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| **Acronym:** | **COCKLES** |
| **Title:** | Co-Operation for Restoring CocKle SheLlfisheries and its Ecosystem Services in the Atlantic Area |
| **Contract:** | EAPA_458/2016 |

## Deliverable 3.5

# COCKLES Project support and recommendations for management

***August 2021***

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| **Lead Partner for Output** | CETMAR |
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| **Dissemination level** | | | |
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| ☒ | **PU** Public | ☐ | **PP** Restricted to other programme participants |
| ☐ | **RE** Restricted to a group specified by the Consortium | ☐ | **CO** Confidential, only for members of the Consortium |




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Contents

# 1. INTRODUCTION

Since the project proposal formulation stage, COCKLES partners have always embraced the purpose of ensuring that the results of the research carried out in the project should be interpreted and brought as close as possible to the needs of the producers and of those bodies responsible for managing cockle production sites and ecosystems, whatever the type of organization in charge and in each of the project territories.

The capitalization actions are specially designed to reinforce this approach. This report in particular compiles the contributions from the different work packages in which the activities of COCKLES have been organized and can be considered for **decision support** and for the **design of management measures**. For this, the report is made of extracts from the deliverables that give evidence of the results achieved, and it highlights and organizes these insights around management recommendations which have been generated or which can derive from the research outcomes delivered.

It should be clarified that this deliverable is not in itself a management plan, however, the recommendations that are provided can be suggested for consideration in the future design of such plans, without forgetting the importance, in general, of adapting management to the specificities of each territory.

It needs to be noticed that in the context of this document the term "management" needs to be understood in a broad sense, not just referring to the management of the fishery but of the ecosystem, and it even compiles some recommendations regarding future research needs about the cockle and other bivalves, which could be also useful information for orienting the priorities of research and innovation funding Agencies in and beyond the Atlantic Area.

Moreover, a fundamental step for sustainable management (of both the fishery and the ecosystem) is the implementation of suitable monitoring plans to gather science-based data, and in this regard, some specific recommendations are also provided based on the findings of the COCKLES project.

The following categories have been used to organise the compilation of recommendations:

- Regular monitoring and data collection
- Fisheries management
- Further ecosystem management and conservation
- Research needs beyond the COCKLES project

To avoid duplicities of information, the tables have been prepared to gather a synthetic description of the recommendation and/or management measures and to facilitate insight; it is provided with the reference of the project deliverable or deliverables where more information can be found.

# 2. COMPILATION OF RECOMMENDATIONS

## 2.1 Regular Monitoring and Data Collection

| REGULAR MONITORING AND DATA COLLECTION | |
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| **SPECIFIC MEASURE/RECOMMENDATION IDENTIFIED** | **WHERE TO LEARN MORE…** |
| **Rebuilding historical information:** Understanding long term changes in species (assessing trends and drivers of fluctuations) is vital for creating policy and planning long-term conservation strategies (Rosenberg, 2005, Engelhard et al., 2016). […] Marine historical ecology is an emerging field of study that uses historical datasets and ecological modelling to describe "what marine ecosystems might have looked like in the past" (Campbell et al., 2009). Many of the sources of historical data, traditionally, would not be considered in a scientific study but are often used in other disciplines such as history and geography (McClenachan et al., 2012) and can be valuable sources of information (Patton et al., 1998). In marine historical ecology, it is important to collect data from a wide range of archival sources (Patton et al., 1998; Swetnam et al., 1999). In the study of shellfish, including cockles, middens for example can be an especially valuable source of information. | Deliverable 4.1. Historical survey of cockle distribution, abundance and population dynamics in the Atlantic Area. |
| **Standardisation of surveying protocols at least at a regional level should be sought** to allow for more accurate predictions in the future, allowing more consistent reporting of results, and enhancing the possibilities for comparison within sites and across production areas. | Deliverable 4.1. Historical survey of cockle distribution, abundance and population dynamics in the Atlantic Area. |
| **Regularity:** Knowledge of cockle population characteristics and dynamics and their interaction with environmental drivers, to date, has been mostly derived from experiments and local-scale studies. While regional standardisation should be sought, broad-scale regulations should be considered with caution. Cockle **population dynamics and health should be monitored locally** and used to guide appropriate management. | Deliverable 4.2. Field survey of cockle distribution, abundance & population dynamics currently. |

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| Understanding **genetic diversity** and **connectivity** between stocks through **larval dispersal** is important to and thus, to inform management decisions. This issue is crucial to select the right cockle sources when cockle bed restoration or restocking activities have to be addressed. | Coscia et al. Fine-scale seascape genomics of an exploited marine species, the common cockle *Cerastoderma edule*, using a multimodelling approach. *Evol Appl*. 2020; 13: 1854– 1867. |
| **Monitoring of environmental parameters** (salinity, sea temperature and primary productivity) is also essential. Despite the fact that *C. edule* populations proliferate across wide environmental ranges, environmental stressors such as low salinity and high parasite levels may cause cockle mortality or detrimental sublethal effects, such as slower growth in early life, and lower fecundity and these drivers can be compounding. These are important findings that should be monitored into the future to enable management and mitigation of potentially harmful effects. | Deliverable 4.2. Field survey of cockle distribution, abundance & population dynamics currently. |
| **Cooperation among all relevant stakeholders** (environmental management agencies, shell-fishers associations, and scientists) is essential to enable **long-term systematic monitoring** programmes and to early identify **emerging threats**.<br><br>The development of collaborative **data and knowledge sharing platforms** with geographically relevant information can become an important support tool for management and to support decision-making processes. | Deliverable 8.1b. Quantifying the role of cockles as ecosystem engineer species supporting coastal ecosystem functioning. |

## 2.2 Cockles Fisheries Management

| Cockle fisheries Management | |
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| **Specific measure/recommendation identified** | **Where to learn more…** |
| **Establishing a TAC**: Fishing is one of the more infrequently reported causes of mass mortalities, it is a potential influencer of cockle dynamics, and therefore recruitment and longevity of populations. Management and legislation can have a positive impact on cockle densities and biomass. The establishment of a TAC (towards an MSY objective) prevents uncontrolled fishing, even when abundance is high, facilitating improved recruitment and population expansion and/or recovery. | Deliverable 4.1. Historical survey of cockle distribution, abundance and population dynamics in the Atlantic Area.<br><br>Mahony et al. Mobilisation of data to stakeholder communities. Bridging the research-practice gap using a commercial shellfish species model. PLoS ONE 2020 15(9): e0238446. |
| **Minimum capture size** has been identified as a quite common management measure, however; it has been noted that growth rates of cockles vary both spatially and temporally and can differ even within a single site due to variations in abiotic factors. Therefore, there is no one-fits-for all minimum capture size that should be applied and local conditions should be considered. While regional standardisation should be sought, broad-scale regulations should be considered with caution and local cockle population dynamics and health should be monitored and used to guide appropriate management.<br><br>Variations in length, wet weight and age were observed across the cockle populations, with smaller cockles at more southern latitudes. This relationship was not apparently related with age. It is likely that at southern populations, cockles divert more energy to reproduction rather than growth.<br><br>Cockle growth is not influenced by primary productivity as strongly as expected. Instead, high density appears to be a | Deliverable 4.2. Field survey of cockle distribution, abundance & population dynamics currently. |

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| more important driver of population dynamics, resulting in smaller cockles.<br><br>From a **precautionary approach**, in terms of fisheries regulation it is better to use the **L95 (length of mass maturity - at which 95% of the population is mature) to determine the suitable minimum capture size.** | |
| **Gear restrictions** also play an important role in the overall effect of fishing. For example, there has been evidence to suggest that suction dredging can harm recruitment (Piersma et al., 2001) whereas low-level hand-racking is unlikely to have the same level of negative impact. | Deliverable 4.3 Cockle reproductive health. |
| **Cockle reproduction**. Seawater temperature and seasonal food availability are factors that likely control the reproductive characteristics of *C. edule*. The spawning season was prolonged at the southern sites, potentially causing a reallocation of energy resources away from individual growth (indicated by smaller size), denoting varying life-history strategies amongst different families, and sites. While the observed spawning peaks were seasonal, the reproductive stage may be influenced by other factors including genetics, food availability and immersion time.<br><br>It is necessary to conduct **fine-scale surveys**, even if cockles are located nearby as large differences between close sites have been reported. Second, it would be beneficial to use molecular analysis to identify cohabiting trematode species, due to the varying distribution of trematodes spatially (de Montaudouin et al., 2009) and the range of effects they can inflict on their hosts. Third, minimum capture size should be set at a local scale, rather than regionally or nationally, due to the evident variations in spawning size spatially. Finally, it is important to consider the phenomenon of “shifting” reproductive cycles (timing and duration) associated with a changing marine environment and atypical years.<br><br>Following these recommendations will be required in the decision-making process to ensure that (a) the **spatial variability** of cockles is accounted for, (b) **sufficient broodstock remain** unfished to contribute to the future fecundity and sustainability of those populations and that (c) the **harvesting/fishing season** does not significantly reduce reproductive input. | Deliverable 4.3 Cockle reproductive health.<br><br>Mahony et al. Latitudinal influence on gametogenesis and host–parasite ecology in a marine bivalve model. Ecol Evol. 2021; 11: 7029– 7041. |
| The development of **restocking programs** supported by advances in *C. edule* aquaculture could be an efficient fishery **management strategy to rebuild stocks**. | Deliverable 7.1. Settling culture procedures at hatchery and outdoor stages. |
| Pooling COCKLES project and state of the art data, the **infectious risks for cockle populations at the COCKLES sites have** | Deliverable 5.1. Parasites |

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| **been hierarchized** from low to high risk, according to the presence of pathogens and diseases, also classified from innocuous to deleterious. COCKLES parasite census book provides specific recommendations for **management according to a risk assessment procedure**.<br><br>In general terms it is recommended to keep monitoring of population parasites and pathogens and, thus, to avoid the translocation of specimens from areas affected by serious pathogens to those free of them | and Diseases of the Common Cockle 'Cerastoderma edule' |
| **Producing marteiliosis-resistant cockle strains** appears to be a promising approach to overcome this disease in endemic areas, considering the difficulties to fight against marteiliosis in an open sea context, and because selective breeding programmes have been successful to increase mollusc resistance against various diseases (Smits et al., 2020). | Deliverable 7.1. Settling culture procedures at hatchery and outdoor stages. |
| With many cockle populations under threat in the AA it is conceivable that **greater levels of management** will be required to maintain future sustainable fisheries. Effective fisheries regulation and management is **founded in scientific data**.<br><br>To enable the development of effective management strategies and focus resources to maximise sustainable exploitation of this resource, concrete data of current **distribution**, **abundance** and **population dynamics** are imperative. | Deliverable 4.1. Historical survey of cockle distribution, abundance and population dynamics in the Atlantic Area. |
| **Building resilience of coastal communities**: There is a high potential for climate change and anthropogenic activity to negatively impact cockle populations, and thus, cockle fisheries. In particular, mass mortalities are likely to increase as a result of changing meteorological conditions, i.e. extreme events (cold winters, heat waves etc.) and their predicted increase in frequency under future climate change scenarios (e.g. Ortega et al., 2012; White et al., 2015). Therefore, it is necessary for fisheries management and conservation to support the future sustainability of this economic activity that many European coastal communities depend on for their incomes. | Deliverable 4.1. Historical survey of cockle distribution, abundance and population dynamics in the Atlantic Area. |

## 2.3 Ecosystem Management and Conservation

| Ecosystem management and conservation | |
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| **Specific measure/recommendation identified** | **Where to learn more…** |
| Today, management strategies mainly aim at protecting exploited species and avoiding severe stock declines. In the future, they should also carefully consider the **role of shellfish populations** (fundamentally depending on their characteristics such as spatial distribution, abundances and age structure) **in the functioning of the whole coastal ecosystem** as well as the sustainability of numerous ecological goods and services they provide. | Deliverable 8.1b. Quantifying the role of cockles as ecosystem engineer species supporting coastal ecosystem functioning. |
| **Biosecurity strategies**: Biotic and abiotic pollutants (both past-frequent and emerging such as microplastics or some pathogens) are likely to increase their presence in the cockle areas (coastal areas suffer from increasing anthropogenic pressure and climate change may have more severe effects in these areas). Regular monitoring of these threats and the establishment of biosecurity areas can help both conservation and production interests. | Deliverable 4.1. Historical survey of cockle distribution, abundance and population dynamics in the Atlantic Area. |
| Information gathered on genetic diversity enables the consideration of **five Operational Conservation Units**, i.e. (i) Irish/Celtic Sea; (ii)English Channel/North Sea; (iii) Bay of Biscay; (iv) northwest Spain and north Portugal; and (v) south Portugal. This information represents the baseline for management of cockles, for designing conservation strategies, founding broodstock for depleted beds, and producing suitable seed for aquaculture production. | Deliverable 4.4. Cockle population genetics. |
| The information from the genetic diversity studies in cockles might be useful to **define sets of markers**, starting from outlier loci, which could be applied to found broodstock for restocking depleted populations and to track individuals to their units that could aid the identification of illegal transferences between countries or from disease-affected areas. | Deliverable 4.4. Cockle population genetics. |
| Advice has been provided to avoid spreading the pathogens/diseases. However, no action is generally recommended in nature conservation areas. | |

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| When considering the diversity of ecological situations where cockles usually constitute dense beds, no obvious direct **effect of cockles on the diversity, composition or on the organization of the associated benthic community** could be demonstrated. There is indeed few evidence of *Cerastoderma edule* effect on other macrobenthic organisms at the small spatial scale of a cockle's bed. This does not mean that *C. edule* plays no role in macrobenthic community structure and diversity, but this role was not evidenced when addressing small spatial and/or relatively short-time (e.g. Cesar & Frid, 2009)-scales. | Deliverable 8.1.a Cockles as ecosystem engineer.Relation between cockles and the structure and diversity of associated macrozoobenthic community. |
| The **intensive exploitation of cockle fisheries has profound consequences on population characteristics** (e.g. patchy spatial distribution, size and age structure, abundance…), **which may directly or indirectly alter many ecosystem processes** and functions. Indeed, through intense filtration and biodeposition activities, *C. edule* populations play a key role in the functioning of coastal pelagic and benthic ecosystems. Moreover, this bioturbating species is considered an ecosystem engineer in the sense that it **can deeply modify the physical properties of the surrounding sediment** such as cohesiveness, compaction with consequences for sediment stability. | Deliverable 8.1b. Quantifying the role of cockles as ecosystem engineer species supporting coastal ecosystem functioning. |
| When cockles are placed in a cohesive organically rich sediment, the flux of recycled nutrients might be especially important for the development of benthic microalgae as compared to non-cohesive sediment with a low proportion of organic matter. Therefore, the influence of cockles on microphytobenthos (MPB) growth might be environment-dependent. Nevertheless, **MPB likely benefits from increased access to inorganic nutrients resulting from cockles metabolic excretion. It may partly compensate for the negative effect of cockles linked to sediment surface reworking**. | Deliverable 8.1b. Quantifying the role of cockles as ecosystem engineer species supporting coastal ecosystem functioning. |
| The magnitude of *C. edule* contribution to coastal ecosystem functioning is fundamentally controlled by the characteristics of their populations (such as **density and size distribution**) as well as their **physiological conditions**, which are **severely altered by parasite infection** (particularly when bivalves act as the first intermediate host). | Deliverable 8.1b. Quantifying the role of cockles as ecosystem engineer species supporting coastal ecosystem functioning.<br><br>Magalhães et al. Trematode infection modulates cockles biochemical response to |

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| | climate change. The Science of the Total Environment. 2018 Oct;637-638:30-40.<br><br>Dairain et al. Does parasitism influence sediment stability? Evaluation of trait-mediated effects of the trematode Bucephalus minimus on the key role of cockles Cerastoderma edule in sediment erosion dynamics. The Science of the Total Environment. 2020 Sep;733:139307.<br><br>Magalhães et al. How costly are metacercarial infections in a bivalve host? Effects of two trematode species on biochemical performance of cockles. Journal of Invertebrate Pathology. 2020 Nov;177:107479. |
| Cockles provide a wide range of ecosystem services but, apart from food provision, cultural ecosystem services, are often more directly and intuitively recognised by local stakeholders. Some studies suggest that the perception of value and the willingness to pay for environmental protection and greater management costs is normally higher in coastal indigenous communities than inland when compared with other trade-offs (Kirsten et al. 2015). Therefore, the **work around cultural ecosystem services in cockles could facilitate the adoption of measures** for a more sustainable approach to the | Deliverable 8.2. Quantifying the ecosystem service benefits that cockles (Cerastoderma edule) provide to society. |

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| management of this important coastal resource. | Ciutat et al.. Ecosystem services provided by a non-cultured shellfish species: The common cockle Cerastoderma edule. Marine Environmental Research, Elsevier, 2020, 158, pp.104931. |
| Non-indigenous species can represent a risk of bio invasions. The set-up of reliable systems for **certification of origin** can be a tool to protect the cockle ecosystems and add market value to genuine and high-quality bivalves<br><br>Programmes for **early detection** and **exhaustive control of recent introductions** can also be effective.<br><br>The promotion of "***Bivalve Sanctuaries***" as a conservation measure could help to guarantee the long-term sustainability of the natural populations. | Deliverable 5.3.Report with NIS-associated risk assessment.<br><br>Cabral et al. Non-indigenous species in soft-sediments: are some estuaries more invaded than others? Ecol. Indic. 2020; 110: 105640 |

## 2.4 Research needs Beyond Cockles Project

| RESEARCH NEEDS BEYOND COCKLES PROJECT | |
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| **SPECIFIC MEASURE/RECOMMENDATION IDENTIFIED** | **WHERE TO LEARN MORE…** |
| To search for possible links between environmental parameter, cockle population dynamics and bacterial communities of the cockle microbiota: It is yet unsolved the differences in the phylogenetic diversity of the bacterial communities associated to cockles from Ria de Noia, from Bassin d'Arcachon or the low prevalence of Endoizoicomonas in the gills of cockle from Ria Formosa. More generally, the functional role of the cockle microbiota has still to be defined. | Deliverable 5.2.b. Cockle response to stress – Microbiota |
| The functional role of the cockle microbiota could be studied based on laboratory or field experiments dedicated to manipulating the cockle microbiota and monitor subsequent effects on the cockle physiology (respiration, reproduction) or ethology as conducted e.g. with parasites (Dairain et al., 2020). Finally, the functional role of the cockle microbiota could also be addressed by targeting typical cockle–bacteria associations based on novel molecular technics such as RNA-seq on isolated single cells or secondary ion mass spectrometry. According to our results, the Endoizoicomonas – C. edule association would be a highly relevant candidate and the timeliest scope regarding the functioning, health and fitness of the C. edule holobiont. | Deliverable 5.2.b. Cockle response to stress – Microbiota |
| It needs to be further studied the quantitative relationships between (1) the characteristics of cockle populations (mean shell length, density, physiological condition), (2) sediment bioturbation intensity and (3) ecological processes that underpin ecosystem functioning. | Deliverable 8.1b. Quantifying the role of cockles as ecosystem engineer species supporting coastal ecosystem functioning |
| Other relevant research needs:<br>- More knowledge on larval behaviour is required (ongoing experiments)<br>- Links between estuaries and large-scale oceanography | Coscia et al. Fine-scale seascape genomics of an exploited marine species, the common cockle Cerastoderma edule, using a multimodelling approach. Evol Appl. 2020; 13: 1854– 1867. |