Adaptation plan/design of interventions/pilot interventions on Sacca di Goro in the Po River Delta

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Abstract

The climate change is a priority issue that involves science, society and politics. In recent years, there has been increasingly strong scientific evidence of the extent of global warming and a growing awareness that it is caused by greenhouse gas emissions deriving from the use of fossil fuels and unsustainable use of land and natural resources. At the same time, people have become more aware of the need to implement global policies to drastically reduce emissions and to mitigate rising temperatures (mitigation), as well as adaptation strategies to limit the impact of climate change that will occur in any case. International milestones on these fronts include the 2013 EU Strategy on Adaptation to Climate Change and, more recently, the 2015 Paris Agreement. In 2015, the Emilia-Romagna region signed the Under2 Memorandum of Understanding, which commits the Region to an 80% reduction of its emissions by 2050, and defined the Mitigation and adaptation strategy for the region. This document has been produced in the framework of the INTERREG Italy – Croatia CHANGE WE CARE Project and it contains propaedeutic information on measures and intervention priorities for freshwater, wetland habitat preservation in the Sacca di Goro area in the Po Delta area in order to climate change adaptation. The measures included here are the results of the LIFE AGREE - coAstal laGoon long teRm managEmEnt (LIFE13 NAT/IT/000115) and of the participatory process which took place during the Change We Care project. Starting from the information obtained by WP3 and WP4, the general objective of this document is the increase of the adaptation ability of the natural, social and economic systems of Sacca di Goro to the impacts of climate change. The partecipatory process identified 9 projects of interventions to contrast the climate change: 1) sand escavation 2) diversion barrier, 3) technical working group, 4) fundraising for climate change, 5) nice to meet you, mrs anguilla! >>> anguilla at 360°, 6) testimonials for the awareness of citizens and network with associations, 7) establishment of the Sacca di Goro observatory starting from a coordinated and interrelated database, 8) Bassunsin's hydraulic restoration and 9) contrast of the decrease of Manila clam recruitment.

1. Foreword

This document has been produced in the framework of the INTERREG Italy – Croatia CHANGE WE CARE Project. CHANGE WE CARE fosters concerted and coordinated climate adaptation actions at transboundary level, tested in specific and representative pilot sites, exploring climate risks faced by coastal and transitional areas contributing to a better understanding of the impact of climate variability and change on water regimes, salt intrusion, tourism, biodiversity and agro-ecosystems affecting the cooperation area. The main goal of the Project is to deliver integrated, ecosystem-based and shared planning options for different problems related to climate change (CC), together with adaptation measures for vulnerable areas, to decision makers and coastal communities. Additional information and updates on the CHANGE WE CARE can be found at https://www.italy-croatia.eu/web/changewecare .

2. Aim and content of the document

Climate change is one of the most relevant challenges on a scale global. Southern Europe and in particular the Mediterranean area will have to face in the next decades significant impacts of climate change linked to the rise in temperatures, the increase in the frequency of extreme events (drought, heat waves, intense precipitation) and the reduction and change in the rainfall regime on a seasonal or annual scale. This document contains propaedeutic information on measures and intervention priorities for freshwater, wetland habitat preservation in the Sacca di Goro area in the Po Delta area in order to climate change adaptation. The measures included here are the results of the LIFE AGREE - coAstal laGoon long teRm managEmEnt (LIFE13 NAT/IT/000115) and of the participatory process which took place during the Change We Care project. Starting from the information obtained by WP3 and WP4, the general objective of this document is the increase of the adaptation ability of the natural, social and economic systems of Sacca di Goro to the impacts of climate changes.

3. CHANGE WE CARE project and the objectives of WP5

CHANGE WE CARE fosters concerted and coordinated climate adaptation actions both at Pilot Sites and transboundary level. The project explores climate risks faced by coastal and transition areas contributing to a better understanding of the impact of climate variability and change on water regimes, salt intrusion, tourism, biodiversity and agro-ecosystems affecting the cooperation area.

WP5 main objective is the preparation of climate change Adaptation Plans in Pilot Site, containing the assessment of present state and of foreseen scenarios, the indication of measures and intervention priorities, monitoring strategies and jurisdictional references.

The Planning options presented are the result of participated processes involving local authorities and stakeholders. The Adaptation Plans include actions and interventions, where appropriate, indicating the timeline and the financial strategy for the implementation of the envisaged activities and Monitoring Plans

(taking stock also of WP4 indications) for observing and ensuring the durability of the project outcomes and of the implementation of the Plan.

4. Summary of strategies of mitigation and adaptation for climate change

4.1 European Union

In December 2019, the European Commission published the European Green Deal, which sets out the means for achieving climate neutrality. Agreement was reached in spring 2021 on the **European Climate Law (Regulation (EU) 2021/1119)**. The European Climate Law sets a legally binding target of net zero greenhouse gas emissions by 2050. The EU Institutions and the Member States are bound to take the necessary measures at EU and national level to meet the target, taking into account the importance of promoting fairness and solidarity among Member States. The European Climate Law includes measures to keep track of progress and adjust our actions accordingly, based on existing systems such as the governance process for Member States' national energy and climate plansSearch for available translations of the preceding, regular reports by the European Environment Agency, and the latest scientific evidence on climate change and its impacts. The European Climate Law aims to 1) set the long-term direction of travel for meeting the 2050 climate neutrality objective through all policies, in a socially fair and cost-efficient manner, 2) set a more ambitious EU 2030 target, to set Europe on a responsible path to becoming climate-neutral by 2050, 3) create a system for monitoring progress and take further action if needed, 4) provide predictability for investors and other economic actors, 5) ensure that the transition to climate neutrality is irreversible. As part of the Green Deal, the Commission has also published a proposal for a **European Climate Pact**, which aims to involve all citizens and stakeholder groups in climate work.

On 24 February 2021, the European Commission adopted its **new EU strategy on adaptation to climate change** (COM/2021/82 final). The new strategy sets out how the European Union can adapt to the unavoidable impacts of climate change and become climate resilient by 2050. The Strategy has four principle objectives: to make adaptation smarter, swifter and more systemic, and to step up international action on adaptation to climate change. Adaptation actions must be informed by robust data and risk assessment tools that are available to all – from families building homes, businesses in coastal regions and farmers planning their crops. To achieve this, the strategy proposes actions that moves the frontiers of knowledge up to adaptation strategy so that we can gather more and better data on climate-related risks and losses, and enhance Climate-ADAPT as the European platform for adaptation knowledge (Figure 1) .

Figure 1. Climate-Adapt Adaptation Policy Cycle from Study on Adaptation Modelling

The effects of climate change are already being felt, and so we must adapt more quickly and comprehensively. The strategy therefore focuses on developing and rolling out adaptation solutions to help reduce climate-related risk, increase climate protection and safeguard the availability of fresh water. Finally, EU climate policy steers both regional and national efforts to mitigate and adapt to climate change. In the next paragraphs a brief summary of national and regional strategies are presented.

4.2 Italy

Starting to 2010, the Italian Ministry of the Environment and Land and Sea Protection (MATTM) included climate change adaptation measures in some strategic documents as the case of the “National Strategy for Biodiversity "and the preparatory documents of the" Strategy for the marine environment". Other ministries have addressed the issue of climate change adaptation in specific sectors, as for example the Ministry of Agricultural, Food and Forestry Policies (MIPAAF) which has published the White Paper "Challenges and opportunities of rural development for mitigation and adaptation to climate change".

In 2015, in order to pursue a strategic approach between the various sectors and government levels, a **National Strategy for Adaptation to Climate Change** was defined by MATTM (**SNAC**, MATTM 2015 Directorial Decree No. 86 of 16 June 2015). The National Strategy has identified the main impacts of climate change on environmental resources and on a set of relevant socio-economic sectors at national level and has indicated for each of them the first proposals for adaptation actions to these impacts. The general objective of adaptation is divided into four specific objectives concerning:

1. The containment of the vulnerability of natural, social and economic systems to the impacts of climate change;
2. The increase in the ability of these ecosystems to adapt;
3. Better exploitation of opportunities;
4. The coordination of actions at different levels.

In 2018, subsequently to the National Strategy, the **National Plan for Adaptation to Climate Change (PNACC)** was defined. This Plan is aimed at implementing the National Strategy by updating and better specifying its contents for operational purposes. Its main objective is to update the reference framework on climate change adaptations. Compared to the Strategy, the National Plan is configured as a more operational tool aimed at supporting national, regional and local institutions from a cognitive point of view in defining their own sectoral and local adaptation paths. In particular, the Plan identifies:

- reference climate scenarios at the district / regional scale;
- sector impacts and vulnerabilities;
- sector adaptation actions;
- roles for the implementation of actions and adaptation measures as well as coordination tools
- between the different levels of government of the territory;
- estimate of the necessary human and financial resources;
- indicators of the effectiveness of adaptation actions;
- methods for monitoring and evaluating the effects of adaptation actions.

4.3 Emilia-Romagna region

In December 2015, the Emilia - Romagna Region approved the path towards a unitary mitigation and adaptation strategy for climate change with Council Resolution 2200/2015 promoted and directed by the Impact Assessment and Environmental Sustainability Promotion Service.

The **Regional Adaptation and Mitigation Strategy** aims to provide an overall reference framework for the regional sectors, administrations and organizations involved, also to assess the implications of climate change in the various sectors concerned. In particular, the unitary mitigation and adaptation strategy intends to:

- enhance the actions, Plans and Programs of the Emilia-Romagna Region in terms of mitigation and adaptation to climate change through the recognition of the actions already in place at the regional level for the reduction of climate-altering emissions and adaptation to climate change;

- contribute to identifying further measures and actions to be implemented for the different sectors, in relation to the existing sector plans, helping to harmonize the regional territorial planning with reference to the mitigation and adaptation objectives;
- define the monitoring indicators (among those already in use by the various plans both for the SEA and for the operational programs of the Structural Funds 2014-2020);
- define and implement a regional and local policy implementation observatory;
- identify and promote a participatory and involvement path of local stakeholders to integrate the theme of adaptation and mitigation into all regional sectoral policies;
- coordinate with local initiatives (municipal and union of municipalities) in relation to the Action Plans for sustainable energy and climate of the Covenant of Mayors (SECAP) and local adaptation plans.

Long-term goals for climate change (2030 - 2050):

- Compliance with the agreements signed with Under2MoU
- Respect for the objectives of the European Union
- Reduction of potential damage deriving from climate change for both territories and citizens.

Short-term ambitions for climate change (2020-2025):

- Updating of sector planning / programming by introducing and / or strengthening mitigation and/or adaptation actions
- Greater integration between planning and multilevel governance also through support for the development of local adaptation plans
- Activation of monitoring on the effectiveness of actions at a global and transversal level and continuous mapping of territorial vulnerabilities
- Development of a culture of 'climate risk' in the design of public works (sizing and innovation) and in stakeholders.

5. The Po Delta area

The Po Delta area (Figure 2) is the the final sub-basin subtending the entire hydrographic basin of the Po River, and it develops as a flat region with an area of 472.55 km2 (1.6 % of the total hydrographic basin), (Management plan of the hydrographic district del Fiume Po, State of water resources, 2016).

In this area, the Po River is divided into several branches: Po di Levante, Po di Maistra, Po di Pila (with the mouths of Scirocco and Tramontana), Po di Tolle, Po di Gnocca in the Veneto Region and Po di Goro in the Emilia-Romagna Region.

This is an area of recent formation, in continuous evolution, due to the contribution of sediments by the Po River. The current morphology is the result of a long history of reclamation and hydraulic interventions. In fact, most of the territory is below sea level and is maintained emerged from the continuous work of various pumping plants. The embankments along the branches of the Po, together with the lagoon banks,

constitute the important defence line of this fragile territory, both against the floods of the Po and against of the effect of rising sea. From an environmental point of view, the Po Delta, with its interconnection of aquatic and land habitats, of fresh and salt water, represents a particularly important environmental and ecological system.The territory is mainly agricultural and consequently the population density is quite low, with urban centers consisting of small villages, hamlets and isolated houses.

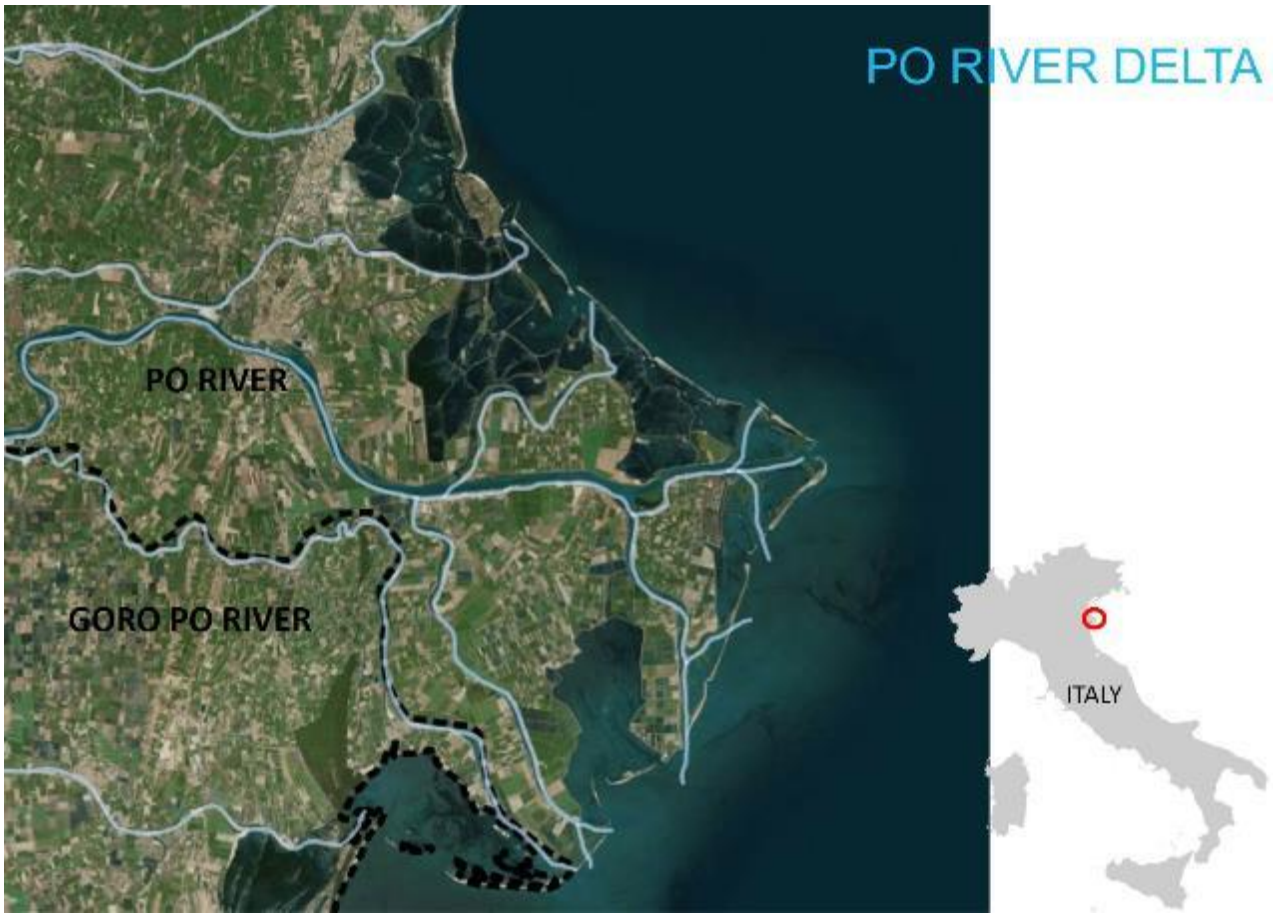

Figure 2. Po Delta area with the Po River and its breaches (blues lines). Dashed line is the regional boundary between Veneto Region (northern part) and the Emilia-Romagna Region (southern part).

4.1 The Sacca di Goro in the Po Delta Area

The Sacca of Goro (Figure) is a shallow-water lagoon, with an average depth of approximately 1.5 m. It receives freshwater inputs from the Po di Goro (the Southern Po River branch), which is bordering the lagoon on the north-east and from the Po di Volano, an artificial canal laying in the ancient bed of a former Po River branch. The Po di Volano Canal is hydraulically regulated by the Local Water Authority, the

Consorzio di Bonifica della Pianura di Ferrara, and is the quantitatively most important freshwater input to the western and central part of the Sacca di Goro.

The Sacca di Goro suffers from many issues related to climate change such as loss of biodiversity, erosion of the barrier island systems, salinity rise in the water of lagoon and sediment deposition. Therefore, there is the urgent need to compensate sedimentation and erosion through effective plan for engineering intervention and wetland preservation, protect the lagoon ecosystem and balance it with aquaculture practices, and reduce the flood and erosional risk.

The current physical structure of the Sacca di Goro is the result of both natural processes and anthropic interventions, such as land reclamation of the bordering managed lagoons, locally called “valli”, once used for extensive aquaculture. Also completed in the '60s is the realization of impressive embankments for coastal defence. Other works date back to the '90s, as canals' excavation and sectioning, for improving internal navigability, water circulation within the lagoon and strengthening the littoral structures, as the Scannone di Goro, the outer sand bank, which closes the lagoon on the south.

The morphological, hydrological and ecological complexity of the lagoon is associated with the intrinsic natural variability, typical of shallow lagoons with limited interchange with the open sea, which naturally promotes the extreme variation of water circulation and therefore different sedimentary depositional patterns. In the recent, the evolution of the Sacca di Goro is characterized by excessive accretion of the outer sand bank, the Scannone , which has led to the progressive narrowing of the main lagoon mouth. To maintain tidal circulation, several interventions have been made by public authorities and anglers cooperatives, comprising both the recurrent excavation and reshaping of internal submerged canals and sediment removal for widening the lagoon mouth, particularly in the last years. Although necessary and extensive, these interventions were not sufficient to prevent summer dystrophic crises, which occurred in some of the years from 1987 to 2016.

General climatic features characterize the lagoon as cold-temperate, with temperature annual minimum in January and a maximum in July. The average precipitation is less than 600 mm per year. Near the coast rainfall shows a tendency to concentrate in the winter, with little precipitation in spring. In the last 25 years, a significant increase of short-term intense meteoric events has been registered, together with an increase of summer peak temperatures. This trend has not helped the mitigation of eutrophication, dystrophy and mortality of farmed clams, which has been affecting the Sacca of Goro, since the late ‘80s. The blooming of the seaweed Ulva rigida and other species of the genera Enteromorpha and Chaetomorpha and the consequent decomposition and long lasting anoxia have threatened clam farming in the lagoon. Several actions for mitigating eutrophication related phenomena have been promoted and set in practice in the last 40 years, with results the most variable, from almost irrelevant to very promising. Most of the population works directly in the pilot site involved in fishery or in the satellite activities such as in transformation of fish products. However, despite the economic values, the area of Sacca di Goro suffers from low schooling rate and tourism is not adequately developed.

Aquaculture is the main activity present in the Sacca di Goro area, it is a recent phenomenon with the development of the sector in the last 15 years, following the import and rapid spread of the Philippine clam (*Tapes philippinarum*) This diffusion has led to great opportunities of a productive, commercial and social nature: in fact, hundreds of very small companies were born in a short time.

Figure 3. The Sacca di Goro (in violet) in the Po Delta area.

6. Summary of the participatory process for the Sacca di Goro pilot site in the Po Delta Area

The project efficacy it was ensured by sharing visions and guaranteeing collaboration in implementation and future management based on the discussion of scenarios and options with stakeholders involved with the participatory process. The participatory process of the Sacca di Goro in the Po Delta area is detailed in the Deliverables 5.6.1, however the main information are reported also in this paragraph.

6.1 General aim of the participatory process

The participatory process aims to involve the stakeholders of Sacca di Goro to improve the quality of public policies, improve cooperation between stakeholders, improve cooperation between stakeholders and institutions, sharing of strategies and decision practices, jointly address of the problems, improve the dissemination of good practices and decrease the conflicts and increase the transparency of decisions.

6.2 Synthesis of the participatory process

The participatory process in the Sacca di Goro is planned as 3 workshops with stakeholders' target group: 1) fisherman, 2) tourist and economic operators, 3) educational bodies and 4) public bodies for a total of 85 participants. During the first Workshop (**Workshop I**), the working groups identified critical issues in the Sacca di Goro and defined aims to solve them. During the second Workshop (**Workshop II**) technicians of project staff showed to stakeholders the projects selected to answer to the critical issues emerging within the Workshop I. The third Workshop (**Workshop III**) contributed to the awareness of the participants and stakeholders with a presentation dedicated to climate change scenarios with a focus on hydrodynamics and on some specific ecological targets of the Po Delta. Furthermore, the progress of the projects defined in workshop II to solve the critical issues emerged in workshop I, was presented. Furthermore, the commitments have been collected by stakeholder groups to favor the realization of the projects. 9 projects were defined at the end of the participatory process:

- For the **Public bodies and competent agencies** stakeholder group:
  Project 1: SAND ESCAVATION
  Project 2: DIVERSOR BARRIER
  Project 3: TECHNICAL WORKING GROUP TABLE
- For the **Tour operators and other competent operators** stakeholder group:
  Project 4: FUNDRAISING FOR CLIMATE CHANGE
- For the **Educational institutions, and environmental associations** stakeholder group:
  Project 5: NICE TO MEET YOU, MRS ANGUILLA! >>> ANGUILLA AT 360°
  Project 6: TESTIMONIALS FOR THE AWARENESS OF CITIZENS AND NETWORK WITH ASSOCIATIONS
- For the for **Fishermen and shellfish farmers** stakeholder group:
  Project 7: ESTABLISHMENT OF THE SACCA OBSERVATORY STARTING FROM A COORDINATED AND INTERRELATED DATABASE
  Project 8: BASSUNSIN'S HYDRAULIC RESTORATION
  Project 9: CONTRAST OF THE DECREASE OF MANILA CLAM RECRUITMENT

7. Preparatory actions in the Sacca di Goro for the Adaptation Plan of the Po Delta Area

The definition of adaptation strategies and measures for increasing resilience to climate change is one of the most relevant aspect of the collaboration between the river Po delta Park and the Department of Life Sciences and Biotechnology of the University of Ferrara, within the WP5 of the Project "Change We Care" ("Pilot Sites: adaptation strategies and measures for increasing resilience to climate change"). The draft of an Adaption Plan represents one the goals of the Action 5.6 and includes the identification of possible priority interventions in the pilot study site (i.e. the Sacca di Goro lagoon).

7.1 The importance of “Bassunsin” area in the Sacca di Goro

The adaptation strategies encompasses the most relevant contributions emerged along the participatory process, more specifically, during the meetings with institutional and private stakeholders. Such meetings highlighted that the outermost area of the lagoon (named Basunsin), historically the most important site for Manila clam recruitment, on which almost all the production of clams in the lagoon depends, is the most vulnerable zone to climate change. This area is also one of the most important for biodiversity conservation in the whole lagoon. Its vulnerability to climate change was also confirmed by the studies carried out in the previously WPs. In fact, such area is separated from the sea only by a sand bar, which makes it highly prone to the effects of environmental perturbations. Therefore, unlike other areas of the lagoon, a number of peculiar ecological and functional features characterizes the zone named Basunsin as unique and is, therefore, subjected to conservation measures and management regulations that guarantee the sustainable use of biological resources, including manila clam seed.

The Basunsin is located in the central-southern part of the Sacca di Goro lagoon and is the result of a complex geo-morphological evolution. The deposition of sediments, mainly sand, transported by the Po river along an east-west direction, together with a continuous sediment reshaping, caused the partial enclosing of a shallow water body. Consequently, the bathymetry reflects this conformation, with shores on both sides and water depth increasing gradually towards the inner zones, but not exceeding one meter with respect to the man sea level. The Bassunsin is thus delimited by two sand benches and is, overall, a smaller lagoon included in a large one. Water exchanges occur only in the western part, where the distance between the two sand bars is the highest, while a cul-de-sac shape in the eastern part leads to relative slow hydrodynamics that hamper water flowing in the whole central and eastern parts of the basin. Such conditions, in synergy with the other factors typical of the area, can be envisaged as the cause of severe dystrophic crisis that follow the intense proliferation of different macroalgae genera (Ulva, Gracilaria, Cladophora, etc.). From a conservation point of view, this ecosystem performs an important function of nursery for various marine organisms that find an ideal sheltered habitat, rich of trophic resources, suitable for the early life stages of many animal species (from Guidelines for the sustainable management of fishing and aquaculture activities within the Basunsin area - Technical report - Turolla E.).

Concerning clam farming, manila clam began to reproduce locally few years after its introduction, concentrating juvenile specimens in areas suitable for settlement and development of the larvae. In particular, the Basunsin represented the most important nursery area for two decades and until 2007, in the absence of particular restrictions, both local and non-local clam farmers indiscriminately exploited the entire basin as a source of clam juveniles for seeding their licensed areas.

In the same year, the area was included among the “Biological Protection Areas” (BPA) established by the Emilia-Romagna region with the aim to safeguard productive yet impacted sites. Accordingly, during the period 2007-2013, the Basunsin was self-managed by farmers' cooperatives, supported by external technical-scientific advice. In this period, 7 annual coordinated sampling campaigns were carried out.

Currently, after a general worsening of the ecological conditions of the area and the decision to release a part of it under concession to selected cooperatives (i.e. cooperative experiencing financial insecurity), although remaining on the BPA regional list, the Bassunsin is not included among the nurseries under concession and managed collectively by farmers (from Guidelines for the sustainable management of fishing activities and aquaculture within the Basunsin area - Technical report - Turolla E.).

7.2 Data collection

For the reasons reported above, as part of action 5.6, the University of Ferrara on behalf of the Park Authority, based on the information collected in the previous WPs, have proceeded with the drafting of the Climate Change Adaptation Strategies for the Sacca di Goro lagoon pilot site. As first, the data collection and validation on the European Union habitats was performed starting to the Sacca di Goro to the entire Po Delta Park and then the adaptation strategies were focused on the Basunsin. The focal point of this area is the inlet, bounded by the two major tongues of the sandy bar. As said, the productive value of the Bassunsin, which reflects also its ecological quality and value for biodiversity conservation, lies in its vocation as recruitment and nursery area for the Manila clam, on which the productivity of the entire Sacca di Goro is based.

The high importance for conservation and production, in turn, gives to the area of Basunsin also the attribute of being a highly informative indicator of the effects of climate change. In practice, data on Manila clam seed production may be correlated to the changes of the area, if the time series are informative. As for other biological and ecological data collected by the Po Delta Park during the Change We Care project, such as those relating to vegetation and birds, data on the manila clam recruitment are central in the description of climate change effects in the Goro lagoon. These data had never been collected by the institutions involved in the management with sufficient detail to be used for these purposes and have been retrieved in this last phase of Change We Care from technicians in the sector who have dealt with the management and related monitoring.

7.3 Results and dicussion

After collecting and organizing the data, we verified their relevance as descriptors of the recent evolution of the area, in the context of climate change effects.

Three habitat maps are available for the whole coastal territory of the Park, at fairly close times: 2007-2010-2014 (Figure 4). Larger increase in surface took place for Lagoons and wooded dunes with Pinus pinea and P. pinaster. While loss concerned Sandbanks which are slightly covered by sea water in all time, Estuaries Mediterranean tall humid herb grasslands and *Salix alba* and *Populus alba* forests. At this stage, there is a clear evidence of dunal habitats loss (left side of the graph). The cumulative loss of dunal habitats and estuaries was balanced by an increase, almost equal in amplitude, of lagoons. Although this trend has to be confirmed by the 2019 map, it may be referred to subsidence and erosion, the latter in turn referable

to sea level rise and extreme climatic events. Other phenomena potentially involved to explain the results are:

1) the salinization and the consequent loss of forests and emergent aquatic vegetation, such as Phragmites australis, and the increase of halophilous vegetation;

2) the phreatic aquifer salinization leads to the reduction of radical apparatus of trees along the coastline. Of consequence the reduced radical apparatus it is not able to contrast the extreme climatic events (e.g. strong winds during storms) and in the general framework of climate change effects. It is also important consider the synergy of these effects.

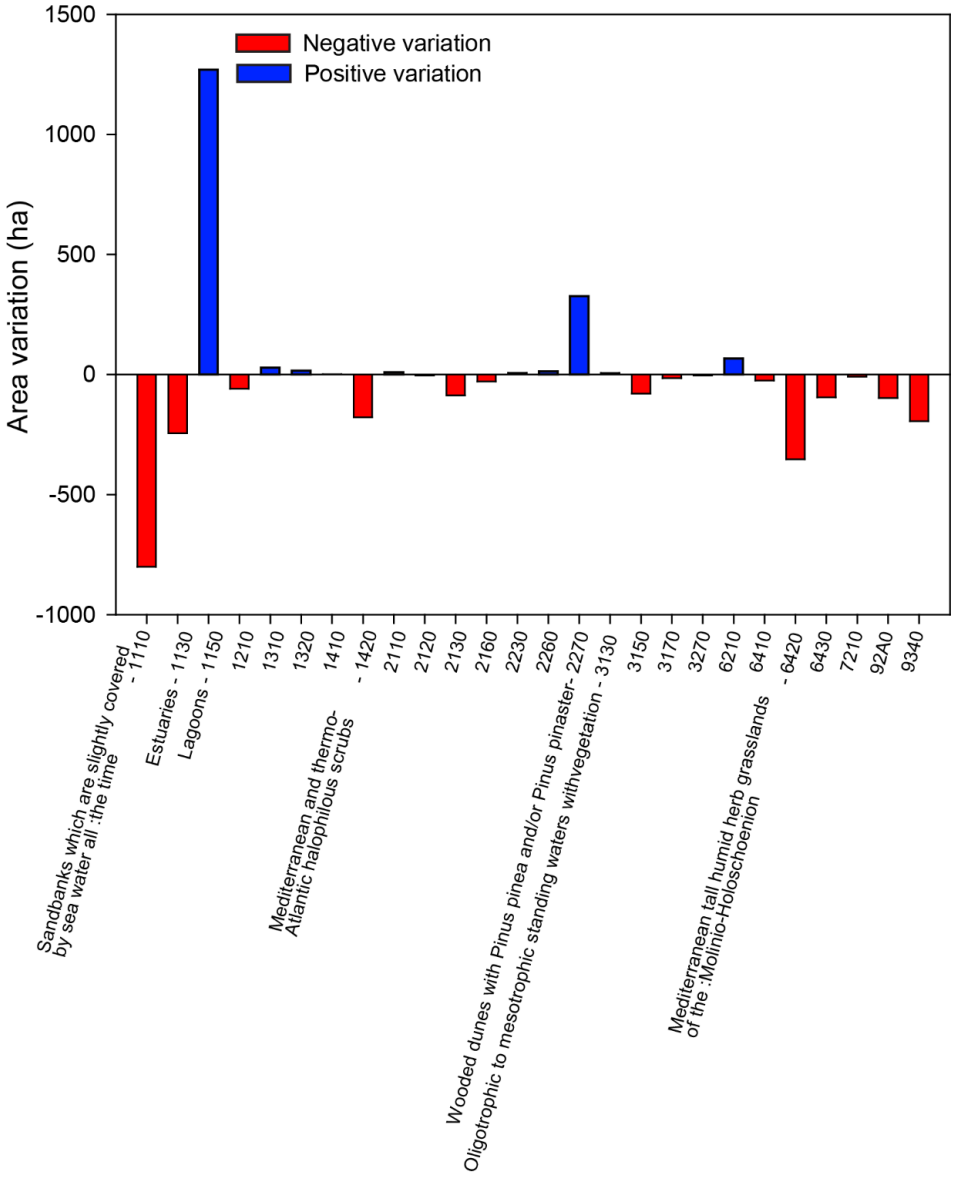

Figure 4. Habitat area (ha) variation between 2007 and 2014.

The manila clam data reported in the following table (Table 1) and figures (figures from 5 to 16), together with those related to a more recent nursery area named Pianaso, located in the open sea, in front of the main mouth of the lagoon. The progressive moving of clam juveniles' recruitment toward the outside of the lagoon (i.e. from Basunsin to Pianaso) can be considered as an indicator of the increasing environmental deterioration on the lagoon, attributable to the constant decrease of connectivity to the sea, as discussed below.

The following table (Table 1) reports the absolute quantities of juveniles recovered from the two nursery areas, expressed in millions of individuals, and the densities, in individuals per square meter. The years in which no data are reported correspond to such poor recruitment as not to motivate the opening of the areas and the carrying out of collection campaigns.

Table 1. Quantities (individuals and density) of juveniles recovered from Basunsin and Pianaso nursery areas

	Basunsin		**Pianaso**	
Year	Total (millions)	Density (ind/m^2)	Total (millions)	Density (ind/m^2)
2007	1076	1195	-	-
2008	1490	1656	-	-
2009	358	398	-	-
2010	1	1	-	-
2011	1267	1408	650	556
2012	234	260	259	221
2013	85	94	2341	2000
2014	-	-	-	-
2015	-	-	-	-
2016	-	-	568	485
2017	-	-	70	59
2018	-	-	100	85
2019	-	-	465	397
2020	-	-	519	444

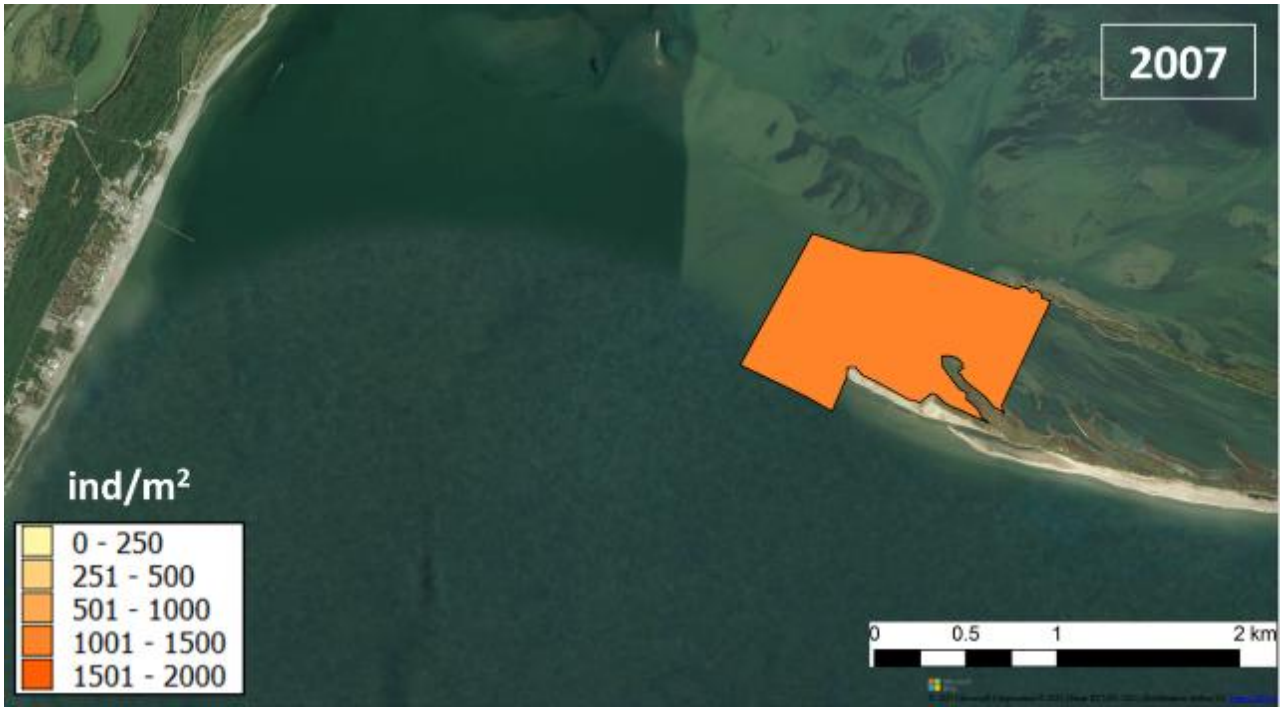

Figure 5. Density of claims juveniles in the Basunsin area in the 2007.

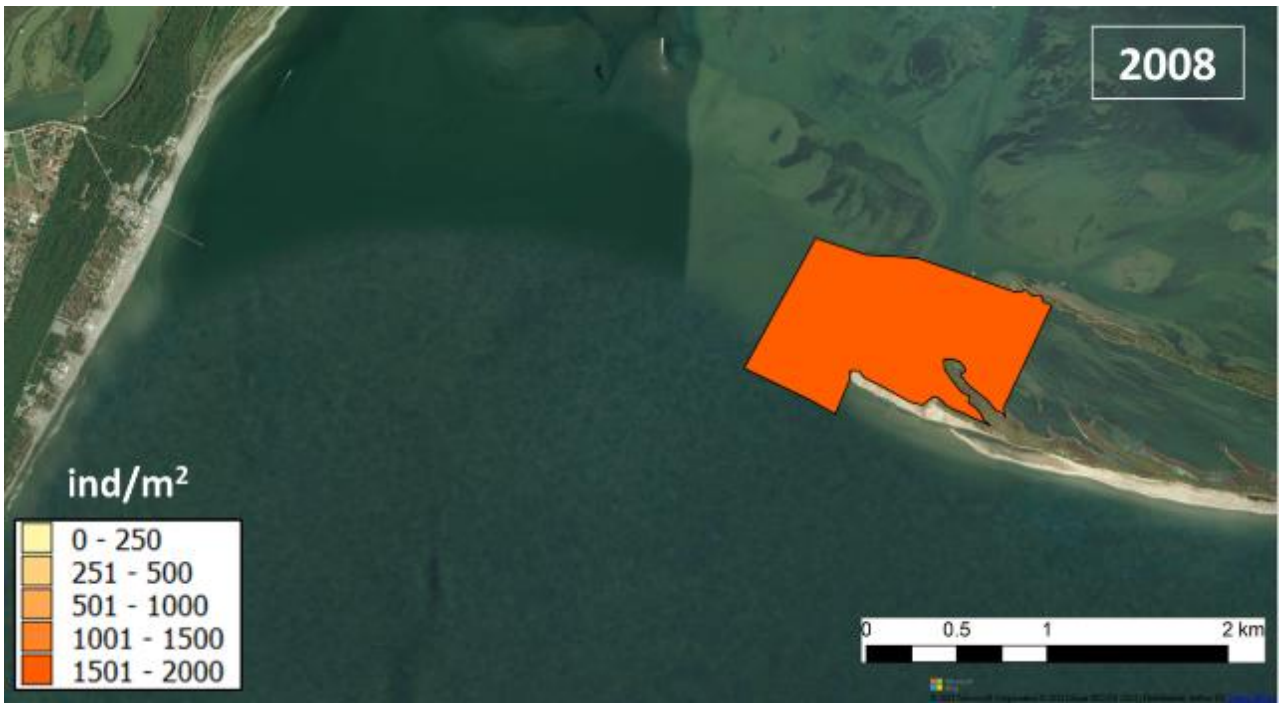

Figure 6. Density of claims juveniles in the Basunsin area in the 2008.

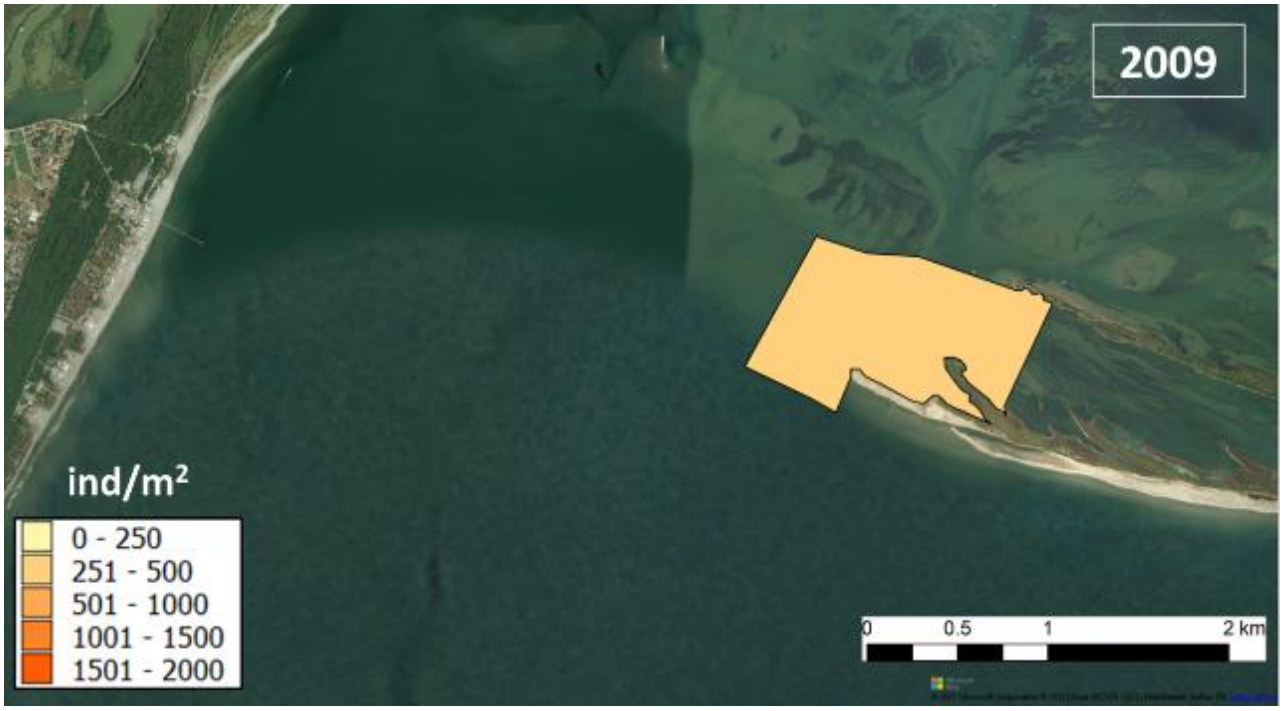

Figure 7. Density of claims juveniles in the Basunsin area in the 2009.

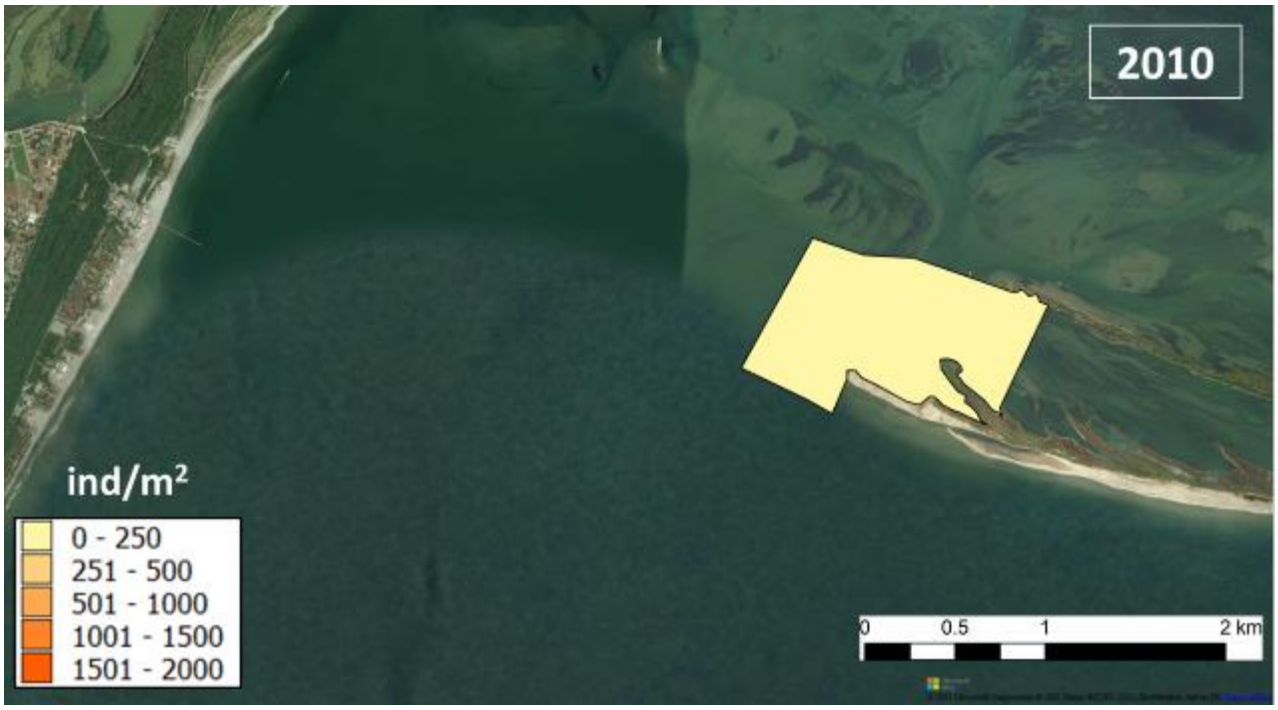

Figure 8. Density of claims juveniles in the Basunsin area in the 2010.

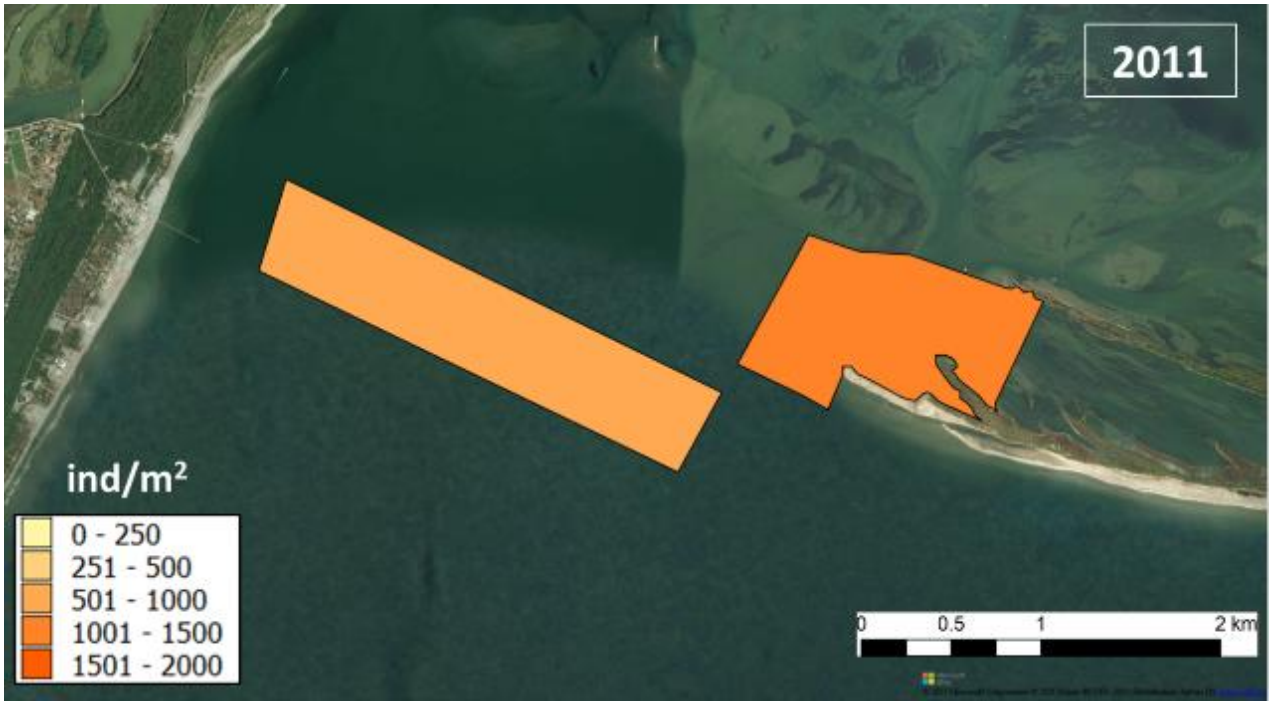

Figure 9. Density of claims juveniles in the Basunsin and Pianaso areas in the 2011.

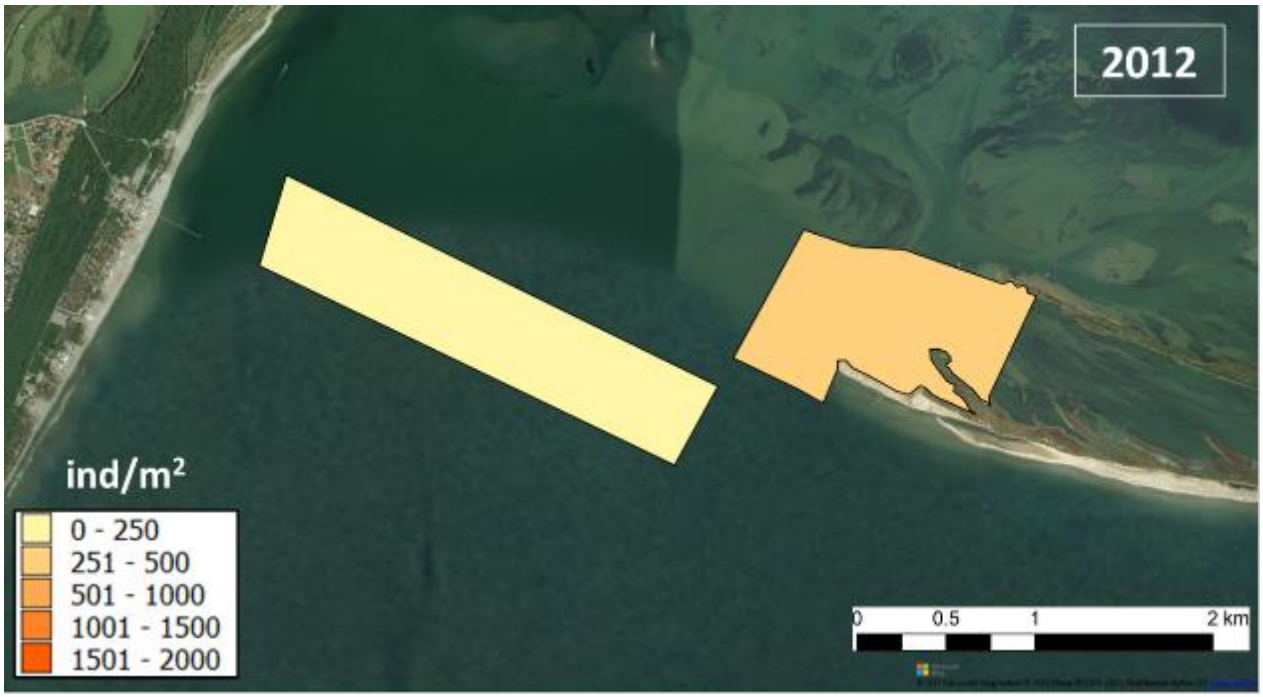

Figure 10. Density of claims juveniles in the Basunsin and Pianaso areas in the 2012.

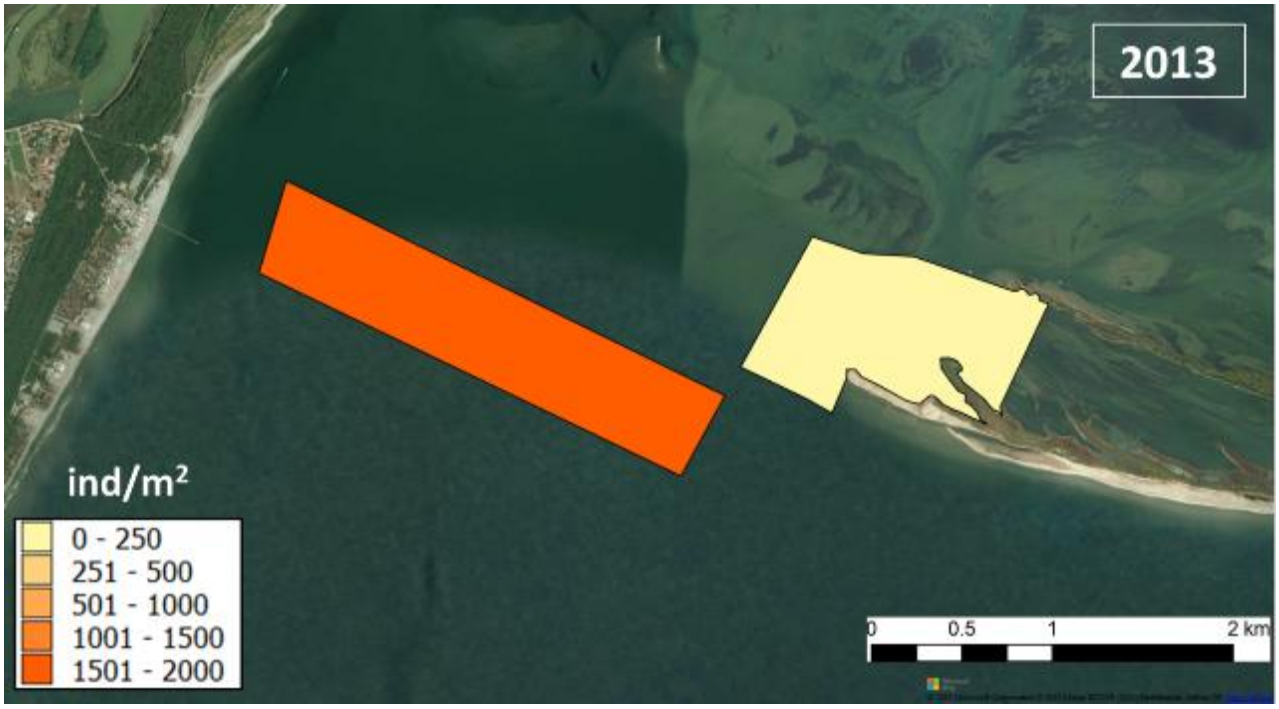

Figure 11. Density of claims juveniles in the Basunsin and Pianaso areas in the 2013.

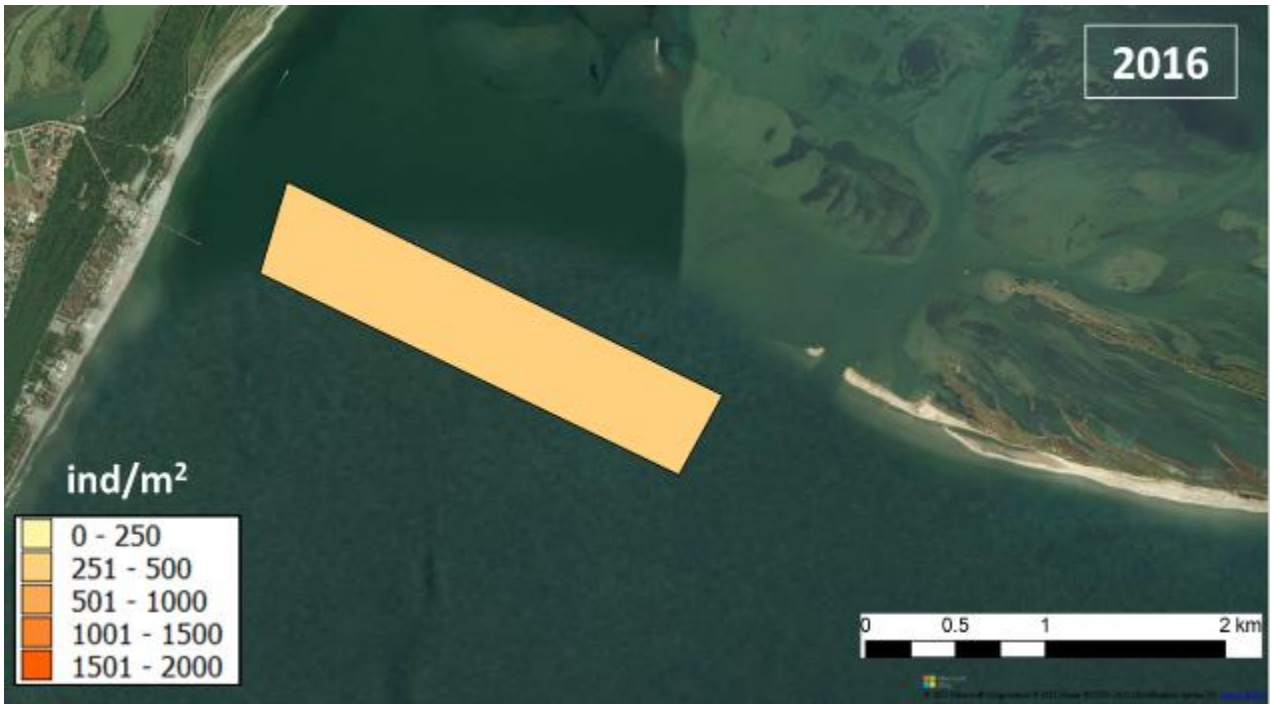

Figure 12. Density of claims juveniles in the Pianaso area in the 2016.

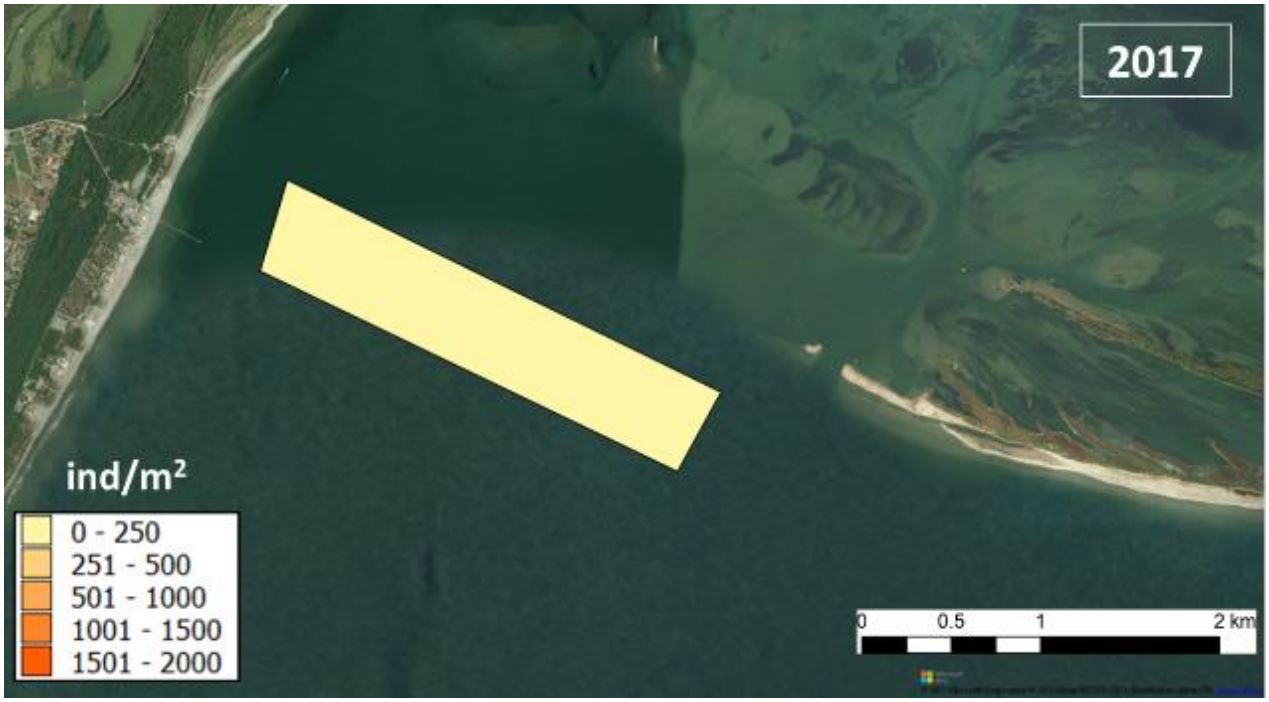

Figure 13. Density of claims juveniles in the Pianaso area in the 2017.

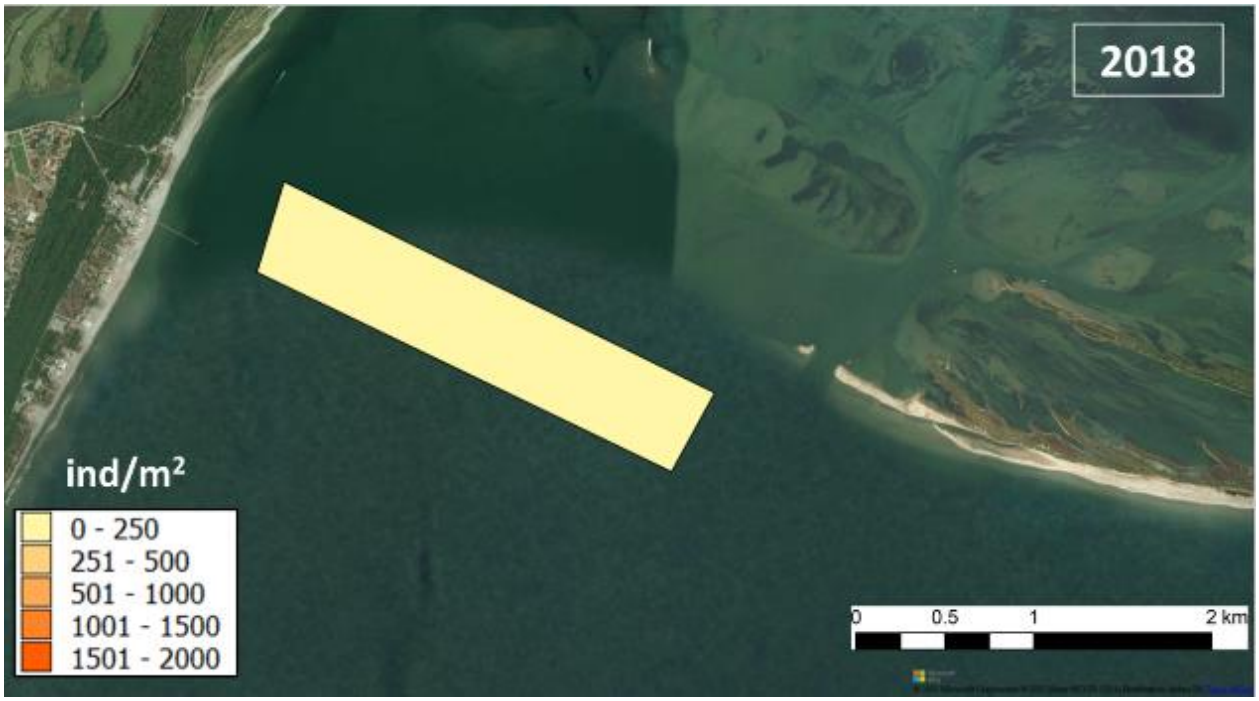

Figure 2. Density of claims juveniles in the Pianaso area in the 2018.

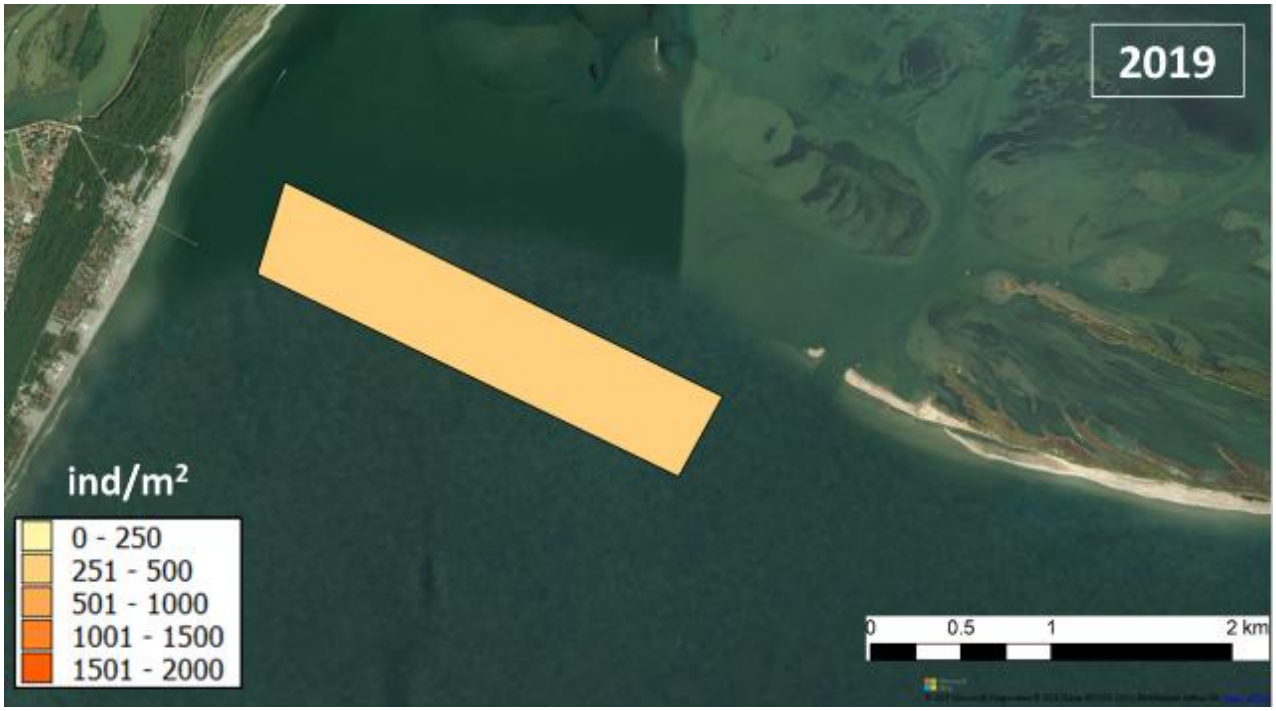

Figure 35. Density of claims juveniles in the Pianaso area in the 2019.

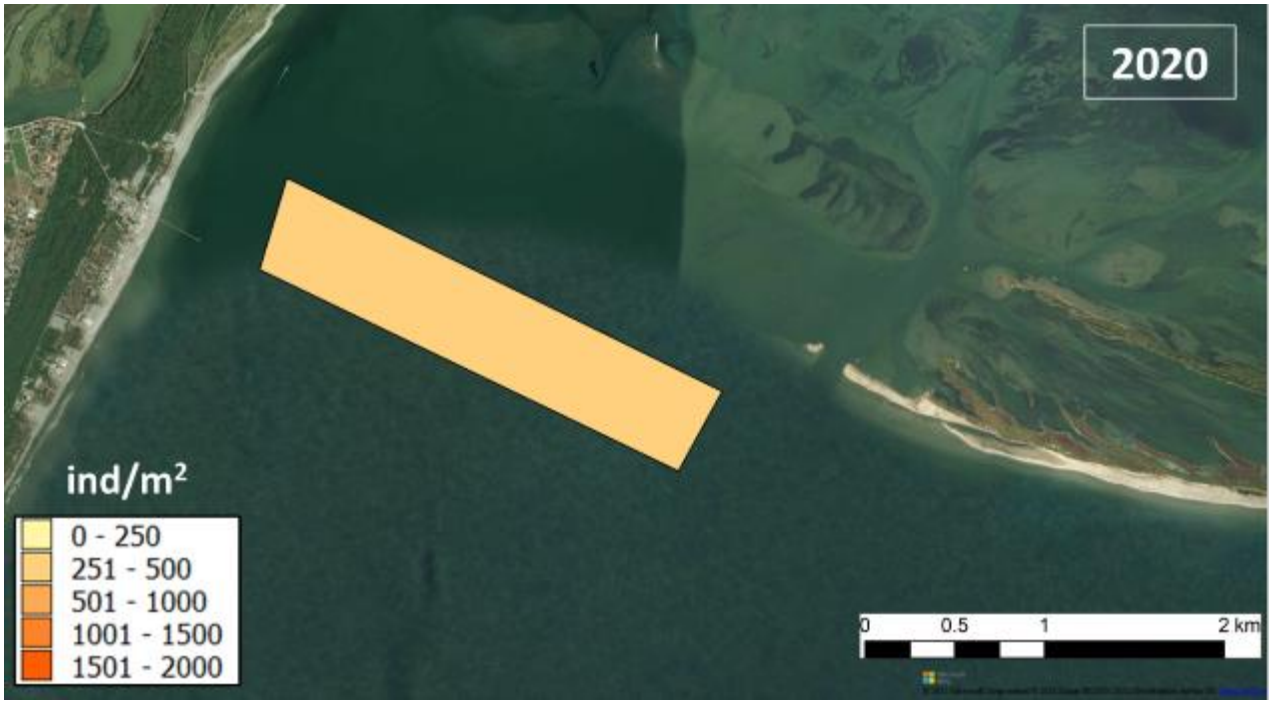

Figure 16. Density of claims juveniles in the Pianaso area in the 2020.

As shown by table and figures, the Basunsin area has gradually lost its importance, until being replaced by the area called Pianaso, entirely locate outside the lagoon.

The data on juveniles collection are of great interest as descriptors of the environmental quality of the lagoon. They provide, in fact, a composite information of two specific phenomena: i) the engraftment of floating clam larvae, depending on a synergy of environmental and biological factors, and 2) their survival, which, even more than engraftment, describes the environmental quality levels of an area. In fact, as commonly observed in confined areas, massive engraftment of bivalve larvae can occur at the bottom. However, after the metamorphosis and the transition to benthic life, the dystrophic summer conditions can cause a massive death of juveniles, often highlighted by the stranding of massive quantities of shells, still small in size, nearby the undertow. On the other hand, the collection of >1 cm-sized clam seed indicates that the summer period has been exceeded, and therefore indicates generally good levels of environment and sedimentary oxygenation.

In the present case, the moving of juvenile collection from Basunsin to Pianaso clearly demonstrates the progressive environmental deterioration during the period 2007-2020, due to the increasing isolation of the area by closing the communication routes with the sea. This is in line with the abovementioned phenomena and with the projections related to solid transport along the coast, described in the previous WPs of the Change We Care Project.

A number of interventions have been carried out over the last decade to mitigate the environmental consequences of the rapid closure of the Sacca di Goro lagoon, as actions of the Life Agree Project: https://lifeagree.eu/).

Behind the experience gained in the latter project, the main stakeholders of the aquaculture sector have recently proposed the following measures: i) the re-shaping of submerged channels in the Bassunsin area, to recover its completely lost hydrodynamics, ii) the opening of a new connection between the Sacca di Goro lagoon and the inner part of Bassunin, and iii) the use of sandy materials resulted from nature interventions, e.g. those resulted from the creation of new nesting habitat for Common ringed plover (Charadrius hiaticula, Linnaeus 1758).

This project, entitled "Improvement of the hydrodynamism of the Basunsin area within the Sacca di Goro lagoon", was commissioned by the Management Consortium of the Sacca di Goro, which brings together most of the cooperatives of clam farmers, and was proposed by Dinamica 3+ and Istituto Delta Ecologia Applicata. The project is currently under examination by the bodies and institutions that are responsible for the management of the lagoon and is certainly a good basis to plan actions aimed to mitigate the effects of climate change in this important and particularly sensitive area of the Sacca di Goro lagoon.

Finally, to increase of an outermost bench and avoid closing the lagoon mouth due to the growth of the current bench of Sacca di Goro a linear structure in chestnut wood poles 6m long and 25cm in diameter, arranged in two staggered and parallel rows was completed within LIFE AGREE – coAstal laGoon long teRm managEmEnt (LIFE13 NAT/IT/000115. The brush is rooted on the emerged beach and extends towards

the sea for a total length of 300 m; the course of the structure is that of a broken one, orientation around 57 ° N with a change of direction (orientation 38 ° N) in the intermediate section (Fugure 17).

Figure 17. Diversion barrier at the seaside of the outer sand bar of Sacca di Goro.

Conclusions

Climate change has both direct and indirect impacts on species and ecosystems. There is clear evidence to show that biodiversity is already responding to climate change and will continue to do so. Direct impacts include changes in phenology, species abundance and distribution, community composition, habitat structure and ecosystem processes. The impact of temperature increases, changes in precipitation regimes or sea-level rise will also affect the productivity and viability of nearly all economic sectors in all EU Member States, with labour market implications. Moreover, several economic sectors are highly vulnerable because of their dependence on regular climate conditions. Sectoral production shifts – in agriculture and tourism for instance – are expected as a consequence of climate change. The Sacca of Goro is particularly susceptible to environmental changes which impact to human activities as manila clams. Adaptation strategies could offer employment and income opportunities in activities such as reinforcing coastal defences, water management and relocation of exposed settlements.

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