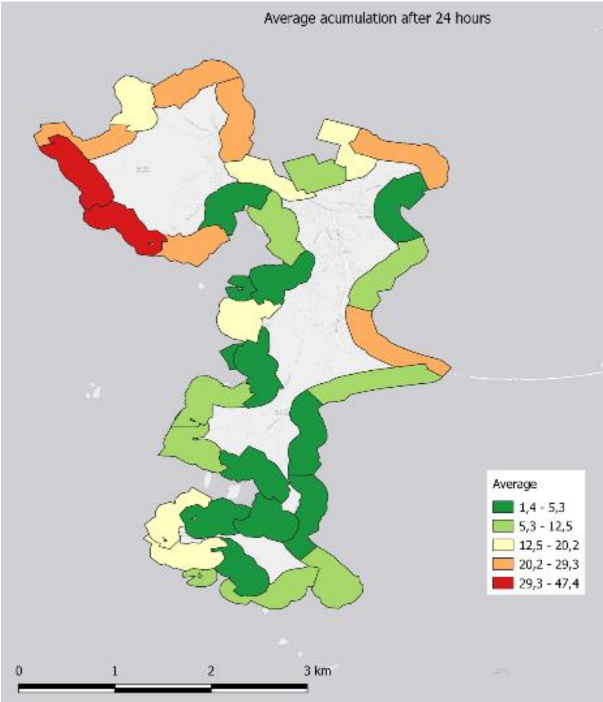
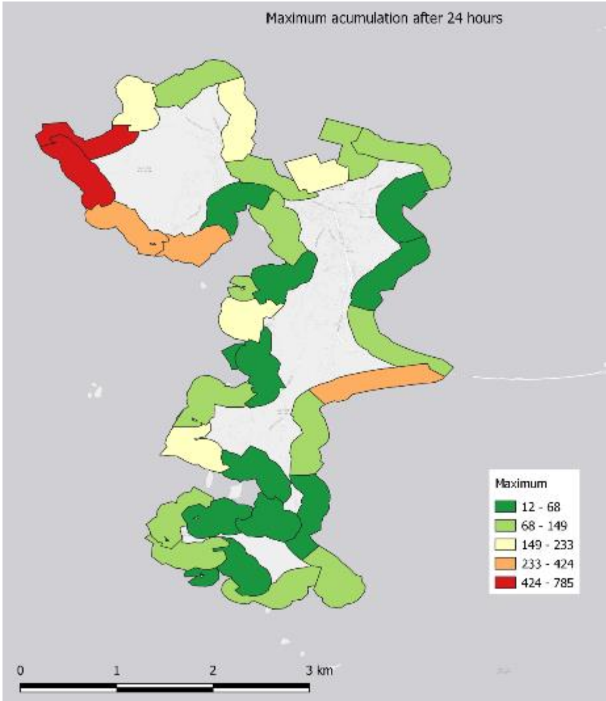


Fig. 14. Satellite image of the Illa de Arousa. It also shows some mussels rafts in polygons.

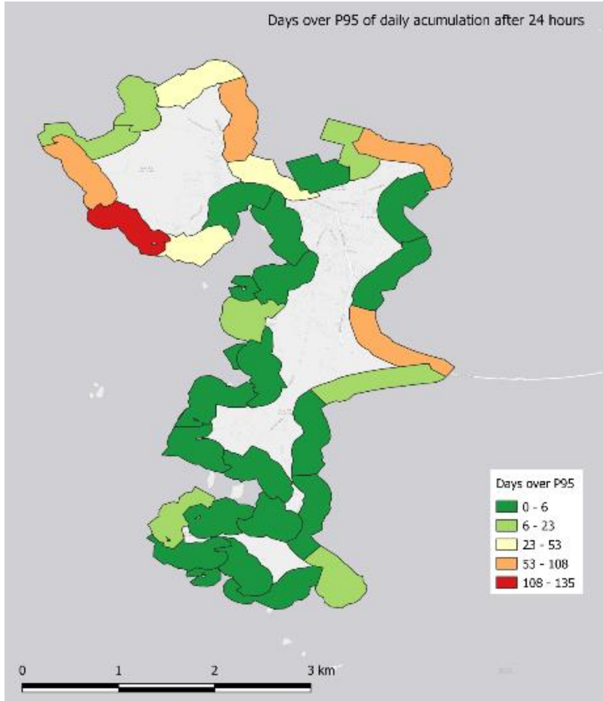
As in the Ría de Arousa, the segmentation of the coastline with the various statistics has been represented: average accumulation in 24 hours (average map), number of days in which the segments were the maximum (maximums map) and number of days in which the segments exceeded the 95th percentile (p95 map).



Average accumulation in 24 hours during Oct. 2018 – Oct. 2019



Number of days in which the segments have been the maximum after 24 hours, since Oct. 2018 - Oct. 2019



Number of days when the daily accumulation exceeds the 95th percentile during Oct. 2018 – Oct. 2019

Fig. 15. Representation of the various statistics applied to the segments of the Illa de Arousa

As can be seen in the maps, the southern area of the island is the one that reflects the least affectation of the accumulations in any of the three statistics. The peninsula in the north-west Illa de Arousa is penalized in all indices, although in a different way. The north-eastern part of the island and the ism that joins the mainland is also an area of accumulations.

For a better perception of how the accumulations are distributed in the Illa de Arousa according to the situations, as well as the investigation of possible patterns in the distribution of accumulations, the segments of the island have been numbered from the NW end and clockwise, arranging the accumulation of each of them over time in a heatmap. This heatmap would reflect the temporal distribution of litter accumulation along the island's coast. Areas with a similar level of accumulations during certain periods could be correlated with a disposition and/or common cause that forced that distribution in that period.

The following map shows the segments used in the Illa de Arousa and their numbering, which corresponds from 1 to 35 clockwise:

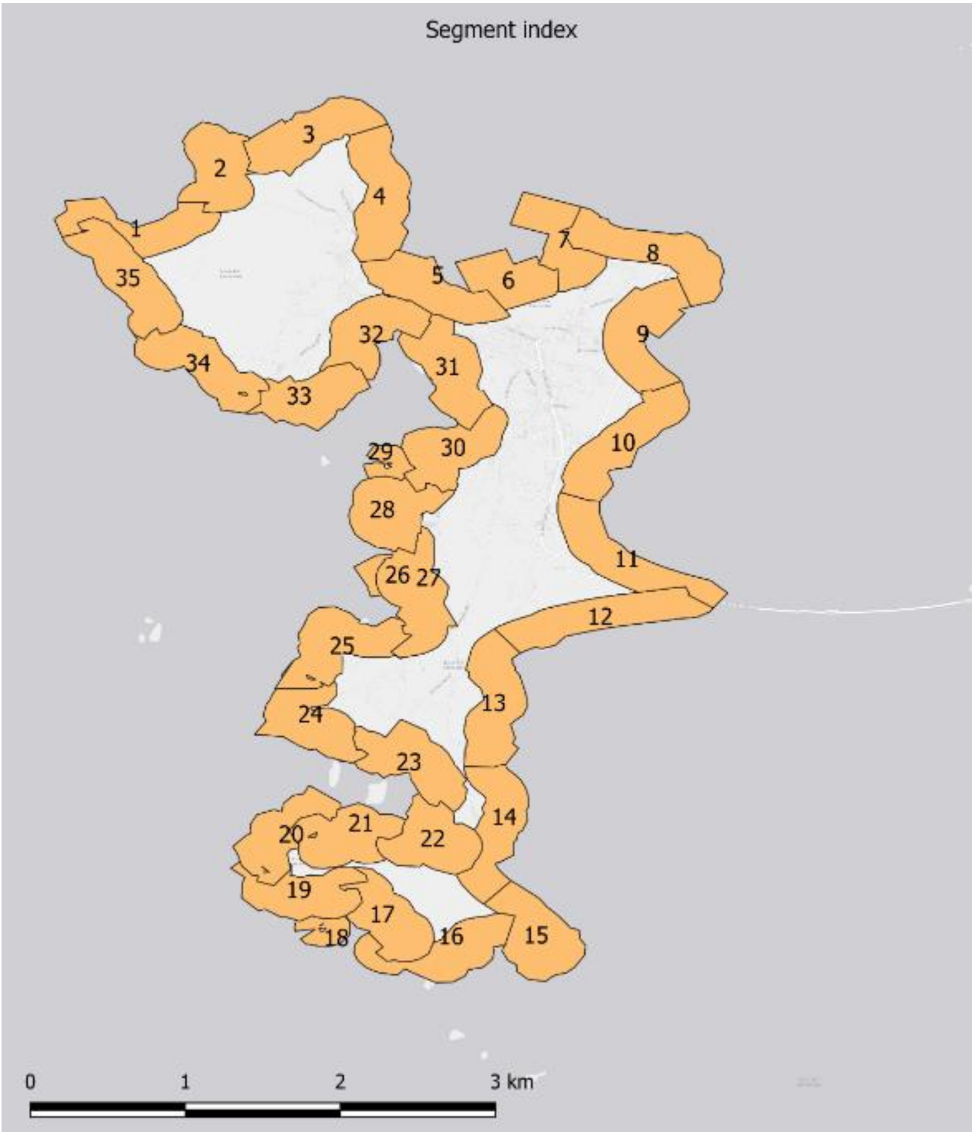


Fig. 16: Segments of the coastline of the Illa de Arousa and their numbering.

The following figure depicts the number of particles accumulated in each segment according to the day of the simulated year. The date is represented in the abscissas and the segment number in the ordinates. The colour indicates the number of accumulated particles. This type of representation allows us to discover, as expected, a series of patterns or behaviours in the accumulation of particles that are directly related to certain specific ocean-meteorological conditions.

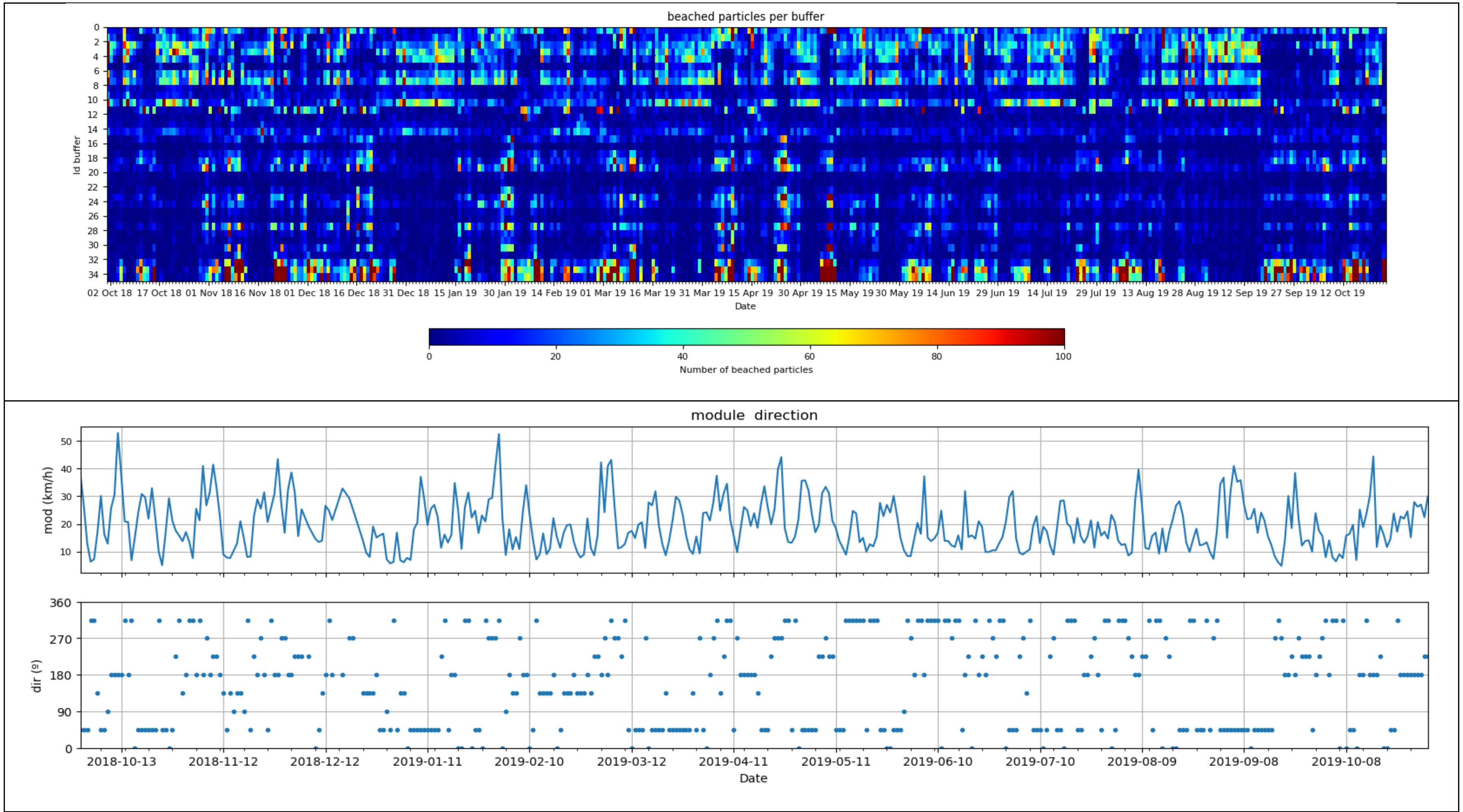


Fig. 17: Heatmap of the results of the modelling of the accumulation in the Illa de Arousa in the period Oct. 2018- Oct.2019 (top); Module and direction of the wind measured in the meteorological station of Sálvora belonging to MeteoGalicia (bottom).

This type of representation allows us to discover a series of patterns or behaviours in the accumulation of particles in the Illa de Arousa throughout the year. For this, the heatmap has been represented along with the time series of the module and wind direction data measured by the meteorological station located on the island of Sálvora belonging to MeteoGalicia. The correlation between wind situations (measured) and different accumulation patterns (simulated) can be checked. The heatmap shows large blue squares in the low part of it (from segment 15 to 32), related to NE winds. When the wind has an S component, the situation is precisely the opposite, accumulating litter in the tips and areas exposed to this wind.

In addition, looking at specific segments, the following stand out among these:

Segments 34, 35 and largely 33, corresponding to the south face of the NW peninsula of the Illa de Arousa are the ones that accumulate the most. This is already indicated by the above statisticians.

The following elements that stand out are the corresponding ones that correspond to the segments of the N face of the Illa de Arousa. It should be noted that element 6 that is at the bottom of a bay has a low level of accumulation. This behaviour, which is due to the model's inability to resolve near-shore dynamics at high resolution, as well as the way the model counts particle accumulation, is possibly contrary to reality. The same can happen in other types of segments that are protected at the bottom of a bay. These places, which are potentially litter hotspots due to being a deposition zone, usually do not accumulate in the model, which only collects the exposed areas and therefore with the potential to impact the particles.

Sections 11 and 12 corresponding to the beaches of the isthmus also stand out.

On the west side to the south of the peninsula, sections 19, 20, 23, 24, 25, 27 and 31 are sections with moderate level of accumulation.

Regarding the time distribution, several behaviours are seen: The main one is the absence of particles in the sections of 12 to 35, all with exposure facing south (also sections 6, 9 and 10) and generalized accumulation in the rest. If compared to the wind direction, these situations are clearly from the NE wind.

A situation very similar to the previous one is the one that occurs with a similar absence, although minor, of accumulation in all the sections except for 34 and 35. NW wind prevails in these situations.

For a greater understanding, the accumulation situations corresponding to the atmospheric situations that have already been reported when describing the Ría de Arousa as a whole, have been represented: prevailing wind situations of W, SW and NE.

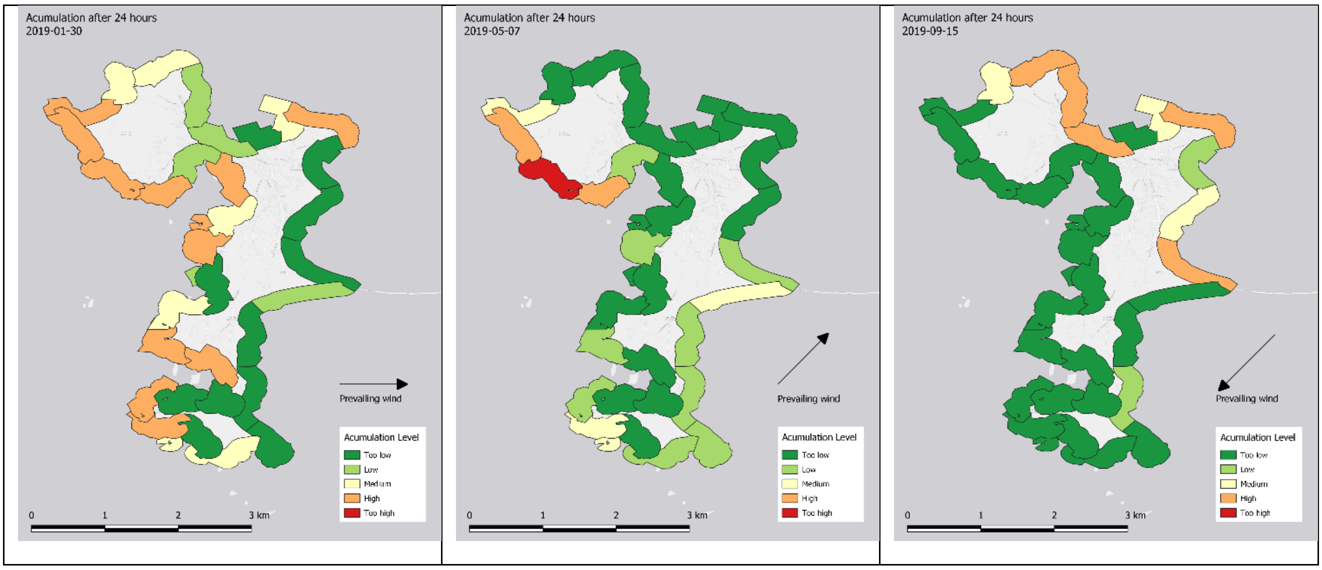


Fig. 18. Accumulation segments after 24 hours for the day30-01-2019,07-05-2019 and 15-09-2019, corresponding to a situation with a prevalent wind of W, SW and NW respectively.

6. MODELLING Vs MONITORING

The following section shows an example of comparing the results of the sampling carried out in *work package 5: Monitoring and Data Management* with the results obtained through the modelling of litter dispersion.

Fig. 19 shows the level of marine litter accumulation on the beaches of the Ría de Arousa (with a zoom to the Illa de Arousa) from the samples carried out in *work package 5: Monitoring and Data Management*. A description of the figure can be found in the report made in that package, entitled "Analysis of strategies for the monitoring and evaluation of accumulations of marine litter on the coast". (CleanAtlantic, 2021)

This figure is compared with the map called p95, which shows the number of days in which the accumulations exceed the threshold of the 95th percentile in each segment, as explained in section 5.1 of this document.

The very high levels of accumulation of the samples coincide with areas of great accumulation indicated by the simulation, except in the case of points 30 and 29. Likewise, both low levels from monitoring and sampling are very similar, except some differences along Illa de Arousa. However, the similarity is higher to the discrepancies, especially taking into account that the magnitudes in both sampling and modelling are indicators.

A more comprehensive comparison between the results of garbage sampling and its modelling can be found in the paper: *"Comparing mussel pegs observational accumulations with MOHID-Lagrangian* *simulations in the Ría de Arousa”* (in progress).

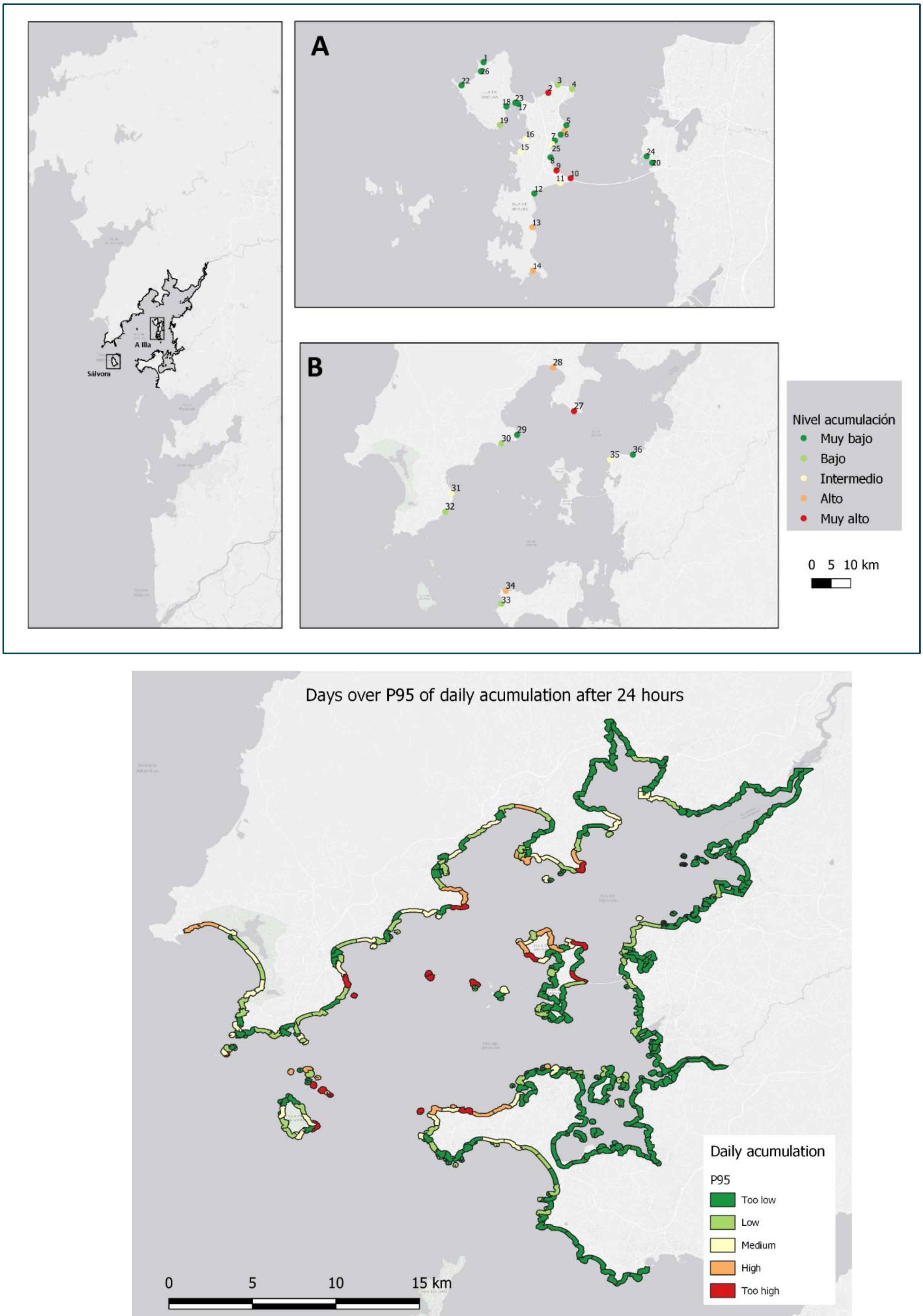


Fig. 19. Above: Level of accumulation from monitoring (WP5) in: A) Illa de Arousa, B) Ría de Arousa. Below: Accumulation level from the p95 map obtained by numerical modelling.

7. CONCLUSIONS

The report uses numerical modelling for the detection of areas of marine litter accumulation of on the coast at the local scale, as well as its possible correlation with ocean-meteorological situations.

The Ría de Arousa has been used as a benchmark of modelling at the local scale since the part of the monitoring of marine litter within the *work package 5: Monitoring and Data Management* was carried out in this estuary. In addition, a specific study has been carried out in the Illa de Arousa, an island located in the same estuary.

The results of the Lagrangian modelling of continuous emissions of particles over a whole year have been obtained. With these data and after the segmentation of the coast, daily accumulation data have been simulated for 24 hours.

To find out the areas with the highest probability of accumulation, several statistics have been used such as the mean accumulation or the number of times that a segment ranks the maximum accumulation. However, the map with the greatest significance corresponded to the number of days in which a segment exceeded a certain accumulation threshold. This threshold was set at the 95th percentile.

It has been found that the distribution of accumulation along the estuary is correlated with the different prevailing winds, pilling up more litter in the bays and capes facing them.

With the intention of investigating patterns in the spatial and temporal distribution of the accumulation of mussel pegs along the Illa de Arousa, a heatmap of the modelled accumulations with respect to time has been represented. Several configurations are seen in the distribution, which correlate very well with the direction of the measured wind.

In the last section, the p95 map has been compared with the map of the distribution of litter resulting from the samples carried out in work package 5. Despite the simplicity of the modelling (simplified coastline, constant beaching probability along the coast, small-scale processes in the lateral boundary layer neglected, influence of waves lack, etc.), there is a high agreement between simulation and sampling. An extended comparison between monitoring and modelling is described in the paper: *"Comparing mussel pegs observational accumulations with MOHID-Lagrangian simulations in the Ría de Arousa"* (in progress).

Thus, this study has demonstrated the possibility of using numerical modelling, even in a very simplistic approach, to locate areas where marine litter can accumulate on the coast. In addition, the use of different statistics measurements and other kind of plots, as heatmap, are useful tools to correlate these marine litter pilled-up areas with meteorological conditions.

To finish just add possible lines of future work:

- Increase the complexity of the simulations with the inclusion of different indices that account for the different morphology of the coast and small-scale phenomena that produce beaching.
- Objectification of accumulation patterns through unsupervised machine learning algorithms.
- For the comparison of modelling with sampling results a quantifiable measure of "accumulation" is needed.

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